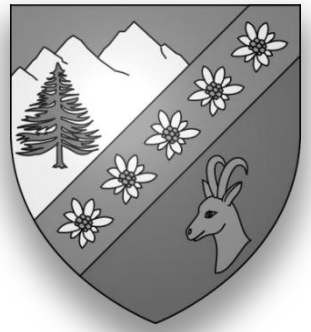
# IWIN2012



# International Workshop on Informatics

Proceedings of
International Workshop on Informatics
September 4-7, 2012
Chamonix, France


Sponsored by Informatics Society
URL: http://www.infsoc.org/

Publication office:
Informatics Laboratory
3-41, Tsujimachi, Kitaku, Nagoya 462-0032, Japan
Publisher:
Tadanori Mizuno, President of Informatics Society
ISBN:
978-4-902523-27-0
Printed in Japan

# Table of Contents

## Session 1: Network 1 (Chair: Yoh Shiraishi)

## (14:30-17:30,Sept.4)

## Session 2: Communication

## (Chair: Tomoya Kitani) (9:30-12:30,Sept.5)



## Keynote Speech 1 (13:30-14:30,Sept.5)

## Session 3: Ubiquitous Computing & ITS

## (Chair: Yoshitaka Nakamura) (14:30-17:30,Sept.5)

## Session 4: Algorithm, Software & System

## (Chair: Takuya Yoshihiro) (9:30-12:30,Sept.6)



## Keynote Speech 2 (13:30-14:30,Sept.6)

## Session 5: Network 2 (Chair: Takaaki Umedu)

## (14:30-17:30,Sept.6)



## Panel Discussion (9:30-11:00,Sept.7)

# A Message from the General Chair

It is my great pleasure to welcome all of you to Chamonix, France, for the Sixth International Workshop on Informatics (IWIN 2012). This workshop has been held annually and sponsored by the Informatics Society. The first, second, third, fourth, and fifth workshops were held in Napoli, Italy in September 2007, in Wien, Austria in September 2008, in Hawaii, USA in September 2009, in Edinburgh, Scotland, UK in September 2011, and in Venice, Italia in September 2011, respectively.

In IWIN 2012, 25 papers have been accepted and 16 papers have been further selected as excellent papers which are considered having significant contributions in terms of the quality, significance, current interest among the professionals, and conference scope through the peer reviews by the program committees. Based on the papers, 5 technical sessions have been organized in a single track format, which highlight the latest results in research areas such as mobile computing, networking, information system, and groupware and education systems. In addition, IWIN 2012 has two invited sessions from Dr. Behzad Bordbar who is a lecturer of School of Information, University of Birmingham, and from Mr. Tatsuo Tomita who is the President and Representative Director of Fujitsu Laboratories Limited, the main R&D organization for Fujitsu Limited, a leading provider of information and communication technology (ICT)-based business solutions for the global marketplace. We really appreciate the participation of the two invited speakers in this workshop.

I would like to thank all of participants and contributors who made the workshop possible. It is indeed an honor to work with a large group of professionals around the world for making the workshop a great success.

We are looking forward to seeing you all in the workshop. We hope you all will experience a great and enjoyable meeting in Chamonix, France.

Teruo Higashino

General Chair

The International Workshop on Informatics 2012

# Organizing Committee

## General Chair

Teruo Higashino (Osaka University, Japan)

## Steering Committee

Toru Hasegawa (KDDI R&D Laboratories, Japan)
Teruo Higashino (Osaka University, Japan)
Tadanori Mizuno (Aichi Institute of Technology, Japan)
Jun Munemori (Wakayama University, Japan)
Yuko Murayama (Iwate Prefectural University, Japan)
Ken-ichi Okada (Keio University, Japan)
Norio Shiratori (Tohoku University, Japan)
Osamu Takahashi (Future University-Hakodate, Japan)

## Finance Chair

Tomoya Kitani (Shizuoka Uinversity, Japan)

## Local Chair

Takaaki Umedu (Osaka University, Japan)

## Program Committee Chair

Kozo Okano (Osaka University, Japan)

## Program Committee

Behzad Bordbar (University of Birmingham, UK)
Naoya Chujo (Aichi Institute of Technology, Japan)
Satoru Fujii (Matsue College of Technology, Japan)
Teruyuki Hasegawa (KDDI R&D Laboratories, Japan)
Haruo Hayami (Kanagawa Institute of Technology, Japan)
Takaaki Hishida (Aichi Institute of Technology, Japan)
Teruhisa Ichikawa (Shizuoka University, Japan)
Tomoo Inoue (University of Tsukuba , Japan)
Masahiko Ishino (Fukui University of Technology, Japan)
Yoshinobu Kawabe (Aichi Institute of Technology, Japan)
Gen Kitagata (Tohoku University, Japan)
Tomoya Kitani (Shizuoka University, Japan)
Tsukasa Kudo
(Shizuoka Institute of Science and Technology, Japan)
Hiroshi Mineno (Shizuoka University, Japan)
Shinichiro Mori (Fujitsu Laboratories, Japan)
Jun Munemori (Wakayama University, Japan)
Yoshitaka Nakamura (Future University-Hakodate, Japan)
Masakatsu Nishigaki (Shizuoka University, Japan)
Yoshia Saito (Iwate Prefectural University, Japan)
Fumiaki Sato (Toho University, Japan)
Jun Sawamoto (Iwate Prefectural University, Japan)
Hiroshi Shigeno (Keio University, Japan)
Toshihiro Shikama (Fukui University of Technology, Japan)
Yoh Shiraishi (Future University-Hakodate, Japan)
Hideyuki Takahashi (Tohoku University, Japan)
Osamu Takahashi (Future University-Hakodate, Japan)
Yoshiaki Terashima
(Mitsubishi Electric Corporation, Japan)
Takaaki Umedu (Osaka University, Japan)
Hirozumi Yamaguchi (Osaka University, Japan)
Koji Yoshida (Shonan Institute of Technology, Japan)
Takuya Yoshihiro (Wakayama University, Japan)
Takaya Yuizono
(Japan Advanced Institute of Science and Technology, Japan)

# Session 1:
# Network 1
# (Chair: Yoh Shiraishi)

# Evaluation of Lump-sum Update Methods for Nonstop Service System

Tsukasa Kudo†, Yui Takeda‡, Masahiko Ishino*, Kenji Saotome**, and Nobuhiro Kataoka***

†Faculty of Comprehensive Informatics, Shizuoka Institute of Science and Technology, Japan
‡Mitsubishi Electric Information Systems Corporation, Japan
* Department of Management Information Science, Fukui University of Technology, Japan
** Hosei Business School of Innovation Management, Japan
*** Department of Information Technology, Tokai University, Japan
kudo@cs.sist.ac.jp

***Abstract*** - In many mission-critical systems, the lump-sum update of large amounts of data is performed. On the one hand, with the development of internet business, nonstop online services have become to be provided in many mission-critical systems. So, the lump-sum update has to be performed concurrently with the online entry. However, in the actual mission-critical systems, there are various kinds of lump-sum update operations corresponding to their business. In this paper, we define the lump-sum update models from the point of view of both the actual business process and characteristics of the target data, and show the problem of the conventional update methods. Then, we propose a novel update method for it, which utilizes the transaction time database, and show the evaluation results of the efficiency of both the lump-sum update and online entry comparing with the conventional update method. Based on these results, we show the proposal method is effective in the case where the update data is related to each other.

***Keywords***: Database, batch processing, mini-batch, transaction, mission-critical system, nonstop service.

## 1 INTRODUCTION

In mission-critical systems, their databases are usually updated by two methods. The first is entries from online terminals (hereinafter "online entry") such as ATM (Automatic Teller Machine) in a banking system, which is performed at any time in the online service time zone and its result is immediately reflected in the database. Because the online entries are performed concurrently by many users, their ACID properties are maintained by the transaction processing based on the lock function of the database. So, the result becomes as if they were performed in a certain order.

The second is the lump-sum update of large amounts of data in the database. For example, large amounts of account transfer in a banking system, which is entrusted by a company, is performed as a lump-sum update. This process is not required rigorous immediacy, so it is performed at the designated time by the system administrator. Therefore, in the old days, it was performed as the night batch to avoid the online service time zone by the method locking the whole target data and updating them in a lump (hereinafter "batch update"). However, in recent years, the electronic commerce has been expanding due to the progress of the internet business, and many systems have become to provide the nonstop online service, such as above-mentioned ATM. As a result, it has become necessary that the batch update is performed concurrently with the online entry.

On the other hand, the mini-batch has been put to practical use, which divides the lump-sum update into small update units to reduce the individual lock time and performs them sequentially [2]. However, because the mini-batch updates data one after another, the state on the way of the update is queried, in which some data is not updated yet and the other is already updated. That is, the ACID properties of the transaction are not maintained in the entire mini-batch.

Here, in our previous study on query methods in a mission-critical system, we showed that there are various kinds of batch operations and the appropriate method should be adopted for each case [3]. This suggests that the various requirements exist for the lump-sum update process according to the business operations, too. So, in this paper, we focus on the local government system as an example of the mission-critical systems and define the lump-sum update models from the point of view of both the actual business process and characteristics of the target data, in which lump-sum update is divided by both the conflict with the online entry and relevance between update data. Then, we show the requirement of the lump-sum update method for each update model. And, in some case where it is performed concurrently with the online entry, we show there is the problem that the consistency of the data cannot be maintained.

For this problem, we propose a novel update method to maintain the ACID properties even in the above-mentioned case. It utilizes the transaction time database, which is a kind of temporal database and supports the record management on the transaction time when some fact existed in the database [4]. Hereinafter we call this method "temporal update". Moreover, we evaluate the efficiency of both the lump-sum update and online entry about the following update methods by developing prototypes: the batch update, the mini-batch and the temporal update. Based on these results, we show the database can be updated in the practical efficiency by the temporal update method, even for the update model that was challenging for the conventional methods. In addition, we show that an appropriate method has to be adopted based on the business operations, for not only the lump-sum update but also the online entry.

In Section 2, we define the lump-sum update models from the point of view of the business operations, in Section 3

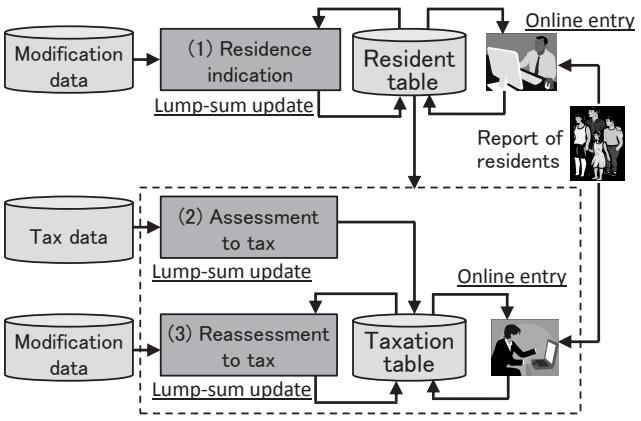



Figure 1: Business processes with lump-sum update

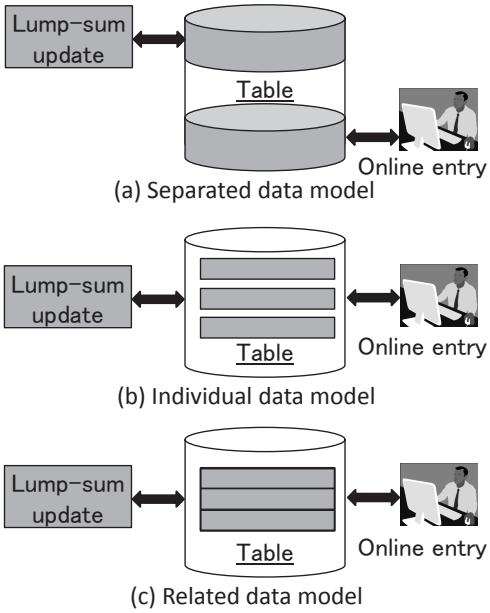



Figure 2: Lump-sum update models about business

we propose the temporal update method and in Section 4 we show the prototype to evaluate its efficiency and characteristic. In Section 5, we evaluate the update methods from the point of view of update models, and in Section 6 we show our considerations.

## 2 MODELING OF LUMP-SUM UPDATE IN MISSION-CRITICAL SYSTEMS

### 2.1 Business Process with Lump-sum Update

In the actual mission-critical systems, there are various kinds of lump-sum update processing corresponding with each business process. Figure1 shows examples of them about the tables in a local government system, which is updated also by online entries. We show the requirement of the lump-sum update based on these cases below.

Resident table of Figure1 stores the data of the resident card, which is used by the various business of the local government office for the attribute information of the resident: name, address and so on. Here, because residents belong to each household, the consistency of the resident data in the same household has to be maintained. In addition, since a series of records from birth to death and so on is managed, the consistency among the records also has to be maintained. In the online entry for this table, the change of the resident such as moving and birth is reflected in the table immediately. And, if the resident requests his or her resident card simultaneously, it is published immediately reflecting the change. On the other hand, for the example of the lump-sum update of this table, the residence indication is given. This business is performed to change addresses to be easy to understand, so it is performed in the whole target district at the same time. That is, since a great deal of data is updated for this business process, it is performed by the lump-sum update in the local government system.

Similarly, Taxation table in Figure1 saves the taxation data for the residents. There is no correlation among the data, because taxation is performed for each resident individually. Since the taxation is managed by the fiscal year, the assessment to tax is performed to add the tax data of the target year at first. Here, several tax declarations from residents are late for this assessment to taxation, and several change of resident also occur after it. So, the reassessment to tax is performed at regular interval to correct the taxation. Since these business processes are performed for a large number of residents, they are executed by the lump-sum update. On the other hand, when a resident is going to move out, taxation is calculated based on the change by the online entry at the report window of the local government office and reflected in the tax table immediately. On this basis, the settlement of tax is performed at the same time.

### 2.2 Lump-sum Update Model about Business

The lump-sum update during the online entry, which is shown in Figure1 from the viewpoint of the business processes, corresponds to the following three types of lump-sum update models from the viewpoint of the update data, which is shown in Figure2. Here, from the viewpoint of the business requirement, we assume that the online entry can update optional target data at the optional time and the update cannot be predicted beforehand. In other words, since it is the business of the report window about residents, the online entry cannot be suspended even during the lump-sum update.

(a) **Separated data model:** the case that the lump-sum updated data and online entry data are isolated as the business process. It corresponds to “(2) Assessment to tax” in Figure1. In this case, the lump-sum update can be executed without considering the online entry. As the other example of this case, there is the business process to append the budget data of the new fiscal year in accounting systems.

(b) **Individual data model:** the case that both the lump-sum update and the online entry are concurrently executed on the same data, though this data independent from the other data. It corresponds to “(3) Reassessment to

tax" in Figure1. In this case, these updates don't effect to the other data, though there are conflicts between the lump-sum update and online entry. As the other example of this case, there is the process of the account transfer in banking systems.

(c) **Related data model:** the case that both the lump-sum update and online entry are concurrently executed on the same data, which is related to the other data. It corresponds to "(1) Residence indication" in Figure1. As for the residents' information of the same household and the records of each resident, their consistency has to be maintained before and after the update. On the other hand, the change of a resident is processed by online entry: transference between households by moving, addition to a household by moving in and so on. Therefore, the lump-sum update has to be processed as a transaction that satisfies the ACID properties for online entries.

## 2.3 Problem of Conventional Lump-sum Update Method

The row lock function is provided by present database management systems, by which each single data of the table can be locked [5]. As for "(a) Separated data model" of Figure2, we can execute the lump-sum update without affecting the online entry by locking only its target data, because the target data is not covered by online entry. So, it can be executed as the transaction processing as follows: its commit is executed if the update succeeded; its rollback is executed if the update failed. In addition, in this model, the mini-batch can be used for this lump-sum update updating data sequentially, because its target data is not covered by online entry. However, in this method, when the update failure occurred, it is necessary to perform the separate compensating transaction to cancel the whole update [2].

As for "(b) Individual data model" of Figure2, the online entry becomes a waiting state when it competes with the lump-sum update, because the both update the same data. So, the lump-sum update is executed by the mini-batch, because the batch update cannot be applied by the above-mentioned requirement. This is the method to update data one after another using the row lock function, which locks the currently updated data only, and it makes the influence on the online entry smaller because the update time of the individual data is short [2]. However, it performs the commit to each update. So, even though the failure occurred and the rollback is executed, the data already committed remains in the state of having been updated. So, the committed data cannot be canceled in this method, because it might have been already used by the online entry. So, it is necessary to complete all the updates finally with removing the cause of the failure and continuing the update process.

On the other hand, as for "(c) Related data model" of Figure2, it is difficult to update data by these conventional methods. First, as for the batch update, when the target data is being tried to update by the online entry concurrently, it obstructs the online entry in the same way as the individual data model. Next, as for the mini-batch, the ACID properties cannot be maintained as the whole lump-sum update because each update is executed as the individual transaction, although its influence on the online entry is small. Therefore, as for the related data model, there is a problem that the integrity of data isn't able to be maintained by the conventional lump-sum update methods.

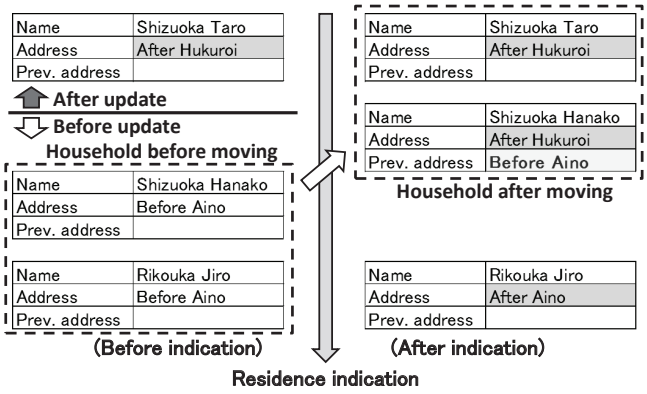



Figure 3: Online entry example of the related data model

For an example of this, we show the case of a resident transference between households by moving, during the residents indication processed by the mini-batch in Figure3. Here, the household that he or her belonged before this moving is not updated yet by the resident indication; the household after this moving was already updated. On the other hand, both of the present address and previous address are listed in the resident card. And, when this moving is processed by online entry, both of the before and after moving household data is locked by the transaction. However, because only the after moving household data has been updated, two types of addresses are listed in the resident card of this resident at the same time: the previous address is before the update; the present address is after the update. Thus, the problem that the integrity of the data isn't maintained occurs.

# 3 PROPOSAL OF A NOVEL LUMP-SUM UPDATE METHOD

For the problem shown in Section 2.3, we propose a novel update method, that is, temporal update method. It utilizes the transaction time database that is a kind of temporal database.

The relation [1] of the transaction time database is expressed as $R(K, T, D)$. Here, attribute $K$ expresses the set of attributes constituting the primary key of the snapshot queried at the designated transaction time. For the proposal method, we include in $K$ the update classification attribute $P$, which shows the kind of process that updated the data, so the configuration of $K$ is expressed by the attribute set $\{K_1, K_2, ..., K_n, P\}$. Here, n is the number of attributes except $P$. $T$ is the time period attribute of the transaction time, which is generated by the system and isn't made public to users. $T$ is expressed by the time set $\{T_a, T_d\}$: $T_a$ shows the addition time that data was added to the database; $T_d$ shows the deletion time that data was logically deleted from the database. As long as the data doesn't be deleted yet, the instance of the attribute

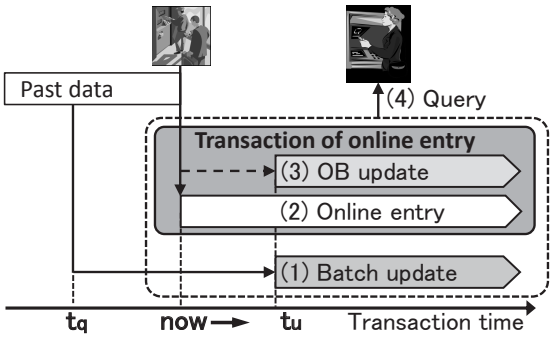



Figure 4: An example of temporal update method

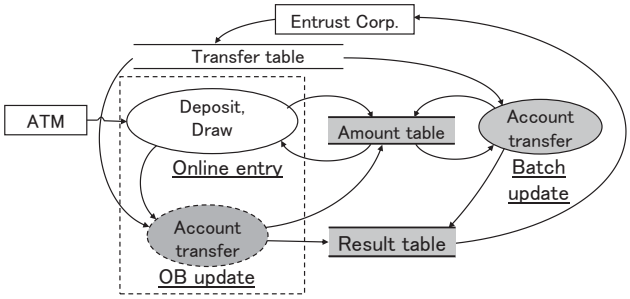



Figure 5: Dataflow of prototype

$T_d$ is expressed by "$now$", which shows the current time and changes with the passage of time [7]. And, $D$ expresses the other attributes.

In the transaction time database, the record of time that some fact was valid in the database is managed. The data once stored in the database is not deleted physically, and the time when the data became invalid is set to the $T_d$ to delete the data logically. Moreover, since records are managed, the snapshot at any designated past time can be queried.

Figure4 shows an example of this method, in which the account transfer is executed by the lump-sum update during the online entry from ATM in the banking system. Here, time period of the lump-sum update process is between $t_q$ and $t_u$. Using the transaction time database, the integrity of the snapshot result at the past time $t_q$ can be maintained even during the online entry. As shown in (1) of Figure4, we perform the account transfer by the lump-sum update on this result, and add the updated result to the database as the data which addition time is $t_u$. Here, since this data is separated from the online entry data by the above-mentioned primary key attribute $P$, we can add it by the batch update in the same way as (a) of Figure2. On the other hand, data is updated by the online entry from the ATM concurrently with this update as shown by (2). However, as shown in Figure3, since the batch update result is not reflected in the online entry, the process of the account transfer has to be executed individually in the same transaction of this online entry as shown by (3). Hereinafter, we call this process "OB update". Thus, since three types of data are added by different update process classified by $P$, the valid data is sorted out in the query process (4).

Briefly, in the temporal update, if the online entry is executed during the batch update, the process of the later is also executed individually as the OB update in the same transaction of the former. Incidentally, the OB update continues until the completion time $t_u$, because $t_u$ have to be set previously.

## 4 EXPERIMENTS

### 4.1 Composition of Prototype

To confirm that we can put the temporal update method to practical use, we constructed the prototypes of both this method and conventional methods, which are the mini-batch and batch update, and evaluated their efficiency and characteristics. The prototype intends for the processing of a banking system shown in Figure4, and we show its data flow in Figure5. That is, the withdrawals and deposits to the bank accounts from the ATM are processed by the online entry to update the balance of "$Amount\ table$". On the other hand, large amounts of the account transfers, which are ordered by the trust company, are processed by the lump-sum update. Basing on the bank account and debit of "$Transfer\ table$", this process updates the balance of $Amount\ table$ and adds its result to "$Result\ table$". Each table is expressed by the following relations. Here, $Transfer\ table$ doesn't need to be the transaction time database, because it isn't updated.

$$Amount\ table(Account, Balance, T, P)$$
$$Result\ table(Account, Result, T, P)$$
$$Transfer\ table(Account, Debit)$$

Here, each attribute shows the following data: "$Account$" shows the bank account; "$Balance$" shows the bank balance of it; "$Result$" shows the result of account transfer from the bank account; "$T$" and "$P$" shows what described above. Incidentally, the instance set of $P$ is as follows.

$$P = \{Batch\ update, Online\ entry, OB\ update\}$$

As for the bank account which account transfer is successful, $Balance$ of $Amount\ table$ is updated, and the result data is added to $Result\ table$, of which $Result$ is "0" (success). On the other hand, as for the bank account which doesn't exist or doesn't have sufficient balance, $Amount\ table$ isn't updated, and the result data is added to $Result\ table$, of which $Result$ is "1" (failure).

That is, the process of this lump-sum update was so complex that we implemented its prototype by Java, because it varies depending on the bank account presence, account balance and debit. And, we used MySQL for the DBMS (database management system); its storage engine InnoDB for transaction feature; JDBC to access the database with the row lock from Java.

We show the procedure of each lump-sum method below.

(1) **The mini-batch:** the row lock with the update mode is executed before each update of $Amount\ table$, and its commit is executed every specified update number. In this experiment, we used 1 and 80 for this number.

(2) **The batch update:** at first the row lock on all the target data with the update mode is executed; and then, the

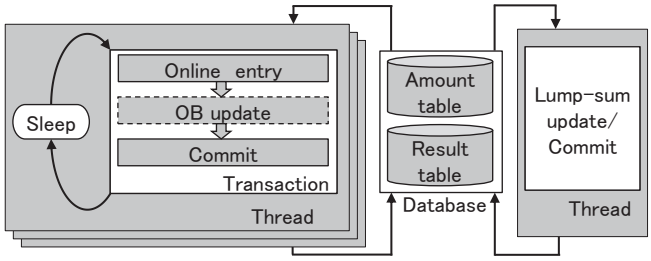



Figure 6: Program composition of prototype

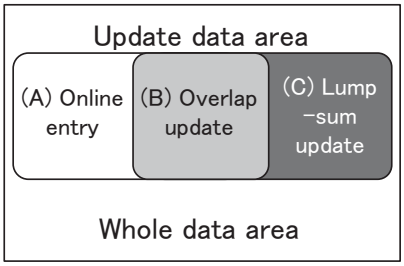



Figure 7: Evaluation data about deterioration of efficiency

lump-sum update by executeBatch statement of Java and the commit at the end are executed.

(3) **The temporal update:** though the target data isn't locked specifically before the batch update of this method, the added data is locked as the row lock until the commit by the InnoDB feature. Here, the commit is executed after the last addition. Incidentally, as shown in Figure4, the corresponding OB update is executed in the online entry transaction.

## 4.2 Experimental Environment

We performed this experiment by the Core i5 PC (Windows 7) in a stand-alone environment with MySQL5.1.40 and InnoDB. Here, we set InnoDB as follows: the isolation level is Repeatable read; "innodb_locks_unsafe_for_binlog" of startup option is "1" (enabled) to suppress the next-key lock [6].

We simulated the behavior of this prototype using thread programs of Java as shown in Figure6. That is, for the online entry, plural thread programs are executed to simulate the concurrent processing from multiple terminals. Here, the execution interval of each terminal was set to 0.5 second to simulate the load of practical environment. That is, supposing that the actual online entry interval of each terminal is 30 seconds, 16 terminals simulate the load by about 1000 terminals that are 60 times of 16 terminals. We used "sleep" method for this process. And, the commit was executed at every processing, and the OB update was also executed between the online entry and commit during the temporal update.

As the data environment, we stored 100 thousand data in $Amount\ table$, and performed 80 thousand of account transfer by the lump-sum update, such that those all succeed. On the other hand, to evaluate the deterioration of efficiency by the competition between the online entry and lump-sum update, we set the data of $Transfer\ table$ so that the data of

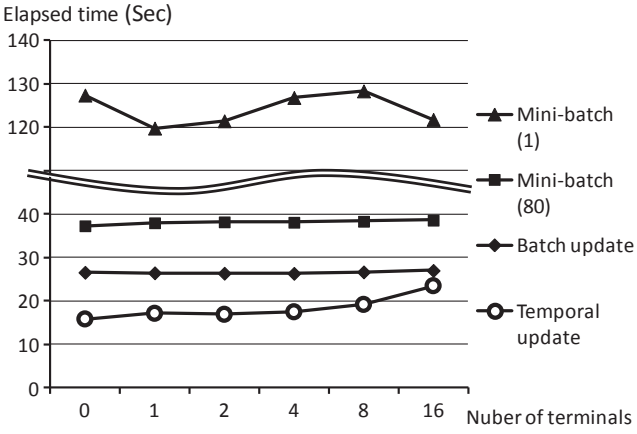



Figure 8: Elapsed times of each lump-sum update methods

Table 1: Elapsed time of lump-sum update (Sec)

| Method | No-conflict | Half conflict |
|---|---|---|
| Mini-batch (1) | 121.8 | 133.3 |
| Mini-batch (80) | 38.6 | 40.1 |
| Batch update | 27.0 | 29.0 |
| Temporal update | 23.5 | 22.4 |

$Amount\ table$ is classified as shown in Figure7 as follows: (A) updated by only the online entry, (B) updated by both of the online entry and lump-sum update and (C) updated by only the lump-sum update. We change their number based on each experimental purpose.

# 5 EVALUATIONS OF LUMP-SUM UPDATE METHODS

To evaluate the efficiency of each update method, we executed them without conflicts with the online entry, that is, there is no overlap update data area shown at (B) in Figure7. Figure8 shows their elapsed time. Incidentally, the elapsed time is not the transaction time $T$ but the real time measured by "currentTimeMillis" method of "System" class. Its horizontal axis shows the number of online entry terminals, that is, the number of thread programs executed concurrently. Here, the case that only the lump-sum update was executed is shown at "0" of the scale. As shown in Figure8, the elapsed time of the mini-batch to commit at every update (hereinafter "mini-batch (1)") is more than 3 times the mini-batch to commit at every 80 update (hereinafter "mini-batch (80)"), and it is about 5 times the batch update. In addition, the temporal update is most efficient, but the elapsed time become long gradually with increasing the number of terminals. It is considered that this is an influence of the OB update shown in Figure6, which is performed only in the temporal update process. We discuss this in Section 6.1.

To evaluate the efficiency and characteristics of the lump-sum update and online entry in the case of their conflict, we executed them as following: the number of online entry terminals is 16; 8 of them conflict with the lump-sum update

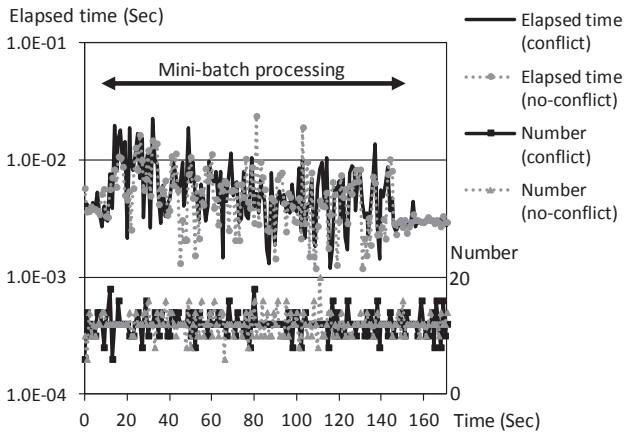



Figure 9: Efficiency of online entry during mini-batch (1)

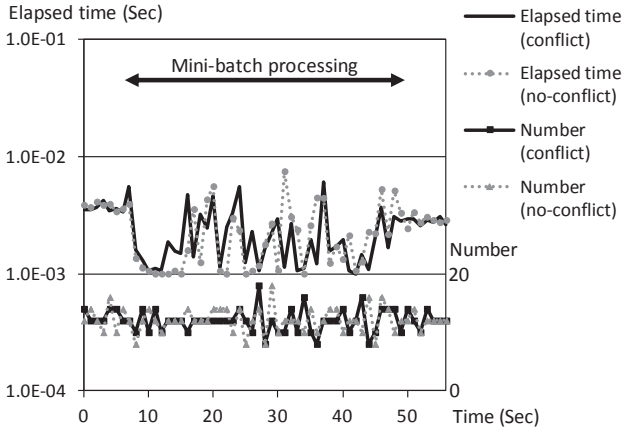



Figure 10: Efficiency of online entry during mini-batch (80)

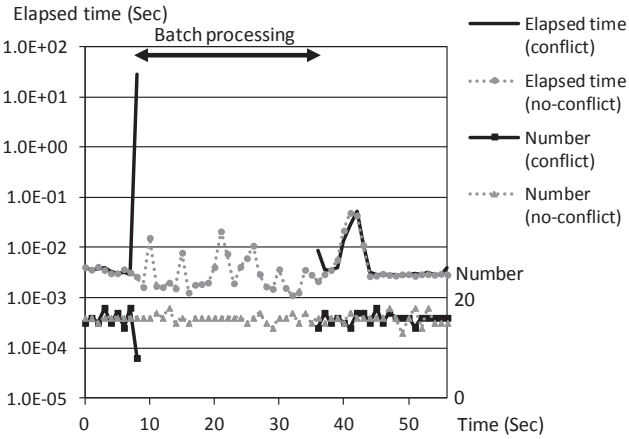



Figure 11: Efficiency of online entry during batch update

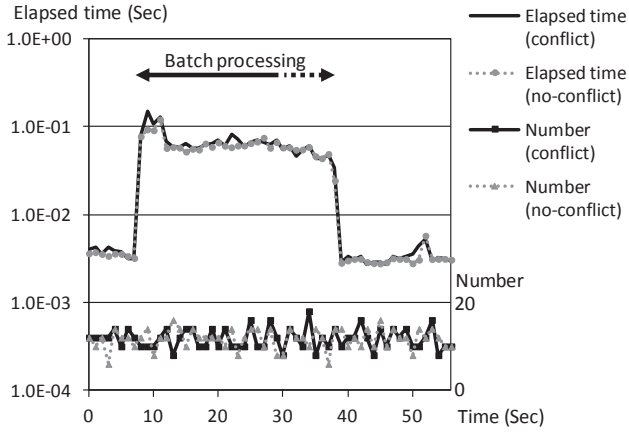



Figure 12: Efficiency of online entry during temporal update

as shown at (B) in Figure7; the other doesn't as shown at (A). As for the conflicting data, to avoid a deadlock, it was updated in ascending order of bank account by both of the lump-sum update and online entry. Table1 shows the elapsed time of each lump-sum update method in both of the following case side by side: there is no conflict as shown at (A) in Figure7, and it corresponds to the data which number of terminals is 0 in Figure8; half of the terminals cause the above-mentioned conflict. As for the temporal update, both of the elapsed time is similar, whereas the other lump-sum update methods take more time in the case of the conflict. Therefore, the elapsed time of the temporal update is also least in the case of the conflict.

Next, from Figure9 to Figure12 show the efficiency of online entries conflicting with each lump-sum update method as for both the elapsed time and number of starting transactions per second. Here, the elapsed time is the average time of the update starting at the corresponding time. The left vertical axis of each figure shows the elapsed time by the logarithmic scale and the data is divided as follows: the data of terminals with conflict; the data of the other terminals without conflict (shown "no-conflict" in these figures). Similarly, the right axis shows the number of starting transactions. In addition, these figures show the time zone of the lump-sum update. Here, the completion time $t_u$ of the temporal update is set beforehand and the OB update continues until $t_u$. So, the time zone of the batch update is shown by the solid line; the OB update after it is shown by the broken line.

The elapsed time of online entries is fluctuating during the execution of the mini-batch or batch update, and it is least in the mini-batch (80) update. On the other hand, as for the batch update, the online entry conflicting with it is waited until its completion. As for the temporal update, though no online entry waited for a long while, the elapsed time of online entry transactions including the OB update became more than 10 times. On the other hand, for the same reason, elapsed time fluctuations of the online entry are smaller than the other methods.

Table2 shows the evaluation about the lump-sum update models shown in Figure2. There are constraints of lump-update method that can be applied to each model as shown in Section 2.3. As mentioned above, as for the separated data model and individual data model, the mini-batch (80) gives the least impact to the online entry. However, since it cannot be applied to the related data model, the temporal update method has to be applied to this model. Moreover, the elapsed

Table 2: Evaluations about lump-sum update model

| Lump-sum update model | Online entry elapsed time | Lump-sum update elapsed time | Available method about the model |
|---|---|---|---|
| Separated data model | MB (80) | T | MB, B, T |
| Individual data model | MB (80) | T | MB, T |
| Related data model | T | T | T |

(Notes) MB: Mini-batch; B: Batch update; T: Temporal update

time of the lump-sum update was least in the temporal update method in the case of this simulation.

# 6 CONSIDERATIONS

In the actual mission-critical system, it is expected that there are various kinds of system operations and restrictions about both of the lump-sum update and online entry. In this section, we discuss the temporal update method based on the evaluation result in Section 5.

## 6.1 Efficiency of Temporal Update Method

The temporal update had the highest efficiency about the elapsed time of the lump-sum update in the above-mentioned experiment. The reason for this is because only the insertion of data is executed in the temporal update, whereas the batch update executes querying of the data to update it. And, since the commit is executed collectively after updates in the temporal update, the increase of the load by the commit was suppressed as well as the batch update comparing with the mini-batch. Moreover, as for the temporal update, the updated data isn't queried until the completion time $t_u$ even if its commit is executed. So, in the case that the target data is increased, its update process can be executed one after another of dividing set with maintaining the ACID properties. That is, even in the case of extremely large number of updates, it is possible to apply the temporal update by executing them one after another.

In addition, the temporal update maintains its efficiency even in the case of conflict with the online entry as shown in Table1, whereas there are declines in the other methods. Its reason is because the other update methods have to wait for the lock completion of the online entries, whereas the temporal update method executes only the data insertion that doesn't need to lock them. By the way, since the online entry in the actual system operations updates data randomly, it often causes the deadlock with the batch update or mini-batch (80). In contrast, the temporal update has an advantage to suppress deadlocks, because it doesn't lock the data specifically.

On the other hand, the elapsed time of the temporal update become longer with the increase of the online entry terminals as shown in Figure8. As mentioned above, there isn't the conflict between the lump-sum update and online entry. So, this is considered to be caused by the load of the OB update. Since this process is executed only during the lump-sum update, it has incidental processing such as monitoring the progress of the lump-sum update. And, we consider its adjustment is the future challenge, because it is expected that the increase of terminals cause the further deterioration of the elapsed time.

Here, as for the temporal update method, its completion time needs to set beforehand, so a margin is necessary for it. On the other hand, it is considered to be effective even for the other models than the related data model from the view point of efficiency. For example, the update that has to be processed in a short time, which processing time can be estimated beforehand. In other words, the appropriate update method should be selected based on the business requirements.

## 6.2 Online Entry Method

Since the OB update is executed in the temporal update, the online entry takes longer time than in the mini-batch as shown in Figure12. Though the adjustment of this part is the future challenge as mentioned above, this time is within about 0.1 seconds, which is different from the wait time for the lock in the batch update as shown in Figure11. Therefore, it is considered that we can apply it to actual mission-critical systems within a certain range of load even under the present condition.

As for the mini-batch (80), since it updates the plural data collectively, the online entries have to complete in a short time. That is, when its target data is locked by an online entry, its update process has to wait with locking the other data updating collectively. So, the other online entries that try to update these data also become to wait. That is, there is the problem that the conflict causes the other online entry to stop. Therefore, the online entry transaction cannot include the processing that needs a long while, such as waiting for user input. This problem is similar as for the temporal update, because the data updated by the batch update become to be valid at the completion time $t_u$ as shown in Figure4. That is, the following updates have to be serialized: the online update before $t_u$, the validation of the batch update and the online update after $t_u$.

Therefore, based on the requirement of the target business, the appropriate method has to be selected for not only the lump-sum method but also the online entry. For example, as for above-mentioned case, there are some choices. As for the mini-batch (1), it is appropriate for the case where the various kinds of online entry methods are used though the restriction on the lump-sum update time is loose. On the other hand, if the online entry time is short, the appropriate lump-sum method can be selected based on the requirement of the business: efficiency, the lump-sum update models and so on. Incidentally, the batch update is not appropriate for the case

of conflict with the online entry as shown in Figure11.

## 7 CONCLUSION

With the spread of nonstop online services caused by the development of the internet business, the lump-sum update has to be executed concurrently with the online entry in the mission-critical systems. In this paper, first, we showed the lump-sum update model from the view point of the businesses of mission-critical systems, and showed that the conventional update methods have the problem in the case to update data relating to each other. Second, we proposed the temporal update method for this problem, and showed it has the practical efficiency through the evaluations by the prototype. Third, we showed that it is necessary to select the appropriate method for both of the lump-sum update and online entry, based on the evaluations including both the proposal method and conventional methods.

Future study will focus on the implementation method of the temporal update for the actual mission-critical system, especially the improvement of the online entry response.

## ACKNOWLEDGMENT

This work was supported by KAKENHI(24500132).

## REFERENCES

[1] E. F. Codd, Extending the database relational model to capture more meaning, ACM Trans. on Database Sys., Vol. 4, No. 4, pp. 397–434 (1979).

[2] J. Gray, and A. Reuter, Transaction Processing: Concept and Techniques, Morgan Kaufmann, San Francisco (1992).

[3] T. Kudo, Y. Takeda, M. Ishino, K. Saotome, K. Mutou, and N. Kataoka, A Correction Reflected Query Method of Database during Online Entry, International Journal of Infomatics Society, Vo3. 1, No. 1, pp. 3–11 (2011).

[4] R. Snodgrass and I. Ahn, Temporal Databases, IEEE COMPUTER, Vol. 19, No. 9, pp. 35–42 (1986).

[5] ORACLE, MySQL Documentation: MySQL Reference Manuals, http://dev.mysql.com/doc/refman/5.5/en/index.html.

[6] ORACLE, MySQL Documentation: MySQL Reference Manuals (14.3.9.4. InnoDB Record, Gap, and Next-Key Locks), http://dev.mysql.com/doc/refman/5.5/en/innodb-record-level-locks.html.

[7] B. Stantic, J. Thornton, and A. Sattar, A Novel Approach to Model NOW in Temporal Databases, Proc. 10th International Symposium on Temporal Representation and Reasoning and Fourth International Conference on Temporal Logic, pp. 174–180 (2003).

# Seamless Application Push with Secure Connection

## - System to realize effective usage of smart devices for business class sustainability -

Yosuke Nakamura*, Kazuaki Nimura* , Hidenobu Ito*, and Nobutsugu Fujino*

*Fujitsu Laboratories Ltd.
4-1-1, Kamikodanaka, Nakahara-ku, Kawasaki, Japan
{nkmr, kazuaki.nimura, itou.hidenobu, fujino}@jp.fujitsu.com

***Abstract*** – It is desired to do a job equally in and out of the office for using Application Push. Here, notification of push should be reached on a smart device even if the device is on the difference network domain. In addition, because a push gateway which issues a notification deals privacy sensitive data and the application server stores applications including confidential data, those data should not be placed on the Internet. Therefore, when the smart device downloads an application from the Internet, a secure connection to company's intranet would be required. It is also required that notification is received even while using the secure connection.

In this paper, we propose architecture of seamless application push which enables to send notification to the smart device regardless of whether it is on the Internet or intranet. Then we implement the architecture using Android smartphone and server. From the evaluation, we confirmed that it could realize the seamless push and the required time through intranet the longest path was reasonably low number; 157.4 [msec].

***Keywords***: Android, smart device, VPN, intranet, seamless push

## 1 INTRODUCTION

In today's rapidly expanding smart devices [1], such as smartphones and tablets, both consumer and company have been replacing their devices with them. However, users sometimes waste much time to set up such kind of devices when they use them. In order to solve the issue, we proposed "Application Push & Play (APnP)" which is a concept of dynamic installation and execution of applications without user operation for the smart devices in IWIN2011 [2] and expanded the concept with secure manner [3]. Notification of push is the baseline technology then the smart device connects to a push gateway (P-GW) with Transmission Control Protocol (TCP) session and during continuity of the session, the smart device can receive a notification of push [4]. A URL of allocated application is transmitted using the notification of push message. After receiving the push message, the smart device downloads the application indicated by the specified URL.

The system works well under the situation where both smart devices and servers which consist of the P-GW to send notification of push and an application server to store application are on the same network domain.

Considering business usage, it is desired to do a job equally in and out of the office. In this case, notification of push should be reached on the smart device even if it is on the difference network domain, In addition, the P-GW deals privacy sensitive data such as an identifier and password of servicers; those data should not be placed on the Internet. i.e. it is required that the P-GW placed on the Internet has not private data.

Meanwhile, the application server should not be placed on the Internet as well because business applications include confidential data. Therefore, when the smart device downloads an application from the Internet, a secure connection to company using such as Virtual Private Network (VPN) [5] would be required in order to connect to the intranet. It is also required that notification of push is received even while using VPN.

## 2 RELATED WORKS

Android Cloud to Device Messaging (C2DM) [6] is a service that sends data from servers to their applications on Android devices. However it does not deal the business usage. In addition, a Google Account is required to use the C2DM. Sometimes it may not be preferable because some companies do not allow to use the dedicated account for business.

Mobile IP [7] is the network protocol that can transfer packets with the same IP address even if the device of destination moved to another network domain. There are two types of protocol: Mobile IPv4 [8] and Mobile IPv6 [9]. In the definition of Mobile IP, Home Agent is located on the same network domain of a sender and Foreign Agent is on the same network domain of a receiver. A packet is capsuled between Home Agent and Foreign Agent and able to be sent to the receiver even if it were located on different network domain. However, a research pointed out two issues of current Mobile IP that would be obstacle of its wide usage [10]. One is the provision of Home Agent that the network environment around it faces some difficulties and another is the conflict with the current internet security mechanisms such as firewalls [11]. In addition, another reason the mobile IP is not suitable for introducing is because it is implemented in network layer 3 that requires dedicated network switch.

# 3 PROPOSED ARCHITECTURE

In this section, we summarize the requirements that described in section 1 and show proposed architecture that meets the requirements.

The proposed architecture is realized in application layer, so that it can avoid the investment on network devices for mobile IP.

## 3.1 Requirement

The requirements to realize the system are summarized as follows:

(a) The smart device should receive a notification of push regardless of whether it is on the Internet or intranet.

(b) The smart device should be able to receive a notification even VPN connection is established.

(c) Both the confidential data and the private data should not be stored on the Internet.

## 3.2 Architecture

We propose architecture of seamless application push which enables to send notification of push to the smart device whether it is on the Internet or intranet.

The architecture of the system is shown as Figure 1.

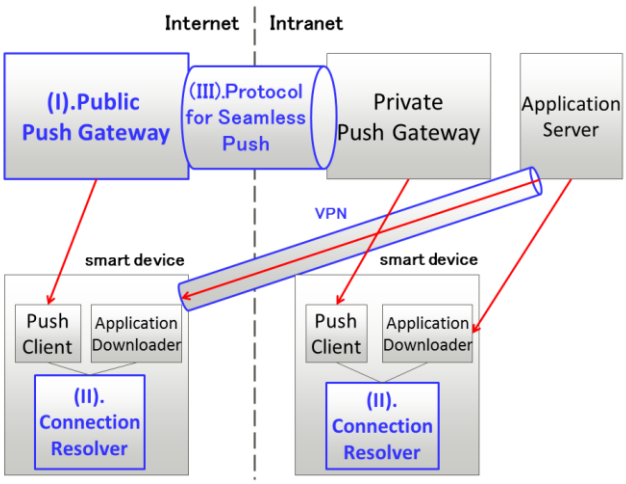



Figure 1: Architecture of Seamless Application Push

The following components are defined in APnP [2]. However, the usage in this system is a little bit different from the conventional usage.

- Private P-GW is equivalent to conventional P-GW. Private P-GW is located on the intranet and accepts the connection from Push Client, receives a request of push, and sends notification of push to smart devices. Private data such as user information and push message is stored in Private P-GW.
- Application server stores applications and is located on the intranet.
- Push Client is a function resides in the smart device that connects to the P-GW with TCP session, receives notification of push, and is transmitted the URL of application by a notification. It extracts the URL from the notification if the notification requested to download application and the extracted is passed to the Application Downloader.
- Application Downloader is a function resides in the smart device and downloads the application from the application server based on the URL.

The proposed architecture has additional three new features as follows:

(I) Public push gateway is placed on the Internet in addition to the private P-GW that manages the connection to the smart device and notifies a push message. The Public P-GW is the shrink version of the private P-GW that especially eliminates privacy related data.

(II) Connection resolver identifies whether the network of the smart device is connected to the Internet or intranet and switches the connection to the public P-GW or private P-GW. In addition, the connection resolver establishes VPN connection to the intranet if necessary. When the smart device is on the intranet, it decides that the Push Client should connect to the Private P-GW without establish VPN connection to download an application. On the other hand, when the smart device is on the Internet, it decides that the Push Client should connect to the Public P-GW and it makes the VPN Client to establish VPN connection to download an application.

(III) Protocol for seamless push is used to synchronize the state of the private P-GW and public P-GW to maintain the consistency.

To meet the requirement (a), the system should have the feature (I), (II), and (III). The smart device connects to the public P-GW when located on the Internet and the private P-GW when located on the intranet [feature (I)]. The Connection Resolver detects where the smart device is and identifies which P-GW it should connect to [feature (II)]. If the smart device is located on the Internet, the Private P-GW receives a request of push and forwards to the Public P-GW [feature (III)].

To meet the requirement (b), the system should have the feature (I) and (II). When the smart device is located on the Internet, the connection resolver is responsible for establishing the VPN connection. Once VPN connection is established, the connection resolver asks the push client to switch to the connection to the Private P-GW. After VPN connection is terminated, the connection resolver asks the push client to switch back to the connection to the Public P-GW.

To meet the requirement (c), the system should have the feature (I) and (III). Private data are required to send the request of push, however the Public P-GW should not store them and should not have the interface to register them. Then the private P-GW receives the request and forwards it to the public P-GW by the protocol for seamless push. In addition, the Private P-GW has the delivery status of push, on the other hand, the Public P-GW should not have them because the delivery status includes privacy information. So the Public P-GW needs to inquire the status to the Private P-GW.

# 4 IMPLEMENTATION

In this section, we describe the components, protocols, and workflows for the implementation of the proposed system.

## 4.1 Components

Figure 2 shows the implementation of proposed system.

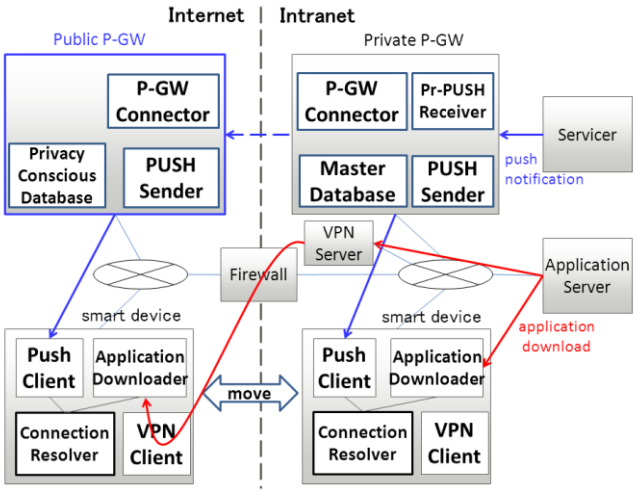



Figure 2: Implementation of proposed system

The system consists of the following components; Private P-GW, Public P-GW, Application Server, VPN Server, and smart device. The Private P-GW, the Application Server, and the VPN Server are located on the intranet. The Public P-GW is located on the Internet. A smart device moves between the Internet and intranet.

The Private P-GW consists of four components.

Private Push Receiver (Pri-Push Receiver) receives a request of push and an inquiry whether a smart device connects to the P-GWs or not from a servicer. In case of the request of push, Pri-Push authenticates the servicer and checks whether destination address is pre-registered. In case of the inquiry, Pri-Push checks whether the smart device is connected.

Push Sender is an access point of Push Client when the smart device is on the intranet. While Push Client connects to the Push Sender, the smart device can receive notification of push. It authenticates the smart device to prevent evil device's connection. It also encrypts communication with Secure Socket Layer (SSL) to protect notification of push [12].

P-GW Connector handles the protocol for seamless push. About the protocol and its usage, see Protocol for Seamless Push in 4.2 and workflow on the Internet in 4.3.

Master Database manages the private data such as the registered identifier and password for the servicer, the destination address which the Private P-GW assigned to the smart device, and message queue including confidential data such as the URL of in-house application required sending push. These data should be stored only in the Private P-GW. The Pri-Push Receiver, Push Sender and P-GW Controller handle notification through Master DB.

The Public P-GW consists of three components.

Push Sender is an access point of Push Client when the smart device is on the Internet. It has the same function with the Private P-GW.

Privacy Conscious Database is a database that is removed private data from Master DB and manages only the connection information of smart devices to send notification of push.

P-GW Connector has the same functions as the Private P-GW's one.

The smart device has four components for handling push.

VPN Client manages to establish and disconnect a VPN connection by the direction from the Connection Resolver. In order to direct to establish and disconnect a VPN connection from the Connection Resolver, it is required to be able to receive the direction from other applications.

Connection Resolver has registered SSIDs of access point on the intranet in advance. When the smart device connects to the network, the connection resolver checks the type of connection. For example, if the connection is 3G or LTE, the connection resolver identifies the smart device is on the Internet. If the connection is Wi-Fi, check the SSID of AP and confirm whether the SSID was registered, then the connection resolver identify the smart device is on the intranet. Otherwise, consider on the Internet. In case of the intranet, it requests to establish VPN connection to VPN client.

As for Push Client and Application Downloader, see section 3.2.

## 4.2 Protocol for Seamless Push

Table 1 shows the protocol for seamless application push conveyed by HTTP POST. Because generally a firewall blocks most communications such as the TCP session of customer-defined, then we use the HTTP protocol that is typically permitted at the firewall.

## 4.3 Workflow of proposed system

In this section, we explain the workflow of proposed system in four situations: the smart device is on the intranet, on the Internet, unconnected to the network, and connect to the Internet.

Firstly, the workflow on the intranet is as follows:

Step 1 to 3 shows the connection establishment between the smart device and the Private P-GW, step 4 to 8 shows the send of notification of push, and step 9 to 13 shows downloading and executing an application.

Table 1: Protocol for seamless application push

| protocol | description | source | destination |
|---|---|---|---|
| FORWARD | Forward notification of push from the Private P-GW to the Public P-GW. The Public P-GW only accepts FORWARD command from the Private P-GW. | Private P-GW | Public P-GW |
| FORWARD _SUCCESS | If notification of push to the smart device completes, the public P-GW replies FORWARD_SUCCESS to the private P-GW. | Public P-GW | Private P-GW |
| REQUEST_ RESEND | In order to resend notification when the smart device connects to the Public P-GW, the inquiry to the Private P-GW is issued to check whether resent of notification of push to the smart device which is needed to connect to the Public P-GW is stored or not in the Private P-GW. | | |

1. The smart device gets IP address assigned by DHCP server of the Wi-Fi access point of intranet.
2. The Connection Resolver detects the network of the smart device is on, once connection to the intranet established and notifies the destination P-GW, in this case Private P-GW, to the Push Client.
3. The Push Client connects to the Push Sender on the P-GW based on the notification. The addresses of the Private P-GW are set in advance. Then the connection between the smart device and the Private P-GW is completed and the smart device is able to receive notification of push. If the connection is closed, the message queues then resent to the smart device automatically.
4. A servicer requests the Pri-Push Receiver to send a notification of push. The message includes the URL of the target application and the identifier of the destination smart device.
5. The Pri-Push Receiver authenticates the servicer and confirms whether the destination smart device connects to the Private P-GW or not. If the smart device has the connection, notification of push is sent to the Push Sender.
6. The Push Sender on the Private P-GW searches the TCP session to the destination smart device and sends notification of push through the TCP session.
7. The Push Client on the smart device replies acknowledgement of notification of push to the Push Sender.
8. The Push Sender changes the delivery status of push to "SUCCESS". Then, the send of notification is completed. If the Private P-GW had not been able to receive the acknowledgement, the notification would be kept in the message queue in the Master DB. This message will be resent when the smart device connects to either the Private P-GW or Public P-GW.
9. The Push Client identifies the type of notification of push and if it is a download request, extracts the URL of application then passes the URL to the Application Downloader.
10. The Application Downloader asks to the Connection Resolver whether the Downloader is able to download the application or not.
11. The Connection Resolver replies to the Application Downloader that the application server is on the intranet and the Downloader is able to download.
12. The Application Downloader starts to download the application to non-volatile memory.
13. The application is executed after downloading.

Secondly, the workflow on the Internet is as follows:

In this case, the workflow of sending notification of push and downloading application is explained separately because the smart device establishes VPN connection in order to download application from application server on the intranet. The smart device can receive notification even if the smart device is establishing VPN connection.

At first, the workflow of sending notification is as follows:

Step 1 to 3 shows the connection establishment between the smart device and the Public P-GW and step 4 to 10 shows the send of notification.

1. The smart device gets IP address assigned by Internet Service Provider.
2. The Connection Resolver detects the network of the smart device is on once connection to the Internet established and notifies the destination P-GW, in this case Public P-GW, to the Push Client.
3. The Push Client connects to the Push Sender of the Public P-GW. The address of Public P-GW is set in advance. Then the connection between the smart device and the Public P-GW is completed and the smart device is able to receive notification of push.
4. A servicer requests to send a notification of push to the Pri-Push Receiver.
5. The Pri-Push Receiver authenticates the servicer and confirms whether the destination smart device connects to the Private P-GW or not. Because the smart device does not connect to the Private P-GW, the message is queued in the Master DB, then delivery status of push is set to "Resend is necessary", and the notification is passed to the P-GW connector.
6. The P-GW connector forwards the notification to the Public P-GW by the "FORWARD" protocol.
7. The Pub-Push Receiver receives notification and confirms whether the destination smart device connects to the Public P-GW or not. Because the smart device connects to the Public P-GW, notification is sent to the smart device via the Push Sender.
8. The Push Client replies an acknowledgement of notification of push to the Push Sender.
9. The Push Sender makes the P-GW connector to deliver the success of push to the Private P-GW by the protocol "FORWARD_SUCCESS" after receiving the acknowledgement.

10. The P-GW connector of the Private P-GW receives ”FORWARD_SUCCESS” and changes the delivery status of push to “SUCCESS”. Then the send of notification is completed.

Next, the workflow of downloading application is as follows:

This workflow starts after sending notification of push (No.10 on the Internet). It explains how the smart device can receive notification during establishment of VPN connection.

11. The Push Client identifies the type of notification and if it is download request, extracts the URL of application then passes the URL to the Application Downloader.
12. The Application Downloader applies to the Connection Resolver whether the Downloader is able to download the application or not.
13. The Connection Resolver judges whether VPN connection is required to download the application or not. Because the smart device is located on the Internet, it judges that VPN connection is required. Continue to the workflow on the Internet with VPN connection to the intranet.
14. The Connection Resolver judges that VPN connection is required and connects to the intranet via VPN by calling the VPN Client. After establishing, it notifies the destination P-GW, in this case Private P-GW, to the Push Client and replies to be able to download the application to the Application Downloader.
15. The Push Client connects to the Push Sender on the P-GW based on the notification. Therefore, the smart device can receive notification of push even if the VPN connection is established to the intranet.
16. The Application Downloader downloads the application then stores it in non-volatile memory of the smart device. After downloading, the Application Downloader passes the completion of the download to the Connection Resolver.
17. The Connection Resolver disconnects VPN connection by calling the VPN Client. After disconnecting, it notifies to the destination P-GW, in this case Public P-GW, to the Push Client.
18. The Push Client connects to the Public P-GW, and then finally the application is executed.

In this case, the smart device on the Internet can receive notification of push without storing private data in the Public P-GW even when the VPN connection is established to the intranet. The Push Client can always connect to the either P-GW by applying the destination P-GW to the Connection Resolver each time switching the network.

Thus, the smart device can receive notification of push both connecting to the intranet and Internet even when the VPN connection is established to the intranet.

Thirdly, the workflow when the smart device is unconnected is as follows:

1. A servicer requests the Pri-Push Receiver to send a notification of push without any network connection to the destination smart device.
2. The Pri-Push Receiver confirms whether the destination smart device connects to the Private P-GW or not. Because the smart device does not connect to the Private P-GW, the notification is queued in the Master DB and delivery status of push is set to “Resend is necessary”. Then, the notification is forwarded to the Public P-GW by the “FORWARD” protocol.
3. The Pub-Push Receiver receives the notification and confirms whether the destination smart device connects to the Public P-GW or not. Because the smart device does not connect to the Public P-GW, notification is deleted in the Pub P-GW in order to prevent the divulging by attack. But notification is queued in the Pri P-GW, so notification will be able to be resent when the destination smart device will connect to the P-GW.

Finally, the workflow the smart device connects to the network is as follows:

In this case, it explains how the message is resent to the destination device. The case of connection to the intranet is not described because the Pri P-GW can solve itself.

1. The smart device connects to the Internet and the Push Client connects to the Pub P-GW when notification of push is queued in the Pri P-GW.
2. The public P-GW inquires whether resent notification exists or not by the protocol of “REQUEST_RESEND”.
3. The Pri P-GW checks whether the resend queue exists or not. The notification of push in resend queue is forwarded to the Pub P-GW by the “FORWARD” protocol because the resend queue exists in this case.
4. The Pub-Push Receiver receives notification and confirms whether the destination smart device connects to the Public P-GW or not. Because the smart device connects to the Public P-GW, notification is sent to the smart device via the Push Sender.
5. The Push Client replies an acknowledgement of notification of push to the Push Sender.
6. The Push Sender makes the P-GW connector to deliver the success of push to the Private P-GW by the protocol “FORWARD_SUCCESS” after receiving the acknowledgement.
7. The P-GW connector of the Private P-GW receives ”FORWARD_SUCCESS” and changes the delivery status of push to “SUCCESS”. Then the send of notification completes.

In this case, notification of push is queued in the Pri P-GW even if the smart device is unconnected and resent when the smart device connects to the Pri P-GW or Pub P-GW.

Thus, our method can guarantee the smart device receives notification of push not only smart device is on the intranet or Internet but also the smart device is unconnected to the network temporarily.

# 5 EVALUATION

In this section, we show the hardware, software, and network environments used for evaluate the system and the performance of notification of push.

## 5.1 Qualitative Evaluation

At first, we compare the proposed system with the conventional push system. The proposed system has two advantages to the conventional push system. One is capability of seamless push as described in Table 2.

Table 2: Capability of seamless push

| | **intranet, include via VPN** | **Internet** |
|---|---|---|
| **Proposed system** | OK: refer in section 4.3 | OK: refer in section 4.3 |
| **Conventional push system on the intranet** | OK | NG: *1 |
| **Conventional push system on the Internet** | NG: *2 | OK |

*1: VPN connection is always required.
*2: The port used by the conventional push is required to open in firewall.

OK shows the smart device can receive notification of push without VPN connection and a setting of the firewall between the intranet and Internet for using the push. And NG shows cannot receive.

The proposed system achieves that a smart device receives notification of push regardless of whether it connects to the Internet or an intranet. Even when it connects to the intranet via VPN, the connection resolver switches to connect the private P-GW. Meanwhile, the smart device cannot receive notification across the networks by using the conventional push system.

Another advantage is protection of both confidential data and private data as described in Table 3.

Table 3: protection of data

| | **intranet** | **Internet** |
|---|---|---|
| **proposed system** | OK: see Master DB in section 4.1. | OK: see Privacy conscious DB in section 4.1. |
| **Conventional push system on the intranet** | OK: *1 | NG: *2 |
| **Conventional push system on the Internet** | NG: *2 | NG: *3 |

*1: DB stores private data, but DB is on the intranet.
*2: A notification of push is not receivable.
*3: DB stores confidential and private data.

OK shows that the system fulfills both requirements that one is confidential data and private data are not stored on the Internet and another is the smart device can receive notification of push both on the intranet and Internet.

NG shows that the system cannot fulfill either.

The proposed one allows that both confidential data and private data are only stored in the intranet. While using the conventional push system as it is, a smart device cannot receive notification of push on the Internet without storing private data on the Internet.

## 5.2 Quantitative Evaluation

We measure delivery time of push from an application server to a smart device that may affect the user experience. In order to evaluate the system, each component shown in Section 4 is operated on the following hardware:

Private P-GW, Public P-GW and Application Server:

- ✧ Fujitsu LIFEBOOK E-8290 is used as the Private P-GW. It has Intel Core2Duo processor T9600 2.80GHz, 4GB of main memory and 160 GB HDD.
- ✧ Cent OS 6.2 [13] is used as the OS. For the Pri/Pub-push receiver and P-GW controller, apache and Java Application Server (tomcat) is used. On the top of the Java Application Server, the Pri/Pub-push receiver and P-GW controller are placed as a servlet. For the Push sender, C-based program handles the communication with the PC. Between the three functions, those are communicating with a socket. For Database, MySQL is used. The application server is a general web server. Apache and Java Application Server (tomcat) is used.

Smart device:

- ✧ Fujitsu F-10D [14] is used as the smart device. It has 1.5 GHz Quad Core and is installed Android4.0 which supports VPN Client API [15]. Android native applications such as the Connection Resolver can control to establish and disconnect VPN connection by VPN Client API.
- ✧ Push Client, Application Downloader, Connection Resolver, and VPN Client are made as Android native application with Java.

VPN Server:

- ✧ Fujitsu LIFEBOOK A550/A is used as the VPN server. It has Intel Core i5 processor 540M 2.53GHz, 4GB of main memory and 128 GB Solid State Disk. Fedora is used as the OS.

Figure 3 shows the network environment of the evaluation.

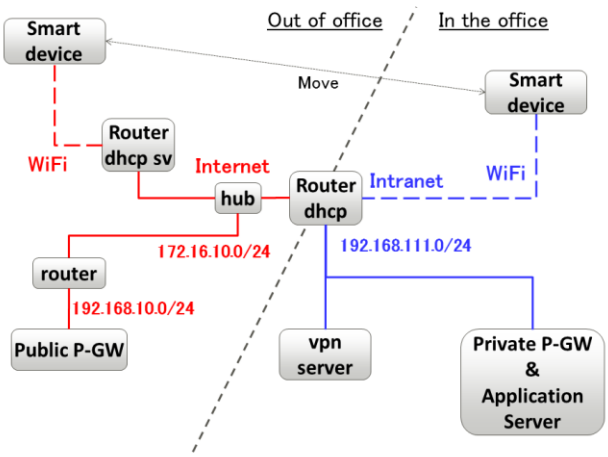



Figure 3: Network environment

It has two network segments. One is treated as the intranet and the address is 192.168.111.0/24. The other is as the Internet and the address is 192.168.10.0/24. Other than the HTTP for the protocol of the seamless push, it cannot transmit between the two networks. For the P-GWs, servers and smart device, refer to the hardware of the above. The information of network devices is as follows:

Router dhcp:

- ✧ WN-G54/R3 is used as the router dhcp. It supports 100Base-TX/10Base-T as a LAN and 802.11b/g as a wireless LAN. It supplies an IP address of the intranet to the servers and the smart device as DHCP server and is assigned the IP address of the Internet from the Router dhcp sv. Only HTTP request from the Public P-GW to the Private P-GW is accepted.

Router dhcp sv:

- ✧ Aterm WM3400RN is used as the router dhcp sv. It supports 100Base-TX/10Base-T as a LAN and 802.11n/b/g as a wireless LAN. It supplies an IP address of the Internet to the router dhcp, the Public P-GW and the smart device.

Router:

- ✧ Aterm LAN-W150N/RSPS is used as the router. It supports 100Base-TX/10Base-T as a LAN and 802.11n/b/g as a wireless LAN. It supplies an IP address to the Public P-GW. HTTP request from the Private P-GW to the Public P-GW and the TCP session from the smart device on the Internet are accepted. Although the Public P-GW can connect to the Internet directly, the buffer such as DMZ is commonly prepared for the server on the Internet. Therefore, we used the router.

Hub:

- ✧ FXG-05IMV is used as the hub which is used to increase the number of ports on the Internet.

Firstly, we evaluate the validation of the system by the delivery time of push when the smart device is located on the Internet. Table 4 lists the result of the delivery time of push both on the intranet and Internet when the servicer requests a thousand time of push.

Table 4: Lists of delivery time of push

| | Delivery time on the intranet [msec] | Delivery time on the Internet [msec] |
|---|---|---|
| **Average** | 104.9 | 157.4 |
| **Max** | 391.0 | 387.0 |

In the case of on the Internet, an average of time is 157.4 [msec] and a maximum time is 387.0 [msec].

Considering a usage of APnP described in section 6.1, applications download comes with the service. A download of application may take several seconds on the Internet using 3G connection. However the delayed time is about 150[msec] and it has small impact comparing with the time of the download. Therefore, it can be concluded that the delay of the delivery time is acceptable.

Secondly, in order to evaluate a performance of Public P-GW, we compare the receipt time of notification between on the Internet and intranet. In Table 3, an average of time is 104.9 [msec] on the intranet and the result of the Internet is inferior to the intranet for 52.5 [msec]. Because the Public P-GW is added to the communication path on the Internet, the increase of a delivery time of push is assumed. In order to verify whether the Public P-GW causes the increase or not, we measure the processing time of the Private P-GW, Public P-GW and communication when sending a push. Figure 4 shows the result of processing time and table 5 lists the result.

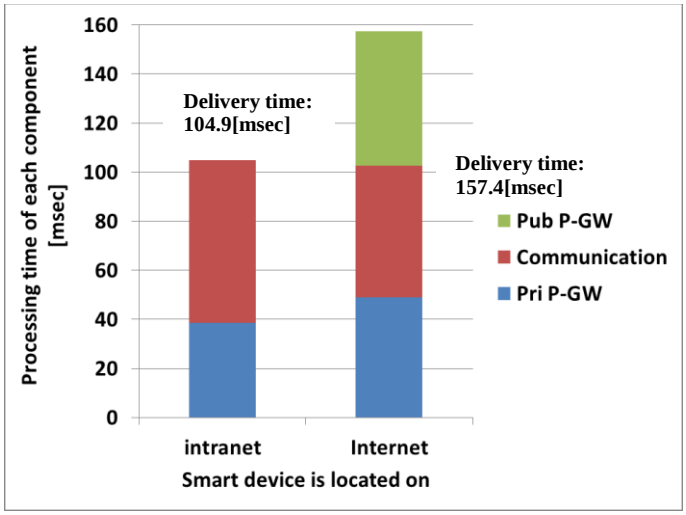



Figure 4: Processing time of each component

Table 5: Lists of processing time

| | Processing time on the intranet [msec] | Processing time on the Internet [msec] |
|---|---|---|
| **Pri P-GW** | 38.6 | 49.1 |
| **Communication** | 66.3 | 53.4 |
| **Pub P-GW** | - | 54.9 |
| **Total** | 104.9 | 157.4 |

The result shows that the sum of the performance of the Private P-GW and communication is almost equal between the intranet and Internet. Therefore, the measurement result

of the Internet shows to add the processing time of the Public P-GW to the result of the intranet and it is as expected.

From these results, the performance of push is sufficient to be functioned APnP and the structure of the proposed system and the Public P-GW is appropriate in terms of the delivery time of push.

# 6 USE CASE

## 6.1 Use Case of Seamless Application Push

Figure 5 shows an example for use case of Seamless Application Push. In this case, applications delivered with APnP are an editor of presentation file in the intranet and a viewer of presentation file in intranet or Internet. In this scenario, a use only on the Internet is not assumed. A user can make a presentation file only on the intranet using the editor and the user can view a presentation file in intranet or Internet. If the user views the presentation on the Internet, the file is downloaded via VPN from a server on the intranet.

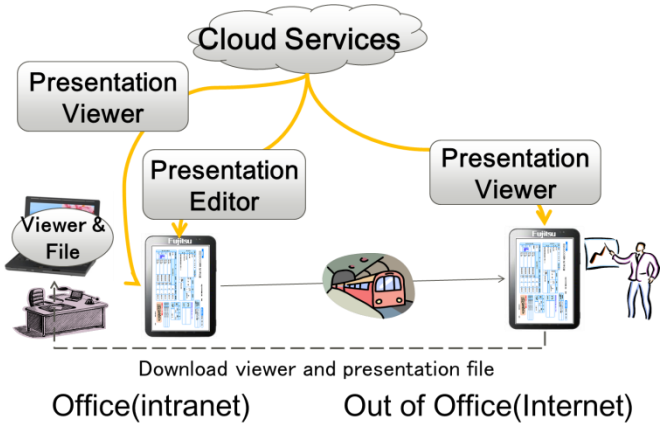



Figure 5: Use case of Seamless Application Push

## 6.2 Multi-tenant Push Service

In this section, we present the extensive use case of proposed system especially focusing on general push service. Figure 6 shows an example for multi-tenant push services which has the multiple private P-GW and the single Public P-GW.

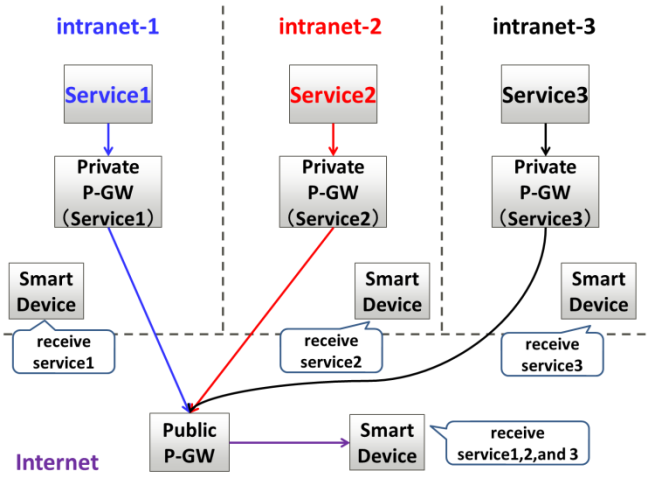



Figure 6: Example for multi-tenant push services

The public P-GW treats notification of push from all services to the smart device by direction of each Private P-GW. The smart device can receive all services in the Internet and each service in the each intranet. The smart device connects to the Public P-GW and can receive all services in the Internet.

# 7 CONCLUSION

We proposed the architecture of seamless application push and implemented the system using Android smartphone. Then we confirmed that it could realize the seamless push by which the smartphone can receive notification of push regardless of whether it is connecting to the Internet or intranet and can download applications from the application server. The smart device automatically could establish VPN connection in conjunction with receipt of notification of push. Because user interaction regarding an input of VPN password is unnecessary, the usability is improved and the security of the smart device is maintained by our architecture. In addition we measured the delivery time of push and the result measured on the Internet was 157.4 [msec]. Our rough requirement is within a second and the result was reasonably low number. Future work would be resume downloading that can continue the download even a device move to different network while downloading the application.

# REFERENCES

[1] Roberta Cozza, Carolina Milanesi, Annette Zimmermann, Tuong Huy Nguyen, Hugues J. De La Vergne, Sandy Shen, Anshul Gupta, Atsuro Sato, CK Lu, David Glenn, Market Share: Mobile Devices by Region and country, 4Q11 and 2011, Market Analysis and Statistics of Gartner,http://www.gartnet.com/DisplayDocument?ref=clientFriendlyUrl&id=1923316, 2012

[2] Hidenobu Ito, Kazuaki Nimura, Yosuke Nakamura, Akira Shiba , and Nobutsugu Fujino, Application Push & Play – Proposal on Dynamic Execution Environment Combined with Personal Devices and Cloud Computing.

-, IWIN2011, Sep 17 -21, 2011

[3] Kazuaki Nimura, Hidenobu Ito, Yousuke Nakamura and Kouichi Yasaki, A Secure Use of Mobile Application with Cloud Service, The Second International Workshop on Smart Mobile Applications in conjunction with PERVASIVE 2012, June 18 - 22, 2012, http://www.mobile.ifi.uni-muenchen.de/aktuelles/smartapps2012/smartapps12_secure.pdf

[4] Kazuaki Nimura, Hidenobu Ito, Yosuke Nakamura, Akira Shiba, and Nobutsugu Fujino, Proposal and Implementation of Pseudo Push Using Network Subsystem and Task Execution for PC, IWIN2011, Sep 17 -21, 2011

[5] Virtual Private Network (VPN) http://en.wikipedia.org/wiki/Virtual_private_network

[6] Android Cloud to Device Messaging Framework https://developers.google.com/android/c2dm/

[7] C. Perkins, IP Mobility Support, IETF RFC2002, http://www.ietf.org/rfc/rfc2002.txt, 1996

[8] C. Perkins, IP Mobility Support for IPv4, Revised, IETF RFC5944, http://www.ietf.org/rfc/rfc5944.txt, 2010

[9] D. Johnson, C. Perkins, J. Arkko, IP Mobility Support in IPv6, IETF RFC3775, http://www.ietf.org/rfc/rfc3775.txt, 2004

[10] Masahiro Ishiyama, Atsushi Inoue, Toshio Okamoto, and Fumio Teraoka, A study of the current Mobile IP status, the obstacles of its wide usage, and the future direction of mobility support, 1998

[11] F. Baker, P. Savola, Ingress Filtering for Multihomed Networks, IETF RFC3704, http://www.ietf.org/rfc/rfc3704.txt, 2004

[12] T. Dierks, C. Allen, The TLS Protocol Version 1.0, IETF RFC2246, http://www.ietf.org/rfc/rfc2246.txt, 1999

[13] The Community ENTerprise Operating System, http://www.centos.org/

[14] F-10D, http://www.fmworld.net/product/phone/f-10d/spec.html?fmwfrom=f-10d_index

[15] Android 4.0 Platform Highlights, Android Developers, http://developer.android.com/sdk/android-4.0-highlights.html, 2011

# Adaptation to school building of the mutual complementary network in address assignment by routing

Kyohei Toyoda[1], Shunsuke Ozawa[1], Phalla So[1], Kouji Yoshida[2], Kunihiro Yamada [1]

[1] Professional Graduated School of Embedded Technology, Tokai University, Japan
[2]Shonan Institute of Technology
{1bejp009, 1bejp004, 1bejp006}@mail.tokai-u.jp, yamadaku@keyaki.cc.u-tokai.ac.jp

***Abstract*** - This research proposes a new communication method and addresses allocation for a mutually complementary wireless and wired network which is developed for residences, for larger university school buildings. Mutually Complementary Network (MCN) is using different types of communication media, wireless and wired, to transmit the same data simultaneously [1]. This research plans to evaluate new proposed method through the simulation. Through the result of the simulation, MCN can be practically used in residences, and larger school building. Also, it can be used to monitor personal and property security, and energy consumption.

***Keywords***: simulation, network, PLC, ZigBee, building

## 1 MUTUALLY COMPLEMENTARY OF WIRELESS AND WIRED NETWORK

Mutually complementary wireless and wired network is designed aiming to improve home security, reduce energy consumption, and provide an affordable and convenience of living [2]. There could be many home appliances connecting to the network as shown in Figure 1.

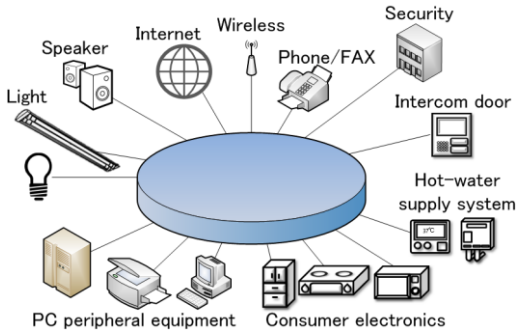



Figure 1: Adaptation of mutually complementary wired and wireless network

However, network of these appliances are working independently. Therefore, an all-inclusive household network in which mutually complementary wireless and wired network are connected to these isolated networks are created through the principal gating. Principal gating does not only mean transmitting all pieces of information, but it also providing an exchange of information in an extent to verify whether that particular network is working. To have these individual networks connecting together, homes, or organizations in the region must have such networks [3].

The communication performance of mutually complementary wireless and wired network is potentially operating very well. As shown in Figure 2, having two distinct types of communication media wireless and wired operating simultaneously extremely improves communication performance over individual network operating independently.

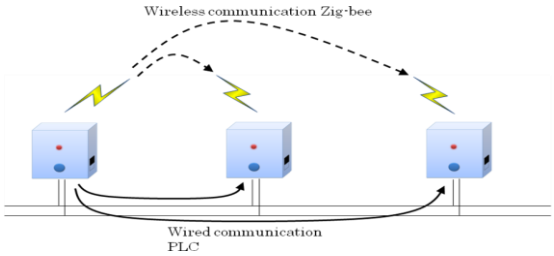



Figure 2: Wireless and wired communication operates simultaneously

## 2 ADAPTATION OF COMPLEMENTARY NETWORK WITH A COMPLEX COMMUNICATION METHOD TO SCHOOL BUILDING

### 2.1 Mutual Complementary Network (MCN)

There are four basic communication methods that are used in Mutually Complementary Network (MCN) adapting to school building. These methods are 1) a direct communication method, 2) a simple routing communication method, 3) a routing communication method, and 4) a complex communication method.

Figure 3 illustrates a direct communication method in which the data is sent directly to the destination node. When the communication could not be established between the source node and the destination node the communication will be terminated.

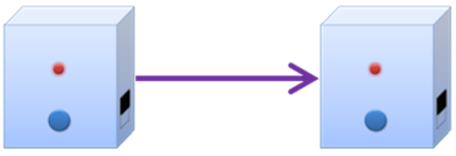


Figure 3: A direct communication method

Figure 4 shows a simple routing communication method in which the data is sent through other possible transmission nodes to the destination node in case the data is unable to be sent directly.

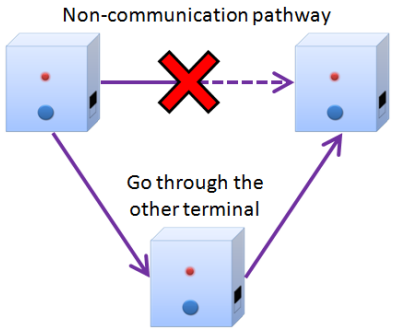



Figure 4: A simple routing communication method

Figure 5 represents a routing communication method in which the data is transferred to the destination via the reliable nearby node that ensures the data transfer.

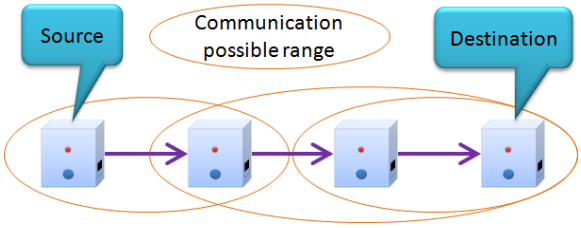



Figure 5: A routing communication method

## 2.2 Complex Communication Method (CCM)

A CCM consists of three methods that are used in a MCN. If the data is transferred within the room, a direct communication is used. A routing communication method is used if the data is transferred within the region. The representative nodes are located in each area. An example in Figure 6 illustrates the communication path from the fourth floor (4F) to the basement B1. A square box represents for a node, and the arrow line represents for communication pathway. This example is also shown that having use CCM in MCN, this network topology can be practically adapted in large building such school building with its promise for a reliable communication performance.

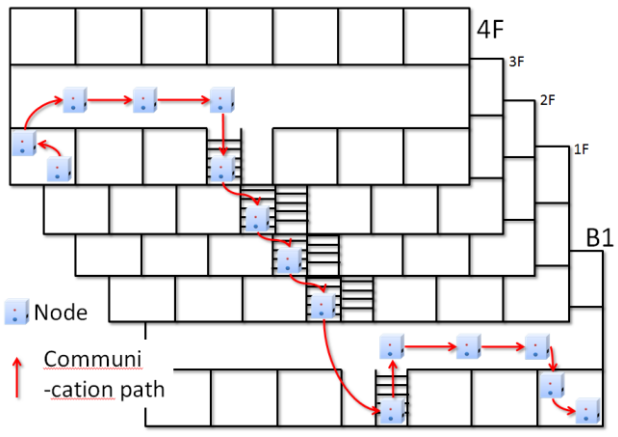



Figure 6: Conceptual diagram of communication, each area always has node connects to the passageway.

Figure 6 shows that before the data is transmitted, the destination address is checked to see if it is located in the same room. In case it is in the same room, the data is sent directly. On the contrary, the communication by a simple routing occurs in the same room before communicating to a destination room. This room has master room node and the passageway connected to the room has guide nodes. These two sets of nodes connect the first room to the passageway and to the destination room. In case the destination node is located in different floor, the data is transferred from the passageway through node located at each stairway and to the nodes located along the pathway, and then, to the master node located in the destination room. Finally, the data can be sent directly from the master node to the destination node. And regarding to the experiment, a one way data transmission requires approximately 0.5 seconds per packet. Therefore, a successful packet transmission would require 1 second at least. Consequently, the maximum number of transmission means the minimum time. In this example, it takes 14 seconds to send data from 4th floor to the basement, B1. In a place having a good pathway for a network, minimizing the transmission time can be accomplished. Based on this result, having use CCM in MCN, it can be seen that MCN can be adapted in large buildings like school building.

However, at the present a limitation arising at CCM because each node address number is inputted manually into routing table. Nevertheless, this research intends to find a better solution for node addresses allocation by determining which node addresses can be dynamically assigned and which can be manually assigned..

# 3 AUTOMATIC ADDRESS SETTING

To deal with the problem of CCM on address setting, this research comes up with three methods for setting node address dynamically. These are 1) an absolute master method, 2) a representative node propagation method, and 3) a divided level address allocation scheme.

## 3.1 An Absolute Master Method (AMM)

AMM is a method in which there is a node called “master node”, and the other nodes connected to it called “slave node”. Master node address is assigned manually, while slave node addresses are generated dynamically from the master. All slave node addresses are managed and maintained by master to ensure the communication reliability. The address number composes of 2 byte, yet master node requires kilobytes of memory to store slave node addresses and routing table.

For communication method, any time the connection establishes between nodes, the communication path is recorded in the routing table. When the slave node sends data to other slave nodes, the data can be transmitted directly if the communication path is found. In case the communication path is not found, it will route through the topper level until reaching the destination. Using this

method, the master node will require high capacity of memory resulting in opposition to the objective of MCN, because the purpose of MCN is to reduce cost and provide a reliable communication performance [3]. Figure 7 illustrates the conceptual diagram of AMM and Figure 8 shows routing table of the master node.

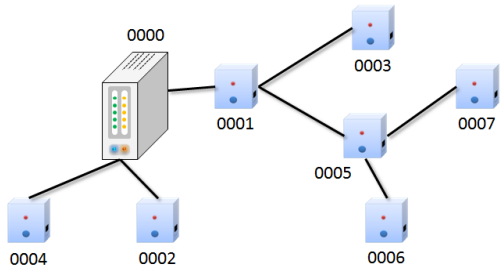



Figure 7: Conceptual diagram of an Absolute Master Method (AMM).

| Connection node table | Routing table | | |
|---|---|---|---|
| 0000 | – | | |
| 0001 | 0001 | | |
| 0002 | 0002 | | |
| 0003 | 0001 | 0003 | |
| 0004 | 0004 | | |
| 0005 | 0001 | 0005 | |
| 0006 | 0001 | 0005 | 0006 |
| 0007 | 0001 | 0005 | 0007 |

Figure 8: Routing table of master node

## 3.2 A Representative Node Propagation Method (RNPM)

RNPM is a method that groups a representative node with slave nodes that are connected to it. Anytime new node is created the number of group also increases. In this method, standard node is determined at each floor and then used it as a representative node. These nodes are required to connect to each other in advance. The communication is established when the representative node of each floor finds a possible communication node. Whenever a representative node allocates address number to new slave nodes a group can be created. A slave node where new node is connected will become a representative node. The conceptual diagram of RNPM can be found in Figure 9, and Figure 10.

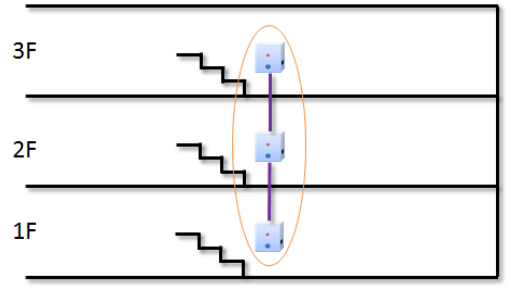



Figure 9: Conceptual diagram of a Representative Node Propagation Method (RNPM) at each floor

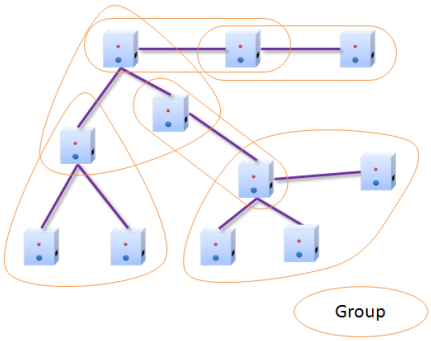



Figure 10: Conceptual diagram of a RNPM grouping technique

Although, this research has discussed two methods for address allocation so far, the problems still exist. As shown in Figure 11, the first problem is that there is no fix length of the address number. The node address is assigned consequently based on the upper level. In this case, when the node layer becomes longer, node address will also become longer. As shown in the Figure 12, the second problem is that the address length is fixed. In this case when the length of layer increases the duplicate address number will occur.

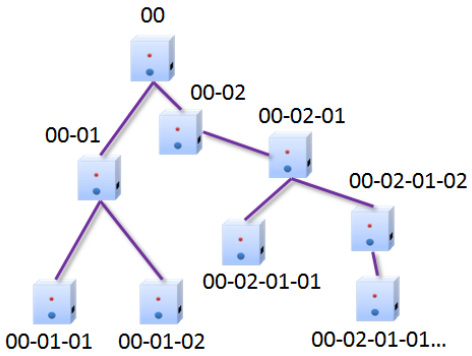



Figure 11: Nested structure address assignment problem

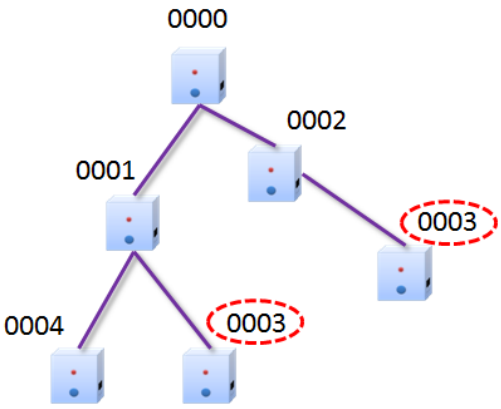



Figure 12: Address contention problem

## 3.3 A Divided Level Address Allocation Scheme (DLAAS)

DLASS is a method that is created in order to deal with the first problem mentioned above. In this method, the foremost master node address is assigned to '00'. The new address allocation will be assigned dynamically in a sequential order.

For example, in the first layer, the second master node address will be 01, and 02 for third master node, and increase accordingly. Hence, the first node address connected from the first master node will be 00-01. However, in this method the length of layer is limited to three. This means that the node address will be reset in the fourth layer by assigning the next sequent number of the first layer to the new node address as can be seen in the dashed circle in Figure 13.

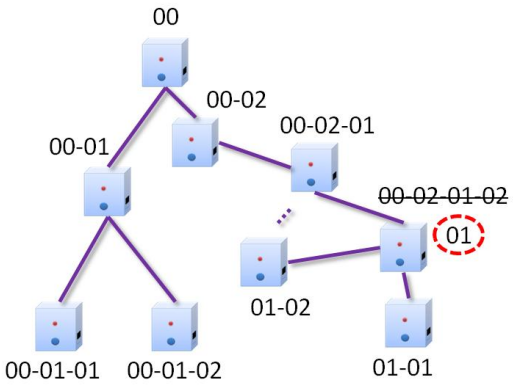



Figure 13: Conceptual diagram of DLAAS

## 4 MASTER COMMUNICATION NETWORK METHOD (MCNM)

From previous section, even though, different methods have been discussed on how to allocate node address dynamically, the problems still exist. To deal with these problems, new method called MCNM has been taken into account. To some extent, the node address will be set manually in this method.

### 4.1 Master Communication Network Method (MCNM)

In MCNM, at the main location the master node address will be set manually in advance. The address of slave nodes located in the same room will be dynamically assigned. After forming the master nodes the slave nodes can obtain their address dynamically from their master node, and then the communication can be accomplished. As the master node is created the communication network connection is not established, yet the master node address is set. This master node holds the state of the address that can be assigned to the slave nodes as requested. The master node will store all addresses assigned to its slave nodes in a routing table as long as the slave node still in power-on status. When the slave node is in power-off status, that node address will be cleared from the routing table. When slave node is powered on, firstly, it starts searching the master node in order to obtain its address. If it cannot acquire the address, the communication cannot be established. Then, the data cannot be sent to the destination. However, if it can acquire the address, the data can be sent to the destination through a nearby node.

For the master communication network algorithm, the data is partitioned and the header information is attached, the data is transferred accordingly to the header information. The header consists of three addresses, the destination address, the source address, and the next destination address. Communication to the next node is taken place based on the destination address and the next destination address. Destination address is referred to a desired destination address. The source address means the address of the original node, whereas the next destination node address is the address that is used to prevent the next node address from sending the data to all the other node addresses. As shown in Figure 14, each address is further divided into four parts: a floor, a pathway, a room, and a node number. Its data format has 4 bits for the floor, 6 bits for the pathway, 2 bits for the room, and 8 bits for the node number. Each node stores all the node address that connected to it where the possible transmission address can be determined.

For the communication algorithm, this paper defines X axis for pathway, Y axis for floor, and Z axis for the room. Based on the positive or negative position on the graph, the direction of the communication can be found and then the data can be sent properly in less time consumption. The base axis is located in each stairway in each floor as shown in Figure 15.

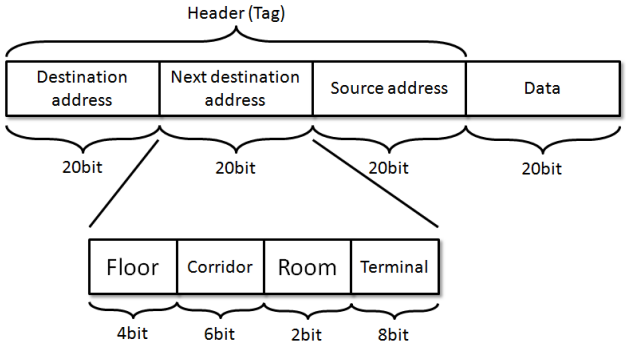



Figure 14: Header and address structure

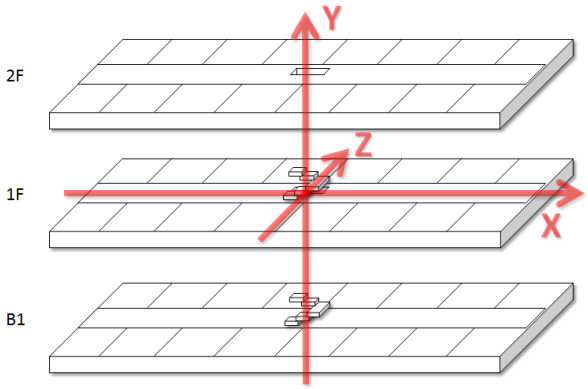



Figure 15: Relationship of axis and building

Among the four configurations of each address; floor, pathway, and room number are determined by each axis. The location where the base axis determines the address number is basically located at the stairway. The center of Y axis can be found at each floor. The center of X axis and Z axis is determined based on the node located at each stairway. 0 axes are determined at the nodes located at each stairway.. The Figure 16 shows the conceptual diagram of

address allocation by axis. The position 0 of X-axis is the location of the stair located in the hallway and the network nodes are possibly located on the minus and plus direction. In case on the plus direction the number will appear to be "1, 2, 3", while on the minus direction the number will appear to be "-1, -2, -3". A room located at Z-axis is determined as having 0 X-axis position based. The node located on the right of the room will be assigned to a positive number such "1", while the opposite side is assigned to negative number such as "-1". For the communication algorithm, the data is transmitted based on the direction sign whether it is plus or minus. For example, in case the data is transmitted to the other floor, it will check the direction of the desired destination address in advance. When the destination of the floor address is negative the data is sent to the minus direction. However, if it is positive the data is sent to the plus direction, because the address number of the hallway and room is set 0. When the destination pathway address is positive the data is sent to the plus direction. In the contrary, the data will be sent to the minus direction. If the number of the destination room is positive the data will be sent from the hallway to the plus direction, and if it is negative the data will be sent to the minus direction. Finally, within the same room, the data is sent directly.

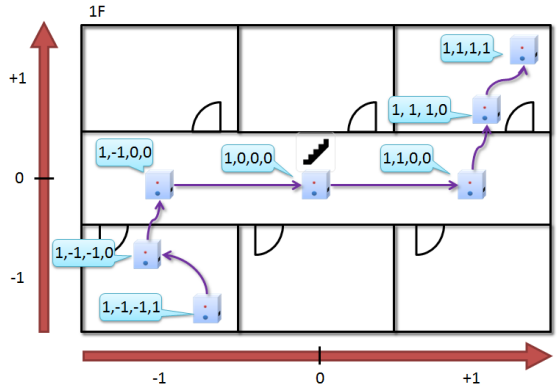



Figure 16: Conceptual diagram of address allocation by axis

## 4.2 Simulation of master communication method

To evaluate the complex communication method, the new simulation for master communication method is developed. This time the simulation will be simulated based on the experiment data collected at Tokai University Building No. 3 consists of four floors and one basement with 1920 square meters reinforce concrete wall as shown in Figure 17 [4]. As the result of the simulation, the address allocation in the master communication method and its communication algorithms are successfully solved the problems discussed in the previous section. Consequently, the adaptation of the master communication network method with a complex communication method in mutually complementary wireless and wired to a school building could potentially be achieved. Figure 18 illustrate the actual result of the simulation.

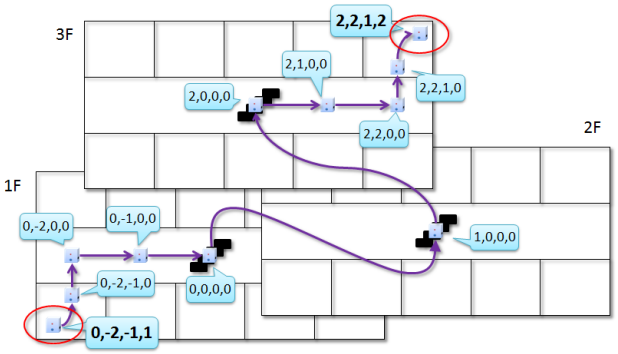



Figure 17: Schematic of school building was simulated

| | Floor | Corridor | Room | Node |
|---|---|---|---|---|
| Source address | 0 | -2 | -1 | 1 |
| Destination address | 2 | 2 | 1 | 2 |

| | Destination address | | | | Next destination address | | | | Current address | | | | Source address | | | | Number of routing |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Generated tag | 0 | -2 | -1 | 1 | 2 | 2 | 1 | 2 | 0 | -2 | -1 | 1 | 0 | -2 | -1 | 0 | |
| | | | | | | | | | 0 | -2 | -1 | 0 | 0 | -2 | 0 | 0 | 1 |
| | | | | | | | | | 0 | -2 | 0 | 0 | 0 | -1 | 0 | 0 | 2 |
| | | | | | | | | | 0 | -1 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| | | | | | | | | | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 4 |
| | | | | | | | | | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 5 |
| | | | | | | | | | 2 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 6 |
| | | | | | | | | | 2 | 1 | 0 | 0 | 2 | 2 | 0 | 0 | 7 |
| | | | | | | | | | 2 | 2 | 0 | 0 | 2 | 2 | 1 | 0 | 8 |
| | | | | | | | | | 2 | 2 | 1 | 0 | 2 | 2 | 1 | 2 | 9 |
| Maxmum number of routing -> | | 10 | | | | | | | 2 | 2 | 1 | 2 | | | | | 10 |

Figure 18: Simulation result

## 5 CONCLUSION

The method of how to allocate node address dynamically has been studies several times since the previous research. However it was found that a complete automation for node address allocation is unlikely to be achieved by some of the issues. To some extent, manually assigning master node address and dynamically assigns slave node addresses were found to be an easy method. Hereafter, this research hopes to continue studying how to further improve dynamic address allocation by identifying the location where manual assignment is required and where automation assignment could be achieved in more effective way.

## REFERENCES

[1] Kunihiro Yamada,"Adaptation to school with wireless and wired networks complement each other" Electronic communications information 2011 network K complementary spring, 2011

[2] Naoki Yusa, etc. "Development and evaluation of a routing simulator for a Complementary Communication System by Wired and Wireless, Wireless", IWIN2010 (2010.9.13-15)

[3] Kunihiro Yamada, Sho Kimura Komura high, etc, "Adaptation to a small building of mutually complementary wired and wireless network", Japan Society for Simulation & Gaming, 2007.10.27-28

[4] Kunihiro Yamada, etc, "Simulation of communication path in the network complement each other to adapt to school", Japan Society for Simulation Technology 2011

# The proposal of a phased expansion plan for smart meters and home network

Kunihiro Yamada[1] ,Takashi Furumura[2], Koji Ishio[2], Handa Chen[2], Toru Shimizu[3],

Kojima Masanori[1] , and Tadanori Mizuno[4]

[1]Professional Graduate School of Embedded Technology, Tokai University, Tokyo, Japan,

[2]Megachips Cooperation, [3]Renesas Electronics Corporation, [4]Aichi Institute of Technology

{yamadaku@tokai.ac.jp}

***Abstract*** **-** In this paper we have carried out research and development for the implementation of a home network and to cut consumption during electric power peak periods. As a result, we propose technological innovations for a home network and a gradual expansion plan for a smart meter and home network. More specifically, the proposal describes #1 a system to create a home network which includes a smart meter in a two-layer configuration with existing networks, #2 implementation of an electric power peak cut system which considers safety, and #3 the installation of a high performance communication system with a "mutual complementary wireless and wired network" into the home network.

***Keywords***: smart meter, home network, energy saving, energy management, regional safety, DSM, Mutually complementary network, wireless and wired ;

## 1 NEED FOR A HOME NETWORK

Since the Great Tohoku Earthquake ended operations of a nuclear power plant, the need for a home network to reduce electric power consumption during maximum power demand, in other words, implement an electric power peak cut in a home has been increasingly discussed. Along this line, and based on the smart grid initiative, researchers have been extensively working on regional energy management technology, building control energy systems and home energy management systems (or HEMS) [1]. Prompted by the Great Hanshin Earthquake on January 17, 1994 and the tsunami which struck Indonesian Sumatra on December 26, 2004, a home network is considered essential for safety and energy saving of a home. Believing that a home network should not be impossible given the current technological level, we have been studying its implementation [2]. Functioning as a sensor for the region, each individual home collects information on nature and man-made disasters. This eventually leads to home and regional safety, energy saving and convenience [3].

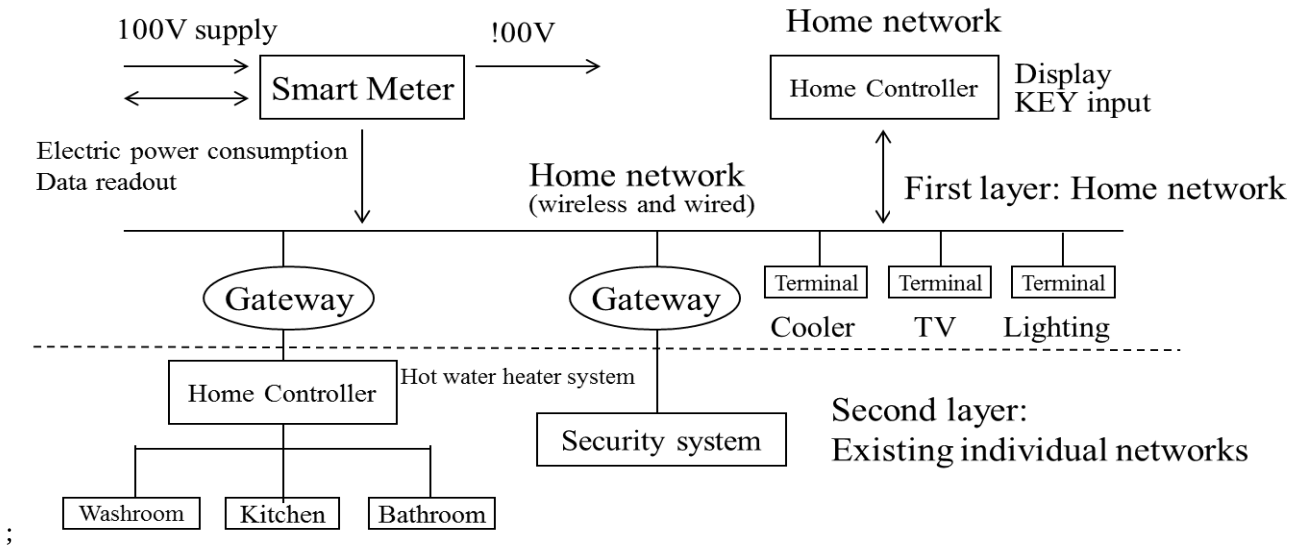
Although researchers have been proclaiming the necessity for a home network since the 1980's under the banner of home automation, this has not been achieved due to three issues. The first issue is the concern regarding integration of a home network for the entire home although there are already existing individual networks. Integration of two different network systems is extremely difficult. The second is the lack of research on the convenience that could be obtained by connecting home appliances, computer peripheral devices and sensors to the network because the home network terminals (nodes) are expensive and have not been standardized. And last is that installation of a home network and adjustment requires work by an engineer, which translates into high prices.

To address the first issue regarding integration of a home network and existing individual network systems, one solution is to configure a two-layer network which can combine both systems. To resolve the second issue of home network terminals being very expensive, a mutual complementary communications system using wireless and wired applications can be realized by a single chip using present semiconductor technologies to reduce costs [4].

By establishing high communications performance which eliminates installation and adjustment, the third issue regarding the high costs of engineering work can be handled [5]. This is the mutual complementary communications system mentioned above, which can provide stable, consistent communication performance at ordinary homes [6]. This communications system is called a "mutual complementary network by wireless and wired communication."

## 2 STRUCTURE OF TWO-LAYER HOME NETWORK

A typical home today has several individual networks, including a hot water heater, an interphone system, a home security system, Internet and a telephone line. Since it is difficult to create a home network that covers the entire home by combining all these existing individual network systems, one solution is to form a two-layer network structure. In this particular structure, as shown in Figure 1, a gateway connects the home network covering the entire home with the existing individual network systems. Various electric and electronic devices, such as home appliances including air conditioners and refrigerators, and computer peripherals including printers, hard disc drives, and lightings, are all hooked up to the home network covering the entire home.




;

Figure1: Structure of a two-layer home network (Patent; similar gateway)

Viewed from either one of the layers, the gateway is a terminal within the network. This gateway chooses the path of least load to the network. In other words, it is an arrangement where the interior conditions are presented, and the information can be used by the other side (or specifications) when helpful. And of course there are no restrictions regarding development and growth between the two layers of network. This particular system of a home network works smoothly with the existing network systems to provide information to avoid various dangerous conditions and contributes to improved convenience. The authors refer to the connection (gating) of these two network systems as "light gating".

## 3 PROPOSAL FOR ELECTRIC POWER PEAK CUT WHICH CONSIDERS SAFETY

One measure to address concerns regarding an insufficient electric power supply is the "electric power peak cut" concept. In the future, the electric power company may directly control home devices such as an air conditioner through a smart meter [7]. However, such a system still requires careful attention as such control may involve risk to human life or cause accidents. In Japan, 30% of the total electric power generated is consumed by households [8]. Attempts have been made to make energy usage "visible" in order to promote an individual sense of economy, thus reducing electric power consumption. Such attempts, however, have limitations. Hence a more advanced idea of "demand side management (DSM)" is proposed at this time.

Our proposal to reduce home electric power demand utilizes demand side management as its core structure, where the appliances in the home are reset with a control mode in the home network controller, based on a "peak cut control table," prepared in advance. Table 1 shows "peak cut control table". The table defines the values which dictate the control mode of each home appliance starting with the level at the time of peak cut. Compared with the normal consumption conditions, the home owner sets up the controller so that Level 1 peak cut reduces consumption to 67%, Level 2 to 50% and Level 3 to 33%. The authors plan to incorporate two features into this control. One readily shows the amount of energy cutback and associated electric power fee by simulation, and another introduces a game which takes advantage of edutainment (educational entertainment) [9].

In the two-layer home network structure shown in Figure 1, electric power of 100vAC is supplied through the smart meter. The smart meter measures, and reports electric power consumption to the electric company while receiving and maintaining electric power during peak cut. The electricity rates in Table 2 are simulation examples to explain this system. The table shows three levels of electricity rates and when they are to be applied. The application time is arbitrarily set at 10:00-16:00.

As shown in Case 1 in Table 2, the electric power consumption is cut back to maintain a constant electricity bill for a home. Within this peak cut time frame, since the electricity fee rate is 300% at Level 3, the usage rate is reduced to 33%, which translates to an 83% overall reduction. If peak cut is implemented for three months for all six hours, the annual total electric power consumption rate becomes 96%. While this is only a 4% reduction, 83% of the total demand, as discussed above, may be sufficient in reducing peak demand supply.

Case 2 in Table 2 is a simulated electric power bill where the electric power consumption remains unchanged at a home even during the peak cut time. At Level 3, the fee rate during the peak cut time period is 300% and the average for one day is 150%. The electricity bill for one month of peak cut time is 104% and 113% for three months. Assuming that half the homes adhere to this cost increase, there is a 92% load reduction. This suggests that simply increasing the electricity bill may not be sufficient. It is necessary that the home controller simulates the electricity bill based on the individual peak cut control table while accumulating the data of actual consumption.

Table 1: Peak Cut Control Table (Patent; Similar).

| | Normal time | | Peak cut time | | |
|---|---|---|---|---|---|
| Home appliances | Level 1 | Level 2 | Level 1 | Level 2 | Level3 |
| Air conditioner (inverter)1 | F | low | off | off | off |
| Air conditioner (inverter)2 | F | low | low | off | off |
| Air conditioner (inverter)3 | F | F | low | off | off |
| Air conditioner (inverter)4 | F | F | F | low | off |
| Air conditioner (inverter)5 | F | F | F | F | low |
| Floor heating 1 | F | low | off | off | off |
| Floor heating 2 | F | F | low | off | off |
| Floor heating 3 | F | F | F | F | low |
| Refrigerator | F | F | low | off | off |
| Washing machine | F | F | low | off | off |
| Rice cooker | F | F | low | off | off |
| Hot water system(Gas) | F | F | F | F | low |
| Hot water system (electric/ Heat storage) | F | F | low | off | off |
| Lighting 1 | F | F | off | off | off |
| Lighting 2 | F | F | off | off | off |
| Lighting 3 | F | F | low | off | off |
| Lighting 4 | F | F | low | low | off |
| Lighting 5 | F | F | F | F | low |
| Desktop PC | F | F | F | off | off |
| Display | F | F | F | off | off |
| HDD | F | F | F | off | off |
| Printer | F | F | F | off | off |
| | Existing network | | | | |
| Hot water system(Gas) | F | F | F | F | F |
| Hot water system (electric) | F | F | off | off | off |
| Hot water system (electric/Heat storage) | F | F | F | off | off |
| Door intercom system | F | F | F | F | F |
| Security system | F | F | F | F | F |

F ： Free setting by resident (assumed to be 100% in load calculation)

Low , off : Selected setting by resident

Table 2: Peak Cut Time Electric Power Rates (Unit%).
Peak cut June - August, 10:00 to 16:00 (4 electricity rate settings: Normal, Level 1, Level 2, Level 3)

| Electricity rate setting | Normal | Level 1 | Level 2 | Level 3 |
|---|---|---|---|---|
| Electric power rate ratio (yen/KWt) | 100 | 150 | 200 | 300 |
| Case 1: Electric power consumption ratio (#1) | 100 | 67 | 50 | 33 |
| Case 1: Electric power consumption ratio (#2) | 100 | 92 | 88 | 83 |
| Case 1: Electric power consumption ratio (#3) | 100 | 98 | 97 | 96 |
| Case 2: Electric power rate ratio (one day) | 100 | 113 | 125 | 150 |
| Case 2: Electric power rate ratio (one month out of 12 months) | 100 | 101 | 102 | 104 |
| Case 2: Electric power rate ratio (three months out of 12 months) | 100 | 103 | 106 | 113 |

In case 1, electric power consumption is regulated to maintain the same electric power fee.
In case 2, electric power consumption is not regulated.
#1: Percentage of electricity within the time frame when peak cut is implemented(%)
#2: Percentage of total electric power consumption within the time frame when peak cut is implemented(%)
#3: Percentage of total electric power consumption for one year when peak cut is implemented(%)

## 4 PROPOSAL OF A MUTUAL COMPLEMENTAR NETWORK BY WIRELESS AND WIRED COMMUNICATIONS

Propose a "mutual complementary network by wireless and wired communications", which leads to high performance, be applied to the home network. The mutual complementary network is a communication system that simultaneously employs two or more different methods to improve the communication performance [5]. As "two or more different methods", this study uses wired and wireless communications. Specifically, the PLC (Power Line Communication) [10] is used for wired communication and Zigbee [11] for wireless.

As shown in Figure 2, when transmitting data from point A to point B, the data is simultaneously sent by wired and wireless methods. In this case, communication is successful if the data communication can be completed by either method. In a three story, 200 square-meter reinforced concrete houses, communication performance by wireless alone is 82% as shown in Figure 3, while wired is 70%. Considering theoretical communication inability for both wireless and wired to be 5.4%, this translates to 94.6% of the communication performance. In fact, however, an even better communication performance of 100% was achieved [6].

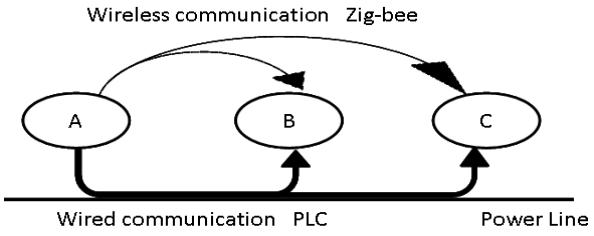



Figure 2: Mutual complementary network by wireless and wired communication

In practical application, using a simpler routing three times reduces the rate of unsuccessful communication to as low as 0.02%. Evaluation of an actual system to determine whether this is sufficient or not, is desired. In a "simpler routing" system, if communication is unable to go through one route, another route is used.

This routing system is completely independent from the previous communication performance while minimizing the software load [12].

| | | Communication | |
|---|---|---|---|
| | | Able 82% | Unable 18% |
| Power line communication | Able 70% | Able 57.4% | Able/Unable → Able 12.6% |
| | Unable 30% | Unable/Able → Able 24.6% | Unable 5.4% |

Figure 3: Communication performance of a mutual complementary network (by wireless and wired communications)

## 5 STEP-BY-STEP ACHIEVEMENT OF HOME NETWORK

A smart meter and home network cannot be constructed overnight. As mentioned above, the home network has not been realized even though researchers have advocated its necessity and effectiveness since the 1980's. Looking back, one reason was that necessity was not as high as expected, and there were technological problems, such as cost. Today, this is no longer the case. The necessity is supported by a more urgent call for energy saving and home safety, while a "mutual complementary network by wireless and wired communications" solves technological and cost issues. One remaining obstacle is the lack of enthusiasm and action to create a home network under one set of standards by concerned parties. The home network definitely needs a common set of standards to connect home appliances.

Figure 4 shows a proposed plan to reduce home electric power consumption based on a step-by-step plan to expand the smart meter and home network. The first step is regarding an electric power supply and electric power consumption meter at a current general home.

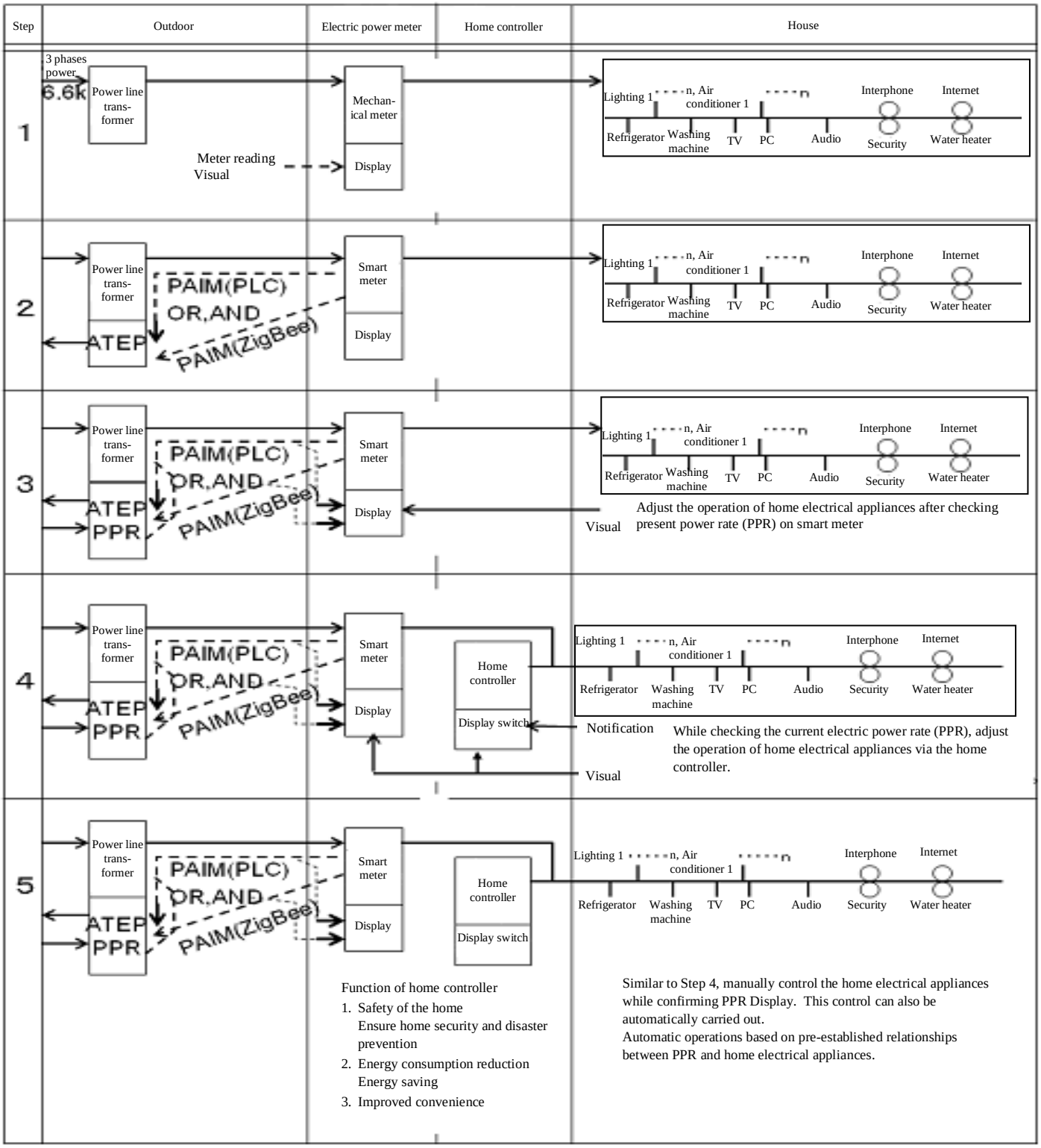



Figure 4: Steps to reduce home energy consumption using a smart meter and home controller

Electric power automatic inspection of a meter ( PAIM) , the amount totalof used electric power (, ATEP) , the present power rates (PPR)

The electric power consumption is visually measured to generate the electricity bill. In the second step, the electric power company uses an electronically operated electric power meter to collect and calculate the electric power consumption from each home through wired and/or wireless communication. Such an electronic meter is called a smart meter. In the third step, the smart meter indicates the consumption status of electricity for the month so the resident can directly control the home electric appliances. The fourth step connects the smart meter to the home controller via the network. In turn, the home controller is connected to various home appliances through the network. To implement peak cut, the home resident uses the home controller to read the peak cut level from the smart meter and implements energy saving measures according to the level.

The fifth step requires setting a "peak cut control table" to control the energy saving measures to a specified level during peak cut. The smart meter posts the electric bill level at the time of peak cut so the home controller can regulate the home appliances. At times other than peak cut, simulation and control functions of the home controller can be used to identify other energy saving opportunities and further improve disaster mitigation, security and convenience in each individual home.

## 6 CONCLUSION

This paper proposes a step by step plan to introduce a smart meter and home network in order to reduce electric power consumption. Three major technologies are discussed: " a two-layer home network", "a system to implement electric power peak cut while considering safety" and "a mutual complementary network by wireless and wired communications" which support the proposed plan. The proposed plan can only be implemented when people at various homes are mutually and socially influenced. Specifically, the following four ways were discussed above.

1) Influence home economics by increasing the electric power rate during peak cut time.
2) Promote the control of the electric power demand by introducing edutainment.
3) The home network is also effective in areas other than energy and energy saving.
   Ensure security and disaster prevention and improve convenience.
4) Raise social issues regarding carbon dioxide emissions and nuclear power plants so that individuals can consider their responsibility as a member of society.

It is also important that electrical appliance manufactures equip their products with terminals so they can be connected to the home network. Once the effectiveness of the home network is recognized, information gained by institutes and organizations regarding the electric power crisis will become a driving force to promote proposed implementations.

The home network is essential in times of electric power crisis. In other words, technology can save mankind. If we are really advanced persons who no longer need nuclear power generation, cutting back on electricity to this degree is only natural. To reduce home electric power consumption more is required than just targeting peak cut. It does not mean to only use electric power when you need it, it means cutting back even outside the peak cut time. It does not simply mean not wasting it. It is that you cut back on the energy or don't use it all. The author et al., will continue to study the subject in order to realize a home network which contributes to home safety, security and energy saving and convenience.

## REFERENCES


[1] Tadashi Matuzaki,Haruki Matuda,Yuzuru Saito,Hirohiko Kaneko.,"Business Approach of Smart Grid and Smart Community",Mitubishi Corp. Monthly technical report, Vol86,No2,2012.,p100.-p128.

[2] Satashi Kawaguchi, Masanori Kojima, Kunihiro Yamada1 ."Mutually Complementary Network Sstem Between Wired and Wireless Communication for Home Appliances" , The 13th IEEE International Symposium on Consumer Electronics (ISCE2009) p.455-459

[3] Kunihiro Yamada, "The mutual complement network by Wireless and Wired"Fair 2005 of industry-university cooperation Guide book p.26,2005.12.7.

[4 ] Jyun Watanabe, Digital Hurd and Course dissection; "Megachips Corp. develops the product of an energy-saving semiconductor and theme of visible of electric power that is an offensive", Japan Industry Newspaper 2012.1.24

[5] Kunihiro Yamada, Yoshihiko Hirata, Yukihisa Naoe, Takashi Furumura, Yoshio Inoue, Toru Shimizu,Koji Yoshida, Masanori Kojima,Tadanori Mizuno "Dual Communication System Using Wired and Wireless Correspondence in Small Space" M.Gh.Negoita et al. (Eds.): KES 2004, LNAI 3214, pp. 898-904, 2004.© Springer-Verlag Berlin Heidelberg 2004

[6] Kunihiro Yamada, Kenichi Kitazawa, Hiroki Takase, Toshihiko Tamura,Yukihisa Naoe, Takashi Furumura, Toru Shimizu, Koji Yoshida,Masanori Kojima, and Tadanori Mizuno "Dual communication System Using Wired and Wireless Correspondence in Home Network" R. Khosla et al. (Eds.): KES 2005, LNAI 3681, pp. 438.444, 2005.© Springer-Verlag Berlin Heidelberg 2005

[7] "The day when electric power meter becomes smart", NIKKI LECTRNICS.,p.105-112., 2008.11.3

[8] "The power consumption ratio classified by trend investigation-field of the present condition about the amount of used electricity of electric power use apparatus, and the near future", Fuji Keizai Management Co.LTD. p.47. 2009.3.23.

[9] Xinyu Zhou, Shunsuke Hata,, Kunihiro Yamada .,"Project-based Learning for Edutainment using Locomotion Robots", International Workshop on Advanced Computational Intelligence and Intelligent Informatics (Suzhou、China) 2011.11.19-23

[10] M16C/6S http://www.renesas.com

[11] URL http://www.zigbee.org

[12] Naoki Yusa, Fumiaki Henmi, Hideaki Banba,Hiroshi Mineno, and Kunihiro Yamada .,"Adaptation a School Building of the Mutual Complementary Network by Wireless and Wired",A. König et al. (Eds.): KES 2011, Part III, LNAI 6883, pp. 227–236, 2011.© Springer-Verlag Berlin Heidelberg 2011

# Stepwise Clustering Algorithm for Wireless Sensor Networks [1]

Shin-nosuke Toyoda[*], Fumiaki Sato[**]

[*]Graduate School of Science, Toho University, Japan
[**]Faculty of Science, Toho University, Japan
[*]6511013t@nc.toho-u.ac.jp
[**]fsato@is.sci.toho-u.ac.jp

***Abstract*** - Sensor networks consisting of nodes with limited battery power and wireless communications are deployed to collect useful information from the field. Gathering sensed information in an energy efficient manner is critical to operate the sensor network for a long period of time. LEACH is very energy-efficient routing protocol based on clustering of the sensor nodes. However, energy consumption of nodes tends to become uneven in LEACH. HEED improves the LEACH clustering algorithm by using information of residual electric power of nodes. Although HEED provides better performance than LEACH, it does not consider the number of adjacent nodes. Therefore, the cluster head does not efficiently cover the nodes in HEED. HIT is based on a small transmission range and multi-hop communication. Though HIT has improved the performance dramatically, unbalance of the electric power consumption is remained. In this paper, we propose energy-efficient clustering algorithm considering adjacent nodes and residual electric power. Characteristics of our approach are stepwise clustering from an initial cluster head and dynamic change of cluster size.

***Keywords***: sensor networks, stepwise clustering, energy-efficient routing.

## 1 INTRODUCTION

In recent years, there has been a growing interest in wireless sensor networks. Wireless sensor networks are composed of a large number of sensor nodes with limited energy resources. Energy efficiency is a key design issue that needs to be enhanced in order to improve the life span of the entire network. Usually, energy consumption can be divided into three domains: sensing, communication and data processing. Of the three domains, a sensor node expends maximum energy in data communication. One of the primary concerns with respect to sensor networks applications is the design and development of energy-efficient routing protocols that consume power more evenly, thus result into a prolonged network lifetime.

Available routing protocols for sensor networks are classified as data centric, location-based, QoS aware, and hierarchical. Data centric protocols use flooding or gossiping to transmit data [1-3]. Though the cost of routing is small, the number of data will be transmitted. Location based routing require the location information to determine an optimal path so that flooding of routing-related control packets is not necessary [4-6]. On the other hand, QoS aware protocols address various requirements such as energy efficiency, reliability, and real-time requirements [7]. Finally, the hierarchical protocols such as LEACH[8], HEED[9], HIT[10] form clusters with cluster heads in order to minimize the energy consumption both for processing and transmission of data.

Clustering in Wireless Sensor Networks (WSNs) provides scalability and robustness for the network; it allows spatial reuse of the bandwidth, simpler routing decisions, and results in decreased energy dissipation of the whole system by minimizing the number of nodes that take part in long distance communication. LEACH is very energy-efficient routing protocol based on the clustering of the sensor nodes. In LEACH, non-cluster-head nodes first send their data to the cluster heads (CHs), and then CHs send the data to the base station (BS). Each link of non-cluster-head to CH and CH to BS is one hop. The cluster formation in LEACH is changed and CH is also changed periodically. Therefore, the load of CH is distributed all sensor nodes. However, energy consumption of nodes tends to become uneven in LEACH. On the other hand, HEED improves the LEACH clustering algorithm by using information of remaining electric power of nodes. Although HEED provides better performance than LEACH, it does not consider the number of adjacent nodes. Therefore, the CH does not efficiently cover the nodes in HEED. HIT is based on a small transmission range and multi-hop communication. Though HIT has improved the performance dramatically, unbalance of the electric power consumption is remained.

To improve the life time of wireless sensor networks, we have proposed an energy-efficient clustering algorithm [11]. The algorithm selects CHs by using information of adjacent nodes and residual electric power. Sensor nodes are covered with few CHs and sensed data is transmitted to sink node by multi-hop communication. Therefore, the life time of the sensor networks is improved. However, because the cluster size is fixed in our previous work, some sensor nodes not covered by CH become single CH which is a problem of our algorithm. In this paper, we propose energy-efficient clustering algorithm considering adjacent nodes and residual electric power. The size of the cluster gradually grows from a small size, and the algorithm can efficiently cover the sensor nodes.

[1] This work was supported by MEXT/JSPS Grant-in-Aid for Scientific Research(C) Grant Number (22500071).

The remainder of the paper is organized as follows. Section 2 summarizes related work. In Section 3 we present our clustering algorithm in detail. In Section 4 we show effectiveness of our algorithm via simulations and compare it to other clustering techniques. Finally, we conclude our paper and draw directions for future work in Section 5.

# 2 RELATED WORKS

## 2.1 LEACH

In this section, we described LEACH (Low-Energy Adaptive Clustering Hierarchy)[8], a clustering-based routing protocol that minimizes global energy usage by distributing the load to all the nodes at different points in time. LEACH is completely distributed, requiring no control information from the base station, and the nodes do not require knowledge of the global network in order for LEACH to operate. The key features of LEACH are:

1) Localized coordination and control for cluster setup and operation.
2) Randomized rotation of the "base stations" or "cluster-heads" and the corresponding clusters.

As a result, the load is distributed, and longevity on the entire network can be extended. Here, the "cycle" is the period which all nodes send the data once to the base station. The "round" is the period between the changes of CH.

All nodes can communicate to the base station directly in LEACH. All nodes know the probability p which each node try to become CH in the first round. When the round changes, node n decide whether try to become CH in the new round based on the equation (2.1). If a random number created by the node n is greater than the result of the equation (2.1), the node tries to become CH.

$$T(n)=\begin{cases}\dfrac{p}{1-p*(r \bmod \frac{1}{p})} & if\ n \in G \\ 0 & otherwise\end{cases} \quad (2.1)$$

Here, the r is a number of rounds, G is the set of nodes which did not become CH in the 1/p past round (0<p<1). In other words, each node must become CH once in 1/p rounds.

The node which tries to become the CH sends the CH advertisement to neighboring nodes. The node which does not try to become the CH waits the CH advertisement during the fixed time. The node which receives the CH advertisement adds the node to the list of CHs with the RSSI (Received Signal Strength Indicator) of the node. When the waiting time is finished, non-cluster head node chooses the CH with the strongest RSSI among the list, and transmits the participation request. Data is transmitted directly to the sink without belonging to the cluster when there is no node which received the CH advertisement. On the other hand, the node transmitting the CH advertisement waits the participation request. When all the participation requests are received, the TDMA transmission schedule of the cluster member is made, and the CH transmits to the member. If the transmission schedule is received, the member memorizes the order of the transmission until the CH alternates. If the round changes, the process is executed for each round.

The cluster member transmits the sensor data to the CH in order on schedule after the schedule reception, and the CH compresses the data and transmits the data to the sink after data is received from all members. This is a flow of one cycle of one round in LEACH.

In LEACH, however, there is a problem that the power consumption of the node becomes unbalance easily. The reason is that the decision to become CH is based on only the frequency. Therefore, the node far from the sink node consumes energy early. There is the CH that no members exist in the cluster. There is the round that any nodes do not become the CH.

## 2.2 HEED

HEED (Hybrid, Energy-Efficient Distributed clustering)[9] is a clustering algorithm that improves the problems in the LEACH. The probability to become CH is based on the ratio of the initial electric power $E_{max}$ and the current residual electric power $E_{residual}$ in HEED. Therefore, the node that has the more electric power is easier to become CH.

There are two states in the CH, the tentative CH and final CH. If the node broadcasts the final CH advertisement, the node serves the CH in the round. On the other hand, if the node broadcasts the tentative CH advertisement, the node may cancel the advertisement and join to other cluster that the total communication cost becomes small.

In HEED, the probability of the node that try to become CH ($CH_{prob}$) is given as follows.

$$CH_{prob}=\max\left(C_{prob}*\frac{E_{residual}}{E_{\max}}, p_{\min}\right) \quad (2.2)$$

Here, $C_{prob}$ is the rate of the CH given beforehand. $p_{min}$ is the minimum value of the $CH_{prob}$, that is decided in inverse proportion to $E_{max}$.

After calculating $CH_{prob}$ by equation (2.2), each node repeats the following process. Flowchart is depicted in Fig.2.1.

(1)When one or more CH advertisements are received including own one:

The node that the communication cost is smallest is selected as CH.

If the node is myself:

a)If $CH_{prob}$=1, the node broadcasts final_CH message.

b) If $CH_{prob}$<1, the node broadcasts tentative_CH message.

(2) When no CH advertisement is received:

a)If $CH_{prob}$=1, the node broadcasts final_CH message.

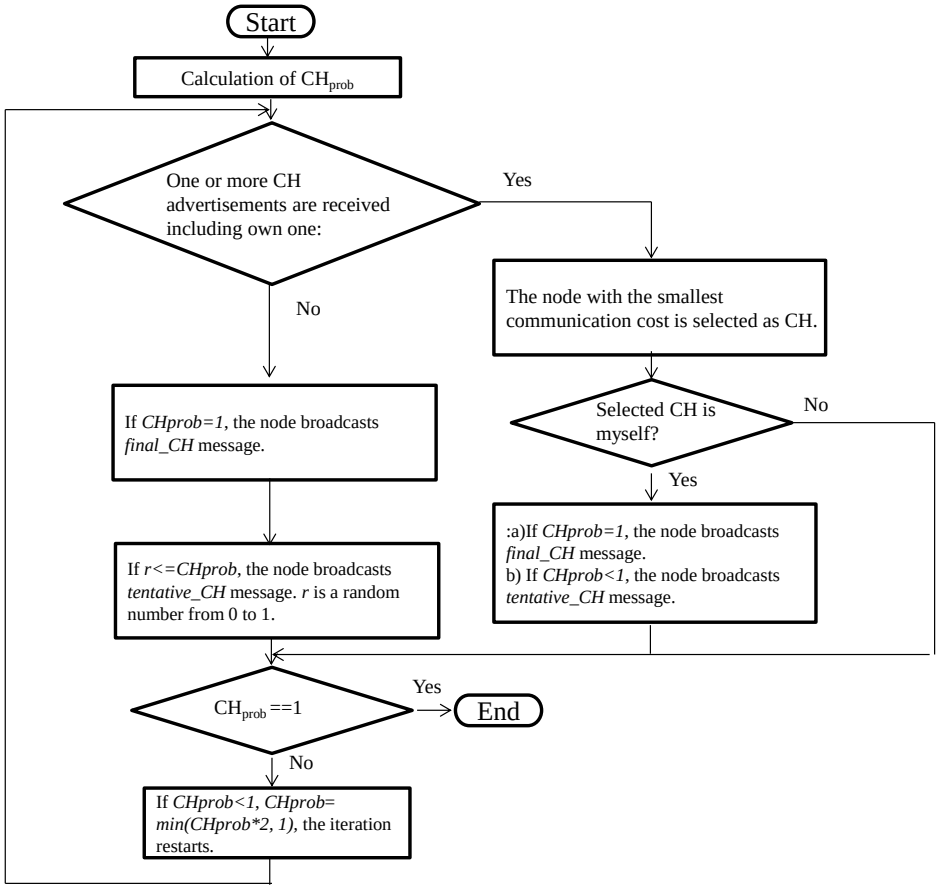



Fig. 2.1 Flowchart of HEED.

b) If r<=$CH_{prob}$, the node broadcasts tentative_CH message. r is a random number from 0 to 1.

(3) If $CH_{prob}$=1, the iteration is end.

(4) If $CH_{prob}$<1, $CH_{prob}$= min($CH_{prob}$*2, 1), the iteration restarts.

If the node does not broadcast the final_CH message in the iteration, the node selects the own CH from other nodes from which the node receives the final_CH message. If there is no node that the node receives the final_CH message, the node becomes CH and broadcasts the final_CH message.

## 2.3 HIT

HIT (Hybrid Indirect Transmissions) [10] uses multi-hop communication to control electric wave interference and to reduce the electric power consumption. It is effective to support parallel communication. HIT consists of the following seven phases.

(1)Phase 1: CH selection

In this phase, one or more CHs are selected. Each cluster has one CH. In case of single cluster, CH can be rotated based on the node ID.

(2)Phase 2: CH advertisement

In this phase, the selected CHs broadcast the node information as the Advertise message. The node j which is not CH and receives the message calculates the distance from the CH and joins to the nearest cluster. The node j has the distance to node H (CH) as the d(H, j).

(3)Phase 3: Cluster set up

In this phase, one or more clusters are created and relation of upstream/downstream are set up. At first, the node j which is not CH broadcasts Member message that includes the CH and distance to CH. By this exchange of information, all nodes calculate the distance to other node and keep the information to the distance to CH of other nodes. From this information, the upstream node u of node i is calculated by that information base on the following condition.

1)d(u, H)<d(i, H)

2)d(i, u)<d(i, H)

The condition 1) means that the transmission cost to the upstream node is smaller than to the CH. The condition 2) means that the upstream node is nearer to the CH than node i.

(4)Phase 4: Route set up

All nodes broadcast the Upstream message that includes the distance to the upstream node after the decision of the upstream node in Phase 3. All nodes are notified that the all upstream nodes of all nodes by this message. All nodes can set up the downstream node set.

(5)Phase 5: Blocking set calculation

In this phase, the node j which is blocked by node i is calculated, when node i transmit to the upstream node. The condition is as follows.

d(i, ui)>d(i, uj)

Now, ui is the upstream node of i and uj is the upstream node of j.

The nodes that satisfy the condition are called as the Block node list. Each node broadcasts the list. The node that the message receives makes the Block table that is the node set blocks to transmit to the upstream node.

(6)Phase 6: TDMA scheduling

In this phase, each node calculates the TDMA schedules that maximize the parallel communication that avoid the collision.

(7)Phase 7: Data transmission

In this phase, each node senses the environment and transmits the data based on the TDMA schedule made by the previous phase.

## 2.4 Other related works

There is PEGASIS[12] as one of the other methods. PEGASIS uses the chain structure instead of the cluster. TPC[13] uses the chain structure in the intra-cluster communication. These methods are based on location information. Because our method is not based on location information, these methods are not compared in this paper.

RPL[14] is a routing protocol for low power and lossy networks. Security improvement of RPL is proposed in [15]. Performance of data gathering is improved in [16]. These protocols are offering routing based on the reliability of the link. Because usual reliability is assumed in the link in our method, these methods are not compared in this paper.

# 3 CLUSTERING ALGORITHM

## 3.1 Basic concept

In this section, we propose the clustering method to consider the adjacent node set and the residual electric power. In the proposal method, all nodes other than the sink exchange the Hello message of each round, which contains information on own residual electric power and the adjacent node set. As a result, each node can maintain information on the adjacent node set and the residual electric power for the nodes.

At first, the sink selects the first CH. Other CHs are selected radially by the first CH to cover the surrounding nodes. To prevent flooding of the CH, the CH is selected to cover a lot of nodes. CH has been selected like evenly consuming the electric power by considering the amount of the electric power remainder. The transmission power is saved as the small range for collection of the sensor data. The range is controlled by the sink node. The collection of the sensor data from the node which cannot communicate with the sink node directly becomes possible by using multi-hop communication of CHs.

The transmission power used in the clustering phase is small at first. The transmission power means the size of the cluster. In our algorithm, some sizes are prepared to the cluster. If all nodes in the network are not covered by any clusters, the size of the cluster is enlarged and clustering is executed again.

## 3.2 Cluster head selection

There In this section, the algorithm for CHs selection in a round is explained. It is designed by modifying the algorithm for the landmark node selection in ad hoc networks[17]. The following is the process of the algorithm.

(1)Hello message exchange phase.
(2)Representative node selection phase.
(3)CH selection phase.
(4)End report phase.

Each phase is explained as follows.

(1) Hello message exchange phase.

When a new round begins, the sink node broadcasts the message that request to exchange the Hello messages with each other. This request message includes the maximum trans-mission range R in this round.

Each node broadcasts the Hello message includes the node ID and residual electric power after receives the request message. Each node receives the Hello message from other nodes and constructs the adjacent node list (ANL) which includes the adjacent node IDs and residual electric power (REP) of them. The adjacent node means the node which exists within the range R. Each node broadcasts the second Hello message which includes the ANL after the first Hello message. Each node receives the second Hello message and constructs the two-hop adjacent node list (TANL). TANL means the list of the nodes which can be reached in just 2 hops from the node.

(2) Representative node selection phase.

After the Hello message exchange phase, each node selects the representative node. The node which has the largest REP is selected as the representative node. Because all nodes receive the Hello message, all nodes can learn who selected as a representative node. Now, the representative node is the one of the CHs.

(3) CH selection of representative node.

After the fixed time, representative node L starts the selection of the other CHs. L calculates evaluation value $v_n$ for all nodes included in the ANL. Here, evaluation value $v_n$ of adjacent node n is calculated by the following equation (3.1) by using $c_n$: the number of overlapping nodes between adjacent nodes of L and adjacent nodes of n, $e_n$: the residual electric power of node n, and eave: the mean value of the residual electric power of all adjacent nodes of L.

$$v_n = \frac{1}{c_n} * \left( \frac{e_n}{e_{ave}} \right)^w \qquad (3.1)$$

Here, the w is a constant which shows the weight of the residual electric power. In a word, the evaluation value rises

in the node that the number of overlapping node between adjacent nodes of n and adjacent node of L is small, and the residual electric power is large. The node n1 with the largest evaluation value is selected as the one of the CHs.

The next CH would be selected if the 2-hop-coverage is smaller than the threshold. The ratio 2-hop-coverage means the ratio between the number of TANL of L and the number of node covered by the n1. L calculates evaluation values $v_n$ of all adjacent nodes n except n1 again. $v_n$ is calculated for the set of nodes which excluded common part with adjacent node of n1 from TANL of L, that is called as non-covered node list thereafter. $v_n$ is calculated by the following equation (3.2) using $d_n$: the number of overlapping nodes between non-covered node and the adjacent nodes of n, $e_n$: the residual electric power of n, $e_{ave}$: the average residual electric power of the adjacent all node of L except n1.

$$v_n = d_n * \left( \frac{e_n}{e_{ave}} \right)^w \qquad (3.2)$$

Here, the evaluation value rises in the node that the number of overlapping node between adjacent nodes of n and non-covered node is large, and the residual electric power is large. The node n2 that has the biggest evaluation value is selected to be the next CH as well as n1, and the adjacent node of n2 is deleted from the list of non-covered nodes. And, if 2-hop-coverage does not exceed the threshold, the next CH is repeatedly chosen until the threshold of 2-hop-coverage is exceeded.

When representative node L finishes the selection of the CH, it broadcasts the CH advertisement in the range R. The CH advertisement includes information on the selected CHs and non-covered node list. The non-covered node list in the advertisement is called as the 3-hop-check-list. Adjacent node n of L which receives the CH advertisement of L adds L to the adjacent CH list of oneself. If n is selected as the CH, L is called as the n's parent CH and n starts to select the next CH with the same process.

When the selection of the CH is finished, node n creates 3-hop-check response for 3-hop-check-list from the parents CH. As for 3- hop-check response, the node which can reach by two hops from n via the adjacent CH of n is stored, which is included in the 3-hop-check-list. The adjacent CHs include the CH that n newly selects. In a word, it becomes nodes which can reach by three hops from the parents CH. After the calculation, n broadcasts the CH advertisement in the range R. The CH advertisement includes information on the selected CHs, 3-hop-check-list of n, and 3- hop-check response to parents CH.

After transmitting 3-hop-check-list, CH n waits 3-hop-check response during the fixed time. n deletes the node included in the non-covered node list, that found in the 3-hop-check response. If the fixed time ends and 3-hop-check-list does not empty, the evaluation value of the node included in the adjacent node list of n is calculated again based on expression (3.2). Node n2 whose evaluation value is the highest is newly chosen to be a CH, and 3-hop-check-list is transmitted to n2 on CH-request message.

CH n2 selects the CH according to the procedure of (3) when this is received, and broadcasts CH advertisement

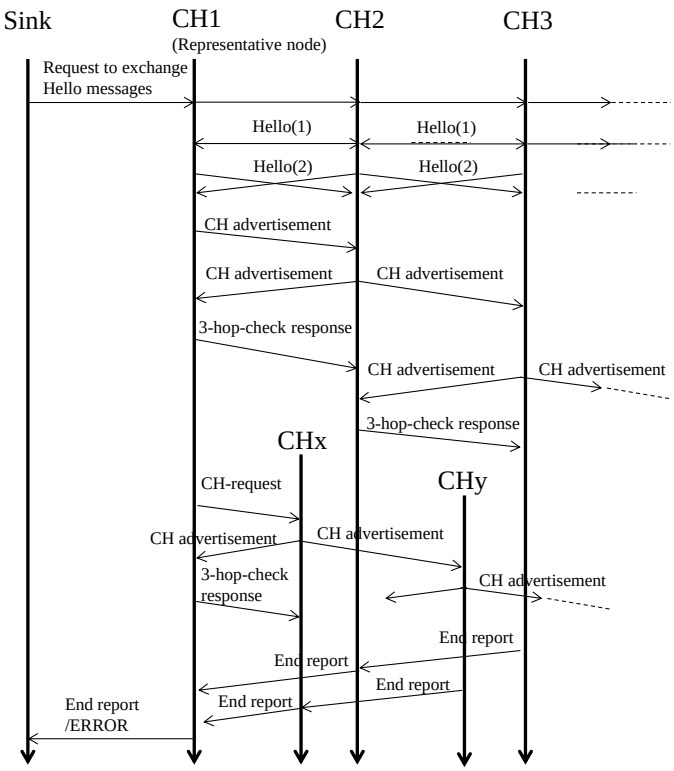



Fig.3.1 Message sequence chart of proposed algorithm.

including 3-hop-check response to n. When 3-hop-check-list does not empty even if n receives this, CH n repeats these processes until 3-hop-check-list empties.

(4)End report phase.

When the non-covered node list empties, and the CH is not selected newly, CH n transmits the end report of the CH selection to the parents CH. In addition, when the end report is received from the all child CHs, and the non-covered node list empties, the parents CH transmits the end report to the upper parents CH. Thus, all nodes on the network can belong to either of CH when the end report is forwarded, and the sink receives the end report. Therefore, the selection of the CH is ended now.

When the selection of the CH ends, the sink node broadcast the request to participate to a cluster. The node which received this makes the CH with the strongest RSSI of the CH advertisement a parents CH among lists of the adjacent CH, and transmits the participation request. On the other hand, in case of the child CH of the CH receives the request to participate to a cluster, the child CH rebroadcast the message. As a result, all nodes will participate to either of CH.

The CH makes the cluster member's data transmission schedule and broadcasts it after the fixed time later of broadcast of the request to participate to a cluster. When the schedule is received, the child node maintains the order of the transmission until the round changes.

However, there is the case that some nodes do not belong to any clusters because the transmission range R is too small. In this algorithm, the representative node enlarges the transmission range R and restarts the clustering.

Message sequence chart of proposed algorithm is shown in Fig.3.1. Representative node in Fig.3.1 is indicated as CH1. CH2 and CH3 are selected CH by CH1 and CH2 respectively. CHx is extra selected CH by CH1 after receiving CH advertisement from CH2. CHy is selected CH by CHx.

### 3.3 Collection of sensing data

The timing of data collection is notified by the data request message from the sink node. If the child CH node of the sink receives the data request, the CH rebroadcasts the message to the cluster members. If there is CH node in the cluster, it rebroadcasts the message. The message is spread in all nodes by repeating this process.

If a CH node receives all sensing data from all member nodes and child CHs, it compresses these data and own data, and send to the upper CH. The parent CH also sends the data to the upper CH similarly.

Thus, the sensor data that all nodes collected from the end of the network is collected in the sink. When the sink finishes collecting all data, one cycle is completed. After some cycles are repeated, it moves to the next round.

## 4 SIMULATION

Simulation program written in Java is used to evaluate the LEACH, HEED, HIT and proposed method. Neither a physical layer nor the MAC layer are included in the simulation program. Therefore, the influences such as the electric wave interferences and obstacles are not considered in the simulation. The communication between nodes that exist in the transmission range is assumed to be dependable. The situation that the sensors are scattered to the observation area that the person cannot enter is assumed. The sink node is out of the observation area. The assumed observation area is shown in the figure as follows.

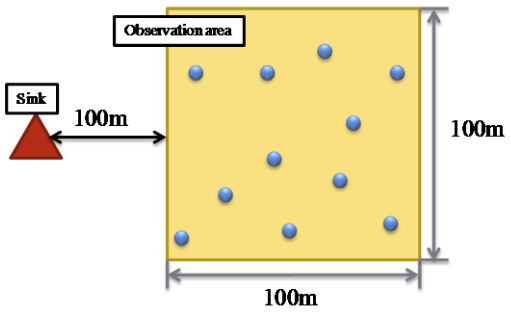



Fig.4.1 Simulation environment.

### 4.1 Simulation environment

In the simulation environment, the observation area is 100m x 100m and the sink node is located at the point that 50m to south and 100m to west from the northwest end point of the observation area. Maximum transmission range of the node is 150m. In the proposed method, 25m is used CH selection process in the observation area.

Power consumption model of the transmission and reception is used in [1]. Consumed power $E_T$ for k bits transmission to the node that d m away from sender is expressed in the equation (4.1). The Consumed power $E_R$ for k bits reception is equation (4.2).

$$E_T = E_{elec}k + \varepsilon_{amp}kd^2 \qquad (4.1)$$

$$E_R = E_{elec}k \qquad (4.2)$$

Here, $E_{elec}$ is the consumed power to send/receive 1 bit, $\varepsilon_{amp}$ is the consumed power to send the data.

The simulation is executed until all nodes exhaust the electric power. After the simulation, the number of cycles, the maximum and average residual electric power is compared. Common parameters used in the simulation are shown in Table 4.1.

Table 4.1 Common parameters.

| Parameter | Value |
|---|---|
| $E_{elec}$ | 50nJ/bit |
| $\varepsilon_{amp}$ | 100pJ/bit/m$^2$ |
| Control message size | 500bits |
| Data size | 2000bits |
| Number of nodes | 100 |
| Max transmission range | 150m |
| Step of transmission range R | 20m, 30m, 40m, 150m (4 steps) |

The number of cycles in a round and the probability of the node to try to become CH should be decided in LEACH. From the preliminary simulation to decide the parameters, the number of cycles and probability is decided as 10 and 0.05 respectively.

The number of cycles in a round and the probability of the node to try to become CH ($CH_{prob}$) should be decided in HEED. From the preliminary simulation like as LEACH, the number of cycles and probability $CH_{prob}$ is decided as 10 and 0.1 respectively.

In HIT, the number of cycles in a round is decided as 250 from the preliminary simulation.

The number of cycles in a round, the threshold of 2-hop-coverage, and the weight $w$ of the residual electric power should be decided in our proposed method. From the preliminary simulation, 50, 0.7, and 2.0 are decided respectively.

### 4.2 Simulation results and discussion

The first simulation result is the number of node alive until the all nodes exhaust the electric power (Fig.4.2). From the simulation results, the number of node alive of proposed method becomes better performance than other methods.

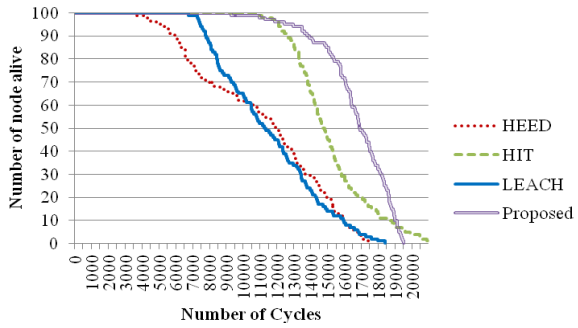



Fig.4.2 Number of node alive.

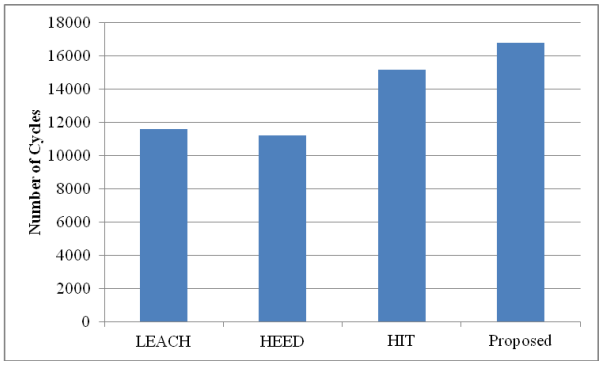



Fig4.3 Average Number of cycles.

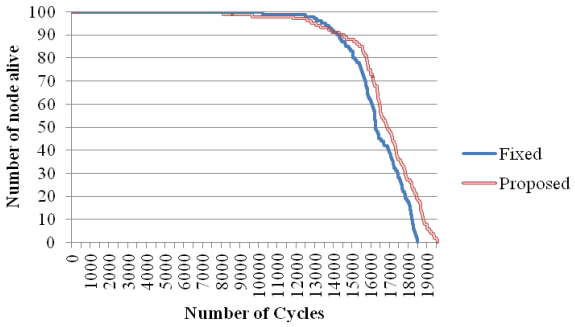



Fig.4.4 Number of node alive.

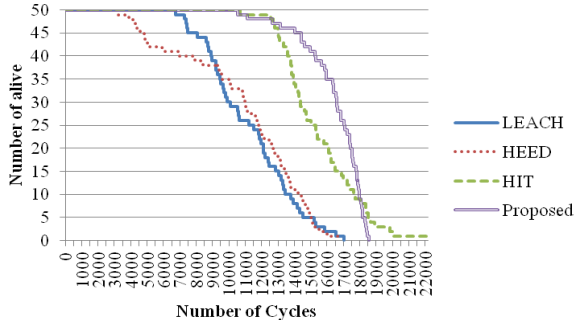



Fig.4.5 Number of node alive.(node = 50)

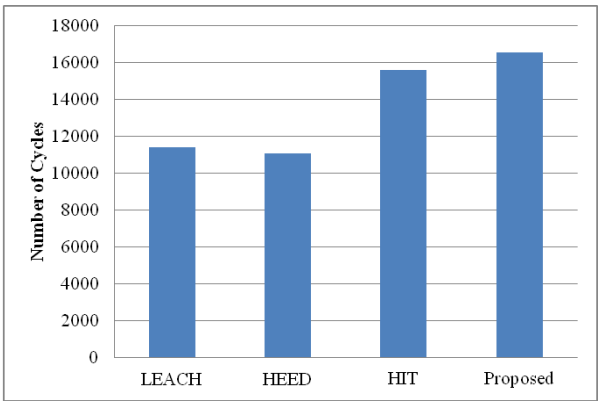



Fig4.6 Average Number of cycles.(node = 50)

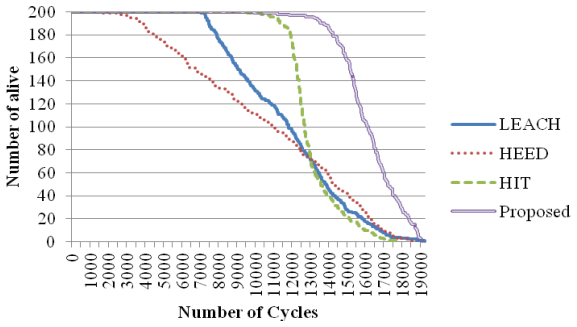



Fig.4.7 Number of node alive.(node = 200)

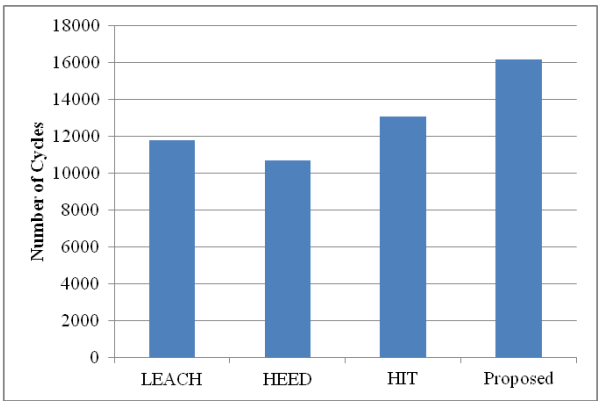



Fig4.8 Average Number of cycles.(node = 200)

Around 1700 cycle, the number of node alive becomes smaller than HIT. However, the number of cycles that 80% node alive becomes 25% longer than HIT. It means that the life time of the sensor network is improved.

Fig.4.3 shows the average number of cycles of node until the all nodes exhaust the electric power. The result of the proposed method is about 10% better than HIT.

Fig.4.4 shows the comparison between the fixed transmission power and the changed transmission power. The changed transmission power proposed in this paper is better than fixed one.

Fig.4.5 to Fig.4.8 show the results of the number of node alive and average number of cycles until the all nodes exhaust the electric power. The number of node is 50 and 200 respectively. Our algorithm shows a good result in each number of nodes. Especially, there is a difference with other methods remarkably when there are a lot of nodes in the network.

## 5 CONCLUSIONS

In this paper, we proposed energy-efficient clustering algorithm considering adjacent nodes and residual electric power. In addition, we inspected effectiveness of our method by comparing our method with the traditional method by the simulation.

As a result, proposed method showed higher performance than LEACH, HEED and HIT. The number of cycles that 80% node alive becomes 125 % of HIT algorithm.

Future work of our research is detailed evaluation based on the well-known simulator. Improvement of our algorithm to consider the coverage of the sensor area is also our future work.

## REFERENCES


[1] W. R. Heinzelman, J. Kulik, H. Balakrishnan, “Adaptive protocols for information dissemination in wireless sensor networks,” Proceedings of the 5th annual ACM/IEEE international conference on Mobile computing and networking (MobiCom '99), pp.174-185, 1999.

[2] C. Intanagonwiwat, R. Govindan, D. Estrin, J. Heidemann, "Directed diffusion for wireless sensor networking," IEEE/ACM Transactions on Networking (TON),Vol. 11 Issue 1, pp.2-16, 2003.

[3] F. Ye, G. Zhong, S. Lu, L. Zhang, "GRAdient Broadcast: A Robust Data Delivery Protocol for Large Scale Sensor Networks," ACM Wireless Networks, Vol.11, pp.285-298, 2005.

[4] J. Hill, R. Szewczyk, A. Woo, S. Hollar, D. Culler, K. Pister, "System architecture directions for networked sensors," Proceedings of the ninth international conference on Architectural support for programming languages and operating systems, pp.93-104, 2000.

[5] J. Zhang, Z. Yang, B. Cheng, and P. McKinley, "Adding Safeness to Dynamic Adaptation Techniques," Proc. ICSE 2004 Workshop Architecting Dependable Systems, pp. 17-21, 2004.

[6] H. Luo, F. Ye, J. Cheng, S. Lu, L. Zhang,” TTDD: A Two-tier Data Dissemination Model for Large-scale Wireless Sensor Networks,” International Conference on Mobile Computing and Networking (MobiCom), pp.148-159,2003.

[7] T. He, J. A. Stankovic, C. Lu, T. Abdelzaher,"SPEED: a stateless protocol for real-time communication in sensor networks," 23rd International Conference on Distributed Computing Systems, pp.46-55, 2003.

[8] W. R. Heinzelman, A. Chandrakasan and H. Balakrishnan: “Energy-Efficient Communication Protocol for Wireless Microsensor Networks”, Proceedings of the 33rd Hawaii International Conference on System Sciences, pp. 1-10, (2000).

[9] O. Younis and S. Fahmy: “HEED: A Hybrid, Energy-Efficient, Distributed Clustering Approach for Ad Hoc Sensor Networks”, IEEE Transaction on Mobile Computing, vol.3, No.4, pp. 366-379, (2004).

[10] B. J. Culpepper, L. Dung and M. Moh: “Design and Analysis of Hybrid Indirect Transmissions (HIT) for Data Gathering in Wireless Micro Sensor Networks”, ACM Mobile Computing and Communications Review, vol.3, pp.61-83, (2004).

[11] Toyoda, S., Sato, F., "Energy-Effective Clustering Algorithm Based on Adjacent Nodes and Residual Electric Power in Wireless Sensor Networks," 26th International Conference on Advanced Information Networking and Applications Workshops (WAINA), pp.601-606, 2012.

[12] S. Lindsey, C. Raghavenda and K. M. Sivalingam: “Data Gathering Algorithms in Sensor Networks Using Energy Metrics”, IEEE Transactions on Parallel and Distributed Systems, vol.13, No.9, pp.924-935, (2002).

[13] W. Choi, P. Shah and S. K. Das: “A framework for energy-saving data gathering using two-phase clustering in wireless sensor networks”, Proceedings of the First Annual International Conference on Mobile and Ubiquitous Systems: Networking and Services, pp.203-212, (2004).

[14] RPL:”IPv6 Routing Protocol for Low power and Lossy Networks, “ ROLL IETF Internet-Draft, 14 September 2011, draft-ietf-roll-rpl-19[work inprogress].

[15] Dvir, A., Holczer, T., Buttyan, L.: “VeRA - Version Number and Rank Authentication in RPL,” IEEE 8th International Conference on Mobile Adhoc and Sensor Systems (MASS),pp.709-714, 2011.

[16] Pavkovi, B., Theoleyre, F., Duda, A.: "Multipath opportunistic RPL routing over IEEE 802.15.4," Proceedings of the 14th ACM international conference on Modeling, analysis and simulation of wireless and mobile systems (MSWiM '11), pp. 179-186, 2011.

[17] J. Ushijima, M. Okino, T. Kato and S. Ito:” Proposal and Evaluation of a Selecting Method of Landmark Nodes for Message Relaying over High Density Ad hoc Network”, IEICE technical report 103(202), 93-96, (2003), (In Japanese).

# Session 2:
# Communication
# (Chair: Tomoya Kitani)

# Short Time Measurement Method for Detection Threshold with Scent Presentation Technique of Pulse Ejection

Aya Fukasawa†, and Ken-ichi Okada‡

†Graduate School of Science and Technology, Keio University, Kanagawa, Japan
‡Faculty of Science and Technology, Keio University, Yokohama, Japan
{fukasawa, okada}@mos.ics.keio.ac.jp

***Abstract*** - A decline in olfaction is reported to be an early symptom of diseases such as Alzheimer's and Parkinson's disease. Thus, from a medical point of view, understanding the condition of the olfactory system is important. However, unlike sight and hearing, olfaction is not examined at a regular health checkup. Because scents linger in the air and measurements require a great deal of care and time. In this study, we construct olfactory measurement method for health checkup. We use inkjet olfactory display. Thus, pulse ejection for scent presentation is able to minimize odor elimination. Measurement algorithm uses binary search. Therefore, we can measure the detection threshold at 192 levels in total by changing the unit average ejection quantity and ejection time. For measurement result, the standard deviations of the detection threshold are large. Furthermore, only 5 min is needed to measure the detection thresholds. From this knowledge, measurement time, burdens on the patient and operator and problem such as odor elimination were cleared up so that olfactory measurement in health checkups is expected to work out.

***Keywords***: olfactory display, olfactory information, pulse ejection, interface application, medical check

## 1 INTRODUCTION

Olfaction is used to detect dangers such as rotten food and gas leaks. Moreover, a decline in olfaction is reported to be an early symptom of diseases such as Alzheimer's and Parkinson's disease. Thus, from a medical point of view, understanding the condition of the olfactory system is important. The predominant measurement method for olfaction is Toyota and Takagi (T&T) olfactometry and venous olfactory test. However, unlike sight and hearing, olfaction is not examined at a regular health checkup. The measurement of many people is carried out at a time at health checkup. If olfactory measurement is carried out, scented paper and bags filled with scents are used in each olfactory check, and a considerable amount of waste is generated that must be dealt with. In addition, the odor preparation and measurement are all performed manually in existing olfactory examinations. Hence, measurements require a great deal of care and time. Furthermore, health checkup is often carried out the room which is difficult to provide adequate ventilation such as gymnasium and classroom. Hence attention is needed that scent does not scatter at the measurement.

In this study, we construct olfactory measurement method using olfactory display which can control scents precisely enough to be used in olfactory measurement. For the measurement, we use olfactory display by using a technique based on an inkjet printer mechanism. This olfactory display uses pulse ejection for scent presentation so that we can measure without diffusion of scent. We use measurement algorithm using binary search for detection threshold. We can measure the detection threshold at 192 levels by changing the number of simultaneous ejections ($NSE$) and ejection time.

## 2 MEDICAL KNOWLEDGE

### 2.1 Disease about Olfaction

Alzheimer's and Parkinson's disease occupy approximately 60% of dementia in Japan and are generally well known[1]. Alzheimer is easy to be mistaken for forgetfulness, and the early detection is difficult. However, here is the risk becoming too late if discovery becomes late. Patients with these disease have risk that olfactory impairment is caused. About lower respiratory infection and inflammatory disease in stage of old age, etiology is discussed in relation to rhinosinusitis. Checking the condition of the olfactory system leads to early detection of disease such as Alzheimer[2].

### 2.2 Existing Olfactory Examinations

To discover whether any olfactory impairment has occurred, a suitable assessment technique is required. In Japanese, T&T olfactometry is usually employed to take such measurements. T&T olfactometry measures a patient's olfactory thresholds by presenting, in front of the nose, paper scented with a basic odorant[3]. Tests thus use five smells. Each test begins at the lowest scent concentration, which is then increased until the examinee detects the odor. This value is set as the detection threshold. Next, the concentration is further increased until the examinee recognizes the scent. At this point, the examiner displays a choice of words to express the quality of the smell. If the correct answer is selected, the corresponding concentration is set as the recognition threshold. Each basic smell is given a score at one of eight levels from -2 to 5, where 0 corresponds with the mean Japanese detection threshold. The result is finally plotted in an olfactogram on graph paper[4].

Intravenous test is also employed to determine the level of olfactory impairment. In this test, Alinamin injection with a strong garlic odor is injected via the cubital vein, and the interval between the start and end of the reported smell perception is timed. In normal participants, the start time for perception is around 5–10 s and the end time is 60–90 s. Although this test is a limited method, which is done in a general clinic,

implementing this test could be important in determining the prognosis of olfaction impairment and deciding upon a treatment regimen. Except for respiratory dysosmia, this test is helpful for olfactory anesthesia. If a long time elapses without recovery of olfaction, the patient will have only a small chance of recovery. Therefore, this test is crucial for early diagnosis and treatment of olfaction impairment[5]. However, a disadvantage of the test is that in one-third of cases, participants experience pain near the injection site from elbow to shoulder[6].

## 2.3 Olfactory Threshold

Olfactory thresholds are values used to express the intensity of a scent. Typically, four types of olfactory thresholds are used: detection, recognition, differential and identification [7].

- Detection threshold: the minimum concentration at which a scent can be detected when the patient does not need to recognize the type of smell.
- Recognition threshold: the minimum concentration at which the type of scent can be recognized. Its value reflects the ability of the patient to express the quality and characteristics of the scent.
- Differential threshold: the minimum concentration at which a patient can distinguish the strength of a scent. Its value reflects the patient's ability to detect changes in the stimulus and to quantify the change.
- Identification threshold: the minimum concentration at which a patient can identify a scent presented beforehand.

In a general olfactory examination, acuity is measured by using these thresholds. For example, T&T olfactometer measures detection threshold. In this study, we measure the detection thresholds. Measuring detection threshold can help to find an early symptom of diseases.

## 2.4 Implementation of the Olfactory Measurement at Health Checkup

The health checkup is the health care service that local government and health insurance union provides publicly. It is mainly carried out by schools, and having a health checkup is needed once a year. In health checkup, various measurement including body measurement, eye exams are performed in a mass. Moreover, the measurement is carried out for hundreds of people per day. Hence, in current olfactory checks, there are problems that a lot of waste such as bags filled with scents and scented paper and a great deal of care and time.

On the other hand, health checkup is carried out in a gymnasium and classrooms as schools, so same people have to be measured at a time in the place where there is not enough ventilation. In olfactory check, it is necessary to pay adequate attention not to fill a room with scent. From the viewpoint of these, existing olfactory examinations are difficult to carry out at health checkup. Hence olfactory examinations are not standard in health checkups today.

# 3 OLFACTOORY MEASUREMENT METHOD FOR HEALTH CHECKUP

Olfactory examinations are not carried out at health checkups on grounds that scent scatter in the air, waste such as scented paper and bags filled with scents is generated, measurements require a great deal of care and time and so on. A decline in olfaction is reported to be an early symptom of diseases such as Alzheimer's and Parkinson's disease. Thus, understanding the condition of the olfactory system is important. Through the solution of the issue, olfactory examination can be utilized in health checkup. To this end, we work out olfactory measurement method aiming to use at health checkup. This method makes it possible to measure detection threshold at health checkup. By using this measurement method, we can easily carry out the olfactory measurement at the plface such as a classroom and a gymnasium. Detection threshold is simple examination that people can understand scent or odorless. Thus, we adopted detection threshold from olfactory threshold because it can make measurement in a short time possible. As for measurement method, we discussed with ear, nose, and throat doctor, and made many improvements. Hence it is more practical measurement method.

The issue such as diffusion of scents, waste and a great deal of care to measure is cleared up by olfactory display we developed, using a technique based on an inkjet printer mechanism. This olfactory display can use a scent presentation technique to emit scent for a short duration that we call "pulse ejection". It has use of the wind and carries scent to user's nose directly, so that user can feel it. Pulse ejection emits aroma chemical minutely small doses, so that user can feel little scent when user departs from the device. Thus, it isn't necessary to worry about scent diffusion. This device uses wind to carry scent and has ink tank filled with aroma chemical in place of ink. Once scent is restocked with tank, more than ten thousand times of ejection is possible. Hence waste isn't generated at measurement. The device is controlled with PC and can change $NSE$ and ejection time freely. Thus, care to measure is alleviated because we can emit scent just to operate a PC.

The olfactory measurement method uses binary search so that measurement can be finished in a short amount of time. Scent intensity is controlled with $NSE$ and ejection time. In this study, measurement algorithm is specific one using binary search to combine with these parameters. Value of these parameters is changed in order to take dynamic range widely. Hence a lot of people who have from good sense of smell to bad sense of smell can be measured. This measurement method is aimed at the utilization of screening. This measurement is also aimed at finding fear of olfactory impairment. If the fear is found at this measurement, the patient shall go to hospital and measure precisely by existing olfactory examinations. Existing olfactory examinations can measure precisely but isn't suitable for measurement with many people at a time in the place such as a gymnasium and classrooms as schools. Hence we worked out olfactory measurement method aiming at health checkup.

We make a measurement and examine the availability of the measurement method. Moreover, at health checkup, measurement have to be finished within 5 minutes. Thus, we

timed measurement and also examine the utility.

## 4 OLFACTORY MEASUREMENT METHOD

### 4.1 Pulse Ejection

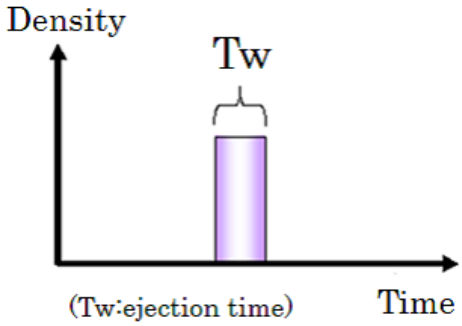



Figure 1: Pulse Ejection

We previously solved the problem of scents lingering in the air by presenting scent at the picoliter level for a short duration with a system that we call ”pulse ejection” (Figure 1). Pulse ejection can minimize the lingering of scents in the air. We measured human olfactory characteristics by this system and developed a presentation method in consideration of these influences. Here, we examine the appropriate olfactory characteristics to use at a health checkup from those that we have measured. Moreover, we devise an olfactory examination using our pulse ejection display.

We consider that olfactory examinations at health checkups should target people of all ages from children to elderly, and should be applicable to tens of people simultaneously. Hence, to the extent possible, the chosen olfactory characteristic must be straightforward and measurable by a simple procedure. With these notions in mind, we designed an olfactory examination method by using pulse ejection.

### 4.2 Olfactory Display

Figure 2: Olfactory Display

We developed an olfactory display shown in Figure 2. This display uses the technique used in ink-jet printer in order to produce a jet which is broken into droplets from the small hole in the ink tank. This device can use pulse ejection for scent presentation so that the issue such as scent lingering and care to eject scent can be minimized. Scent intensity is controlled with $NSE$ and ejection time. The device can change the ejection time at 667 $\mu$s intervals so that measurement can be controlled precisely.

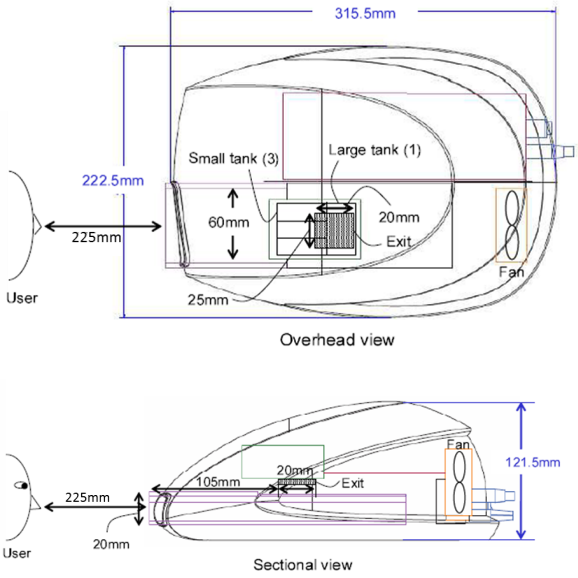



Figure 3: Plane and side view of the olfactory display

Figure 3 shows internal design of the olfactory display. The display can set up an ejection head. This head can store three small tanks and one large tank, thus this display can contain 4 kinds of scents maximum. In this study, we used large tank. The display is equipped with a fan and there are 10 phases of wind velocity control in the range of 0.8 m/sec-1.8 m/sec. The scent presentation hole is a rectangle of 2 cm length and 6 cm width.

It is possible to change the ejection quantity and the kinds on 100msec rate at this display. The ejection quantity (EQ) is calculated as follows.

$$EQ(pL) = UAEQ(pL/time) \times NSE \times V(times) \quad (1)$$

Here, UAEQ is the unit average ejection quantity (the average ejection quantity from each minute hole in the head), NSE is the number of simultaneous ejections (the number of minute holes in the head that emit at one time), and V is the volume (explained below). There are 127 minute holes in the head connected to the small tank and 255 minute holes in the head connected to the large tank. Moreover, the display can emit scent from multiple holes at the same time, so $NSE$ is adaptable to 0-127 (small tank), 0-255 (large tank). In addition, the user can set the number of ejection times 1-150 in 100msec from one hole, which we denote the ”volume”. By setting the volume, ejection control of 667 $\mu$ s for a unit is

possible. The concept of volume is shown in Figure 4. Volume is converted at time and expressed in ”ejection time” in the measurement.

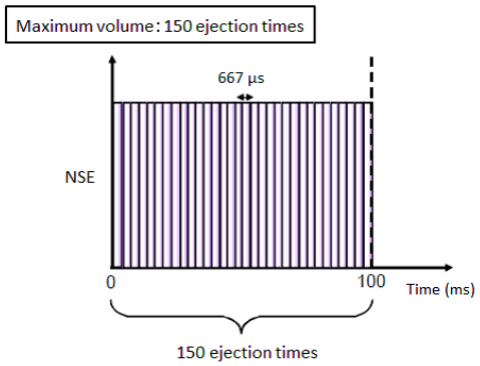



Figure 4: Concept of Volume

UAEQ from one minute hole on large tank is 7.3 pl. It was confirmed to be approximately constant without depending on the residual quantity of ink on examination. In this study, we adjust EQ by changing NSE. We put the change of EQ into ”scent intensity” and denote as follows. And scent is diluted by 5% with ethanol and water. So scent quantity is practically calculated as follows.

$$Scent\ Intensity = UAEQ(pL/time) \times NSE \quad (2)$$

$$Scent\ Quantity = EQ \times 0.05 \quad (3)$$

### 4.3 Measurement Algorithm using binary search

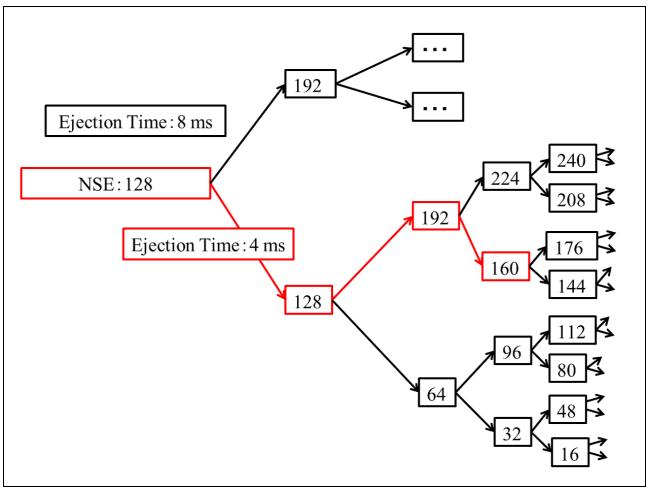



Figure 5: Measurement Algorithm for Detection

In this study, we use $NSE$ from 0 to 255 and ejection time 8ms and 4ms. We previously measured olfactory characteristics by using 100ms and 13.3ms ejection time. However, average of detection threshold was low, and hence people who have a good sense of smell were found little difference[8]. We repeat preliminary experiment and adjust value to measure people who have a good sense of smell. Thus, we adopted 8ms and 4ms.

We use the algorithm shown in Figure 5. This algorithm is binary search algorithm $NSE$ with ejection time. $NSE$ is decreased if the answer is correct and increased if the answer is incorrect. We begin with 128 $NSE$ and an ejection time of 8ms. $NSE$ is changed from 0 to 255 in the measurement, and hence we start measurement from median $NSE$. For the first measurement, the ejection time changes to 4ms if the participant’s answer is correct and stays at 8ms if the answer is incorrect. We give an example and explain the way of value change. First, we begin with 128 $NSE$ and an ejection time of 8ms. For the first measurement, the ejection time changes to 4ms if the participant’s answer is correct. Second, $NSE$ changes to 192 which is the value added 64 that is half 128 value to 128 if the participant’s answer is incorrect. Next, $NSE$ changes to 160 which is the value subtracted 32 that is half 64 value from 192 if the participant’s answer is correct. Similarly, we measure until a change level becomes 2.

In this way, we take dynamic range widely by changing value of $NSE$ and ejection time. Detection threshold is measured at 192 levels in this measurement method.

## 5 EXPERIMENTAL OUTLINE

### 5.1 Experimental Environment

Figure 6: State of the experiment

Each participant was required to sit in front of the olfactory display and place their chin on the chin rest such that the distance from the olfactory ejection point to the nose was fixed at 22.5 cm as shown in Figure 6. The patient experiences a feeling of oppression if he gets too close the device and he can’t feel scent if too far from one. For this reason, this is the value we adjusted to meet conditions. The fan of the display was switched on during experiments to stop participants being able to tell when the scents were delivered to them. A previous experiment found that a scent will not linger in the air if the wind speed is higher than 1.2 m/s[9], and so the wind speed in the current experiment was set to 1.8 m/s.

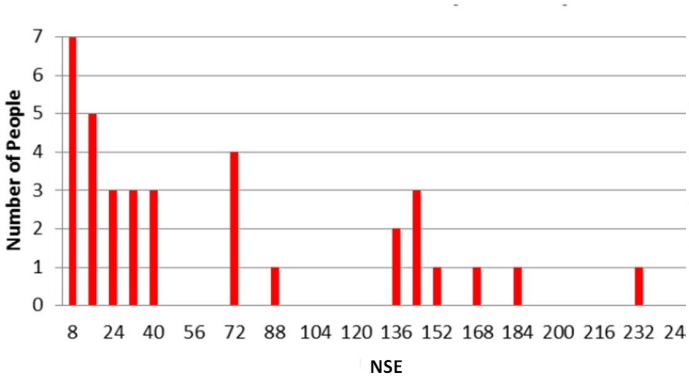



Figure 7: Detection threshold in 4ms

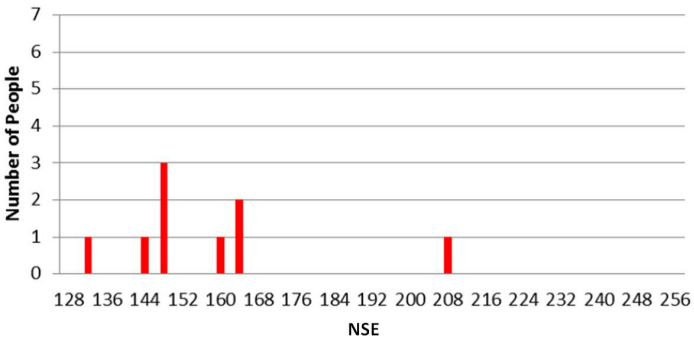



Figure 8: Detection threshold in 8ms

## 5.2 Experimental Method

By following olfactory measurement method shown in Section 3, we conducted olfaction examinations on 44 participants, measuring their detection threshold. A description of the participants is given in Table 1. Participants were 33 men and 11 women in their 20s to 40s. There were many participants in their 20s and all participants had perfect olfactory function.

Table 1: Description of Participant(people)

| | Male | Female | Sum |
|---|---|---|---|
| 20s | 26 | 9 | 35 |
| 30s | 6 | 2 | 8 |
| 40s | 1 | 0 | 1 |
| All | 33 | 11 | 44 |

To determine the detection threshold, we use isoamyl acetate, which smells like banana. This scent is simple chemical substance, and hence it does not come under an influence by a production area and the preservation organization unlike natural fragrance and there is an advantage to be superior in reproduction. We use this scent in the measurement because scent of banana is relatively easy to detect. We use the triangle test to judge the detection threhold in the measurement. In the triangle test, three stimuli are presented at random, where one of them is scented and the other two are odorless. The participant then answers when the scented odor was presented. When the scent is ejected, the countdown starts with the auditory cue. Scent emission then commences 0.5 s after giving the cue ”Go” according to previous study[10]. At the same time to find a value of the detection threshold, we timed measurement from beginning to finishing.

# 6 RESULTS

## 6.1 Measurement Result of Detection Threshold

The results of detection threshold measurements for the 44 participants are listed in Table 2, which shows average, standard deviation, max and min on the 4ms and 8ms results. Depending on measurement algorithm, $NSE$ is from 2 to 255 when ejection time is 4ms, and from 128 to 255 when ejection time is 8ms. Here, the standard deviations are large. Thus, a definite expression of a person's olfactory ability can be obtained. Minimum value participants can detect is 2 in 4ms, and it fits in minimum value in measurement algorithm. Hence, measurement for person who has a good sense of smell was possible in this measurement. Moreover, Maximum value participants can detect is 206 in 8ms. It was found that the detection threshold for participants who have perfect olfactory function depended on personal olfactory ability in this measurement method.

Table 2: Result for detection threshold

| | 4ms(35 people) | 8ms(9 people) |
|---|---|---|
| Average | 60.06 | 155.78 |
| Standard Deviation | 62.64 | 21.39 |
| Max | 228 | 206 |
| Min | 2 | 130 |

Figures 7 and 8 show distribution of measurement result. In fact, we measure detection threshold at 192 levels. However, we show the measurement result at 48 levels in Figures 7 and 8, so that distribution of the number of people can be easy to understand. Abscissa axis shows $NSE$, which is detection threshold of each person. Vertical axis shows a number of people and expresses it how many participants who became each detective threshold there is. Performing $U$ tests on the 4ms and 8ms results, no significant difference was found between men and women or between age groups ($p>0.05$). We measured the detection threshold precisely in this study, and

hence a measurement finishes has been completed up to eight times. It cannot take time for the per person measurement at health checkup. Because the screening of olfactory impairment is a purpose at health checkup, it is thought that such delicate measurement is not necessary. We measure detection threshold at 192 levels, however, we show the measurement result at 48 levels in Figures 7 and 8. Through this, it is revealed that personal ability to smell is seen even if the number of the measurement is reduced to some extent.

## 6.2 Measurement Time

The average measurement time was 4 minutes 21 seconds and the standard deviation was 37.1 seconds. Thus, measurement could be finished within 5 minutes regardless of participants. Measurement time for per person has to be kept to the minimum at health checkup. According to ear, nose, and throat doctor, olfactory measurement has to be finished within 5 minutes at health checkup. Then, this measurement method is finished within 5 minutes and is easy to carry out at health checkup.

In this measurement, participants had no experience in olfactory check, so they got bewildered and got thoughtful, and hence there were many persons who took time more than radical measurement time. It is thought to shave off time if olfactory check is carried out at health checkup and persons are used to measure. In fact, measurement of us who are used to measure olfactory check was finished in 3 minutes 40 seconds. Moreover, we measured finely, so it took time. As cited in chapter 6.1, it was found that personal ability to smell is seen even if the number of the measurement is reduced to some extent. Thus, a number of levels are decrease so that measurement time can reduce more than result in this time.

# 7 CONCLUSION

A decline in olfaction is reported to be an early symptom of diseases such as Alzheimer's and Parkinson's disease. Thus, from a medical point of view, understanding the condition of the olfactory system is important. The predominant measurement method for olfaction is Toyota and Takagi (T&T) olfactometry and venous olfactory test. However, unlike sight and hearing, olfaction is not examined at a regular health checkup on grounds that scent scatter in the air, waste such as scented paper and bags filled with scents is generated, measurements require a great deal of care and time and so on.

In this study, we worked out olfactory measurement method aiming to use at health checkup. We used inkjet olfactory display which can use pulse ejection for scent presentation to minimize odor elimination. Measurement algorithm uses binary search. Therefore, we could measure the detection threshold at 192 levels in total by shift in the number of simultaneous ejections. For measurement result, only 5 min was needed to measure the detection thresholds. Moreover, the standard deviations were large. Thus, a definite expression of a person's olfactory ability could be obtained.

Based on this technique, we will devise olfactory measurement method to enable the measurement in the short time more in future.

# 8 ACKNOWLEDGMENTS

This work is supported in part by a Grant-in-Aid for Scientific Research (B), 2012, No. 23300049 from the Ministry of Education, Culture, Sport, Science and Technology Japan, Dr. Kanzaki at Keio University Hospital and Takasago International Corporation.

# REFERENCES

[1] T. Nagao, Physical and laboratory findings in the differential diagnosis of dementia, Advanced age dementia study bulletin, Vol. 16, pp. 61–62 (2010) (in Japanese).

[2] K. Kurihara, Taste and Olfaction, Chemical coterie (1990) (in Japanese).

[3] Product Information, T&T olfactometer, http://www.j-ichiyaku.com/medical/t-t.html(2012/3/13)

[4] Y. Toyokoka and M.Sotouchi, Applied engineering of the smell, Asakura Publishing (1994) (in Japanese).

[5] Uehara K., Kanazawa T., Hasegawa M., Ura M., Noda Y., Tono T., A Clinical Study of Olfactory Disturbance. The Society of Practical Otolaryngology, Vol.97, No.1, 25-30(2004)(in Japanese).

[6] Kamio T., The Method of Olfactory Test Especially on Clinical Studies of the Method of Venous Olfactory Test. The Oto-Thino-Laryngological Society of Japan, Inc., Vol.66, 469-485(1947)(in Japanese)

[7] O.C.A. of Japan, Term and Commentary of Odor(2003)(in Japanese).

[8] S. Sugimoto, Y. Bannai, K. Okada, Measurement of Smelling Ability Using Olfactory Display, Trans. of Virtual Reality Society of Japan, Vol. 16, No. CS-2, pp. 31–36 (2011) (in Japanese).

[9] A. Kadowaki, J. Sato, Y. Bannnai and K. Okada, The Response Model of Human Sense of Smell in a Pulse Emission, Trans. of Virtual Reality Society of Japan, Vol. 12, No. 2, pp. 9–14 (2007) (in Japanease).

[10] Noguchi, D., Sugimoto, S., Bannai, B. and Okada, K.:Time Characteristics of Olfaction in a Single Breath, CHI'11 Proceedings of the 2011 annual conference on Human factors in computing systems, pp.83–92, (2011).

# Smart grid management system – Design and trial development

Naoto Miyauchi [*], Hiroshi Mineno [**] , and Tadanori Mizuno [***]

[*] Graduate School of Science and Technology, Shizuoka University, Japan
[**]Faculty of Informatics, Shizuoka University, Japan
[***]Faculty of Information Science, Aichi Institute of Technology
Miyauchi.Naoto@ab.MitsubishiElectric.co.jp, mineno@inf.shizuoka.ac.jp, mizuno@mizulab.net

***Abstract*** - Electric power systems are consists of power plants, electric delivery networks and customers.
Conventional systems are characterized by a one-way flow of electricity and information, which flows from power plants to customers.
However recently customers begin to introduce renewable power plants such as photovoltaic, and it causes reverse power flow, i.e., from customer to electric delivery networks.
In order to involve renewable power to current power systems, "smart grid" is proposed in worldwide. Smart grid is an automated, widely distributed electricity delivery network. It is characterized by a two-way flow of electricity and information. To realize smart grid, a power system technology and ICT (Information & Communication Technology) should be well-integrated.
This paper provides a brief introduction the basic design and the results of the trial management systems for smart grid..

***Keywords***: SMART GRID, NETWORK ARCHITECTURE, NETWORK MANAGEMENT SYSTEM

## 1 INTRODUCTION

An electric power system consists of an electric power plant, an electrical power grid, and a consumer.
In the conventional electric power system, electric power was flowing into one way from plant to a consumer, in order for a consumer to begin to introduce the power generator using renewable energy, such as a solar cell and wind power generation. In recent years, it is necessary to also take into consideration the reverse power flow of the electricity from a consumer to an electrical power grid.

Authors examine the architecture of the telecommunications system for realizing a smart grid, and are developing a trial production system.

This paper describes the outline and requirements for a smart grid, the electric-power-supply-and-demand control system which are main subsystems of a smart grid, a power distribution control system, and a smart meter system.

After those discussions, the architecture of the smart grid management system, a trial production system, and its evaluation are reported.

## 2 SMART GRID

### 2.1 Overview of Smart Grid

A smart grid is a next-generation electricity grid.
In the U.S., the smart grid is examined as part of a Green New Deal Policy, and development is promoted by the following technical field[1].

**Wide-area situational awareness:** Monitoring and display of power-system components and performance across interconnections and over large geographic areas in near real time. The goals of situational awareness are to understand and ultimately optimize the management of power-network components, behavior, and performance, as well as to anticipate, prevent, or respond to problems before disruptions can arise.

**Demand response and consumer energy efficiency:** Mechanisms and incentives for utilities, business, industrial, and residential customers to cut energy use during times of peak demand or when power reliability is at risk. Demand response is necessary for optimizing the balance of power supply and demand.

**Energy storage:** Means of storing energy, directly or indirectly. The significant bulk energy storage technology available today is pumped hydroelectric storage technology. New storage capabilities—especially for distributed storage—would benefit the entire grid, from generation to end use.

**Electric transportation:** Refers, primarily, to enabling large-scale integration of plug-in electric vehicles (PEVs). Electric transportation could significantly reduce U.S. dependence on foreign oil, increase use of renewable sources of energy, and dramatically reduce the nation's carbon footprint.

**Cyber security:** Encompasses measures to ensure the confidentiality, integrity and availability of the electronic information communication systems and the control systems necessary for the management, operation, and protection of the Smart Grid's energy, information technology, and telecommunications infrastructures.

**Network communications:** The Smart Grid domains and sub domains will use a variety of public and private communication networks, both wired and wireless. Given this variety of networking environments, the identification of performance metrics and core operational requirements of different applications, actors, and domains—in addition to the development, implementation, and maintenance of appropriate security and access controls—is critical to the Smart Grid.

**Advanced metering infrastructure (AMI):** Currently, utilities are focusing on developing AMI to implement residential demand response and to serve as the chief mechanism for implementing dynamic pricing. It consists of the communications hardware and software and associated

system and data management software that creates a two-way network between advanced meters and utility business systems, enabling collection and distribution of information to customers and other parties, such as the competitive retail supplier or the utility itself. AMI provides customers real-time (or near real-time) pricing of electricity, and it can help utilities achieve necessary load reductions.

**Distribution grid management:** Focuses on maximizing performance of feeders, transformers, and other components of networked distribution systems and integrating with transmission systems and customer operations. As Smart Grid capabilities, such as AMI and demand response, are developed, and as large numbers of distributed energy resources and plug-in electric vehicles (PEVs) are deployed, the automation of distribution systems becomes increasingly more important to the efficient and reliable operation of the overall power system. The anticipated benefits of distribution grid management include increased reliability, reductions in peak loads, and improved capabilities for managing distributed sources of renewable energy.

In Japan, the government installs a study group and is overhauling the issues of an electric power system and information and communication technology as follows [2].

- Renewable energy (unstable power supplies, such as sunlight and wind force)
- Influence on power transmission and an electricity grid
- Integrated method of the communication technique for electric power control (non-IP), and the Internet technology

The concept of a smart grid is shown in figure 1. In a figure, an electric power system consists of following equipment.

- Plant: It generates electricity using fire power, hydraulic power, atomic power, etc.
- Power line: The electric power generated in plant is turned to a substation, and electricity is transmitted.
- Substation: Transforming the electric power
- Power line: Electricity is supplied to a consumer.
- Consumer: The ordinary homes, the commercial establishment, the industrial institution which consume electric power.

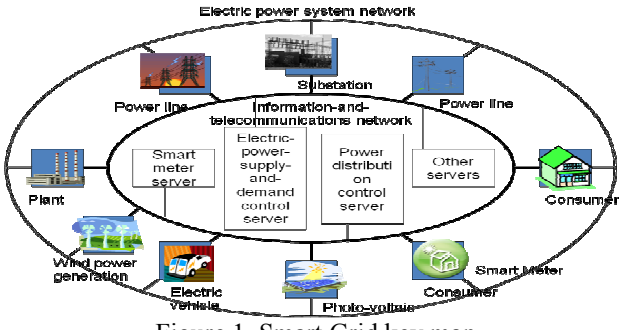



Figure 1. Smart Grid key map

The circle of the outside in a figure shows an electric power system network, and an inside circle shows the information-and-telecommunications network which supervises and controls power equipment.

Server groups, such as an electric-power-supply-and-demand control server of a central portion, a power distribution control server, and a smart meter server, employ and control the whole smart grid.

## 2.2 Electric-Power-Supply-and-Demand Control

In the electric power company, frequency is kept constant by maintaining the demand of electric power, and the balance of supply.

Spread of power generation by renewable energy, such as sunlight and wind force, may lost the demand-and-supply balance of electric power greatly according to the weather.

Conventionally, in order to take the demand-and-supply balance of electric power, have absorbed change of demand-and-supply balance by thermal power generation by basing on the nuclear power generation of output regularity, and the pumped hydro power generation which buries the big demand difference during day and night, but If renewable energy increases, it will become impossible to store change of frequency in a rated value, and it will be expected that it becomes difficult to maintain the present electric power quality.

In order to control the demand-and-supply balance of electric power, the supply-and-demand-control system in consideration of power generation by renewable energy which carries out cooperation employment of a dynamo and the storage battery is needed (shown in figure2).

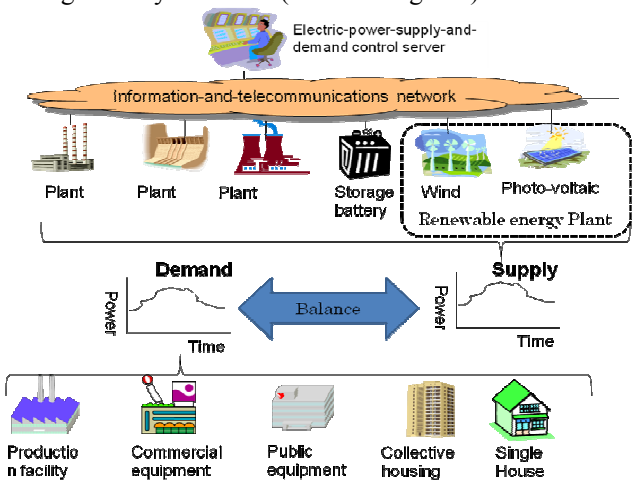



Figure 2. The outline of electric-power-supply-and-demand control

## 2.3 Power Distribution Control

A power distribution control system controls to stop a power failure part at worst, also when the whole distribution system is supervised and an accident occurs, in order to supply electric power to a consumer stably on proper voltage (shown in figure3).

In the distribution system which connects a substation and a consumer, although wind power generation spreads through a subject and photo-voltaic is spreading home use through a subject, a large-lot user, Since it is easy to be subject to the influence of weather change, if power generation by these renewable energy spreads, the flow of the electric power of a distribution system may change suddenly in the unit of a part -- the reverse power flow

turned to the substation from the consumer occurs -- and maintenance of proper voltage may become difficult only by conventional power distribution apparatus.

In order to solve these subjects, the flow of electric power is analyzed at high speed, voltage is predicted, and the voltage control system which supplies the electric power of proper voltage is needed.

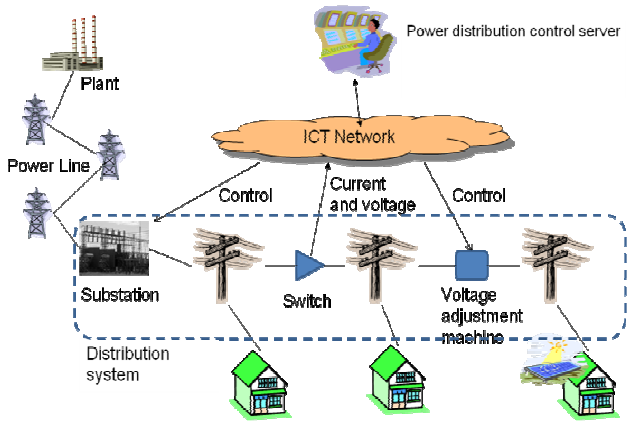



Figure 3. The outline of power distribution control

## 2.4 Smart Meter

In the electric power company, in order to advance laborsaving of the electric power meter inspection-of-a-meter business installed in the consumer, the electric power automatic inspection-of-a-meter network system is planned.

An electric power automatic meter reading system consists of smart meters with a communication function (shown in figure 4).

By introducing a smart meter, it becomes possible to carry out the remote inspection of a meter of the power consumption of a consumer through a communication network.

By realization of the remote inspection of a meter, the timing of the inspection of a meter is subdivisible every 30 minutes from conventional 1 time per month, for example.

Also it becomes possible to grasp an amount demanded in real time.

It is expected that introduction of a smart meter enables it to perform electric-power-supply-and-demand control more correctly than before.

By introducing a smart meter, the following effect is expectable.

By collecting and controlling the production of electricity of the sunlight installed in a consumer, or wind power generation, electric-power-supply-and-demand control and power distribution control may be finely realizable.

Moreover, the mechanism in which energy saving is promoted may be able to be built by connecting a smart meter with the electrical machinery and apparatus in a consumer.

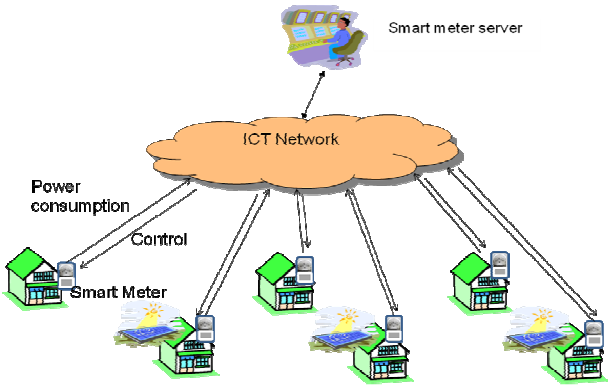



Figure 4. The outline of smart meter

# 3 TELECOMMUNICATIONS SYSTEM FOR REALIZING SMART GRID

## 3.1 Requirements

As Chapter 2 described, a smart grid mainly consists of subsystems of electric-power-supply-and-demand control, power distribution control, and a smart meter. Since these subsystems had been built independently conventionally, information systems, such as a server, and a communication network were loose coupling.

However, in order to realize a smart grid, it is necessary to unify electric power system technology and information and communication technology, and to cooperate closely.

In order to realize a smart grid, the telecommunications system which satisfies the following requirements is required.

- Interconnection can be carried out at high speed, diverting the telecommunications system for the existing electric power systems as much as possible.
- A secure system can be built so that failure of a subsystem may not affect a whole system.
- It prepares for the new service which will appear in the future, and has an open interface.

## 3.2 Outline of Trial Production System

The trial production system was designed based on the requirements for the telecommunications system for realizing a smart grid. Figure 5 shows the schematic structure of a trial production system. [3]

An electric-power-supply-and-demand server controls the apparatus in power generation plants, such as plant, and controls an electric power supply according to the electricity demand expected. In order to control apparatus, two kinds of networks (The RPR transmission system network of a 1 Gbps-Ehternet base, and a bus type controller network) were adopted.

A power distribution control server carries out the output surveillance of the electric power of a distribution system, measurement of voltage, and the photo-voltaic by the side of a consumer.

In order to supervise and control apparatus, the cable transmission network of the OFDM system was adopted.

Moreover, in order to carry out comparative evaluation, the optical fiber network of the GE-PON system was also used together.

A smart meter server controls a switch while collecting electric energy from a smart meter.

The optical fiber network of the GE-PON system was adopted between the concentrators used as a server and the base station of a smart meter, and the 920MHz small electric power radio mesh network was adopted between the concentrator and the smart meter.

Currently, a trial production is completed partially and these servers and networks are under evaluation.

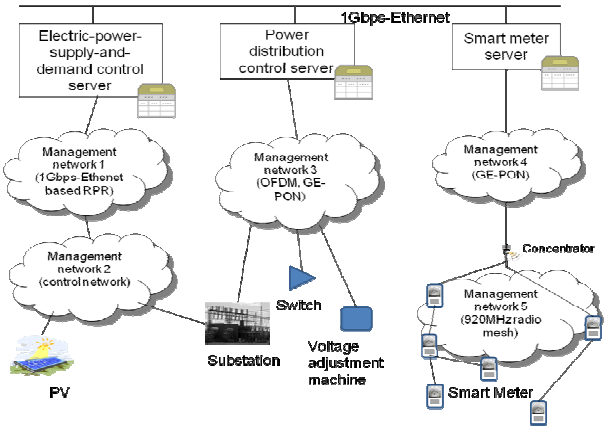



Figure 5. The schematic structure of a trial production system

## 3.3 Telecommunications System for Electric-Power-Supply-and-Demand Control

The conventional supply-and-demand-control system made the controlled object only thermal power generation and pumped hydro power generation.

In the smart grid, in consideration of power generation by renewable energy, the control characteristic of the storage battery for systems was modeled, and it was considered as thermal power generation, the pumped hydro power generation containing the adjustable speed, and the system which cooperates and employs the storage battery for systems.

Since dispersed-type power sources, such as photo-voltaic and a storage battery for systems, were distributed and introduced in a system, according to control characteristics, such as conversion efficiency of apparatus, and installed capacity, the electric-power-supply-and-demand control system in a smart grid was put in block from the central telecommunications system, and the controllable class management system was used for it.

The network using RPR technology was adopted as the network for supervisor control of a power generation plant by basing on a high speed and large scale, and 1 Gbps-Ethernet that realizes high reliance.

## 3.4 Telecommunications System for Power Distribution Control

The power distribution control system in a smart grid supervises the output of the photo-voltaic by the side of a consumer, analyzes the influence which the output fluctuation of photo-voltaic has on a distribution system in real time, and performs control for optimizing the current of electric power while it measures the electric power and voltage of a distribution system from a switch.

It controls by ordering a power distribution control system, a voltage regulator, a storage battery, etc. to keep the voltage of a system proper.

OFDM system cable transmission technology was adopted as the electric power of a distribution system, measurement of voltage, and the communication network for power distribution control that carries out the output surveillance of the photo-voltaic by the side of a consumer so that an established metal communication line might be diverted and it could accelerate.

## 3.5 Telecommunications System for Smart Meters

Over 10 million electric power meter is installed in each electric power company in Japan, the communication network which connects with these electric power meter the smart meter server which collects and manages the measurement data of electric power meter is newly needed. [4]

In order to reduce construction and maintenance costs of a communication network, the 920MHz radio mesh network was adopted, and the trial production system is designed.

A radio mesh network is a system transmitted to a concentrator, relaying subsequent data to the electric power meter in which the next adjoins the measurement data received from adjoining electric power meter, and had composition which stores 500 sets of electric power meter in one set of a concentrator.

Moreover, in order to avoid that the signal which two or more meter sends collides in order to judge transmitting timing autonomously, sharing the frequency to which each terminal was restricted, the transmitting timing control scheme was introduced.

# 4 REQUIREMENTS FOR SMART GRID SURVEILLANCE AND MANAGERIAL SYSTEM

## 4.1 Management Protocol

SNMP is used about the equipment in which IP communication is possible.

About the equipment in which IP communication is impossible, the management protocol of a local definition is used and protocol conversion is carried out to SNMP in the equipment in which IP communication is possible.

## 4.2 Management Function

Generally, although FCAPS is needed as a controlling function of a telecommunications system, as management of

a smart grid, it is thought that fault management, configuration management, a performance management, and a security management are required.

Since it was assumed in the future that many vendors and organizations participate in a smart grid, it was thought that a fee collection controlling function was also needed, but it carried out the outside of the range of a trial production system.

### 4.3 Management Information

About the equipment in which IP communication is possible, in order to use SNMP as a management protocol, management information also defines management information on the basis of MIB specified in IETF.

Also about the equipment in which IP communication is impossible, management information is defined on the basis of MIB as a definition of management information.

### 4.4 Managed Objects

When managing a smart grid, the equipment used as the candidate for management is as follows.

Smart grid surveillance and a managerial system supervise the equipment state and measurement value in these candidates for management.

(1) Electric-power-supply-and-demand control: A photo-voltaic panel (PV), a power conditioner (PCS), various dynamos, a storage battery, electric-power-supply-and-demand server

(2) Power distribution control system: Current transmission (CT), a transformer (VT), a protective relay, a stationary type reactive power compensating device (SVC), a pole transformer (SVR), the transfer device uncut [ the electric current ] off, a switch, power distribution control server

(3) Automatic meter reading system: A watt hour meter (electric power meter), a concentrator, automatic inspection-of-a-meter server

(4) HEMS (Home Energy Management System) : A HEMS controller, lighting setup,

(5) BEMS (Building Energy Management System) : A lighting setup, an air conditioner, power equipment

(6) FEMS (Factory Energy Management System) : A production facility, a lighting setup, an air conditioner, power equipment

(7) CEMS (Community Energy Management System) : Power generation equipment, electric car (EV)

When defining the candidate for management, in order to use SNMP as a management protocol, about the equipment in which IP communication is possible, management information also defined management information on the basis of MIB specified in IETF.

Also with the equipment in which IP communication is impossible, the extended definition was carried out on the basis of MIB as a definition of management information.

Smart grid surveillance and a managerial system perform the control actions (starting, a stop, reset, etc.) to these candidates for management while supervising the attribute information, including a state, an observed value, etc., and notice information in these candidates for management, including the notice of an obstacle, the notice of a change of state, etc.

In smart grid surveillance and a managerial system, it designed according to the candidate for management to change a surveillance cycle.

About an electric-power-supply-and-demand control system and a power distribution control system, it is 3?5. It supervised in the dividing term and designed about the automatic meter reading system to supervise in a cycle of 30 minutes.

In addition, it designed about the control action to perform in real time.

Table 1 shows assumption surveillance / control frequency to be the typical candidates for management.

Table 1. Assumption surveillance / control frequency

| Sub system | Managed Object | Frequency | |
|---|---|---|---|
| | | Surveillance | Control |
| **Electric-power-supply-and-demand control system** | PV, PCS, battery | Every 3 minutes | Any time |
| **Power distribution control system** | SVC, SVR | Every 3 minutes | Any time |
| **Automatic meter reading system** | Smart meter, Concentrator | Every 30 minutes | Any time |
| **Others** | HEMS | Every 30 minutes | Any time |

## 5 A DESIGN AND CONSIDERATION OF SURVEILLANCE AND A MANAGERIAL SYSTEM

The schematic structure of smart grid surveillance and a managerial system is shown in Fig. 6.

One smart grid surveillance and a managerial system assume that it is applied in the same unit as an electric power company, and is the Japan whole country 10 It was assumed that the divided area was managed.

Each smart grid surveillance and managerial system consists of an electric-power-supply-and-demand control management server, and a power distribution control management server and a smart meter (SM) management server.

An electric-power-supply-and-demand control management server supervises and manages electric-power-supply-and-demand equipment of PCS etc. through a RPR network and the network for control.

A power distribution control management server supervises and manages power distribution control systems, such as SVR, through an OFDM network or a GE-PON network, and the network for control.

SM management server supervises and manages a smart meter and a concentrator through a GE-PON network and a specific power-saving wireless network.

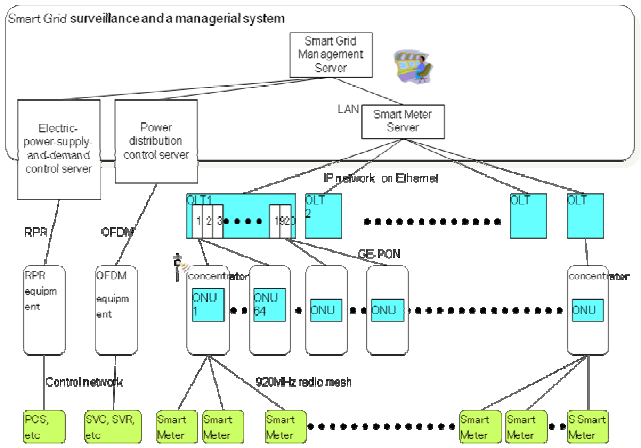



Figure 6. The schematic structure of smart grid surveillance and a managerial system

The candidate for management of smart grid surveillance and a managerial system is shown in Table 2.

Table 2. Managed Objects

| Sub system | Managed Object | Protocol |
|---|---|---|
| **Electric-power-supply-and-demand control system** | PV, PCS, battery | Local |
| **Power distribution control system** | SVC, SVR | Local |
| **Automatic meter reading system** | Smart meter, Concentrator | SNMP |
| **Others** | HEMS | SNMP |

### 5.1 Surveillance and management of an electric-power-supply-and-demand control system

An electric-power-supply-and-demand control management server performs surveillance and management of an electric-power-supply-and-demand control system.

With PCS which controls PV, the main candidates for management are storage batteries, and it supervises and manages them using RPR etc.

- Attribute: current, voltage, electric power, electric energy, device status, and a communication state, etc.
- Action: Reset etc.
- Notification: Failure information etc.

### 5.2 Surveillance and management of a power distribution control system

A power distribution control management server performs surveillance and management of a power distribution control system.

The main candidates for management are distribution plants, such as SVR and SVC, and associated equipment of those, and it supervises and manages them using GE-PON, OFDM, etc.

- Attribute: Current, voltage, electric power, reactive power, a power-factor, frequency, electric energy, reactive energy, zero phase voltage, crossing gate opening-and-closing time, device status, a communication state, etc.
- Action: Reset etc.
- Notification: Failure information etc.

### 5.3 Surveillance and management of an automatic meter reading system

A smart meter management server performs surveillance and management of an automatic meter reading system.

The main candidates for management are the smart meter which combined the wireless-communications function and the watt hour meter, and a concentrator which collects the information on a smart meter.

- Attribute: 30 minutes inspection-of-a-meter value, Device Status, Communication State, etc.
- Action: Reset etc.
- Notification: Failure information etc.

These attributes are supervised every 30 minutes, because a smart meter transmits inspection-of-a-meter data to the server every 30 minutes.

## 6 CONCLUSION

This paper described demand conditions and a realization means about the surveillance and managerial system of the smart grid. Since a smart grid consisted of two or more electric power systems, smart grid surveillance and a managerial system prepared management equipment for two or more electric power systems of every, and made it the structure of managing them hierarchical. Moreover, in order to supervise and manage systematically the management information on two or more electric power systems, it based on the MIB definition to the SNMP protocol which serves as a de facto standard by the IP network, and designed surveillance and a managerial system. From now on, based on the basic design described in this paper, the trial production of surveillance and a managerial system is due to be continued.

## REFERENCES

[1] NIST Framework and Roadmap for Smart Grid Interoperability Standards (2010).

[2] The study group about the international standardization concerning a next-generation energy system, Toward the international standardization concerning a next-generation energy system. (2010).

[3] Naoto Miyauchi, et.al , Smart Grid Monitoring and Managing System, IPSJ SIG Technical Report (2011).

[4] Kohithi Ishibashi, Smart network technology which realizes a smart grid, Business creation symposium of Japan and the Asia cooperation No.2 (2011).

# Analysis comparison of brain waves at the learning status by simple electroencephalography

Kouji Yoshida[1], Yuuta Sakamoto[1], Isao Miyaji[2],Kunihiro Yamada [3]

[1] Shonan Institute of Technology
1-1-25, Tsujido Nishikaigan, Fujisawa, Kanagawa 251-8511, Japan
[2] Okayama University of Science, 1-1 Ridaicho, Okayama, 700-0005, Japan
[3] Tokai University, 1117 Kitakinme, Hiratsuka, Kanagawa 259-1292, Japan
yoshidak@info.shonan-it.ac.jp, 11T2007@info.shonan-it.ac.jp,
miyaji@mis.ous.ac.jp, yamadaku@tokai.ac.jp

***Abstract*** - We have been developing systems using remote learning and blended learning. However, no equipment has ever been able to measure human states easily. Inexpensive electroencephalogram sensors have become available lately, which enable us to measure electroencephalograms, to monitor human states thereby, and to obtain information easily as digital data. We analyzed the relation between α and β waves using this simple electroencephalograph. The results revealed that measurement of β/α enables us to evaluate the activity and vital activity of the human brain. In addition, this paper reports because it was able to become clear that the problem of language has a bigger change of the value of β/α than the problem of calculation.

***Keywords***: Brain wave sensor, Meditation, α wave and β wave, Distance Learning, e-Learning, Blended Learning, e-Collaboration

## 1 INTRODUCTION

As software development has recently become complicated and large in scale, it is seldom the case in which one system is built irrespective of others. Moreover, students tend to be poor at modern system design and communication. It is therefore necessary for teachers to instruct students repeatedly to teach a programming language. We have patterned this to some degree and have studied a learning mechanism conducted effectively and repeatedly using a distance learning system.

Since inexpensive brain wave sensors have become available, we have sought to apply this to a distance learning system for effective learning. This inexpensive and simple electroencephalograhic sensor provides information with which the status of activity and vivacity of a student's brain can be evaluated.

## 2 ELECTROENCEPHALOGRAPHY

### 2.1 Application of Electroencephalographic Information

Electroencephalography (EEG) is widely used as a performance index of the information processing procedure of a brain. For example, it is employed in medicine for integrative functional evaluation of a brain, and is used to investigate brain disorders such as epilepsy and vascular disorder. Moreover in bionics, the feature quantity of EEG is extracted and is used for operation of a mouse pointer on a computer screen. Especially among the characteristics of EEG, it is recently demonstrated that its frequency response is related closely to cognitive processes such as learning, language, and perception, so that biofeedback study using EEG has been actively pursued[1].

### 2.2 Electroencephalographic Measurement and Analysis Methods

An EEG shows the electrical potential change in the brain that arises from brain activity measured using an electrode set on the scalp. It is displayed as a wave.

The measurement of the following is considered effective to observe human mental conditions: The power spectrum of α and β waves obtained by discrete Fourier transform of obtained EEG, the fraction of α or β waves to the whole EEG, and the ratio of α waves to β waves[2]. Particularly, β waves (12–14 Hz) are regarded as highly related to thinking status, and some studies have addressed the relation between intellectual endeavors and EEG. Giannitrapani et al.[3] describe measurement of the EEG of healthy people during an intelligence test. They discovered that the low-frequency component of β waves became predominant during a reading test, a mathematics test, and a figure alignment test, but they were less superior during other tests. This result demonstrates that β waves are effective to some degree as an index for presuming thinking status. Matsunaga et al.[4] developed a satisfaction measurement system that evaluates satisfaction of a person by EEG, and verified a hypothesis by experiment that pleasantness increases when a brain treats less information, although unpleasantness occurs when much information is handled. Hayashi et al.[5] measured EEG as an objective evaluation index of a high-definition image, and

demonstrated that the power spectrum of α waves is correlated with subjective evaluation.

However, there is not yet seen the article about the load of the brain by $\beta / \alpha$ index other than the references [2]. This study adopts α waves, β waves, and β/α as indices for easy comparison with knowledge acquired through previous studies[6].

# 3 BRAINWAVE SENSOR

## 3.1 Electroencephalography in Recent Years

Conventional electroencephalographs used for EEG measurement were bulky, time-consuming, and expensive. However, simple electroencephalographs that can measure EEG inexpensively and noninvasively have come to attract attention recently by virtue of progress in brain science study and development in miniaturization and precision technology in information machines and equipment. Particularly, studies for presuming the thinking status of a person in ordinary scenes is prevailing[7].

When medical-level precision is necessary for collection of EEG data, EEG equipment based on the international 10–20 system must be used. However, when applying EEG information to a simple EEG input interface and application assuming ordinary use, medical type electroencephalograph with many electrodes presents problems in that it demands time and effort for wear and also restricts a subject's movement. For this reason, it is easy and effective to use a simple electroencephalograph rather than the medical type electroencephalograph for introducing electroencephalography to education, as in this study.

## 3.2 Simple Brainwave Sensor

This study conducted EEG measurement using MindSet™ by NeuroSky, Inc.[8] Herein we enumerate features of this brainwave sensor and describe related key words.

• Compact and wearable instantly

Conventional brainwave sensors, which have been employed in the field of medicine, brain science, and psychology, have demanded time, effort, and cost, with such large-scale equipment providing precise data collection, but demanding long measurement times, and application of gel to the scalp. In contrast, this sensor is like a headset. Gel need not be applied to electrodes. Moreover, it is inexpensive. It is affordable for anyone.

• Easy EEG data collection

This brainwave sensor analyzes data with an on-board chip in the ear pads. The acquired EEG original waveform is subject to filtering. Then output data are obtained there from. They serve as indices of brain activity levels, such as attention level and meditation level. Consequently, the subject's mental condition can be analyzed effectively through comparison of the obtained EEG and the index data.

• Linking EEG sensors and application for original application development

The mental status of a subject is fed back directly by the application that processes specific events according to EEG variation.

(1) NeuroSky Inc.

A company in San Jose, California, U.S.A., developing brainwave sensors for consumers.

(2) MindSet™

The brainwave sensor used for this study that employs Bluetooth and can transmit data to a specified PC.

This brainwave sensor determines a reference point with three electrodes in the ear pad. Then it detects its potential with a sensor on the forehead as EEG. The δ, θ, α, and β wave signals are obtained from EEG data acquired in addition to these EEG data. Levels of attention and meditation are computed with an algorithm using these waves as base components.

Moreover, various experiments in comparison with the NeuroSky brainwave sensor were conducted using the biomedical signal measuring equipment of BIOPAC SYSTEM, Inc.[8], a laboratory standard. A FFT analytic test demonstrates that data acquired using the NeuroSky brainwave sensor are acquired with sufficient sensitivity to detect important frequency bands including cognitive states and emotional states. Particularly, various studies relevant to EEG and IT are in progress these days.

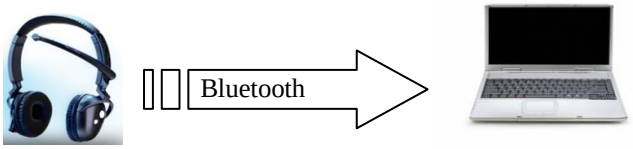



Figure 1: MindSet EEG sensor.

(3) Frequency component analysis

The electroencephalogram can show a basic rhythm that includes specific brainwave activity that reflects most brain activity. The basic rhythm is classified by the number of amplitudes of the electroencephalogram (fluctuation waves of electric potential in the brain). Generally in states of rest, eyes closed, and wakefulness for a healthy person, many α waves appear, centering on the back of the head. This study was undertaken for data collection for associating "subject's movement", "EEG", and "state of mind", and construction of a learning system based on the collected data.

Table 1: Frequency component table

| Frequency band (Hz) | | Acquisition frequency range by MindSet (Hz) | | State of mind |
|---|---|---|---|---|
| δ wave | 0.5 ~ 3 | δ wave | 0.5 ~ 2.75 | unconsciousness |
| θ wave | 4 ~ 7 | θ wave | 3.5 ~ 6.75 | Doze, flash |
| α wave | 8 ~ 13 | Low α wave | 7.5 ~ 9.25 | Relaxation, peace |
| | | High α wave | 10 ~ 11.25 | Normal state |
| β wave | 14 ~ 29 | Low β wave | 13 ~ 16.75 | Contemplation |
| | | High β wave | 18 ~ 29.75 | Tension, excitement |
| γ wave | 30 ~ | Low γ wave | 31 ~ 39.75 | Alert, wakefulness |
| | | Mid γ wave | 41 ~ 49.75 | High-order cognitive activity |

### 3.3 Brainwave Sensor Mechanism

A brainwave sensor, which has the function of measuring α, β, γ, θ, and δ waves, has an application that portrays the waves graphically using their values. Figure 2 presents an example of a graphical representation of each wave in a radar chart.

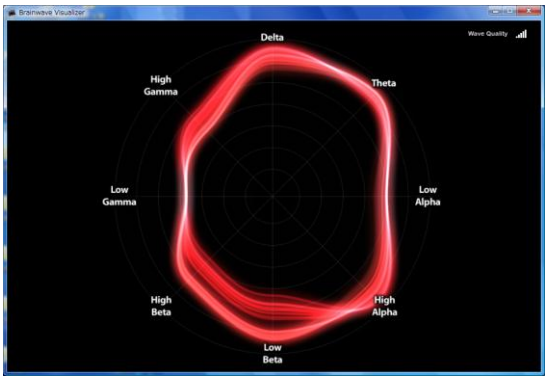



Figure 2: Display screen showing respective waves.

It then measures attention and meatation states, and displays them with the application or output of the data.

• Attention level

It rises when β waves appear mainly and strongly from EEG data, and represents the attention level of a subject. Figure 3 is an example that displays the attention level with a meter and a line graph. The vertical axis expresses the attention level on a 0–100 scale, whereas the horizontal axis represents elapsed time.

• Meditation level

It rises when α waves appear mainly and strongly from EEG data, and represents the relax degree of a subject. Figure 4 presents an example that displays the meditation level with a gauge and a line graph.

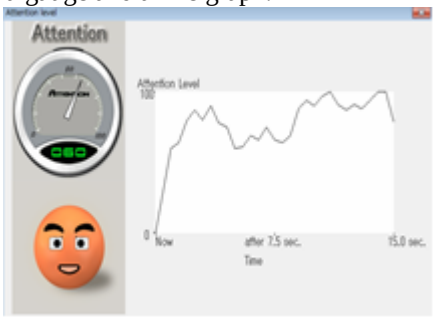



Figure 3: Example representation of the attention level by application.

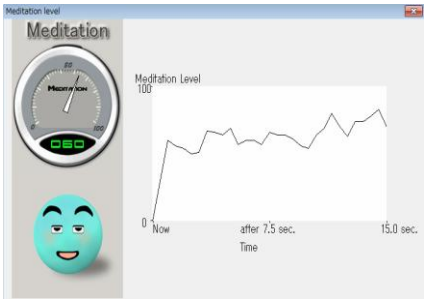



Figure 4: Example representation of the meditation level by application.

## 4 SYSTEM OUTLINE

### 4.1 Acquisition of an Electroencephalogram

A system for measuring and analyzing EEG was constructed. MindSet has an application for motion control for its exclusive use, which however can only display EEG data according to frequency, but cannot acquire and process digital data. Therefore, an EEG measurement / recording program was developed with PHP.

### 4.2 Outline of System Using MindSet

A schematic diagram of the system is presented in Figure. 2. EEG data collected with MindSet are transmitted to a PC via Bluetooth and are accumulated temporarily in an attached server program (ThinkGearConnector). The PHP program prepared in this study connects with this server program via socket communication and acquires EEG data. A local environment is constructed with an Apache HTTP Server, and the PHP program is executed to acquire the EEG. The PHP program produced for this study carries out socket communication to port 13854 of the local host, and acquires data every other second. The binary data undergo type conversion. The power spectrum of each frequency is recorded.

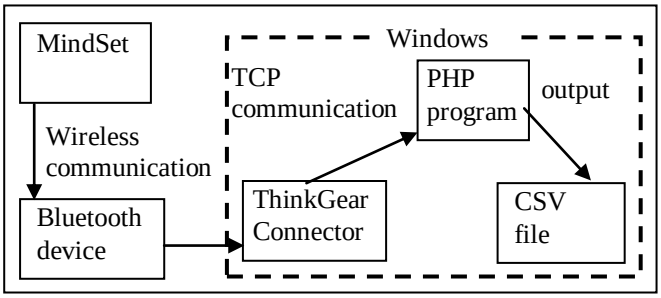



Figure 5: Schematic diagram of the system.

## 5 EXPERIMENTAL

### 5.1 Experimental Environment

The present experiment employs a PC, a brainwave sensor, and a program written in the PHP language for recording EEG data. EEG data under cognitive work are recorded one-by-one using this program at a sampling frequency of 512 Hz. According to the referential derivation (single earlobe) method, the reference electrode is placed at the left ear. This technique can measure only the frontal region. However, β waves that are notably detectable in the frontal region appear strongly during work that requires thinking, and it has strong correlation with a contemplation state. Therefore, this derivation is considered valid for this research.

A brainwave sensor can acquire the frequency components of δ, θ, α, β, and γ waves. However artifacts (noise) should be excluded from acquisition of EEG. The δ and θ wave regions are excluded because of possible mixing

of myogenic potential by biological phenomena such as eye movement. The γ wave region is also excluded from the measuring range because noises such as body motion and electronic devices are prone to mix. Consequently, two wave forms, α and β waves, are collected in experiments.

Notes for experiments are listed below.

• The experiment contents should be explained to the subject and consent should be acquired.

• The top of the data array should be disposed because data should be collected after cognitive work is stabilized at the measurement start.

• It should be considered that the test accompanying handwriting tends to pick up noise because of body motion.

## 5.2 Procedure

The experimental procedure is described below.
(1)Explanation of experiments
Explanations of the experiment and the electroencephalograph are given to a subject.
(2)Preparation of the experimental apparatus
The state of equipment is checked and the system is set up.
(3)Explanation of cognitive work
The cognitive work in which the subject is engaged is explained.
(4)Start of EEG measurement
The program is launched and recording of EEG data is started.
(5)Performance of cognitive work
Linguistic theme learning are performed in Experiment 1.
Arithmetic theme learning is performed in Experiment 2.
(6)Analysis of EEG data
Comparative analyses of α and β waves and β / α component in the collected EEG data are conducted.

## 5.3 Experiment 1

An experiment was conducted by the following contents according to the procedure described in Section 5.2. This experiment is aimed at making a comparative analysis of each frequency component in cognitive work wearing a simple electroencephalograph, and to observe the correlation with learning.

- Subject: Five men in his 20s (university student)
- Measuring time: 6 min
- Cognitive themes

(1) Linguistic subject learning difficulty (easy)
(2) Linguistic subject learning difficulty (medium)
(3) Linguistic subject learning difficulty (hard)

## 5.4 Result of Experiment 1

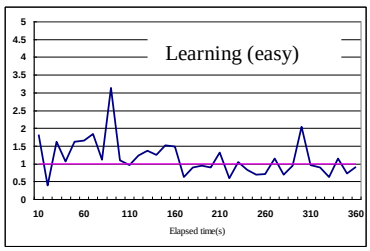
Table 2 presents the experimentally obtained results, which represent the spectrum average of α and β waves, and β/α as the relative amount of α and β. The α wave and β wave took the average of the value every one second when they got nervous for six minutes.

Table 2: Average of α and β components

| | Cognitive process | α wave average | β wave average | β/α |
|---|---|---|---|---|
| SubjectA | Learning (easy) | 1.26109 | 1.2093 | 1.44567 |
| | Learning (medium) | 1.96269 | 2.47465 | 1.76377 |
| | Learning (hard) | 1.74877 | 2.56023 | 1.96959 |
| SubjectB | Learning (easy) | 4.6368 | 4.54035 | 1.59968 |
| | Learning (medium) | 4.70366 | 4.63363 | 1.60887 |
| | Learning (hard) | 3.73338 | 4.15227 | 1.87143 |
| SubjectC | Learning (easy) | 4.40083 | 3.16771 | 0.95328 |
| | Learning (medium) | 4.39984 | 3.39577 | 1.02228 |
| | Learning (hard) | 3.78256 | 3.1996 | 1.10567 |
| SubjectD | Learning (easy) | 2.7104 | 1.79221 | 0.96829 |
| | Learning (medium) | 2.72002 | 2.10628 | 1.14712 |
| | Learning (hard) | 2.2783 | 2.31493 | 1.43774 |

The items of the cognitive process in Table 2 are arranged in the order for which it is generally believed that contemplation is indispensable. β/α values are aligned in the same order. Especially learning (medium) shows high α and β components, which suggests high brain activity, whereas learning (hard), which requires further thinking, shows α and β components not high in proportion. This is considered to be true because the difficulty of the themes was so high that there were many parts that were difficult to answer and which required a mental load, so that the component values rose.

Next, β/α was examined to estimate the fraction of α waves and β waves. Figure 6 shows graphs of α/β for 6 min during experiment, which suggests that α/β is stable during easy learning and greatly varying during hard learning. Furthermore, it is higher and varies more during learning (hard) than during learning (easy). Results show that the value of α/β is greater in the order of learning (easy), learning (medium), and learning (hard). This order is the same as the order of necessity of thinking.



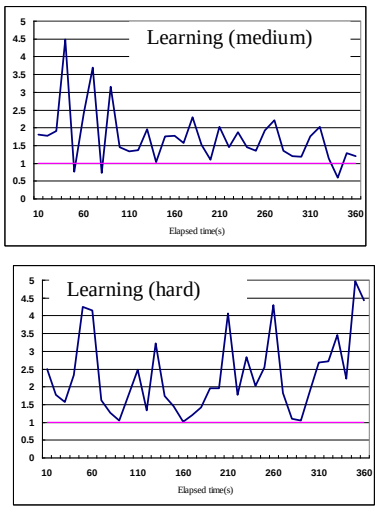



Figure 6: divide (beta wave spectrum)by(alpha wave spectrum) in Experiment 1.

## 5.5 Experiment 2

An experiment was conducted by the following contents according to the procedure in Section 5.2. This experiment aims to compare difference in individual EEG during execution of about the issue of calculation and the issue of sentence.

• Subject: Four men in their 20s (Department of Information Science, Shonan Institute of Technology)
• Measuring time: Until the work is finished, or until a time limit of 10 min is reached.
• Cognitive themes
(1) Arithmetic:The issue of calculation of the CAB
(2) Language:The issue of sentence of the CAB

## 5.6 Result of Experiment 2

Tables 3 and 4 present the experimentally obtained results, which respectively show the spectrum averages of α and β waves of each subject, and β/α as the relative amount of α and β.

Table 3: Arithmetic:The issue of calculation of the CAB

| | Cognitive process | α wave average | β wave average | β/α |
|---|---|---|---|---|
| SubjectA | Learning (medium) | 1.339352 | 1.114065 | 1.246556 |
| SubjectB | Learning (medium) | 1.612259 | 0.894291 | 0.711768 |
| SubjectC | Learning (medium) | 3.483706 | 3.203498 | 1.429599 |
| SubjectD | Learning (medium) | 1.201489 | 0.989478 | 1.149417 |

Table 4: Language:The issue of sentence of the CAB

| | Cognitive process | α wave average | β wave average | β/α |
|---|---|---|---|---|
| SubjectA | Learning (medium) | 1.06738 | 1.57862 | 2.16062 |
| SubjectB | Learning (medium) | 2.39961 | 2.79527 | 1.48792 |
| SubjectC | Learning (medium) | 5.28791 | 4.38061 | 1.17385 |
| SubjectD | Learning (medium) | 3.49102 | 2.34771 | 0.86969 |

The issue of calculation of the CAB were answered within 10 min. Especially, subject B made correct answers in a short time. If contemplation activity is proportional to b/a, as in Experiment 1, then it is suggested that the attention level of subject B toward the themes was high.

No subject finished the issue of sentence of the CAB by the time limit. Consequently, a subject's contemplation state is divided into two patterns: to confront a challenge with more attention or to lose motivation. The α and β wave averages shown respectively in Tables 3 and 4 show an increase in all components for subject B,C and D, but a decrease for subjects A. The following is assumed. Because the thinking power necessary for a theme of each subject differs, the attention that is necessary to exercise thinking power also differs. Furthermore, because the present themes were arithmetic and language, habituation might occur in response to questions. Presumably this habituation alters the contemplation that is an indispensable capability as a correction value. Figure 7 shows β/α for 1 min during the experiment for subject B.

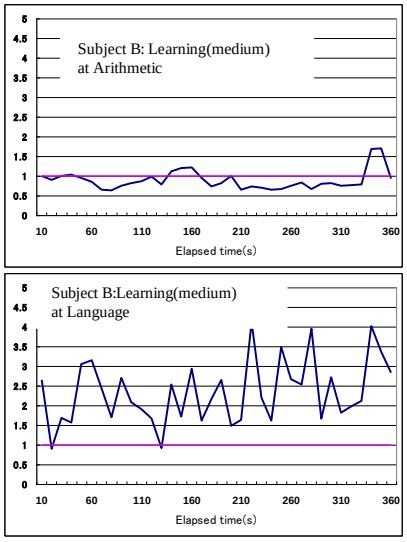



Figure 7: divide (beta wave spectrum)by(alpha wave spectrum) in Experiment 2.

# 6 EVALUATION

The results of Experiment 1 demonstrate that α waves mainly represent relaxed state of a person, although β waves

express the attention level and tension level. β/α is often lower than 1 when solving an easy problem. However, when thinking or solving a difficult problem, a state with β/α over 1 continues for a long time. This result suggests that the value of β/α can be an index of activation of contemplation state and high attention level.

Comparison among subjects A, B, C, and D from the result of Experiment 2(Arithmetic) reveals that β/α of subject B who could finish earlier averaged high even when the same problem is solved. Thereby, the contemplation state is presumed to be relaxed.

As described above, the result of Experiments 1 and 2 suggest that β/α can be an index of activity and attention level in the case of solving a problem.

## 7 CONCLUSION AND FUTURE SUBJECTS

Comparative analyses of the power spectrum of α and β waves and β/α in multiple cognitive processes was conducted experimentally in this study for correlation analysis of contemplation in a learning state using a simple electroencephalograph. In fact, α waves represent the relaxed state of a person. They tend to decrease when a subject is bearing a great mental load, although β waves express the attention level and tension level.

The rate of change and fraction of the power spectrum of α and β wave components are useful as an index of attention level. Particularly a trend appears by which β/α is independent of individual differences. Moreover, it has a small average when solving an easy problem. However, β/α increases in solving a problem of medium or high difficulty, when a brain is working actively including a state of stress.

By this experiment, we measured it for a student of the physical science, then they were good at calculation problem. We want to measure the student of the faculty of liberal arts in future. Detailed analysis and application study of these will be conducted in the future, aiming at employing these for feedback information to a distance learning system. This study was supported by grants-in-aid for scientific research No. 24501219.

## REFERENCES

[1] Dennis J. McFarland, Jonathan R. Wolpaw: "Brain–Computer Interfaces for Communication and Control," Communications ACM, Vol. 54, No. 5, pp. 60–66.

[2] Ueda, Ishida, Matsuda, Fukushima, Nakamichi, Ohira, Matsumoto and Okada , "Evaluation of Software Usability Using Electroencephalogram – Comparison of Frequency Component between Different Software Versions",Human Interface Society,Vol.10,No.2,pp.233-242,(2008).

[3] D. Giannitrapani: "The role of 13–Hz activity in mentation," The EEG of Mental Activities, pp. 149–152 (1988).

[4] Dennis Matsunaga Hisashi,Nakazawa Hiromu, " Relation between Mental Workload and Satisfaction Measures Evaluated from EEG", The Japan Socirty of Mechanical Engineers, C-editing,Vol.66,No.648,pp.2884-2890(2000).

[5] Hayashi Hidehiko, Kunifuji Susumu, Miyahara Makoto, " Assessment of High-Order Sensations in Extra : High-Quality Images Using Electroencephalography", The Institute of Image Information and Television Engineers, Vol.56,No.6,pp.954-962,(2002).

[6] Koji Yoshida, Yuuta Sakamoto, Isao Miyaji, Kunihiro Yamada, Satoru Fujii, "Trial of a distance learning system using a brain wave sensor", KES'2011,Part III, LNAI 6883,Proceedings, Knowledge-Based Intelligent Information and Engineering Systems, pp.86-95 (2011).

[7] Murai Moriyasu, Arita Norihito, Naakashima Mitumi, "About Analyzing Brain Waves with Computer", Japan Society for Science Education,Vol 12,pp.73-76(1997).

[8] Neuro SKY Sensor http://www.neurosky.com/

# People want the primary information: Use and behavior around the official municipal Twitter accounts in the Great East Japan Earthquake

Tomoo Inoue*

*Faculty of Library, Information and Media Science, University of Tsukuba, Japan
inoue@slis.tsukuba.ac.jp

***Abstract*** – More and more official organizations have been using Twitter for information distribution or interactive information exchange. Such official information sources are supposed to be relied upon by citizens when a disaster breaks out, but how such social medium accounts should be operated is not known.
This research investigated the user behaviors around the Twitter accounts of official organizations in the Great East Japan Earthquake. Through the analysis, it was revealed that people most wanted the primary information.

***Keywords***: Social media, Twitter, Information behavior, the Great East Japan Earthquake

## 1 INTRODUCTION

Together with the rising popularity of social networking services, a micro blogging service Twitter had been used extensively when the Great East Japan Earthquake happened on March 11, 2011.

There were a few types of use of Twitter; information broadcasting to public, information receiving from public, and information exchange among closed members, which was useful anyway when other media disclosed their own weaknesses. The mass media worked well for nation-wide broadcasting but not so much for regional broadcasting. The phone line was overloaded to connect [1][2]. People were anxious about what was happening and what would be going on and wanted the information.

As for the Twitter use by municipal organizations, it was still the beginning stage of big growth at that time. This might be because new technologies in general tended to be adapted a little late in public sectors after their spreading in the world. Some such Twitter accounts were relatively new and some other already had numbers of followers. Soon after the disaster, we gained increasing momentum to use such social media. More numbers of municipal organizations officially started to use them, especially Twitter. Recently the government officially encouraged the municipal organizations to use the social media for their information broadcasting [3].

However, we do not know exactly how the official Twitter account of a municipal organization worked despite the fact that now we are running more of such an account. Thus in this paper, we investigate the use and behavior around the official municipal Twitter accounts in the Great East Japan Earthquake, and draw operation guidelines.

## 2 RELATED WORKS

### 2.1 Twitter

Twitter is an online microblogging service. It provides almost real-time online short text communication. It can be used from various internet devices including a personal computer, a smart phone, and other mobile phones. A short text message called “tweet” can be viewed from the world if it is not sent from the specially closed account. This normal tweet can be searched by keywords, tags, and accounts. Subscribing an account called “following” is a feature of Twitter. By this, a subscriber called a “follower” can view the tweets of the account without any operation. Thus an account that sends useful information regularly to the receiver is likely to be followed. A tweet can be repeatedly sent out by the receiver of the tweet, which is called “retweet.” When the receiver thinks to distribute a tweet, the tweet is retweeted.

### 2.2 Twitter Use in Disaster

Mendoza et al. studied the behavior of Twitter users in the 2010 Chilean earthquake in the hours and days following this disaster [4]. They performed a preliminary study of the dissemination of false rumors and confirmed news. They analyzed how this information propagated through the Twitter network to assess its reliability as an information source under extreme circumstances, and showed that the propagation of rumors differed from that of news because rumors tended to be questioned more than news by the Twitter community.

Longueville et al. studied how Twitter could be used as a reliable source of spatio-temporal information by focusing on the 2009 French forest fire, aiming to demonstrate its possible role to support emergency planning, risk assessment and damage assessment activities [5]. They studied the temporal dynamics of the tweets, how location names were cited, who published the tweets, what type of domains were cited as URLs.

Vieweg et al. analyzed the tweets generated during two concurrent emergency events in North America 2009, the Oklahoma Grassfires of April and the Red River Floods in March and April [6]. They focused on communications broadcast by people on the ground, investigated the tweets in terms of location information and update with their dissemination. They then identified information that might contribute to enhancing situational awareness during emergencies.

Qu et al. studied the messages in a microblogging site Sina-Weibo that is very similar with Twitter and is popular

in China in the 2010 Yushu Earthquake [7]. They investigated the content of the messages, the trend of different topics, and the information spreading process.

Miyabe et al. studied the tweets in the Great East Japan Earthquake in terms of their locations [8]. They concluded how people used Twitter was different from the locations depending on the damages.

Umejima et al. studied the false rumors and their corrections in a disaster, and indicated that a false rumor is easier to disseminate [9].

These studies analyzed the Twitter uses by people at large in emergency cases, where this study focuses on the use of municipal accounts in emergency cases.

### 2.3 Twitter Use by Public Institutions

Alam et al. studied six governmental Twitter accounts in Australia [10]. They analyzed the content of the tweets as well as the responses from the citizens.

Kavanaugh et al. studied the local governmental use of social media including Twitter [11]. They conducted a survey to local governmental institutions, the analysis of the followers of governmental Twitter accounts, and the analysis of the messages in Facebook accounts.

These studies analyzed the use of Twitter by public institutions in normal circumstances, while our study focuses on the use in the emergent times.

## 3 DATA AND ANALYSIS

### 3.1 Data

The analyzed data were from the Twitter accounts that were registered in "Govtter," the link site of official municipal Twitter accounts [12]. Govtter only lists the Twitter accounts that were confirmed as those operated by governmental institutions. A total of 363 accounts were listed as of January 2012 including the municipal accounts, the governmental accounts, and other public institutions. Among those accounts, 149 accounts were older than March 11th of 2011, before the earthquake.

In Twitter, a tweet is stored with the links to the date and time of the tweet, the identifier number called Status ID, and the account information. These tweets can be acquired from the latest tweet to as far back as 3200 tweets by Twitter API in the official site [13]. However the number of follows and the number of followers in the account information are those at the time of getting the tweet data, which means chronological change of those values cannot be obtained by this method.

Thus we used Twilog service to get the change of the number of followers [14]. Twilog is not an official service of Twitter but the number of follows and the number of followers are recorded along with the tweet itself for the registered Twitter accounts. We used all the data of the municipal accounts that were listed in Govtter and registered to Twilog before March 11th of 2011, which counts to 34 accounts.

The data were obtained from February 1 to April 30 in 2011 to conduct the comparative analysis between the normal period and the focused period. The total number of the tweets was 42825.

The data was analyzed in the following way. First after

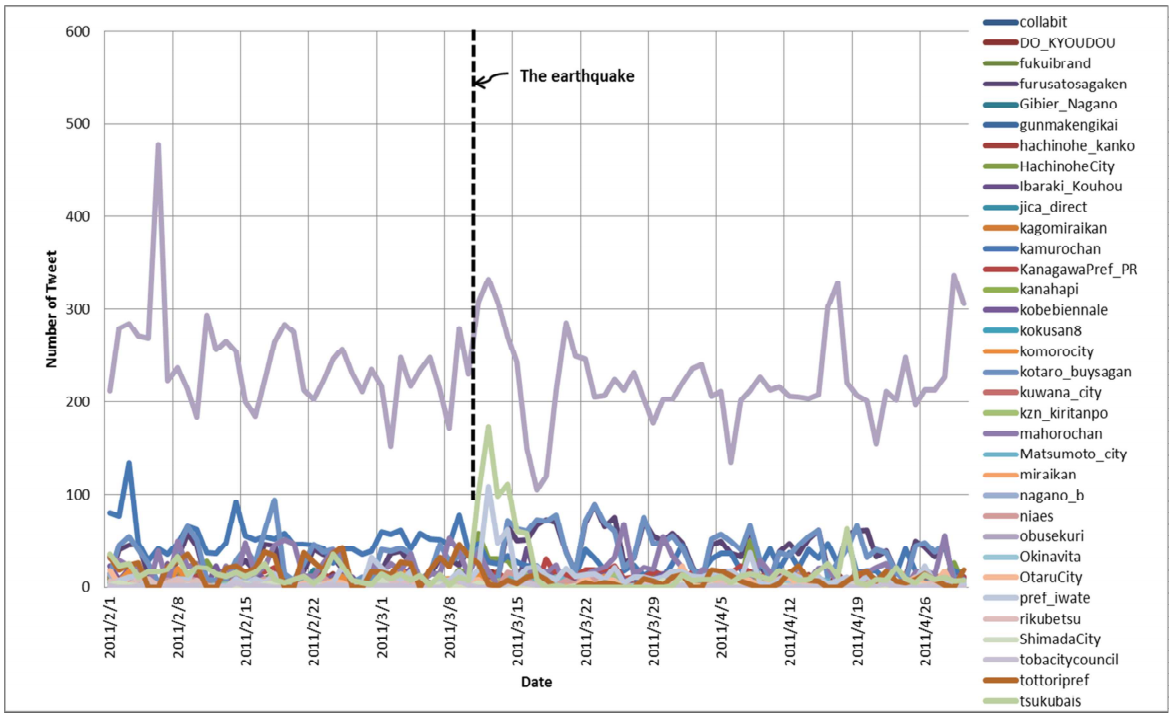



Figure 1: Change of the number of tweets for all the accounts

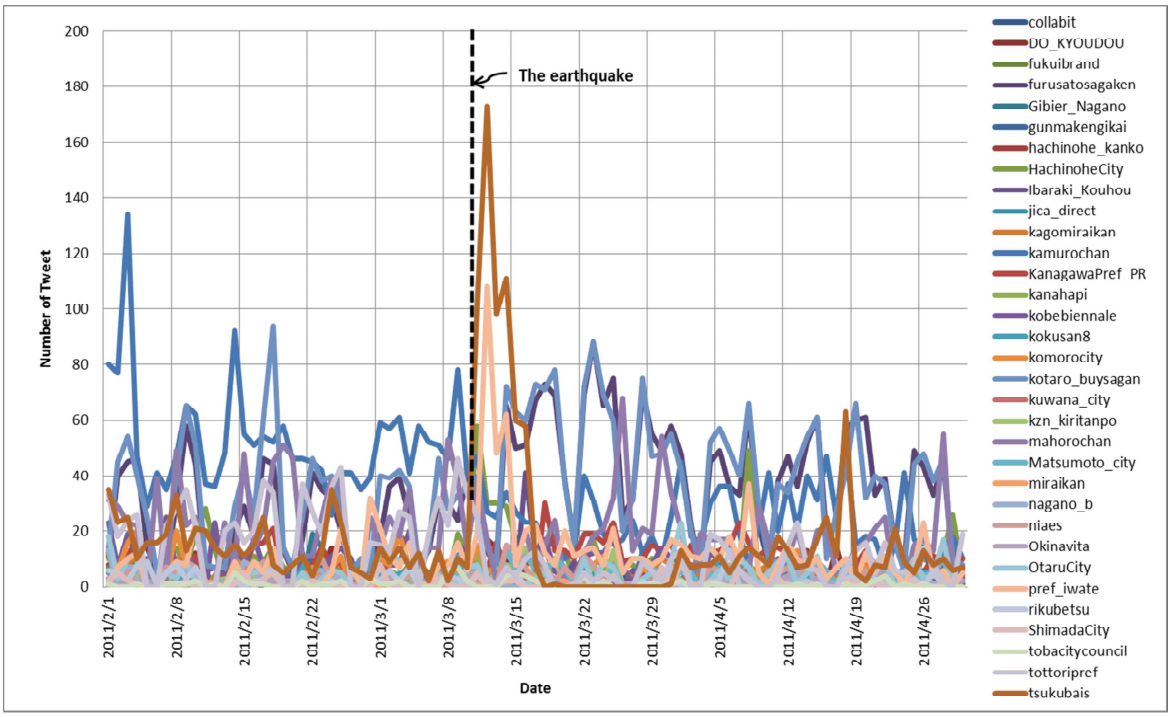



Figure 2: Change of the number of tweets for the 33 accounts

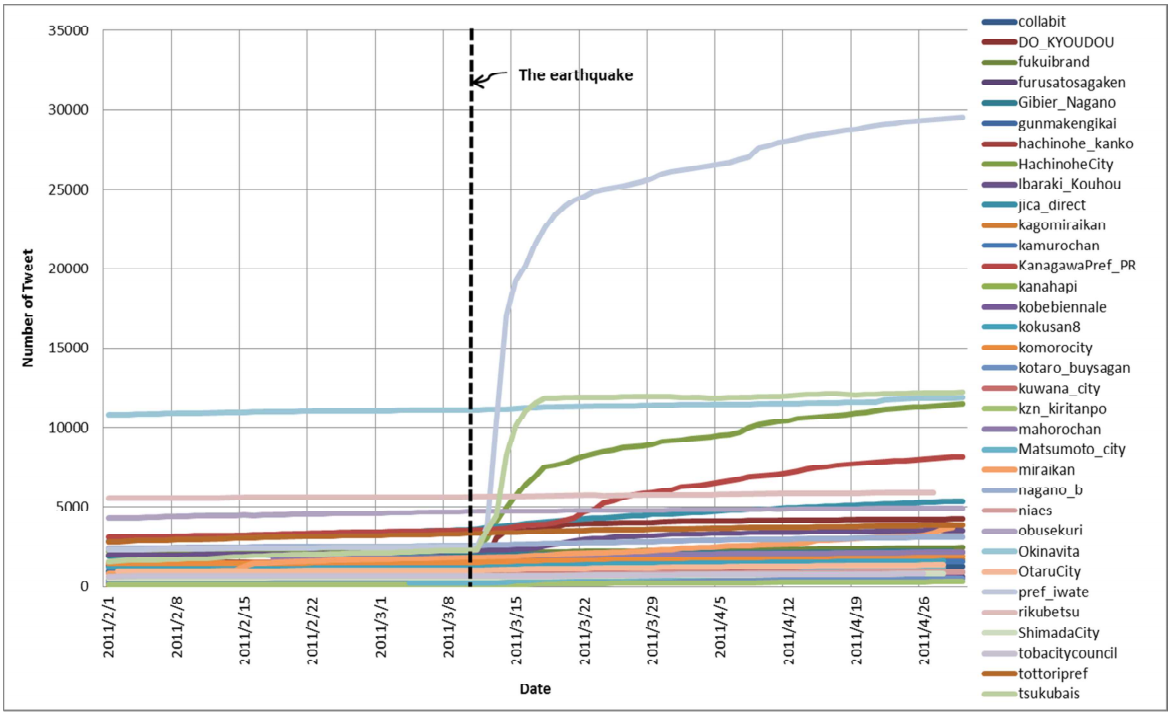



Figure 3: Change of the number of followers for all the accounts

getting the general idea of the number of tweets and the number of followers for all the accounts, the accounts were categorized according to the number of the tweets and the number of followers across time. Then, each category was investigated. Furthermore, the contents of the tweets were categorized.

# 4 RESULT

## 4.1 Change of the Number of Tweets and Followers

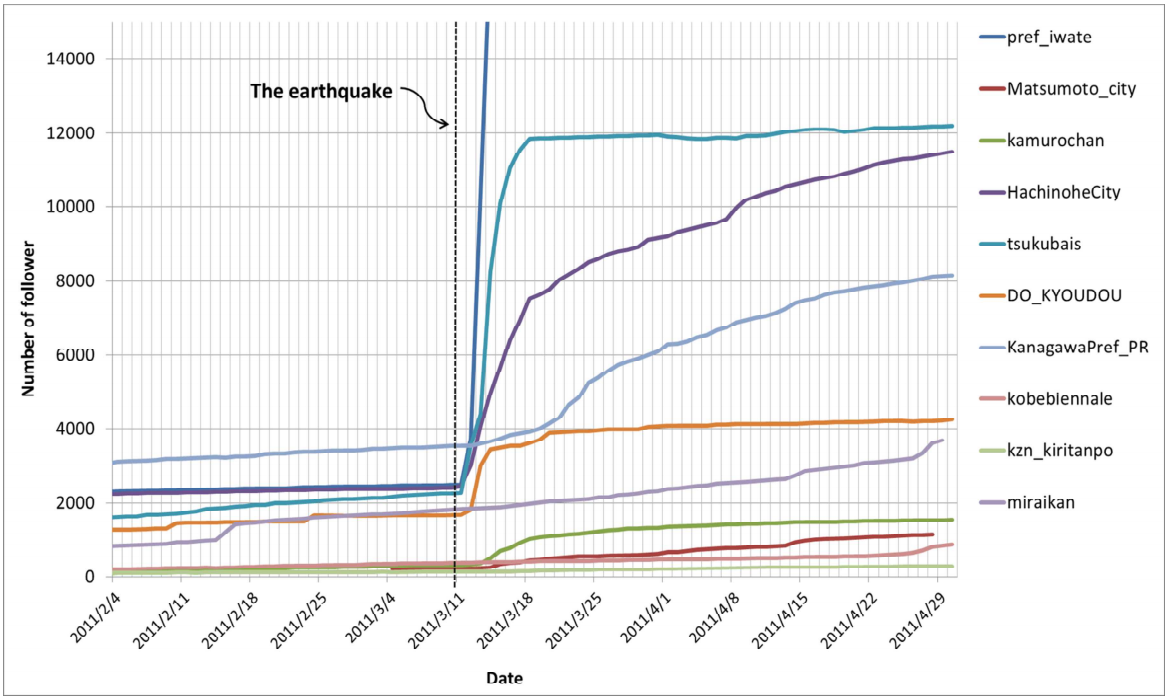



Figure 4: Change of the number of followers for the accounts that were above the average in the increasing rate of the followers

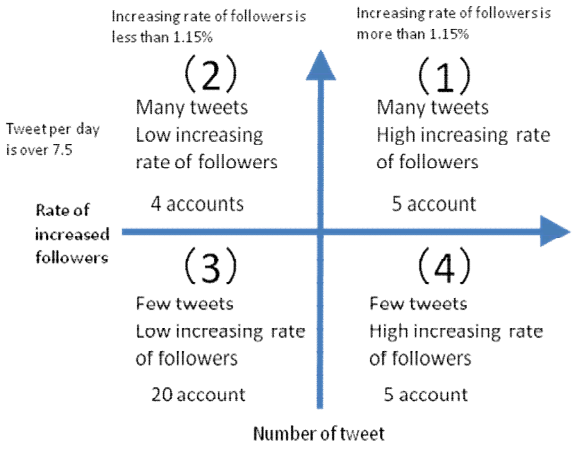



Figure 5: Quantitative categories of the accounts

The change of the number of tweets for all the 34 accounts is shown in Figure 1. The account names in the legend are simply in alphabetical order. Because Figure 1 has a tweet bot "Obsekuri," which was an extremely frequent tweeter than other accounts, we have Figure 2 that deleted the account to get the general idea of the change of the number of tweets.

The Change of the number of followers for all the accounts is shown in Figure 3. Because we see too many lines in the bottom area of Figure 3, we extracted some accounts that had increasing rate of the followers more than the average shown in Figure 4.

As for the change of the number of tweets, we naturally can see the peak right after the day 3/11, but the patterns seem to be varying for the other parts. As for the change of the number of the followers, some accounts have increasing number of followers while other accounts do not have such rapid increasing number of followers. There seems to be that the accounts that already had many followers before the day 3/11 were likely to have more increasing rate of the followers after the day 3/11.

## 4.2 Account Categorization

To better understand what was going on after the general view in 4.1, we categorized all the accounts into four according to the number of tweets and the increasing rate of the followers across time, as shown in Figure 5. The lines to divide categories are the averages. The average number of tweet per day was 7.5 and the average increasing rate of followers per day was 1.15%. As shown in Figure 5, we numbered each category from (1) to (4) that were same with the quadrant.

Figure 6 shows the features of the group (1) with the many tweets and the high increasing rate of followers, which five accounts belonged to. In the figure are some additional graphs besides the number of tweets and the number of the followers. Those are the number of tweets that were categorized in their content, which are explained later. This group gained rapid increasing number of the followers after the day 3/11.

Figure 7 shows the features of the group (2) with the many tweets and the low increasing rate of the followers, which four accounts belonged to. Although this group had many tweets but the change of the number of the tweets was not very noticeable.

The group (3) is the category with the few tweets and the low increasing rate of the followers, which twenty accounts belonged to. Although most number of the accounts

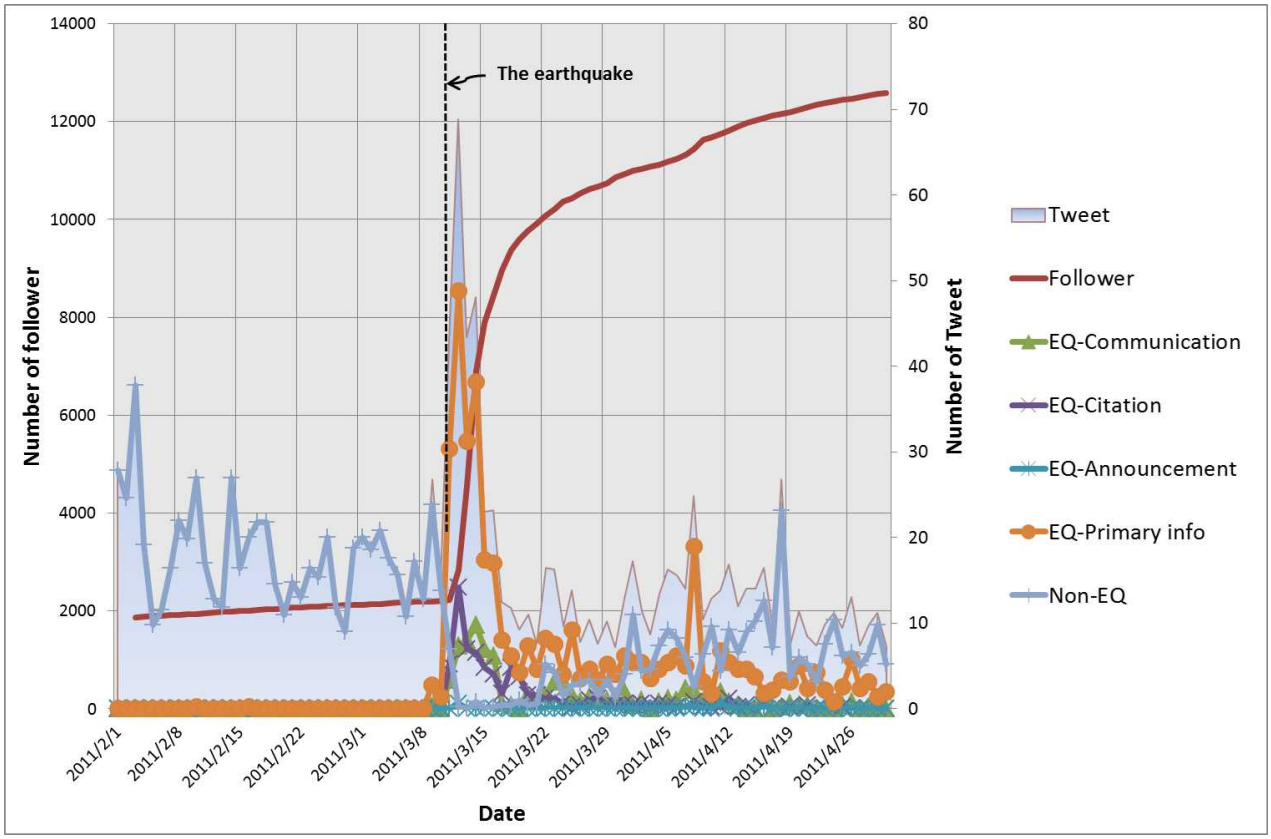



Figure 6: Features of Group (1) with the many tweets and the high increasing rate of followers

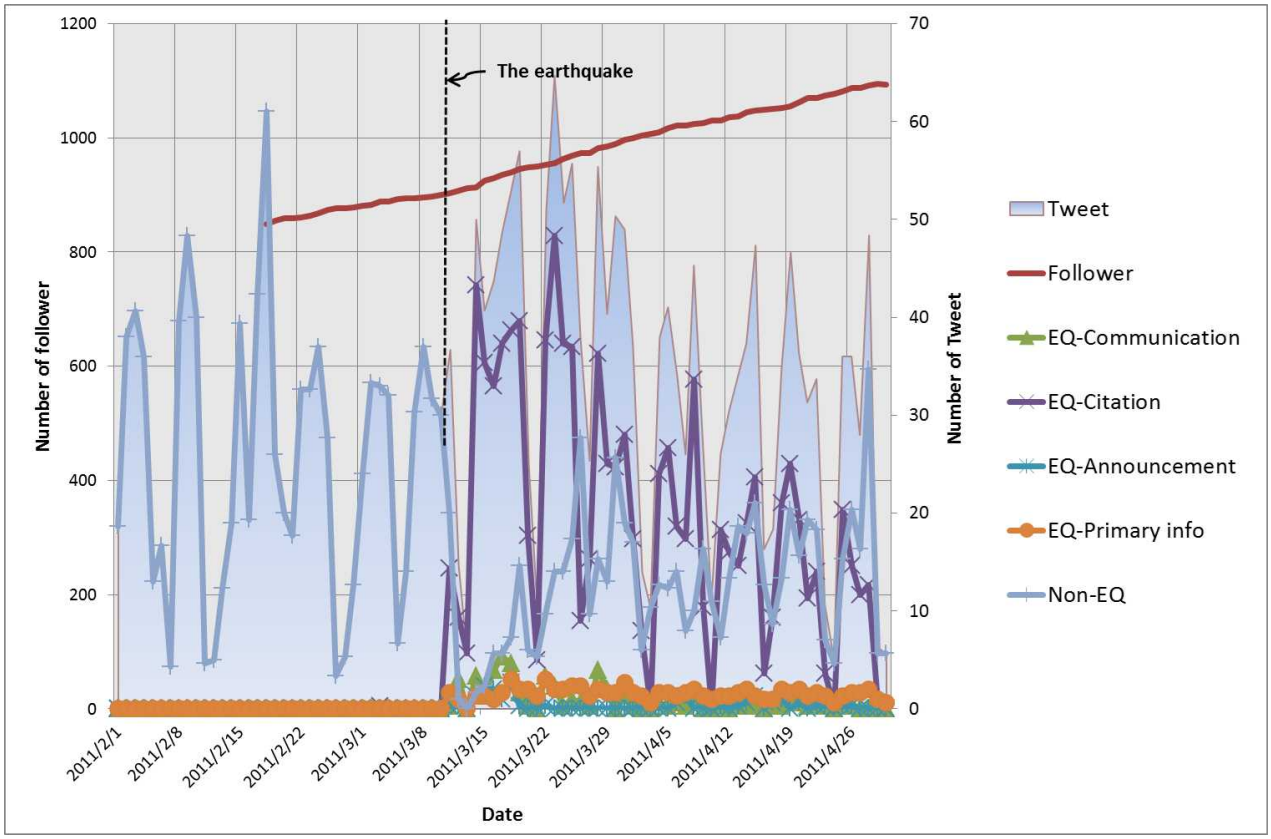



Figure 7: Features of Group (2) with the many tweets and the low increasing rate of followers

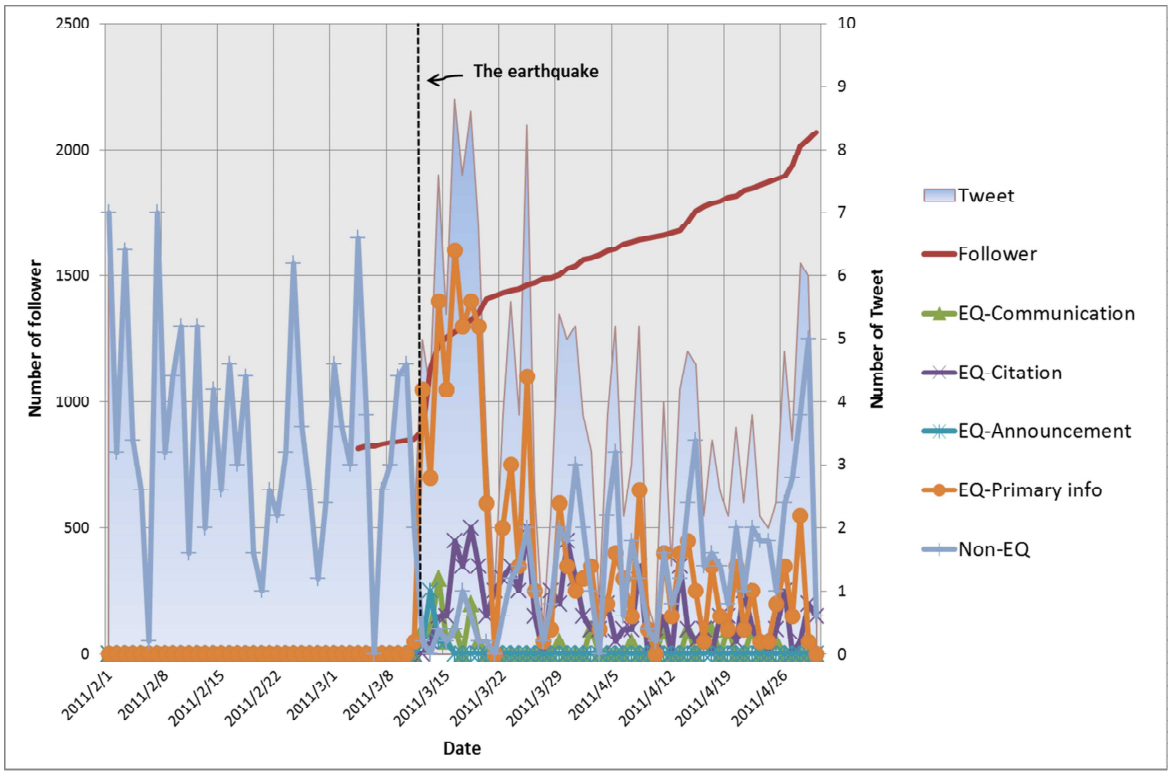



Figure 8: Features of Group (4) with the few tweets and the high increasing rate of followers

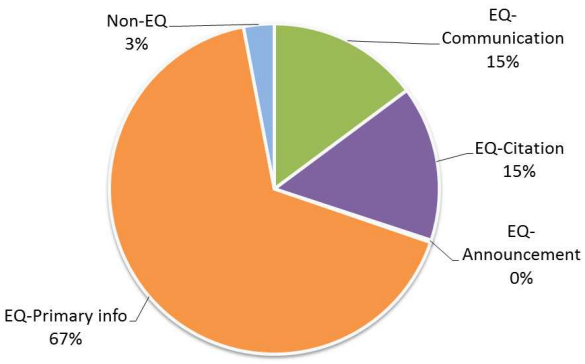



Figure 9: Tweet content of Group (1)

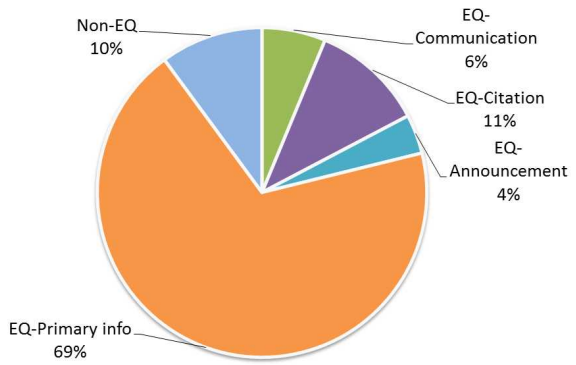



Figure 10: Tweet content of Group (4)

inactive accounts. Thus this group is not focused in this paper hereafter.

Figure 8 shows the features of the group (4) with the few tweets and the high increasing rate of the followers, which five accounts belonged to.

From the group (2) and the group (4), we see that some accounts with not so many tweets had many followers. As a common feature of the group (1) and (4), which both had the high increasing rate of followers, the content of the tweets seems to be related.

## 4.3 Content of the Tweets

The content of the tweets were investigated and categorized in the following five types.

a-1) Earthquake related: Communication with other account.

This includes the tweet of reply using @ to communicate with other specific account.

a-2) Earthquake related: Citing exiting information

This includes the tweet that cites information related to the earthquake. Not only is the retweet, a tweet of a link to the related news in a web site for example is included in this category.

a-3) Earthquake related: Announcing to people

This includes the tweet that is related to the earthquake and that can be taken as the announcement to the unspecified followers. A tweet of general caution for blackout is an example.

a-4) Earthquake related: Announcing primary information

This includes the tweet that provides the information where the tweeter is the primary source. The

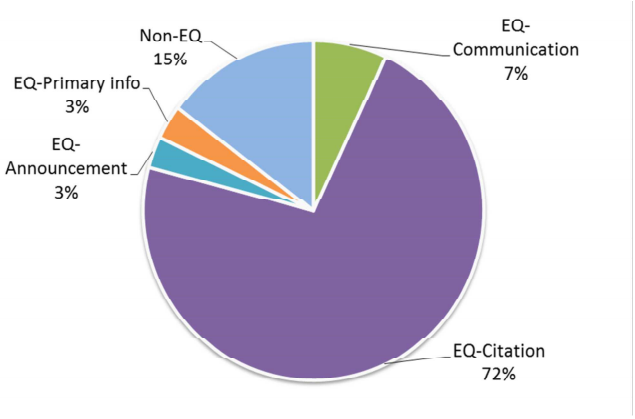



Figure 11: Tweet content of Group (2)

tweet of primary information when the official Web site was not running, and the tweet of notifying the Web update where the Web site had new information related to the earthquake are examples.

b) Earthquake non-related

This includes the tweet whose content is not related to the earthquake. The tweets before the earthquake belong to this category.

### 4.4 Account Categories and Their Content

The content of the tweets in each category of the accounts are also shown in Figure 6-8. We see that both in the group (1) and (4), which had the high increasing rate of the followers, major portion of the tweets were "a-4) Earthquake related: Announcing primary information."

Then to analyze the relation between the account categories and the content more, the content of the tweets during after a week of the day 3/11, namely from 3/11 to 3/17, was investigated in each of the three groups. The content of the group (1), (4), and (2) are shown in Figure 9, 10, and 11 respectively.

We see that the group (1) had the most primary information tweets. The communication tweets and the citation tweets followed. The group (4) also had the most primary information tweets, and the citation tweets followed. In contrast to these groups, the group (2) had the most citation tweets.

From this analysis, we see that the accounts that tweeted primary information were followed by many people.

## 5 OPERATION GUIDELINES

From the result of the previous section, we can draw operation guidelines of a municipal Twitter account in emergency.

(1) First and foremost, provide the primary information. People want it.

Other things are relatively not so important, but we still can draw things from the graphs.

(2) Immediate tweet is helpful. This can be observed from Figure 6 and Figure 8. The content changed, and also the number of tweets changed after the earthquake in the group (1) and (4). The group (1) accounts that had been relatively active before the earthquake responded more immediately than other accounts, and were followed by much more people.

(3) Communication can also be helpful. The group (1) accounts, which can be considered most useful because they were most followed, had more communication tweets than other accounts.

(4) Citation can be tweeted, but many citation may not be appreciated very much. All accounts had some citation tweets, but the group (2) which tweeted citation mainly did not get increasing followers especially.

(5) Daily activity to have followers is significant. The group that gained the most number of followers, and the group that gained the most increasing rate of followers was the same group (1). The group that had the most number of followers before the earthquake was this group (1). Having more followers means having stronger dissemination ability, and resulting to draw more people.

## 6 CONCLUSION

In this paper, we focused on the use of Twitter accounts by municipal organizations and the people's behavior around them in the Great East Japan Earthquake, because we still do not know how those accounts can be used effectively in the emergency although such social media, Twitter especially, are encouraged to use by the Japanese government. Through the data acquisition and analysis of the twitter use in the earthquake, we could reveal that:

1) There were types of behaviors of the municipal accounts and some were useful and were followed by many people.
2) People wanted the primary information.
3) Immediate response is helpful.
4) Daily activity is significant.

As a result, the operation guidelines for the future Twitter account operation by municipal organizations were drawn.

## ACKNOWLEGMENT

The author would like to thank Naoko Yoshimura for her contribution to the data collection and analysis.

## REFERENCES

[1] T. Tokuda, Crisis Responses to the Great East Japan Earthquake: 11. Local Government Crisis Response and Information Technologies, Information Processing Society of Japan Magazine, Vol.52, No.9, pp.1082-1083 (2011).

[2] K. Wakita, Crisis Responses to the Great East Japan Earthquake: 9. Smartphone Applications at the Time of Crisis, Information Processing Society of Japan Magazine, Vol.52, No.9, pp.1078-1079 (2011).

[3] METI (Ministry of Economy, Trade and Industry), On information broadcasting by governmental or municipal organizations using social media, http://www.meti.go.jp/press/2011/04/20110405005/20110405005.html (accessed 2012-06-20).

[4] M. Mendoza, B. Poblete, and C. Castillo, Twitter under crisis: Can We Trust What We RT?, Proceedings of the

First Workshop on Social Media Analytics, pp.71-79 (2010).
[5] B. De Longueville, R. S. Smith, and G. Luraschi, "OMG, from here, I can see the flames!": A Use Case of Mining Location Based Social Networks to Acquire Spatio-temporal Data on Forest Fires, Proceedings of the 2009 International Workshop on Location Based Social Networks, pp.73-80 (2009).
[6] S. Vieweg, A. L. Hughes, K. Starbird, and L. Palen, Microblogging During Two Natural Hazards Events: What Twitter May Contribute to Situational Awareness, Proceedings of the 28th international conference on Human factors in computing systems, pp.1079-1088 (2010).
[7] Y. Qu, C. Huang, P. Zhang, and J. Zhang, Microblogging After A Major Disaster in China: A Case Study of the 2010 Yushu Earthquake, Proceedings of the ACM 2011 conference on Computer supported cooperative work, pp.25-34 (2011).
[8] M. Miyabe, E. Aramaki, and A. Miura, Use Trend Analysis of Twitter after the Great East Japan Earthquake, IPSJ SIG Technical Report, Vol.2011-GN-81, No.17, pp.1-7 (2011).
[9] A. Umejima, M. Miyabe, E. Aramaki, and A. Nadamoto, Tendency of Rumor and Correction Re-tweet on the Twitter during Disasters, IPSJ SIG Technical Report, Vol.2011-DBS-152, No.4, pp.1-6 (2011).
[10] A. Lubna and R. Lucas, Tweeting Government: A Case of Australian Government Use of Twitter, IEEE International Symposium on Dependable, Autonomic and Secure Computing, pp.995-1001 (2011).
[11] A. Kavanaugh, E. A. Fox, S. Sheetz, S. Yang, L. T. Li, T. Whalen, D. Shoemaker, P. Natsev, and L. Xie, Social Media Use by Government: From the Routine to the Critical, Proceedings of the 12th Annual International Digital Government Research Conference: Digital Government Innovation in Challenging Times, pp.121-130 (2011).
[12] METI (Ministry of Economy, Trade and Industry), Govtter, http://govtter.openlabs.go.jp/ (accessed 2012-06-20).
[13] H. Tsujimura, Twitter API Programming, Works Corporation, p.344 (2010)
[14] Ropross, Twilog, http://twilog.org/ (accessed 2012-06-20).

# Evaluation test sight of Hybrid communication

Takashi Furumura[1], and Kunihiro Yamada*

[1]General Manager, Ecology and Energy Business Development, Division No.3, Megachips, Japan
furumura.takashi@megachips.co.jp
*Professional Graduate School of Embedded Technology, Tokai University, Japan
yamadaku@tokai.ac.jp

***Abstract*— We have developed a hybrid communication module recently [1]. This module has various applications to our customers. At any place close to the environment where they think the module is installed, it is important that they easily make sure it works well. Therefore, we have opened the experimental field test site close to their desire. The experimental field is a building of approximately 1800 square meters 5 floors above ground, one-storey underground. At this building sight, there are many obstacles to the communication environment when compared with experiments on the desk and small detached houses. We think that evaluation experiments in an environment close to the truth in this way has enough meaning. We have opened the field experiment building in the hope that we can get the basic concept of the system which we must develop. The original purpose was to show the difficulty of communication, but we have gotten more opportunity to know the possibilities of communication beyond the boundaries. We think it is the great achievement just after 3.11 big earthquake.**

***Keywords-component; home network, smart meter, electric power peak cut, home energy management system, mutual complementary wireless and wired network***

## 1. THE NEED FOR HOME-BUILDING NETWORK

In the wireless communication, and sometimes in communication between different rooms (floor), RF module can not communicate by the bad material of the building walls and ceilings. In addition, PLC (Power Line Communication ) is used to communicate at a wired power supply lines. But in Japan, at the two different phase of single-phase three-wire 100-volt-powered, there is a problem that communication performance is degraded. The communication performance between the two points can be improved of course by increasing its output in wireless communication, but there will be a particular manner of the wireless interference.
In addition, the communication performance can be improved with a dedicated line to be placed in the wired communications, which can take a very cost and time to placement of the communication line. In such networks there is a problem. Different from the current Internet network, there are many discussion about HAN: Home Automation Network to give the appropriate human control function to home equipment.

For networks that lead to all electrical equipment including lighting fixtures in the home or office, we pursue the possibility of mutually complementary wireless & wired network as research level. We have studied it from around 2004 [2] and now we are going to develop actual business by using the technology we call it Hybrid communication network.

As shown in Figure 1, we have used OSI standard Layer 1 and 2 with IEEE802.15.4 wireless and PLC:D2DL [3]. As for Layer 3 and 4, we have developed original Multi-hop HYBRID control software with network function. In fiscal 2009, we confirmed the usefulness of participating in the PLC communication demonstration experiment of the Ministry of Economy, Trade and Industry (METI) Smart House [4]. In fiscal 2010, we established a communication system using a hybrid visualization system at power distribution panel portion of the actual housing of more than 500 units. This is the same METI experiment carried out in four major area in Japan. This was domestic long-term effectiveness confirmation of hybrid communication concept [5].

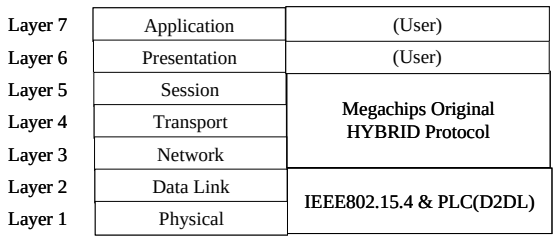



Figure 1: OSI reference model of a hybrid communication module

## 2. CHARACTERISTICS OF "HYBRID COMMUNI-CATION"

Mutually complementary hybrid network is a unique communication method to use at the same time two or more different means of communication, and to improve characteristics of the communication performance [2]. Figure 3 shows an ideas of this communication method . In this study, we used wired and wireless communication using the PLC [3] and the IEEE802.15.4 [6] . And then we constructed

mutual complementary networks as a result. In apartment houses and 200 square meters of steeled rebar three floors house, was obtained in 70% of PLC communication performance alone so far. IEEE802.15.4 alone has been evaluated to be 82% of communication performance. See Figure 2. In these mutual complement each other network used in communication at the same time, these performance values are a mathematical theory 94.6%. In the actual measured value, we have gotten the communication performance of 100% [2].

| | | IEEE802.15.4 (wireless) | |
|---|---|---|---|
| | | true 82% | error 18% |
| PLC (wired) | true 70% | true 57.4 | true*error−>true 12.6 |
| | error 30% | error*true −>true 24.6 | error*error 5.4 |

Figure 2 : Success rate of Wired and Wireless

In this way, complementary network communication performance has been observed in the normal house and home. However, we have not gotten satisfactory communication performance of network communication such as in the school building. It is currently being evaluated in 4.1% [7]. We have tried to consider the hopping method against this problem, to improve communication performance. We have done some research to know that all of these nodes has been established where each node is, and enhance the communication performance by the hopping method [8]. However, because of the very low end computer system in above hybrid system compared to PC systems in home appliances and office equipment, when we build a network of these devices, we need to make smaller impact on above hopping method.

This management is a method to put the other stateless routing information to each packet. The packets have three pieces of information; <1> information during the relay node, <2> information either wired or wireless, and <3> information about LQ or RSSI communication quality.

RSSI: Receive Signal Strength Indicator

LQ : Link Quality

With these 3 information, the gateway or relay node will make broadcast command for each next node. At each node is responsive to return to the gateway routing information back in the reply information. We made up a four-stage hopping method. Each node will not reply (because through self) if there is a packet of information about themselves at the broadcast command. This allows to avoid congestion due to broadcast, it is possible to broadcast up to four deep hopping in the back stage.

Some others have also announced idea of using wireless and wired [9] as well as the present study, the methods for selecting the wireless and wired for each space, but it does not mean always use both the communication. To communicate using the wireless communication and wired communication at the same time is a unique feature of this complement network.

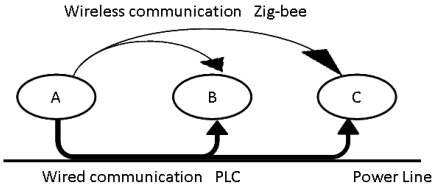



Figure 3 : Conceptual diagram of the communication networks complement each other

## 3. SYSTEM DEVELOPMENT AND ADAPTATION OF HYBRID COMMUNICATION MODULE.

We have developed the power visualization system with hybrid module using above hybrid communication method. Figure 4 shows overview of Hybrid Electric Power measurement system.

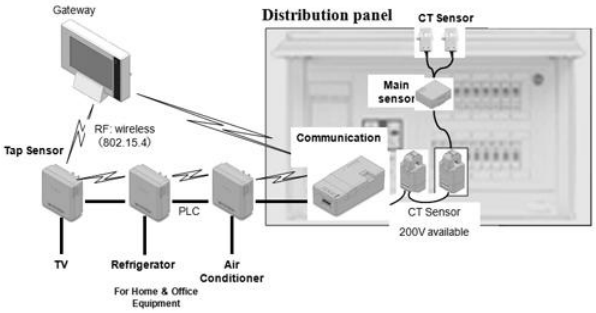



Figure 4 : Overview of Hybrid Electric Power measurement system

Tap sensor are set to measure the power of each individual electric device installed in a normal 100V outlet of each home office, as shown in Figure 5. The convex portion of each device power outlets will be located in the recess at the bottom of this Tap sensor.

The Communication Units and main / sub CT (current trans type) sensors are located in distribution panel. They measure the power of over 15A and 200V devices. The measured electric power value are collected to Gateway through wired PLC and wireless communication with using same Hybrid method.

| | Gateway | Sensor Tap | CT Sensor & Communication unit |
|---|---|---|---|
| Look |  |  |  |
| Outline | GW is a product to collect data measured by the sensor to display. Feature enables the gateway to the Ethernet, is available to work with the server application. | Sensor tap is a product that has the ability to measure the type of power plug outlet. Power measurements can be made of individual equipment unit. . | CT sensor circuit is a product that has the ability to power measurement of each system, including the main power line of power distribution panel. Power measurements can be made of individual circuit units. Are compact, built-in to the power distribution panel, is possible. |

Figure 5 : Outline of Gateway, Tap and Communication Unit.

As we mentioned above, due to the noise emitted by electrical equipment, each disturbance and weak wireless communication through the ceiling-wall, in-home office, we will not be able to collect the measurement values in a simple wireless communication (or simple plc communication) and it can not communicate to gateway. But Gateway can gather to collect the measurement results with high reliability by the newly developed Hybrid communication system. Tap sensors and Communication unit each holds the power value of each minute. Gateway can collect data each from Tap sensor and Communication unit once a minute. Gateway has a web server function, it generates xxxx.csv file passed to PC or equivalent . Consumers can read the graph chart which shows electric power data easily by PC's application software .

## 4. HYBRID COMMUNICATION EVALUATION TEST SITE.

We have performed and evaluated Hybrid communication experiments by placing the following devices to building 300m2 with 5 floors on each floor in the Hanzomon Tokyo.

**3rd Floor**: In floor distribution power panel , 4 Communication units have been set to the power lines of refrigerator, water heater, copiers, printers, lighting and air conditioning indoor units. Each unit has max 16 another individual CT sensor system to each power line. It is possible to measure separately the total power of up to 64 by this point. At 3rd floor, we also set up Gateway to collect all electric power information. At Figure 6, each small CT sensors of the power distribution panel installation can be seen.

**4th Floor:** Measurement sensor was installed distribution panel as well as power distribution panel of 3rd floor. This floor is currently empty. So we can get environments with low noise communication. It is possible to compare with noisy 3rd floor. 3rd & 4th floor are using different AC power line from transformer, so theoretically PLC can not communicate to another different PLC through the different power line.

**5th Floor:** We installed in the distribution panel section same as 4th floor: 5th floor is also using other power line different with 3rd floor. So, theoretically PLC can not communicate to another different power line. Therefore wireless function of Tap sensor (or Communication unit) must translate (hop) the information to other different devices by using HYBRID communication method.

**Rooftop:** We set up a communication unit on inside the rooftop cubicle, to verify the possibility of communication in the vertical direction of the building by PLC on the main big AC lines. Wireless signal is also verified and checked the impact of an iron door of the cubicle again.

Figure 6 : CT sensors installation in power distribution panel. 14 CT sensors can be seen. The green LED shows 100v operation, LED red Indicates the system 200V operation.

## 5. THE RESULTS OF HYBRID COMMUNICATION EVALUATION TEST SITE.

The communication path changes from moment to moment. The hybrid route is changed due to the noise emitted by each device. Plc will help wireless if the communication becomes difficult, and vice versa also wireless will help wired, PLC. Sometimes when they both communication becomes difficult, that the communication is not actually collapse by that another communication on the route will take over. In that sense, said reliability is growing more and more according to more multiple nodes which we set up even afterwards.

There is no problem even in the worst case loss of communications. The lost data before is measured when communication is restored to the later time. So the collection data can be gathered to the gateway.

Between different strains of trans, PLC communication is impossible. AC power waveform has been shifted 120 degrees or 240 degrees even in theory, so the PLC signal is not transmitted.

Although it is difficult for the 2.4GHz radio to exceed the wall of the concrete, if there is a opposite building nearby, sometimes reflected signal can reach by the wall. Sensors for relay tap is preferable to set at the location of the window installation by this theory. Specifically, we decided to set up a tap sensor (role of the repeater) to the outlet of water heater installation location near by a window.

As bad case, we found the case that the communication exceed the floors is not connected. We found that tap sensor can be used with the advantages of wireless communication to the floor up and down in part stair-shaft portion. Also we observed that wireless communication is useful up and down to the floor by the wall of the building by the radio wave reflection at the wall.

If there is a communication unit installed in a cubicle, we can also ensure that the communication was wired up to about 10 floors established in the plc using the vertical trunk of the power supply.

Figure 7 shows actual communication status. For example, the GW route status of node 04 is different according to each different noise situation . As for node 04, sometimes GW-z-04: GW gets data from node 04 by z: wireless communication. And in some other time, GW gets data from node 04 by z through node 01 by z.
As for node 05, sometimes GW-z-02-p-05: GW gets data from node 05 by p through node 02 by z. And in some other time, GW gets data from node 05 by z through node 01 by z.
This means GW will get data through different node according to each wired and wireless communication status.
That can lead to improving the situation of communication by performing the experiment to continue the experiment reflected in the communication environment that we get from the customer in this way.

| HEAD | date | node 01 | node 02 | node 03 | node 04 | node 05 | node 06 |
|---|---|---|---|---|---|---|---|
| DATA | 2012-03-18T13:22:00 | GW-Z-01 | GW-Z-02 | GW-Z-03 | GW-Z-02-Z-04 | GW-Z-02-P-05 | GW-Z-06 |
| DATA | 2012-03-18T13:26:00 | GW-Z-01 | GW-Z-02 | GW-Z-03 | GW-Z-02-Z-04 | GW-Z-02-P-05 | GW-Z-06 |
| DATA | 2012-03-18T13:27:00 | GW-Z-01 | GW-Z-02 | GW-Z-02- | GW-Z-02-Z-04 | GW-Z-02-P-05 | GW-Z-06 |
| DATA | 2012-03-18T13:29:00 | GW-Z-01 | GW-Z-02 | GW-Z-03 | GW-Z-04 | GW-Z-02-P-05 | GW-Z-06 |
| DATA | 2012-03-18T13:30:00 | GW-Z-01 | GW-Z-02 | GW-Z-03 | GW-Z-04 | GW-Z-02-P-05 | GW-Z-06 |
| DATA | 2012-03-18T13:32:00 | GW-Z-01 | GW-Z-02 | GW-Z-03 | GW-Z-01-Z-04 | GW-Z-02-P-05 | GW-Z-06 |
| DATA | 2012-03-18T13:33:00 | GW-Z-01 | GW-Z-02 | GW-Z-03 | GW-Z-01-Z-04 | GW-Z-02-P-05 | GW-Z-06 |
| DATA | 2012-03-18T13:35:00 | GW-Z-01 | GW-Z-02 | GW-Z-03 | GW-Z-01-Z-04 | GW-Z-02-P-05 | GW-Z-06 |
| DATA | 2012-03-18T13:36:00 | GW-Z-01 | GW-Z-02 | GW-Z-03 | GW-Z-01-Z-04 | GW-Z-02-P-05 | GW-Z-06 |
| DATA | 2012-03-18T13:37:00 | GW-Z-01 | GW-Z-02 | GW-Z-03 | GW-Z-01-Z-04 | GW-Z-02-P-05 | GW-Z-06 |
| DATA | 2012-03-18T13:39:00 | GW-Z-01 | GW-Z-02 | GW-Z-03 | GW-Z-04 | GW-Z-01-Z-05 | GW-Z-06 |
| DATA | 2012-03-18T13:40:00 | GW-Z-01 | GW-Z-02 | GW-Z-03 | GW-Z-02-Z-04 | GW-Z-01-Z-05 | GW-Z-06 |
| DATA | 2012-03-18T13:49:00 | GW-Z-01 | GW-Z-02 | GW-Z-03 | GW-Z-02-Z-04 | GW-Z-03-Z-05 | GW-Z-06 |
| DATA | 2012-03-18T14:00:00 | GW-Z-01 | GW-Z-02 | GW-Z-03 | GW-Z-01-Z-04 | GW-Z-01-P-05 | GW-Z-06 |
| DATA | 2012-03-18T14:10:00 | GW-Z-01 | GW-Z-02 | GW-Z-03 | GW-Z-01-Z-04 | GW-Z-01-Z-05 | GW-Z-06 |

Figure 7 the actual results of PLC and wireless communication with electric power information

GW indicates Gateway portion which gets electric power data from each node 01-06
Z indicates that it has been in wireless communication.
P indicates that it has been in communication (plc) wired.

## 6. RESULTS AND FUTURE CHALLENGES

By the above results, we were able addition to the results of the experiment in the home fiscal 2009, fiscal 2010, to confirm the usefulness of complementary wired and wireless hybrid communication at the building test sight. As future work to put on / off control of lighting, such as real-time communication is important. In this regard, it is necessary to further pursuit of the things that we must hold down to a minimum the time delay in the relay function of hybrid communication.

As for HEMS&BEMS, currently the power sensor HYBRID communication is attached to the outlet part of AC concent, but to be incorporated in the future such as air conditioners, electrical appliances is the goal that enables you to choose new hybrid communication LSI[10]. Power measurement and communication has been thought to be commercialized with a matter of course. The ability to remote control at your fingertips such as air conditioning, air conditioning to control from outside the house on mobile phones must be considered. Our goal is Home & Building Energy Management = HEMS & BEMS and to control the energy consumption of the whole-house building. We believe strongly that we can contribute to energy savings of time and smart grid relating issue.
Now the principal power supply is AC, but LED light bulbs and other original works in DC also.
For home use in fuel cells and storage batteries, such as solar and energy farm (enefarm) can be directly with the DC power supply, the efficiency with DC must the best. We believe that hybrid communications technology can be applied widely not only to AC lines but also DC lines in the future.

## Reference


[1] Megachip's Eco-Energy Products http://www.megachips.co.jp/english/product/ecoene/index.html

[2] Kunihiro Yamada,etc. "Dual Communication System Using Wired and Wireless Correspondence in Small Space" KES2004,Springer LNAI3214,pp.898-904,2004

[3] M16C6S: PLC Lsi http://www.renesas.eu/products/mpumcu/plc_mpumcu/m16c60_plc/m16c6s/index.jsp

[4] Edit to the original "smart house demonstration project report in FY 2009" the Ministry of Economy, Trade and Industry http://www.jipdec.or.jp/dupc/forum/eships/results/h21report_dl.html#a

[5] Next-Generation Energy demonstration project Keihanna social system http://www.meti.go.jp/committee/summary/0004633/014_05_00.pdf

[6] Wireless LSI, Zigbee, http://www.zigbee.org

[7] Daiki Watabe, Kunihiro Yamada "Route simulation in mutually complementary network between wired and wireless" 2010Information Processing Society of Japan,pp.3-313-3-314,2010

[8] Kunihiro Yamada,Takashi Furumura,Yukihisa Naoe, Kinichi Kitazawa,Toru Shimizu,Kouji Yoshida,Masanori Kojima,Tadanori Mizuno "Home-Network of a Mutual Complement Communication System by Wired and Wireless" KES2006,Springer Part LNAI4253,pp.189-196,2006

[9] Incorporating the Best of Both Worlds for Improved Functionality Industrial Environments"Hybrid Wired/Wireless Network for Real-Time Communications" IEEE Industrial Electronics Magazine March2008 Volume2 Number1,pp.8-20

[10] New Network Technologies http://www.megachips.co.jp/english/product/technology/new01.html

# Keynote Speech 1:

# Dr. Behzad Bordbar

# (University of Birmingham, UK)

# Automated prevention of failure in complex and large systems: fighting fire with fire

Behzad Bordbar

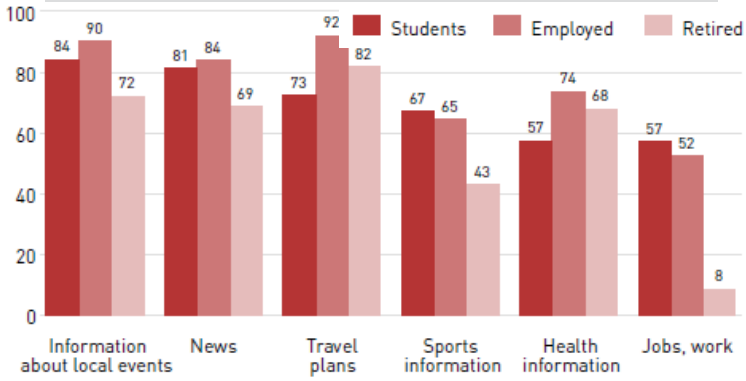
School of Computer Science
University of Birmingham
www.cs.bham.ac.uk/~bxb

THE UNIVERSITY OF BIRMINGHAM

## Contents

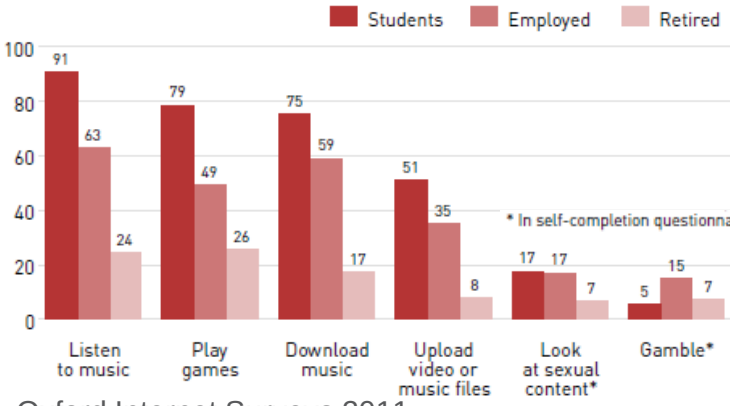
- Motivation: developing method of automated detection of fault or undesirable scenarios
- Examples from Telecom services and Cloud
- Diagnosis of fault in telecom services via DES
- Absence of models (Process Mining)
- Diagnosis in Cloud
- What we can't do well!
- Conclusion

## Internet usage at work



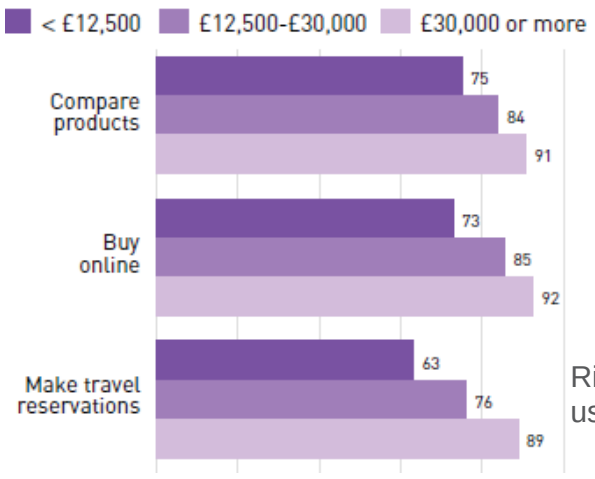

Oxford Internet Surveys 2011

## Internet for leisure activities




Oxford Internet Surveys 2011

## Shopping



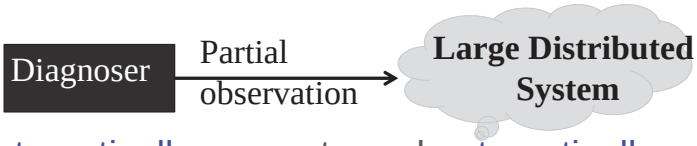

Rich people use it more!

## We can conclude that

- Research problems related to services used via Internet are of crucial important to UK and EU.
- Various research councils in the UK and EU support research programs related to Internet, Mobile computing, Service oriented Architecture and Cloud.

**A major challenge is**
How can we deliver crucial services reliably while reducing the price!

## Focus of my research




Automatically generate and automatically deploy Diagnosers (Software modules, services…) to diagnose occurrence of failure or undesirable scenarios in real time or near-real-time

**Question:** what is failure and undesirable?|

## Area of application

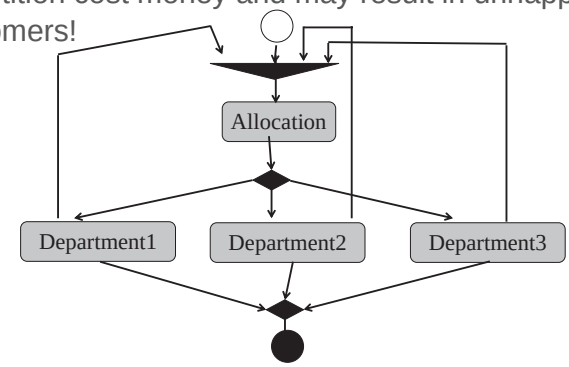
Current interest on SoA and Cloud:

- BT: Fault detection in Service oriented Architectures used in Telecom (2 projects)
- HP: Monitoring of Cloud for detecting malicious behaviour (G-cloud)

**Older research:** Electric Power Grids
**New research:** on monitoring/diagnosis of green credentials.

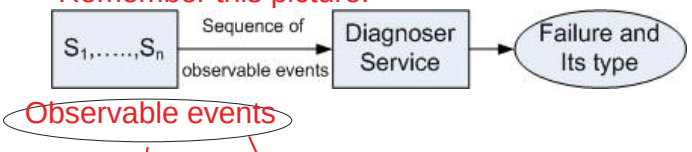
## Right-first-time failure

An extensively simplified example by BT based on RFT failure: "**System should conduct the task right 1st Time i.e repetition means failure**". ***Why?***
Repetition cost money and may result in unhappy customers!




## Diagnosis in DES

Remember this picture:




Observable events

τ1, τ2 , τ3 , τ4 , τ5 , τ6 … **outsider only sees** τ3 τ6

- **Diagnosis** means using **observable events** detecting with a finite delay occurrence of the failure and its type
- **Underlying idea:** Creating a Diagnoser (say an automata or Petri net) which **listens** to observable events and reports on failure … then implement it



## Notation: Projection to obs events

Define: P: $\Sigma \rightarrow \Sigma o \cup \{\varepsilon\}$

where ε is the identity of the alphabet $\alpha\varepsilon = \varepsilon\alpha = \alpha$ by

- P(α)= ε if $\alpha \notin \Sigma o$, *i.e.* α *is unobservable*
- P(α)= α if $\alpha \in \Sigma o$, *i.e.* α *is observable*

Extend P: $\Sigma^* \rightarrow (\Sigma o \cup \{\varepsilon\})^*$ by defining
P(α1 α2 … αn) = P(α1) P(α2) … P(αn)
For example in previous slide
P(τ1 τ2 τ3 τ4 τ5 τ6)= τ3τ6



## Diagnosability and creating Diagnosers

- Early formulation efforts [Ramadge 88], but established formulation [Sampath 93-95]
- Two main problems:
  1. **Diagnosability:** is it possible to create a Diagnoser?
  2. Algorithm to create Diagnosers from any given model

A system is diagnosable with respect to fault class T if there are no two firing sequences s1 and s2 satisfying the following
1) P(s1) = P(s2),
2) no failure transition appears in s1
3)there exists at least one failure transition in s2
4) It is possible to make s2 arbitrary long after the occurrence of a fault
[Def published 2007 equivalent to classic definition for regular languages]

## Diagnosability and creating Diagnosers

- [Sampath …Lafortune 95] present an alg. for creating Diagnosers + an if-and-only if condition for diagnosability in regular languages
- Extended the results for Decentralised in 95-00 (3 Algs)
- Decentralised Diagnoser should be able to identify all faults found by centralised and conversely …
- Extended to hierarchical Automata by Genc in early 00
- For Petri Nets the problem was studied by teams of researchers R. Boel, A. Guia and Lafortune… [02-09]



## Diagnosability and creating Diagnosers

Some recent results:

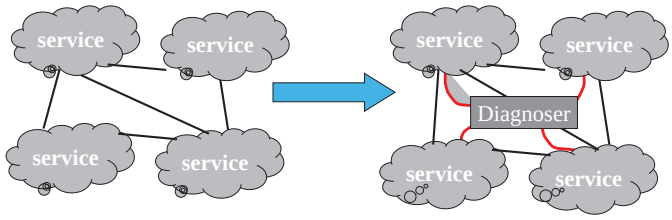
- Jirovanu, Boel and Bordbar 08 algorithm for creating Diagnosers for very large PN (seems to be the fastest)
- PN languages are not regular: [Cabasino 09] presents if-and-only if condition for Diagnosability in PN languages
- Jirovanu and Boel 09-10: extend alg. to timed systems
- Bordbar, Alodib (2012) creation of Diagnosers from logical constraints



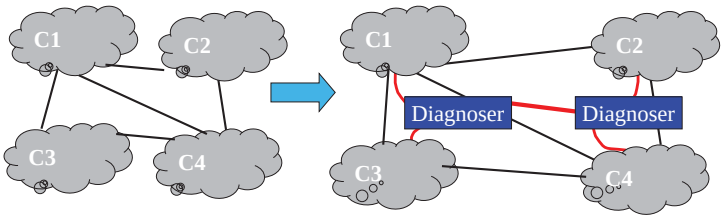
## Online Fault Diagnosis

Our aim is to:

**Automatically produce** Diagnosers to be deployed for identifying if a failure has happened or may have happened in real-time (near-real-time)




## Other architectures




**Architectures:** centralised, decentralised, Hierarchical…

This work is being patented with BT



## What if there are no models?

*DES requires models of the system*

***What if there is no model?***

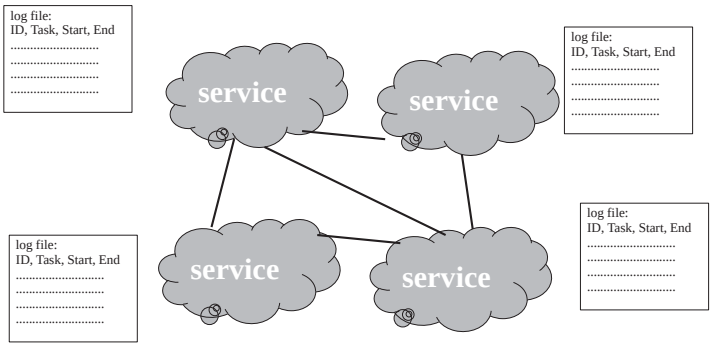
- *Services made up of legacy systems*
- *Too complex to model*
- *Dynamically changing and we don't know of changes*

*We started a second project with BT Process mining (based on wil van der Aalst and Majeed's work)*



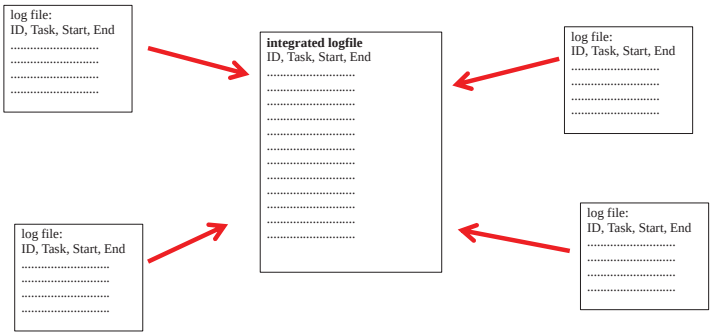
## Services produce log (we can access)

Execution details (for all customers!)



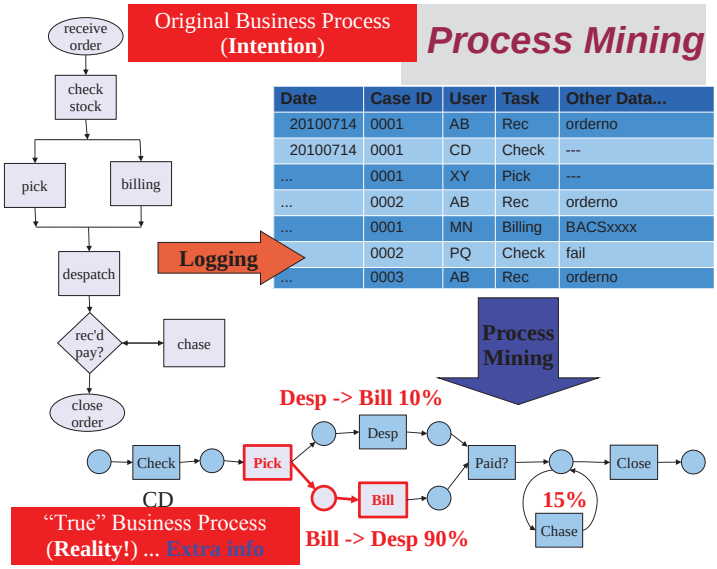
## Log files can be integrated

Using ID and time of execution




**Summary:**
1) Business Processes when executed Logs are produced
2) Logs can be processed, related and integrated

## Process Mining




| Date | Case ID | User | Task | Other Data... |
|---|---|---|---|---|
| 20100714 | 0001 | AB | Rec | orderno |
| 20100714 | 0001 | CD | Check | --- |
| ... | 0001 | XY | Pick | --- |
| ... | 0002 | AB | Rec | orderno |
| ... | 0001 | MN | Billing | BACSxxxx |
| ... | 0002 | PQ | Check | fail |
| ... | 0003 | AB | Rec | orderno |

## Central to PM: algorithms

Algorithms (20+)

- Alpha, Alpha++ (formal)
- HeuristicsMiner, Genetic Miner, Region Miner (practical)
- Probabilistic Approaches (Datta, Herbst)

Clustering (Variants)Fuzzy (Abstraction of complex or flexible processes)

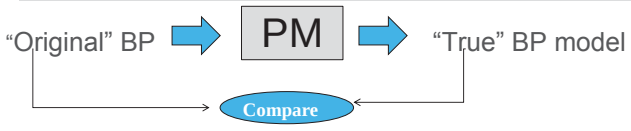
**Many of these are adaptation of approaches in other domains, but not always!**

## Example of (over) simplified PM algorithm

1) Consider two events *a* and *b*. *Walk through logs and work out:*
   - *a* > *b* (always *a* appears immediately before *b*)
   - *a* || *b* (sometimes *a* appears immediately before *b*, sometimes immediately after )
   - *a* # *b* (never before or after)
2) Create a PN or Workflow model that include ALL this information

**Question:** *a* before *b* 1000000 times and *b* before *a* *ONLY once:* *mistake* or *rare scenario*?

## Why Process Mining?




- Troubleshooting
  - Why is the model different?
  - Fault/error in implementation
- Streamlining
  - Order and timing of event
  - where are the bottlenecks? Load balancing
  - People interactions: is work passed efficiently? (provide training!)

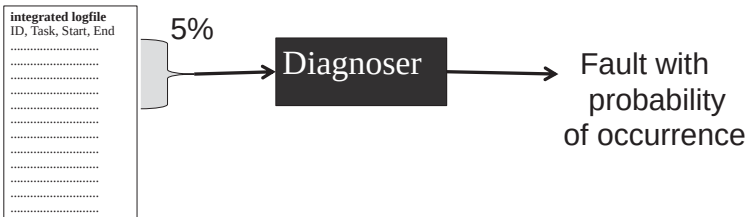
## Why Process Mining?

- Audit and governance (emerging area)
  - Show conformance to SLA
- Planning, energy conservation, ....
- Current projects:
- A framework for the comparison of process mining algorithms.
- Real-time and Near-real-time Process mining
- Forecasting in real-time

## (near) Real time process mining

-Log files are large
- Processing them is computationally expensive

**-If we use X% of a logs what is the probability of identifying an undesirable scenario?**
- Given probability, we calculate X?




## Can we diagnose new fault that we haven't seen before?

## Malicious Behaviour in Cloud

Benefits of moving to Cloud
- Lower cost of IT due to economics of scale
- Reduction in up-front cost for infrastructure
- Decrease development time using off-the-shelf components
- Green credential ….

But, on the other hand
- provide bigger and richer targets for attackers
- homogeneous structure ☹
- Historically, we are 1-step behind bad guys (**almost**)

Can we diagnose unseen malicious behavior? **Seems something is wrong!**

## Component-based malware

Writing malware is hard:
- how to gain entry to a machine
- how to install itself
- how to evade detection
- how to prevent the infected machine informing the owner
- how to propagate,
- how to make forensic analysis difficult and so on.

…
There is financial incentive in writing good malware
Studies comparing malware market for Skilled-Hackers and script-kiddies show that malware is becoming component-wise

## Detecting symptoms

Analogy with symptoms in human illness
Examples of symptoms:
- Missing processes (Confiker C aborts sysclean, tcpview, wireshark, confik and autorun)
- Modifying time of the files (Zeus modifies the time of some malicious files to the installation time)
- Modification of in-memory code (Stuxnet inject itself in some cases to Winlogon)
- Tampering with registry keys (Confiker modifies and adds strings such as app, audio,.. to obfuscate)
- High entropy strings (encryption keys used in in Confiker and DuQu)
- ….

## Detecting symptoms

- Detecting symptoms associated to components can point to malicious activities. Even if we don't know what the malicious activity is!
- The more symptoms the more compelling evidence that we have malicious activities

But how?

## Virtualisation

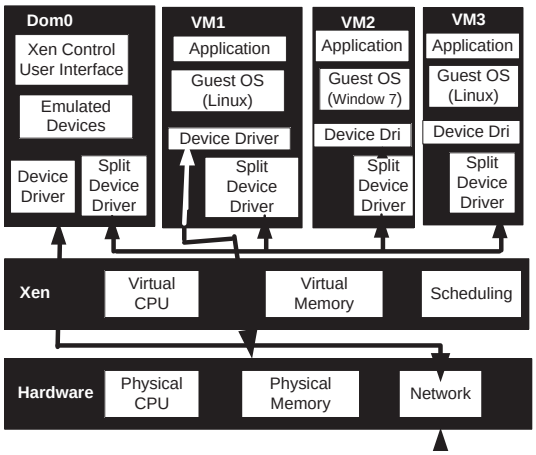



Fig from Williams and Garcia, Virtualization with Xen:

## Virtual Machine Introspection

- a virtualisation based technique that enables one guest VM to monitor, analyse and modify the state of another guest VM

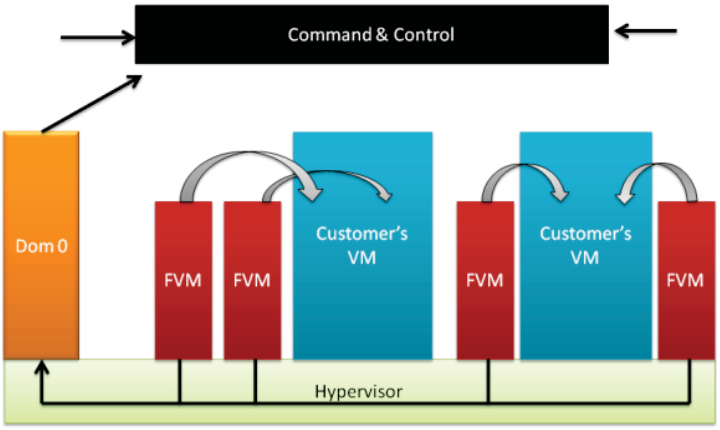
We can both read and write to the second guest but don't write:

**we can observe the symptoms without being observed**

## Example of symptoms that can be checked via VMI

- changing state of a VMs memory,
- processes that take inordinately long times to initialize,
- snippets of program code that has been obfuscated,
- snippets of code containing known crypto algorithms,
- any modifications to the system code
- …

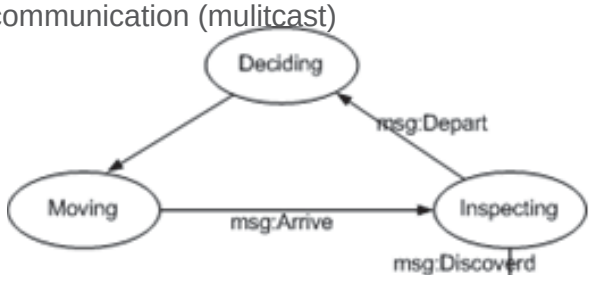
## Forensic Virtual Machine




## Characteristics of FVM

Benefits

- FVM only reads
- FVMs are small (clients can manually inspect)
- one symptom per FVM
- FVM inspect only one VM and flush its memory
- Secure communication (mulitcast)
- Mobility




## Mobility algorithm

Distributed algorithm that ensures:

- No starving: all VMs must be visited.
- Important VMs or VMs carrying crucial duties are visited more often
- urgency of visiting a VM increases when more symptoms are detected. (patient is showing multiple disease symptoms)
- Movement of the VM does not follow a predetermined pattern.
- Simultaneous inspection of VMs by multiple FVMs (swamp to increase the coverage)

## Command and Control

Receives information from FVMs (and external sources)
Observing sufficient symptoms C&C can infer the system is under attack (Diagnosis)
C&C use the virtualisation mechanism to “freeze” the VM by denying it any CPU cycles, as a result to stop the malicious activity.
The memory will remain frozen until it can be forensically examined or copied for further analysis.

## Question

I came across these challenges:
Challenge 1: DES techniques are designed for closed systems (embedded systems, robots, mars rover,…)

- How can I apply existing techniques to open systems?

Challenge 2: scalability

- Can you cope with large systems?
- Can we produce elastic Diagnosers?

Challenge 3: Implementation of the Diagnosers
We have large memory, multiple-cores, ability to make many virtual machines:

- How can we design Diagnosers that process huge amount of observation?

## Conclusion

- Internet-based systems are becoming very complex
- We are ever increasingly dependent on them for commerce, trade, banking, pleasure, …
- The cost of failure is high
- We looked at examples motivated by real-world scenarios
- Human being is not fast enough to identify the problems
- Hence fighting fire with fire

We looked at overview of some of the methods of using modelling and formal methods to monitor complex and large systems

## Supplementary slides

Extra slides not used due to short time

## Service oriented Architectures

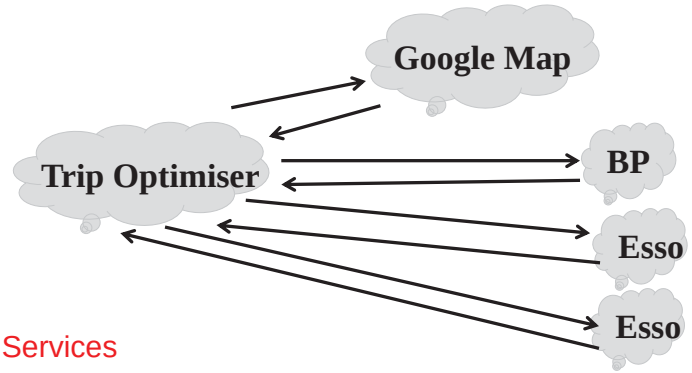
IWhat is SoA?

**Problem:** Given two postcode (hotel in Chamonix to my home in Bham) where do I buy my Diesel?

1) Map, which Petrol stations? Distance between, types of station Esso, total, BP,…
2) How much do they charge?
3) How much petrol per miles?
4) …

If I know the answer, I can make a service (website) and become rich? ☺

## Service oriented Architectures




1. Services
2. Interfaces
3. Protocols for communication

## Key role of standards

- SoA is open (services and protocols can be changed)
- Everything revolves around standards:
  - Interfaces: WSDL, XSD
  - Protocols: SOAP, HTTP

**Most essential is the business process** (How services interact to complete a task such as purchasing a book)
BPEL, BPMN,…

## Discrete Event Systems (DES)

**Discrete-state**, **event-driven** system whose state depends on the occurrence of asynchronous discrete events over time.

[Ramadge 86]

*… although time is not often modelled explicitly.*

**DES uses models to curb complexity.**

**Various modelling languages used:** flavours of automata, Petri nets, ad hoc graphical representations (+ some semantics), Workflow graphs models [vanhatalo 07, Alodib&Bordbar 12]

**We see the following elements often:**



## DES (continue)

G:=( X , *A*, Σ , δ , $x_0$ , *L* )

*X* := a set of *states* (Automata: state, PN: marking)

Σ denotes a set of *events* (Automata, PN : transitions)

$\delta \subseteq X \times \Sigma \times X$ (transition from one state to another)

$x_0$ := an initial state (or a set of …)

Often we need a labelling function:

*A* : = Alphabet of the system

*L* : $\Sigma \rightarrow A$ *(labelling function)*

But, for this talk, let us forget about L and keep it simple

## Observable, Unobservable and failure

- Events are **Partially Observable**: either **Observable** or **Unobservable**

$\Sigma = \Sigma o \cup \Sigma uo$ *(disjoint)*

- Some Unobservable event are *failure* $\Sigma f \subset \Sigma uo$
  - **Why?** If you can observe it, then you don't need Diagnosers!
- Different types of failure: $\Sigma f = \Sigma f1 \cup \Sigma f2 \cup \ldots \cup \Sigma fn$



# Session 3:
# Ubiquitous Computing & ITS
# (Chair: Yoshitaka Nakamura)

# Integrated Control System Using Notebook PC Batteries for Peak Power Demand Reduction

Masako Shinohara*, Masahiko Murakami*, Hidenao Iwane*, Satoru Takahashi*, Shohei Yamane*, Hirokazu Anai*,**, Toshihiro Sonoda*, and Nobuhiro Yugami*

* Fujitsu Laboratories Ltd., Japan **Kyushu University, Japan
{m-shinohara, mul, iwane, t.satoru, yamane.shohei, anai, toshihiro, yugami}@jp.fujitsu.com

***Abstract*** –In this paper, we propose an integrated control system that reduces peak power demand by using the internal batteries of notebook PCs. The system forecasts multiple power demand curves based on the power consumption of an office, and plans a charging/discharging schedule for each PC battery by considering the forecasts and information about the notebook PCs. By controlling the charging and discharging of PC batteries, the system reduces the peak power demand without restricting usability. We also evaluated the efficiency of peak power demand reduction in the simulation experiments and during field testing.

***Keywords***: Peak power demand reduction, control of charging and discharging, internal batteries of notebook PCs, demand forecasting, and optimization.

## 1 INTRODUCTION

To address power supply shortages resulting from the impact of the Great East Japan Earthquake, Japan's energy conservation regulation was revised to reducing just peak power demand from reducing overall power demand. In the future, it is anticipated that numerous energy storage devices will be placed in a wide range of locations, such as buildings and houses. Therefore, there is greater need for a mechanism to enable peak power demand reduction by charging energy storage devices (storing energy) during off-peak periods and discharging them (utilizing stored energy) during the peak time.

Here, to save power urgently, the use of the internal batteries of notebook PCs is attracting attention. This is because early dissemination of energy storage devices is difficult in terms of cost and operation, while lots of notebook PCs already exist in offices and homes. In the summer of 2011, many computer manufacturers released peak shift applications that can control the charging and discharging of a notebook PC battery. Figure 1 shows the peak shift setting utility released by Fujitsu Limited [1]. These applications charge and discharge PC batteries during periods each specified by the PC user. In this paper, "discharge a PC battery" means "force a notebook PC to be powered by its battery." Therefore, if these applications discharge PC batteries during the peak time and charge them during off-peak periods, we can save the power consumed by notebook PCs during the peak time and reduce the peak power demand.

This approach, however, has two problems. First, in a small-scale environment like an office, power consumption

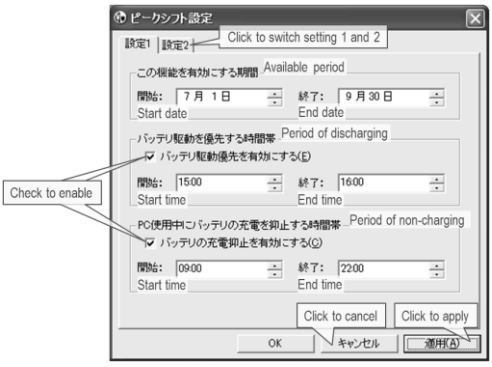



Figure 1: Peak shift setting utility released by Fujitsu Limited.

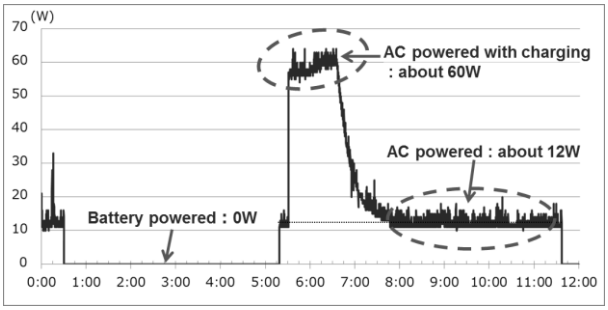



Figure 2: Power consumption of a notebook PC.

will change significantly depending on the number of users and electronic devices utilized, making it difficult to accurately forecast such fluctuations and decide when to charge and discharge PC batteries. In addition, since the power consumed during charging of a PC battery is very high (see Figure 2), there is a risk of increasing the peak power demand when multiple notebook PCs charge their batteries at the same time. Also, frequent charging/ discharging and long-term discharging of a PC battery may cause the battery to deteriorate and be empty when needed (e.g., outside).

In this paper, we propose an integrated control system that reduces the peak power demand without restricting usability by controlling the charging and discharging of PC batteries based on the power consumption of an office. The reminder of the paper is organized as follows. In section 2, we propose an integrated control system. In section 3, we present the implementation of the proposed system and give the evaluation results after using the implemented system. In section 4, we discuss some related works; then in section 5, we conclude the paper.

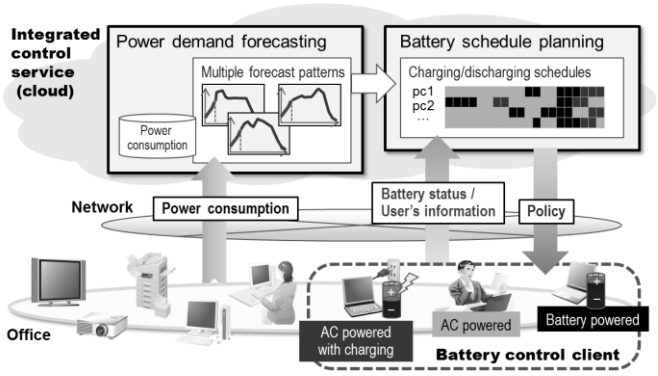



Figure 3: System schema.

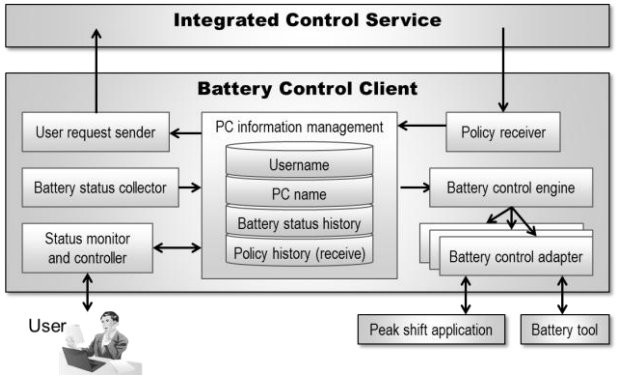



Figure 4: Architecture of battery control client.

## 2 INTEGRATED CONTROL SYSTEM

An overview of the integrated control system is given in Figure 3. The system consists of a battery control client that works at each notebook PC and an integrated control service that works as a cloud-based service.

The battery control client periodically collects the PC battery level and the user's information, and sends them to the service. The client also controls the charging and discharging of the PC battery based on the received policy from the service. The client does all these things without any help from the PC user.

On the other hand, the integrated control service collects data sent by clients and the office power consumption data over a network. Based on the collected data, the service performs power demand forecasting and battery schedule planning, and sends the policy (the control information to charge and/or discharge the PC battery) to each client. Here, a cloud-based service has the advantages of ensuring data collection and integrated control, and easily applying to multiple offices.

In the following, we further explain the battery control client, the integrated control service, and two algorithms to solve problems described in section 1.

### 2.1 Battery Control Client

Figure 4 shows the architecture of the battery control client. The function of each module is as follows.

1. PC information management
   This module manages the following information on the battery control client.
   - **Username:** The name of the PC user.
   - **PC name:** The hostname of the notebook PC.
   - **Battery status history:** The history of battery statuses collected at [2. Battery status collector].
   - **Policy history (receive):** The history of policies received at [4. Policy receiver].
2. Battery status collector
   This module periodically collects the power configuration (battery powered / AC powered / AC powered with charging), the battery level [%], and the remaining battery lifetime [sec]. The module stores them together with the present time in [1. PC information management].
3. User request sender
   This module sends to the service the username, the PC name, the latest battery status (these are managed at [1. PC information management]) and the present time. The module periodically sends this in order to help the service to grasp information about the connecting clients.
4. Policy receiver
   This module receives the policy from the service, and stores it and the receipt time in [1. PC information management]. The module also notifies [5. Battery control engine] of the received policy.
5. Battery control engine
   This module transfers the notified policy to one of [6. Battery control adapter] which is available at the notebook PC, except in cases in which control is temporarily suspended.
6. Battery control adapter
   This module controls the battery tool that charges and discharges the PC battery based on the transferred policy. Since there are many battery tools (include peak shift applications), this module masks the differences among them and is transparent to [5. Battery control engine].
7. Status monitor and controller
   This module shows the PC user the change of state when a service is connected or a policy is received, the current status of the PC battery, and the control status. The module also accepts user instructions for temporarily suspending and resuming control, and terminating the client.

### 2.2 Integrated Control Service

Figure 5 shows the architecture of the integrated control service. The function of each module is as follows.

1. Information management
   This module manages the following information on the integrated control service.
   - **Power consumption history:** The history of power consumption collected at [2. Power consumption collector].
   - **Demand forecasting history:** The history of forecasts (power demand curves) and their related parameters created at [3. Power demand forecaster].
   - **User request history:** The history of user requests received at [4. User request receiver].

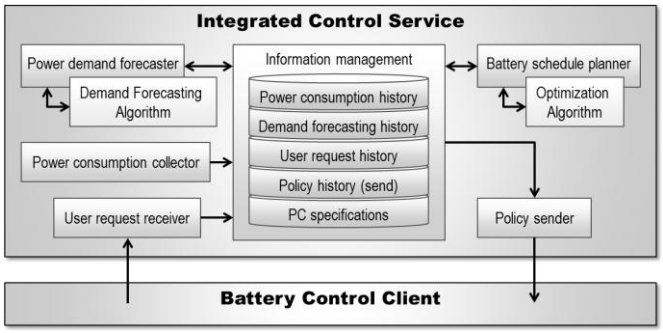



Figure 5: Architecture of integrated control service.

- **Policy history (send):** The history of policies sent at [6. Policy sender].
- **PC specifications:** The following specifications of notebook PCs with which the clients will work.
  - *Power consumption of each power configuration* (battery powered / AC powered / AC powered with charging) [W]
  - *Battery capacity* [Wh]
  - *Maximum battery level* [%]:
    The highest battery level to which a PC battery can be charged. By setting the level lower than 100, the system prevents the PC battery from being fully charged (a factor that accelerates battery deterioration).
  - *Minimum battery level* [%]:
    The lowest battery level to which a PC battery can be discharged. By setting the level slightly higher, the system prevents the PC battery from being discharged for a long time which might make it empty when needed
  - *Starting battery level* [%]:
    The highest battery level at which a PC battery can start to charge. By starting to charge only at a lower than specified level, the system prevents the PC battery from being repeatedly charged and discharged (a factor that also accelerates battery deterioration).
  - *Charging and discharging battery curves*:
    The curves showing the relation between the elapsed time and the battery level, where the PC battery is charged/discharged.

2. Power consumption collector
   This module periodically collects current power consumption and stores it together with the present time in [1. Information management].
3. Power demand forecaster
   This module forecasts multiple power demand curves by invoking the demand forecasting algorithm described in subsection 2.3.
   - **Inputs**: All daily power consumption (these are managed at [1. Information management]).
   - **Outputs**: Multiple power demand curves and their related parameters (these are to be stored in [1. Information management]).

   The module periodically performs this procedure because the size of the power consumption history increases with time.
4. User request receiver
   This module receives user requests from clients, and stores each of them and their receipt times in [1. Information management].
5. Battery schedule planner
   This module plans charging/discharging schedules by invoking the optimization algorithm described in subsection 2.4.
   - **Inputs**: Power consumption of the day, latest forecasts and their related parameters, PC specifications, and user requests (these are all managed at [1. Information management]). To ensure peak power demand reduction, the PC specifications and the user requests are limited to those of the connected clients, where a connected client denotes the client that has sent the user request to the service within a set period.
   - **Outputs**: Charging/discharging schedules for PC batteries of the connected clients.

   After planning schedules, the module creates a policy for each connected client from the corresponding schedule, and notifies [6. Policy sender] of the policy. The module periodically performs these procedures because users carry around their own notebook PCs and connected clients vary over time.
6. Policy sender
   This module sends a client the notified policy, and stores it together with the present time in [1. Information management]. The module performs these procedures when the policy is notified not only from [5. Battery schedule planner] but also from other external programs.

## 2.3 Demand Forecasting Algorithm

In a small-scale office, as described in section 1, power consumption will change significantly depending on the number of users and electronic devices utilized, making it difficult to forecast a power demand curve in a simple way. Moreover, since the service plans charging/discharging schedules based on a forecast, a wrong forecast may increase the peak power demand by charging PC batteries during the peak time.

Therefore, the demand forecasting algorithm forecasts the multiple power demand curves of the day. As shown in Figure 6, the algorithm initially classifies daily power consumption into several patterns based on the daily peak power demand and its peak time, e.g., a pattern in which power consumption during the morning, daytime, or evening is high, and a pattern in which power consumption does not vary much throughout the day. Then, the algorithm extracts the days in which power consumption during the periods before the forecasting time is similar to the power consumption of the day. Finally, the service calculates the power demand curve and the parameter for each classified pattern. In this paper, the power demand curve of a pattern is the hourly-averaged power consumption of the extracted day in the pattern, and the parameter is the ratio of the extracted day in the pattern.

Since the service plans charging/discharging schedules based on multiple forecasts, it can handle any potential level

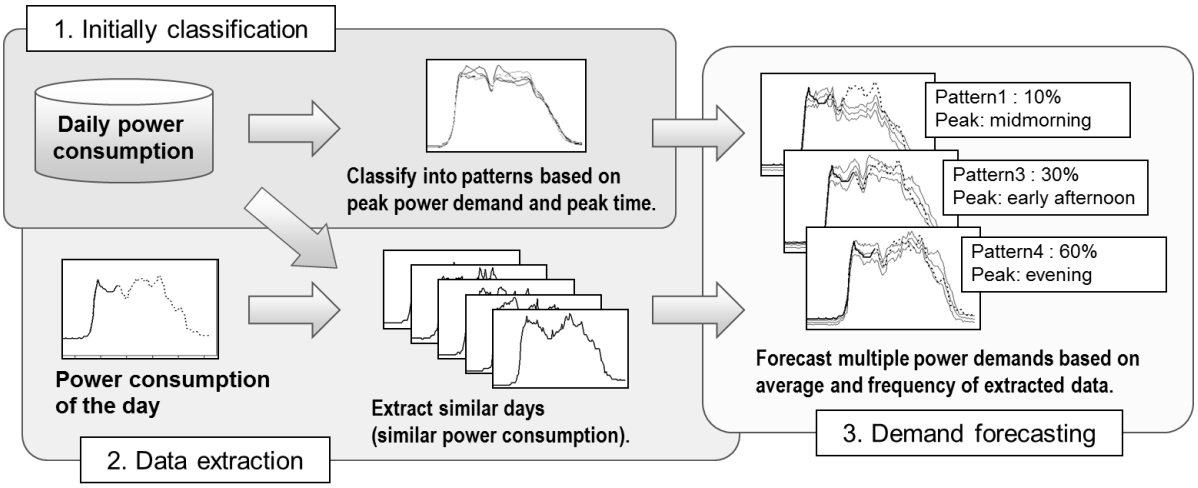



Figure 6: Diagram of demand forecasting algorithm.

of power consumption and reduce the peak power demand even in a small-scale environment like an office.

## 2.4 Optimization Algorithm

To reduce the peak power demand for power using the PC batteries, it is necessary to efficiently control the charging and discharging of them based on power demand. Moreover, not to restrict usability, the service has to prevent PC batteries from deteriorating and being empty when needed.

Therefore, the optimization algorithm regards the planning schedules as a multi-objective combinatorial optimization problem and finds approximate solutions using a local search algorithm. The detailed algorithm is proposed in [4].

- **Objective functions:**
  1. Minimizing peak power demand.
  2. Maximizing battery levels of notebook PCs at the end of the day. This function makes the service charge PC batteries to prepare for peak power demand reduction of the following day.
  3. Minimizing the overall power demand. This function indirectly prevents PC batteries from deteriorating by not charging and discharging more than necessary.
  4. Maximizing the minimum power demand.
  5. Minimizing the number of times power configuration is switched. This function also improves the usability.

  These functions are listed in order of priority, and the optimization algorithm finds solutions according to this order.
- **Constraints:** The features of the PC battery including the variation and the range of the battery levels. The range constraint prevents PC batteries from being empty.
- **Solutions:** The power configuration of each notebook PC at each time interval of the day.

Using the optimization algorithm, the service can reduce the peak power demand without restricting usability. Moreover, by setting the constraint based on each user's usage pattern, the service can keep higher battery levels for notebook PCs which are frequently used without a power supply (e.g., when the PC users are out of the office), and prevent PC batteries from being empty when needed.

# 3 IMPLEMENTATION AND EVALUATION

We implemented the integrated control system described in section 2, and evaluated the efficiency of peak power demand reduction using the implementation. In the following, we describe the implementation details of the system, and the results of simulation experiments and field testing.

## 3.1 Implementation Details

We implemented the battery control client as a Java application on Windows. We also implemented two battery control adapters that control the peak shift setting utility (Figure 1) and the Fujitsu system extension utility that supports system extension functions for Fujitsu notebook PCs. To facilitate usability, the client automatically starts on logon and puts its icon in the system tray. It also shows a message balloon during a state change, a tooltip of the current status when the PC user hover the pointer over the icon, and a control menu when the PC user right-clicks the icon.

On the other hand, we implemented the integrated control service as a Java servlet running on Tomcat 6.0. The service obtained the office power consumption data from the ftp server that collected data from each power distribution board. We also implemented the demand forecasting algorithm as an R script and the optimization algorithm as a Java plug-in.

## 3.2 Simulation Experiments

We evaluated the ideal efficiency of peak power demand reduction. For this purpose, we used the power consumption of our office on a weekday in August, 2011, and regarded it as a forecast (in other words, the service did not invoke the demand forecasting algorithm).

We simulated the power consumption after controlling the charging and discharging of the PC batteries according to the planned schedules. We assumed that there were $N$ notebook PCs and that they had the uniform specifications described in Figure 7. Here, the power consumption of each

| Item | | value |
|---|---|---|
| Power consumption [W] | | |
| | AC powered | 12 |
| | AC powered with charging | 60 |
| | Battery powered | 0 |
| Battery capacity [Wh] | | 63 |
| Maximum battery level [%] | | 100 |
| Minimum battery level [%] | | 20 |
| Starting battery level [%] | | 89 |

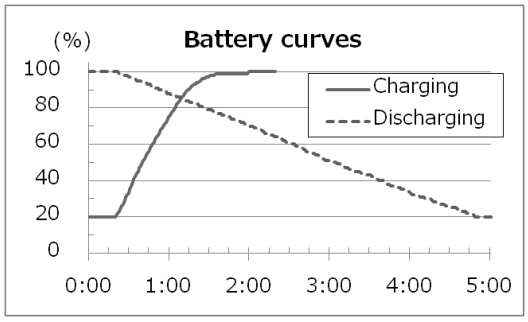
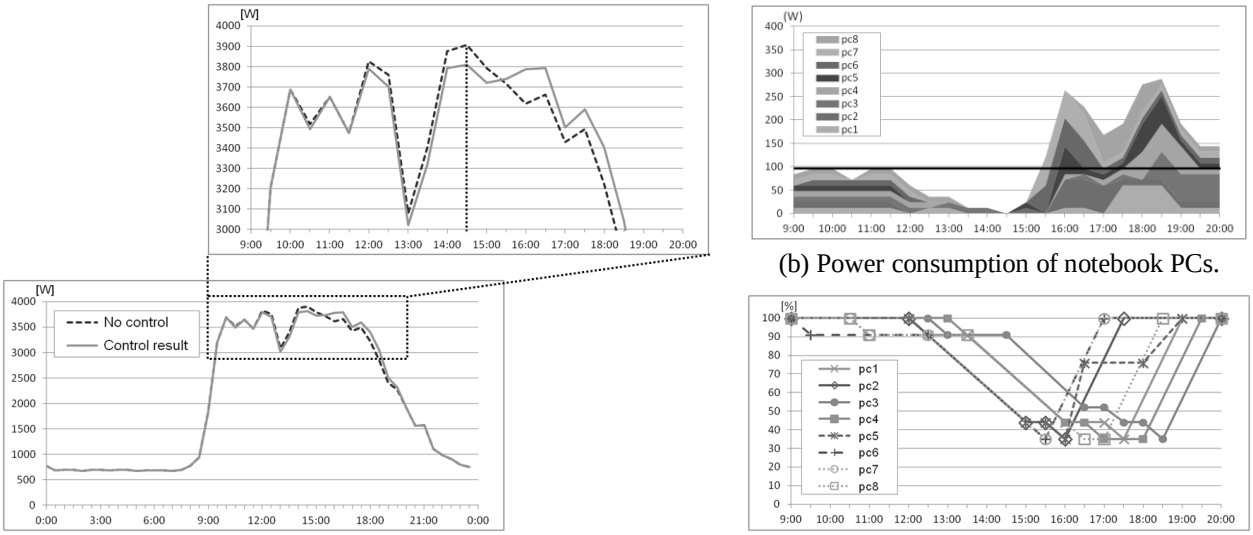



Figure 7: Specifications of a notebook PC (Fujitsu LIFEBOOK A561/C).




(a) Office power demand.

(b) Power consumption of notebook PCs.

(c) Battery level of each notebook PC.

Figure 8: Effectiveness of peak power demand reduction.

power configuration was measured using the smart power strip [6], and the charging and discharging battery curves were created by periodically measuring the battery level while charging and discharging the PC battery. In addition, we assumed that the service controlled the charging and discharging of PC battery only from 9:00 to 20:00, for example assuming that users put their own notebook PCs in the locked box after work for security reasons.

### 3.2.1 Effectiveness of the system

First, we examined the experiment where *N* (the number of controllable notebook PCs) is 8. Figure 8 shows the simulation results. In these graphs, the horizontal axis indicates the time. The vertical axes indicate the office power demand, the power consumption of the notebook PCs and the battery level of each notebook PC, respectively.

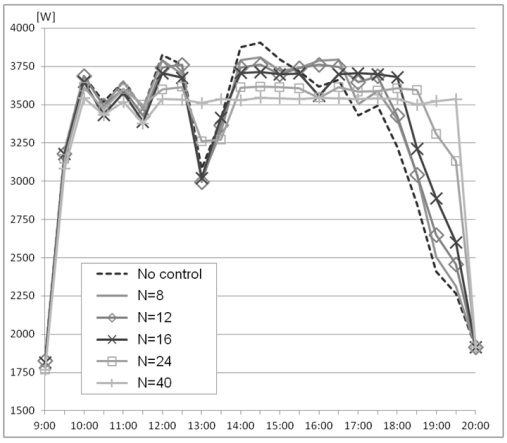
In Figure 8(a), the peak power demand is reduced 96W (about 2.5%) from 3906W to 3810W. In Figure 8(b) and (c), at the peak time (14:30), the system discharges all PC batteries and saves the most power, in other words, the power consumed by the notebook PCs is 0W. Moreover, at the time of the 2nd highest peak power demand (12:00), the system also discharges some PC batteries and saves some power in order not to exceed the reduced peak power demand. After 15:30, the system charges the PC batteries that have low battery levels because of discharging. Even though the controllable time range is restricted, the system can charge all PC batteries to 100% without exceeding the peak power demand. The overall power demand is increased 240Wh (about 0.5%) from 48032Wh to 48272Wh due to the loss of energy by charging and discharging PC batteries.

### 3.2.2 Effects of *N*

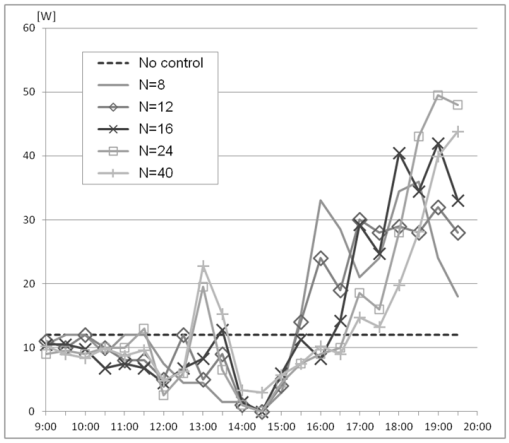
Next, we examined the experiments while changing the number of controllable notebook PCs, *N*, from 8 to 40. Figure 9 shows the office power demand and the average power consumption of each notebook PC, respectively.

In Figure 9(a), as *N* gets larger, the peak power demand gets lower because the system saves more power by discharging PC batteries. Moreover, when *N* is 40, the system balances the power demand by charging the PC batteries at the time when the power demand is low (around 13:00).

In Figure 9(b), except when *N* is 40, the system discharges all PC batteries at the peak time and saves as much power as the system can. Actually, the amounts of the peak power demand reduction in the case when *N* is 8, 12, 16, 24, and 40 are 96W, 144W, 192W, 288W, and 360W, respectively, and when *N* is less than or equal to 24, the amount is proportional to *N*. These results show that, when *N* is 40, the battery level of each PC battery reaches the minimum battery level, in other words, the system exhausts all energy stored in the PC batteries sometime during the day, and the peak power demand is not reduced any more.




(a) Office power demand.




(b) Average power consumption of each notebook PC.

Figure 9: Effects of number of controllable notebook PCs.

Table 1: Specifications of notebook PCs used in field testing.

| Item | pc1 | pc2 | pc3 | pc4 | pc5 | pc6 | pc7 | pc8 | pc9 | pc10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Model name | A561/C | | | A540/C | S761/C | | | P770/B | S8490 | S560/B |
| Power consumption [W] | | | | | | | | | | |
| AC powered | 11 | | | 11 | 10 | | | 13 | 22 | 14 |
| AC powered with charging | 70 | | | 65 | 79 | | | 68 | 89 | 70 |
| Battery powered | 0 | | | 0 | 0 | | | 0 | 0 | 0 |
| Battery capacity [Wh] | 63 | | | 56 | 67 | | | 63 | 63 | 63 |
| Maximum battery level [%] | 100 | 100 | 100 | 80 | 80 | 100 | 100 | 100 | 80 | 80 |
| Minimum battery level [%] | 20 | 25 | 23 | 20 | 40 | 40 | 40 | 40 | 40 | 40 |
| Starting battery level [%] | 89 | 89 | 89 | 69 | 69 | 89 | 89 | 89 | 69 | 69 |

Table 2: Parameter configuration.

| | Parameter | Value |
|---|---|---|
| Battery control client | | |
| Battery status collector | Time interval of collecting battery status | 1 minute |
| User request sender | Time interval of sending user request | 10 minutes |
| Integrated control service | | |
| Power consumption collector | Start time and time interval of collecting power consumption | 8:44, 10 minutes |
| Power demand forecaster | Start time and time interval of invoking demand forecasting algorithm | 8:45, 30 minutes |
| Battery schedule planner | Start time and time interval of invoking optimization algorithm | 8:46, 30 minutes |
| | Time range of charging/discharging schedules | From 9:00 to 20:00 |
| | Time unit of switching power configuration | 10 minutes |
| | Time period to define the connected client | 15 minutes |

## 3.3 Field Testing

During the period from September 21th to October 20th, 2011, we conducted field testing at our office of 40 employees. The service obtained the power consumption data of our office. There were 10 notebook PCs with which the battery control clients worked during the field testing. Table 1 shows their specifications (all Fujitsu LIFEBOOK series). Here, different from the simulation experiments, the power consumption of each power configuration is the value given in the product catalogs. In addition, the maximum and minimum battery levels are set based on users' activities (e.g., the frequency of the use without a power supply). Table 2 shows the parameters and their values used in this field testing.

Figure 10 shows the result of one day. The upper graph shows the office power demand while the lower table shows the power configuration of each notebook PC at each time interval of the day. In the graph, the line indicates the forecasts, and the bar indicates the actual power consumption. In the table, the black cells, light gray cells and dark gray cells indicate whether the power configurations of the notebook PCs are battery powered, AC

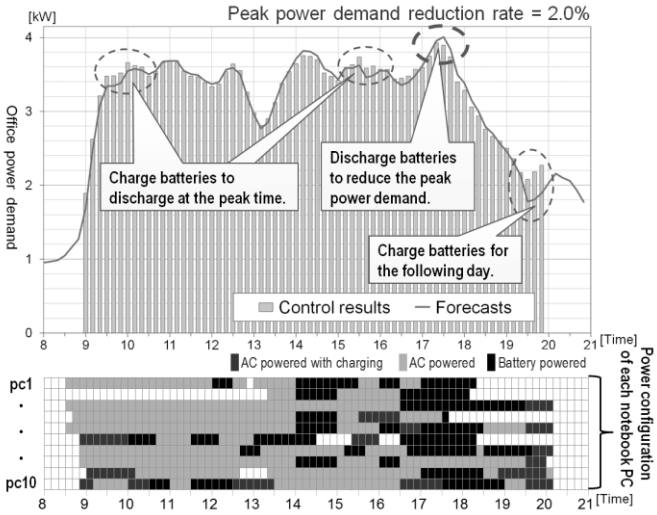



Figure 10: Result of a field testing.

powered, or AC powered with charging, respectively. Meanwhile, a white cell indicates the status in which the notebook PC does not connect to the service at the corresponding time due to a network disconnection or system power-off.

In Figure 10, the peak power demand was reduced 80W (about 2.0%) from 4006W to 3926W. At the peak time (17:30), the system discharged 9 PC batteries (except for the battery of PC8) and saved the consumption power of these notebook PCs. Moreover, at the 2nd peak time (14:10), the system discharged 6 PC batteries in order not to exceed the reduced peak power demand.

We analyzed the reason why the system did not discharge the battery of PC8 at the peak time. The analysis shows that the user of PC8 attended a meeting from 16:00 and used PC8 without a power supply, making the battery level of PC8 low (less than its minimum battery level). Even if the system did not discharge the battery of PC8, however, it also did not charge the battery for not increasing the peak power demand.

After 18:50, the system charged 6 PC batteries (all notebook PCs that charged their batteries were connected clients) to prepare for peak power demand reduction of the following day.

Here, the system charged several PC batteries before 18:50. We analyzed this result and found that these batteries can be separated into two groups. One group is the PC batteries with battery levels that are already low in the morning (e.g., the notebook PCs did not charge their batteries during the previous day or were used without a power supply during the last night). The other group is the PC batteries with battery levels that are also low because of discharging before the peak time. As a result, the system charged the PC batteries that had low battery levels so that they could be discharged at the peak time.

These trends occurred in other testing days even though the peak power demand and the power configurations of the notebook PCs were different during these days. Therefore, in any case, our system reduces the peak power demand by discharging PC batteries at the peak time.

# 4 RELATED WORKS

Until recently, while many studies on power demand forecasting have been made, most studies forecast the peak power demand for optimized operation of power generators and power supply stabilization. After the Great East Japan Earthquake, some studies forecasted the power demand curve for peak power demand reduction using energy storage devices. In [7], we proposed a forecasting method that forecasts the power demand curve with high accuracy. In this method, the curve is created by combining the power consumption of days which characteristics are similar to that of the forecasting day, and then revised based on the peak power demand forecasted by multiple regression analysis. These studies may forecast the wrong curve in our environment because, in their assumed environment, the law of great numbers is applicable and the power consumption does not change significantly.

Generally, an optimization problem such as a planning schedule can be solved as a mixed integer programming problem. In our assumed environment, however, it is difficult to solve as a mixed integer programming problem because there are minimax type objective functions and the symmetry of the problem is high. On the other hand, it is also difficult to find the global optimal solution by an enumerative method. In this paper, therefore, we found approximate solutions using a local search algorithm. The detailed algorithm is proposed in [4].

Some studies on the control system of energy storage devices have been made for not only reducing the peak power demand but also for the compensation of power demand. In [5], the authors proposed a compensation system that controls the charging and discharging of the lithium-polymer batteries based on whether or not the provided power is larger than the power demand. In [8], the authors proposed a supply/demand control system that plans the operation based on generation and demand forecasting by using a neural network and fuzzy systems. Since these studies do not assume other uses of the energy storage devices, the energy storage devices may be empty when needed, for example when needed during a power outage. Moreover, early dissemination of energy storage devices is difficult in terms of cost and operation as described in section 1.

Recently, many peak shift applications were released by computer manufacturers, such as Fujitsu Limited [1], IBM Japan [3], and NEC Corporation [2]. These applications can reduce the peak power demand by controlling the charging and discharging of a notebook PC battery. The following are parameters of the peak shift setting utility [1] as shown in Figure 1. (Other applications also need similar setting.)

- **Available period:** The start and end dates. During this period, the utility enables control.
- **Period of discharging:** The start and end time of discharging. During this period, the utility forces the notebook PC to discharge its battery, i.e., to be powered by its battery.
- **Period of non-charging:** The start and end time of non-charging. During this period, the utility does not allow the notebook PC to charge its battery.

However, in most applications, these parameters need to be set manually by a PC user. Although the peak shift setting tool [2] can set these parameters by considering the power demand forecasted by electric power companies, it may increase the peak power demand because the forecasted power demand is almost different from the office power demand.

## 5 CONCLUSION

In this paper, we proposed an integrated control system (battery control client and integrated control service) that controls the charging and discharging of PC batteries based on the power consumption of an office. The integrated control service performs power demand forecasting and battery schedule planning based on the collected data, and sends the policy (the control information) to each client. On the other hand, the battery control client controls the charging and discharging of its battery based on the received policy from the service.

We evaluated the efficiency of peak power demand reduction in the simulation experiments and during field testing. From the results, at the peak time, the system discharges many PC batteries and reduces the peak power demand about 2.5% in a simulation experiment (2.0% in field testing). Moreover, during off-peak periods, the system charges the PC batteries that have low battery levels because of discharging.

As part of our future work, we plan to extend the system and conduct additional field testing to verify the efficiency of peak power demand reduction in various office environments. We also plan to consider the control of the energy storage devices for deployment in smart cities.

## REFERENCES

[1] Peak shift setting utility, Fujitsu Limited, http://www.fmworld.net/biz/fmv/powersaving/peakshift/ [in Japanese].

[2] Peak shift setting tool, NEC Corporation, http://www.nec.co.jp/products/bizpc/promotion/eco/peakshift/ [in Japanese].

[3] M. Hatori, Peak-Shift Method for Notebook Computers – A power management approach for load leveling, Proc. of IEEE Int'l Symposium on Electronics and the Environment, pp.117–121 (2004).

[4] H. Iwane, H. Anai, M. Shinohara, and M. Murakami, An Optimal Control of the Internal Batteries of Office Notebook PCs for Peak Power Demand Reduction, Proc. of SICE Annual Conf. on Control Systems, P0010, 8pages (2012) [in Japanese].

[5] D.Y. Jung, Y.H. Ji, S.W. Lee, C.Y. Won, Y.C. Jung, and K.D. Seo, Grid-Connected Peak-Load Compensation System Based on Lithium-Polymer Battery, Proc. of IEEE Int'l Telecommunications Energy Conf., pp. 1–4 (2009).

[6] F. Nakazawa, H. Soneda, O. Tsuboi, A. Iwakawa, M. Murakami, M. Matsuda, and N. Nagao, Smart Power Strip Network and Visualization Server to Motivate Energy Conservation in Office, Proc. of IEEE Int'l Conf. on Industrial Informatics, pp.352–357 (2011).

[7] S. Takahashi, S. Yamane, Y. Yoshida, T. Sonoda, N. Yugami, and T. Takebayashi, Prediction Technology of Energy Demand for Energy Management System in Smart City, Proc. of SICE Annual Conf. on Control Systems, P0009, 5pages (2012) [in Japanese].

[8] T. Tanabe, Y. Ueda, S. Suzuki, T. Ito, N. Sasaki, T. Tanaka, T. Funabashi, and R. Yokoyama, Optimized Operation and Stabilization of Microgrids with Multiple Energy Resources, Proc. of Int'l Conf. on Power Electronics, pp.74–78 (2007).

# Proposal and Evaluation of Ubiquitous Creativity Consistent Support System for Actual Work Environment

Tomohiro Kokogawa*, Toshihiro Ajiki*, Junko Itou** and Jun Munemori**

*Graduate School of Systems Engineering, Wakayama University, Japan
**Faculty of Systems Engineering, Wakayama University, Japan
koko@fw.ipsj.or.jp, munemori@sys.wakayama-u.ac.jp

***Abstract*** - In recent times, it has become increasingly important to maximize the knowledge and the expertise gained at work, and to create new knowledge from them. Creativity methods such as the KJ method[1] for effective development of creative ideas are suitable for addressing these challenges. We propose a ubiquitous creativity consistent support system with "Quiccamera" and "GUNGEN-SPIRAL II" for effective application of knowledge at work without the constraints of time and place. Further, we present the results of experiments that evaluate the system and demonstrate the effectiveness.

***Keywords***: KJ method, photograph, creativity support system, tablet gadget

## 1 INTRODUCTION

In recent times, the growth of information and communication technology has highlighted the realities of economic globalization and world-scale business competition. Companies must foster continuous innovation by short-cycle product development, business efficiency improvement, cost reduction, and rapid decision-making in order to accommodate the diversity of markets and technologies. Therefore, it becomes increasingly important to maximize the knowledge, experience, and expertise accumulated in the organization, and to create new knowledge from them.

Further, in the event of natural disasters such as floods, earthquakes, and tsunamis, people may provide additional information through social media. Various studies have analyzed this behavior, and have attempted to utilize it for disaster management measures [1], [2]. Such information includes knowledge, experiences, and expertise from victims or experts, and it will be useful in designing crisis management measures for similar disasters in the future. Major disasters also highlight the importance of risk assessment of events that are rare and have a great impact [3]; such information is difficult to extract without the aid of divergent opinions.

Creativity methods for developing creative ideas effectively are suitable for addressing these challenges. Various creativity methods [4]-[8] and their support systems [9]-[11] have been proposed. However, the application of idea generation methods requires a certain level of practice, and a specific amount of time is necessary in order to achieve results of good quality. Many organizations encounter the dilemma between satisfying the requirements of gathering knowledge and resolving the difficulties of dedicating time to gather these requirements. Most of the creativity methods and their support systems are designed to be practiced and applied in meetings that require the participants to be present inside a closed meeting room. In order to gather the members concerned and their ideas, particularly in the actual work environment, these methods should be applicable irrespective of time and place.

In this study, we propose a ubiquitous creativity consistent support system, which can support the entire process of a creativity method at any place and at any time. Further, we describe the implementation of this system using tablet gadgets with cameras. Our experiments demonstrate the effectiveness of the proposed system.

## 2 RELATED WORK

The KJ method [5] is a creativity method that is also referred to as an “affinity diagram” and is included in the Seven Management and Planning Tools [8] used in total quality control. The KJ method, developed by Jiro Kawakita, is based on the theory of problem solving and teamwork. The typical process used in the KJ method, which is based on the human thinking process for creative problem solving [9], is as follows:

(0) Data gathering
Data (ideas, opinions, issues, etc.) is gathered with a specific theme.
(1) Label creation (divergent thinking)
Each idea is jotted down as an idea label by selecting data and brainstorming.
(2) Category creation (convergent thinking)
The labels are organized into groups based on the natural relationship between each label, and each group is given a title.
(3) Chart creation (idea crystallization)
Each group is allocated spatially to a chart (affinity diagram) according to the natural relationships between groups.
(4) Concluding (idea verification)
Concluding sentences are added to express the meaning of the diagram.

PAN/KJ [10] is a KJ method support system that can utilize multimedia data such as images or audio data. This

[1] The KJ method is a trademark of Kawakita Research Institute.

system uses multimedia data as hyperlinks of card labels; it does not use multimedia data directly in the form of labels.

GUNGEN-SPIRAL II [11] enables the consistent process of the KJ method to be implemented as a Web application, thus facilitating idea generation using multiple gadgets such as PCs or smart phones with modern Web browsers.

Geographical Location Information-Based Bulletin Board System (GLI-BBS) [12] is a groupware system that can share geographical location information among communities. This system enables the data upload of photographs from a cellular phone with GPS to the BBS and shows the photograph in the BBS with related geographical information.

Evernote [2] is a memo sharing system based on cloud computing. This system enables submission of text memos, freestyle drawing memos, and photographs easily by using PCs or smartphones, and facilitates sharing among the devices. Some case studies demonstrate the effectiveness of the functionality of Evernote in the collaboration process [13].

Digital Card Cabinet [14] was featured in a special exhibition of the work of Tadao Umesao at National Museum of Ethnology in Osaka, Japan. Tadao Umesao was known for his special B6 size paper cards (known as "Kyoto Univ. cards" in Japan) that improve intellectual productivity [15]. The Digital Card Cabinet system allowed visitors of the exhibition to create personal Umesao's style cards, store them in the digital form in a digital cabinet, and share them with other visitors by using a tabletop touch screen panel. Each card was created with text, photographs, and freestyle drawings by using the iPhone[3] App, or with the image of a paper card obtained by using a scanner.

## 3 REQUIREMENTS

There are two kinds of work sites at actual work environment, the head office site and the actual work site. The people of the head office site gather data from the actual work site, analyze them, and make decision to solve their problem. In the head office site there are executive officers and staffs to judge their decision eventually, and their advisors such as external experts. The people in the actual work site gather data there and send to the head office site to get the decision. In the actual work site there are actual workers who have various amounts of knowledge and experiences about the work environment. In the disaster situation there also include victims and volunteer staffs to rescue the victims.

Most of past creativity support systems only support the process at the head office site with sufficient infrastructures such as PCs, networks, and hot-wired meeting rooms. To get effectual decision with a creativity method, it is important to collaborate with people between in the head office site and in the actual work site, in order to combine their different implicit knowledge at each thinking process. However it is difficult to gather both people at a time because of the restrictions of time and place, especially at the actual work site with restrictions of infrastructures.

In this study, we propose a "ubiquitous creativity consistent support system". The concept model of our proposed ubiquitous creativity consistent support system is shown in Figure 1. The arrow in the figure shows the flow of human thinking process at a creativity method such as the KJ method. The dashed arrow in the figure shows the flow of data for collaboration between the head office site and the actual work site. The purpose of our proposal system is to support the creativity process at the actual work site with many restrictions, and collaboration with the head office consistently.

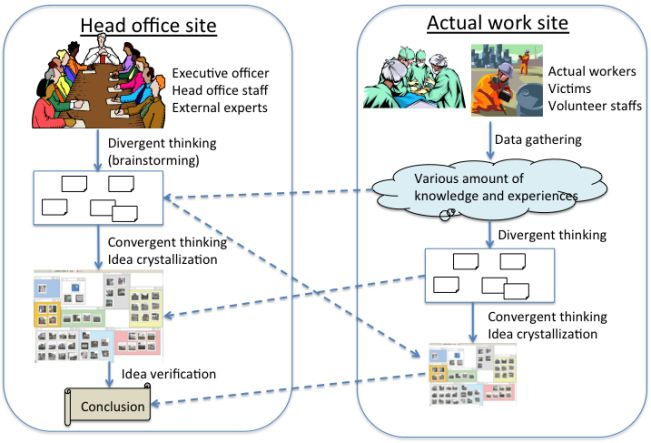



Figure 1: Concept model of ubiquitous creativity consistent support system.

The requirements of the system are as follows:

(1) System users
In order to collect useful and divergent opinions, a variety of people should join the system and implement creativity methods as a team. In addition to head office staff, the group must also consist of external experts or staff from actual work site such as industrial plants, construction fields, or disaster sites.

(2) Time and place
The system should be accessible from any place and at any time, thus enabling the participating members to implement the creativity method whenever necessary.

(3) Target process
As described earlier, a method based on the KJ method has a sequence of processes (from divergent thinking to convergent thinking or concluding) to obtain results using creativity methods. Each process may be executed at a different place or time.

(4) User ability
Members with a variety of skills may use the system and creativity methods, and hence, a simple user interface is required. In addition, most of the creativity methods need a large workplace in order to gather a large number of ideas and obtain the overview of an entire idea.

[2] http://www.evernote.com/
[3] http://www.apple.com/iphone/

# 4 APPROACH

## 4.1 Basic Design

We developed "Quiccamera" as a support system that enables rapid data gathering and label making in the actual work environment [16]. In Quiccamera, comments can be added to photographs captured at the location by using text, pictograph stamps (emoji), or freestyle handwritings, and then, the photographs can be sent directly to the "GUNGEN-SPIRAL II" [11] as idea labels for implementing the KJ method.

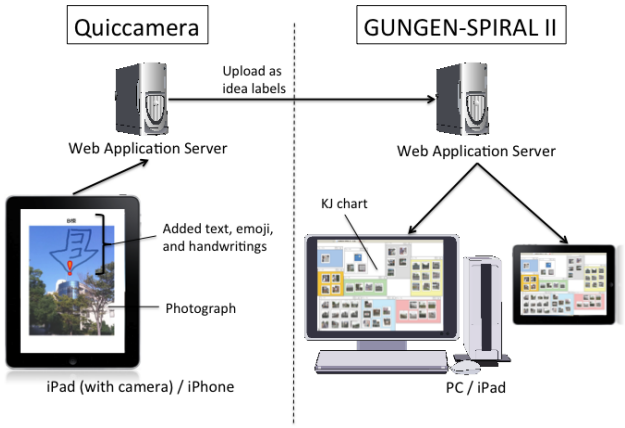



Figure 2: Overview of ubiquitous creativity consistent support system based on Quiccamera and GUNGEN-SPIRAL II.

The overview of our complete implementation of a ubiquitous creativity consistent support system based on Quiccamera and GUNGEN-SPIRAL II is shown in Figure 2.

## 4.2 Function Design

The main functions of Quiccamera are as follows:

(1) The use of client terminal with touch panel and camera
The system should support short handwriting notes with a photograph; hence, the client function is enabled for a smartphone or tablet gadget with a touch panel and camera, such as iPhone and iPad[4] (except the first model).

(2) Single button for image submission
In a smartphone or tablet gadget, an image can be uploaded to a specific server by several methods such as e-mail or ftp. However, these methods are not simple because they require multiple applications or operations. Hence, we implemented the entire operation (capturing, editing, and uploading the photo to a server) in an application that requires minimum operating effort.

(3) Multi-style comment drawings on the photograph
Freestyle handwriting is one of the simplest methods for adding comments to a photograph. However, sometimes, handwritten letters are difficult to read or manage, and therefore, the text input function is a more useful method. In addition, the variety of pictograph stamps can also be used to convey the feelings related to the target object on the photograph [17].

(4) Direct use of photographs with comments as idea labels in GUNGEN-SPIRAL II
Photographs uploaded to the Quiccamera server are converted and uploaded directly to the GUNGEN-SPIRAL II server as XML-style idea labels. Thus, we can implement the consistent process of the entire KJ method with our proposed system.

[4] http://www.apple.com/ipad/

## 4.3 System Implementation

We developed "Quiccamera" as a native iPhone or iPad App written in Objective-C and a server application written in PHP for submission of photographs from the App.

GUNGEN-SPIRAL II is a Web-based server application written in PHP and JavaScript. It enables the KJ method on any terminals having a modern Web browser, such as PCs, smartphones, and tablet gadgets.

We choose an iPad2 (2nd generation iPad) as the client terminal of Quiccamera and GUNGEN-SPIRAL II because, similar to notebook PCs, the iPad2 has a camera and a wide display.

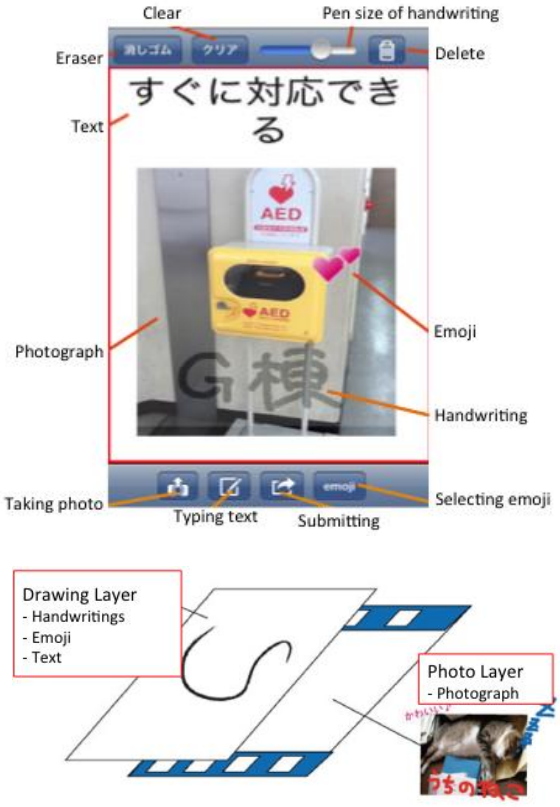



Figure 3: Overview of the main screen of Quiccamera App.

First, the user launches the Quiccamera App and captures a photograph using the built-in camera of iPad2. The captured photograph is displayed on the main screen of the

Quiccamera App, and the user can add several comment drawings on the photograph by using text, various pictograph stamps (four types of stamps were implemented: funny, cry, surprise, and love), or freestyle handwriting with multiple pen sizes. Figure 3 shows the main screen of the Quiccamera App. The comment drawings are stored in the drawing layer, which is separated from the photograph layer, and the user can edit them flexibly.

After the editing is complete, the user activates the upload button to save the data in the PNG format by combining both the layers, and submits it to the Quiccamera server. The data is automatically uploaded to the GUNGEN-SPIRAL II server in the form of idea labels. Then, the user launches the Web application of GUNGEN-SPIRAL II to initiate the category and chart making process of the KJ method by using the uploaded idea labels (photographs with several comment drawings).

# 5 EXPERIMENTS AND DISCUSSION

## 5.1 Experimental Environment

The experiments were conducted with six groups of participants; each group consisted of three students from Wakayama University. The theme of the KJ method was "ultimate methods for adopting measures to deal with the occurrence of a disaster or tsunami". We selected two target locations: the district of Arita (Yuasa Town and Hirokawa Town) in Wakayama prefecture as an actual work site, which is known for an old tsunami story [18] [5], and Wakayama University, simulated as a head office site. The participants executed all the steps of the KJ method (from data gathering to concluding), and four other individuals evaluated the quality of the result sentences by Yagishita's method [19], which expands the scope of the application of traditional Analytic Hierarchy Process (AHP) [20]. We adopted six evaluation factors (originality, usability, appeal, concreteness, possibility of realization, and possibility of application) to calculate satisfaction scores of result sentences by the method.

Our experiments were conducted and evaluated based on three aspects:

(1) Evaluating the effect of photo idea labels (2 groups: A, B)
The participants took their iPad2s or iPhones to the actual work site (the district of Arita) and gathered data by capturing photographs (Data Gathering) and create idea labels by drawing several memos with Quiccamera. After several days, they perform the remaining process of the KJ method (category creation, chart creation, and concluding) with GUNGEN-SPIRAL II at the head office (Wakayama University) using a PC. For the purposes of comparison, they also create text-only idea labels (without using Quiccamera) just before performing the category creation.

(2) Evaluating support for a consistent process (3 groups: C, D, E)
The participants took their iPad2s to a location near the head office site (Wakayama University) as an actual work site with less restriction of time, place, and infrastructures. They gathered data and created idea labels in a manner similar to the manner described in (1). Then, they returned to the head office and performed the remaining process of the KJ method with the iPad2 consistently.

(3) Pre-evaluating support for a consistent process in the real actual work site (1 group: F)
The participants took their iPad2s to the actual work site (the district of Arita) and gathered data and created idea labels in a manner similar to the manner described in (1). Then, they assembled at a suitable location in the area and performed the remaining process of the KJ method with the iPad2 consistently.

Table 1 shows the environments for all the experiments. 'W' and 'O' represent the location at which the participants executed each process of the KJ method. 'W' indicates the actual work site (the district of Arita) and 'O' indicates the head office site (Wakayama University). In each experiment, the category creation, chart creation, and concluding processes were simultaneously performed at the same place.

Table 1: Experimental Environments.

| Group | | Data Gathering | Label Creation | Category Creation |
|---|---|---|---|---|
| A | A1 | W | W (iPad) | O (PC) |
| | A2 | W | O (Text) | O (PC) |
| B | B1 | W | W (iPad) | O (PC) |
| | B2 | W | O (Text) | O (PC) |
| C | | O | O (iPad) | O (iPad) |
| D | | O | O (iPad) | O (iPad) |
| E | | O | O (iPad) | O (iPad) |
| F | | W | W (iPad) | W (iPad) |

Figure 4 shows an example of providing idea labels as input by using Quiccamera in the actual work site (Yuasa Town). Figure 5 shows an example of using Quiccamera to submit an idea label. The text in Figure 5 shows a short question about the addition of the dike in the photograph. The pictograph stamp (exclamation mark to indicate "surprise") emphasizes the need to focus attention. The freestyle drawing (arrow) shows the size of the added dike.

Figure 6 shows an example of the KJ method being performed at the head office (Wakayama University) by using a PC. KJ charts on GUNGEN SPIRAL II were displayed by using a projector on the wall in order to share the entire workspace among all the participants. The submitted photographs were shown as idea labels on GUNGEN-SPIRAL II. The participants applied the KJ method by displaying the entire screen of GUNGEN-SPIRAL II using a projector.

[5] The story was translated as "Inamura-no-hi" by Tsunezo Nakai, and used as a teaching material of elementary school in Japan before the World War II.

Figure 4: Experiments at Yuasa town.

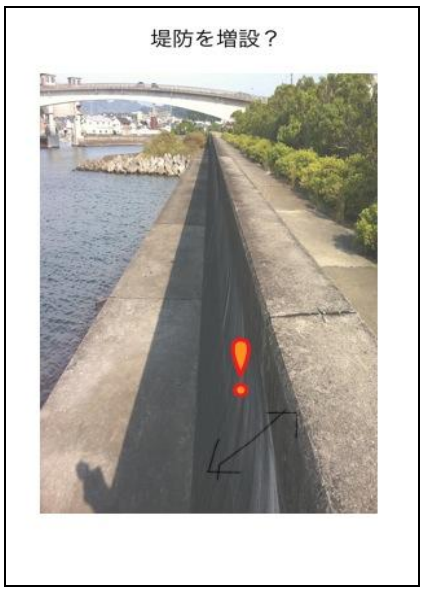



Figure 5: An example of photo idea label with text, pictograph stamp, and handwritings.

Figure 6: Performing the KJ method at the office using a PC.

Figure 7 shows an example of the KJ method being applied in an actual work site (a tearoom in Yuasa Town) with an iPad2. The iPad2 was connected to the GUNGEN-SPIRAL II server at the head office by using a 3G-WiFi router.

Figure 7: Performing the KJ method at a tearoom in Yuasa Town using an iPad2.

## 5.2 Results

Figure 8 and Figure 9 show the results of the KJ chart, considering experiments of group A as examples. Figure 8 shows the result of KJ chart after chart creation process using idea labels from Quiccamera. Each idea label contains photograph with text, pictograph stamps or freestyle handwritings. Figure 9 shows the text only (traditional) KJ chart.

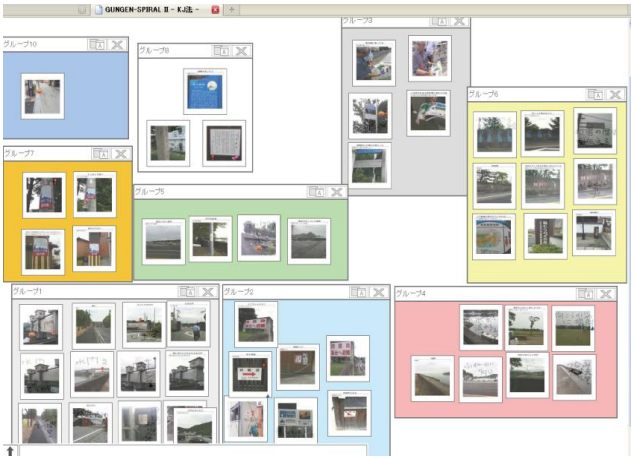


Figure 8: Example of the KJ chart using photo idea labels from Quiccamera (A1).

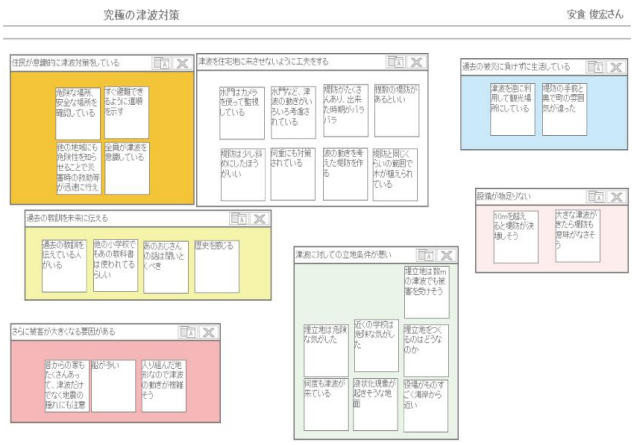



Figure 9: Example of the KJ chart using text-only idea labels (A2).

Table 2 shows the results of the experiments. The time is represented in minutes.

Table 2: Experimental results (1).

| Experiments | Num. Label | Num. Category | Time (min.) | Ave. Score [19] |
|---|---|---|---|---|
| A1 | 53 | 9 | 40 | 4.0 |
| A2 | 30 | 7 | 20 | 2.7 |
| B1 | 31 | 6 | 52 | 4.3 |
| B2 | 35 | 10 | 45 | 2.0 |

Table 3 also shows the results of the experiments. In experiments (2) and (3), the number of labels were limited to 21 (each participant gathered and created seven labels) to satisfy experimental conditions.

Table 3: Experimental results (2) and (3).

| Experiments | Time (min.) | Ave. Score [19] |
|---|---|---|
| C | 50 | 3.9 |
| D | 25 | 2.8 |
| E | 56 | 4.9 |
| F | 41 | 2.8 |

Table 4: Questionnaire results for Quiccamera.

| No. | Questionnaire | O (C-E) | W (F) |
|---|---|---|---|
| 1 | Did you feel a burden to take and to submit a photo from Quiccamera? *(1:Not a burden-5:Felt it strongly)* | 1.6 | 1.3 |
| 2 | Was the addition of memo writing by electronic handwriting simple? *(1:Did not feel it strongly-5: Felt it strongly)* | 3.9 | 4.0 |
| 3 | Was the addition of memo written by text simple? *(1:Did not feel it strongly-5: Felt it strongly)* | 3.7 | 4.3 |
| 4 | Was it effective to add the contents of electronic handwriting to one's own memos? *(1: Did not feel it strongly - 5: Felt it strongly)* | 4.0 | 4.7 |
| 5 | Was it easy to upload photographs? *(1: Not easy -5: Easy )* | 4.6 | 4.7 |
| 6 | Did the pictograph stamps help in adding information? *(1:Do not feel so strongly-5:Feel so strongly)* | 2.9 | 2.7 |
| 7 | Was the variety of pictograph stamps suitable? *(1:Too few-5:Too many)* | 2.6 | 3.0 |
| 8 | Do you think that electronic handwriting memos are effective even without photographs? *(1:Do not feel so strongly-5:Feel so strongly)* | 2.0 | 2.7 |

Table 5: Questionnaire results for GUNGEN-SPIRAL-II.

| No. | Questionnaire | W PC (A1,B1) | O iPad (C-E) | W iPad (F) |
|---|---|---|---|---|
| 1 | Were the idea labels completely readable? | 3.3 | 3.0 | 4.0 |
| 2 | Was it more convenient to perform the KJ method with the proposed system than with the paper-based method? | 4.0 | 3.6 | 4.7 |

Table 4 shows the questionnaire regarding the usability of Quiccamera. Table 5 shows the questionnaire regarding the usability of GUNGEN-SPIRAL II.

## 5.3 Discussion

In the experiments above, we observed the following results:

(1) Evaluating the effect of photo idea labels

In Table 2, the average score for concluding sentences is higher with photo idea labels than with text-only labels, although there were no significant differences between the number of generated labels or categories.

Table 6 shows a portion of the concluding sentences of group A as examples. The underlined portions highlight the significant differences between the photo idea labels and text-only idea labels. With photo idea labels, the concluding sentences include more specific expressions such as examples of an actual scenario. This would help in the generation of more practical output for actual work environments.

Table 6: Citations of concluding sentences.

| **Concluding sentences with photo idea labels (A1)** |
|---|
| Ultimate action to prepare measures for dealing with tsunami is to exploit the review to past experiences. For example, conscious measure was taken by locating a sign for people living in the area to escape to safety upland against tsunami, or by locating a signage how dangerous the place is at tsunami. |
| **Concluding sentences with text-only idea labels (A2)** |
| Ultimate action to prepare measures for dealing with tsunami is to hand on the past lesson to the future. That makes possible to take conscious measures by indicating the way for inhabitants to escape immediately, or checking the safety place. |

(2) Evaluating support for a consistent process

In Table 2 and Table 3, we compared the average scores of concluding sentences between a non-consistent process (A1, B1) and a consistent process (C, D, E and F). The results showed that there were no significant differences between them.

Table 4 shows that the score for uploading a photo is high (4.7) and that the effort to submit photo idea labels is low (1.6). This result indicates that the main function of Quiccamera is achieved.

Although Table 5 shows that the readability and operability are slightly higher when a PC is used than when an iPad2 is used, there is no significant difference between them.

Table 7 shows the results for label making by using text comments, freestyle handwritings, and pictograph stamps. In each case, text comments were predominantly used. The score for pictograph stamps usage was lower than the score for the other types of comments. In our experiments we prepared four types of pictograph stamps shown in Figure 10. The "surprise" stamp was typically used in pictograph stamps.

Table 7: The breakdown of making idea labels with Quiccamera.

| **Contents** | | **A1** | **B1** |
|---|---|---|---|
| All labels | | 53 | 31 |
| Labels with text comments | | 24 | 28 |
| Labels with freestyle handwritings | | 28 | 10 |
| Labels with pictograph stamps | | 11 | 11 |
| Variety of pictograph stamps | Funny | 4 | 0 |
| | Cry | 1 | 0 |
| | Surprise | 9 | 11 |
| | Love | 1 | 0 |

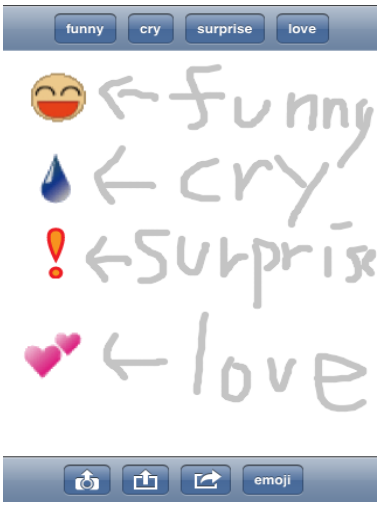



Figure 10: Variety of pictograph stamps.

(3) Pre-evaluating supporting consistent process at actual work site

The experimental results of group (F) showed that there was no significant differences of the score of conclude sentences between (C, D, E) and (F), although the average score of concluding sentences is lower. It indicates that there were no dependencies with performing place. So the system could support the whole KJ method consistently at both head office and actual work site.

# 6 CONCLUSION

In this study, we proposed a ubiquitous creativity consistent support system, which can apply creativity methods without the constraints of time and place. We also demonstrated the effectiveness of our proposal by conducting experiments.

The proposed system consists of Quiccamera and GUNGEN-SPIRAL II. Quiccamera supports the divergent thinking process and GUNGEN-SPIRAL II supports convergent thinking for conclusions. This system could support the entire process of creativity method consistently at any time and any place by using a tablet gadget (iPad2) as a client terminal.

Experimental results showed that the usage of photo idea labels is easier with Quiccamera. Further, the quality of the concluding result is better when photo idea labels are used owing to more concrete idea generation than when text-only idea labels are used. In addition, there were no significant differences of the quality of conclude sentences between using a PC and an iPad2, and between working at the head office and in the actual work site.

In future studies, we will increase the variety of comment drawings by including multiple color handwriting and additional pictograph stamps to support the creativity method more effectively.

# REFERENCES

[1] D. Yates and S. Paquette, Emergency knowledge management and social media technologies: A case study of the 2010 Haitian earthquake, International Journal of Information Management, Vol. 31, Issue 1, pp. 6-13 (2011).

[2] S. Doan, B. H. Vo, and N. Collier, An Analysis of Twitter Messages in the 2011 Tohoku Earthquake, Electronic Healthcare, Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, Vol. 91, pp.58-66 (2012).

[3] K. J. Hole, Toward Risk Assessment of Large-Impact and Rare Events, IEEE Security & Privacy, Vol. 8, Issue 3, pp. 21-27 (2010).

[4] A. F. Osborn, Applied Imagination: Principles and Procedures of Create Problem Solving (Third Revices Edition), Charles Scribner's Son, New York, NY (1963).

[5] J. Kawakita, The Original KJ Method (Revised Edition), Kawakita Research Institute (1991).

[6] T. Buzan with B. Buzan, The Mind Map Book, BBC WorldWide Limited (1993).

[7] M. Brassard and D. Ritter, The Creativity Tools Memory Jogger, Goal/QPC (1998).

[8] M. Brassard, The Memory Jogger Plus+ Featuring the Seven Management and Planning Tools, Goal/QPC (1996).

[9] S. Kunifuji and N. Kato, Consensus-making support systems dedicated to creative problem solving, International Journal of Information Technology Decision Making, 6(3), pp.459-474 (2007).
[10] Y. Ohmi, K. Kawai, and H. Ohiwa, A Card-handling Tool for Multimedia, Proc. 1999 IEEE International Conference on Multimedia Computing & Systems, IEEE CS, pp. II-250-254 (1999).
[11] J. Munemori, H. Fukuda, and J. Itou, Application of a Web Based Idea Generation Consistent Support System, Proc. 16th International Conference on Knowledge-Based and Intelligent Information & Engineering Systems (KES2012), IS23 (2012) (to appear).
[12] A. Abe, T. Sasaki, and N. Odajima, Development and Operational Evaluation of the Groupware Based on Geographical Location Information for Local Community Activities, IPSJ Journal, Vol. 45, pp.155-163 (2004) (in Japanese).
[13] F. Geyer and H. Reiterer, Experiences from Employing Evernote as a Tool for Documenting Collaborative Design Processes, Proc. the ACM Conference on Designing Interactive Systems (DIS 2012), Workshop: Supporting Reflection in and on Design Processes, Newcastle, UK (2012).
[14] T. Takahashi, H. Vermeulen, H. Ueda, and Y. Konagaya, Digital Card Cabinet - Gathering and Sharing Impressions about a Exhibition with both Analog and Digital Ways, Proc. VRSJ the 16th Annual Conference, pp.550-553 (2011) (in Japanese).
[15] T. Umesao, The Art of Intellectual Productivity, Iwanami-shoten (1969) (in Japanese).
[16] T. Ajiki, H. Fukuda, T. Kokogawa, J. Itou, and J. Munemori, Application to the Disaster Data of an Idea Generation Consistent Support System, Proc. FINA 2011 in conjunction with IEEE AINA 2011, pp. 153-158 (2011).
[17] J. Munemori, T. Nishide, T. Fujita, and J. Itou, Development of a Distributed Pictograph Chat Communicator IV, Proc. 15th International Conference on Knowledge-Based and Intelligent Information & Engineering Systems (KES2011), Vol. 6883, pp. 77-85 (2011).
[18] L. Hearn, A Living God, Gleanings in Buddha-Fields, Houghton Mifflin Company (1897).
[19] K. Yagishita, J. Munemori, and M. Sudo, A Proposal and an Application of an Evaluation Method for Sentences of B Type KJ Method Based on Contents and Structures, IPSJ Journal, Vol.39, No.7, pp.2029-2042 (1998) (in Japanese).
[20] T. L. Saaty, The Analytic Hierarchy Process, McGraw-Hill (1980).

# Evaluation experiment of the mutual complement network by wireless and wired

Shota Oda[1],Syunya Fujiwara[1],Kunihiro Yamada[1]

[1]Professional Graduate School of Embedded Technology, Tokai University 2-2-12, Takanawa, Minatoku, Tokyo, 108-0074, Japan

{1bejp005@mail.tokai-u.jp, 1bejp012@mail.tokai-u.jp,yamadaku@tokai.ac.jp}

**Abstract:** This paper aims to conduct experiments based on various environment conditions to evaluate the communication reliability of a mutually complementary network by wireless and wired which was developed for residences, large university school building. The experiment will measure the electrical wave form in different format in detail adopted at a university building that consists of five floors. In [1] there are three methods, 1) simple communication method; 2) routing communication method; 3) combined communication method. However, this research plans to conduct the experiment based on the last method, combined communication method. This paper expects that the result of this research will help to improve this network topology and makes it become more practical and easy to adopt in school building as well as individual home.

**Keywords:** Network, PLC, Zig-Bee, Wired and Wireless, Experiment, communication reliability, home security, reduce energy consumption

## 1. Introduction

The mutual complementary network is intended to improve the convenience of living in the home, home safety, energy consumption control and suppression where safety including disaster prevention as well as crime prevention.
In the home network, also present a number of intercoms, security, Internet, such as digital TV, all are independent.
Therefore, the mutual complementary network by wireless and wired network connect an isolated network by the "principal gating", which there is a potential to improve such network. Principal gating is communicating all piece of information rather than a minimum amount of information. For instance, principal gating also convey whether the communication is possible between the networks and whether the mutually complementary network operates as an emergency network. Having network run as an emergency network, many home or organizations in the region must have such network.

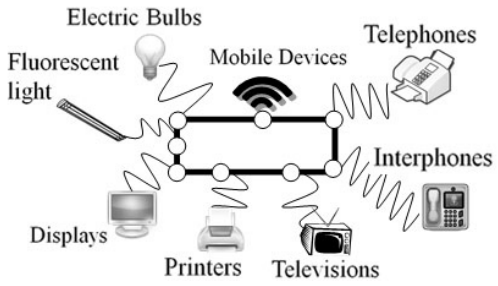



Fig.1 The mutual complement network by wireless and wired in home or school building

## 2. The mutual complement network by wireless and wired

The mutual complementary network by wireless and wired is a communication method in combination of two different types of communication media, wireless and wired, to transmit the data in the same time. Having such communication method adopts in the network, the communication performance is significantly improved compared with the network which use wireless and wired media in isolation.

This network, if you want to send data from the source to the destination, wired communications (PLC) and wireless communications (Zig-Bee) will always send the same data at the same time.

As a concrete example of improving communication performance, this research will show an evaluated example of concrete house at the third floor of 200 square meters.

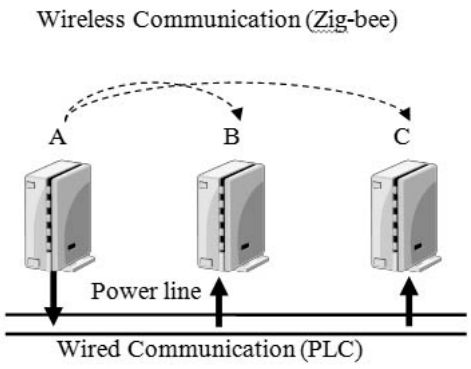



Fig.2 communicating at same time

Having use Zig-Bee for wireless and PLC for wired media as simultaneously for university building, and individual home, the communication performance could improve sig-

nificantly. Based on the previous research in [1, 3] communication performance adopted in home was 80.0% for wireless and 72.8% for wired communication. The theoretical communication performance for the slave should be 94.56% when the two types of communications take place simultaneously and independently [1][3]. The actual evaluation, however, resulted in a better communication performance of 100%. In other words, communication can be establish between two nodes either by wireless or wired or both.

## 3. Adaptation of combined communication method in a school building by mutually complementary network

Combined communication method is derived from the combination of simple routing communication method and routing communication method where simple communication method is used to transmit data from one node to another within the same room. Whereas, routing communication method is used to transfer the data from a node located in the room to the node located outside the room. For example, the node located along the hallway, located in the other floors, and located in different rooms.

Fig.3 shows simple routing communication method in which the data is sent from source A to destination C. However, the connection by both wired and wireless cannot be established between A and C. In this case, the data will be transferred to the destination via other nearby node that ensures the data transmission [2][4][5]. It means that the data will be sent from node A to node C through B, because the connection from A to B is made possible by wireless. Then, from node B to C the connection is made possible by wired media.

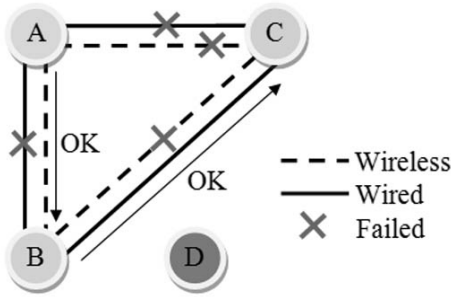



Fig.3 Simple routing communication method

Fig 4 illustrates the network communication using routing communication method. This method is used when the data is sent from the node located in the room to the node located outside the room via the representative node exists in each room. In case, the data is sent to the other room the communication is routed through the hallway when the source and the destination located in the same floor. However, to transmit data to the room located in different floor, data will be transfer from source to the hallway, to stairway, to hallway before reaching the destination.

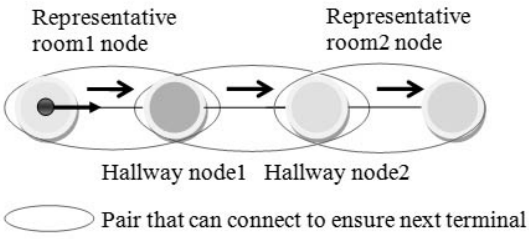



Fig.4 routing communication method

We illustrate these methods clearly.

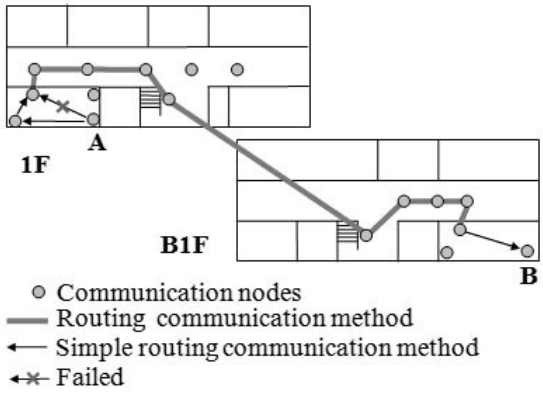
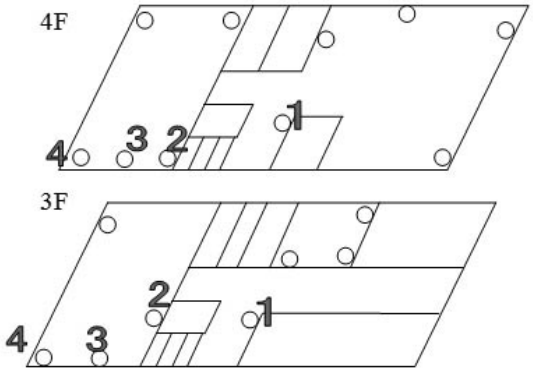



Fig.5 Combined method

## 4. Experiment with these method

This research experimented with these methods in Takanawa School building. In order to match the condition of PLC, Zig-bee is set a fix location to the wall sockets.

Fig 6 illustrates the sketch of the experimental building, Takanawa School building, and Fig 7 shows part of the reliability of the communication.



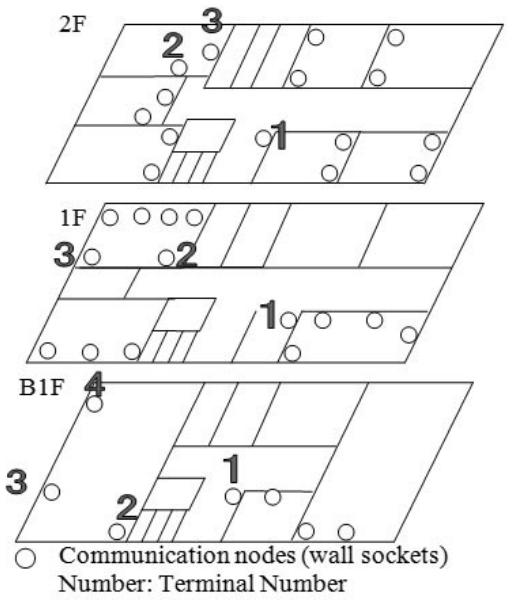



Fig.6 Sketch of Takanawa School building

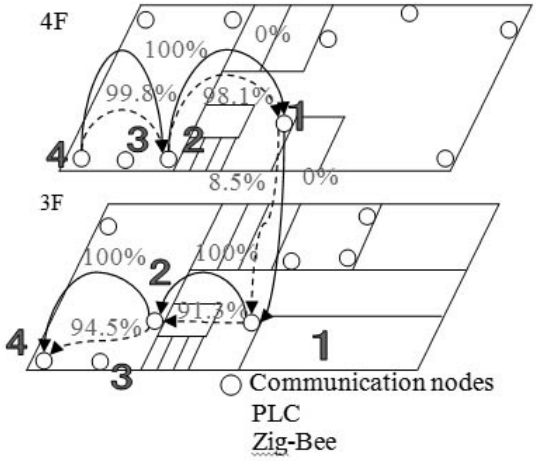



Fig.7 Part of reliability of the communication

In this condition, reliability of the communication from 4 of 4F to 4 of 3F was only 8.33%.

$$\frac{100}{100} * \frac{98.1}{100} * \frac{8.5}{100} * \frac{100}{100} * \frac{100}{100} = \frac{833950000}{10000000000} = 8.3385\ \% \qquad (1)$$

This could be caused by either power line in PLC when the data is transmitted to different layer, and divergence waves in Zig-Bee. So, although conditions would change, a midpoint is made available for Zig-bee communication. Fundamentally, communication between stairs and stairs midpoints are used.

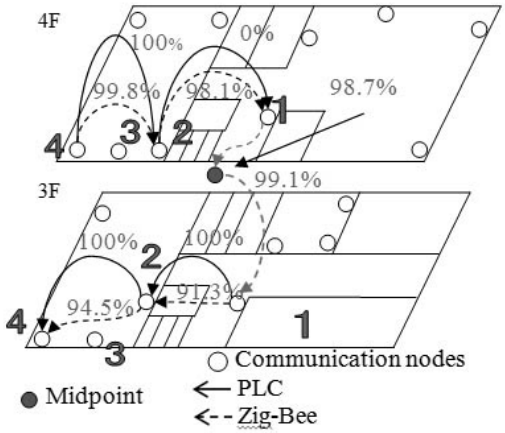



Fig.7 Part of reliability of the communication

$$\frac{100}{100} * \frac{98.1}{100} * \frac{98.7}{100} * \frac{99.1}{100} * \frac{100}{100} * \frac{100}{100} = \frac{959532777000}{1000000000000} = 95.95\% \qquad (2)$$

## 5. Conclusion

Based on the experiment, it can be seen that unreliable data transmission occurs in PLC when the data is sent to the destination node located in different layer. In addition, the problem also occurs in Zig-Bee communication when the node communicates between stairs and stairs. Regarding to these results, this research has set up a midpoint where we can get reliability of the communication of 95.95% from number 4 in Fig 7 of 4F to number 4 of 3F with combined method. Therefore, to achieve higher and more reliable communication performance these communication method need to further improve for the future need. The research plans to conduct the experiment in other school building in other conditions.

## 6. Reference

[1] Kunihiro Yamada, etc. "Dual Communication System Using Wired and Wireless Correspondence in Small Space," KES2004, Springer LNAI3214, pp. 898-904, (2004)

[2] Kunihiro Yamada, etc, "Home-Network of a Mutually Complementary Communication System by Wired and Wireless," KES2006, Springer Part III LNAI4253, pp. 189-196, (2006)

[3] Kunihiro Yamada, Kouji Yoshida, etc, “New System Structuring Method That Adapts to Technological Progress of Semiconductors”, KES2009, Springer Part II, LNAI5712, pp.773-781, (2009)

[4] Daiki Watabe,Kunihiro Yamada “Network Simulation of the mutual complement network by wireless and wired” Proceedings of the 50th National Convention of IPSJ2010.3.8-12 pp.3-313-314

[5] Kakeru Kimura,Takashi Furumura,Kunihiro Yamada,et al. “Adaptation a small building of the mutual complement network by wireless and wired”,Proceedings of JASAG National Conference October 2007.10.27-28 pp.111-118

# A Vehicular Mobility Model Considering Acceleration for Realistic Simulation of ITS Applications

Takaaki Umedu†, Akira Uejima†, Teruo Higashino†

†Graduate School of Information Science and Technology, Osaka University, Japan
{umedu, a-uejima, higashino}@ist.osaka-u.ac.jp

***Abstract*** - In this paper we propose a realistic mobility model of vehicles considering acceleration for evaluation of ITS (Intelligent Transport System) applications such as safety driving assistance. It is known that reproduction of realistic mobility of communication nodes in simulation environments is very important in order to evaluate the performance of ad-hoc network protocols accurately. In the previous work, we have proposed a realistic mobility model of vehicles that can reproduce realistic distribution of vehicles on the roads. It can be used for precise performance evaluation of vehicluar communications. However in this model, quick acceleration or sudden stops often occur even under not urgent situations. So it is difficult to evaluate safety applications that are expected to prevent dangerous behavior under urgent situations by using such a model. To solve the problem, we have analyzed what is the main cause of the problem and improved the vehicular behavior at intersections.

***Keywords***: ITS, Realistic mobility model, Traffic simulation.

## 1 Introduction

With the progress of ITS (Intelligent Transport System) technology, many inter-vehicular ad-hoc communication systems have been emerging. Some of such systems are expected to be infrastructures, providing traffic information to the drivers. When we design a new inter-vehicular communication system, we usually combine a traffic simulator and a network simulator to evaluate the designed system. However, most of the existing traffic simulators are not designed to evaluate such systems, constructing vehicular networks. Variable density of nodes causes variable connectivity in a vehicular network and data throughput between nodes, therefore it is essential to consider the interval between vehicles in order to construct vehicular network realistically. This makes it absolutely necessary to simulate the distances between the nodes accurately.

Our research group has developed the vehicular behavior model which simulates the realistic distribution of vehicles. In this model, the velocity and the driving lane of each vehicle are determined according to the two parameters. They are the distance between the vehicles in-front and the tendency of the change in their velocity. This enables to simulate the distance between the real vehicles in large areas while reducing the amount of calculation and evaluate the realistic communication of inter-vehicular communication systems. We have found that it is difficult to evaluate the ITS, such as a driving safety support system which needs to simulate the characteristic vehicular behavior in a realistic way since the unnatural vehicular behavior such as quick acceleration or sudden stops can be observed in this model. Such applications are often designed to avoid dangerous situation that cause unnatural vehicular behaviors. So we need simulation results in that unnatural acceleration occurs only in unusual situations for evaluation of such applications. Also, to reduce the amount of $CO_2$ emission is a significant problem, today. In [1], the authors shown that not the acceleration of vehicles affects fuel consumption of them. To evaluate the ITS applications that aim to reduce $CO_2$ emission such as [2], it is important to reproduce acceleration realistically. For this purpose, we also need a realistic vehicular mobility model considering acceleration.

Especially, such quick acceleration or sudden stops often occur when traffic signals are changed or roads and/or lanes are merged into one. To solve these problems, we have modeled the behavior at traffic signals and in merging lanes by extending the above vehicular mobility model. At first, we have introduced a decision process that checks the approaching traffic signal will be changed before the vehicle reach it. If the signal will be changed soon, the vehicle starts slowing down to avoid a sudden stop. Also, we have modeled a behavior model in the merging lanes. Since in simulations, the speed of a vehicle is calculated from the distance to the preceding vehicle, if the preceding vehicle is replaced by another one, the speed is changed suddenly. To avoid this problem, our new margin behavior model decides the speed of a vehicle not only from the distance to the current preceding vehicle when another vehicle is cutting in front of it. The simulator combines two speeds that are calculated from the distances to the preceding vehicle and the vehicle cutting in. This model simulates smooth merging, without sudden stop, by considering the positions of the merging cars in different lanes and controlling the distances between them.

For the proposed model, we have conducted the tests based on the benchmark data which is used in many previous simulators and have verified the simulation. Moreover, we have conducted a test scenario based on the real data to confirm our model can reproduce realistic trace data.

## 2 Related Works

### 2.1 Traffic simulators

A number of traffic simulators have been developed to analyze various problems on road traffic environment. At first, the typical purpose of the analysis was to solve the problems such as traffic jams by creating efficient city planning. Then

as the importance of ITS has been increased, the target area of traffic simulators has been spreading. In the field of traffic engineering, first *macroscopic traffic simulators* have been developed, and then *microscopic traffic simulators* have been developed so that more precise mobility of vehicles can be treated. Macroscopic traffic simulators reproduce large-scale traffic flows by modeling vehicles ' behavior with some abstraction or simplification. They are mainly aimed to reproduce traffic flows in wide areas, and they are suitable to predict traffic conditions such as traffic jams. They are often used to evaluate traffic measures, forecast volume of traffic or make plans for future traffic infrastructures. On the other hand, microscopic traffic simulators are specialized to reproduce relatively small areas of traffic flows in more details and/or to predicate how effects newly installed intelligent transportation systems give. They calculate each vehicle 's behavior individually and are used to evaluate more detailed traffic conditions. For example, they are used to examine the usefulness of collision avoidance mechanisms using radars and inter-vehicle communication at intersections.

Until now a lot of traffic simulators have been developed.

- NETSTREAM[3]
- AVENUE[4]
- INSPECTOR[5]
- NETSIM[6]
- SIPA[7]
- SOUND/4U[8]
- SOUND/P[8]
- GrooveNet[9][10]

We can classify AVENUE, SOUND/4U and SOUND/P as macroscopic and NETSTREAM, INSPECTOR, NETSIM, SIPA and GrooveNet as microscopic simulators, roughly.

Most of them are designed to reproduce realistic situation of traffic jams. Some of them are developed for more specific analysis such as behavior of vehicles at intersections. On the other hand, the wireless communication technology has been significantly improved and on-vehicle devices have been equipped with communication functions. Then demands to evaluate so-called ITS applications developed based on such communication technologies has been increased and traffic simulators have become to be used also in the area.

For example, GrooveNet[9][10] is developed to simulate inter-vehicle communication. It is a macroscopic traffic simulator, which has basic traffic reproduction functions. Also it has functions to simulate wireless communication and wireless communication protocols such as DSRC, 802.11 and EVDO are implemented on the simulator.

## 2.2 Existing Vehicular Mobility, Road Traffic Flow Model

It is widely known that reproducing realistic mobility of vehicles is important for simulation based evaluation of network applications based on vehicles to vehicles communication[11]. A number of researches have been carried out for this purpose[12]–[16]. In [12], the difference between a macroscopic traffic model and a simple random mobility model known as random waypoint is discussed and a method to implement a more realistic mobility model is proposed. In [13], a vehicular mobility model is designed considering the reality of speed distribution of vehicles and the route selection policy. In [15], [16], not only the speeds of vehicles but also acceleration of them is considered by calculating appropriate speeds from surrounding traffic environment. In [14], a microscopic vehicular mobility model is proposed, however it has not been implemented into traffic simulators.

In [17], the authors analyzed the data about packet transmission ratio of inter-vehicle communication derived from simulation results by using realistic traffic scenario and shown how the performance is affected by short-term and long-term changes of traffic environments. In [18], a method to realize smooth merging of vehicles, which can double the throughput of intersections, at most, is proposed. In the method, vehicles exchange their positions and speeds by inter-vehicle communication to adjust their positions.

However, we cannot find any road traffic simulator that is released enough publicly and satisfies all the requirements for evaluation of systems based on inter-vehicular communication. So we have proposed a realistic microscopic mobility model and implemented it into a famous road traffic simulator VISSIM[19].

# 3 Proposed Realistic Vehicular Mobility Model

In this paper, we propose a realistic vehicular mobility model. We have designed it considering the following three points for more realistic evaluation of inter-vehicle communication systems, such as driving safety assist systems.

- behavior of straight driving
- behavior of lane change
- behavior at merging points

## 3.1 Speed decision policy

According to the traffic engineering theory, it is said that each vehicle's speed $V$ can be modeled by Greenshields' function 3.3 from density $K$ of vehicles in general [20].

$$V = V_{MAX} \times \left(1 \quad \frac{K}{K_{MAX}}\right) \tag{1}$$

$V$ : speed of the target vehicle
$K$ : density of vehicles around the target vehicle
$V_{MAX}$ : the maximum speed at which vehicles run on density $K = 0$
$K_{MAX}$ : the saturated density of vehicles when their speeds become 0

Since the density $K$ of vehicles is roughly proportional to the average distance $D$ between vehicles, we decide the speeds of those vehicles according to the following formula.

$$V = V_{MAX} \times (1 \quad \frac{D_{MIN}}{D}) \tag{2}$$

$D$ : the distance to the preceding vehicle
$D_{MIN}$ : the minimum distance between two vehicles

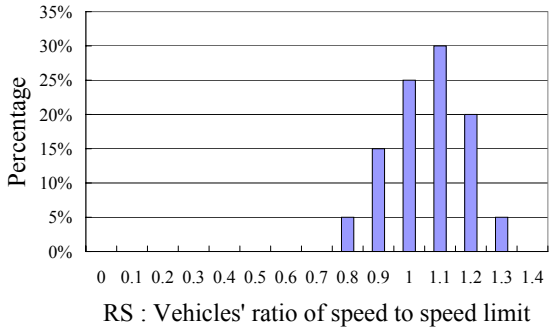



Figure 1: Distribution of vehicles' speed (ratio to speed limit)

In some traffic simulators, the speed limit of each road is used for the maximum speed $V$ of all the vehicles, and it is considered as a constant. In our model, we introduce a parameter $RS$ ($0.8 \quad RS \quad 1.3$) for representing fluctuation of the maximum speeds of those vehicles. The fluctuation $RS$ has been decided as Fig. 1 based on investigation of real traffic measured at major roads with multiple lanes in Japan. Using the fluctuation $RS$, the speed of each vehicle can be calculated as follows (Fig. 2).

$$V = RS \times V_{MAX} \times \left(1 \quad \frac{D_{MIN}}{D}\right) \tag{3}$$

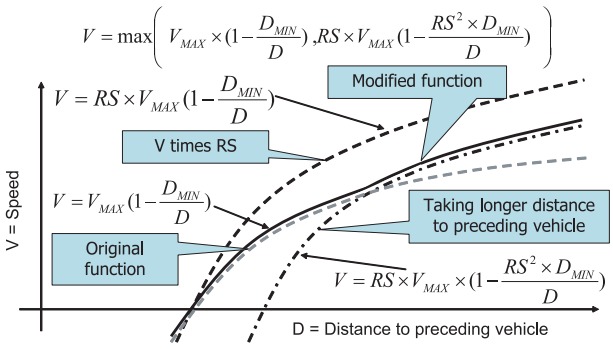
$RS$ : ratio of each vehicle's speed to speed limit ($0.8 \quad RS \quad 1.3$)

However, by this simple modification, some undesirable problems occur. When a slower vehicle ($RS$ is small) decreases its speed and its following vehicle runs faster ($RS$ is larger), the following one might collide with its preceding one. To avoid such situations, faster vehicles must decrease their speeds earlier than slower ones. So in our model, the speed $V$ is calculated as follows (Fig. 2 (1)).

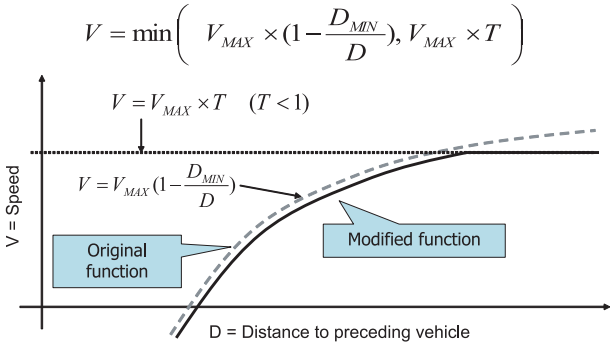
$$V = \begin{cases} RS \times V_{MAX} \times \left(1 \quad \dfrac{D_{MIN}}{D}\right) & (RS \quad 1) \\ RS \times V_{MAX} \times \left(1 \quad \dfrac{RS^2 \times D_{MIN}}{D}\right) & (RS > 1) \end{cases} \tag{4}$$

On the other hand, a bottleneck capacity test is defined as one of the verification process standardized by traffic engineering society in Japan. Here, the bottleneck capacity means how many vehicles can pass in a specified time period through a bottleneck shape of the specified road. Since the above function spreads distance between all the vehicles, the bottleneck capacity gets smaller. Moreover, the minimum distance of slower vehicles also become longer under high density conditions.

So, we have slightly modified it as follows in order to make their minimum distances under high density conditions as the same as the original one so that they do not affect the results of the bottleneck capacity test (Fig. 2 (2)).




(1) $RS > 1.0$




(2) $RS \quad 1.0$

Figure 2: Speed decision function

$$V = \begin{cases} \min\left(V_{MAX} \times \left(1 \quad \dfrac{D_{MIN}}{D}\right), RS \times V_{MAX}\right) & (RS \quad 1) \\ \max\left(V_{MAX} \times (1 \quad \dfrac{D_{MIN}}{D}), \right. & \\ \quad \left. RS \times V_{MAX} \times \left(1 \quad \dfrac{RS^2 \times D_{MIN}}{D}\right)\right) & (RS > 1) \end{cases} \tag{5}$$

At last, we have used function 5 to decide the speeds of vehicles on straight driving.

## 3.2 Lane selection policy

In macroscopic traffic simulation, since information about lane selection is not important, vehicles in simulation usually do not change their lane without necessity. That is, each vehicle changes its lane only when it reaches to its preceding vehicle with the specified minimum distance. However, in reality, drivers may change their lanes before reaching its preceding vehicle with the minimum distance for smooth driving. Considering this observation, we have modeled vehicles' behavior such that each vehicle changes its lane according to the probability $P$, whose value becomes larger as it closes to its preceding one.

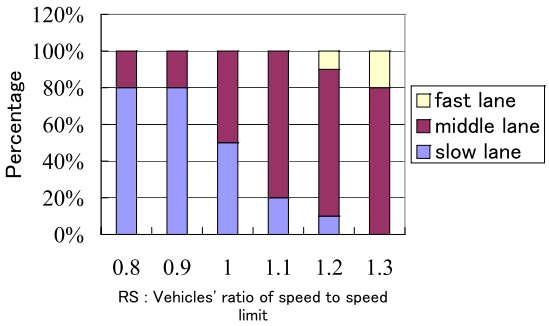



Figure 3: Lane selection based on each vehicle's maximum speed

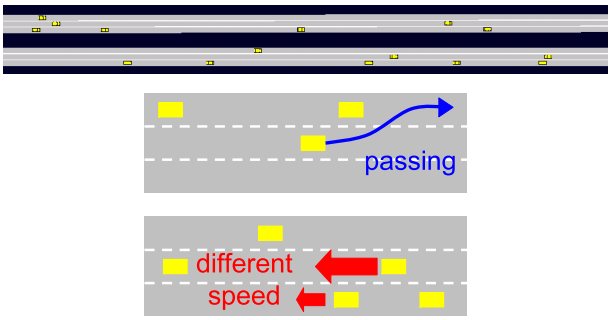



Figure 4: Distributed lane selection

On the other hand, the decision of lane change is affected by driving speeds as shown in Fig. 3. Even when a driver drives a vehicle slower than his/her favorite maximum speed, if he/she feels the speed enough acceptable, he/she may not change his/her lanes to pass the preceding vehicle. So in our model, the above lane change policy is ignored when each vehicle's speed is enough large, that is, when it is larger than $\times V$ $\times RS$ ( $= 0.5$ here).

By introducing this policy to road traffic simulator, we can reproduce realistic cluster of vehicles under light traffic conditions on highways, such that faster vehicles follow a bit slower ones(Fig. 4).

$$P = \begin{cases} 1 & (D \quad D_{MIN}) \\ \left(\dfrac{D_{MIN}}{D}\right)^2 & (D > D_{MIN}) \end{cases} \tag{6}$$

P : the probability that a vehicle changes its lane
$D_{MIN}$ : the minimum distance between two vehicles
$D$ : the distance to the preceding vehicle

## 3.3 Behavior at merging points

In using the proposed mobility model shown in Sect. 3.1, the speed of a vehicle is calculated basically depends on the distance to the preceding vehicle. So, in a case when the preceding vehicle is replaced by another one, the speed might be changed suddenly and unrealistic acceleration might occur. Such problems have been occurred especially at the merging points of roads. For example, as shown in Fig. 5, assume that two vehicles are running on a main road. In the case, the following vehicle's speed is calculated from the distance $D$ to the preceding vehicle. When another vehicle cuts in from a branch line between them, the preceding vehicle of the follower is replaced by the vehicle newly cutting in and the distance $D$ is also replaced by the distance to the new one. As a result, the speed of the follower is suddenly changed with unusual acceleration, although it is a usual situation. On the other hand, in order to evaluate safety support applications, it is important to check how the system can reduce the number of dangerous situations. It is often assumed that such situations can be detected from unusual acceleration in the simulation results. So it is important to prevent such unusual acceleration in the situations without any danger like smooth merging of vehicles.

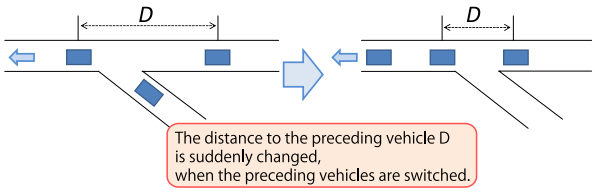



Figure 5: Sudden speed change at merging lanes

At first, we have tried to solve the problem by putting a restriction that limits the values of acceleration in a given range simply. The goal of the proposed method is to keep vehicles' acceleration in the range of -0.3G to 0.3G. However, the restriction worked all over the simulation to limit the speeds and affected total simulation results too much. The simulation results were completely changed from the original ones, which are guaranteed as enough realistic by the simulator maker. So in the mobility model we propose in this paper, we have introduced existing speed decision model, at first, and the most of unusual acceleration can be prevented without affecting macroscopic results of simulations. However, a number of unusual acceleration has occurred yet. Here, since most of the cases are happened at merging process of vehicle flows, we have introduced an exceptional behavior model for merging process.

We have designed our model referring Intelligent Driver Model(IDM)[15], which is a behavior model. In IDM, the following function is used to decide the acceleration of vehicles.

$$\begin{cases} \dfrac{dv}{dt} = a \times \left[1 \quad \left(\dfrac{v}{v}\right) \quad \left(\dfrac{s^*}{s}\right)^2\right] \\ s^* = s \quad + \left(vT \quad \dfrac{v \times \Delta v}{2 \times \quad ab}\right) \end{cases} \tag{7}$$

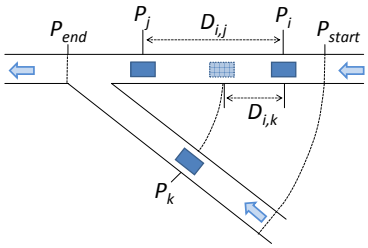



Figure 6: Proposing merging behavior model

| | | |
|---|---|---|
| $v$ | : | the current velocity of the vehicle |
| $v$ | : | the desired velocity |
| $s$ | : | the distance to the preceding vehicle |
| $s^*$ | : | the desired dynamical distance |
| $s$ | : | the minimum distance between two vehicles |
| $vT$ | : | the minimum safe time headway |
| $\Delta v$ | : | the speed difference with respect to front vehicle velocity |
| $a$ | : | the maximum acceleration |
| $b$ | : | the maximum deceleration |

In this function 7, the speed is calculated from the state of vehicle and the distance to the preceding vehicle. Here, the term $(\frac{v}{v_0})$ represents how the current speed is close to the desired speed. The value of the term comes to 1 as the current speed comes to the desired one and the acceleration will come to 0 when the current speed reaches the desired speed. The term $(\frac{s^*}{s})^2$ represents how safe the current distance to the preceding vehicle is. The safeness is calculated from three factors; the current distance, the distance that might be shortened caused by the delay of reaction and the distance shortened after breaking. The value of this term becomes larger as the distance to the preceding vehicle is shortened. In the straight driving state, the speed is adjusted by the acceleration calculated by this function. However, the function is not suitable for control the behavior of vehicles at cross points. So another model IDM-IM[16] is used in such situations.

$$\begin{cases} s = & S \\ \Delta v = v \end{cases} \tag{8}$$

| | | |
|---|---|---|
| | : | the current distance to the intersection |
| $S$ | : | the gap between the center of the intersection and the point the car would actually stop at |

In IDM-IM, when a vehicle approaching yellow signal, the distance the vehicle can stop safely is calculated as $\frac{v^2}{2b}$ and it is compared with the distance to the signal. If the distance is shorter than the distance needed to stop safely, the vehicle will pass the cross at the speed calculated by the functions 7 and 8. By using the functions, the simulator can keep the speeds of vehicles in the specified range.

Additionally, we have modified the behavior model of merging process of vehicles' flows. In the modified process, smooth changes of speeds can be realized. The cause of the problem is that in general, there is some gap between the speed calculated from the distance to the preceding vehicle on the same lane and the one calculated from the distance to merging vehicle in front of it. In our method, the simulator calculates the two speeds and switches them smoothly. For example, we assume a situation that a vehicle $k$ running on a branch road is cutting in between two vehicles $i$ and $j$ running on the main road as shown in Fig. 6. We call the merging point as $P_{end}$ and the start point of this process as $P_{start}$, where the distance from $P_{start}$ to $P_{end}$ is defined by a given parameter value. The positions of vehicles $i, jandk$ are represented by $P_i, P_jandP_k$, respectively. We have defined a virtual vehicle $k'$ for the actual vehicle $k$ on the main road and its position as $P_{k'}$, where the distances from $P_{end}$ to $k$ and $k'$ are the same. Hereafter, we represents the distance between two vehicles $i$ and $j$ as $D_{i\,j}$. From the Greenshields's function , two speeds before and after the merging process are calculated as follows.

$$V_i = V_{MAX}\left(1 \quad \frac{D_{MIN}}{D_{i\,j}}\right) \tag{9}$$

$$V_i' = V_{MAX}\left(1 \quad \frac{D_{MIN}}{D_{i\,k}}\right) \tag{10}$$

In our method, two speeds $V_i$ and $V_i'$ are merged linearly to calculate the speed of the vehicle $i$. Here, the ratio of the progress of the merging process $R$ can be calculated by the following formula.

$$R = \frac{P_{end} \quad P_i}{P_{end} \quad P_{start}} \tag{11}$$

So, the speed of the vehicle $i$ can be calculated as follows.

$$V = (V_i \quad V_i')R + V_i' \tag{12}$$

By substituting the formulas above, the final speed decision function is shown in the following.

$$\begin{aligned} V &= V_{MAX}R\left(\frac{D_{i\,k}D_{MIN} + D_{i\,j}D_{MIN}}{D_{i\,j}D_{i\,k}}\right) \\ &\quad +V_{MAX}\left(1 \quad \frac{D_{MIN}}{D_{i\,k}}\right) \\ &= V_{MAX}\left\{1 \quad \left(\frac{RD_{i\,k} + (1 \quad R)D_{i\,k}}{D_{i\,j}D_{i\,k}}\right)D_{MIN}\right\} \end{aligned} \tag{13}$$

Note that, the above function is equivalent to the function made from function (2) by replacing $D$ by the following.

$$D = \frac{D_{i\,j}D_{i\,k}}{RD_{i\,k} + (1 \quad R)D_{i\,k}} \tag{14}$$

Here, the distances $D_{i\,j}$ and $D_{i\,k}$ are changed smoothly, the distance calculated by the above function (15) is also changed smoothly. So, the speed of the vehicle is not changed suddenly and unusual acceleration can be prevented.

## 4 Evaluation of proposed mobility model

We have implemented our model in a road traffic simulator VISSIM[19] and evaluated the reliability of its output. In this section we discuss about the evaluation results as follows.

- the limitation of acceleration
- the reality of behavior of vehicles in the resulted traffic flows
- reproduction ability of realistic traffic flows

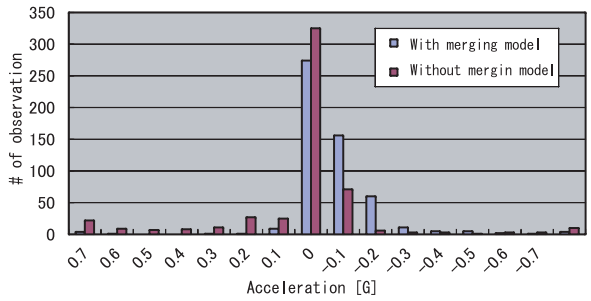



Figure 7: Distribution of acceleration

## 4.1 Magnitude of acceleration

At first, we have evaluated if the acceleration in usual situation is limited in the usual range. Here, we defined usual range as 0.3G according to the drivers' license examination in Japan. In the examination, drivers are required to keep the acceleration in the range of 0.3G to get the license. In this evaluation, we have compared the distributions of acceleration of two mobility models; with merging speed model and without it.

The result is shown in Fig. 7. In this graph, the x-axis represents acceleration, and y-axis represents the number of observations for each acceleration. The number of unusual acceleration is significantly reduced by our speed model.

Note that, in this result, unusual acceleration have been observed for 24 times. We have examined the situations in detail and each of them has occurred at the moment when a have moved from a road segment to another road segment. In VISSIM, the whole road structure consists of small straight road segments, and the data may have some errors between the positions of segments. At the moment a vehicle moves between such road segments that have position errors to each other, the position of the vehicle is changed suddenly and it is recorded as unusual acceleration. The problem could be avoided by designing the road structure carefully and setting the positions of road segments precisely. However, since it is easier to remove such errors from log data after simulation than to correct the input road data, in this paper, we do not discuss about the correction of input data in detail.

## 4.2 Reality of vehicles' behavior

In this section, we show the appropriateness of our modification of vehicles 'movement patterns by testing reproduced traffic flows based on validation processes standardized by a traffic engineering society in Japan for evaluating whether target traffic simulators can reproduce realistic macroscopic traffic flows. The rough process of each validation can be shown as follows.

1. according to the validation manual, prepare specified road structures for benchmark tests on the target simulator

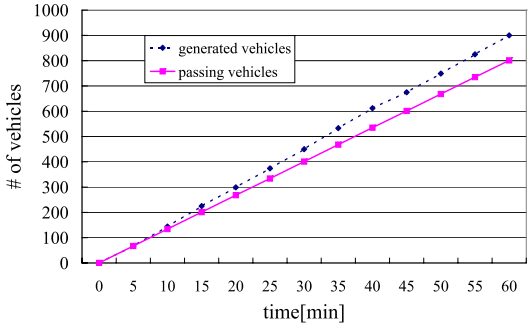



Figure 8: Amount of passed vehicles at the bottleneck point (capacity : 800 vehicles/hour)

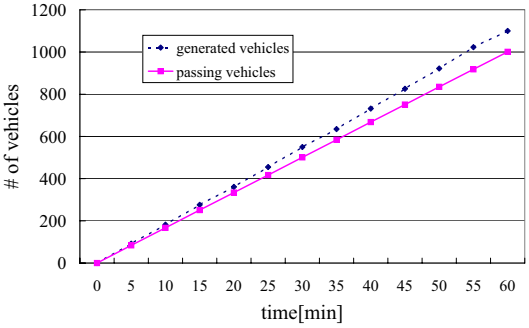



Figure 9: Amount of passed vehicles at the bottleneck point (capacity : 1000 vehicles/hour)

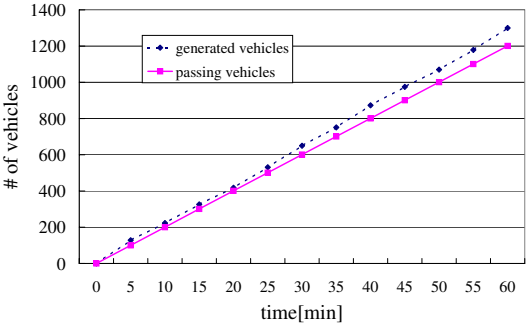



Figure 10: Amount of passed vehicles at the bottleneck point (capacity：1200 vehicles/hour)

2. reproduce traffic flow by using specified parameters for benchmark tests

3. compare the reproduced traffic flows with the reference ones shown in the validation manual

Hereafter, we show the validation results. Here we have tested the mobility model by three validation processes; (1) bottleneck capacity test and (2) spreading speed of *shockwave* (extending and untying speeds of traffic jams).

## 4.3 Bottleneck capacity test

In this test, the bottleneck is a point where the capacity of a road gets smaller as the width of a road gets narrower. The bottleneck capacity test verifies if traffic simulators can reproduce acceptable traffic capacities at such points. In the validation process, the following three constraints about bottlenecks

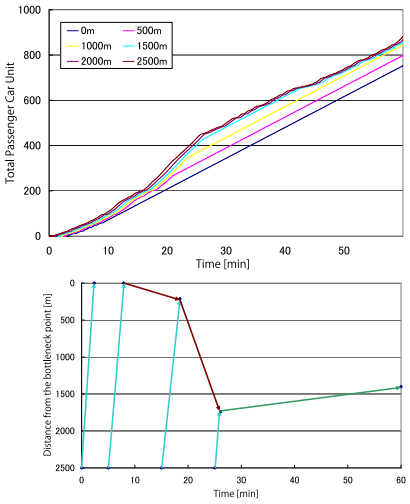



Figure 11: Behavior of shockwave (capacity : 800 vehicles/hour)

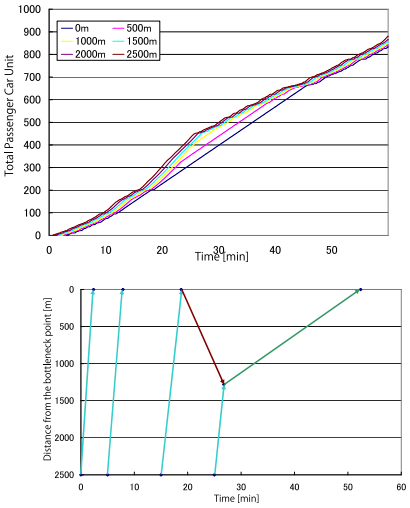



Figure 12: Behavior of shockwave (capacity : 1000 vehicles/hour)

are given.

1. Each road is straight and has a bottleneck at the center.
2. Each bottleneck is designed so that a fixed number of vehicles can pass through it; 800, 1000 and 1200 vehicles per hour. The other roads are designed to have the capacity of 2200 vehicles per hour.
3. In the simulation, 1500 vehicles per hour reach the bottleneck point.
4. For each parameter, the simulation is executed for one hour and the amount of traffic passing the bottleneck point is counted and logged.
5. The data are plotted into graphs to check the target bottleneck capacities are satisfied.

As simulation results, we have got the graphs shown in Fig. 8, 9, 10. From the results, we can see the bottleneck is

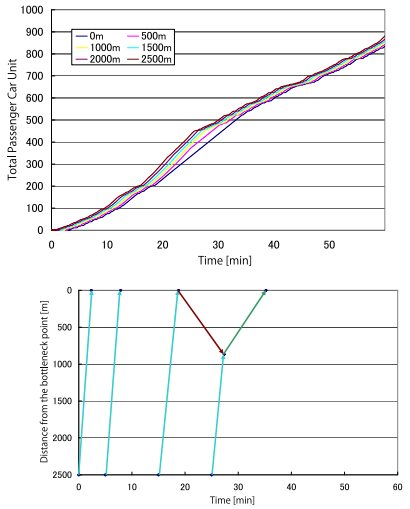



Figure 13: Behavior of shockwave (capacity : 1200[vehicles/hour])

correctly reproduced for each parameter and our model have passed the validation process.

### 4.3.1 Spreading speed of shockwave

A shockwave is a spreading border between different states; a usual flow and a traffic jam. That is, the speed of a spreading shockwave means the extending or untying of speed of a traffic jam. In the validation process, we must prepare three road segments with different bottleneck capacities and connected straightly, at first. Then, we give a traffic stream that has a peak at the middle of it. Through the simulation, a traffic jam occurs around the peak and will be untied after it. The validation process requires the length of the traffic jam increases and decreases at the theoretically derived speeds. The detailed parameters for this process are shown as follows.

1. We prepare the road structure for the validation in the target simulator. Here, we must prepare a straight road, where the center part of the road consists of three segments, of which capacities are 800, 1000 and 1200 vehicles per hour. The capacity of the left of the road is set to 1800 vehicles per hour.
2. A traffic stream of vehicles that has a peak is input to the road. The amount of vehicles per hour is changed according to the time from the start of the simulation as follows.
   - from 0 to 5 minutes : 750 vehicles/hour
   - from 5 to 15 minutes : 900 vehicles/hour
   - from 15 to 25 minutes : 1500 vehicles/hour
   - from 25 to 60 minutes : 750 vehicles/hour
3. The data is plotted into a graph that represents the change of the traffic jam length.
4. The extending and untying speeds of the traffic jam are measured from the graph and compared with the theoretical values.

Figure 14: Measurement environment

The results are shown in Fig. 11, 12 and 13. The extending and untying behavior of the traffic jam is normal and the speeds of them are within the required range of the validation process. So we can say our model passes the test.

## 4.4 Reproduction ability of realistic traffic flows

We have tried to create a parameter setting that can reproduce realistic traffic flows from the observation of a real road traffic flow. In this evaluation, we have selected typical merging point where two roads are merged into one road and put video cameras at the upper and lower points of it. Then, we have extracted data of traffic flow by hand from the data recorded by the video. At last, we have evaluated if our model can reproduce the similar traffic flow with the data by adjusting the parameters.

We have measured the traffic flows at a merging point on Japan National Route 423 in front of Ryokuchi-koen station of Kita-Osaka Kyuko Railway. The area is shown in Fig. 14. We have put video cameras at the points indicated by read line in the figure to collect the data of the amount and travel times of the vehicles. Then we have made the same road structure in the simulator and tried some parameter sets to check if our simulator reproduces the similar traffic flow with the real one. We have carried out this test twice on difference times to evaluate our model on different conditions.

The comparison between most similar reproduced traffic flow and the real one is shown in Fig. 15. We were able to make the median and the distribution similar to the real ones in each test. However, only in the simulation, there are some vehicles that take more than 90 secs. to pass the segment. In the tests, the process to extract traffic data from the video data takes considerable much time and it might be not so correct. To evaluate our model by using more traffic flow data is our future work.

## 5 Conclusion

In this paper, we have proposed a realistic vehicular mobility model for evaluation of inter-vehicle ad-hoc communication application. Especially, we have improved the behavior of acceleration of them to make it possible for evaluation

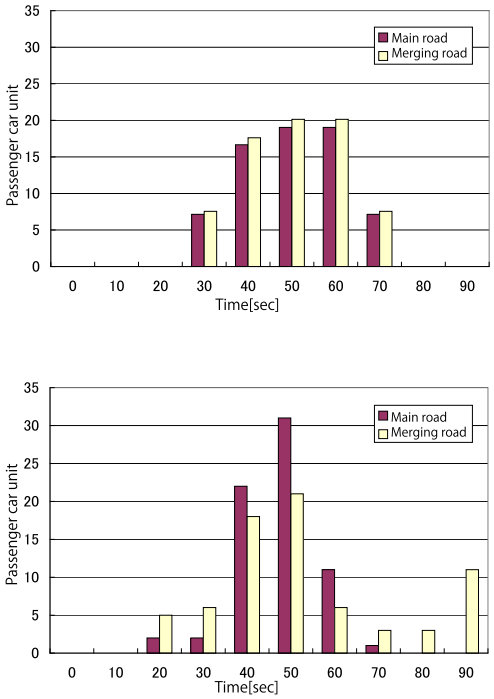



Figure 15: Reproduced traffic flow and real one

that requires reality of acceleration. For example, it is important for evaluation of safety driving assistance systems to distinguish the dangerous situations from the results. Also, to evaluate $CO_2$ emission, reproduction of realistic accelerating behavior is important. By our method, the vehicles can stop at intersections without sudden slowdown and marge into another flow smoothly without unusual acceleration.

We have evaluated our model through standardized validation processes for road traffic simulators and some extra tests to reproduce realistic traffic flows. To apply our method to more data is our future work.

## REFERENCES

[1] L. I. Panis, S. Broekx, R. Liu : “Modelling Instantaneous Traffic Emission and the Influence of Traffic Speed Limits”, *Science of the Total Environment*, Vol.371, pp.270-285, Elsevier Science, 2006.

[2] T. Umedu, Y. Togashi and T. Higashino: “A self-learning traffic signal control method for $CO_2$ reduction using prediction of vehicle arrivals”, Proc. of 15th IEEE Intelligent Transportation Systems Conference, 2012. (to appear)

[3] E. Teramoto, M. Baba, H. Mori, H. Kitaoka, I. Tanahashi, Y. Nishimura, et. al.: ”Prediction of Traffic Conditions for the Nagano Olympic Winter Games Using Traffic Simulator : NETSTREAM”, Proc. of the 5th World Congress on Intelligent Transport System, Vol.4, 1998.

[4] J. Bhattacharya and R. Horiguch: “Implementation of Transportation Management Strategies using AVENUE

for developing countries" Proc. of 7th Asia-Pacific ITS Folum, 2005.

[5] H. Nakamura, K. Suzuki: "INSPECTOR - The Integrated Network Simulator for Performance Evaluation on Comprehensive Traffic OpeRation", Proc. of 11th World Congress on Intelligent Transportation Systems, CD-ROM, 2004.

[6] A. K. Rathi : "Urban network traffic simulation TRAFNETSIM program", Journal of Transportation Engineering, Vol.116, No.6, 1990.

[7] R. Horiguchi, M. Kuwahara: "Verification Process and ITS Application to Network Traffic Simulation Models", Journal of Advanced Transportation, Vol. 36, Issue 3, pp. 243-264, 2002.

[8] G. Tamamoto, Mm Kuwahara, R. Horiguchi, E. Chung, S. Tanaka, K. Satou and T. Shiraishi："Application of Traffic Simulation SOUND to the Tokyo Metropolitan Network", Proc. of 11th World Congress on Intelligent Transport Systems, 2004.

[9] R. Mangharam, D. Weller, R. Rajkumar, P. Mudalige and F. Bai : "GrooveNet : A hybrid simulator for vehicle-to-vehicle networks", Proc. of 2nd Int. Workshop on Vehicle-to-Vehicle Communications 2006 (V2VCOM 2006), 2006.

[10] F. Bai, T. Elbatt, G. Hollan, H. Krishnan and V. Sadekar : "Towards characterizing and classifying communication-based automotive applications from a wireless networking perspective", Proc. of 1st IEEE Int. Workshop on Automotive Networking and Applications (AutoNet 2006), 2006.

[11] A. Jardosh, E. M. Belding-Royer, K. C. Almeroth and S. Suri : "Towards realistic mobility models for mobile ad hoc networks", Proc. of 9th ACM Int. Conf. on Mobile Computing and Networking (MobiCom 2003), pp.217-229, 2003.

[12] A. K. Saha and D. B. Johnson : "Modeling mobility for vehicular ad-hoc networks", Proc. of 1st ACM Int. Workshop on Vehicular Ad Hoc Networks (VANET 2004), pp.91-92, 2004.

[13] D. R. Choffnes and F. E. Bustamante : "An integrated mobility and traffic model for vehicular wireless networks", Proc. of 2nd ACM Int. Workshop on Vehicular Ad Hoc Networks (VANET 2005), pp.69-78, 2005.

[14] J. Harri, F. Filali and C. Bonnet : "A framework for mobility models generation and its application to inter-vehicular networks", Proc. of 3rd IEEE Int. Workshop on Mobility Management and Wireless Access (MobiWac 2005), 2005.

[15] M. Trieber, A. Hennecke and D. Helbing : "Congested traffic states in empirical observations and microscopic simulations", Phys. Rev. E 62, Issue 2, pp.1805-1824, 2000.

[16] M. Fiore, J. Harri, F. Filali and C. Bonnet : "Vehicular Mobility Simulation for VANETs", Proc. of the 40th IEEE Annual Simulation Symposium (ANSS'07), pp.301 - 309, 2007.

[17] F. Bai, B. Krishnamachari : "Spatio-Temporal Variations of Vehicle Traffic in VANETs: Facts and Implications", Proc. of 6th ACM Int. Workshop on Vehicular Ad Hoc Networks (VANET 2009), pp. 43-52, 2009.

[18] Z. Wang, L. Kulik, and K. Ramamohanarao : "Proactive Traffic Merging Strategies for Sensor-Enabled Cars", Proc. of 4th ACM Int. Workshop on Vehicular Ad Hoc Networks (VANET 2007), pp. 39-48, 2007.

[19] Project Centre : "VISSIM", http://www.projectcentre.co.uk

[20] U.S. Department of Transportation Federal Highway Administration : "Traffic flow theory — A state of the art report", http://www.tfhrc.gov/its/tft/tft.htm.

# A Motion Sensing System to Grasp a Motorcycle's Behavior with Sensors as mounted on a Smartphone

Tomoya Kitani[1)], Akihito Miyazawa[2)], Tsukasa Kamimura[3)], Akichika Shiomi[3)] and Takashi Watanabe[3)]

[1)] Division of Global Research Leaders, Shizuoka University, Japan
[2)] Graduate School of Informatics, Shizuoka University, Japan
[3)] Faculty of Informatics, Shizuoka University, Japan
t-kitani@ieee.org

***Abstract*** -

ITS (intelligent transport system) is a system with information technologies to achieve vehicle safety and to improve traffic convenience. ITS includes vehicle motion control systems for safety. Such ITS devices as ESC (electronic stability control systems) have been developed, but most of them are designed for four-wheeled vehicles (cars and buses) or they are not designed for two-wheeled vehicles (motorcycles). Motorcycle riders are more likely to be injured at traffic accident than car drivers. However, ITS for motorcycles have not been popular because such devices are costly and heavy in comparison with the price and the weight of a motorcycle, respectively. In this paper, we propose a motion sensing system for a motorcycle at a moderate price in order to encourage development of ITS services for the motorcycle. It reduces costs by using a smartphone which is getting popular as a sensing device The proposed system can be used to evaluate the availability of a smartphone as such sensing device.

***Keywords***: vehicle behavior, motion sensing, motorcycle, ITS (intelligent transport systems)

## 1 Introduction

With the development of information technologies, intelligent transport systems (ITS) have been richly researched and developed for vehicle safety and improving traffic convenience. One of the latest systems is "EyeSight" developed by Subaru [1][2] that senses the distance to the car in front and the surrounding environment with a stereo camera, another is that with a millimeter-wave radar, and one other uses wireless communication to grasp the surrounding environment. However, most of such ITS devices, services and applications are designed for four-wheeled vehicles (cars). A motorcycle is different from a car in the following two principal points: shape and behavior. Due to the differences, it is difficult to adopt most of the developed ITS applications, especially that for vehicle safety, for motorcycles.

The body shape of a motorcycle is open and its rider is undefended whereas a car driver is in the cabin of the car and is protected. A motorcycle rider injures about five times and die about 2.5 times as much as a car driver at traffic accident [3]. Therefore, it is important to develop a system for vehicle and traffic safety for motorcycle.

The behavior of motorcycle is classified into vehicle motion and mobility. As vehicle motion, a motorcycle is not able to be self-standing. As a result, a rider should always keep the motorcycle's balance. To grasp the current motion of a motorcycle is important for the motorcycle because to lose the balance invites or is involved in a traffic accident. Additionally, the motion to turn a corner is different between a motorcycles and a car because a motorcycle leans its body whereas a car does not.

As mobility, a motorcycle can go through narrow streets and can run through cars in front of it in heavy traffic even if whereas a car cannot do both. ITS services and applications that does not consider such a motorcycle's mobility could misrecognize running through cars as rear-ender, or they could not work well.

For these reasons, it is difficult to apply conventional ITS services and applications to motorcycles. To grasp the behavior of a motorcycle by sensing its motion can promote development of ITS services and applications for motorcycles' traffic safety. In our research, we build a motion sensing system for a motorcycle and develop an algorithm to grasp the current behavior of a motorcycle from the sensed data.

Since the body size of a motorcycle is smaller than that of a car, a motorcycle has less space to equip such ITS devices. Moreover, since the price of a motorcycle is cheaper than that of car, the cost of the proposed sensing system should be kept down. Practical ITS services and applications can be achieved if such a service consists of cheap and easily-available devices as on-board ITS devices.

As mentioned above, the behavior of a motorcycle is classified into vehicle motion and mobility. The current motion can be grasped with an acceleration sensor and a gyro sensor. The trajectory as mobility can be grasped with a speed sensor, a rotation angle sensor of the handle, a compass sensor, a GPS receiver and so on.

An acceleration sensor, a gyro sensor, a compass sensor, a GPS receiver are equipped in a smartphone which is getting popular these days. A rider's smartphone can be used as the sensing device for grasping vehicle motion and mobility and as the platform for an ITS application for the motorcycle. This idea can alleviate the problem that make the development of ITS services and applications for motorcycle difficult as mentioned above.

To achieve a practical system for traffic safety needs dependability and reliability. As a result, to use a smartphone as the sensing device might not be appropriate even though it is convenient. In this research, we develop a dedicated sensing unit for vehicle motion and evaluate the availability of a smartphone as the sensing device.

In this paper, we introduce a prototype of the motion sensing system for a motorcycle with the dedicated sensing units.

## 2 Related Work

One of the major ITS (intelligent transport systems) is active safety. Active safety systems are classified into the following two groups: systems in a single vehicle; systems among neighboring vehicles and roadside units with wireless communication. The systems in a single vehicle include a system to grasp the surrounding environment of a vehicle with cameras and radars, a brake control system with the rotation sensor of each tire, and many of them have been in practical use. The systems with wireless communication include have been researched and are developing.

Examples of active safety systems in a single vehicle in practical use are ABS (antilock brake system), TCS (traction control system) and ESC (electronic stability control system). ABS utilizes the rotation sensor of the tires, controls the brake so that the tires are not locked, and reduces the braking distance. TSC also utilizes the rotation sensor of tires and controls the engine output so that the tires run idle. ESC utilizes the rotation angle sensor of the handle and the rotation sensor of each tire, detect the instability of the vehicle and control the brake of each tire separately.

In the last few years, several motorcycles equip ABS. However, since such devices are heavy and expensive relatively for a motorcycle, this could spoil the advantages of motorcycle. Since a motorcycle cannot be self-standing and it is a unstable vehicle, it is difficult to apply active safety systems designed for cars to motorcycles. Moreover, to control the brake of a motorcycle without the rider's consent makes the motorcycle lost its balance and fall easily.

## 3 Target Traffic Safety for Motorcycle

### 3.1 Novel ITS for Motorcycle

Since the differences between a car and a motorcycle about the body and behavior, it is difficult to apply active safety technologies (vehicle stability control) for a car without considerable modification to a motorcycle. Therefore, we discuss a vision of ITS for motorcycles about active safety and its practical systems with information technologies.

In order to solve the problem about diffusion of ITS for motorcycles and to develop a practical active safety system in a single motorcycle, we assume that a motorcycle is not equipped with such heavy and expensive hardware for the conventional system but a motorcycle is equipped with a system to let the rider realize the current situation of the motorcycle so that the rider handles it well. The proposed system should consist of inexpensive sensors.

In the future, we will modify the proposed system and let it collaborate with neighboring vehicles. Since a motorcycle can topple over whereas a car does not, a motorcycle is more likely to cause traffic accident than a car. After a motorcycle causes a traffic accident by itself, the toppled motorcycle is often involved the second traffic accident with vehicles following from the same direction or vehicles coming from the opposite direction. In order to avoid such the second accident in advance, it could be effective to send a message about the first accident to neighboring vehicles. Moreover, if there is a system which can detect the situation that the motorcycle is going to topple over, it can be called a collaborative active safety to notify the rider and neighboring vehicles of the situation before the accident occurs.

Most of the conventional active safety systems control actuator devices (brake, etc.) by the sensing values directly. In our research, however, a proposed system processes the sensing values, derives what the current situation is, and achieve active safety for the motorcycle. This concept derives the current situation of a motorcycle, in other words, it converts sensing values to a meaningful primitive of vehicle motion. It allows us to consider how to grasp the situation and how to control the motorcycle separately. In this research, we develop a motion sensing system to grasp the situation of a motorcycle.

### 3.2 Requirements of Proposed System

The proposed system considers the behavior of a motorcycle, distinguishing between vehicle motion and trajectory as mobility. The vehicle motion is classified into speed and attitude. We assume that the state of speed is classified into the following four primitives: stationary, accelerating, constant speed and decelerating. The state of attitude is classified into the following three primitives: uprightness, left-leaning and right-leaning. Complex behaviors like turning a corner, turning around and running through cars are expressed by a combination of such primitives. We design the proposed system so that it can assess which primitives the current sensing values indicate and it can derive the current situation from the combination of the current and past primitives.

The proposed system uses the attitude angle and speed of a motorcycle. The attitude angle can be obtained from acceleration sensors and gyro sensors, and the speed can be obtained from acceleration sensors and a GPS receiver. Additionally, the trajectory can be obtained from a GPS receiver. The acceleration sensors and the gyro sensors are also used to obtain the trajectory because GPS is not enough to obtain accurate trajectory for traffic safety.

A smartphone off the shelf is equipped with not only a three-axis acceleration sensor, a three-axis gyro sensor and a GPS receiver but also a compass sensor. Nowadays smartphone is getting popular and many people have one. To utilize a rider's smartphone as a sensing device instead of a dedicated on-board sensor, the rider and their motorcycle can be received ITS services and application without extra cost for the devices. However, it has not confirmed whether a smartphone is capable as a sensor for such traffic safety services and applications. The proposed system can be used to evaluate the capability of sensors in a smartphone for vehicle motion sensing.

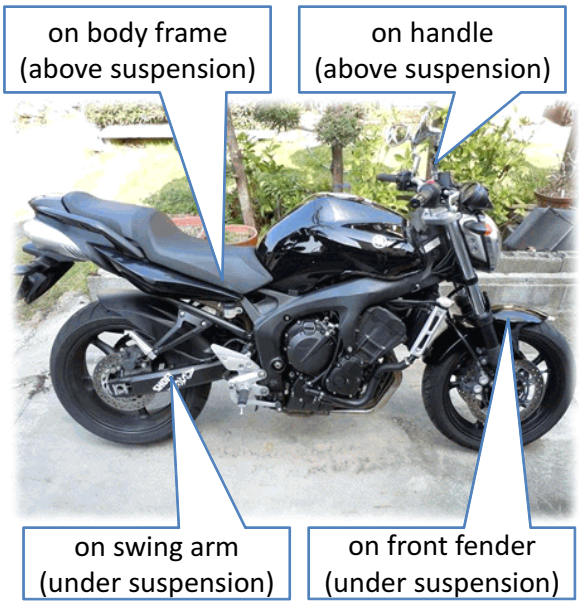



Figure 1: Sensing points on Motorcycle

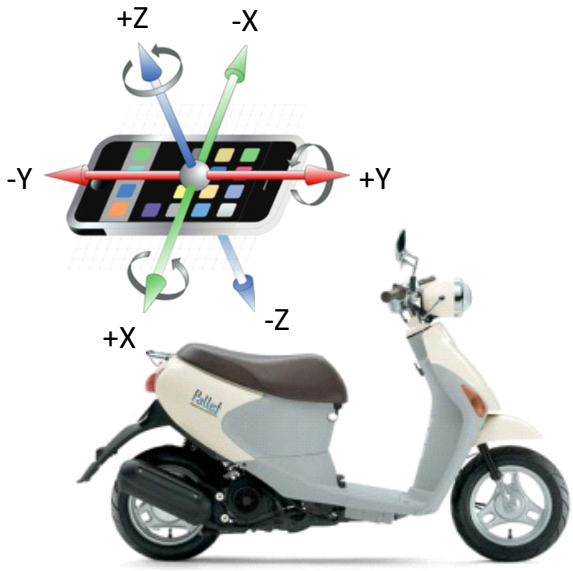



Figure 2: Axes of sensors

## 4 Prototype of Proposed Motorcycle Motion Sensing System

### 4.1 Structure of System

The proposed motion sensing system for a motorcycle consists of a GPS unit and several sensing units. The GPS unit consists of a microcomputer and a GPS receiver. The sensing unit consists of several sensors including an acceleration sensor and a gyro sensors for motion sensing. A general motorcycle has two joint points: one is between the front tire with the handle and the body frame; the other is between the body frame and the rear tire with the swing arm as shown in Fig. 1. Therefore, the body of a motorcycle consists of the three parts. The system equips the sensing unit on each of the parts as shown in Fig. 1 because each of them moves different slightly. Each of the units of the system in this paper records the sensing values on the internal memory card during riding a motorcycle, and we analyze it off line. In the future, we will let the system output the sensing values in real time.

The sensing unit consists of a three-axis acceleration sensor, a three-axis gyro sensor, a three-axis geomagnetic sensor (compass sensor), a barometric sensor and a temperature sensor. A reason why the unit includes a barometric sensor and a temperature sensor is the following. A motorcycle is easily to be affected by wind and air since a motorcycle can not be self-standing and generally unstable without a rider's control. Especially, when a motorcycle runs on a bridge and overtakes a large-size car like a truck or a bus, the motorcycle is often subject to lateral forces from wind or the atmosphere. The change in the air pressure level can be used to decide if the motorcycle is running through neighboring cars. Therefore, we put the two sensors in the sensing unit.

We define the axes for the three-axis acceleration sensor, the three-axis gyro sensor and the three-axis geomagnetic sensor as shown in Fig. 2.

### 4.2 Requirement Study of Sensing Range of Each Sensor

Here, we discuss the sensing range of each sensor for a motorcycle's motion sensing.

The proposed system is designed to distinguish the following primitives as mentioned in Sec. 3.2 in order to grasp a motorcycle's behavior.

**[The primitives of a motorcycle's behavior]**

**Speed** Stationary, Accelerating, Constant speed, and Decelerating

**Attitude** Uprightness, Left-leaning, and Right-leaning

Note that Left-leaning and Right-leaning could be subdivided in the future.

The proposed system targets at the vehicle motions caused by a rider's operation. We assume that the target range of the acceleration sensor is wider than $1.5$G because the current most fast stock motorcycle needs at least two seconds from 0 to 100km/h ($\simeq$ 30m/s). The target sensing range of the barometric sensor and the temperature sensor is within the usual range.

The target sensing range of the gyro sensor and the sampling rate of each sensing value are decided according to the following preliminary experiment in Sec. 4.2.1. As another preliminary experiment, we have developed a simple smartphone application on iPhone4S and the application records the three-axis acceleration values, the three-axis gyro values, and the compass value and the latitude and longitude from GPS on the internal storage. The application is running at maximum 80Hz sampling on iPhone4S without any other applications on its memory, and it runs at 50Hz sampling stably with other applications on its memory. Therefore we have decided that the sampling rate of a smartphone application is 50Hz when iPhone4S is used as a sensing device.

The system could sense other things like the engine revolution speed and the road surface condition then the primitives mentioned above. To detect the engine revolution speed with an acceleration sensor, the sensor needs to detect high frequency signal from the engine vibration. The frequency of the signal is 20Hz when the engine runs idle at 1200rpm (20Hz), and the frequency reaches 100Hz even when a motorcycle is running as usual (about 6000rpm). As a result, it needs more than 200Hz sampling to detect the exact engine speed from the signal and, thus, it is not reasonable, so the proposed system does not consider detecting the engine speed. The engine speed can be detected easily and exactly with another simple device on the line from the ignition coil or ECU (electronic control unit) of a motorcycle.

The maximum frequency $f$ of vibration caused by the road surface condition is derived as $f = \frac{v}{x}$ where the vehicle speed is $v$m/s and the minimum distance between bumps on the road is $x$ meters. Given the sampling rate $s$ Hz, $s$ $f$ should hold in order to detect the bumps. The sampling rate $s$ becomes 600Hz when the speed is 30m/s (108km/h) and the distance between bumps is 10cm. Additionally, 1.2 meter-spaced bumps can be detected with 50Hz sampling and 60cm-spaced bumps can be done with 100Hz sampling when the speed is 30ms. As a result, the proposed system can be used to detect big bumps on the road surface.

The width of a motorcycle is usually between 60cm to 1 meter. We need to decide the sampling rate in order that the system can estimate where a motorcycle is in a lane and detect whether a motorcycle is running through neighboring cars. A vehicle at 30m/s runs 30cm (half of the width) within 0.01 seconds (100Hz). Therefore we have decided that the sampling rate of the dedicated sensors in the proposed system is 100Hz.

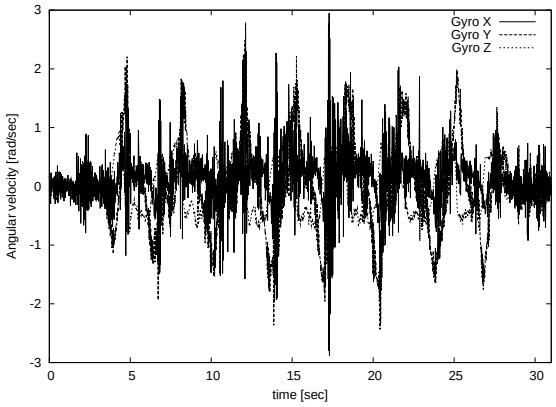



Figure 3: Original sensed values of Slalom behavior

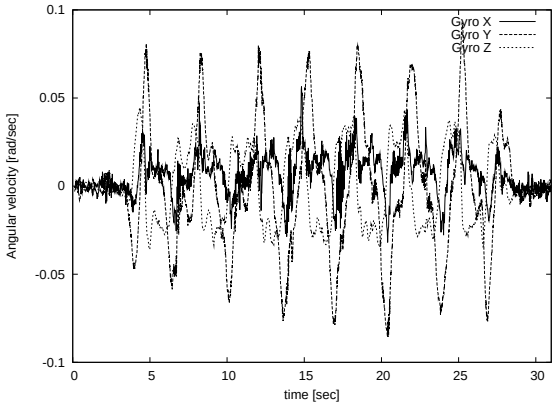



Figure 4: Noise-reducted sensed values of Slalom behavior (LPF: FIR(N=4, CO=5Hz))

#### 4.2.1 Preliminary Experiment

We have investigated the frequency of the behavior of a motorcycle through this preliminary experiment. The quickest motion of a motorcycle caused by its rider's usual operation is regarded as slalom. In this experiment, we have been obtaining sensing values of the equipped gyro sensor on a motorcycle while the motorcycle runs through a slalom course with 10 meter-intervals. We used a standard-type 600cc motorcycle, YAMAHA FZ6N and set the sampling rate to 50Hz.

The original sensed values of the three-axis gyro sensor is shown in Fig. 3. These values contain much of high-frequency noise and, thus, we applied a low pass filter, FIR (finite impulse response) filter with $N = 5$ and the cut-off frequency is 5Hz, to the original values and obtained the noise-reduced values as shown in Fig. 4. The signals in Fig. 4 shows that left-leaning and right-leaning motion occurred eight times within 30 seconds. In addition, according to the result in Fig. 3, it is reasonable that the sensing range of the gyro sensor is rad/s.

Figure 5 shows the frequency analysis result of the sensed values. According to Fig. 5 (b), the peak of each of the signals is at 0.3Hz. The reason is that it took about three seconds to run through an interval in the slalom course. Additionally, the second peak of the signal of X-axis value is around 0.6Hz and that of Y and Z-axis are around 1Hz. As a result, the quickest motion cause by a rider's operation is at most 1Hz and, thus, sampling at 50Hz is enough to detect such vehicle motions.

### 4.3 Specification of Proposed System

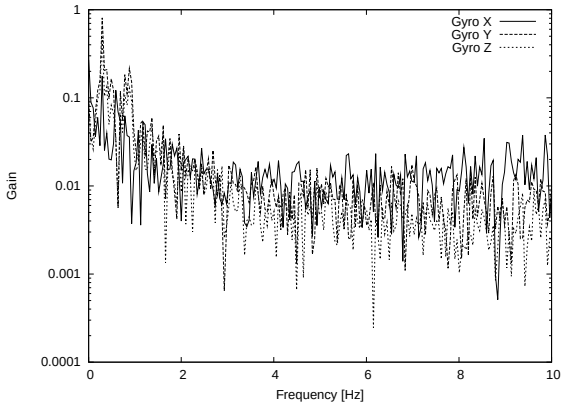
We utilize mbed LPCA1768 [4] as the microcomputer of both the GPS unit and the sensing unit. Mbed consists of a low power 32bit CPU running at 96MHz and 50mW and six analog input/output ports with A/D converter and 20 digital input/output ports. There are many useful peripheral devices and an integrated development environment. Mbed is suitable to be used for a prototype of a system, and we can built it easily. The price of Mbed is about 5000JPY and that of a peripheral board named Board-Orange including a 16x2 LCD and a microSD slot is about 4000JPY. We develop the units of the system with Mbed and Board-Orange.

The GPS unit consists of an Mbed and a GPS receiver. We use a GPS module GT-723F by CANMORE ELECTRONICS CO., LTD. This module outputs location information complaint with NMEA-0183. GPS receiver is connected to Mbed, and Mbed records the latitude and longitude on a microSD card every second. Table 1 shows the specification of the modules in the GPS unit.

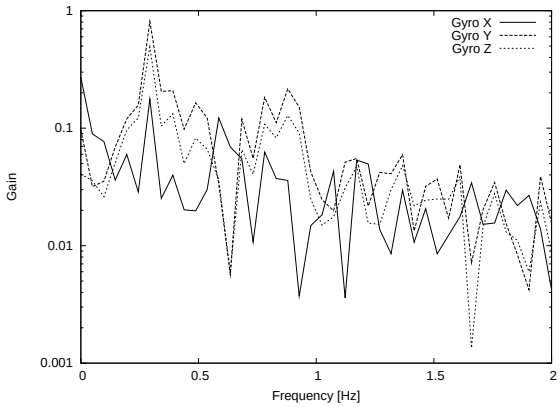
The sensing unit consists of an Mbed, a three-axis acceler-

Table 1: Specification of Modules in GPS Unit

| sensor | maker | model | sensing range | price |
|---|---|---|---|---|
| microcomputer | mbed | LPCA1768 | – | 5000JPY |
| peripheral module | Kiban honpo | board Orange | – | 4000JPY |
| GPS | CANMORE ELECTRONICS | GT-723F | – | 2800JPY |
| MicroSD card | Transcend | microSDHC 8GB | Class 6 | 840JPY |




(a) Frequency = 0 to 10 Hz




(b) Frequency = 0 to 2 Hz

Figure 5: Frequency Analysis of Sensed values of Slalom behavior

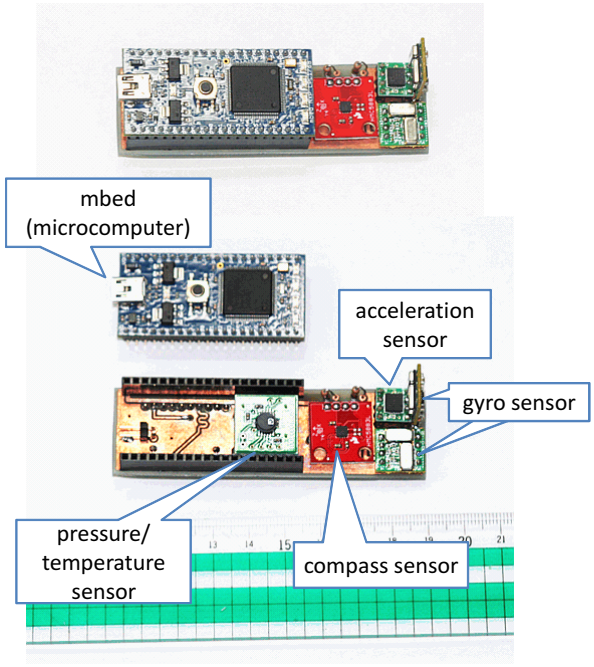



Figure 6: Overview of Developed Sensing Unit

ation sensor, two two-axis gyro sensors, a three-axis geomagnetic sensor and a barometric and temperature sensor. The two two-axis gyro sensors are used like a three-axis gyro sensor because a three-axis gyro sensor was not available when we developed the unit. One of the two two-axis gyro sensors is rotated by 90 degree from the other, and its positional relation has been kept in the unit. The sampling rate of each sensor is 100Hz. Table 2 shows the specification of the modules in the sensing unit.

Figure 6 shows the overview of the sensing unit and Fig. 7 shows the definition of the three axes of sensing data.

## 5 Experiment

To evaluate the proposed system, we equipped the system on two motorcycles: the standard-type 600cc motorcycle mentioned above and a sport-type 400cc motorcycle. The GPS unit is on the gas tank and each of the four sensing units is on the handle, on the front fender, on the body frame, and on the swing arm as shown in Fig. 1. We also put a smartphone with the sensing application as mentioned in Sec. 4.2.1 on the handle.

To get the sensing values on various situations, we went through highways and expressways with the system. Figure 8 shows the sensing values while the sport-type motorcycle was changing from the left lane to the right lane on an expressway. We have confirmed the following things through the experiment.

Since the sensing unit on the body was located above a suspension whereas the sensing unit on the front fender was located under the suspension, the amplitude of the sensed values on the body (“body” in Fig. 8) is smaller than that on the front fender (“tire”). Moreover, since the rider steers first before leans the body when turning a corner or changing lanes, the sensed values on the front fender (“tire”) reacted first before that on the body reacted. Comparing the sensed values of the sensing unit on the front fender (“tire”) with that of the smartphone on the handle (“iPhone”), the sensors on iPhone4S are enough to sense these motions.

Table 2: Specification of Modules in Sensing Unit

| sensor | maker | model | sensing range | price |
|---|---|---|---|---|
| microcomputer | mbed | LPCA1768 | – | 5000JPY |
| 3axis acceleration | Kionix | KMX52-1050 | 2G | 1000JPY |
| 2axis gyro | Murata | ENC-03R | 5.2rad/s | 400×2 JPY |
| 3axis geomagnetic | Honeywell | HMC5883L | – | 1495JPY |
| barometric and temperature | VTI technologies | SCP1000-D01 | 30k–120kPa | 1800JPY |
| MicroSD card | Transcend | microSDHC 8GB | Class 6 | 840JPY |

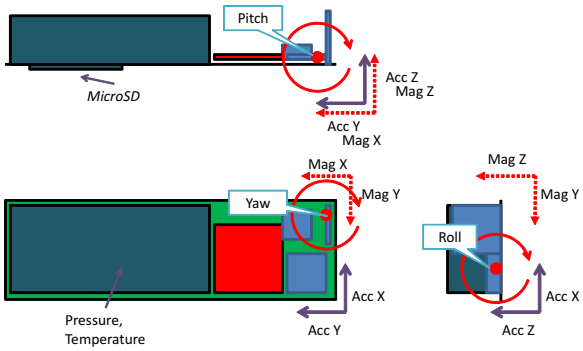



Figure 7: Sensing Axes of Developed Sensing Unit

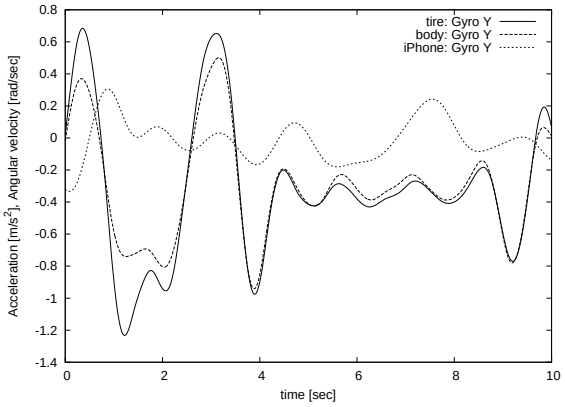



Figure 8: Sensed values of Developed Sensing unit and Smartphone

## 6 Conclusions

In this paper, we have proposed a motion sensing system to grasp the situation of a motorcycle for vehicle and traffic safety. We have developed a dedicated sensing unit for the system and have evaluated the availability of a smartphone as the sensing device with the system. Comparing the sensed values of the sensing unit on the front fender (“tire”) with that of the smartphone on the handle (“iPhone”), the sensors on iPhone4S are enough to sense these motions.

In future work, we will develop an algorithm to classify the primitive from sensed values and detect the motorcycle’s behavior.

## REFERENCES

[1] Eiji Shibata. Development of driving assist system “EyeSight” by new stereo camera. *Journal of Automotive Engineering*, 63(2):93–98, 2009. (in Japanese).

[2] Subaru. EyeSight. `http://www.subaru.jp/eyesight/`. (in Japanese).

[3] Japan National Police Agency. Statistics of traffic accidents in FY2010. `http://www.npa.go.jp/hakusyo/`.

[4] NXP Semiconductors NV. mbed: Rapid Prototyping for Microcontrollers. `http://mbed.org/`.

# Session 4:
# Algorithm, Software & System
# (Chair: Takuya Yoshihiro)

# Task-Driven Device Ensemble System Supporting Seamless Execution of User Tasks Despite Multiplexed Interruptions

Tatsuo Tomita[*], Kazumasa Ushiki[**], Yoshiaki Kawakatsu[**], Nobutsugu Fujino[***], and Hiroshi Mineno[****]

[*]Fujitsu Laboratories Ltd., Japan
[**]Human Solution Laboratory, Human Centric Computing Laboratories, Fujitsu Laboratories Ltd., Japan
[***]Human Centric Computing Laboratories, Fujitsu Laboratories Ltd., Japan
[****]Graduate School of Science and Technology, Shizuoka University, Japan
{tomita.tatsuo, ushiki.kazumasa, kawakatsu.yoshi, fujino}@jp.fujitsu.com, mineno@inf.shizuoka.ac.jp

***Abstract*** – In the real world, multiple tasks that people conduct in their daily lives are often interrupted. In particular, when multiplexed interruptions occur while people are conducting tasks, they often forget to complete tasks that they were in the midst of accomplishing, prior to such numerous interruptions. It would be possible for people to accomplish such multiple tasks more efficiently if information and communication technologies (ICT) were leveraged to assist and support them in completing their tasks.

We have been proposing a "task-driven device ensemble system", which employs a user's handheld mobile device linked with various electronics devices available in the user's surroundings, to support execution of user tasks. We have expanded on this system to enable seamless execution of user tasks even when faced with multiple interruptions of such tasks. This paper provides an overview of requirements of our proposed system, and describes a prototype system we implemented, in addition to describing a sample case study of how the system can support retailers with their task execution. We also evaluate usability and practicality of our proposed system. Our qualitative and quantitative evaluation results verify that our proposed system satisfies the following targeted requirements and objectives, thus demonstrating that the system is sufficient for practical use.

***Keywords***: device ensemble, UPnP, task-driven, multiplexed interruptions, human centric

## 1 INTRODUCTION

We are currently conducting R&D in "Human-Centric Computing", in which information and communication technologies (ICT) subtly and unobtrusively support users, without the need for explicit user-operation. In the real world, depending on the users' real-time situations, users are often interrupted while they are in the midst of accomplishing various tasks in their daily lives – at times, if such interruptions are multiplexed, users may forget to complete some of those tasks.

For example, as illustrated in a hospital scenario in reference [1], nurses are assigned numerous patients and must complete routine tasks. However, if a nurse is interrupted during a task, while bearing in mind the priority of various tasks, the nurse is required to complete a multitude of tasks within limited time – if ICT could be leveraged to assist them in task management, nurses would have more time to focus on the tasks themselves as their core duties, thereby helping to prevent medical malpractice.

We have been proposing a "task-driven device ensemble system", which employs the users' handheld mobile devices such as smartphones, linked with electronic devices readily available in user surroundings, to enable greater efficiencies for task execution by individuals. In view of the aforementioned, the primary issue is how well the task-driven device ensemble system can handle multiplexed task interruption.

This paper describes a newly designed task-driven device ensemble system that operates seamlessly even with multiplexed task interruptions. The remainder of this paper is comprised as follows:

In Chapter 2 we describe related work. In Chapter 3, we present the concept of task-driven device ensemble systems, and our proposed newly designed task-driven device ensemble system. In Chapter 4, to evaluate usability of our proposed task-driven device ensemble system, we describe a prototype system that supports store clerks at retailers for consumer electronics and home appliances. In Chapter 5, we verify the results of our usability and performance evaluations. Chapter 6 describes our conclusion and future works.

## 2 RELATED WORK

There is already a considerable body of research addressing human behavioral support that is dependent on a person's context, or context-aware navigation systems [2]–[12], as well as research related to device collaboration. At the same time, very little work has been conducted on the two fields in combination.

Examples of work on context-aware navigation systems or human behavioral support are as follows: "Task-based mobile service navigation system" [2] employs a task model that analyzes real-world problems, thereby making it possible to search for service provider sites when a user specifies a task. iHospital [3] instantaneously supports business tasks in the real world. By providing hospital staff with Bluetooth-enabled communications units so that they can determine the location of other staff, and by sharing each other's status using mobile phones equipped with messaging capabilities, they are able to quickly respond to emergency surgeries. Wieland et al. [4] proposes and

describes the implementation of a system for creating workflows based on sensor-detected contexts. WTAS [5] models tasks using a Petri net and decides which task should be performed based on the user's context as ascertained using wearable sensors. Once a task is decided, information such as maps is provided to support the execution of the task. Most of these papers focus on how to acquire the user's context and leverage it in supporting the user's tasks. Although these papers share the same objective as our work in this paper, they do not involve the linking of devices.

There have been a number of works addressing device collaboration [13]-[19], particularly using Universal Plug and Play (UPnP) [20], such as the following examples: Mets et al. [13] describes a context-aware multimedia management system for the home environment using UPnP. All content is integrated in a way that prevents the user from being aware of its location, and the MediaRenderer [21] closest to the user is automatically selected. Gashti et al. [14] makes use of UPnP proxies. In addition to enabling UPnP services (this includes fine-grained services that would ordinarily be called "functions") to be employed across subnets, each user's device and service information is registered, making it possible for users to automatically use services depending on the context. Ubiquitous e-Helper [15] is a composable UPnP-based service platform for linking among smartphones. Each of these studies uses UPnP to link between devices, and contexts. At the same time, they do not go as far as to consider interruptions in tasks.

The following are works that combine context-aware navigation and device linking: Task Computing [22] proposes a task-centric technology for supporting people in performing tasks using services in the user's vicinity. In this study, human tasks are regarded as collections of services in nearby devices. In its implementation, however, the system first collects nearby services and then displays available tasks to the user based on these services. By contrast, in the system we propose, tasks are defined based on the user's context and then services on nearby devices are collected to execute those tasks. To add to this, their research is focused on an ontology for service linking. Bidot et al. [23] proposes, and then discusses the implementation and evaluation of, a workflow-management system in which workflows are created based on contexts and devices are controlled according to workflows. This system involves device ensembles. For example, to achieve the goal of helping a user relax at home, the system will control the lighting, as well as the air conditioning and a music player. UPnP is employed for this, and the Device Manager (DM) exists on household and other networks. This approach does not, however, take into account linking between the user's handset and nearby devices when the user moves around. While these works share the same goal as our research, they differ in their implementation from the task-driven device ensemble (device collaboration) that we have originally proposed.

Each of these works is focused on collecting contextual information and suggesting tasks for the user. In contrast, we are focused on what happens after a task is executed, i.e. multiplex interruptions that occur during a task and the recovery from these interruptions.

# 3 TASK-DRIVEN DEVICE ENSEMBLE

## 3.1 Concept behind the Task-Driven Device Ensemble

To support users in executing tasks, we have proposed a task-driven device ensemble in which the task at hand is first determined by the user's context, and then devices necessary for that task are discovered and are linked together. Figure 1 illustrates the concept behind the task-driven device ensemble.

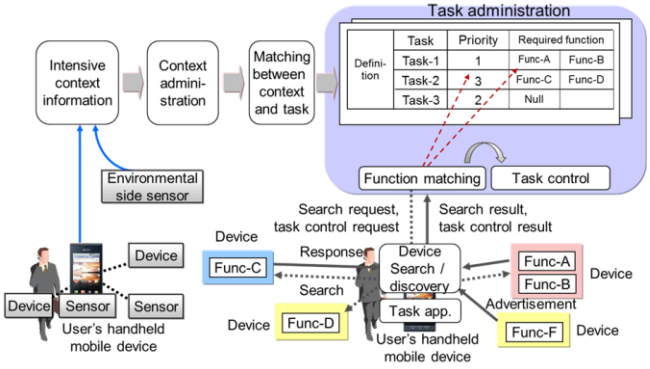



Figure 1: Concept behind the task-driven device ensemble

We presume that users will always be carrying with them handheld mobile devices such as smartphones equipped with multiple sensors. In the cloud, this sensor data can be combined with other environmental sensor data and abstracted in the user's context.

The task that best matches the user's context is selected. A task administration mechanism manages the priority of each task and the functions required to execute tasks. Tasks for users to perform are defined in advance by the users themselves, or particularly in the case of fixed job tasks, by a field manager. The task manager searches for devices in the user's vicinity that feature functions needed to perform a task - if all the functions are discovered, the task is selected, devices that have the required functions are linked, and the task is executed.

If multiple tasks can be executed given the functions in the devices, the highest priority task is selected and executed. If the task can be performed on the user's handheld mobile device itself even without being linked to any nearby devices, there is no need for requested functions for the task. In such a case, the requested functions in the task definition table shown in Figure 1 are defined as null.

## 3.2 Proposed Task-Driven Device Ensemble

We propose a task-driven device ensemble that allows multiplexed interruptions, in which it possible for the user to resume a previous task after encountering multiple task interruptions. In the workplace, in particular, there is typically a flow for tasks. At the same time, user task flows

do not simply proceed in a linear order. Taking into consideration the priority of the tasks at hand, users may occasionally be interrupted during a task in order to perform a new task, only to return to the previous task upon completing the interrupting task.

To implement such a system, we expanded a basic task-driven device ensemble system, by adding a task state administration function to the task administration server. Figure 2 illustrates the task administration function added to the task administration server. If, during the execution of Task-2, a higher priority Task-1 arrives, the already-running Task-2 is put into interrupt mode and pushed onto the interrupt stack. Once Task-1 is complete, Task-2 is popped off the stack. This, in turn, enables multiplexed interruptions to be handled correctly.

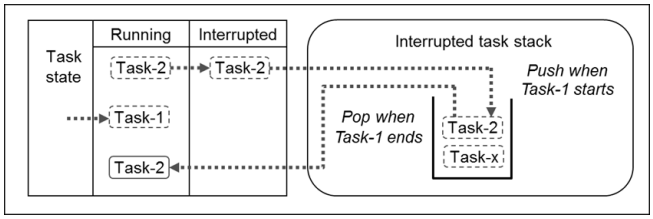



Figure 2: Task state administration for handling multiplexed interruptions

Figure 3 outlines the sequence whereby an already-running application for Task-2 is interrupted by an application for Task-1.

(1) When the start request message for Task-1 arrives, the task control compares the priority of Task-1 with the priority of Task-2, which at that moment is running on the user's handheld mobile device (e.g. smartphone). Because Task-1 has a higher priority, the sequence proceeds to step 2.
(2) The task control causes the function matching unit to determine whether the functions required by Task-1—that is, Func-A and Func-B—can be supported by the devices nearby the user's handheld mobile device.
(3) The function matching unit sends a search request message to the user's handheld mobile device's device search/discovery unit.
(4) To determine whether nearby devices can support the functions required by Task-1, the device search/discovery unit multicasts a UPnP search message to nearby devices.
(5) Devices that are able to offer any of the needed functions respond to the search request message.
(6) The device search/discovery unit sends the search results received from the devices to the function matching unit.
(7) The function matching unit checks if Task-1 can be executed by those devices. In this case, it decides that Task-1 can be executed, and it notifies the task control of this result.
(8) Before starting the Task-1 application, the task control sends a suspend request message to the task execution control on the user's handheld mobile device in order to suspend the Task-2 application.
(9) Upon receiving the suspend message, the task application execution control suspends the Task-2 application.
(10) The task application execution control sends a reply message informing of the Task-2 application's suspension.
(11) After the Task-2 application has been suspended, the task control requests the start of the Task-1 application.
(12) The task application execution control starts the Task-1 application.
(13) Task-1 is executed using device collaboration with the devices near the user.
(14) Upon the completion of Task-1, the Task-1 application notifies the task application execution control of the completion.
(15) The task application execution control sends the task control notice that Task-1 is complete.
(16) The task control requests that the Task-2 application, which had been suspended by the Task-1 application, be resumed.
(17) The task application execution control resumes the suspended Task-2 application.

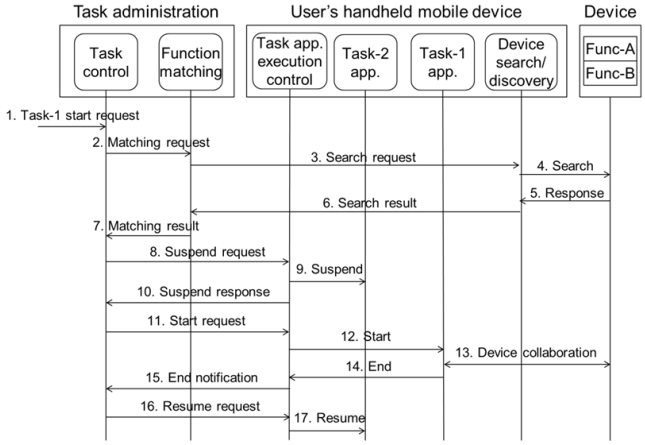



Figure 3: Sequential chart of task interruption control

The interworking between the task administration server and the user's handheld mobile device enables automated task switching, thus preventing users from forgetting to accomplish tasks, without additional burden to the user. As a user support system, it is ideal if user intervention can be kept to a minimum to minimize erroneous user operation, thus enabling appropriate task switching via the user support system.

# 4 PROTOTYPE SYSTEM

We developed a prototype system based on the concept described in the preceding chapter, in order to evaluate its usability and practicality. This chapter is comprised of a description of the system design, implementation and a service scenario.

## 4.1 System Design

Requirements and quantitative objectives for the prototype system were set as follows:

(1) Management of multiplexed task interruptions and resumption
As described in the previous chapter, for the purpose of supporting human tasks, the system should be able to manage multiplexed interrupted tasks and then enable suspended tasks to be resumed.
As a numeric objective, in view of the system's practical use, it should be able to handle 20 multiplexed interruptions which is anticipated will be sufficient for use at nearly any feasible worksite or field.

(2) Real-time task processing
For reasons of usability and to enable a user-friendly and stress-free experience for users, the time between user operations and the delivery of device collaboration results should be within 2.0 seconds, comparable to the minimal average latency experienced when a TV is turned on by remote control.

(3) Scalability for simultaneous task execution
The task administration server handles numerous users' handheld mobile devices, and processes the tasks of these handheld mobile devices simultaneously. Therefore, scalability is important. As a numeric objective, in light of practical considerations, each server should have a capacity of handling 10,000 users' handheld mobile devices.

To satisfy requirement (1), we are deploying the task state administration mechanism that was described in Figures 2 and 3 of Section 3.2. This will ensure that users can resume suspended tasks without fail, even when there are multiple interrupting tasks. For the remaining system requirements and objectives, we have designed an implementation structure as described in the following section.

## 4.2 Implementation

Figure 4 illustrates the structure of the prototype system and Table 1 outlines the system's hardware specifications. The system has been implemented using C++ for the nearby devices and Java for everything else.

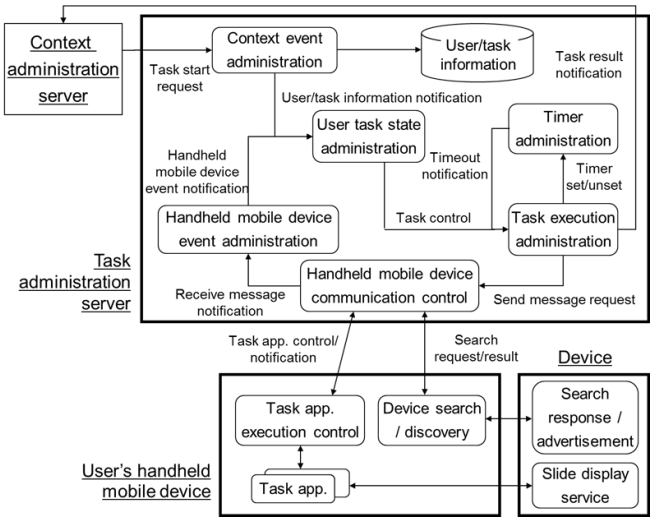


Figure 4: Prototype system configuration

On the server side, the system consists of a context administration server and task administration server, and the device side consists of user's handheld mobile devices and nearby devices. Each of these is discussed below.

Table 1: Hardware specifications of prototype system

| Equipment Name | Specification |
|---|---|
| Context administration server | CPU: Xeon 2.4GHz × 2, Memory: 1GB, OS: Fedora |
| Task administration server | CPU: Xeon 3.06GHz, Memory: 1GB, OS: Windows Server 2003 |
| User's handheld mobile device | Android smartphone, OS: Android 2.1 |
| Device (notebook PC) | CPU: Celeron 1.2GHz, Memory: 2GB, OS: Windows XP Professional SP3 |

**Context administration server**

The role of the context administration server is essentially to derive the user's context from information collected by the user's handheld mobile device and sensors in the user's environment. With this said, our research is primarily focused on the task administration server. Therefore, for the purpose of this study we have implemented a pseudo-context administration server that only sends task start requests and receives task execution result notifications.

**Task administration sever**

The task administration server executes tasks at the request of the context administration server and sends acknowledgement of task execution results to the context administration server. The functions of the server are as follows:

(1) Context event administration
Upon receiving an event from the context administration server, this function will employ user information and task information to determine which users and tasks relate to the event. It will then send a notification to the user task state administration function containing information about the user and the executable task.

(2) User task state administration
In accordance with each of the server's event administration functions, this function manages each user's task execution state, i.e. whether a user is executing a task or waiting to execute a task. It also instructs the task execution administration function to execute, interrupt and resume tasks. In addition, it stacks interrupted tasks and controls the interruption of higher priority tasks.

(3) Task execution administration
This function receives instructions from the user state administration function, issues search requests for functions needed by users' handheld mobile devices, and issues requests for the execution, interruption and resumption of task applications.

(4) Handheld mobile device event administration
This function awaits events from user's handheld mobile devices. Upon receiving an event, it will notify the user state administration function of the event.

(5) Handheld mobile device communication control

This function controls communications with users' handheld mobile devices and sends/receives messages.

(6) Timer administration
This function manages timers when various kinds of requests are resent by the task execution administration function.

**Users' handheld mobile devices**

Android smartphones were used for the users' handheld mobile devices, and UPnP was employed for controlling the devices and searching for functions available on the devices and user handheld mobile devices. We used a UPnP library developed by Fujitsu for use with Android. The functions of the prototype user handheld mobile devices user are as follows:

(1) Task applications
These are applications intended to support the execution of tasks. We developed applications based on a test scenario for supporting sales clerks at an electronics retail store. Details of the scenario are described in section 4.3.

(2) Task application execution control
This function awaits events from the user state administration function. Upon receiving an event, it will execute, suspend, or resume a task application, and then acknowledge the result.

(3) Device/service search
This function will use UPnP's M-SEARCH to search for devices or UPnP services (functions for executing tasks) that have been specified by the task administration server.

**Nearby devices**

For this prototype, we employed a notebook PC as a nearby device. The implemented features are as follows:

(1) Search response/advertisement
Search response will respond to the user handheld mobile device if the searched service (functions) exists on the device. Advertisements will periodically multicast the services offered by the device.

(2) Slide display service
In terms of the UPnP services on our prototype, we only developed a slide display service.

## 4.3 Service Scenario

As illustrated in Table 2, we developed a task application to support sales clerks working at an electronics retail store. Because the purpose of our study was to perform a basic test with multiple task interruptions, we selected a relatively simple scenario. Even for more complicated scenarios, the process during multiplex interruptions will remain basically the same.

We envision a work support flow for these applications as follows:

(1) Store clerk A is replenishing merchandise (default state).

(2) If a customer visits the store, the customer care task application will interrupt clerk A's merchandise replenishment job. We assume that each customer can be identified by means of a store membership card, etc. Clerk A operates the customer care task application to access the customer's information and then serves the customer.

(3) If there is a display device available, such as a notebook PC, that can be used to explain a product, the task application for product explanation is executed and the previous customer care task application is interrupted. Clerk A operates the current product explanation task application and then gives an explanation using product sales slides shown on the nearby display device.

Table 2: Task applications of prototype system

| Application Name | Device Collaboration | Overview |
|---|---|---|
| Merchandise replenishment | × | The staff can confirm the number of sales items to be replenished. |
| Customer care | × | The staff is notified that there is a customer to be taken care of. |
| Product explanation | ○ | The staff can explain the sales items by displaying description slides on a nearby PC display. |

# 5 EVALUATION

We evaluated the prototype system for usability and practicality. This chapter discusses the system's qualitative and quantitative evaluations.

## 5.1 Qualitative Evaluation

We confirmed that the implemented prototype operates with accuracy. Figure 5 is a screenshot of an actual user's handheld mobile device. It displays the various phases of the system's operation. First, store clerk A is executing the merchandise replenishment task. Second, a customer arrives at the store, and the customer care task interrupts the previous task. Third, store clerk A serves the customer, and the explanation task interrupts the previous task. Last, the interrupted tasks resume in sequential order.

This demonstrates that the task applications were executed properly and that transitions with multiple task interruptions worked well.


(a)Merchandise replenishment (b) Customer care (c) Product explanation

Figure 5: Screenshots of user's handheld mobile device in prototype system

## 5.2 Quantitative Evaluation

In terms of quantitative objectives, we evaluated the prototype system for the number of multiplexed interruptions, processing time, and scalability.

**Number of multiplexed interruptions**

We estimated the number of possible multiplexed interruptions for the system. To accomplish this, we measured the elapsed time for multiplexed task interruptions (namely, the processing time required for interrupting and resuming) for each number of concurrent multiplexed interruptions. We then measured the time interval from when the pseudo-context administration server sends a new task execution notification, through the interruption of the previous task by the new task, and up until the screen of the newly executed task is displayed. 5 measurements were taken and averaged for each number of concurrent multiplexed interruptions from 2 to 20. Figure 6 shows these measurement results.

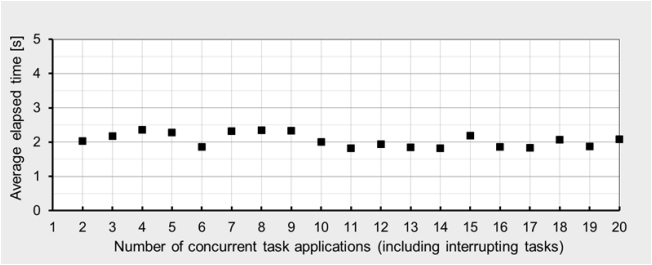



Figure 6: Elapsed time for task interruption

This graph shows an average time between 1.9 to 2.3 seconds for the entire range of measurement, despite variations in time intervals resulting from fluctuations in the handheld mobile device load due to wireless network traffic and other factors. These results indicate that, for up to at least 20 interruptions, the number of multiplexed interruptions does not have an impact on processing time. Therefore, the maximum number of multiplexed interruptions is at least 20. This, in turn, satisfies the quantitative objective for system requirement (1).

**Processing time**

We measured processing time in terms of usability. For this purpose, 2 kinds of time were measured: (1) the amount of time for handheld mobile device-side device collaboration to have an impact on practical usability; and (2) server-side task event processing time.

With respect to (1), we evaluated the operability of a task application running on the user's handheld mobile device. To do so, using the product explanation task, we measured the time elapsed between when the user presses the slide control button and when the result of the designated slide control is actually displayed on the PC through the device collaboration.

Table 3 shows the average elapsed time after performing this operation 5 times.

Although the slide show start time includes the time required for Adobe Acrobat Reader to launch and is therefore longer than other operations, all of the operations run in a sufficiently short enough amount of time. This confirms that the device collaboration mechanism works for users without any stress.

Table 3: Elapsed time for device collaboration

| Operation | Elapsed Time (sec) |
|---|---|
| Start slide show | 2.0 |
| Change slide | 0.3 |
| End slide show | 0.4 |

For (2), we evaluated the task-related event processing time of the task administration server, i.e. the server response time when responding to context changes, such as when task execution becomes possible, from the context server, as well as the task administration server response time when responding to operations on users' handheld mobile devices. To do so, we measured the processing time of the task administration server while gradually increasing its processing load. The specific evaluation criteria are outlined below:

(1) Task execution without interruption:
Under the condition that there is no task application running in the user's handheld mobile device, the time between the pseudo-context administration server requesting the execution of the merchandise replenishment task and the task administration server requesting that the user's handheld mobile device executes the task.

(2) Task execution with interruption:
Under the condition that the merchandise replenishment task application is running in the user's handheld mobile device, the time between the pseudo-context administration server requesting the execution of the customer care task and the task administration server requesting that the user's handheld mobile device executes the task.

(3) Task resuming:
The time between receiving notice of the completion of the customer care task from the user's handheld mobile device, up through notifying completion of the task to the pseudo-context administration server and sending a request to the user's handheld mobile device in order to resume the merchandise replenishment task.

Figure 7 shows the average time for each of the above processes, each of which was measured 30 times.

Each processing time displays a slight upward trend on account of increased server load, but even the longest time was only 130 milliseconds. Therefore, it can be said that task execution and handheld mobile device processing can be performed in almost real time.

This satisfies system requirement (2). Discrepancies between the processing times are considered to be due to differences between each of the executed processes. This graph also demonstrates that task interruptions require CPU power and that resuming tasks consumes the largest amount of CPU power.

If searching for devices or services (functions) is performed prior to the execution of a task, the search time should be added to (1) or (2) in Figure 7. According to

UPnP specifications, the wait time for M-SEARCH must be greater than or equal to 1 second and should be less than 5 seconds inclusive. As a result, this wait time is dominant, and in consideration of usability, it should be set to 1 second.

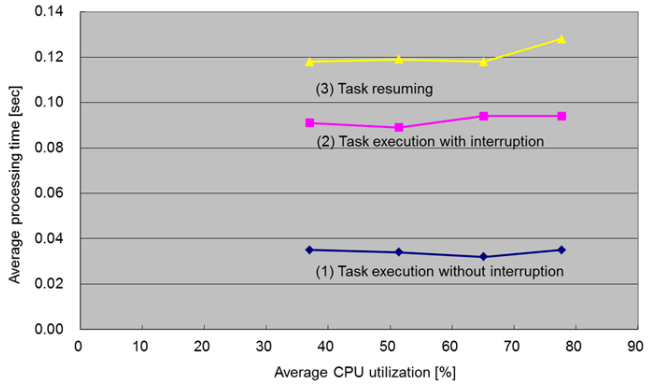



Figure 7: Task event processing time of prototype system

**Scalability**

We evaluated the prototype system for scalability. For this purpose, we estimated (1) the capacity of the task administration server, and (2) the processing performance of the task administration server.

With respect to (1), our prototype system consumes exclusively 1 thread per user. Therefore, the system capacity is equivalent to the number of threads that can be simultaneously generated on the server. In the case of our prototype system, this number was 12,000.

For (2), we measured the number of tasks that the task administration server was able to process in one hour while gradually increasing the server processing load. We defined the maximum server capacity to be the largest number of tasks possible before CPU utilization reached 80%. We measured processing performance for 2 scenarios: 1) The simplest single-task scenario, and 2) the most complicated 3-task scenario. The single-task scenario only executed the merchandise replenishment task from Table 2. The 3-task scenario executed the 3 tasks and interruptions in the order listed in Figure 5.

The results are shown in Figure 8 and 9. The number of tasks processed per hour was approximately 760,000 for the single-task scenario and 670,000 for the 3-task scenario. In both scenarios, only 1 task is processed at a time, so if a user were to perform each task in an average of 3 minutes, for a single user it would be possible to process 20 tasks in an hour. Therefore, the potential system capacity would be approximately 38,000 users for single-task scenarios and 33,000 users for 3-task scenarios. This difference is considered to be due to the additional overhead required for task interruptions and resuming.

The previous capacity estimate of 12,000 user threads is thought to be due to limitations in the settings of the Java programming language, which is used on the server. In any case, these results satisfy the quantitative objective for system requirement (3) of our prototype system.

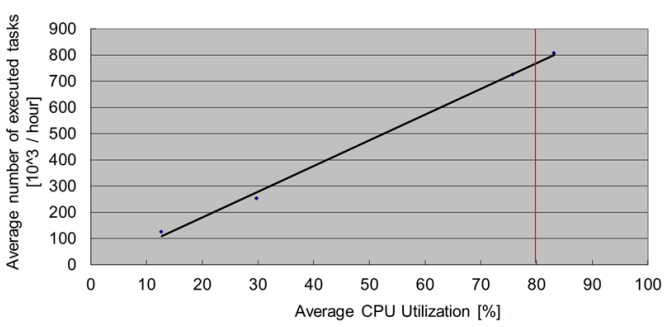



Figure 8: Task processing capacity for single-task scenario

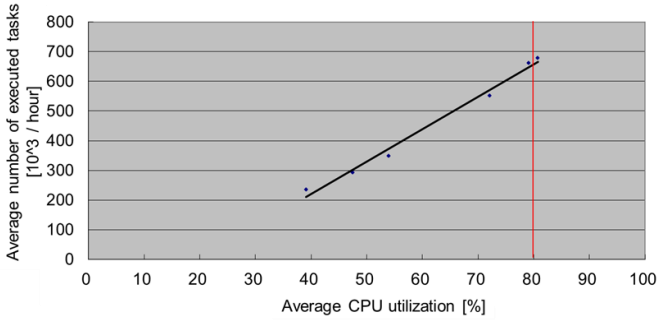



Figure 9: Task processing capacity for 3-task scenario

## 6 CONCLUSION

We proposed an expanded "task-driven device ensemble system" that supports user behavior, via seamless execution of user tasks despite multiplexed interruptions. We also implemented a prototype system envisioned to support store clerks at retailers, and evaluated the prototype system to verify that it indeed operates with precision as intentionally designed. Our quantitative evaluation results were: (1) Seamless execution of user tasks even with at least 20 multiplexed interruptions, (2) Real-time processing within 2.0 seconds via linked devices, and task processing time of less than 130 milliseconds in the task administration server, (3) Scalability of system capacity for at least 12,000 users per server. Our results verified that the implemented prototype system satisfied our requirements and objectives, and is sufficient for practical use.

In our future works, we aim to achieve the following: (1) Increase system capacity, (2) System expansion to include operability with non-UPnP devices, (3) Conduct user-derived/user-centric evaluation. For (1), although the system capacity of our current prototype system is dependent on and limited by the number of threads that the system can simultaneously generate, to enable practical use, in future works we will eliminate this limitation by dynamically generating threads as needed. In regards to (2), we will target system operability that includes linking with non-UPnP devices that are widely available. Regarding (3), although for this work our evaluations were primarily to verify our prototype system performance, in future works we intend to evaluate user experience and efficacies through field trials.

## REFERENCES

[1] A. Terada, T. Takaya, R. Nishino, M. Iida, E. Sato, M. Matsutani, Y. Hirabayashi, Y. Sakyo, T. Ibe, N. Matsuzaki, Y. Murakami, and M. Momoi, Anticipating Professional Nursing Practice: Trial and Evaluation of a Bridge Program for Graduating Students Part 3 – Multitasking Scenario Exercises -, Journal of St. Luke's Society for Nursing Research, Vol.12, No.2, pp. 58-64 (2009).

[2] Y. Fukazawa, T. Naganuma, K. Fujii, and S. Kurakake, Proposal and User Evaluation of Enhanced Task-based Mobile Service Navigation System, Information Processing Society of Japan (IPSJ) Journal, Vol.50, No.1, pp.159-170 (2009).

[3] T. R. Hansen, J. E. Bardram, and M. Soegaard, Moving out of the Lab: Deploying Pervasive Technologies in a Hospital, IEEE Pervasive Computing, Vol.5, No.3, pp.24-31 (2006).

[4] M. Wieland, P. Kaczmarczyk, and D. Nicklas, Context Integration for Smart Workflows, Sixth Annual IEEE International Conference on Pervasive Computing and Communications, pp.239-242 (2008).

[5] S. Xiahou, and X. Xing, The WTAS Framework: A Petri net based wearable task assistance system, 2nd International Conference on Information Science and Engineering, pp.2487-2490 (2010).

[6] D. Cheng, H. Song, H. Cho, S. Jeong, S. Kalasapur, and A. Messer, Mobile Situation-Aware Task Recommendation Application, The Second International Conference on Next Generation Mobile Applications, Services and Technologies, pp.228-233 (2008).

[7] A.Terracina, S. Beco, T. Kirkham, J. Gallop, I. Johnson, D. Randal, and B. Ritchie, Orchestration and Workflow in a mobile Grid environment, Fifth International Conference on Grid and Cooperative Computing Workshops, pp.251-258 (2006).

[8] M. Michou, A. Bikakis, T. Patkos, G. Antoniou, and D. Plexousakis, A Semantics-Based User Model for the Support of Personalized, Context-Aware Navigational Services, First International Workshop on Ontologies in Interactive Systems, pp.41-50 (2008).

[9] F. Tang, M. Guo, M. Dong, M. Li, and H. Guan, Towards Context-Aware Workflow Management for Ubiquitous Computing, International Conference on Embedded Software and Systems, pp.221-228 (2008).

[10] Z. Chen, Z. Shao, Z. Xie, and X. Huang, An attribute-based scheme for service recommendation using association rules and ant colony algorithm, Wireless Telecommunications Symposium, pp.1-6 (2010).

[11] D. Bouneffouf, A. Bouzeghoub, and A. Gancarski, Following the User's Interests in Mobile Context-Aware Recommender Systems: The Hybrid-e-greedy Algorithm, 26th International Conference on Advanced Information Networking and Applications Workshops, pp.657-662 (2012).

[12] A. Seetharam, and R. Ramakrishnan, A context sensitive, yet private experience towards a contextually apt recommendation of service, 2nd International Conference on Internet Multimedia Services Architecture and Applications, pp.1-6 (2008).

[13] K. Mets, J. Nelis, D. Verslype, P. Leroux, W. Haerick, F. De Turck, and C. Develder, Design of a Context Aware Multimedia Management System for Home Environments, Computation World: Future Computing, Service Computation, Cognitive, Adaptive, Content, Patterns, pp.49-54 (2009).

[14] S. Gashti, G. Pujolle, and J. Rotrou, An UPnP-based context-aware framework for ubiquitous mesh home networks, IEEE 20th International Symposium on Personal, Indoor and Mobile Radio Communications, pp.400-404 (2009).

[15] J. Zao, Y. Liu, M. Yang, S. Li, W. Chen, C. Chen, K. Huan, J. Hu, and L. Kuo, Ubiquitous e-Helpers: An UPnP-based home automation platform, IEEE International Conference on Systems, Man and Cybernetics, pp.3682-3689 (2007).

[16] K. Togias, C. Goumopoulos, and K. Achilles, Ontology-Based Representation of UPnP Devices and Services for Dynamic Context-Aware Ubiquitous Computing Applications, Third International Conference on Communication Theory, Reliability, and Quality of Service, pp.220-225 (2010).

[17] J. Ding, Y. Sheng, C. Tu, C. Huang, and J. Su, The Management of Device Group for Home Automation Network, Fifth International Conference on Digital Telecommunications, pp.44-47 (2010).

[18] Y. Cui, and H. Lee, Method of Device Matching for QoS Based UPnP Framework in Cloud Computing Service, First ACIS/JNU International Conference on Computers, Networks, Systems and Industrial Engineering, pp.222-227 (2011).

[19] E. U. Warriach, E. Kaldeli, J. Bresser, A. Lazovik, and M. Aiello, Heterogeneous device discovery framework for the Smart Homes, IEEE GCC Conference and Exhibition, pp.637-640 (2011).

[20] UPnP Forum, http://www.upnp.org/.

[21] UPnP Forum, MediaRenderer: 3 Device, http://upnp.org/specs/av/UPnP-av-MediaRenderer-v3-Device.pdf (2010).

[22] R. Masuoka, B. Parsia, and Y, Labrou, Task Computing - The Semantic Web meets Pervasive Computing -, The Second International Semantic Web Conference, pp.866-881 (2003).

[23] J. Bidot, C. Goumopoulos, and I. Calemis, Using AI Planning and Late Binding for Managing Service Workflows in Intelligent Environments, 2011 IEEE International Conference on Pervasive Computing and Communications, pp.156-163 (2011).

[24] K. Ushiki, T. Tsunoda, Y. Kawakatsu, N. Hasegawa, and N. Fujino, Development and Evaluation of Task Driven Device Orchestration System for User Task support, IPSJ SIG Technical Report, Vol. 2011-MBL-58, No.21, pp.1-6 (2011).

[25] Y. Kawakatsu, K. Ushiki, T. Tsunoda, N. Hasegawa, and N. Fujino, Development and Evaluation of Task Driven Device Orchestration System for User Work support, FIT2011, Proceeding No.4, M-019, pp.309-310 (2011).

[26] JAVA, http://www.oracle.com/jp/technologies/java/overview/index.html

# Implementation of a Prototype Bi-directional Translation Tool between OCL and JML

Kentaro Hanada†, Hiroaki Shinba†, Kozo Okano†and Shinji Kusumoto†,

†Graduate School of Information Science and Technology, Osaka University, Japan
{k-hanada, h-shimba, okano, kusumoto}@ist.osaka-u.ac.jp

***Abstract*** - OCL (Object Constraint Language) is an annotation language for UML. It can describe specification more precisely than natural languages. In recent years, MDA (Model Driven Architecture) based techniques have emerged, thus translation techniques such as translation from OCL to JML (Java Modeling Language) have gained much attention. Our research group has been studying not only a translation method from OCL to JML but also a translation method from JML to OCL. Bi-directional translation between OCL and JML supports (1) development by RTE (Round Trip Engineering) at the design level, and (2) multi-translations among various formal specification languages. This paper presents our implementations based on model translation techniques.

***Keywords***: Model-Driven Architecture, OCL, JML, design by contract

## 1 Introduction

In recent years, MDA (Model Driven Architecture) [14] based techniques have emerged. MDA targets a lot of languages; thus, translation techniques such as translation from UML (Unified Modeling Language) to some program languages, have gained much attention. Several research efforts have proposed methods which automatically generate Java skeleton files from UML class diagrams [6], [11]. Some of them are publicized as plug-ins for Eclipse. Translation techniques such as OCL (Object Constraint Language) [20] to JML (Java Modeling Language) [15] have been also studied.

- OCL is a language to describe detailed properties of UML and standardized by OMG (Object Management Group).
- JML is a language to specify properties of a Java program. It is also used in some static program analyzers such as ESC/Java2[8].

JML aims for describing more detail properties than OCL does. Both OCL and JML are based on DbC (Design by Contract) [18] and able to provide property descriptions of classes or methods.

We have already proposed a concrete method which translates a UML class diagram with OCL into a Java skeleton with JML [19]. Our translation tool is implemented by mapping each of statements in OCL and JML by Java program. However, model translation which uses some abstract models representing common aspects of the target languages, is the main-stream of MDA. Also one of our original goals is providing uniform techniques to translate from OCL to a lots of specification languages. Our previous prototype of translation tool and other tools provided by other researchers [19], [23] have low reusability. Thus, we consider that we have to develop a useful tool which supports the above issues. And, a major aim of existing tool is fulfillment of translation, so existing tool has low usability.

This paper presents a prototype translation tool from OCL to JML. First, we define syntax of UML with OCL using Xtext [5]. Next, we describe translation rules from UML with OCL to Java skeleton with JML. The syntax and rules are used to translation in a framework provided by Xtext which is a plug-in for Eclipse. The syntax description is independent of translation rules in Xtext, therefore, the syntax part has high reusability. Xtext can generate a dedicated editor of the defined syntax. The editor has some high usability functions. For example, code completion, detection of syntax errors, and so on.

We also implemented a tool which translates from JML to OCL by using the same approach of translation from OCL to JML. Round Trip Engineering (RTE) [17], [25] is a method which gradually refines model and source code by the repeated use of forward engineering and reverse engineering. The aim of implementation of translation from JML to OCL is to support RTE at specification description level.

The organization of the remainder of the paper is as follows. Sec.2 describes the background of this research and related work. Sec.3, 4, and 5 describe the implementation of our tool, experimental results, and discussion, respectively. Finally, Sec.6 concludes the paper.

## 2 Background

In this section, we present background of our research such as some techniques and related works.

### 2.1 Design by Contract

Design by Contract is one of the concepts about Object Oriented software designing. The concept regards specifications between a supplier (method) and a client (calling the method) as contract. It is introduced to aim at enhancing software quality, reliability and reusability. The contract means that if caller of its class the pre-condition then its class must also ensure the post-condition. A pre-condition is the condition that should be satisfied when a method is called. For example, conditions for the arguments of method are pre-conditions. On the other hands, a post-condition is the condition that should be satisfied when a process of method ends. If the pre-condition is not satisfied then caller of its class has errors and if the post-

condition is not satisfied then class has errors. These separate responsibilities have a clear distinction between the role of developers, and it is useful to distinct the causes of software defect.

## 2.2 OCL and JML

OCL details properties of UML models. It is standardized by OMG. UML diagram alone cannot express a rich semantics of relevant information on an application. OCL allows to describe precisely the additional constraints on the objects and entities present in a UML model.

JML is a language to detail constraints of Java methods or objects [15]. The constraints are based on DbC. It is easy for novices to describe properties in JML because the syntax of JML is similar to that of Java. There are various kinds of tools to verify the source codes with JML annotations. For example, JML Runtime Assertion Checker (JMLrac) [24] checks that there are no contradictions between JML constraints and runtime values of the program. JMLUnit automatically generates a test case skeleton and a test method for JUnit [1]. The original use of JML was for runtime assertion checking [4]. Several program verification tools are, however, provided such as ESC/Java(2) [7], [13], JACK [3], KeY [2], Krakatoa [16], and so on.

## 2.3 Model Translation

In order to represent an overview of a system to develop, in usual, a model for the system is used in design phase. For example, UML class diagram is one of such models.

QVT [9] and ATL [12] are typical model translation techniques. Model translation has two types. One is Model2Model (M2M) that translates from model to model. The other type is Model2Text (M2T) that translates from model to code. For example, UML2Java [6] provides a M2T translation capability.

## 2.4 Round Trip Engineering

RTE (Round Trip Engineering) is a method that gradually refines model and source code by the repeated use of forward engineering and reverse engineering. RTE makes some feature changes and requirement changes easier [17], [25]. RTE development has needs to keep the conformity of the models with source code. In general, when the code or models are changed, then the corresponding models or code are changed automatically by using tool of supporting RTE.

## 2.5 Xtext

Xtext [5] is a framework to support to define syntax of model and to define translation rule from model to text. Xtext can generate a dedicated editor of the defined syntax. The editor has some high usability functions. For example, code completion, detection of syntax errors and so on. Moreover, if Textual models are written on the editor, the models are translated to text according to defined translation rules automatically.

## 2.6 Related Work

Some existing methods [10][23] do not enough support iterate feature that is the most basic operation among collection loop operations. Our research group proposed a technique to resolve this problem by inserting a Java method that is semantically equal to each OCL loop feature [19].

An iterate feature is an operation which applies an expression given as its argument to each element of a collection which is also given as its another argument.

$$\text{Set}\{1, 2, 3\} \; > \text{iterate}(i\text{: Integer; } sum\text{ : Interger} = 0 \mid sum \quad i) \tag{1}$$

Expression (1) defines an operation that returns a value which represents a sum of all elements in Set. In expression (1), the first argument ($i : Integer$) defines an iterator variable. The second argument ($sum : Integer = 0$) defines a variable which is used to store the return value and it's initialization. The third argument ($sum \quad i$) stands for an expression that is executed iteratively in the loop.

In JML or Java, expressions like "$sum \quad i$" cannot be evaluated dynamically. For example, if Expression (1) was resolved by the same way of Expression (2), the result of the translation would be like Expression (3).

$$\text{JMLTools.flatten}(setOfSets) \tag{2}$$

$$\text{JMLTools.iterate}(\text{int } i, \text{int } sum = 0, sum \quad i, set) \tag{3}$$

In Expression (3), the expression "$sum \quad i$" is evaluated only once when the method is called. In other words, the expression is not evaluated iteratively and dynamically in every collection element.

Our research group proposed a technique to resolve this problem by inserting a Java method that is semantically equal to each OCL loop feature [22]. It is worthful that the algorithm deals with the iterate feature because an iterate feature is widely used.

Expression (4) shows the general format of an iterate feature. The variables $e$, $init$, $body$ and $c$ mean an iterator variable, a declaration of the return value and its initialization, an expression executed in the loop, and a Collection type variable respectively.

$$c \; > \quad \text{iterate}(e; init \mid body) \tag{4}$$

Figure 1 shows a general format of our newly created method. The keywords $\mu()$, $T_1$, $T_2$ and the variable $res$ mean a function which translates an OCL expression into a Java expression, a variable declared in $init$, a variable $e$, and the name of a variable declared in $init$, respectively.

# 3 Implementation

In this section, we will present the implementation of our translation tool.

```
private T1 mPrivateUseForJML01(){
   μ(init);
   for (T2 e: μ(c1))
      res = μ(body)
   return res;
}
```

Figure 1: General Java Template of the Method for Iterate Feature

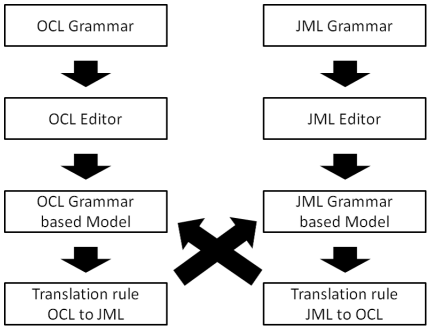



Figure 2: overview of implementation using Xtext

## 3.1 The policy of Implementation

We implemented translation tools using Xtext. First, we defined the syntax of the models. Next, we defined translation rules from the syntax of model to source code. Both translations from OCL to JML and from JML to OCL, respectively, are implemented by above method. Figure 2 is the overview of the implementation.

Our implementation method has the following advantage.

- Syntax and translation rules are defined independently; thus the part of syntax description can be reused.
- Xtext can generate a dedicated editor of the defined syntax. The high usability functions explained in the before section.

## 3.2 Translation from OCL to JML

In this section, we will present the implementation of translation from OCL to JML.

### 3.2.1 Syntax definition of UML with OCL annotation

We defined syntax of UML class diagram with OCL. In terms of parts of UML, we use a conventional syntax rules, and we extended the syntax. The extended syntax can append OCL constraints. In terms of parts of OCL, we take account of some cases of return type and others. Translation rules depend on syntax of model, therefore careful thought of case analysis helps semantic analysis and enhances utility for reuse syntax of model. The function of the generated editor depend defined syntax. Therefore, the more we take account of case analysis, the more the generated editor has high usability. With all these factors, careful thought of case analysis helps in usability and reusability.

```
entity Sample {
    inv : sampleVariable >= 0
    sampleVariable : Integer
}
```

Figure 3: input model

```
package ;
public class Sample {
/*@
invariant ((sampleVariable)>=0);
@*/
    private Integer sampleVariable;

    public Integer getSampleVariable() {
        return sampleVariable;
    }

    public void setSampleVariable(Integer sampleVariable) {
        this.sampleVariable = sampleVariable;
    }
}
```

Figure 4: result of translation from OCL to JML

### 3.2.2 Definition of translation rule from OCL to JML

Table 1,2 and 3 are a part of the translation rules of OCL to JML. A translation function of an OCL statement to a JML statement is expressed by $\mu$. Here, Integer, Real and any type of Boolean are expressed by $a_i$. Any type of Collection is expressed by $c_i$.

We defined translation rules OCL-JML in much the same rules as the existing research [19]. As Table 4, many collection loops can be replaced by iterate features. Therefore, our existing research replaced the collection loop with the iterate feature. However, this translation method has some challenges. For example, low readability of generated code is one of challenges. In order to resolve this problem, if OCL loop feature directly translates JML loop feature, we do not replace the collection loop with the iterate feature.

Figure 3 is an example of a textual model based on the defined syntax. Figure 4 is an example of a result of a translation from the model to the text.

### 3.2.3 Type of Oclvoid

OclVoid type is a class which has only a constant, Undefined. It is returned when an object is casted into an unsupported type or a method gets a value from empty collection. Its counterpart of JML is null. However, in OCL, a logical expression such as “True or Undefined”, is not evaluated as undefined expression but True. To deal with OclVoid correctly, the trans-

Table 1: $\mu$ translation table of the numeric type

| | | |
|---|---|---|
| $\mu(a_1 = a_2)$ | = | $\mu(a_1) == \mu(a_2)$ |
| $\mu(a_1 > a_2)$ | = | $\mu(a_1) > \mu(a_2)$ |
| $\mu(a_1 < a_2)$ | = | $\mu(a_1) < \mu(a_2)$ |
| $\mu(a_1 >= a_2)$ | = | $\mu(a_1) >= \mu(a_2)$ |
| $\mu(a_1 <= a_2)$ | = | $\mu(a_1) <= \mu(a_2)$ |
| $\mu(a_1 <> a_2)$ | = | $\mu(a_1) != \mu(a_2)$ |

lation tool needs to treat OclVoid as below.

```
(a_1 == null ? false :
        throw new JMLTranslationException())
```

## 3.3 Translation from JML to OCL

In this section, we will present the implementation of translation from JML to OCL.

### 3.3.1 Syntax definition of Java skeleton code with JML annotation

We defined the syntax of Java skeleton with JML. In regard to Java, we defined syntax of class declaration, class modifier, field variable and method declaration as target of translation. Variable type and others are needed to translate correctly, so we defined the syntax of Java skeleton. In terms of parts of JML, our translation tool can translate a part of formula that defined in JML Reference Manual. JML is more concrete language than OCL, and JML has complex expression that cannot express by OCL. For example, JML has assignment operation and shift operation, but OCL does not have these operations. At the time of syntax definition, we omitted these operation and syntax that cannot translate from JML to OCL. By omitting syntax that does not support translation from JML to OCL, user can input only JML supported by generated editor. Because of this, it becomes that much easier to understand corresponding syntax.

### 3.3.2 Definition of translation rule from JML to OCL

Table 5 is a part of translation rules of JML to OCL.

In terms of elementary operation, translation of JML to OCL only has to replace operator of JML with operator of OCL. However, in order to translate correctly, a part of operator needs to interchange operand. The syntax of JML is similar to that of Java. For example, "+ operator" is used in various cases, "Integer + Integer", "String + Integer" and others. However, OCL does not support operation among different types. On the other hand, JML supports "+ operator" among types not involving numerical type. In terms of loop operation, exists and forall and others are defined as operation of Collection type in OCL. However, it sometimes happens that exists and forall and others are used as for loop of Java in JML. Therefore, loop operation of JML cannot be translated loop operation of OCL. If loop operation is used as Collection in JML, our tool translates JML to OCL. If loop operation is not used as Collection in JML, our tool outputs error messages.

Table 2: $\mu$ translation table of the collection type

| | | |
|---|---|---|
| $\mu(c_1 = c_2)$ | = | $\mu(c_1)$.equals($\mu(c_2)$) |
| $\mu(c_1 > c_2)$ | = | $\mu(c_1)$.containsAll($\mu(c_2)$)&&!$\mu(c_1)$.equals($\mu(c_2)$) |
| $\mu(c_1 < c_2)$ | = | $\mu(c_2)$.containsAll($\mu(c_1)$)&&!$\mu(c_1)$.equals($\mu(c_2)$) |
| $\mu(c_1 >= c_2)$ | = | $\mu(c_1)$.containsAll($\mu(c_2)$) |
| $\mu(c_1 <= c_2)$ | = | $\mu(c_2)$.containsAll($\mu(c_1)$) |
| $\mu(c_1 <> c_2)$ | = | !$\mu(c_1)$.equals($\mu(c_2)$) |

## 3.4 Type inference

In OCL, "==" is used to evaluate whether or not two objects are equivalent. However in JML, "==" is used in order to evaluate whether or not two reference types are equivalent, and "$equals()$" method is used in order to evaluate whether or not two reference types are equivalent. In order to translate correctly, there is a need to distinguish variable type and so on correctly. When translate from JML to OCL, our tool can distinguish type information correctly. However, when user write textual model, our tool cannot distinguish type information.

# 4 Experiments

This section will explain experiments in detail.

## 4.1 Overview of Experiments

We conducted two experiments. The aim of the first experiment (Experiment1) is to evaluate quality of translation from JML that is described in experimental object to OCL. The aim of second experiment (Experiment2) is to evaluate quality of translation from OCL that is generated by our translation tool to JML. It is in order to ensure that our tool has possible application of RTE.

## 4.2 Measurements

In order to evaluate results of translation, we measured two items of the following.

**Ratio of Transformation**

$$Ratio = OCL_{translated}/JML_{all}$$

**Ratio of Reverse Transformation**

$$Ratio = JML_{reverse}/OCL_{translated}$$

$JML_{all}$ is the number of pre-conditions and post-conditions. $OCL_{translated}$ is the number of OCL statements that are translated from JML statements by our translation tool. $JML_{reverse}$ is the number of JML statements that are translated from generated OCL statements by our translation tool.

## 4.3 Results of Experiments

### 4.3.1 Experiment 1

Experiment 1 uses a warehouse management program. Figure 5 shows the class diagram of the warehouse management program. It consists of seven classes. Table 6 shows components of the warehouse management program in details.

Table 3: $\mu$ translation table of the operation of the collection type

| | | |
|---|---|---|
| $\mu(c_1$ >size()) | = | $\mu(c_1)$.size() |
| $\mu(c_1$ >isEmpty()) | = | $\mu(c_1)$.isEmpty() |
| $\mu(c_1$ >notEmpty()) | = | !$\mu(c_1)$.isEmpty() |
| $\mu(c_1$ >excludes($a_1$)) | = | $\mu(c_1$ >count($a_1$) = 0) |
| $\mu(c_1$ >count($a_1$)) | = | $\mu(c_1$ >iterate( $e$; $acc$ : Integer = 0 \| if $e = a_1$ then $acc$ 1 else $acc$ endif)) |

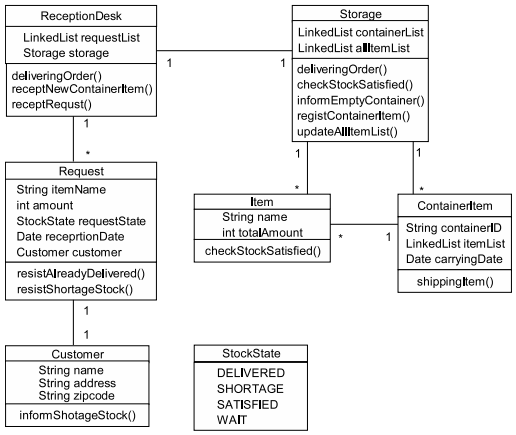



Figure 5: UML class diagram of a warehouse management program

The warehouse management program [21] has correct JML statements by the past research [21]. The number of described pre-condition, post-condition and class-invariant is 130. We used these statements in order to evaluate quality of translation. The result shows that the number of correctly translated statements is 102, Ratio of Transformation is 78.4%. Figure 6, and 7 show the cases of failure translation.

There are many cases of failure translation. For example, if multi-variables are declared in forall feature, then translation from JML to OCL fails. Additionally, we can enumerate the following expressions as other fails : expressions with type operations, typeof operations, applying "+" between String type and numeric type expressions and so on.

### 4.3.2 Experiment 2

In Experiment 1, 102 statements are translated correctly. We rechecked that these generated statements become recognized as translation object of prototype translation tool from OCL to JML. In terms of correctly translated OCL, Ratio of Transformation of translation from OCL to JML is 100%. For this reason, translation from JML to OCL by our tool has no problem. These are, however, some bugs in translation from OCL to JML, because our translation rule is still in the trial phase.

Table 4: a part of correspondence table of Collection-Iterate

| | | |
|---|---|---|
| $c_1$ >exists($a_1 \mid a_2$) | = | $c_1$ >iterate( $a_1$; $res$ : Boolean = false $\mid res$ or $a_2$) |
| $c_1$ >forAll($a_1 \mid a_2$) | = | $c_1$ >iterate( $a_1$; $res$ : Boolean = true $\mid res$ and $a_2$) |
| $c_1$ >count($a_1$) | = | $c_1$ >iterate( $e$; $acc$ : Integer = 0 $\mid$ if $e = a_1$ then $acc$ 1 else $acc$ endif) |
| $st_1$ >select($a_1 \mid a_2$)) | = | $st_1$ >iterate( $a_1$; $res$ : Set($T$) = Set {} $\mid$ if $a_2$ then $res$ >includeing ($a_1$) else $res$ endif) |
| $st_1$ >reject($a_1 \mid a_2$)) | = | $st_1$ >select( $a_1 \mid$ not $a_2$) |
| $c_1$ >any($a_1 \mid a_2$) | = | $c_1$ >select( $a_1 \mid a_2$) > asSequence() >first() |
| $c_1$ >one($a_1 \mid a_2$) | = | $c_1$ >select( $a_1 \mid a_2$) >size()= 1 |

```
/*@
ensures \result.matches("containerID." + containerID
          + "CarryingDate | " + carryingDate + "\n{1}")
@*/
String toString(){
}
/*@
ensures (\forall Request r; requestList.contains(r);
         r.getAmount() > 0);
ensures (\forall Request r; requestList.contains(r)
         && r.getAmount() != \old(r.getAmount());
         r.getRequestState() == StockState.SHORTAGE);
@*/
List deliveringOrder(){
}
```

Figure 6: An example of a failure translation from JML to OCL (input)

```
context ContainerItem::toString()::String
post : result.matches('ContainerID.'
       [type error][type error][type error][type error])

context ReceptionDesk::deliveringOrder()::List
post : requestList->forAll(r:Request|r.getAmount() > 0)
post : requestList and r=(r)@pre and ->forAll(
       r:getRequestState() = StockState.SHORTAGE)
```

Figure 7: An example of a failure translation from JML to OCL (output)

As a result, 98 statements out of 102 statements as input statements are translated correctly, and Ratio of Transformation is 96.1%. And, the result shows that 4 statements have some bug. Figure 8, and 9 show a part of failure case.

OclAsType method is described in the lexical specification. OclAsType method is not, however, described in the translation rules, so that our tool could not translate oclAsType method. We, however, have the modified method of unsuccessful to translate 4 statements. Therefore we will modify our translation rule in the aftertime.

## 5 Discussions

Result of Ratio of Transformation is 78.4% in Experiment 1. Here we implemented our tool as prototype, so our tool has unsupported statements. However, Ratio of Transform of experimental result shows that majority of JML are consisted

Table 5: $\mu$ translation rule from JML to OCL

| | | |
|---|---|---|
| $\mu(b_1?b_2:b_3)$ | = | if $\mu(b_1)$ then $\mu(b_2)$ else $\mu(b_3)$ endif |
| $\mu(b_1<==>b_2)$ | = | $\mu(b_1)$= $\mu(b_2)$ |
| $\mu(b_1<=!=>b_2)$ | = | $\mu(b_1)$ <> $\mu(b_2)$ |
| $\mu(b_1==>b_2)$ | = | $\mu(b_1)$ implies $\mu(b_2)$ |
| $\mu(b_1<==b_2)$ | = | $\mu(b_2)$ implies $\mu(b_1)$ |
| $\mu(b_1 \&\& b_2)$ | = | $\mu(b_1)$ and $\mu(b_2)$ |
| $\mu(b_1 \mid\mid b_2)$ | = | $\mu(b_1)$ or $\mu(b_2)$ |
| $\mu(b_1 \mid b_2)$ | = | $\mu(b_1)$ or $\mu(b_2)$ |
| $\mu(b_1 \hat{} b_2)$ | = | $\mu(b_1$ xor $\mu$(b) |
| $\mu(b_1 \& b_2)$ | = | $\mu(b_1)$ and $\mu(b_2)$ |
| $\mu(\backslash$result) | = | result |
| $\mu(\backslash$old($a_1$)) | = | $\mu(a_1)$@pre |
| $\mu(\backslash$not_modified($a_1$)) | = | $\mu(a_1)$ = $\mu(a_1)$@pre |
| $\mu(\backslash$fresh($a_1$)) | = | $\mu(a_1)$.oclIsNew() |

```
pre : o.oclIsTypeOf(Request)
post : result = (receptionDate.getTime()-
       (o.oclAsType(Request)).getReceptionDate())
       .oclAsType(Integer) or result = 0
op compareTo(o : Object)
```

Figure 8: An example of a failure translation from OCL to JML (input)

```
/*@
requires o.getClass().equals(Request);
ensures (\result == (receiptionDate.getTime()-
         ((o.oclAsType(Request)).getReceiptionDate()))
         .oclAsType(Integer)) || (\result == 0);
@*/
public void CompareTo(Object o){
}
```

Figure 9: An example of a failure translation from JML to OCL (output)

of elementary operation. It shows validity of our translation tool. We describe a part of failure translation.

Our tool could not translate \type keyword which is a primitive operator returning a type name. The reason why the above situation happens is that OCL has no counterpart of \type operator to identify a type name from a designated expression. In terms of this problem, the following manner is thought as a solution approach. First, our tool keeps information on parameter type before translation from JML to OCL. Next, our tool outputs the parameter type directly in OCL statements.

Result of Ratio of Reverse Transformation is 96.1% in Experiment 2. There are some unsuccessful translated statements in the result of translation, because our translation tool from OCL to JML is a prototype. Input OCL was recognized as correct input, therefore it shows that a quality of translated OCL has no problem. It shows that translation rules have some imperfection.

For this reason, the generated OCL has high quality. There is some failure translation due to omission of implementation. In terms of this failure translation, our tool will be able to translate correctly by additional implementation.

## 6 Conclusion

This paper presents concrete method of implementing translation from OCL to JML and reverse translation. The aim of implementation of translation from JML to OCL is to support RTE at specification description level. Also, we applied our tool to a warehouse management program as experimental object and show results of experiments. One of future work is to complete our translation tool. Now, our tool is at the experimental stage, therefore we will implement the rest of our translation tool. For example, our tool cannot treat Undefined correctly and needs to modify on that point. After accomplish implementation of our tool, we will conduct the additional experiment. In terms of evaluation of tool, we will additionally evaluate quality of translation from OCL to JML and from JML to OCL. We have not yet evaluated translation from OCL to JML except for the number of successful translation.

Table 6: Components of warehouse management program

| Class Name | # of methods | # of lines |
|---|---|---|
| ContainerItem | 12 | 224 |
| Customer | 10 | 156 |
| Item | 7 | 110 |
| ReceptionDesk | 8 | 162 |
| Request | 16 | 245 |
| StockState | 0 | 9 |
| Storage | 10 | 258 |
| TOTAL | 63 | 1164 |

For the future, we will make a comparison between result of applying generated JML to review tool for JML and result of applying described JML manually to review tool for JML. As examples of review tool for JML, there is esc/java2, jml4c and so on. In terms of translation tool from JML to OCL, we will make a comparison between generated OCL and described OCL manually to evaluate readability. Also, we will applying generated OCL to review tool for OCL. As examples of review tool for OCL, there is Octopus and so on. Also, we will check carefully to see if our tool can do mutual transformation repeatedly by using our translation tool from OCL to JML and from JML to OCL.

## 7 Acknowledgments

This work is being conducted as a part of Grant-in-Aid for Scientific Research C (21500036).

## REFERENCES

[1] JUnit. http://www.junit.org/.

[2] W. Ahrendt, T. Baar, B. Beckert, M. G. R. Bubel and, R. Hahnle, W. Menzel, W. Mostowski, A. Roth, S. Schlager, and P. Schmitt. The KeY tool. *Software and System Modeling*, 4(1):32–54, 2005.

[3] L. Burdy, A. Requet, and J.Lanet. Java applet correctness: A developer-oriented approach. *K. Araki, S. Gnesi, and D. Mandrioli, editors, FME 2003*, 2805:422–439, 2003.

[4] Y. Cheon and T. Leavens. A runtime assertion checker for the Java Modeling Language (JML). *In Hamid R. Arabnia and Youngsong Mun, editors, the International Conference on Software Engineering Research and Practice (SERP'02)*, pages 322–328, 2002.

[5] Eclipse Foundation. Xtext - Language Development Framework. http://www.eclipse.org/Xtext/.

[6] G. Engels, R.H.ücking, S. Sauer, and A. Wagner. UML collaboration diagrams and their transformation to Java. In *UML1999 -Beyond the Standard, Second International Conference*, pages 473–488, 1999.

[7] C. Flanagan, K. Rustan, M. Leino, M. Lillibridge, G. elson, J. Saxe, and R. Stata. A runtime assertion checker for the Java Modeling Language (JML). *Extended static checking for Java. In ACM SIGPLAN 2002 Conference on Programming Language Design and Implementation (PLDI'2002)*, pages 234–245, 2002.

[8] C. Flanagan, K. Rustan, M. Leino, M. Lillibridge, G. Nelson, J. Saxe, and R. Stata. Extended static checking for Java. In *Proceedings of the ACM SIGPLAN 2002 Conference on Programming language design and implementation*, pages 234–245, 2002.

[9] O. M. Group. Documents associated with meta object facility (mof) 2.0 query/view/transformation, v1.1, 2011. http://www.omg.org/spec/QVT/1.1/PDF/.

[10] A. Hamie. Translating the Object Constraint Language into the Modeling Language. In *In Proc. of the 2004 ACM symposium on Applied computing*, pages 1531–1535, 2004.

[11] W. Harrison, C. Barton, and M. Raghavachari. Mapping UML designs to Java. In *Proc. of the 15th ACM SIGPLAN conference on Object-oriented programming, systems, languages, and applications*, pages 178–187, 2000.

[12] F. Jouault, F. Allilaire, J. Bézivin, and I. Kurtev. ATL: A model transformation tool. *Science of Computer Programming*, 72(1-2):31–39, 2008.

[13] J. Kiniry and D. Cok. ESC/Java2: Uniting ESC/Java and JML. *Construction and Analysis of Safe, Secure and Interoperable Smart devices (CASSIS'2004)*, 3362:108–128, 2005.

[14] A. Kleppe, J. Warmer, and W. Bast. *MDA explained: the model driven architecture: practice and promise*. Addison-Wesley Longman Publishing Co., Inc. Boston, MA, USA, 2003.

[15] G. Leavens, A. Baker, and C. Ruby. JML: A Notation for Detailed Design. *Behavioral Specifications of Businesses and Systems*, pages 175–188, 1999.

[16] C. Marche, C. Paulin-Mohring, and X. Urbain. The KRAKATOA tool for certification of Java/JavaCard programs annotated in JML. *J. Log. Algebr. Program*, 58(1-2):89–106, 2004.

[17] N. Medvidovic, A. Egyed, and D. S. Rosenblum. Round-trip software engineering using uml: From architecture to design and back, 1999.

[18] B. Meyer. *Eiffel: the language*. Prentice-Hall, Inc., Upper Saddle River, NJ, 1992.

[19] K. Miyazawa, K. Hanada, K. Okano, and S. Kusumoto. Class enhancement of our ocl to jml translation tool and its application to a curriculum management system. *In IEICE Technical Report*, 110(458):115–120, 2011.

[20] Object Management Group. OCL 2.0 Specification, 2006. http://www.omg.org/cgi-bin/apps/doc?formal/06-05-01.pdf.

[21] M. Owashi, K. Okano, and S. Kusumoto. Design of Warehouse Management Program in JML and Its Verification with Esc/Java2 (in Japanese). *The IEICE Transaction on Information and Systems*, 91(11):2719–2720, 2008-11-01.

[22] M. Owashi, K. Okano, and S. Kusumoto. A Translation Method from OCL into JML by Translating the Iterate Feature into Java Methods (in Japanese). *Computer Software*, 27(2):106–111, 2010.

[23] M. Rodion and R. Alessandra. Implementing an OCL to JML translation tool. 106(426):13–17, 2006.

[24] A. Sarcar and Y. Cheon. A new Eclipse-based JML compiler built using AST merging. *Department of Computer Science, The University of Texas at El Paso, Tech. Rep*, pages 10–08, 2010.

[25] S. Sendall and J. Küster. Taming model round-trip engineering. In *In Proceedings of Workshop Best Practices for Model-Driven Software Development*, pages 1–13, 2004.

# The Research for the Historical Development of Japanese ICT System Technology & SE Project Management

Masaru Makino*, Tadanori Mizuno**
*Graduate School of Business Administration and Computing Science
(Doctoral Program), Aichi Institute of Technology
**Faculty of Information Science, Aichi Institute of Technology
*m-makino@canvas.ocn.ne.jp
**mizuno@mizulab.net

***Abstract*** — The speed of ICT technological innovation comes fast recently. It had started as science-internet and then business-internet started 30 years ago. In those days the author had jobs in business SE for 30 years and in university associate professor for 17 years.

In this research, the author makes a study of three great technologies (Client-Server, Web Service Technology, and Cloud Computing) & in connection with project management.

In this research, the author has aim that is how project development occurs. And then the author infers technological establishment that is ICT system technology innovation for business network.

## 1. THE HISTORICAL DEVELOPMENT FOR JAPANASE ICT — SYSTEM TECHNOLOGY [10]

Japanese computer history has started as "Computer investigative committee in the radio wave technology" that has investigated in USA.

They have developed computer cooperation works. The member companies were Oki-Electric, Toshiba, NEC, Hitachi, Fujitsu, Mitsubishi Electric Machinery, Matsushita communication industry, Hokusin electric machinery. The interval years of the works were from 1995 to 1960.

And then, computer industry had started from 1961 to 1964. And next time, the second stage companies of the second stage had started. They were technological cooperation systems with USA companies and Japanese companies. Examples: Hitachi — RCA/ Mitsubishi-TRW / NEC-Honeywell / Oki—Electric-Remington Rand (Univac).

Then, third generation computers had announced as IBM System/360. In these eras, it had divided into 3 partitions from 1970 to 2000. The partitions were from following section 1.1 to section 1.3.

### 1.1 Main frame Era(1970~1989)

"IBM" was pronoun in the front half of this Era. Passing for a period of time, by the leadership of the Ministry of International Trade and Industry in 1971, those were 6 makers had been divided to organizations of 3 groups (Fujitsu-Hitachi groups, NEC-Toshiba groups, and Mitsubishi-Oki Electric groups).

### 1.2 Personal Computer Era(1980~1995)

From just before 1980, three personal computers were sold. Those were Hitachi MB-6880 in 1978, NEC PC-8001 in 1979, MZ-80K in 1979. They were called in Japanese "Gosanke" of 8 bits personal computers.

In the Era of 1980, as common standard in general home were put forward by ASCII and Microsoft companies. These systems had continued to 1990.

The type of personal computers was MSX1/ MSX2/ MSX2+/ MSX turbo R.

As domestic production of 16 bits personal computer in 1981, from Mitsubishi Electric Corporation, Genuine 16 bits –personal computer had been sold those have kanji expression CRT display and standard equipment of Floppy disk-driver.

### 1.3 Internet Era(1995~2010~)

In 1994 Netscape Company made public for Web-Browser software. In those Era, Internet Demonstration software were popular those were show using USA white house URL. We could see the page of President of the United States-President Clinton. The author tried this demonstration and then I had noticed this auto-return internet system. The existence of internet was become aware in 1995 as Hanshin Awazi great earthquake disaster. And then reasoning Windows95 had TCP/IP as standard software system, the year of 1996 were called "The first year of Internet". The era of internet, three great ICT system technologies ({1} Client/Server technology, {2}Web service technology, {3}Cloud computing) now had been continued.

### 1.4 Analysis for original knowledge of author's experience (Learning from the Japanese historical ICT -systems) [22][23]

Japanese historical ICT systems are following numbers (1) ~ (8).

(1) History of computer (hardware, software, network), (2)

History of project, (3) History of application system, (4) History of security system, (5) History of Japanese ICT-systems, (6) Cloud computing, (7) Smart computing, and (8) other special systems.

These (1) ~ (8) computing systems are learning target systems.

These were scattered in 1.1 ~ 1.3. Japanese computer industries are full of variety. Nowadays Japanese computer industries are increasing with cooperation system works.

Next future era would like to compose various systems by the combination of mobile money data & other big scale data. In references [22] and [23], there are future estimation that those are loads from cloud to social and big data. It's similar to author's estimation.

## 2 WHAT IS SE-PROJECT [18]

### 2.1 Examples of Project

Before starting the story of SE project, let's probe globally the examples of the project.

Projects are jobs but conditional jobs. What's condition? The conditions are 1) they have time period of jobs, 2) they have budgets, 3) they have theme for purpose, 4) they have WBS (work breakdown structure), 5) the human structures of the project have vender and user, 6) there are stakeholders in vender and in user, and 7) the projects have types and fields. The "types" of projects are the development of production, business transaction, event, and so on. The "fields" of projects are government, economy, society, culture, sports, individual, and so on. Therefore, these types and fields come length and wide, and then the combination of length and wide comes to each project.

Speaking by types and fields, SE projects are combinations of development and economy, culture, society, sports, and so on. SE Projects are placed on the next table.

Table 1: Placement for SE Project

<table>
<tr><td rowspan="3">Work</td><td rowspan="2"></td><td rowspan="2">*PROJECT</td><td>General PROJECT</td></tr>
<tr><td>*SE PROJECT Informatics</td></tr>
<tr><td>Non regular</td><td>Work</td><td colspan="2">Non Project</td></tr>
<tr><td>Business</td><td colspan="3">Regular Work (Daily Work), Business</td></tr>
<tr><td colspan="4">Non Work, Non Business</td></tr>
</table>

In SE project, we developed information systems. In these projects, we say work flow of river water "upper stream (upper term), middle stream (middle term), down stream (down term)".

In upper stream, we do work planning: occurrence of needs, start of project, start of WBS (Work Breakdown Structure), start of WG (Working Group), requirement Definition, and development planning.

In middle stream, we do work designing (system study, system design, software design, decision for method, and so on.). In down stream, we do work making software and making use of the software. We say this work flow as X-axis (upper stream・middle stream・down stream).

Following these work flow, we say Y-axis these are "resources": human, goods, money, information, technology, methodology, thinking method. Moreover, we say Z-axis those are management activity, purpose, strategy, planning, evaluation, control, and so on.

In SE project, project activity cannot succeed if 3 dimensions (X-axis, Y-axis, Z-axis) do not meet well. Project managers are requested thinking power and doing power simultaneously.

### 2.2 Difference between work and business on the Table 1

Difference between work and business is that (1) ~ (3).

(1) Work has wide meaning than business. For example, work means labor or project non-project.

(2) On the other hand, always business has purpose for benefit.

(3) The third section is non work or non business.

## 3. PRACTICE FOR SE PROJECT[3]

### 3.1 "3 Practical - Powers" of SE Projects

The author had explained about "3 dimensions (X-axis, Y-axis, Z-axis)". The SE must have the power that the SE can use these 3 dimensions (X-axis, Y-axis, Z-axis) in the SE Project. The 3 practical powers can display on the next Table2.

### 3.2 Analysis for original knowledge of author's experience

The author wants to say that the SE must have three practical powers those are in the Table 2.

On the other hand, the SE meets various work scenes. Three practical powers must match to the work scenes (please see outline and Note on the Table 2.).

First of all, there are various work scenes, and next many system engineers have many powers. These powers must match to the case by case.

The author thinks that most important power in the 3 powers is mental power (see 5.5).

## 4. FUTURE DEVELOPMENT FOR THE SE-PROJECT MANAGEMENT

### 4.1 Future contract for systems development

From now, we must look at cloud computing and we must think systems development contract for cloud computing.

Table 2: "3 Practical Powers" for SE Project

| 3 Practical Powers | Outline | Notes |
|---|---|---|
| (1)Technology | Fundament/Appli (Industry,Business | System,Software Hardware,Interrnet |
| (2)Management | Plan, Control, Check Process, Quality, Rule | Negotiation Target, Education |
| (3)Mental | Definition Tool(Soft, Hard Internet Etc. Work, Human, Life | Health care Physical power, Heart, Vitality Brave, Spirit |

Especially, in case of global systems, we must have many systems development for assuming cloud computing that we must make estimation and system synthesis

## 4.2 Information system model contract by the Ministry of Economy & Industry [19]

In the world ICT system, we have cloud computing systems. In these systems, we hear that many troubles occur in the world. Then in Japan, we have model contract system for cloud computing systems.

These models are made by MITI (Ministry of International Trade and Industry).

By reference [19], we can see next item theme

(1) MITI model contract for cloud system.
(2)Guide line for Information system security of ASP/ SaaS.
(3) Attention for introduce of cloud computing.
(4) Negotiation for contract on the systems development, especially cloud systems.
(5) All figures of model contract for users.

# 5. PROJECT MANAGEMENT

## 5.1 PMBOK (Project Management Body of Knowledge) Guide [17]

PMI (Project Management Institute) is world maximum wide project management institute. The authorization of most known acknowledgement is "PMP" (Project Management Professional) qualification.

PMBOK (Project Management Body of Knowledge) is the base of ISO 10006 (Project Management Quality Guide). PMBOK is basic knowledge of general items. The structure of PMBOK is systematized as 9 items. Those are (1) Integration, (2) Scope, (3) Time, (4) Cost, (5) Quality, (6) Human Resources, (7) Communication, (8) Risk, and (9) Procurement. We say these items those are "Knowledge area".

On the other hand, we have time flow of project management. We say these time flow of 5 processes as A (Start Process), B (Planning Process), C (Execution Process), D (Watching & Control Process), E (Close Process).

We have big table of many technologies these are composed by 9 knowledge items X 5 processes. Please see next table.

Table 3: Classification of Project Management・Process group & Knowledge Area

| Knowledge Area | (A) progress | (B) progress | | (E) progress |
|---|---|---|---|---|
| (1) | | | | |
| (2) | | | | |
| (3) | | | | |
| ・ ・ | | | | |
| (9) | | | | |

Notes 1:
Table 3 is called "Process Map". This is main table in PMBOK. This table has knowledge & technology by the cross point of horizontal X vertical position those are next representative names.
(A) (1) Making Project Charter
(A) (7) Stakeholder Identification
(B) (2) Requirement Item, Scope Definition, WBS
(B) (3) Making Schedule
(B) (4) Cost Estimation
(B) (9) Planning for Provide
(C) (1) Project Practice Management
(C) (5) Quality Assurance
(D) (1) Watching & Control for Work
(D) (2) Scope Verification
(D) (3) Schedule Control
(E) (1) Ending for Project or Phase
(E) (9) Ending for Provide
Notes 2:
Horizontal name:
(A) Start process, (B) Planning process
(C) Practice process, (D) Watching & Control process, (E) Close process.
Notes 3:
Vertical name
(1) Synthetic Management,
(2) Scope Management,
(3) Time Management,
(4) Cost Management,
(5) Quality Management,

(6) Human Resource Management,
(7) Communication Management,
(8) Risk Management,
(9) Supply Management

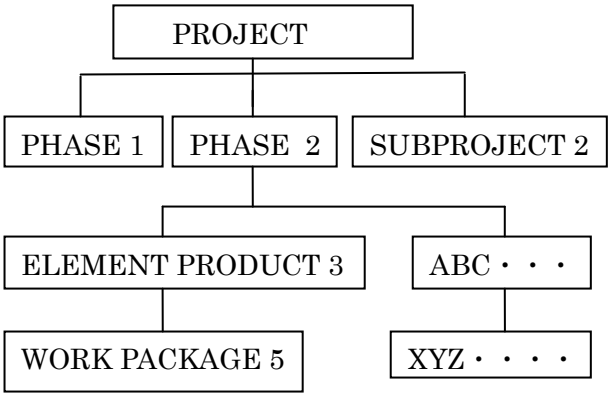
## 5.2 Making of WBS (Work Breakdown Structure) [17]

By PMBOK, WBS is work of making product in this project. Making of WBS is making team and software (Object results in this project team) and related goods. All processes in PMBOK have input, tool & technology, and output.

Then WBS has input (project scope, request statement, group process property), tool & technology (element analysis), output (WBS, dictionary of WBS, scope baseline, project documentation). Therefore by project scope management, WBS has project documentation, making project management planning documentation, definition of activity, cost estimation, setting up budget , quality planning, setting up risk, and supply planning.

## 5.3 Example of WBS (Work Breakdown Structure [13]

Chart 1: Example of WBS




## 5.4 Earned Value Management [12]

EVM is the method for measurement of Scope, Cost, and Schedule. This method is useful for finding of progress status (right/delay/etc.).

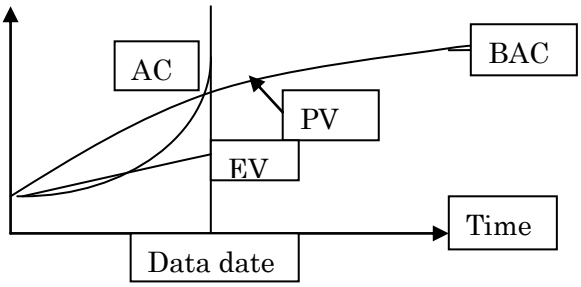
EVM is one of the methods for all projects. In EVM, it explains following fundamental three sides and controls project.

(1) Planed Value (PV): PV is the budget for assigned to performance of the work break down structure.
(2) Earned Value (EV): EV is the value that is performed. It is the budget for assigned to activity of the work.
(3) Actual Cost (AC): AC is the cost that has occurred at the real work. There is no upper limit in the AC.

Actual cost and the difference that is watched base line cost is watched, too. There are Schedule Difference (SD), and Cost Difference (CD).

- The Schedule Difference (SV):SV=EV-PV
- The Cost Difference (CV):CV=EV-AC
- The Schedule Efficiency Index (SPI) : SPI=EV/PV
- **T**he Cost Efficiency Index (CPI): CPI=EV/AC
- Budget At Completion **(**BAC)

Chart 2: EVM (EV/PV/AC) Accumulations




## 5.5 Analysis for original knowledge of author's experience

The author says on 3.1 "3 Practical-powers" of SE projects. The 3 Practical-powers are (1) Technology, (2) Management, (3) Mental.

The author considers that mental power is very much important. Those are work, human, life, heart, vitality, brave, spirit. The author says that he could not see mental power on the PMBOK guide. The author had experience for mental power on his SE-projects (Please see 3.2).

## 6. SYSTEM UNIFICATION OF RIGHT ATTACK FOR THE WORLD-MAXIMUM SCALE PROJECT [7]

We can see the world－Maximum ICT system for the Bank of Mitsubishi Tokyo UFJ「Day2」. Engineer of members have participated in the Max-project ( 6,000 members ). Development period was 1,000 days. The money for development was ¥250,000,000,000.

In this system, we can see many project management technology, for instance WBS (Work Breakdown Structure), PMBOK Guide, Quality control (We can see system),Risk control, WWTIT (World Wide Technical Assurance TASK), SWIFT (Society for Worldwide Interbank Financial Telecommunication).

They say that we can server unification, and then at that time we can use new infra cloud computing. The leader of this develop system says next words.

(1) We go on the royal statesmanship.

(2) Open and aboveboard.
(3) Doing by myself.
(4) Have you seen it?
(5) Job Enrichment & Job Enlargement
(6) Confirmation!
(7) OK? = deadfall
(8) Future is making now.
(9) We can see information.
(10) Everything by name.

## 7. AUTHOR'S TAKING CHARGE OF SE PROJECTS IN HIS LIFE WORK

### 7.1 The author's taking charge of SE Projects

The author's sorts of works were as SE & SE project manager. The author had worked about half century, and he had taken charge of many SE projects. The numbers of times for SE projects were about 15 and so on.

His taking charges of SE projects can divide 3 parts of period in his life works..

At the beginning era, he had worked at the 2 projects. The sort of beginning project was Japan national computer project. He had worked as software developer. This project reader was the MITI (Ministry of International Trade and Industry) on the 1961.

The software name on that Project was "SIP300". This program was the common software name for Japan national computer.

At the second era of Project, the author had taken charge of instructor for SIP300 and then was entrusted with computer science application.

The application was numerical analysis and simulation (operations research) from many universities.

At the middle era of many projects, the author had taken charge of SE projects. In these eras the author had many charge of business online applications.

Among the projects, there was USA company (TRW Corp.).

At the third era of many projects, the author had taken charge of computer instructor: For example, the teacher of HCC (Computer Special School of the Ministry of Labor in Hokkaido), and then special computer school of MITI. Last project of author was instructor in Mitsubishi Kamakura Instruction Center by artificial satellite.

### 7.2 The author's taking charge of SE Projects (No.2)

Table 4 was authors taking charge SE Project. The author took charge about 15 SE Projects.

### 7.3 Analysis for original knowledge

The author had various experience through the SE project on the Table 4. There are 15 projects on the table 4. First of all, the author did not know the word "Project". A few years had passed from the starting his computer work. At that time, the word "project" was born. However, the members of the project did not know how to precede the project.

Through the few projects, the author was worried about the method of job proceeding. The states of affairs are next situation.

(1) Work group of members are mixture from before organization.
(2) The systems of the work were coming apart.
(3) The technologies of the work were coming apart.

At that time, the author had established the work method.

(4) This method of working was called System, Subsystem, and Module-method. This method is similar to WBS (Section5.2/5.3).

Table 4: The author's SE project

| Start | End | PROJECT Name |
|---|---|---|
| 1961 | 1963 | Mitsubishi Corp (Kansai) |
| 1963 | 1965 | Mitsubishi Corp (Kamakura) |
| 1964 | 1965 | Cement Engineer Corp (Tokyo) |
| 1965 | 1966 | Mitsubishi Oil Corp (Yokkaichi) |
| 1967 | 1968 | Toyama Nohkyou |
| 1968 | 1969 | Mitsubishi (Niigata) |
| 1969 | 1970 | Mitsubishi Iron Corp (Tokyo) |
| 1970 | 1971 | Mitsubishi Corp (Tokyo) |
| 1971 | 1973 | Information Corp (Kantou) |
| 1974 | 1977 | Mitsubishi Corp (Kamakura) |
| 1978 | 1983 | Mitsubishi Corp (Tokyo) |
| 1984 | 1988 | Mitsubishi Corp (Tokyo2) |
| 1988 | 1991 | HCC (Hokkaido Comp Colledg) |
| 1991 | 1992 | Mitsubishi Corp (Kamakura) |
| 1992 | 2009 | (University of Fukui Kougyou) |
| (Notes: 2009-1960 = 49 , Half century) | | |

## 8. SYSTEM DEVELOPMENT CONTRACT

### 8.1 Model Contract for System Development by METI (Ministry of Economy, Trade and Industry) [3]

In this subsection, reference [3] is very much useful. In this reference, we can see explanation for commission of software development. I suppose that this commission is one of the laws. And then there are many ICT terms, too.

For examples: RFP (Request for Proposal), SLA (Service Level Agreement), SLM ( Service Level Management ), Stakeholder, License, RFI(Request for Information), ERP

(Enterprise Resource Planning), Cloud Computing, Cloud vender, System Integrator, Security, Risk, Trouble, Mediation, and so on.

## 9. SUCCESS FOR THE SE PROJECT [18]

### 9.1 The Theme for the SE project

As author's theme for the last chance of this paper, the author proposes theme for the SE project. The words of "Success for the SE project" have many meaning.

The answer of this theme should be clearing for many themes of these SE projects. Then what is theme of these SE projects? The author says those are following table 5.

The author says that many projects have many themes. And then project manager keeps each other well informed rule or theme.

In activity of SE project, they should have meeting every morning and evening. On this meeting, they should have each other situation for progress and idea of their SE project.

Table 5: What is the theme of SE Projects?

| Number | outline of the theme |
|---|---|
| 1 | Various matter for those should be resolved. |
| 2 | Goal, Objectives, Target, Aim |
| 3 | Questionable, Doubtful, Trouble |
| 4 | Problems, Tasks |
| 5 | Various special Mission |
| 6 | Various special Duty |
| 7 | Others |

### 9.2 The forward theme and backward theme

There are forward theme and backward theme. The forward theme is the number 2 in the table 5. The backward theme is the number 3 in the table 5. We must think that SE project is one of the economic activity.

### 9.3 general theme of the SE project

As the general SE project, the author arranges the theme of SE project in the next table.

SE project has flow of work (Cf. Section 2). SE project has general work flow and corresponding to timing flow of the work. Table 6 has 4 timing term (Base/First/Middle/Last). General theme has different theme corresponding to 4 timing term.

Table 6: General theme of the SE project

| | The theme of the SE project |
|---|---|
| Base | (1) Making good system<br>(2) Foundation of the system<br>(3) Satisfaction<br>(4) Economy, Safety |
| First Term | (1) Strategy<br>(2) Project Planning<br>(3) Requirements and Cost<br>(4) Standard Rule |
| Middle Term | (1)Think is Important<br>(2) Design and review are important |
| Last Term | (1)Project Data Analysis<br>(2) Success is important<br>(3) Quality control<br>(4)Limit of Power |

## 10. PRODUCTION CONTROL

Now, since first section to this last section, we have discussed much investigation about SE Project. Those are "What is SE Project?" Those are Characteristics, Activities, Organization, Schedule, System development Planning.

The flow of SE Project (The upper stream, middle stream, down stream ), "3 Powers and 3 dimension" of the SE project, SE project management.

One of the most important systems is progress stage control. In work of progress control, we get status information from work information terminal. Work information of progress control are day's program schedule, the load factor, work analysis. Those are next Chart 4 / Chart 5/ Table 7.

## 11. CONCLUSION

The author had been systems engineer, his life with computer SE that was about 50 years. The table 4 is his taking charge of SE projects. This era was Computer Era. And now it is progressive.

His life was continuity for computers and information systems. The author says that this is "Revolution". And then this revolution will continue more and more.

The reasons for revolutions are information and evolutional words. Those were Internet, Web, Project, Twitter, Cloud computing, Mobile, Smart, ICT, Widget, Wi-Fi, Cloud, SaaS/PaaS/IaaS, Shin Client, SNS, Tablet device, pdf, ITIL, and so on.

Revolution era will be continuing more and more. The new

Chart 4: Progress control (Day control)

Note: This is " Gant Chart "

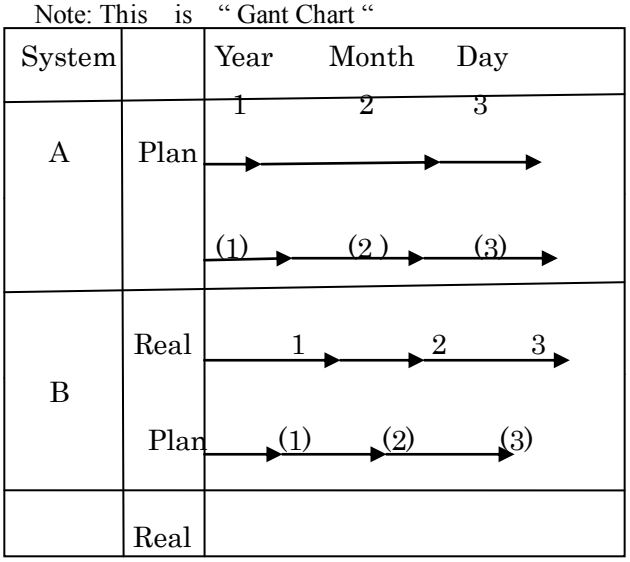



Chart 5: Progress control (Load control)

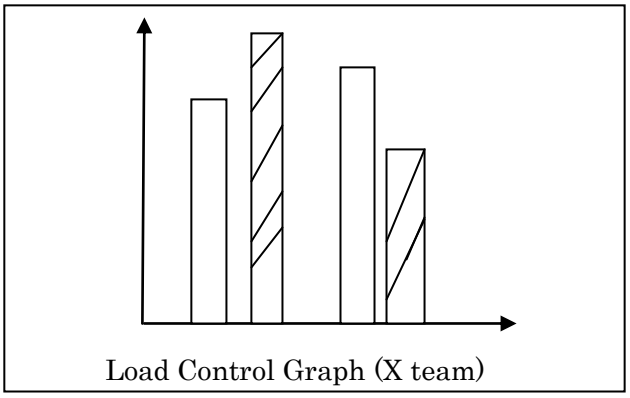



Table 7: Work Analysis (This month)

| Work | Time | Ratio |
|---|---|---|
| a | 80 | 5% |
| b | 110 | 6.9% |
| c | 25 | 1.6% |
| d | 205 | 12.8% |
| ----- | ------ | ------- |
| Summation | 1,600 | 100% |

words of new computer era are in section 6, section 8, and section 9.

## REFERENCES


[1] Syouji Okamura, "Complete Explanation! Project Management" Nikkei BP (2003.10).

[2] Katsuyuki Seino, "Design Analysis for Cloud Architecture", Syuhwa SYSTEM (2010.9).

[3] Haruhisa Ishida Editing, etc, "Famous & Classic 100 Publications", Impress Communications (2004.5).

[4] Haruki Inoue, etc," Information Basis on the Evolving Cloud Computing ", Co. ITSC Shizuoka Academic Publishing Enterprise (2011.3).

[5]Information Processing Society of Japan,"Information Processing (2012.1)", IPSJ (2012.1).

[6]History Committee in Information Processing Society of Japan," Information Processing Technology Heritage(2011)", Information Processing Society of Japan(2012.3).

[7] Nomura Sougou Laboratory, "IT load Map", Touyou Keizai Simpou (2011.3).

[8] Shohzou Yamato, Kouichi Nagachi, "IT Project Management by WBS/EVM", Soft Research Center(2009.4) .

[9] Hiroyuki Kurosaki, "IT Service Management Corresponding ITIL V3/JIS Q 20000", Gizyutu Hyouronsya (2010.12).

[10] Information Process Society Japan-History Special Committee,"Japanese Computer History", Ohmsha, pp.31~129(2010.10).

[11] Shintou Teramoto,"Law Practice in the Cloud Computing Era ", Shojihoumu(2011.1).

[12] Masaki Nakagawa, Jun and other 5 authors, " Learning Project Management through Practice and Example" ,Softbank Creative Corp. (2011.4) .

[13]Kenzi Hatsuda, "Making Method for WBS (Work Breakdown Structure)", Nikkei BP (2012.3).

[14] Yoshiaki Konishi,"Microsoft Project 2002", Society of Japan Plant Maintenance (2003.5).

[15]Akira Ikuma Other 2 Person, "Perfect Master for PMP (PROJECT MANAGEMENT PROFESSIONAL)" Hyohgensya (2011.12) .

[16] Project Management Institute, Inc."PMBOK Knowledge System Guide" 2008 Project Management Institute, Inc. All rights reserved.

[17] Project Management Institute Inc., "PMBOK (Project Management Body of Knowledge ) Guide, Version 4 " Project Management Institute Inc. (2008).

[18] Shin Satou, Masaru Makino, "Success Key of the SE Project", Nikkagiren, pp.31~129(2010.10).

[19] Tsuyoshi Nishimoto,"System Development Contract; Seeing Cloud ", Shojihoumu(2011.5).

[20] Naotaka Ohwada, "System Unification of right Attack for World Maximum Scale Project", Nikkei BP (2009.11).

[21] Atsushi Nakada, "The Complete Cloud Computing (Cloud Daizen)" , Nikkei BP(2010.7).

[22] Makoto Shirota, "The shock on the big data", Touyou keizai shimbunn sya (2012.8).

[23] Nomura sougou laboratory (ICT consalting), "InformationTechnologyNavigator,(2012)", Touyou keizai shinpousya (2011.11).

[24]IPSJ,"Iormation Processing",IPSJ(2012.9).

# Verification of Safety Property of Line Tracer Program using Timed Automaton Model

Kozo Okano[†], Toshifusa Sekizawa[‡], Hiroaki Shimba[†], Hideki Kawai[‡], Kentaro Hanada[†], Yukihiro Sasaki[†], and Shinji Kusumoto[†]

[†]Graduate School of Information Science and Techlology, Osaka University, Japan
[‡]Faculty of Informatics, Osaka Gakuin University, Japan
{okano, h-shimba, k-hanada,y-sasaki, kusumoto}@ist.osaka-u.ac.jp
{sekizawa,09s0100}@ogu.ac.jp

***Abstract*** - Recently reliability of embedded systems has become very important. Such reliability can be ensured by formal verification techniques including model checking. We study such verification technique through a real example of embedded systems, a line tracer. This paper mainly describes how to model the behavior of the line tracer in a network of timed automata, as well as experimental results of verification. Using the model, several safety properties are successfully verified with a model checker, UPPAAL. The line tracer is built with LEGO Mindstorms kit. This paper also describes the implementation using LeJOS, a Java development environment for LEGO Mindstorms kit.

***Keywords***: Embedded System, Real-time System, Formal Verification, Timed Automaton

## 1 INTRODUCTION

Recently, embedded systems have become important in our society. Embedded systems exist everywhere in our daily life. Therefore, to ensure safety properties of the embedded systems becomes much important. In order to ensure such property, model checking techniques are often used. Most of model checking techniques are based on finite state machine model. The behavior of the target systems is modeled in a tuple of automata. In usual, program variables, such as integer variables are translated into finite state variables. For example, a general 32-bit integer variable might be translated into an 8-bit integer as long as the target program does not use constants with large values greater than 127. Even such modeling can detect important faults in design phases. On the other hand, some of embedded systems require time properties as their specification. In order to model such systems (real-time systems), several models have been proposed. Timed automaton is proposed by Alur and Dill[1]. The most interesting point of timed automaton is that it uses clock variables where the range of a clock variable is real numbers. Locations and transitions of timed automaton have constraints on clocks in limited syntax forms. Timed automaton, therefore, can represent naturally behavior of real-time systems. The famous verifier for timed automaton is UPPAAL[2], which is developed by Wang-Yi's research group. The timed automaton used in UPPAAL is a strong extension of the original timed automaton. It can deal with bounded integer variables and guard expressions on its transitions can express constraints on such variables. Several success applications of verification have reported, including verification of audio-video protocols[3], a gear controller[4], timeliness properties of multimedia systems [5], and so on.

Embedded systems sometimes control continuous systems. For examples, water level controller observes level of water in a certain water tank and controls incoming and outgoing valve flow associated with the tank. Note that the water level and the valve flow are usually continuous values. In order to deal with such a system consisting of discrete sub-systems and continuous sub-systems, hybrid automaton has been also proposed. Several studies have proposed simulators for hybrid systems.

Our research question is how to verify formally behavior of such hybrid systems[6]. Our first step of the research is to find what properties can be verified using conventional verifiers such as UPPAAL and so on, through a real application. We use a line tracer as a real application for the following reasons.

- It contains time properties as design specification;
- We can implement a real system with reasonable costs using LEGO Mindstorms kit [7]; and
- We can freely describe the control program in Java using LeJOS[8], which is free software for LEGO Mindstorms.

A line tracer is an autonomous robot which traces a line painted in black on white background sheet according to read values of color sensors.

Through experiments, we have succeeded in verification of safety properties of a line tracer, using timed automaton model and UPPAAL.

The rest of the paper is organized as follows. Sec. 2 provides preliminaries. Sec. 3 and 4 will describe the model and implementation of our line tracer. Sec.5 and 6 show some preliminary but promise experiments and discussion. Finally, Sec. 7 concludes the paper. The final section also provides future plan of our work.

## 2 PRELIMINARIES

Here, we will provide several definitions and notions used in this paper.

## 2.1 Timed Automaton

A timed automaton is an extension of the conventional automaton with clock variables and constraints for expressing real-time dynamics. They are widely used in the modeling and analysis of real-time systems.

**Definition 1 (constraints)** *We use the following constraints on clocks.*

1. *$C$ represents a finite set of clocks.*
2. *Constraints $c(C)$ over clocks $C$ are expressed as inequality of the following form.*

$$E ::= x \sim a \mid x - y \sim b \mid E_1 \wedge E_2,$$

*where $x, y \in C, \sim \in \{\leq, \geq, <, >, =\}$, and $a, b \in \mathbb{R}_{\geq 0}$, in which $\mathbb{R}_{\geq 0}$, is a set of all non-negative real numbers.*

The above time constraints are used to mark edges and nodes of the timed automata for describing the guards and invariants.

**Definition 2 (timed automaton)** *A timed automaton $\mathscr{A}$ is a 6-tuple $(A, L, l_0, C, T, I)$, where*

- *$A$: a finite set of actions;*
- *$L$: a finite set of locations;*
- *$l_0 \in L$: an initial location;*
- *$C$: a finite set of clocks;*
- *$T \subseteq L \times c(C) \times A \times 2^C \times L$ is a set of transitions. The second and fourth items are called a guard and clock resets, respectively; and*
- *$I : L \to c(C)$ is a mapping from location to clock constraints, called a location invariant.*

A transition $t = (l_1, g, a, r, l_2) \in T$ is denoted by $l_1 \overset{a,g,r}{\to} l_2$.

A map $v : C \to \mathbb{R}_{\geq 0}$, is called a clock assignment (or clock valuation). We define $(v + d)(x) = v(x) + d$ for $d \in \mathbb{R}_{\geq 0}$ and some $x \in C$.

For a guard, a reset and a location invariant, we introduce some notations with regard to clock valuation. For each guard $g \in c(C)$, a function $g(v)$ stands for the valuation of the guard expression $g$ with the clock valuation $v$. For each reset $r$, where $r \in 2^C$, we shall introduce a function denoted by $r(v)$, and let $r(v) = v[x \mapsto 0], x \in r$. For each location invariant $I$, we shall introduce a function denoted by $I(l)(v)$, which stands for the valuation of the location invariant $I(l)$ of location $l$ with the clock valuation $v$.

Dynamics of a timed automaton can be expressed via a set of states and their evaluations. Changes of one state to a new state can be as a result of firing of an action or elapse of time.

**Definition 3 (state of timed automaton)** *For a given timed automaton $\mathscr{A} = (A, L, l_0, C, T, I)$, let $S = L \times \mathbb{R}^C_{\geq 0}$ be a set of whole states of $\mathscr{A}$, where $\mathbb{R}^C_{\geq 0}$ is a whole set of clock evaluation on $C$.*

*The initial state of $\mathscr{A}$ can be given as $(l_0, 0^C) \in S$.*
*For a transition $l_1 \overset{a,g,r}{\to} l_2$, the following two transitions are semantically defined. The first one is called an action transition, while the latter one is called a delay transition.*

$$\frac{l_1 \overset{a,g,r}{\to} l_2, g(v), I(l_2)(r(v))}{(l_1, v) \overset{a}{\Rightarrow} (l_2, r(v))}, \qquad \frac{\forall d' \leq d \quad I(l_1)(v + d')}{(l_1, v) \overset{d}{\Rightarrow} (l_1, v + d)}$$

Semantics of a timed automaton can be interpreted as a labeled transition system.

**Definition 4 (semantics of a timed automaton)** *For a timed automaton $\mathscr{A} = (A, L, l_0, C, T, I)$, an infinite transition system is defined according to the semantics of $\mathscr{A}$, where the model begins with the initial state. By $\mathscr{T}(\mathscr{A}) = (S, s_0, \overset{\alpha}{\Rightarrow})$, the semantic model of $\mathscr{A}$ is denoted, where $\alpha \in A \cup \mathbb{R}_{\geq 0}$.*

**Definition 5 (run of a timed automaton)** *For a timed automaton $\mathscr{A}$, a run $\sigma$ is finite or infinite sequence of transitions of $\mathscr{T}(\mathscr{A})$.*
$\sigma = (l_0, \nu_0) \overset{\alpha_1}{\Rightarrow} (l_1, \nu_1) \overset{\alpha_2}{\Rightarrow} (l_2, \nu_2) \overset{\alpha_3}{\Rightarrow} \cdots$

## 2.2 UPPAAL

UPPAAL[2] is a famous model checker for extended timed automata by Wang-Yi et al. It also supports model checking for the conventional timed automata. UPPAAL allows verification of expressions described in an extended version of CTL. In addition, it supports local and global integers and primitive operations on integers, such as addition, subtract and multiplication with constants. Such expressions are also allowed on the guards of transitions. The model of the system can be created from multiple timed automata which are synchronized together via CCS-like synchronization mechanisms.

The important point is that even the extended timed automaton used in UPPAAL cannot deal with real variables except clocks. We, therefore, have to round real values to integer values when we model the target systems.

# 3 MODEL

The term "line trace" means that a vehicle traces a course starting from a certain point. The point might be on the course or not. The course is assumed to be painted in black color on white background with the same width. For example, an oval course (the same as the track used in an athletic field) is used.

A model for a line tracer consists of the following three models:

- Controller Behavior,
- State Transition of Environment, and
- Disturbance.

Controller behavior can be modeled using a state machine. Usually, controller program changes values of some of state variables based on values of some state variables.

For example, the state variables of a line tracer will be the location of the tracer, the locations of the right and left sensors, the output values of the right and left sensors, direction

Table 1: State Variables of a Line Tracer

| variable | description |
|---|---|
| $x$: | x-coordinate of the center of a line tracer |
| $y$: | y-coordinate of the center of a line tracer |
| $\theta$: | direction of a line tracer |
| $slx$: | x-coordinate of the left sensor of a line tracer |
| $sly$: | y-coordinate of the left sensor of a line tracer |
| $srx$: | x-coordinate of the right sensor of a line tracer |
| $sry$: | y-coordinate of the right sensor of a line tracer |
| $wl$: | revolution speed of the left wheel of a line tracer |
| $wr$: | revolution speed of the right wheel of a line tracer |
| $sl$: | the sensed value of left sensor |
| $sr$: | the sensed value of right sensor |

Table 2: Constants

| constant | description |
|---|---|
| $w$ : | width between left and right wheels of the line tracer |
| $los$: | offset to the left sensor from the vehicle center |
| $ros$: | offset to the right sensor from the vehicle center |

of the line tracer, the rotation speed of left and right wheels, and so on.

The output values of the right and left sensors are used as inputs of the controller. The rotation speed of left and right wheels are used as outputs of the controller

State transition of environment can be normally represented in differential equations on state variables. In a hybrid system, such equations are used, while in a finite sate model, differential-difference equations are used as approximation.

For a line tracer, the principle state variables are summarized in Table 1.

We need some other constants to model, especially constants on the size of the line tracer. Table 2 shows some of them. In the table, $los, ros$ are tupple of $(l, a)$, where $l$ and $a$ are distances and angle by the center of the vehicle, respectively. Figure 1 also illustrates the relations on the state variables and constants.

Let assume that a line tracer turns with the speed of left and right wheels at $h_s$ and $l_s$. Then equations of motion can be given as follows.

$$\frac{d\theta}{dt} = \frac{h_s - l_s}{w} \quad (1)$$

$$\frac{dx}{dt} = -r_c \cdot \sin\theta \cdot \frac{d\theta}{dt} \quad (2)$$

$$\frac{dy}{dt} = r_c \cdot \cos\theta \cdot \frac{d\theta}{dt} \quad (3)$$

$$r_c = \frac{w}{2} \cdot \frac{h_s + l_s}{h_s - l_s} \quad (4)$$

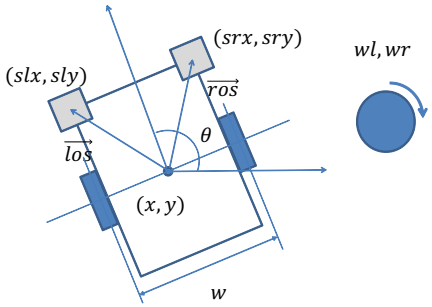



Figure 1: Constants and State Variables

Table 3: Conversion Table for Sine Function

| domain of $x$ (degree) | round of $100\times \sin(x)$ |
|---|---|
| $[0, 10)$ | 8 |
| $[10, 20)$ | 26 |
| $[20, 30)$ | 42 |
| $[30, 40)$ | 57 |
| $[40, 50)$ | 71 |
| $[50, 60)$ | 82 |
| $[60, 70)$ | 91 |
| $[70, 80)$ | 96 |
| ⋮ | ⋮ |
| $[350, 360)$ | -9 |

Disturbance can be modeled as uncertain error for each of observation variables. For example, a line tracer has sensors. The value $s$, the output of the sensor may change with uncertain value as like the following equation:
$s_o = s_r + \varepsilon(s)$, where variables $s_o$, $s_r$, and $\varepsilon(s)$ represent the observed value, ideal value and error in observation, respectively.

## 3.1 Quantization

The timed automaton used in UPPAAL can model the controller behavior. It, however, uses integer variables only. As we know, most of state variables must have values in real. Therefore, we have to approximate such variables into integer variables.

Most of state variables use trigonometric functions (see equations (2) and (3)). Thus, we have to approximate the functions to round up into integers as long as we use finite models. Though, the values of trigonometric functions range in [-1,1], it is not a good idea that we use only three values -1, 0, and 1. Therefore, we assume that trigonometric functions range in [-100, 100]. Also we adopt degree as unit for angle. Table 3 shows an approximation conversion table for sine function.

## 3.2 Sampling

Yet another problem is that we cannot deal with functions on time. Usually state variables can be represented as func-

Table 4: Logic for Color Sensors

| | | RightSensor | |
|---|---|---|---|
| | | black | white |
| LeftSensor | black | go straight | turn left |
| | white | turn right | go straight |

tion on time, however, even UPPAAL does not provide functions on time. Therefore, we have to regard state variables as discrete signals.

Sampling is a great tool to reduce a continuous signal into a discrete signal. For a discrete signal, we can model its change on time as an timed automaton with update functions.

Let's consider again state variables, $x$, $y$, $\theta$, $slx$, $sly$, $srx$, $sry$, $wl$, $wr$, $sl$, and $sr$. In usual, $slx$ and $sly$ are calculated using $x$ and $y$ with some parameters in Table 2. The values of $sl$ and $sr$ are also determined from the value of $x$, $y$, $los$, $ros$, and a course model, which consists of some parameters and the equations of the course. The values of $wl$ and $wr$ are determined by the controller.

Therefore, we need calculate the current value of $x$, $y$ and $\theta$ like as equations (1) $\sim$ (4).

Using sampling and update functions, we can model that the values of variables are updated every some fixed unit of time using small deltas. We will explain concrete update expressions in Sec. 5.

## 4 IMPLEMENTATION

LEGO Mindstorms NXT[9] is a kit for assembling robots with various actuators and sensors by LEGO®. Users can program its behavior. The actuators include stepping motors which users can accurately control rotation angles. The sensors include color sensors, touch sensors, sound sensors and so on. Various programming languages are provided for control of the NXT kit. The famous languages are NXC (Not eXactly C)[10] and LeJOS. LeJOS is a development environment for Java. NXC and LeJOS have classes for the above sensors and actuators.

This research uses LeJOS for developing the line tracer. Our line tracer has two color sensors locating left front and right front of the tracing car.

Table 4 shows the logic for the sensors. For example, if LeftSensor and RightSensor sense white and black colors, respectively, then the controller issues the turn right command to motors.

The output of sensors is a bounded integer value. If the value is greater than some threshold, then controller treats it as white. For the command, left and right wheel motors react independently. For example, "turn left" command makes left and right wheel motors speed up and down, respectively

Figure 2 shows the controller in LeJOS. Figure 3 shows the implemented line tracer.

## 5 EXPERIMENTS

Here, we deal with an ideal model. Therefore, we ignore disturbance. Figures 4 and 5 corresponds to controller be-

```
import lejos.nxt.Button;
import lejos.nxt.ColorSensor;
import lejos.nxt.SensorPort;
import lejos.nxt.ColorSensor.Color;
import lejos.nxt.LCD;
import lejos.nxt.Motor;
public class Controller {
  public static void main(String[] args)
    throws Exception {
   int rid,lid;
   final int HS = 420, LS = 120, BLACK = 7,
   MS = 360, HSEC = 500;
   Color colorR ,colorL;
   ColorSensor sensorR =
     new ColorSensor(SensorPort.S3);
     // 1(S3):right
   ColorSensor sensorL =
     new ColorSensor(SensorPort.S4);
     // 2(S4):left
   Motor motor = new Motor();
   motor.B.setSpeed(MS);
   motor.C.setSpeed(MS);
   Thread.sleep(HSEC);
     // wait for devices to be stable
   motor.B.forward();
   motor.C.forward();
   while(true) {
     rid = sensorR.getColorID();
     lid = sensorL.getColorID();
     if (rid == BLACK)
       motor.B.setSpeed(LS);
     else       motor.B.setSpeed(HS);
     if (lid == BLACK)
       motor.C.setSpeed(LS);
     else
       motor.C.setSpeed(HS);
     if (Button.readButtons()
       == Button.ENTER.getId())
       break;
   }
  }
}
```

Figure 2: Controller in LeJOS

Figure 3: The Implemented Line Tracer

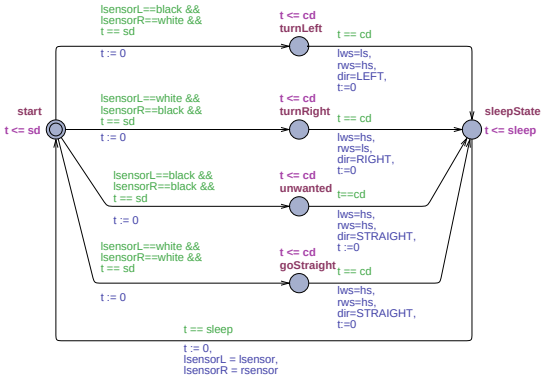



Figure 4: Timed Automaton Representing the Controller

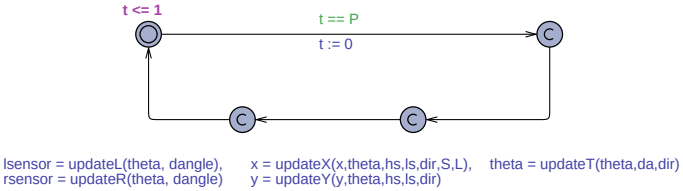



Figure 5: Timed Automaton Representing Update

havior model and state transition of environment model. In this experiment, we use a simple controller program, where revolution speed of wheels has only two values, $h_s$ and $l_s$. Moreover we assume that sensors only tell white and black colors on the track. In other words, the values of $sl$ and $sr$ are determined by only the position of the line tracer. On the other hand, we model the delay of sensors and actuators. Concretely, we have parameters $d_s$, $d_a$, and $d_t$ for delay between the time when program senses color and the time when the sensors obtain the values of colors, delay between the time when program issues a command and the time when the motor reacts, and sleeping time for next sense-act loop, respectively. This modeling represents real behavior of a line tracer.

Figure 4 shows the control behavior model of the program.

Figure 5 shows the timed automaton which updates periodically state variables every unit of time. The automaton periodically calls functions updateX, updateY, updateT, updateL, and updateR which update state variables $x$, $y$, $\theta$, $sl$, and $sr$, respectively. The automaton first updates the value of $\theta$, and then values of $x$ and $y$. Finally it updates values of $sl$ and $sr$ based on the values of $x$, $y$, and $\theta$.

The following equations are equations for $\theta, x$, and $y$ used in update functions.

$$\theta' = \theta + \alpha \quad (5)$$

$$x' = x + \frac{wl + wr}{2}\cos\theta \quad (6)$$

$$y' = y + \frac{wl + wr}{2}\sin\theta \quad (7)$$

$$\alpha = 90 \cdot \frac{wr - wl}{w \cdot \pi} \quad (8)$$

If we assume that the unit of time is small then the moving distance of the vehicle can be approximated to $(h_s + l_s)/2$. The above equations uses this fact.

Please note that we actually use not $\sin$ but pseudo sin $/100$ defined in Table 3. Also we let the values of the parameter $p$ range in $[0, 360]$ by using an expression $(p + 360)\%360$.

We assume that if the value of $x$ becomes greater than 1000 then the value of $x$ is reset to 50. This device let a line tracer run infinitely in the finite state model. We also assume that the course is a straight line along with $x$-axis.

We can verify the following queries:

1. $E\Diamond(900 < x)$.
2. $E\Diamond(\texttt{C.turnRight})$.
3. $E\Diamond(\texttt{C.turnLeft})$.
4. $E\Diamond(\texttt{C.unwanted})$.
5. $A\Box\neg(\texttt{C.unwanted})$.
6. $E\Diamond(\texttt{C.goStraight})$.
7. $A\Box((x > 280) \Rightarrow (-100 < y < 100))$.
8. $A\Box((x > 280) \Rightarrow (\theta < 10 \vee 350 < \theta))$.
9. $E\Diamond((x > 280) \Rightarrow \texttt{C.turnRight})$.
10. $E\Diamond((x > 280) \Rightarrow \texttt{C.turnLeft})$.

The first query (1) means that the line tracer will reach the area $x > 900$. Queries (2) and (3) mean that the controller eventually reaches state C.turnRight and C.turnLefit. Queries (4) and (5) mean that the controller eventually reaches state C.unwanted and that the controller never reaches state C.unwanted, respectively, where both of sensors detect black color. Please note that query (4) and (5) contradict each other, i.e., query (5) is negation of query (4). Query (6) means that the controller eventually reaches state C.goStraight.

Queries (7), (8), (9) and (10) use the assumption that a line tracer is in stable state. Please note that we consider the tracer is in stable after the point $x = 280$. We can observe it from several traces of simulation. The traces can be obtained from the UPPAAL using the simulation mode view. Queries (7) and (8) mean that the line tracer roughly keeps the track and appropriate direction, respectively, in the stable state. The last two queries mean that the line tracer eventually turns left or right even if the tracer is in stable state.

Every of the verifications (except the query (4)) has succeeded with the parameters in Table 5. Every verification is performed within one second using UPPAAL ver. 4.0.13 academic licence on Windows 7 64 bit OS, Intel Core i7 960 3.20GHz, with 12 GB memory. Figure 6 shows verification process using UPPAAL.

Here, let us think about influence of changing parameters. Query (4) passed if we change the parameter $los$ and $ros$ as (170, 30°) and (170, -30°). In this time, of course, Query (5) changes to false. This is because changing positions of two sensors, $los$ and $ros$, results narrowing the distance between these sensors. On the other hand, the width of line is unchanged. Therefore, possibility of detecting black by

Table 5: Parameters under Verification

| params | value | description |
|---|---|---|
| $wc$: | 100 | width of the track line |
| $w$: | 120 | width between left and right wheels of the line tracer |
| $los$: | (180, 30°) | offset to the left sensor from the vehicle center |
| $ros$: | (180, −30°) | offset to the right sensor from the vehicle center |
| $h_s$: | 12 | high speed |
| $l_s$: | 6 | low speed |
| $x_0$: | -200 | initial value of x-coordinate of the center of the vehicle |
| $y_0$: | 200 | initial value of y-coordinate of the center of the vehicle |
| $\theta_0$: | 340° | initial value of direction of the vehicle |
| $d_s$: | 1 | time delay of sensors |
| $d_a$: | 1 | time delay of actuators |
| $d_s$: | 2 | periodical sleeping time |

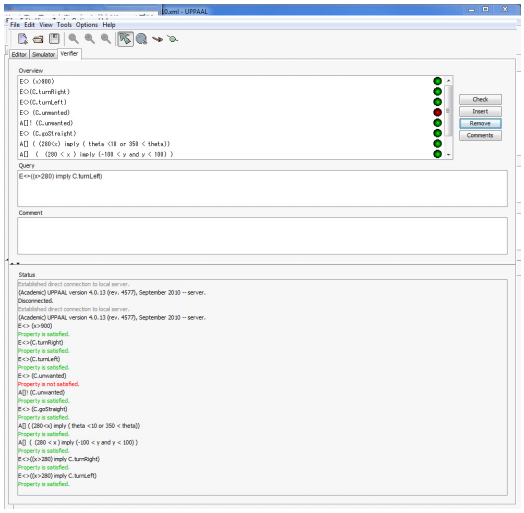


Figure 6: Verification using UPPAAL

both sensors at a time becomes higher. Verification result mentioned above means that state C.unwanted is eventually reached.

# 6 DISCUSSIONS

Here, we will describe discussions on the experiments and hybrid systems.

## 6.1 Discussions on The Experiments

The results are not enough to convince us that the line tracer runs safely. The results, however, show that from the theoretical point of view, our approach using a verifier for timed automata, will work.

The parameters used in verification are not the same to the parameters used in the implementation. This might lessen the validity of the model. However, the proportional relations of the parameters are acceptable. For example, the width $ws$ between the left sensor and the right sensor is 190 and it is greater than 100, the width of the track.

The value $ws$ is greater than 120, the width of the line tracer. It is very different from the implementation in Figure 3. The parameters are, however, acceptable. Also the wheel speed 6 or 12 is acceptable with regard to the size of the line tracer.

The workload of modeling is in fact not less (it takes over 2 month-persons) due to our limit of know-how on modeling, especially how to deal with continuous model. Some of parameters in Table 5 are very sensitive, in other words, if these values are different by a little, the behavior of the whole system differs; consequently, verification will fail. For example, with the parameters in Table 5 if we change the value of $d_s$ as 4, then the verification fails.

You might think that slow wheel speed increases the possibility of success of verification. In other words, the slower a line tracer moves, the more successively it keeps the track. However, due to the quantization, a small wheel speed causes the delta values per unit of time to be 0 in our model. Therefore, we cannot set smaller value than 6 as the low speed of the wheel. Such a problem can be resolved by increasing the physical sizes in the model. However, such a revise, in turn, causes so called state explosion in which a model checker cannot response in a reasonable time or exhausts whole of the memory space.

Nevertheless such situations, it shows the importance of design analysis and verification in an early stage of development.

During the modeling, we think that there should be an automated generation tool which translates from an abstract parameter model to a concrete UPPAAL model, as well as a simple tool to analysis counter-examples and simulation results obtained from UPPAAL. They would be very useful to refine the model.

## 6.2 Hybrid System

In order to analyze the model more precisely, hybrid systems seem promise models.

Hybrid system[11] is a system in which continuous dynamics and discrete dynamics are mixed with time progress. Hybrid systems are important in many fields such as physics and control engineering. Several approaches are proposed to deal with hybrid systems. One of the approaches is hybrid automaton[12] which is a formal model for describing mixed discrete-continuous systems. Hybrid automaton consists of variables, control graph, continuous flow, discrete jump and events. A model checker for linear hybrid automata is HyTech [13]. Another approach is hybrid constraint languages such as Hybrid cc[14] and HydLa[15]. These languages are declarative and provide power to write programs with logical formulas. Execution environment of these languages are implemented, Hybrid cc interpreter and Hyrose, respectively.

A line tracer can be a hybrid system by describing its movement using differential equations and its control program in discrete time. However, there are difficulties if a line tracer is

modeled accurately. For example, modeling with characteristics of motors and sensors, and disturbances are difficulties. Fehnker et al. presented a study of verification of behaviors of a line tracer[16]. In the paper, the authors presented verification of a safety property, a line tracer move along a straight line and never run off the line, by constructing a model using hybrid I/O automata and correctness proof. However, as the authors mentioned, some kinds of time is not considered such as time delay between two motors.

## 7 CONCLUSION

We have modeled a controller of a line tracer in timed automata. Also we have verified the model to ensure that the line tracer keeps the track, using a model checker, UPPAAL.

Future plans are summarized as follows. First, we want to model a PID controller (proportional-integral-derivative controller), which is a kind of feedback controls. PID control enables a line tracer to behave more smoothly. PID control, however, needs some historical data on the past values of state variables, and also requires complicate calculation, thus hybrid modeling becomes more suitable. We want to use hybrid model, as well as its verifiers and simulators to determine suitable parameters for PID control. It is said that to find suitable parameters for PID control for an instance of problems, is a difficult problem for a long time. We think our approach might work well.

Another direction of our research is timing analysis of motor delay. From preliminary experiments, we have found that motor delay cannot be ignored for design of controller program if we want to obtain a high quality controller.

## ACKNOWLEDGEMENT

This research is partially supported by Grant-in-Aid for Scientific Research (C) (21500036). We also thank
Prof. Nobukazu Yoshioka, National Institute of Informatics (NII) for providing several education materials related to modeling and verification of a line tracer.

## REFERENCES

[1] R. Alur and D. L. Dill: “A theory of timed automata,” Journal of Theoretical Computer Science, 126(2), pp.183-235 (1994).

[2] J. Bengtsson and W. Yi: “Timed Automata: Semantics, Algorithms and Tools,” In Lecture Note in Computer Science, vol.3098, pp.87-124 (2004).

[3] J. Bengtsson, W. O. D. Griffioen, K. J. Kristoffersen, K. G. Larsen, F. Larsson, P. Pettersson and W. Yi: “Verification of an Audio Protocol with bus collision using UPPAAL,” In Lecture Note in Computer Science, vol.1102, pp.244-256 (1996).

[4] M. Lindahl, P. Pettersson, and W. Yi: “Formal Design and Analysis of a Gear Controller: An Industrial Case Study using UPPAAL,” In Lecture Note in Computer Science, vol.1384, pp.289-297 (1998).

[5] B. Bordbar and K. Okano: “Verification of Timeliness QoS Properties in Multimedia Systems,” In Lecture Note in Computer Science, vol.2885, pp.523-540 (2003).

[6] J. Fitzgerald, P.G. Larsen, K. Pierce, M. Verhoel, and S. Wolff: “Collaborative Modelling and Co-simulation in the Development of Dependable Embedded Systems,” in Proceedings of IFM 2010, pp.12-26 (2010).

[7] B. Bagnall: “Intelligence Unleashed: Creating LEGO NXT Robots with Java,” Variant Press (2011).

[8] LeJOS Java forLEGO Mindstorms: `http://lejos.sourceforge.net`

[9] LEGO Mindstorms NXT Official website: `http://www.legoeducation.jp/mindstorms/`

[10] NXC Tutorial: `http://bricxcc.sourceforge.net/nbc/nxcdoc/NXC_tutorial.pdf`

[11] J. Lunze and F. Lamnabhi-Lagarrigue: “Handbook of Hybrid Systems Control: Theory, Tools, Applications,” Cambridge University Press (2009).

[12] T. A. Henzinger: “The theory of hybrid automata,” In Proc. of Eleventh Annual IEEE Symposium on Logic in Computer Science, LICS ’96, pp.278-292 (1996).

[13] T. A. Henzinger, Pei-Hsin Ho, and H. Wong-Toi: “HYTECH: A model checker for hybrid systems,” In Lecture Notes in Computer Science, vol.1254, pp.460-463 (1997).

[14] V. Gupta, R. Jagadeesan, V. Saraswat, and D. G. Bobrow: “Programming in hybrid constraint languages,” In Lecture Notes in Computer Science, vol.999, pp.226-251 (1995).

[15] K. Ueda, H. Hosobe, and D. Ishii: “Declarative semantics of the hybrid constraint language HydLa,” Computer Software, JSSST, 28(1) pp.306-311 (2011). (in Japanese).

[16] A. Fehnker, F. W. Vaandrager, and M. Zhang: “Modeling and verifying a lego car using hybrid I/O automata,” In Proc. of 3rd Int. Conf. on Quality Software, pp.280-289. IEEE Computer Society (2003).

# Design and Development of a Security Evaluation Platform Based on International Standards

Yuji Takahashi, and Yoshimi Teshigawara

Graduate School of Engineering, Soka University, Japan
{e08d5203, teshiga}@soka.ac.jp

***Abstract*** - In order to obtain acquisition of security attestation, the organizations evaluate security products by using evaluation systems based on the international standards. However, they have to use individual systems corresponding to changes to the standards. Therefore, we have been studying a platform that realizes evaluation corresponding to changes of the standard contents and evaluation targets only by focusing changes of the standards used as evaluation criteria. We developed and implemented the platform in consideration of a layered structure and reference relations of the standards. The platform provides such functions as reference-related arrangement of the whole standard, the display of a reference tree, and score calculation. As the results of experimental evaluation, it is recognized covering all items and avoidance of human errors by supplementing technical knowledge and by utilizing visual effects, and the validity of the platform is confirmed.

***Keywords***: Security management, Information security, International standard, ISO/IEC 27000

## 1 BACK GROUND AND PURPOSE OF RESEARCH

In recent years, the scope of the purpose of security management is expanding from security of self-defense for protecting the assets of the organization to the security of preventing from becoming the attackers who cause damage to the organization. As a result, it becomes highly important to assess the status of the implementation of safety and security measures by an external agency [1]. There is a specific standard called ISO/IEC 27001. As the number of the organizations that are being attested by this standard is continuously increasing, by June, 2012 more than 7,000 companies in the world have been attested. In particular, more than 4,000 companies and organizations among them that have been attested are in Japan [2].

As for most of the security certifications, standards such as ISO/IEC 27001, ISO/IEC 27002, JIS Q 15001 are taken as reference and the organizations have been attested by satisfying all the items that are described in those standards. In addition, security assessment systems are used to validate the achievement of criteria in the process of certification [3]. However, the items of the standard are frequently changed as time passes. Compared to other standards, the security related standards are more frequently changed because they are not tested precisely, user comments are taken into consideration and changes are made accordingly. In addition, as the certification process differs depending on the size of the organization etc., the items of the criteria for assessment also differ. If the organization and the objective of the assessment change, changes such as revision of the standard will cause to create a situation where a new system should be created for redoing each certification using individual tools or personnel. Hence lot of time, personnel and cost are required and this leads to problems that have huge personnel and monetary impacts in the company activities. In order to solve such problems without depending on the items of the standard, the need for a mechanism to achieve an assessment tool corresponding to the changes in the organization and the purpose of assessment, rather than individual security assessment tools, has been increasing.

In this study, we have been studying a security assessment platform which enable to realize security assessment only by the replacement of raw data (Hereinafter referred to as fundamental data) that has regulated the fundamental standard without depending on the target standard [4]. In this platform, focusing on the hierarchical structure of sentences (hereinafter referred to as hierarchical structure) which is its characteristic structure, the items of the standard as well as the statements indicating the detailed conditions that have references and instructions to other items (hereinafter reference relation), we registered the organized standard data by the hierarchical structure. In addition, by estimating the assessment level using the hierarchical structure and a reference relation, we have been studying a platform that aims achieving security requirements. Thus, we have developed the platform system and registered the data of ISO/IEC 27000 series etc. [5]. In the same way, as for the security assessment used in the platform, security assessment needs to be done without depending on the type of reference standard and a method of estimating the assessment level without depending on the type of standard is required. So far in this study, security assessment is conducted by changing the impact of assessment against each component of the reference tree as mentioned below. Based on the result of the experiments for security assessment methods that consider the distance in the reference trees as well as the relation of each item with assessment items, we found that changing impact is effective. Considering the relation of each item with assessment items we proposed these methods of the estimating impact are changed and experimented these methods [5] [6] [7]. Thus, as for those users who do not have a deep knowledge of attestation, we experimented regarding the sample providing function and the data migration function using relevant information based on the past cases in order to support

countermeasure selection and implementation and confirmed the validity of the proposed platform [7] [8]. We found that the effectiveness of the data migration function can be increased by interlocking with the sample function [8]. In this paper, we studied not only to evaluate separately the result of each experiment done for each function but also studied comprehensively, summarized the results and then concluded.

# 2 ANALYSIS AND UTILIZATION OF STANDARD

## 2.1 Relevant Standards

In this paper, the experiments and verifications are done mainly using the security standard data that has been summarized as the ISO/IEC 27000 series. This has adapted the concept of PDCA (Plan-Do-Check-Act) cycle, which is widely used in the standards of security management represented by the ISMS.

This security assessment platform is intended to be used not in a single phase of the PDCA cycle but in every phase of the PDCA cycle that matches the applicability. If it is applied in the Plan stage, the loopholes in the countermeasures can be checked by entering the results of the present data analysis. In the Do stage when it is recognized that enforcing countermeasures do not cover the planning item the confirmation of the loophole in its entirety is possible by the means of checking those items. In the Check stage it is possible to check the functionality of each countermeasure according to the plan made in the countermeasure enforcement stage. It is possible to check the loopholes by summing up those changes in the corresponding conditions that match the conditions in practice. In the Act stage as with the Plan stage, the loopholes of the corresponding countermeasures that were re-defined can be checked.

### 2.1.1. ISO/IEC 27000-series

The ISO/IEC 27000-series is an information security standard family, established by the collaboration between the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). This series is broad in scope covering privacy, confidentiality and information technology security issues. Therefore, it is applicable to organizations of all sizes and types.

To get the security attestation in this series, organizations first assess their information security risks and then implement appropriate information security controls according to their needs. Given the dynamic nature of information security, the ISMS concept incorporates continuous feedback and improvement activities based on the PDCA cycle. At present, by the end of 2011, 10 standards of ISO/IEC 27000 have been developed and many other standards are under development [9]. ISO/IEC 27000 is a standard reference in many areas and it shows the importance of the PDCA cycle operation based on ISMS.

### 2.1.2. ISO/IEC 27001

The objective of ISO/IEC 27001 is to provide a model for establishment, implementation, operating, monitoring, review, maintenance and improvement of ISMS [10]. In addition, the contents shown in each item of this standard in the operational manual created during the process of ISMS attestation, corresponds to the security requirements. It should cover all the items including those that specify outside the scope. During the inspection for ISMS attestation, the security countermeasures corresponding to each item of this manual will be subject to inspection.

## 2.2 Standard Configuration

Generally the body in the relevant standard, as for thesis, has often been described in a hierarchical structure of three phases namely; 'Chapter', 'Section' and 'Item'. In 'Chapter', the assessment targets are roughly classified. In 'Section' the assessment targets are described in detail and in 'Item' the contents are further described in more detail.

However, there are many individual items which are not only described as separate items but also as the conditions or supplementary matters that refer to other items. For instance, 7.1 General of ISO/IEC 27001 has a description in the text with reference to 4.3.3 and it is expressed in the reference tree used in this study as shown in Figure 1.

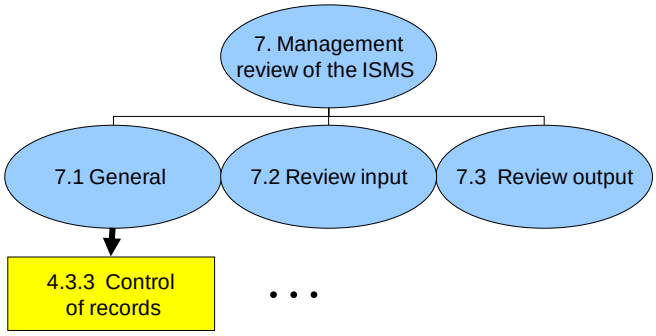



Figure 1: Reference-related example of ISO/IEC 27001

## 2.3 The difficulty and solutions of covering the items related to countermeasures

In security attestation, the criteria should be comprehensively covered. Depending on the framework of each chapter of the configuration the concerned policy decisions such as implementation of countermeasures and acceptance of the risk will be made. At that time, since there is a need for the comprehensive cover of the standard for each chapter, it is necessary to grasp precisely the layered structure of each chapter and reference relations from each items.

However, it is not only limited to ISO/IEC 27001, in the standards there are many statements indicating the references and there is a wide variety of contents (items) of which each item should be covered. Hence, there exist problems such that understanding all of them precisely and

choosing comprehensive measures become difficult. Therefore, it is desirable to collectively manage all the items covered in each chapter. Since the hierarchical structure and reference relations that are described in the standard are described as information of similar characteristics, it can be treated as information of similar characteristics if there is a change in the standard or even if the standard is a different one. In this study, we focus on the hierarchical structure and the reference relations. In order to solve these issues, we propose a platform that can collectively manage all the items to be covered by using the hierarchical structure and the reference relations.

# 3 OVERVIEW OF THE PLATFORM

## 3.1 Structure of the platform

This platform has been divided into three parts namely, the data input unit, the data management unit and the score calculation unit. The configuration of the platform is shown in Figure 2. In the data input unit, the raw data of the standard, structural information, reference information, countermeasure information and relevant information are entered. While entering the countermeasure information, the data input can be made based on the sample information created by the data management unit. Based on the raw data and structural information of the standard inputted, the data management unit organizes, develops the reference relations using the reference information and configures the reference tree. Further, in the score calculation unit, the calculated assessment values (score data) are managed. Also, based on the countermeasure information or the relevant information inputted, the sample data is created. In the score calculation unit, based on the reference information by the reference tree and the countermeasures information of the registered countermeasures, the assessment value is calculated and the calculated data is passed to the data management unit.

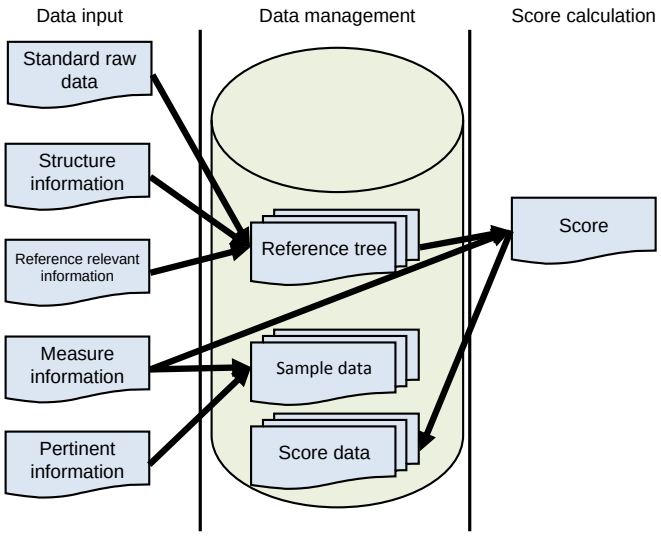



Figure 2: Structure of proposed platform

## 3.2 Behavior of the platform

First, the data input is done in the data input unit. The raw data of the standard is registered first. Then the structural information based on the hierarchical structure described in section 2.3 is registered against the previously registered data. Subsequently, reference related information is registered. As for the structural information and reference information that are registered here, the hierarchy based information and the direct reference information (Hereinafter referred to as direct reference) that have been described in the standard document are registered. The registered multiple criteria (standard) are related to each other and if relevant information is provided showing the requirement of measures, in terms of which item of each criterion for what item, that information is also registered. After data registration is completed, the registered data is delivered to the data management unit and then migrated to the next operation.

In this platform, the hierarchy is defined using levels. Define chapter as level '1' and continue numbering the following stages as level '2' and so on. Level 'm' is assumed to directly refer the items of level 'm+1'. In this study, this type of hierarchical structure is also defined as a part of reference relations.

Configure the basic tree with the item that has direct reference as the root (Hereinafter referred to as the parent reference) and the described items that should be referenced (hereinafter referred to as referenced) as the leaves of the tree. If the leaf of a basic tree becomes the root of another basic tree, configure a new tree combining the part of the leaf of the former tree with the root of the latter tree. In addition, during configuration, it may have the same item as reference as seen from the root of the tree. If this repeated reference relation has multiple references at multiple locations with the same field as a reference, it will be a reference loop that causes a loop to occur when you configure the tree. When these references occur, the part that is overlapped is determined as the leaf and the configuration of the tree shall be continued. Thus, binding of the tree is continued until it becomes impossible to bind further and the largest tree becomes the reference tree.

In a reference tree, the relation between the items is expressed as distance. The distance of those that are referenced directly is 1 and for each iteration of the following references the distance between the items goes on increasing gradually.

Subsequently, a standard for security attestation using that reference tree is created in the score calculation unit. The criterion is intended to measure the assessment value of the entire reference tree that the chapters, sections and items of the standard have references within the parent reference. In fact, in the data input unit, information of the countermeasure implementation using the information of the reference tree, countermeasures in the past projects based on the sample data and the sample of the compliance status of each item in the standard are suggested. It is suggested to input the implementation information of the countermeasures of additions and changes. Based on the countermeasure information and the reference tree

information inputted assessment value shall be calculated. In addition, only in case that providing the sample data is set in the data management unit during that time, countermeasures and the supported data within the compliance status information of each item will be stored as the sample data. After that, when the compliance status of the corresponding countermeasure is inputted by another user (or subject), the sample data can be inputted referring to the sample data that has been provided.

In case the relevant information of other criteria is referred to when the assessment is done against the new criteria, using the data migration function in the data management unit, the sample data is created based on the compliance status data of the underlying criteria and it can be inputted in the data input unit while browsing.

## 3.3 Features of the platform

In this platform, when there is a change in the standard, the information in the data input unit is updated. After updating the information, the reference tree will be automatically reconfigured in the data management unit. In the score calculation unit, reassessment and the recalculation of the score can be done in accordance with the changed contents of the standard.

In addition, the relationships between the items can be visualized by configuring the reference tree. Choosing the countermeasures while checking the reference tree can help to set the countermeasures effectively. In the sample data display function, managers who may not have sufficient expertise can share the information. In the data migration function, during reassessment process, the sample data that can be used as reference can be created without any extra efforts.

## 3.4 System configuration of the platform

This platform is developed using Visual Basic and various experiments have been performed so far. First, the entire platform is configured as a single program. The program composes independent subprograms. Namely, they are subprogram that that composes information for configuring the reference tree, after registering the criteria, hierarchical structure information and reference relation information, the subprogram that displays the reference tree, the subprogram that organizes the status of the countermeasures and the subprogram that performs assessment value calculation. These subprograms are made to ensure smooth running of the system by performing in the background. For instance, when the data is first registered or when there is any change made in the data, changes are made in the reference relation of the entire criteria in the background and even during the process of making changes, the history of the data can be viewed. In addition, the body of the platform can always be run by operating the time consuming subprograms as independent programs during the processes such as displaying the reference tree and changing the status of the countermeasures.

Apart from that, when introducing or trying multiple methods of assessment value calculation, by separating the assessment value calculation program and replacing one particular program, it can be smoothly changed to a new assessment value calculation method. Similarly, in the display function of the reference tree, instead of replacing the program to meet the user's demands, a display program that matches the user's preferences can be introduced easily.

# 4 METHOD OF CALCULATING IMPACT OF EACH COMPONENT OF THE REFERENCE TREE

In this study, focusing on the number of items of the reference tree and the distance, the value of the assessment can be compared using the security assessment method that changes the impact of each component. In addition when items from other chapters are referred to in the reference tree, it is possible to obtain the result of the validation of the change in the calculation method of the degree of impact on the calculation results of those items. In this paper, we compare the results of the all experiments and investigate them comprehensively.

There are four methods tested so far. The estimation method focusing only on the component number is taken as method 1. As for the evaluation value score corresponding to the conditions of existing measures, measures in progress and measures yet to be implemented, the number of component as '*n*' of the reference tree which is the root of the estimated item is made as the denominator, the *i*th component is made as $x_i$ where $x_i$ is equal to 1, if the estimation item is applicable and is equal to 0 otherwise and the summation of $x_i$ is made as the numerator and *Score* is calculated. In the above calculation, the ratio agreeing with the actual estimation item within the component is denoted. The evaluation value $Score_1$ is given in equation (1).

$$Score_1 = \frac{\sum_{i=1}^{n} x_i}{n} \tag{1}$$

The estimation method depending on the maximum distance is taken as method 2. Here, in each component of the reference tree which is the root of the evaluation item, the *i*th distance is taken as $d_i$, maximum distance is taken as $d_{max}$, the component number is taken as '*n*' and the *i*th component is taken as $x_i$, which is equal to 1 if the estimation item is applicable and equal to 0 if the estimation item is not applicable. Using this, the degree of impact of the distance 1 item is taken as $d_{max}$ and subtracting the increment of all distances by one from $d_{max}$. And summing it through all values of *i* from 1 to *n*. This summation value is taken as the denominator. The numerator is taken as the summation value of the degree of impact of the corresponding completed items. Using this, the evaluation value is calculated. The evaluation value $Score_2$ is given in equation (2).

$$Score_2 = \frac{\sum_{i=1}^{n} \{x_i (d_{\max} - d_i + 1)\}}{\sum_{i=1}^{n} (d_{\max} - d_i + 1)} \tag{2}$$

In this method, though there is change in the impact based on the maximum distance in the reference tree, depending on the distance, the impact of the degree of assessment is determined in monotonically decreasing form. Characteristically, the impact of each item on assessed item is slowly falling. Subsequently, let the assessment method that uses the reciprocal of the distance be method 3. Taking the sum of the reciprocal of the distance as the denominator, and the sum of the reciprocal of the distance of the supported component as the numerator, the assessment score is calculated. The assessment value $Score_3$ is given in equation (3).

$$Score_3 = \frac{\sum_{i=1}^{n} \frac{x_i}{d_i}}{\sum_{i=1}^{n} \frac{1}{d_i}} \quad (3)$$

In this method, the impact of each component will not get affected by the maximum distance of the reference tree. Impact will be determined purely by distance only. As for characteristics, the distance between the items greatly affects even within a small distance. In this method as the distance gets larger, the impact slowly falls.

The last method 4 is the method that changes the impact based on the nature of the components of the reference tree. In this method, the degree of influence of each component is not impacted by the maximum distance of the reference tree. Impact will be determined purely by distance only. As for characteristics, the distance between the items greatly affects even within a small distance. In this method as the distance gets larger, the impact slowly goes down. The last method 4 being the method that changes the impact based on the nature of the components of the reference tree. In this paper, through the experimental results obtained in chapter 6, if by the standard in which each item differs with assessment items, then a change in the degree of influence is added. In the method 4, the method 2 is suggested in the case that the evaluation item and the item is the same category, and in the case that the category is different method 3 is adopted.

In method 4 the evaluation item represented in the hierarchical structure and the chapter of the component, when same, the condition of the degree of impact is gradually reduced; when the represented chapter at the reference structure is different, sudden reduction in the degree of impact is manifested in accordance with the distance. In addition, when the similar concept is referred to even in the reference structure, it has the characteristic of the degree of impact being calculated relatively high.

# 5 CALCULATION OF SIMILARITY

## 5.1 Similarity Calculation method

In the classification and search of the documents related studies have been actively made in recent years, and many methods of calculating the similarity have been proposed. In this paper, we adopt the most commonly used technique in our similarity calculation method. The general procedure for calculating the similarity is shown in Figure 3.

First of all, when calculating the similarity method, the text information of each document is to be determined. ((1) in Figure 3). Then, by morphological analysis, the text information that was determined is resolved into morphemes and extracts ((2) in Figure 3) the index terms (items represent the contents of the document) [11]. Morphological analysis program is a program such as “ChaSen” [12] developed by Nara Institute of Science and Technology. Morpheme or a noun etc. can be mentioned as the unit of the index terms. Then, the words that become dissonant are removed as unnecessary words. ((3) in Figure 3). In addition, the extracted words are weighted. ((4) in Figure 3). As for the weighting method, index word frequencyTF (Term Frequency) and IDF (Inverse Document Frequency), a combination of these, TFIDF, is often used [11]. Finally, calculate similarity between texts which were shown to vector or matrix by weighting. ((5) in Figure 3)

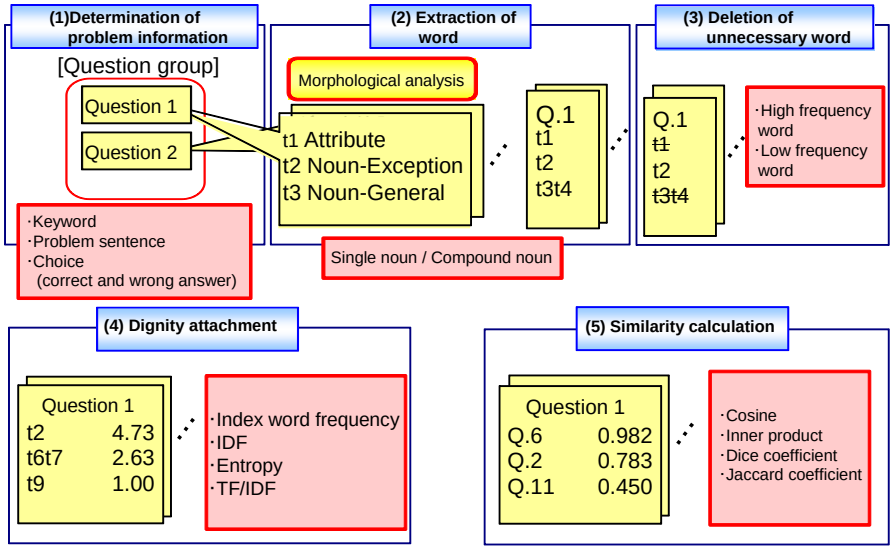



Figure 3: General procedure of calculating similarity

Table 1: Evaluation value in an all method

| Category | standard value | evaluation values 1 | evaluation values 2 | evaluation values 3 | evaluation values 4 |
|---|---|---|---|---|---|
| 4. Information security management system | 20% | 11.32% | 11.92% | 10.45% | 13.98% |
| 5. Management responsibility | 50% | 13.24% | 10.79% | 13.36% | 18.06% |
| 6. Internal ISMS audits | 0% | 13.24% | 10.34% | 10.14% | 4.91% |
| 7. Management review of the ISMS | 0% | 0.00% | 0.00% | 0.00% | 0.00% |
| 8. ISMS improvement | 0% | 13.24% | 8.78% | 8.59% | 1.84% |

Table 2: Differences in all proposed type

| Category | standard value | difference 1 | difference 2 | difference 3 | difference 4 |
|---|---|---|---|---|---|
| 4. Information security management system | 20% | −8.68% | −8.08% | −9.55% | −6.02% |
| 5. Management responsibility | 50% | −36.76% | −39.21% | −36.64% | −31.94% |
| 6. Internal ISMS audits | 0% | 13.24% | 10.34% | 10.14% | 4.91% |
| 7. Management Review of ISMS | 0% | 0.00% | 0.00% | 0.00% | 0.00% |
| 8. ISMS improvement | 0% | 13.24% | 8.78% | 8.59% | 1.84% |

## 5.2 Application Example

When the experiments carried out in this chapter assess using a different standard, the data of the countermeasure's status of the already assessed standard is assumed.

Another application example is if the standard that becomes criteria is updated, it differs from the old version. Locating the items of the chapter or those that are moved to a newly summarized chapter, if global criteria of the international standard etc. is taken as base, while creating the local criteria of internal standard etc., to what extent the underlying contents of the standard can reflect, whether any loophole has occurred or not are verified. In case the internal standards are already provided and while aiming to get security attestation, if current criteria exist, it is applicable in case of checking whether it meets the criteria to get closer to the standard to the extent that it is aiming to get closer to.

# 6 EXPERIMENT BASED ON EACH FUNCTION

## 6.1 Experiment 1: Evaluation value calculation

We compared the evaluation value using the security evaluation method which adds a weight factor to each item paying attention to the number of items and distance of a reference tree using the above-mentioned method 1-4. In addition, we were able to obtain the result that it was effective to change the impact to a calculation result about the items, when the items of other chapters were being referred to within a reference tree. In this paper, all the results of experiments were compared and comprehensively examined.

### 6.1.1. Experiment outline

At first, we asked an evaluator who fully has the security knowledge to evaluate security of an organization, and we summarized the results in the table for every category. Next, we used the method 1, 2, and 3, evaluated in the situation of the same security countermeasures, and compared the evaluation values by the evaluator's sense and those by the platform. And we verified whether an improvement of a value could be performed using the method 4 based on the knowledge acquired from the experiment.

### 6.1.2. Experimental result

1) Calculation of evaluation values using the method 1, 2, 3, and 4

We inputted the situation of security countermeasures into the platform, and calculated the evaluation value by each system of the method 1, 2, 3, and 4. The evaluation value calculated by each system, they called the evaluation values 1, 2, 3, and 4, the results are shown in Table 1.

2) Comparison of evaluation values

We compared with a standard value and the evaluation values 1, 2, 3, and 4. And we investigated which method shows the value nearest to a standard value in each management field. We took difference from the standard value to each evaluation value, and showed the result for each category in Table 2 as the difference 1, 2, 3, and 4. Since it can say that what has a lower absolute value of difference is closer to a standard value, among the method 1-3, method 2 became the most effective in "category 4." It results that countermeasure of the items of the category is progressing. On the other hand, method 3 became the most effective in "category 5, 6 and 8." It results that correspondence of the item of a reference instead of the item of the category is progressing. We could not obtain either method 1, 2 or 3 was the most effective in all the categories. We found out a limit that calculates evaluation values by only the method 2 or 3. Therefore, we used the method 4 as an impact calculation method in the form where the feature of each method was harnessed. As the result, we compared

the difference 4 with the difference 2 and 3, and have improved the value in all categories.

## 6.2 Experiment 2: Sample presentation

### 6.2.1. Experiment outline

We investigated whether the support which distinguishes correspondence of the countermeasures to items of standards by showing the sample data could be performed for administrators who have not enough knowledge of security attestation. This experiment was executed in the form of role play. The sample data was created by the author who had experience in general security operation and have knowledge about security standards. Countermeasure data was created by graduate students of our laboratory who has general knowledge about security but does not have enough knowledge about security standards.

### 6.2.2. Experimental result

1) Analysis of the countermeasures by the administrator

At first, we asked an administrator to distinguish manually items of standards corresponding to the countermeasures. Since the administrator's knowledge of security standards was not enough, he chose the items focusing on his sense of a countermeasure. Therefore, the selected results have many effective items to every countermeasure.

Then, the same work was done, showing information reference-related by a reference tree by using this method for the same work. By having worked looking at a reference tree, it became the reply improved by "not yet" in the item with low relevance over the main items about each management measure. The same work was done once again by showing the sample data. The sample data was displayed in the two forms where the data created when extracting a countermeasure, and the data created by the administrator, are distinguishable. As the result, furthermore, narrowing down of the items judged corresponding to the countermeasures was performed.

2) Hearing of the administrator

We made the hearing the administrator about change of criteria of choices and the result. As the result, he was able to arrange the relationship among items by using the platform. And he has chosen the items with confidence by presentation of the sample data. In addition, he answered that he left the data which is not in samples with confidence to of his sense in practical jobs.

## 6.3 Experiment 3: Data conversion

### 6.3.1. Experiment outline

At the first, we distinguished the corresponding situation of countermeasures from two viewpoints, that is "the ISO/IEC 27001 Annex A" and "an ISMS attestation standard Ver.2.0 attachment. Next, we checked the results by carrying out data conversion from each data. We asked a graduate student who is an administrator of our laboratory to experiment using the situation of the countermeasures in our laboratory.

### 6.3.2. Experimental result

We used the about 20 countermeasures. Different items with a correspondence became a little more than 120 items. We could obtain all the patterns including opposite selection contents and one side selection. And as the result of comparing the contents of the item which showed a different situation and analyzing a situation, we could classify into the following six patterns.

i. The contents of the item were specified in detail.
ii. The contents of the item became ambiguous.
iii. As the contents of the item of the higher level of an item differ; those to which it points also the same contents differ.
iv. The contents are a difference in expression; the pointed-out contents do not change.
v. The same contents are viewed from the other aspect.
vi. It does not belong to the same category on both standards.

## 6.4 Experiment 4: Pertinent information extraction by similarity

### 6.4.1. Experiment outline

We calculated the similarity between two standards, "the ISO/IEC 27001 Annex A" (hereinafter the standard A) of the international standard and "an ISMS attestation standard Ver.2.0 attachment "detailed management measure"" (hereinafter the standard B) of Japanese standard, that the pertinent information between standards is already specified. We defined items what takes the maximum for the calculated similarity in view of both standards as "the items with relation". And we checked how many relations specified were reproduced. And we classified items that are not reproduced into three categories. Namely, FN(False Negative) which was not extracted although there is a relation, FP(False Positive) about which was extracted although there is no relation, and NG which is extracted the wrong item, and analyzed them in detail.

### 6.4.2. Experimental result

The result compared the item with the pertinent information on the standards A and B the item extracted as items with relation is shown in Table 3. The reproduced rates exceed 80% in top category, middle category, and bottom category. And each assurance became a high value exceeding 89%.

Regarding the errors, 26 FN, 2 FP and 3 NG, we checked wording of the similarity to each items seen from both standards A and B, and each item, in order to investigate the cause of errors about each combination. And we found out that most combinations which causes of errors have low similarity.

Table 3: Reproduced rates and assurance of an item with relation

| | Number of pertinent | Number of extraction | OK | FN | FP | NG | Reproduced rates | Assurance |
|---|---|---|---|---|---|---|---|---|
| Top category | 10 | 8 | 8 | 2 | 0 | 0 | 80.00% | 100.00% |
| Middle category | 31 | 28 | 25 | 5 | 2 | 1 | 80.65% | 89.29% |
| Bottom category | 116 | 97 | 95 | 19 | 0 | 2 | 81.90% | 97.94% |

We checked each of top category, middle category, and bottom category. In the top category with few amounts of texts at the extraction time of a technical term, if more suitable judgment could be made, we could lead one of FNs to the right combination. Besides if the similar words could be correctly distinguished about the items, we could also lead to the other FN in the right combination. Each of three combinations detected as FP and NG in the middle category was the low values in which similarity is less than 0.5. Moreover, regarding the item extended as NG using only an item name, the similarity became 1, and full match was carried out. However similarity was falling by uniting the portion of detailed description. About the combination of FN, like NG, there exist the cases which show coincidences or high similarity of item names. Or, the maximum similarity is low viewing from both of standards A and B and the similarity is the maximum viewing from one side, however the similarity is the second or third value from the other side and could not detect because of small margin. Or, on the whole, the similarity is less than 0.5 in all the combinations. In case of bottom category, the combination of FP did not appear. However, when there is two combinations of NG, the both showed the maximum similarity seen from one side, and have the second and the third similarity seen from the other side. Although there are combinations of 19 FNs, we could classify into the two cases as same as the middle category except some combinations.

The following knowledge was able to be acquired from the above the analytical results.

i. The item which shows the low value that the maximum of similarity is less than 0.5 does not have a related item in many cases.
ii. When description form is divided into an item name and detailed description, the similarity of an item name becomes more important.
iii. Related items can be detected in many cases if it inquires including the item of higher category of similarity when the maximum of similarity from both sides is judged that there are no related items which do not specify the same items.

## 6.5 Considerations of experiments

### 6.5.1. Experiment 1

Through these experiments regarding the thinking direction of the evaluator we found that the influence on achievement level in the management category as for the long distance of the reference tree of the platform and referencing items outside of the management category. In addition, we found that the calculation method using reference trees is effective to avoid the human errors which overlooks the influence of items referring to the other category with potential influence.

Moreover, the evaluation value has been improved also about "5. Management responsibility" by changing a method reflecting the comments from hearing. However, the difference of the subject's evaluation value is still large. About this cause, possibilities may be added as an evaluation criterion, or the contents besides actual evaluation criteria may be reflected on a result. In this case, since it was an early stage which aims at attestation acquisition, we found that an additional point about possibilities was included.

### 6.5.2. Experiment 2

There was a tendency that the subject who has not enough professional knowledge chose more items for countermeasures. We found out that relationship of standards is difficult for the administrator who had not enough knowledge from the hearing result. And we found out that it is effective to express visually using reference trees. We also found out from the hearing result about presentation of the sample data that the administrator who has not enough knowledge of standards, was supported by showing the sample data. The item and relationship which he referred to sample data, narrowed down information further and finally remained them items became clear and eventually we found that the correspondence about the items which were not chosen only by his knowledge is added.

### 6.5.3. Experiment 3

About i., ii. and iii. shown in the 6.3.2, since changes may come out in countermeasures by expressional range, we recognize that it is not appropriate only by changing data simply. About iv., v. and vi., when the subject in the experiments overlooked and his knowledge was not enough, we also recognize it is possible to avoid errors by showing the sample data.

### 6.5.4. Experiment 4

We confirmed that the high reappearance can be obtained by extracting the items which have relations using the text similarity. We found especially that assurance of the items extracted was very high. Some of the causes of errors were due to improper range division of words at the time of the

analysis of wording. In addition, the other causes were due to the fact that it is impossible to judges automatically the different words pointing same meaning because technical terms are used and the similarity became low. In spite of using simple similarity calculation the high reproduced rate and high assurance were obtained. Therefore, we found out that it is effective to use the technique of extracting the items which have relations in quest of the similarity between standards using the similarity calculation method between the texts currently used in the field of natural language processing. Moreover, it is expected that the still higher reproduced rate and assurance can be obtained by creating pertinent information using a more sophisticated technique.

Since the data for sample presentation is made, it seems to be important to reduce FP and NG even if FN increases. It is because we assume such users who do not have enough specialized knowledge. For example, the following methods can be considered to improve. When the standard document is divided into item names and detailed description, importance will be put to the item name instead of weighting used in the experiments. Since a standard has a layered structure, the similarity and detection of relation of an item in higher categories are taken into consideration.

#### 6.5.5. All experiments

We found out that platform is effective in prevention of human errors from the experiments 1, 2, and 3. The errors which can be prevented in each experiment are different, however what is considered as the primary cause of errors depends on the complicated composition of the standards used as the base document what is one of the target of this research. In this approach, sensuous and visual correspondence was carried out by using reference trees, and it has contributed to problem solving.

In particular, visual support was performed by using reference trees about the omission in evaluation in the experiments 1 and 2, and it contributed to prevention of errors. And about the experiments 2 and 3, visual support was carried out by presentation of the sample data, and it also contributed to prevention of human errors.

Moreover, in the experiment 4, by using the technique of text similarity calculation pertinent information can be estimated to the standards where relations are not indicated. We confirmed it is possible to create pertinent information between various standards such as a global standard and a local standard.

These experiments have high flexibility and they can be applied not limited to security specified standards. However, since the experiment 2 is supported for choosing the relation between security countermeasures and a standard exactly, the security viewpoint is strongly reflected.

## 7 FUTURE WORKS

The sample presentation function has a basic issue, such as a sample collecting rule and reliability. Currently, we are considering the solution in the aspect of practical use rather than technical side. Regarding the sample collection rule we have proposed the rule where the data made using the sample data is provided as a new sample. Regarding reliability we have proposed the following method by using a central server in order to improve the reliability of the sample data. If more than fixed numbers corresponding to the same item about the same measures are stored, the server will judge the sample data automatically that it is reliable, and adopted as the sample data. Else if less than fixed numbers, the data is checked by human and adopted if the validity can be accepted.

We have experimented by the phase of gap analysis and present data analysis. However, there exist many phases which carry out security evaluation besides. Some of examples are the phase where the detailed risk analysis is conducted, and the phase where already has finished attestation acquisition and it has already employed the PDCA cycle corresponding to the phase which carries out security evaluation. Therefore, we will also conduct a security evaluation experiment of an organization with other phases, and examine the validity.

We conducted the experiment using the similarity in the experiment 4. We used the standard which has pertinent information in the experiment. However, the problem that the relation to the mistaken item (FP and NG) about some items is shown has occurred. We will avoid the error by using the similarity of semantic, and raise text analysis accuracy. For example, we use the structure information such as a layered structure and reference information on a standard. We are planning the next experiments where we calculate the similarity by judging that the item name is more important, if the standard consists of an item names and detailed description.

## 8 CONCLUSION

In this paper, we verified not the validity of an individual function but the validity of the whole platform based on the experimental results.

We found that it is effective for such problems as oversight and insufficient knowledge by using visual support that presents reference trees or samples. In this platform, we confirmed that potential influence is expressed using reference-related information in case that influence may be overlooked even if the evaluator has professional knowledge. In addition, we recognized that the visual information by reference trees and sample presentation is very effective for the oversight and misapprehension, when knowledge was insufficient.

Furthermore, we found that each function can be utilized more effectively by interlocking two or more functions effectively, as the sample presentation and data conversion. We expressed the situation of countermeasures by the two choices "done" and "not yet" for simplification in this experiment. In addition, we expect that evaluation of potentiality can be added by getting to know the rate of perfect "not yet." if potentiality and the state under way are expressed by using the third choice "doing".

We experimented using two standards where pertinent information is clearly specified. As the result, we have created the pertinent information on the high reproduced rate and high assurance. Thus, we were able to lessen the

rollback of the reappraisal carried out when the standard changes by creating such pertinent information.

It is very effective for reappraisal of the security to create of pertinent information when the standard is updated. Moreover, since we could obtain high reproduced rate and the high assurance by the similarity calculation technique, it is expected that the still higher reproduced rate and assurance can be obtained by creating pertinent information using a more sophisticated technique.

We will work for the future works shown in Chapter 7. We will examine the adaptability of our platform to various phases and we will try to improve the validity of the platform.

## REFERENCES


[1] JIPDEC, The international trend of ISMS, and the actual condition of a measure<2004 editions >,(2005)

[2] Information Management Systems Promotion Center (IMSPC) : The number transition of attestation acquisition organizations, The attestation acquisition organization of a certificate authority exception and a prefecture level, http://www.isms.jipdec.jp/lst/ind/suii.html

[3] IPA, Security design evaluation supportive tool V03, http://www.ipa.go.jp/security/fy13/evalu/cc_system/CCtool_V03/secevtoolv03.htm

[4] Y. Takahashi, and Y. Teshigawara, A Study on a Security Evaluation Platform Based on International Standards, IPSJ Computer Security Symposium 2008 The 2nd separate volume of collected papers, pp.815-819(2008)

[5] Y. Takahashi, and Y. Teshigawara, A Study on an Effectiveness of Security Evaluation Platform Based on International Standards, IPSJ CSEC: Computer Security Group Vol.2009-CSEC-46, No.13(2009)

[6] Y. Takahashi, and Y. Teshigawara, A Study of Security Evaluation Method Based on Reference Relationships among International Standards, IPSJ DPS 142 and CSEC 48, Vol.2010-DPS-142 No.53 Vol.2010-CSEC-48 No.53, (2010)

[7] Y. Takahashi, and Y. Teshigawara, A Study on Measures Presentation Function for Non-Professional Persons of Security Evaluation Method Based on Reference Relationships among International Standards, Multimedia, Distributed, Cooperative, and Mobile Symposium.(DICOMO2011), pp.127 – 134(2011)

[8] Y. Takahashi, and Y. Teshigawara, A Study on Data Conversion Function of Security Evaluation Method Based on Reference Relationships among International Standards, IPSJ Computer Security Symposium 2011(CSS2011), pp.666 - 671(2011)

[9] Information Management Systems Promotion Center (IMSPC) : International trend "ISO/IEC 27000 family" http://www.isms.jipdec.or.jp/27000family_20111220.pdf

[10] ISO/IEC 27001 Information technology - Security techniques - Information security management system - Requirements, 2005

[11] T. Tokunaga, Information retrieval and language processing, University of Tokyo Press (1999).

[12] Yuji Matsumoto, Akira Kitauchi, Tatsuo Yamashita, Yoshitaka Hirano, Hiroshi Matsuda, and Masayuki Asahara, Japanese Morphological Analysis System ChaSen 2.0 Users Manual, NAIST Technical Report, NAIST-IS-TR99012, Nara Institute of Science and Technology (1999).

# Keynote Speech 2:

# Mr. Tatsuo Tomita

# (Fujitsu Laboratories Ltd., Japan)

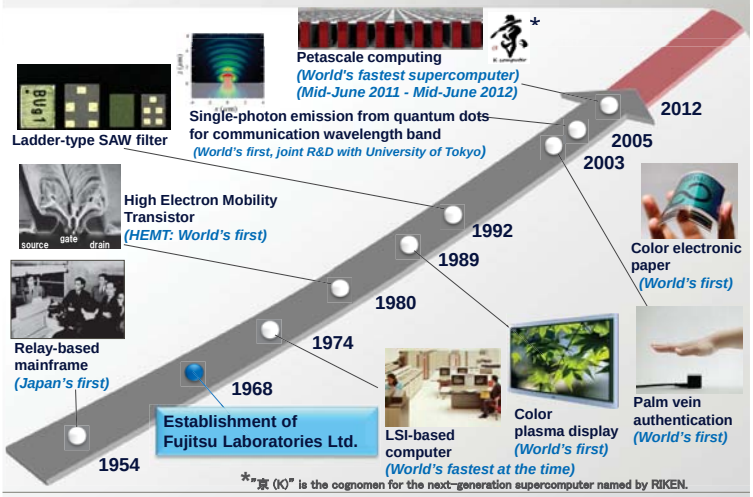
FUJITSU
shaping tomorrow with you

# Human-Centric Computing to Enable and Support a Prosperous Society

Tatsuo Tomita
Fujitsu Laboratories Ltd.
September 6, 2012



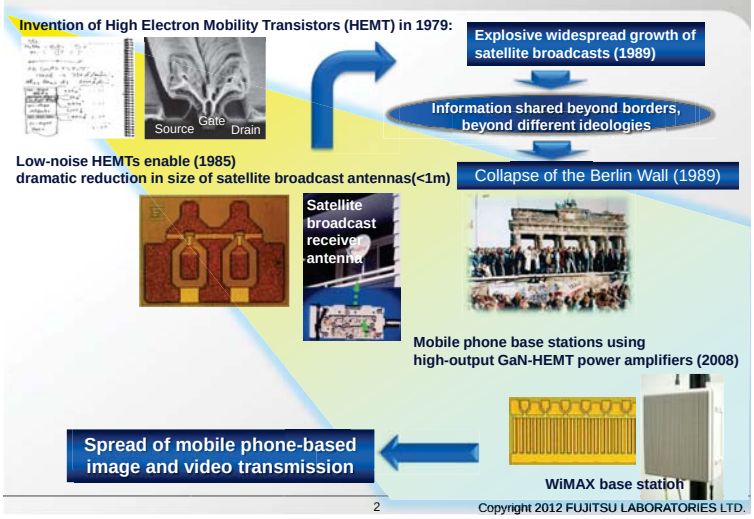
## FUJITSU's Innovations







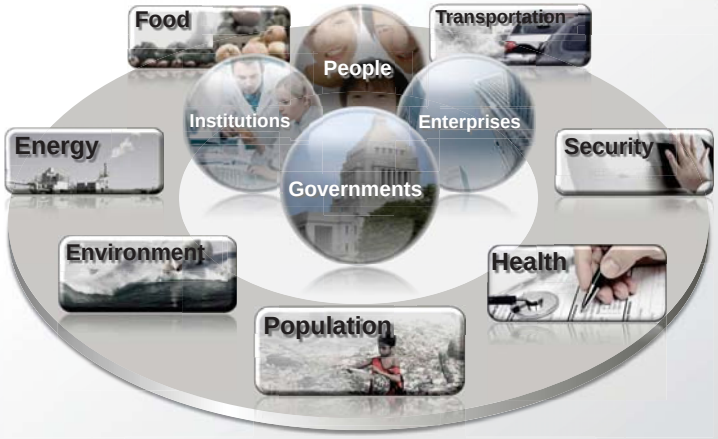
## Technology Innovation, Business, and Society







## What is happening in the world?




Increasingly complex societal issues




## What is happening in Japan?

Great East Japan Earthquake & Tsunami

Nuclear power generation

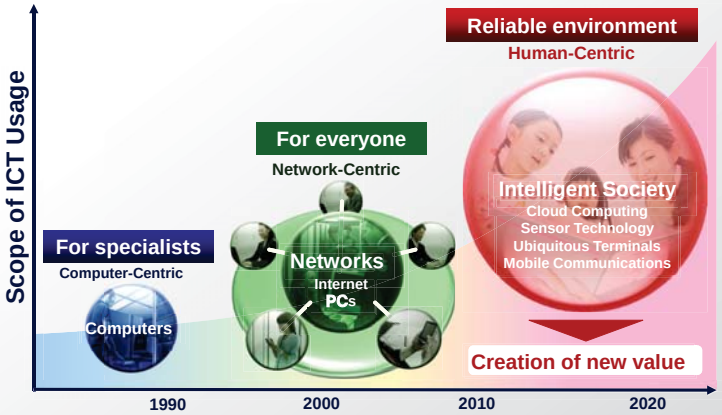
Typhoons

**Building a society that is resilient to disasters**




## Paradigm Shift in ICT

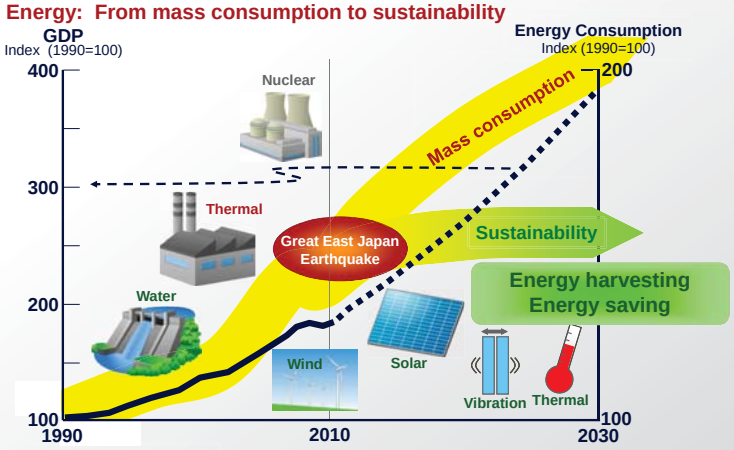
From "Technology-Centric" to "Human-Centric"



## Paradigm Shift in Energy

FUJITSU

**Economy: Maintaining growth**
**Energy: From mass consumption to sustainability**




Source: BP Energy Outlook 2030

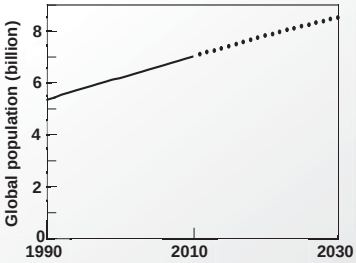


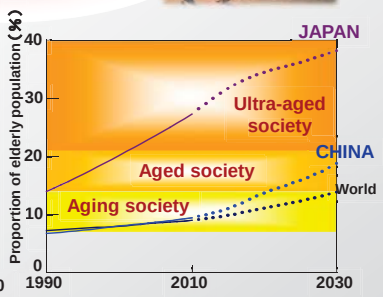

## Rise in Population & Aging Societies

FUJITSU

**Rise in population** | **Aged society**

**Healthcare networks**
**Remote medicine**
**Food & water security**




Source:United Nations Population Division




## Changes in Risks Surrounding People & Enterprises

FUJITSU

**Secure and safe utilization of ICT**

### Increase of menaces
- Natural disasters such as earthquakes, floods
- New-type influenzas

### Increase of security risks
- Information leakage by insiders
- External threats such as falsification of websites and computer viruses

### External requirements
- Reinforcement of internal controls
- Reinforcement of environmental regulations
- Global support

### Changes in ICT
- Diffusion of cloud business: from possession to use
- Fullness of ubiquitous environment




## Fujitsu's vision

FUJITSU

**Enabling a Human-Centric Intelligent Society**


**Real-world value creation through human-centric computing**




FUJITSU

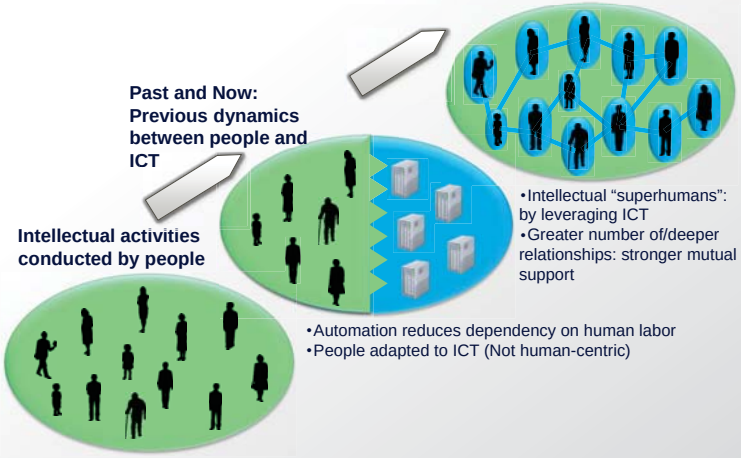
## Human-Centric Computing: Concept



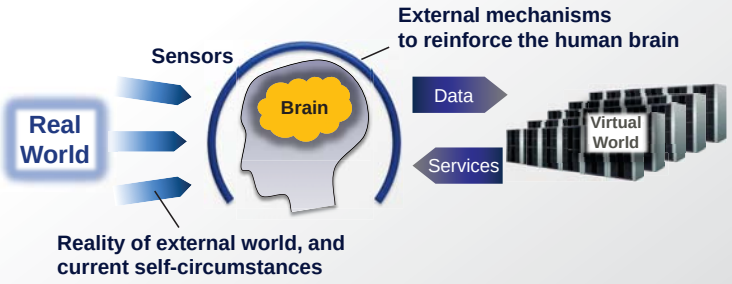

## Shift in dynamics between people and ICT

FUJITSU

**Future: Society that HCC aims to achieve through ICT**



## Human-Centric Computing Model

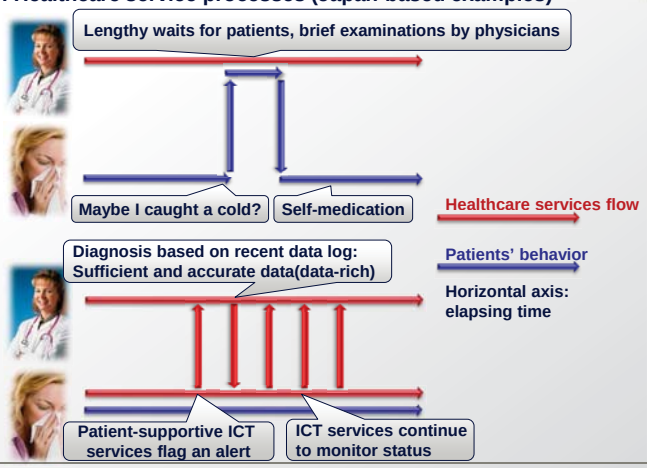






## Life "Blanketed" with Services

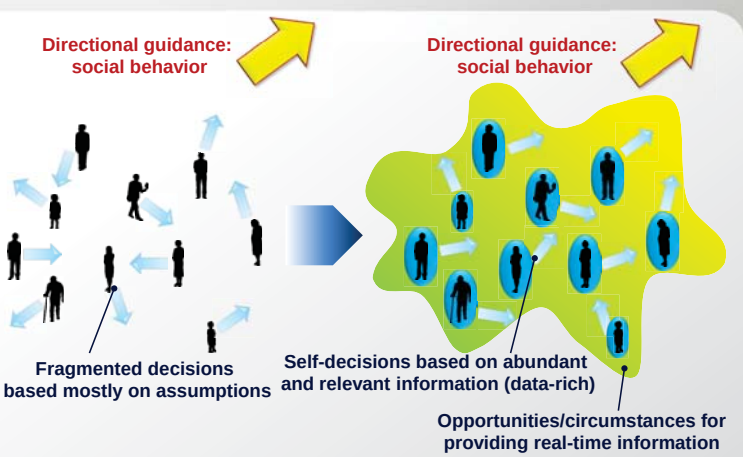
Example: Healthcare service processes (Japan-based examples)







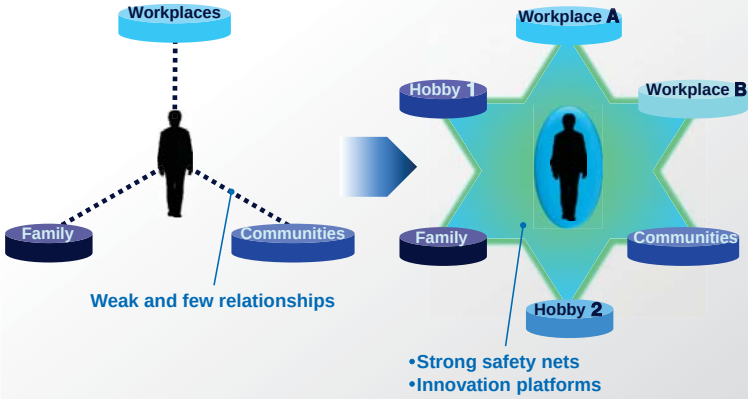
## Social Catalyst : Social Behavior




**Unobtrusive/subtle guidance leveraging relevant & timely information**




## From "Trees" to "Networks": Social Communication



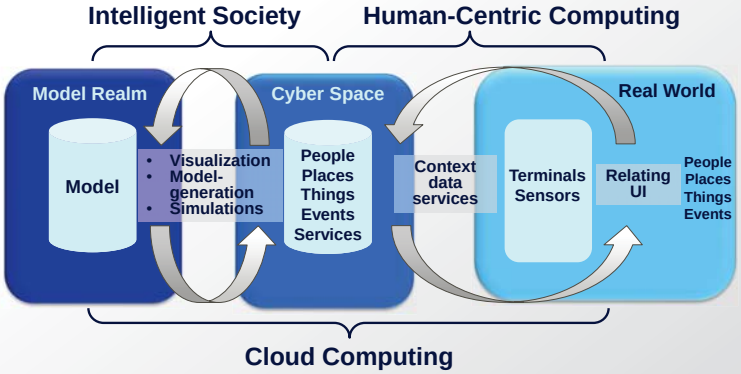

**Social capital accumulated in multiple and lively communities**




## Human-Centric Computing: Technologies



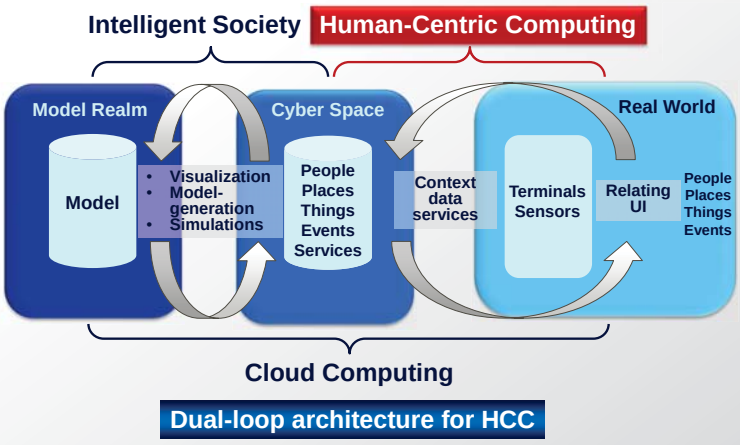

## Human-centric computing : ICT architecture




**Dual-loop architecture for HCC**

## Technologies: Human-centric computing domain

FUJITSU




**Dual-loop architecture for HCC**

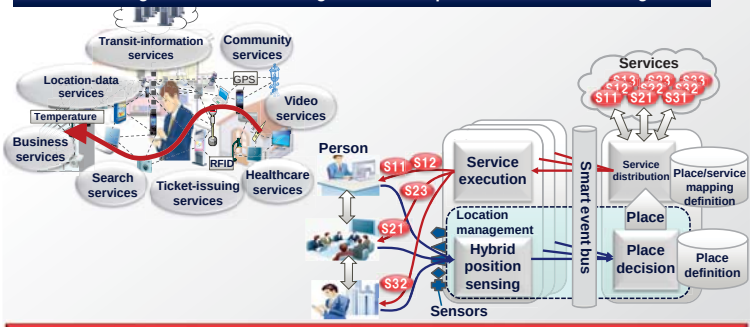



## Location-aware services

FUJITSU

**Providing location-aware tailored services to smart devices**

Cloud computing-based location-aware services platform technologies :
Gather smart devices-derived sensing data on the cloud/ select location/ pro-actively provide services
Location-management services : Plug-in of various position-measurement engines




**Enables timely location-aware services, without necessitating user-selection of services or user-based access to required data**




## DNA-based bio-sensor technology

FUJITSU

**Accurately detects proteins 100 times faster than before with 1/100 sample volume**

Technology for manipulating DNA via an electric al field: Uses DNA charge to control movement via an electrical field
Enables visibility of DNA movement: Fluorescent dye applied to ends of the DNA makes DNA movement visible
Protein detection/analysis technology: Uses DNA movement to detect target proteins bonded to the ends of DNA

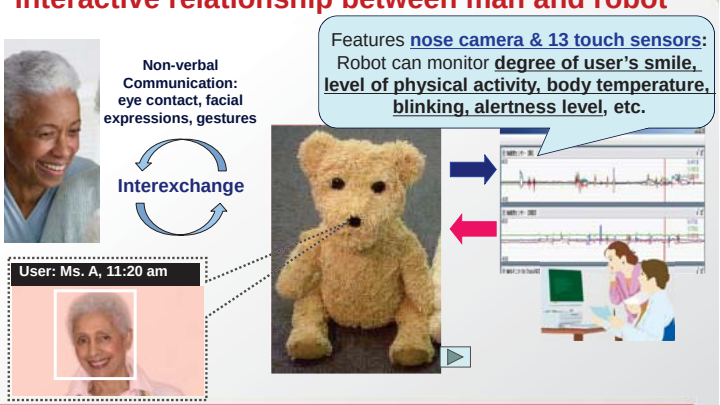

**Contributes to health maintenance and disease prevention by quickly and accurately detecting proteins: disease markers**




## Socially-interactive teddy bear robot prototype

FUJITSU

**Interactive relationship between man and robot**

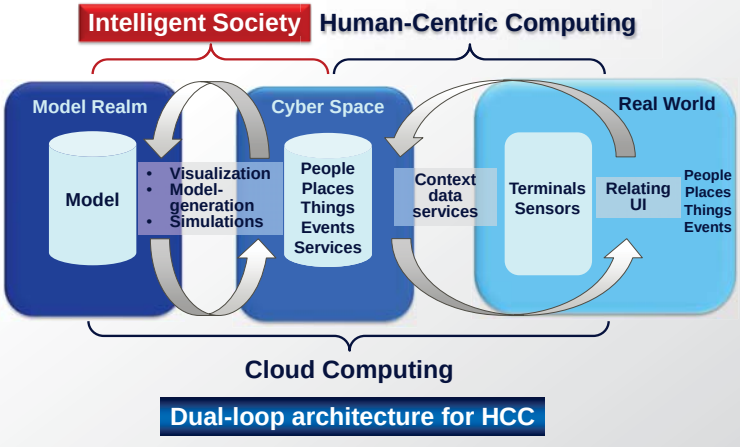



**Interactive companion that blends into daily life and delivers people-friendly services**




## Technologies: Intelligent Society domain

FUJITSU



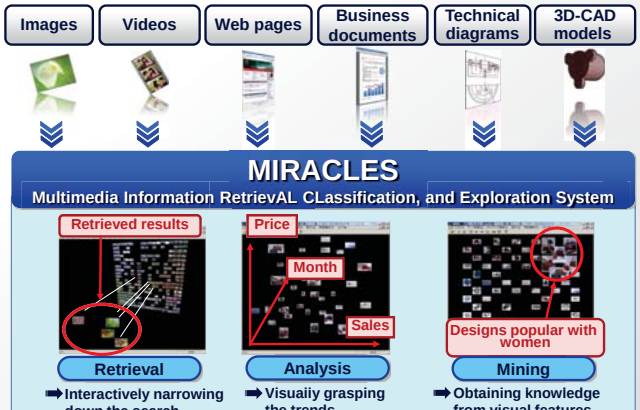

**Dual-loop architecture for HCC**




## Multimedia Information Retrieval, Classification, and Exploration System: MIRACLES

FUJITSU

**Analysis & visualization of massive data: text & images**

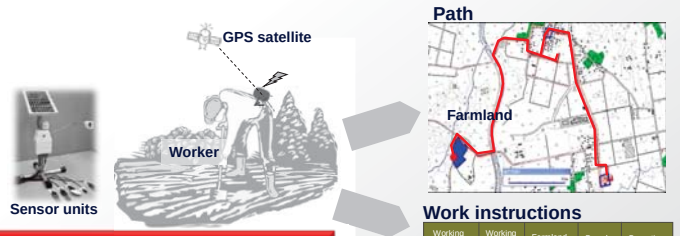



**Extraction of interactively derived data: Customer or user preferences, etc.**

## Agricultural knowledge management

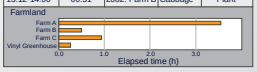
FUJITSU

**Converts agricultural tacit knowledge to explicit knowledge**




Work instructions

| Working time | Working hours | Farmland | Breed | Operation |
|---|---|---|---|---|
| 08:00-10:58 | 02:58 | 2003:Farm A | Tomato | Thinning-out |
| 11:30-12:05 | 00:35 | 2003:Farm A | Radish | Thinning-out |
| 13:12-14:00 | 00:51 | 2082: Farm B | Cabbage | Plant |

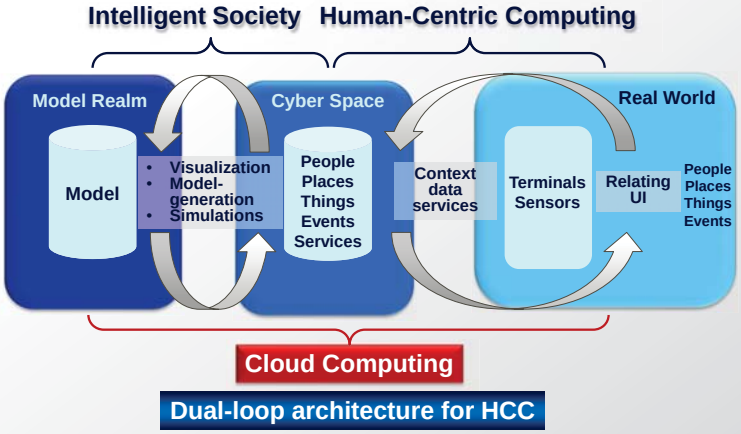



- Share/pass on technical knowledge and know-how
- Improve work efficiencies
- Reduce inconsistencies of workers' output




## Technologies: cloud computing domain

FUJITSU




**Dual-loop architecture for HCC**

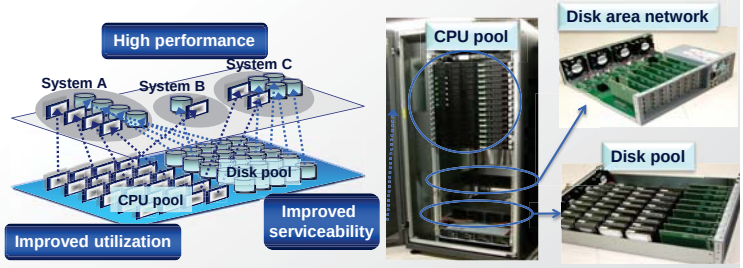



## Next-generation server enabling both high-performance and flexibility

FUJITSU

**Delivers optimal server and storage capabilities as needed through a resource pool architecture**

Pool management feature: Allocates resources from the pool and employs them in server provision
Middleware configuration for constructed server: Delivers storage capabilities
Disk area network: High-speed connection of the disk pool




**Helps enable new ICT services, such as those supporting big data, by delivering flexible, high-performance IT infrastructure**

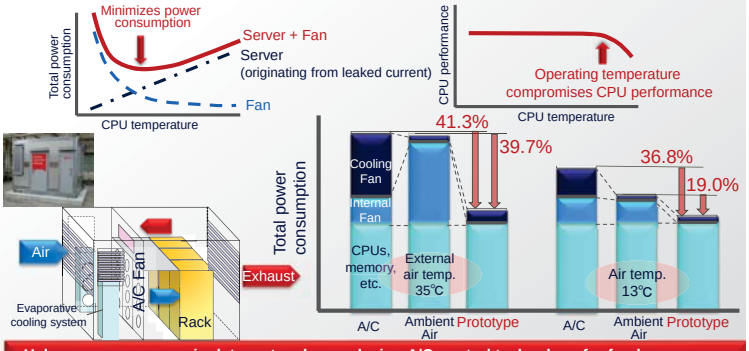



## Power-saving system control technology for Container Datacenters

FUJITSU

**Reduces total energy consumption by up to 40%**

Container air conditioning fan control technology :
CPU temperature, server power consumption ⇒ Controls entire system to minimize overall power consumption
CPU temperature, location information ⇒ Local controls prevent the system from reaching an operating temperature that will decrease CPU performance




**Helps conserve power in datacenters by employing A/C control technology for fan-less servers**

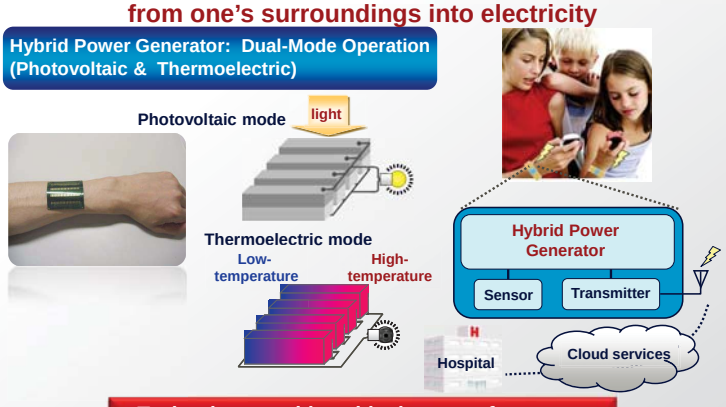



## Energy harvesting technology

FUJITSU

**Harvesting and conversion of energy (light, heat) from one's surroundings into electricity**

**Hybrid Power Generator: Dual-Mode Operation (Photovoltaic & Thermoelectric)**




**Technology could enable the use of sensors in previously unserved application and regions**




## Human-Centric Computing to Enable and Support a Prosperous, Secure and Resilient Society

shaping tomorrow with you

30

## Cautionary Statement

These presentation materials and other information on our meeting may contain forward-looking statements that are based on management's current views and assumptions and involve known and unknown risks and uncertainties that could cause actual results, performance or events to differ materially from those expressed or implied in such statements. Words such as "anticipates," "believes," "expects," "estimates," "intends," "plans," "projects," and similar expressions which indicate future events and trends identify forward-looking statements. Actual results may differ materially from those projected or implied in the forward-looking statements due to, without limitation, the following factors:

- general economic and market conditions in the major geographic markets for Fujitsu's services and products, which are the United States, EU, Japan and elsewhere in Asia, particularly as such conditions may effect customer spending;
- rapid technological change, fluctuations in customer demand and intensifying price competition in the IT, telecommunications, and microelectronics markets in which Fujitsu competes;
- Fujitsu's ability to dispose of non-core businesses and related assets through strategic alliances and sales on commercially reasonable terms, and the effect of realization of losses which may result from such transactions;
- uncertainty as to Fujitsu's access to, or protection for, certain intellectual property rights;
- uncertainty as to the performance of Fujitsu's strategic business partners;
- declines in the market prices of Japanese and foreign equity securities held by Fujitsu which could cause Fujitsu to recognize significant losses in the value of its holdings and require Fujitsu to make significant additional contributions to its pension funds in order to make up shortfalls in minimum reserve requirements resulting from such declines;
- poor operating results, inability to access financing on commercially reasonable terms, insolvency or bankruptcy of Fujitsu's customers, any of which factors could adversely affect or preclude these customers' ability to timely pay accounts receivables owed to Fujitsu; and
- fluctuations in rates of exchange for the yen and other currencies in which Fujitsu makes significant sales or in which Fujitsu's assets and liabilities are denominated, particularly between the yen and the British pound and U.S. dollar, respectively.

# Session 5:
# Network 2
# (Chair: Takaaki Umedu)

# Efficient VPN construction method using UPnP

Hiroshige Nakahara*, Yoshitaka Nakamura** , and Osamu Takahashi**

*Graduate school of Systems Information Science, Future University Hakodate, Japan
**School of Systems Information Science, Future University Hakodate, Japan
{g2111025, y-nakamur, osamu}@fun.ac.jp

***Abstract*** - There has been a rapid proliferation of small mobile devices such as Android phones and iPhones which can use the Internet. These devices include VPN (Virtual Private Networks) functions as a standard feature. These days, we can economically construct VPNs by using VPN technology of IPsec (Security Architecture for Internet Protocol) and so on. However, setting up a VPN still has issues such as the need for the person doing the set up to be knowledgeable about networks, the setup itself being complex, and the authentication taking a long time even if the VPN is to be used for only a short time. To alleviate these problems, we propose a method for exchanging VPN set-up information between VPN devices automatically and efficiently by using UPnP (Universal Plug and Play). We implemented our proposal in an Android phone and measured the authentication time.

***Keywords***: VPN, UPnP, IPsec.

## 1 INTRODUCTION

In recent years, LAN environments have become popular ways of making devices communicate with each other in the home or office. Many LAN environments are built as private communication networks, and they restrict outside access. Therefore, we must build another communication environment for an "outside" device to communicate to a device in the LAN.

We generally use VPN technologies to access devices belonging to a LAN. Currently, IPsec is the most popular VPN technology. It enables us to set up a VPN at low cost. In addition, smart phones such as the iPhone and Android mobile phones have rapidly become prevalent. These devices have VPN using IPsec as a standard feature. The proliferation of these devices will affect the use of VPNs. However, VPNs have issues, in particular they require specialized knowledge to set up and are complicated. Moreover, if we only want to use a VPN for a short time, for example, for checking intra-office network mail or a website, a VPN would take too long to set up and would cause an increase in the authentication time.

In this study, we propose a method for exchanging VPN set up information between VPN devices automatically and efficiently by using UPnP [1]. We implemented our proposal in an Android phone and here show measured results about the authentication time.

## 2 RELATED TECHNOLOGY

In this study, we used UPnP technology. On-demand VPN is a related technology that is used to build a VPN automatically. The following overviews these technologies.

### 2.1 UPnP

UPnP is a protocol to control personal computers and peripherals connected to a home network. It is used in broadband routers, TVs, and so on.

The protocol is divided into six main functions: Addressing, Discovery, Description, Control, Eventing, Presentation, and it detects devices, device information, control devices, detect devices' information by using these functions.

When a home network detects a UPnP compatible device it sends an XML file describing the features and information that can be provided to it. This XML file can be modified to some extent depending on the design and functions of the device.

To control the devices and detect their state, the network has a UPnP device called a UPnP control point device that can operate using SOAP messages [2] written in XML.

### 2.2 On-demand VPN

The On-demand VPN system builds an IPsec-VPN [3]. The IPsec-VPN authenticates and exchange keys with a partner and builds and manages an SA (Security Association) in order to use IPsec [4][5]. In the past, we needed setup information in order to use the IKE (Internet Key Exchange) [6] on the devices that set up the VPN connections. The on-demand VPN system registers device information with a device management server as a preliminary for this purpose. The VPN management server generates and delivers the necessary information to devices registered in the device management server in accordance with the user's request to build the IPsec-VPN. This means the devices do not have to have any VPN configuration information, and the VPN management server delivers pre-set information to the devices on demand.

### 2.3 Issues

The On-demand VPN system has following two issues.

i. It needs a number of servers provided by a third party

The On-demand VPN system needs a third-party device management server for managing devices and a VPN management server for generating and delivering

information. Therefore, this system is high cost and constitutes a hurdle to innovation for typical consumers.

ii. Authentication time for constructing a VPN

The On-demand VPN system needs extra sequences before the normal VPN authentication phase because of the characteristics of the system. For example, it needs a device authentication, and it generates and delivers the connection information. Hence, it requires a long authentication time to build a VPN.

# 3 PROPOSED METHOD

We propose a VPN construction method that avoids the issues described in section 2.3.

The method assumes that mutual authentication between the VPN server and the VPN client takes place when they belong to the same LAN. Second, we assume that the VPN client sends a request for a connection to the VPN server from outside the LAN when the VPN is being built. Third, we assume that the devices have been installed with proper software to use the proposed method and they can use UPnP through this software. Finally, we assume that the VPN is built using a pre-shared key.

Mutual authentication between the VPN server and the VPN client using UPnP is used to generate and exchange VPN connection information between devices. More specifically, the mutual authentication process corresponds to Phases 1 and 2 in IKE.

To build the VPN, the VPN client sends a connection request to the VPN server by using our method's authentication sequences. The following details the mutual authentication sequence.

## 3.1 Mutual authentication using UPnP

Our method authenticates using UPnP. UPnP has a message by which devices advertise themselves when they want to join a network and it triggers mutual authentication. In addition, UPnP uses plaintext for this purpose. Accordingly, this method encrypts messages using the Diffie-Hellman key exchange algorithm, which is used in IPsec based on common key cipher algorithms such as DES, Triple DES, and AES. Figure 1 shows the details of this process.

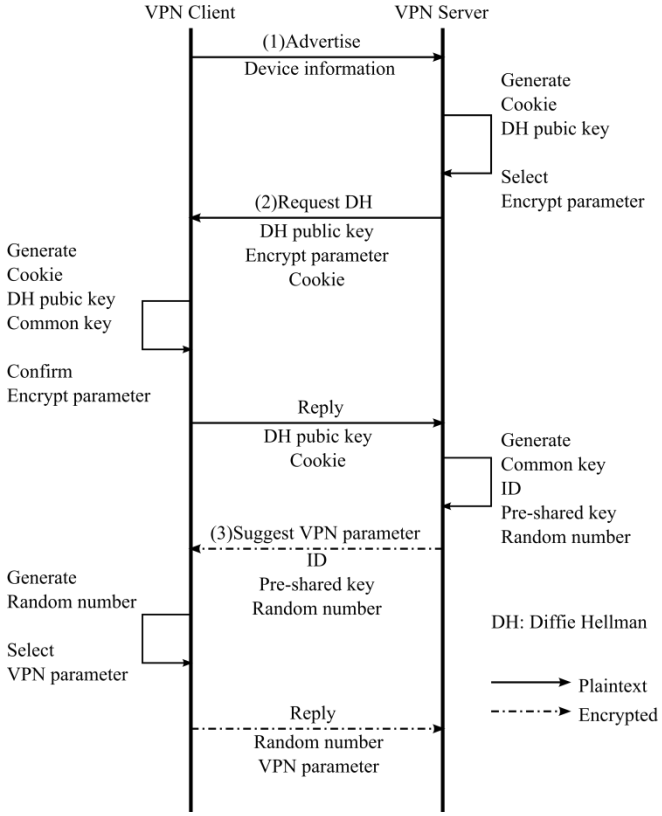



Figure 1: Mutual authentication using UPnP

(1) Advertise

When all UPnP devices join the network, they advertise their presence with an Advertise message. In addition, the advertise message contains where to get a Description file of the device's supported functions. Therefore, the VPN server gets the device's supported functions from the Description file when it receives this message, and it selects those that satisfy a requirement parameter.

(2) Request DH

The VPN server generates the required values in order to send a request to share a key using encrypted communication. First, the VPN server generates the VPN server's cookie by using a random number. Second, it generates a Diffie-Hellman public key for sharing. Finally, it sends a SOAP message containing these values and the parameter selected in (1).

The VPN client generates the required values in order to encrypt communications. First, it generates the VPN client's cookie by using a random number. Second, it generates a Diffie-Hellman public key for sharing. Third, it confirms that the parameters in the received SOAP message from the VPN server are supported. Finally, the VPN client sends a SOAP message containing these values and confirmation information as a reply message to the VPN server.

(3) Suggest VPN parameter

The VPN server generates a common key from the received Diffie-Hellman public key, and the common key is used in the subsequent encrypted communications. Next, it generate an ID in order to uniquely identify the VPN client.

This ID is a hash value generated by combining cookies. The pre-shared key and a number used for constructing the VPN are generated randomly. In addition, the VPN server sends the IP address when the VPN client connects to it from outside the network. These values are encrypted with a pre-selected encryption algorithm using the common key and sent by the VPN server to the client.

The VPN client decodes the received SOAP message by using the common key and selects the most satisfactory requirement parameter in the decoded SOAP message. In addition, the VPN client takes the ID and pre-shared key from the SOAP message and generates a random number in order to build the VPN. It saves these values as VPN connection settings information. Finally, it sends the SOAP message containing the selected parameter and random number as a reply message to the server.

When the VPN server receives the reply message, it saves the associated generated ID together with the pre-shared key.

## 3.2 Building a VPN

In build the VPN, the VPN client makes a VPN construction request from outside the LAN by using mutual authentication with UPnP. Figure 2 shows the details of this procedure.

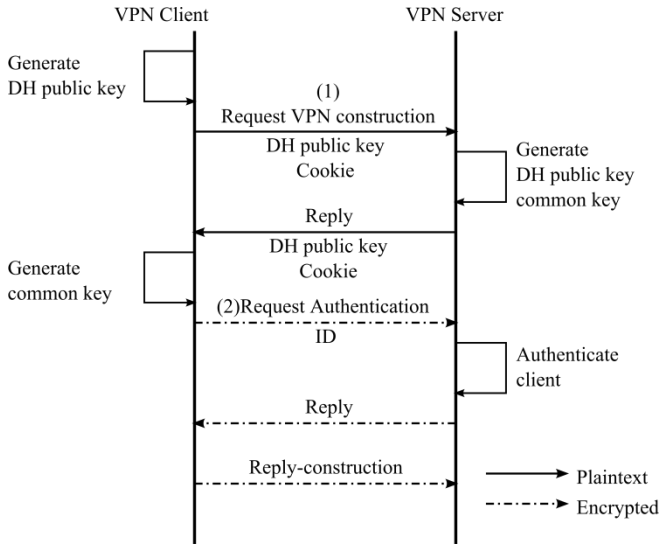



Figure 2: Process of build VPN

(1) Request VPN construction

The VPN client generates a Diffie-Hellman public key for encrypted communication and sends a VPN construction request message containing a Diffie-Hellman public key and Cookies.

The VPN server generates a Diffie-Hellman public key and common key from the received VPN client's Diffie-Hellman public key. Then, the VPN server sends a reply message containing the Diffie-Hellman public key and Cookies to the VPN client. Moreover, it selects the encryption method associated with the Cookies and subsequently uses encrypted communication.

When the VPN client receives the reply message, it generates a common key from the received Diffie-Hellman public key and subsequently uses encrypted communication.

(2) Request Authentication

The VPN client selects the encryption method based on the saved VPN connection settings information through mutual authentication using UPnP. Then, it sends an authentication request message containing its own ID and so on. Additionally, the message is encrypted with the common key, which is MAC from HMAC, by using the saved pre-shared key and random number.

The VPN server authenticates the VPN client by confirming the ID included in the stored authenticate request message. After authenticating the client, the VPN server sends a reply message containing the proper authentication response information.

The VPN client sends a Reply-construction message to the VPN server after receiving the reply message. Thus, VPN built between the VPN client and the VPN server is complete.

# 4 IMPLEMENTATION AND EVALUATION

We performed a basic experiment on an implementation of the proposed method and a conventional VPN authentication method. Moreover, we did a comparative evaluation of the proposed method, an existing VPN, and on-demand VPN.

## 4.1 Implementation

We implemented a key exchange method based on ISAKMP [6] using IKE for both the conventional VPN authentication, and the proposed method. We used Java to implement the send and receive ISAKMP messages and used Datagram Socket for the proposed method's messages.

Table 1 shows the encryption parameters used in IKE and the proposed method.

Table 1: Encryption parameters

| | |
|---|---|
| Encryption Algorithm | AES-CBC 256bit |
| Hash Algorithm | SHA |
| Diffie-Hellman group | 2048bit MODP |
| HMAC | HMAC-SHA-1 |

## 4.2 Comparative evaluation

Table 2 shows the comparative evaluation of ISAKMP using IKE (below, ISAKMP-IKE), on-demand VPN, and the proposed method in regard to the issues described in Section 2.3. "Yes" means the method is easy to deploy or takes a short time. "No" means there is high cost or a problem with innovation.

Table 2: Comparative evaluation of methods

| | ISAKMP-IKE | On-demand VPN | Proposed method |
|---|---|---|---|
| Difficulty of VPN settings | No | Yes | Yes |
| VPN construction time | Conditional | No | Yes |
| Server Installation | Yes | No | Yes |

First, as to the difficulty of setting up a VPN, the ISAKMP-IKE method essentially requires someone who is an expert in networks and VPNs. In contrast, the on-demand VPN system delivers set-up information for the VPN from a third party and the server provides it to the client automatically. The user side does not need to do anything to set up the VPN. Our method exchanges settings information between the server and client automatically by replacing the VPN software with the proposed method-based software, and so, the user side does not need to do anything to set up the VPN. For these reasons, the on-demand VPN system and proposed method are easier than the ISAKMP-IKE method.

Second, as far as the VPN construction time goes, the ISAKMP-IKE method, which is commonly used in constructing VPNs, will be the criterion for the construction time. Thus, compared with the ISAKMP-IKE method, the on-demand VPN system requires an additional sequence including device authentication, connection information generation and connection information delivery; hence, it takes much longer to set up a VPN. Therefore, on-demand VPN take longest construction time. On the other hand, our method exchanges the required information before the VPN is set up using UPnP, so there is no increase in information when the VPN is constructed. Regarding the sequence size, the ISAKMP-IKE method requires 9 steps for constructing a VPN, whereas the proposed method requires only 5. Therefore, the proposed method has the shortest VPN construction time.

Finally, regarding the Server Installation, the ISAKMP-IKE method requires the VPN server to have a VPN function. The on-demand VPN system requires a number of servers, such as a VPN management server, provided by a third party. Thus, this system is costly and difficult to innovate. Our method is enabled by changing the ISAKMP-IKE method's server software. Therefore, it does not require other servers.

## 4.3 Basic experimentation and evaluation

### 4.3.1 Experiment environment

This section describes the experimental results for the authentication time needed for a VPN to be set up by using the key exchange method using ISAKMP-IKE and the proposed method. We define the authentication time as the length of time between when the VPN client sends the VPN connection request to the VPN server and the VPN client finishes sending the last message to the VPN server. Table 3 shows the VPN server and the VPN client that we used. Figure 3 shows the network composition.

Table 3: Experimental environment

| | VPN server | VPN client |
|---|---|---|
| CPU | AMD Athlon 64 X2 3.00GHz | QSD8250 1GHz |
| OS | Ubuntu Linux 10.04 | Android 2.2.1 |
| Java | 1.6.0 | NA |

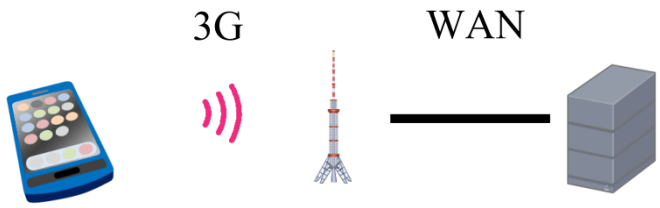



Figure 3: Network composition

### 4.3.2 Results of experiment

The experiment was based on the content described in Section 4.3.1. We experimented with the ISAKMP-IKE method and proposed method 100 times each. Figure 4 shows the authentication times of each method. Table 4 shows the average time for the 100 experiments.

Table 4: Average authentication time

| ISAKMP-IKE | Proposed method |
|---|---|
| 3656.09 [msec] | 1884.33 [msec] |

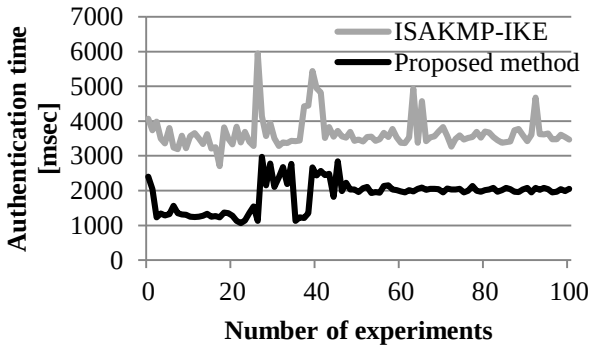



Figure 4: Change in authentication time

From the experimental results, the proposed method can authenticate about 50% faster than the ISAKMP-IKE method. The experiment was conducted in a high-latency network such as a 3G or WAN. Thus, an additional delay is incurred with each communication. Consequently, the difference in the authentication times between the ISAKMP-IKE method

and our method would increase and therefore, the usefulness of our method would increase with the delay.

## 5 CONCLUSION

To reduce the complexity of settings and enable faster authentication for constructing a VPN, we propose a method of exchanging setup information automatically using UPnP and the VPN authenticate sequence. The method reduces the complexity of settings for constructing a VPN through mutual authentication using an UPnP, which changes the required information automatically. In addition, it reduces the authentication sequence by getting the required information before constructing the VPN. An experimental evaluation showed that our method can authenticate faster than existing protocols such as ISAKMP-IKE. Additionally, we found that it is more effective in a high-latency network environment.

We will evaluate the use of our method by implementing the VPN server program. In addition, we will evaluate the security and processing time of our method.

## REFERENCES

[1] UPnP Forum, http://www.upnp.org/
[2] Nilo Mitra, and Yves Lafon, SOAP Version 1.2 Part 0: Primer (Second Edition), World Wide Consortium (2007)
[3] Hiroaki Kamoda, Tomoyuki Hoshikawa, Masaki Yamaoka, and Shuichiro Yamamoto, Implementation and evaluation of on-demand VPN system, IPSJ, Vol. 47, No. 8, pp. 2371-2383(2006)
[4] Tatsuya Baba, Mastering IPsec, O'Reilly Japan (2001)
[5] D. Harkins, and D. Carrel The Internet Exchange, RFC2409 (1998)
[6] D. Maughan, M. Schertler, M. Schneider, and J. Turner, Internet Security Association and Key Management Protocol (ISAKMP), RFC2408 (1988)

# Agent Devices for Personal Wireless Communications

Osamu Yuuki[1,a)] Kunihiro Yamada[2] Tadanori Mizuno[3,5] Hiroshi Mineno[4,5] Masakatsu Nishigaki[1,5]

[1]Graduate School of Science and Technology, Shizuoka University, Shizuoka 432–8011, Japan
[2]Professional Graduate School Embedded Technology, Tokai University, Tokyo 108–8619, Japan
[3]Faculty of Information Science, Aichi Institute of Technology, Toyota, Aichi 470–0392, Japan
[4]Faculty of Informatics, Shizuoka University, Shizuoka 432–8011, Japan
[5]Japan Science Technology and Agency, CREST, Chiyoda, Tokyo 102–0075, Japan
a)f5045016@ipc.shizuoka.ac.jp

***Abstract*** –There are many blind zones of electric wave. For example, the inside of factory or tunnel is a blind zone of electric wave. A signal cannot be transmitted and received when a mobile phone or the receiver of GPS enters there. We started developing a new solution for our scenario. We propose the wireless telecommunication service using the agent device for a person who wants to communicate in a blind zone of electric wave. We have so far proposed various agent devices. There are the strong points and issues in each agent device. These strong points and issues are summarized in this paper. For developing an agent device, we conducted experiments for characterization by path loss models at outdoor environments and indoor environments. Statistical models are obtained when a lot of measurement data are available. First, we considered about the free-space path loss model. The free-space path loss model is adapted for the area between the transmitter and receiver as an area free of obstacles. Next, we investigated about the path loss exponent that indicates how fast path loss increases with distance. We used the Log-normal path loss model. Finally, we used this model in this investigation in order to explore the route for communication. According to this method, an agent device is able to arrive at the goal in shorter time than case of using other algorithms. This approach has significantly increased the lifetime of the device by reducing energy consumption.

***Keywords***: agent device, path loss, blind zone of electric wave, wireless telecommunication, path loss, Log-normal

## 1 INTRODUCTION

In recent years, the sensor network based on network technology [1] is investigated to acquire environmental monitoring. The sensor network is beginning to be utilized with crime prevention, security, a university environmental monitoring, an office environmental monitoring, agricultural products support, etc. It is effective to arrange many static low cost sensor nodes for visualization of information in case of the sensor network. A mobile phone is equipped with GPS, and the dynamic sensing services using individual walk position information are increasing. There are many static sensors and wireless communication spots in urban areas. Therefore sensing and communications are possible at many spots. In such urban areas, the emergency communication became easy by the spread of mobile communication devices.

However, it is difficult to foreknow an occurring disaster or an accident. There are many blind zones of electric wave such as the tunnels or buildings far from urban areas; in these zones, enough sensing devices or communication infrastructures are not installed for an emergency communication. In many cases, mobile terminals cannot communicate any information in such a zone. Bidirectional communications are important when a disaster or an accident occur.

For example, even if his legs injure and he cannot move while passing through a tunnel, he cannot communicate with the exterior. There is only one method. You just wait for a person who passes through the tunnel by chance.

We have so far proposed various agent devices. These agent devices are useful for telecommunications of information in a blind zone of electric wave. There are the strong point and the issue in each agent device. In this paper, these strong points and the issue are summarized.

And we measures path loss at UHF for the developing of agent devices. We investigated about the path loss exponent indicates how fast path loss increases with distance. We used the Log-normal path loss model. Finally, we used this model in order to explore the route for communication.

The rest of this paper is organized as follows. In section 2 we present the related work of networks in disaster. Section 3 describes the concept of agent devices 3 describes the architecture of agent devices designed by our researcher for the wireless telecommunication in blind zones of electric wave. Section 4 analyzes the devices architecture, RSSI variability and routing of communications. Finally our conclusions are obtained in Section 5.

## 2 RELATED WORK

There have been many works of Wireless networking. The research of Wireless sensor networking has been information defined by the type of available sensors mainly focused on internal wireless sensor network and their spatial and temporal conditions to the issues such as MAC and routing protocols, energy interested users [2]. Recent year, sensor networks separates from MAC and a routing protocol, and acquires the information on a thing, and analyze the phenomenon in the real world increasingly [3].

On the other hand, the research of Sensor actuator network has been focused on the multifunctional sensing terminal. Human's position information, posture information, etc. are able to be acquired from such a terminal. Moreover, the robotic sensor is equipped with the robotic actuator described by this paper [4] which can move a sensor.

Moreover, a Robotic sensor expands the spots of sensing of temperature sensor which measure several cm. And a Robotic sensor expands the fixed sensing area from several m by a RFID leader to hundreds m by two or more sets of the robotic actuators which can move. However, the issues are left to realization of the ad hoc communication protocol method, and to performing the autonomous cooperation distribution of two or more of these sets of the moved type nodes.

The free space propagation model is used to predict received signal strength when the transmitter and receiver have clear, unobstructed line-of-sight path between them. Satellite communication systems and microwave line-of-sight radio links typically undergo free space propagation. The electric wave which came out of the antenna will be decreased in the distant place, and will become weaker ,the received power of electric wave which is transmitted in free space, without any obstacle in circumferences, is expressed by Friis's transfer formula [5].

The received power: $P_r$ is expressed by the following equation.

$$P_r = \frac{G_{r\times}P_t}{4\times\pi\times d}\times\frac{\lambda^2\times G_r}{4\times\pi} = \left(\frac{\lambda}{4\times\pi\times d}\right)^2\times G_r\times G_t\times P_t \quad (1)$$

Where,
Transmitted electric power: $P_t$
Transmit and receive antenna gain: $G_t$, $G_r$
Received electric power: $P_r$

Propagation loss: L is expressed by the equation (2).

$$L = \left(\frac{4\times\pi\times d}{\lambda}\right)^2 \quad (2)$$

Where,
Distance between transmission and reception: $d$ ,
Wavelength: $\lambda$

The Friis free space model is only a valid predictor $P_r$ for values of $d$ which are in the far-field of the transmitting antenna. In mobile radio system, it is not uncommon to find that $P_r$ may change by many orders of magnitude over a typical coverage area of several distances. The free-space loss model considers the area between the transmitter and receiver as an area free of obstacles that can absorb or reflect the transmitted energy, besides to consider the atmosphere perfectly uniform and no absorbent. However, in practice, this model is not accurate to describe the real behavior of the radio mobile channel [12] [13] [14] [15]. Therefore, it's necessary to modify this model in order to consider the complexity of the environment analyzed [11].

Next, we refer to Log-distance Path Loss Model [7].

Both theoretical and measurement-based propagation models indicate that average received power decrease logarithmically with distance, whether in outdoor or indoor radio channels. The average large-scale path loss for an arbitrary Transmitter-Receiver separation is expressed as a function of distance by using a path loss exponent, $n$ . $n$ = 2 apply for free space, and n is generally higher for wireless channels. The log-distance path loss model presents by equation (3).

$$PL(d) = PL(d_0) + 10\cdot n\cdot\log(d/d_0) \quad (3)$$

Where n is the path loss exponent which indicates the rate at which the path loss increases with distance, $d_0$ is the close-in reference distance which is determined from measurements close to the transmitter, and d is Transmitter-Receiver separation distance. The component $PL(d_0)$ is due to free space propagation from the transmitter to a 1 m reference distance ( $d_0$ ).

Path loss - Link budget calculations require an estimate of the power level so that a signal-to-noise ratio or, similarly, a carrier-to-interference ratio may be computed [6]. Because mobile radio systems tend to be interference limited (due to other users sharing the same channel) rather than noise limited, the thermal and man-made noise effects are often insignificant compared to the signal levels of co channel users. Thus, understanding the propagation mechanisms in wireless systems becomes important for not only predicting coverage to a particular mobile user, but also for predicting the interfering signals that user will experience from other RF sources.

Finally, we refer to log-normal path loss model [7].

The log-distance path loss model does not consider the fact that the surrounding environmental clutter may be vastly different at two different locations having same Transmitter-Receiver separation. This leads to measured signals which are vastly different than the average value predicted by equation (3). The log-normal path loss model presents by equation (4).

$$PL(d) = PL(d_0) + 10\cdot n\cdot\log(d/d_0) + \mathrm{X}_\sigma \quad (4)$$

The term $\mathrm{X}_\sigma$ models the path loss variation across all locations at distance d from the source due to shadowing, a term that encompasses signal strength variations due to artifacts in the environment (i.e., occlusions, reflections, etc.). Accordingly, received signal strengths at locations that are of equal distance from the transmitter are considered normal random variables. The term $PL(d_0)$ simply gives $PL$ at a known close in reference distance do which is in the far field of the transmitting antenna (typically 1 km for large urban mobile systems, 100 m for microcell systems, and 1 m for indoor systems) and X, denotes a zero mean Gaussian random variable (with units of dB) that reflects the variation in average received power that naturally Occurs when a PL model of this type is used. Since the PL model only accounts for the distance which separates the transmitter and receiver, and not any of the physical

features of the propagation environment, it is natural for several measurements to have the same Transmitter-Receiver separation, but to have widely varying PL values. This is due to the fact that shadowing may occur at some locations and not others, etc. While accounts for signal variations over large scales, the received signal strength can vary considerably over small distances (in the order of wave length) and small time scales, due to multipath fading [8]. As a result, packet loss can exhibit wide variations even when d changes. Indoor RF signal propagation models, including models that take into account the number, delay, and power of indoor multipath components [9]. This model can be used over large and small distances [10], while empirical studies have shown that it can effectively model multipath indoor channels. There has been a study of implications of the log-normal path loss model [16] [17] [18] [19]. The approach has significantly increased the lifetime of the system by conserving energy that the sensing nodes otherwise would use for communication [20]. And, Efficient Receiver-Initiated Link Layer for Low-Power Wireless has been described [21]

We proposed the direct routing algorithm by using log-normal path loss model. By this method, it takes shorter time than other algorithms; an agent device will reduce the energy consumption very much.

# 3 CONCEPT OF PROPOSED DEVICES

## 3.1 Concept of an Agent Device

Concept of a routing by using an agent device is shown in Fig. 1. The inside of a tunnel which is surrounded by thick concrete has a high possibility that the electric wave is intercepted. We call such a zone a blind zone of electric wave. The blind zone of electric wave is shown as the area surrounded with the dotted line in Fig. 1.

We describe the workflow of the service below.

An agent device is equipped with a GPS receiver or mobile Wi-Fi router. Therefore, an agent device needs to move to the external of exit, or a nearby window, for receiving a satellite signal or cellular phone signal. As shown in Fig. 1, a sensing device such as a Bluetooth GPS and a wireless router such as a Mobile Wi-Fi router, etc. are moved to the exterior from the inside of a blind zone of electric wave being covered with buildings. By this way, the information receiving-and-transmitting functions of these communication devices are recovered.

After that, the internal portable device equipped with Bluetooth and Wi-Fi performs communication with an external sensing device and wireless router. Bidirectional communications become available from a blind zone of electric wave.

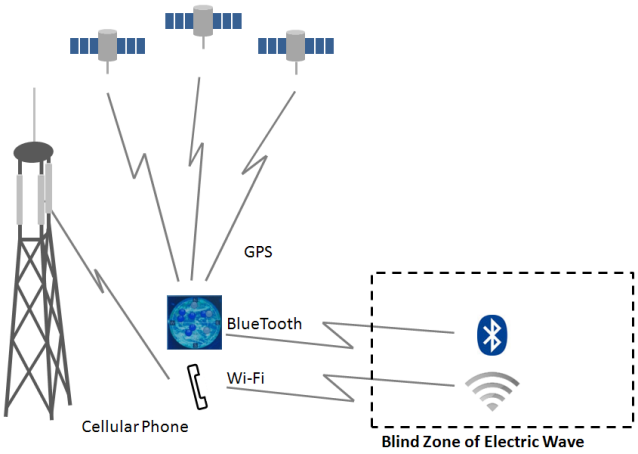



Figure 1: Pathway of the proposed communication in a blind zone of electric wave.

The scenario is shown in Fig 2. We prepared the mobile terminal in blind zone of electric wave. Then, we measured the RSSI of the one line. We calculate the RSSI map around the person containing the path loss variations. A RSSI map is made from the value by mobile terminal. Then, exploration of the communication path is performed. The route to the target point can be calculated from the RSSI map. We can decide the target point. The agent device moves this goal. At last, we succeed in making a communication path. The agent device performs the bidirectional communication. We can receive the position by GPS. Then, we can send the message with the position information to the terminal at other distant place.

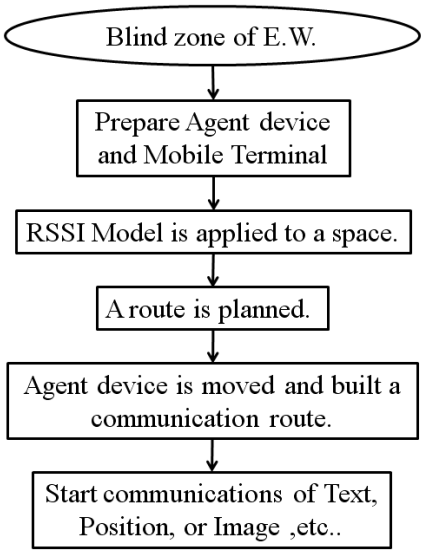



Figure 2: The scenario in a blind zone of electric wave.

# 4 PROF OF CONCEPT

## 4.1 Architectures of Agent Devices

We have so far proposed various agent devices. We show the various agent devices in Fig. 3.

(1) Agent Device of Ball Type

Agent Device of ball type is having the device structure as shown in Fig. 3 (c), in order to be thrown.

Agent device of ball type is equipped with a sensing device such as a Bluetooth GPS (a) [26], a router such as a mobile Wi-Fi router (b) [27], and etc.. In order to absorb the shock that happens by the collision to the surface of a wall etc. after a throwing, the perimeter of these functional devices is wrapped with the low rebounding rubber or low repellence urethane foam.

Furthermore, the low rebounding rubber or low repellence urethane foam are covered with a synthetic rubber [22].

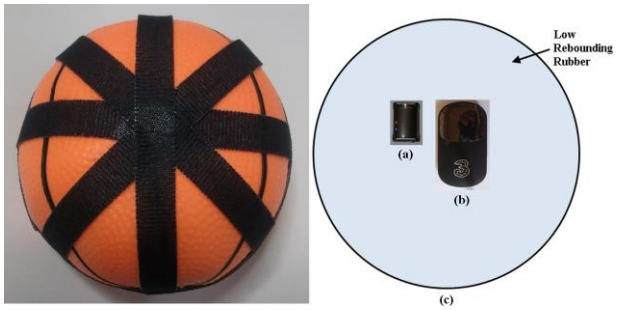



Figure 3: Parts of the agent device. (a) GPS; (b) Mobile Wi-Fi Router, (c) Agent device [Ball Type]

(2) Agent Device of Vehicle Type

Agent device of vehicle type (c) is equipped with a sensing device such as a Bluetooth GPS (a) [26], a router such as a mobile Wi-Fi router (b) [27], and etc..

Agent device of vehicle type moves on the ground in a building or tunnel of the electric wave blind zone, and constructs a communication path [23].

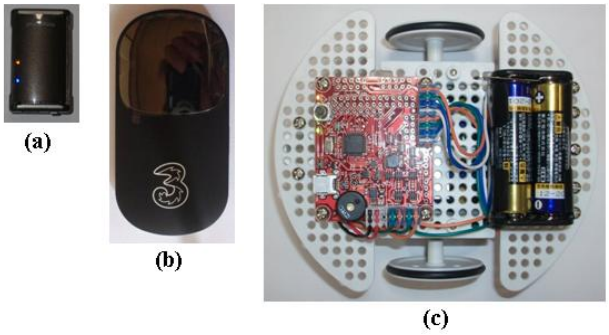



Figure 4: Parts of the agent device. (a) GPS; (b) Mobile Wi-Fi Router, (c) Agent device [Vehicle Type]

（3） Agent Device of Flight Type

Agent device of flight type is shown in Fig. 5. Agent device of flight type (c) is equipped with a sensing device such as a Bluetooth GPS (a) [26], a router such as a mobile Wi-Fi router (b) [27], and etc..

Constructing a communication path by the agent device becomes possible, even if there is an obstacle on grounds or an electric wave window is at a high position [24].

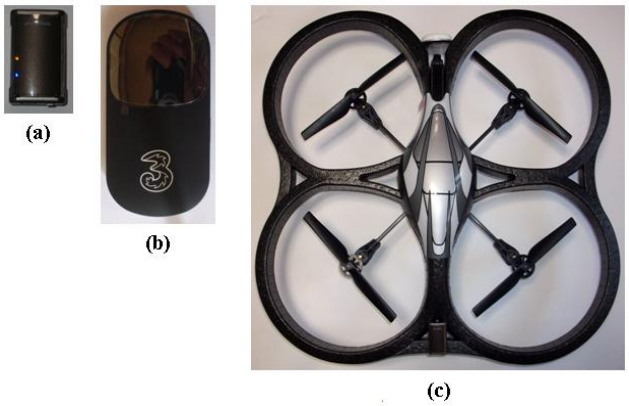



Figure 5: Parts of the agent device. (a) GPS; (b) Mobile Wi-Fi Router, (c) Agent Device [Flight Type]

(4) Agent Device of Smart Robot Type

Agent device of smart robot type (c) is shown Fig. 6. Agent Device of smart robot type is equipped with equipped with a sensing device such as a Bluetooth GPS (a) [26], a router such as a mobile Wi-Fi router (b) [27], and etc.. The agent device constructs a communication path between a blind zone of electric wave and a communication feasible zone by autonomously searching RSSI using the RSSI receiver. At last, it enables bidirectional telecommunications. [25].


Figure 6: Parts of the agent device. (a) GPS; (b) Mobile Wi-Fi Router, (c) Agent Device [Type of a Smart Robot]

## 4.2 Comparison of Four kinds of Agent Devices

We compared of various agent devices. And, we researched the strong points and issues of the devices. There are many strong points and issues in each agent device. These strong points and issues are summarized in table.1.

Table.1 Strong points and Issues of Agent Devices

| Operating Condition | Construction of Agent Devices | Strong Point | Issue |
|---|---|---|---|
| Road,<br>High Position Window |  <br>Ball Type | ①Cheap<br>②It is easy to carry.<br>③It does not ignite to an inflammable thing.<br>③If the sphere device is wrapped in adhesives, the device can adhere to the window made at high position. | ①This device may roll too much by thrown acceleration.<br>②Person's physical strength is required. |
| Flat Road |  <br>Vehicle Type | ①Comparatively Cheap<br>②It is easy to carry.<br>②The run is stable. | ①A routing plan is required.<br>②It cannot move, if an obstacle is on a passage. |
| Obstacle on a Road,<br>High Position Window |  <br>Flight Type | ①The flexibility of movement is large. | ①The weight saving of a loading thing is required.<br>②A flight control is difficult.<br>③Since there is the protrusion, it is difficult to carry.<br>④Comparatively, a price is high. |
| Road |  <br>Type of a Smart Robot | ①Autonomous movement is possible.<br>②It is possible to install as infrastructure in a blind zone of electric wave, and it can move autonomously for detecting the communication path. | ①Since there is the protrusion, it is difficult to carry.<br>②Comparatively, a price is high. |

## 4.3 Indoor Environment of the Evaluation

We conducted the RSSI measurement experiments in the room at urban area. The relation between a transmitter (Pocket Wi-Fi) and receiver (Wireless LAN adapter) is shown in Fig. 7. For every measurement, the height of transmitter was moved by 20 cm for every coordinates of x, y from 0 cm to 160 cm. The transmitter was sequentially moved from the height and x, y coordinates position, and then it was set to the next position.

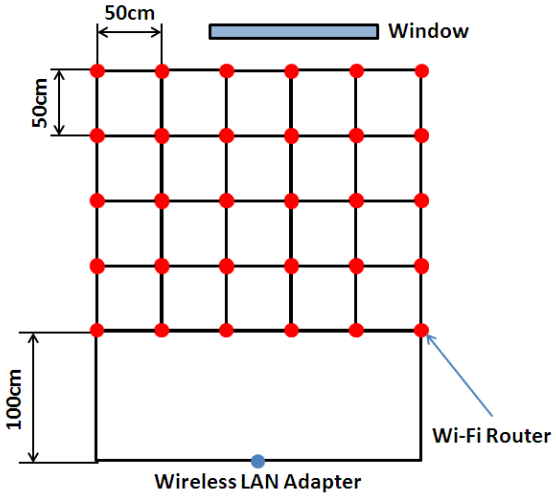



Figure7: A position of transmitter and a receiver

Electric waves at ISM band in the room are shown in Fig. 8. About 17 waves were simultaneously received by the

wireless LAN adapter. We assumed that much interference occurred between electric waves in this place.

Figure8: RSSI at ISM band in the room

## 4.4 RSSI Experiment

We measured 300 points of RSSI data per place in the room. We show data of mid row points in Fig. 9. The approximation lines are presented by equation (4). While n is 2 for free space, but is generally higher for wireless channels.

The component PL0 is due to free space propagation from the transmitter to a 1 m reference distance. And Xσ denotes a zero mean Gaussian random variable that reflects the variation in average received power that naturally Occurs when a PL model of this type is used. Since the PL model only accounts for the distance which separates the transmitter and receiver, and not any of the physical features of the propagation environment, it is natural for several measurements to have the same Transmitter-Receive separation, but to have widely varying PL values. The term Xσ models the path loss variation across all locations at distance d from the source due to shadowing; the term that encompasses signal strength variations due to artifacts in the environment (i.e., occlusions, reflections, etc.). Multipath delay spread Time dispersion varies widely in a mobile radio channel due to the fact that reflections and scattering occur at seemingly random locations, and the resulting multipath channel response appears random, as well.

The received signal strength can vary considerably over small distances due to multipath fading. As a result, packet loss can exhibit wide variations even when d changes. Indoor RF signal propagation models are influenced from the amount of number, delay, and power of indoor multipath components. We employ the popular log-normal path loss model. This model can be used over large and small distances, while empirical studies have shown that it can effectively model multipath indoor channels. We investigated of implications of the log-normal path loss model on deploying and moving an agent device. The measured RSSI values are varied by surrounded physical environment. For example, the received signal strength y at 80cm height is expressed in equation (5).

$$y = -24.034 + 10 \times (-5.488) \times \log(d / d_0) + x_{\sigma(2.665)} \quad (5)$$

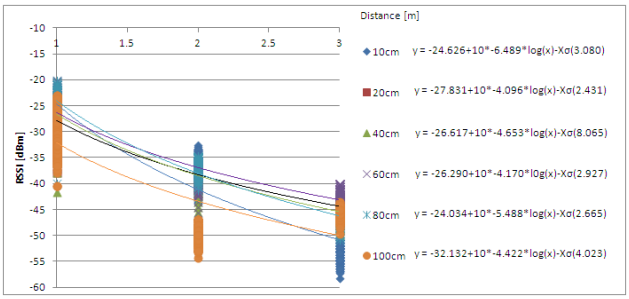



Figure9: RSSI in the room

## 4.5 Experiment & Results

First, we simulated RSSI in the room. In this case, we use the log-distance path loss model for the simulation. We used the equation (6) without the path loss variation (term $X_\sigma$) to calculate the 3D distribution of RSSI in the room.

The RSSI values are shown in Fig. 10. The PL model only accounts for the distance which separates the transmitter and receiver, and not any of the physical features of the propagation environment, it is natural for several measurements to have the same Transmitter-Receiver separation, but to have widely varying PL values.

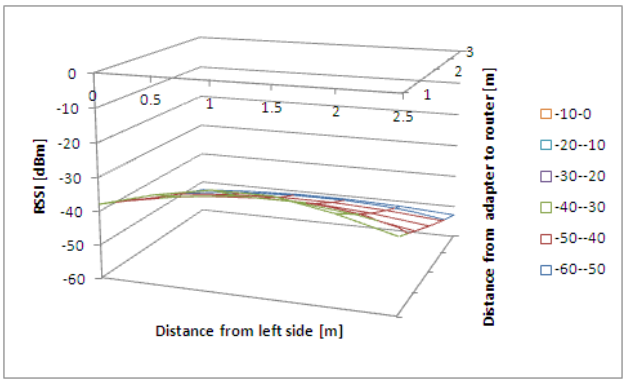



Figure10: The distribution of RSSI by the simulation

Next, we simulated RSSI with the log-distance model path loss model with log-normal shadowing. We use the equation (6) for the simulation. The equation contains the term of Gaussian distribution. The model gives the more similar value to the measured RSSI. We show the results in Fig. 11.

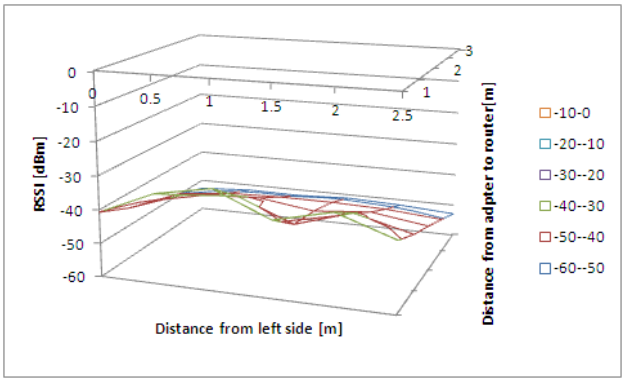



Figure11: The distribution of RSSI with Gaussian noise by the simulation

Finally, we measured the 3D distribution of RSSI in the room. Measured RSSI values are shown in Fig. 12. The measured values contain more variations than simulated value. There were so many other electric waves in the room. These waves were received by the wireless LAN adapter. We think that there are some values which do not match to the value of Gaussian distribution. However, the map from the measured value showed the same tendency as the map from the simulation data value. Therefore, we assume that the log-normal path loss model can use to explore the route for communications.

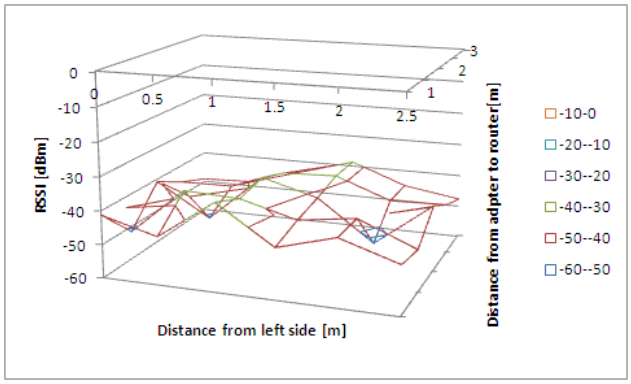



Figure12: Measured RSSI in the room

## 4.6 Exploration of the Route of Communications Using the Log-Normal Path Loss Model

We investigated the communication path between a Pocket WiFi and wireless LAN. It is related to fundamental communication routing problems. We show cells of transmitters in the Fig. 13. A position of transmitter and position of receiver are shown in Fig. 7.

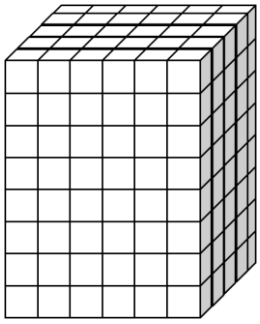


Figure13: The cells of transmitters

The agent device, represented as a transmitter in this case, searches the appropriate RSSI in order to communicate with the receiver. While an agent device in our proposed system may use the both of a wireless LAN and cellular phone network, at least, the agent device should search the equal or stronger RSSI position which is able to communicate with the mobile terminal. The target cell is shown as a red color circle in Fig. 14. As shown in Fig. 7, there is a window near the cell in order to communicate with GPS or cellular phone networks. As shown in Fig. 1, the agent device is equipped with a GPS receiver and/or mobile Wi-Fi router. Therefore, an agent device may need to move to a nearby window, in order to receive a satellite signal or cellular phone signal. The target cell should match to the above-mentioned RSSI conditions. Moreover, the RSSI is expected to be stronger than -90dBm. Fig. 14 shows the basic method for the routing. The route may pass through all cells in a box. A box has 240 cells. We show the path which passes through a cell as a gray color circle in Fig. 14. The equation (6) presents the number of routes.

$$G_n = (n-1)! \tag{6}$$

Where, $n = 240$, $\therefore D_n = 1.695e + 466$

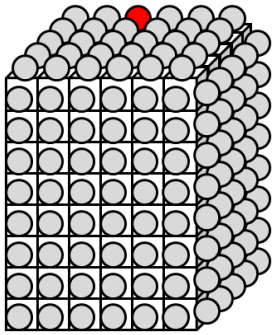


Figure14: Method 1:
Exploration of all cells of transmitters

An agent device should reach the target cell as quickly as possible. If it takes long time to reach the target cell like an aforementioned algorithm, an agent device will consume up to all the energy of the battery. An agent device should reduce its energy consumption by using the other algorithms. We have to search the shorter path to reach the target cell for an agent device. The well-known Dijkstra's algorithm

can be used for this purpose. The equation (7) presents the number of routes.

$$D_n = \frac{1}{2} \times n \times (n-1) \quad (7)$$

Where, $n = 240$, $\therefore D_n = 28{,}680$

We show Dijkstra's algorithm in Fig. 15. An agent device can find the shorter route. An agent device tries to pass Dn routes in a box by Dijkstra's algorithm. The route is shown with the line in Fig. 15.

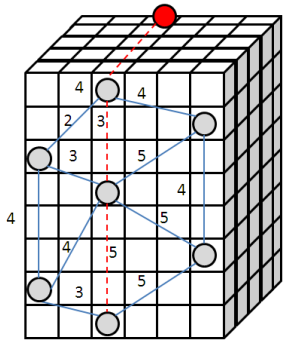


Figure15: Method 2:
Exploration by Dijkstra's Algorithm

If it takes long time to reach the target cell like above-mentioned algorithms, an agent device will consume up to all the energy of the battery. We have to search the shorter path route for the agent device to reach the target cell. Therefore, we propose the direct routing algorithm for this purpose.

$$DI_n = 1 \pm \alpha \quad (8)$$

We show proposed algorithm in Fig. 16. We can decide the target cell by the log-normal path loss model. The route to the target cell can be calculated. The route is connected to the target cell directly. The route is shown with the blue color line in Fig. 16. The route passes only one path in the box. Some simulation values may do not match to the actual measurements values. In rare case, an agent device may have to find the other cell around the target cell by try and error. The numbers of try and error routes are presented as term $\alpha$ in equation (8).

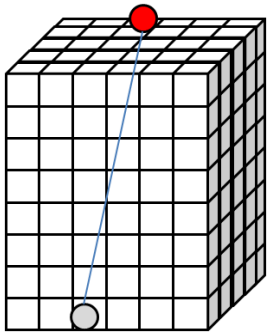


Figure16: Method 3:
Exploration by predicting signal attention

## 4.7 Outdoor Environment of the Evaluation

We evaluated RSSI or Broadband Speed around the blind zones of electric wave. There are many tunnels in Kanagawa prefecture around 200 m in length. We conducted the experiments in these tunnels as the blind zone of electric wave. There is an about 1.5m width sidewalk in the tunnels. The deep forest surrounds each selected tunnel.

The positions of these tunnels on Google map [28] are shown in Fig. 17.


Figure17: Tunnel Locations for the experiment

The specification of a tunnel is shown in Table 2.

Table2 Tunnels Spec

| Tunnel name | AIKAWA | OOSAWA | RYOUMUKAI |
|---|---|---|---|
| Length | 146m | 223m | 233m |
| Width | 9.75m | 9.25m | 9.25m |
| Hight | 4.50m | 4.50m | 4.50m |

We show the photograph of tunnels in Fig. 18, 19, and 20.

Figure18: Picture of RSSI experiment in AIkawa tunnel

Figure19: Picture of RSSI experiment in Oosawa tunnel

Figure20: Picture of RSSI experiment
in Ryoumukai tunnel

## 4.8 RSSI Experiment

Although depending on the position of each satellite at the time, the GPS electric wave signal from the satellite near the zenith will be intercepted by the outer wall of a tunnel. If it tries to perform positioning of a position from the signal of three or more sets of satellites inside a tunnel, it is difficult to receive all the signal of them simultaneously.

On the other hand, the prospective angle which looked at the point of the base station transmitting the electric wave from the inside of a tunnel is used for the distance which the direct wave of mobile phones, such as 3G Cellular phone signal, reaches into a tunnel, Calculation is possible by equation (9).
(Buildings, such as a factory, are also possible to calculate the range of electric wave from the height of the opening of an entrance using same equation) The figure containing the parameter for calculation is shown in Fig. 21.

The distance until the direct wave from one base station reaches a road surface from a tunnel entrance is expressed by the following equation.

$$a = \frac{h_t}{\tan\Theta} \tag{9}$$

Here,

$a$ : It is the direct electric wave range from tunnel entrance.

$h_t$ : Tunnel height

$\Theta$ : The visual angle which the extension line from a base station antenna to the exit edge of a tunnel makes from a road surface.

The base station is architected with the cell method or sector composition. The range of electric wave in a tunnel is changed by these architectures and the numbers of base stations. Furthermore, the equation does not include the influence of multi path fading that occurs by the reflection from a wet road surface. Therefore, the distance calculated by the equation is a rough value.

On the other hand, the range of electric wave of Bluetooth is about 100 meters in Class1.

The range of electric wave of a Wi-Fi standard is also about 100m. Therefore, the tunnel length up to 200m can be covered by choosing the nearer exit from the inside person position of a tunnel. It is presumed that the range of 100m is also a practical communication distance in a building like a factory.

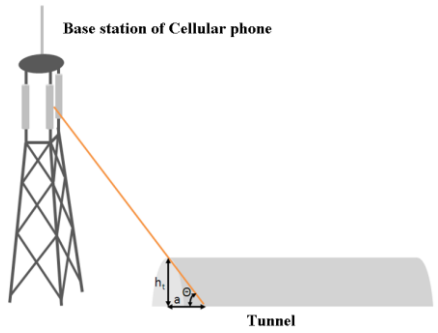



Figure 21: The range of access of
the cellular phone direct signal in a tunnel

## 4.9 Experiment & Results

We measured the RSSI using Pocket WiFi [29]. The RSSI in the outside of tunnel is shown in Fig. 22 (a). The communication by the 3G Cellular phone signal is available in this level. The RSSI in the inside of tunnel is shown in Fig. 22 (b). In this case, the communication by the 3G Cellular phone signal is not available. The display of Pocket WiFi shows “No Service”.


(a) (b)

Figure 22: Cellular phone signal conditions
(a)Outside of a tunnel, (b) Inside of a tunnel

We measured the GPS signal strength. The signal strength in the outside of tunnel is shown in Fig. 23 (a). The positioning by GPS signal is available in this level. The RSSI in the inside of tunnel is shown in Fig. 23 (b). The positioning by GPS signal is not available in this level. The display shows the entire satellite signal is 0.

(a) (b)

Figure 23: GPS signal conditions
(a) Outside of a tunnel, (b) Inside of a tunnel

We measured the RSSI in three tunnels. The RSSI of the left-side exit is shown in Fig. 24.

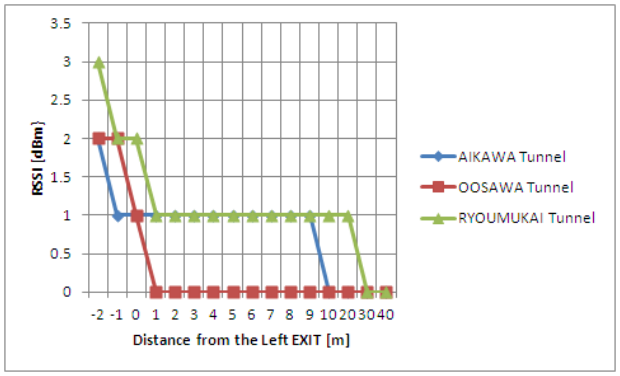



Figure24: RSSI in the tunnels (Left-side Exit)

The RSSI of the right- side exit is shown in Fig. 25.

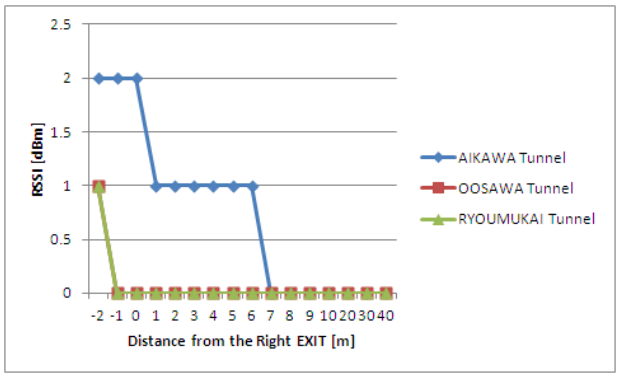



Figure25: Level of RSSI in the tunnels (Right-side Exit)

RSSI of the right-side exit of Oosawa and Ryoumukai tunnels are bad. This is because the circumference of the exit is surrounded in the mountain. The environment around the right-side exit of the Oosawa tunnel is shown in Fig. 26. (The tunnel in the photograph is another one.) Difference of the RSSI value is caused by Geometrical feature.

Figure26: Photograph of the right-side exit of Oosawa tunnel

We set Pocket WiFi to the exit of the tunnel at 0 m, and measured RSSI of the internal of the tunnel.

The RSSI values show the tendency of free space path loss model, as shown in Fig. 27.

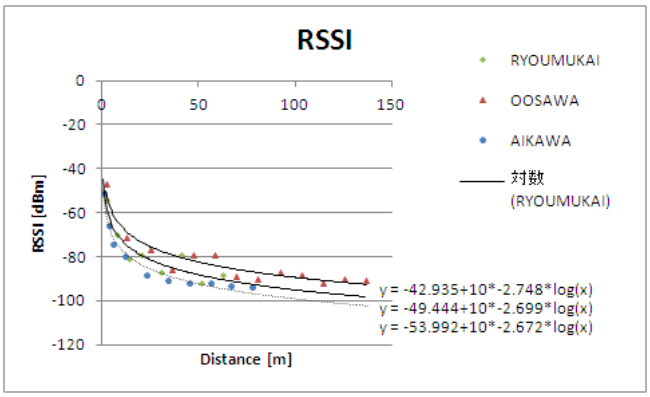



Figure27: RSSI in the tunnels

Next, we confirmed RSSI and Broadband speed by difference of the four kinds of architectures.

The models used for the experiment are shown in Fig. 28.

Ball type agent device is equipped with Pocket WiFi. Pocket WiFi is put in the ball as shown in Fig. 28 (a).

Pocket WiFi of Vehicle type was placed on the ground as shown in Fig. 28 (b).

Flight type was installed in a height of 1 m from the ground as shown in Fig. 28 (c).

(There are two communication methods for Flight type agent device; one method, the communication is started after the agent device landed on the ground. And another method, the communication is started during the flight. In the case of former, it becomes nearly equal to the value measured by the model of 28 (b), and, in the case of the latter, becomes nearly equal to the value measured by the model of 28 (c). )

Pocket WiFi of Robot type is put in a box as shown in Fig. 28 (d).

(a) (b) (c) (d)

Figure28: Four kinds of simulation model

SIDDR [31] was used for measurement of RSSI.

Broadband Speed Test [32] was used for measurement of the transmission speed of broadband.

The screen of measurement results of RSSI and broadband speed is shown in Fig. 29.

In this experiment, the AC/DC adaptor was used for the power supply of the Wi-Fi router.

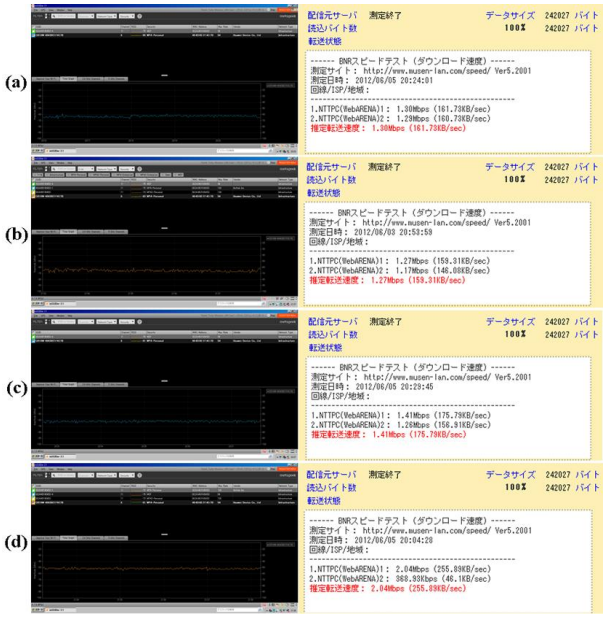



Figure29: RSSI level and Broadband speed

Fig. 30 shows the RSSI of four kinds of simulation models.

Since RSSI of the type (a) is surrounded by low repellence urethane, the RSSI is weaker than the type (b). RSSI of the type (c) is stronger than the value of the type (b). And the RSSI of the type (4) is stronger than other models. This phenomenon will be occurred by the reflection of electric wave from a metal surface of the case. At the result, the RSSI is going up.

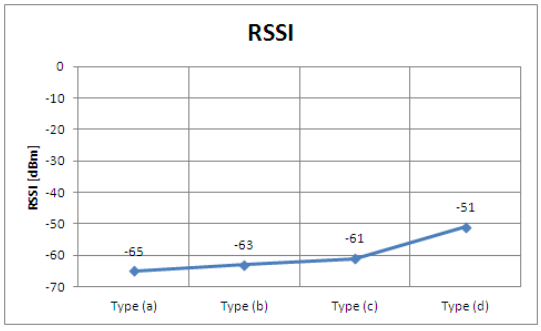



Figure30: RSSI of four kinds of Simulation models

The measurement result of the broadband speed is shown in Fig. 31. RSSI and the speed have are correlated each other. Although we think that the relationship between the type (a) and type (b) is the opposite, we assume the difference of these values is within the range of measurements error. The almost of RSSI and Broadband speed are related with the architectures.

At the result of this experiment,

Type (d) > Type (c) > Type (a) > Type (b)

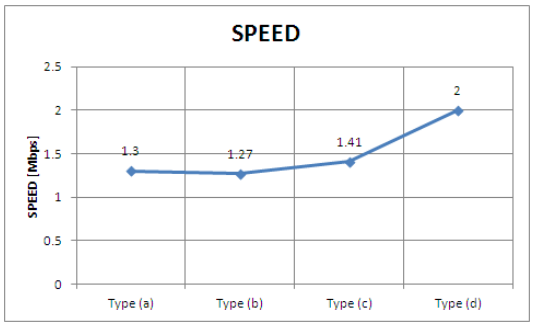



Figure31: Broadband speed of four kinds of Simulation models

## 4.10 Controlling the Agent Device

We conducted the experiment to control the flight type agent device. The control flow is shown in Fig 32. We prepared a mobile terminal. And, we made the program in the mobile terminal. We used Eee-PC 900A with a 8.9 inch display [30] as a mobile terminal in this experiment (iPhone or the other Smart phone, and iPod also can be used). The agent device is equipped with the photoMate Mini GPS Recorder 887 [26], Pocket WiFi C01HW [29], and a built-in camera. Then, we measured the RSSI of the one line. We show the RSSI in Fig. 33. This program calculates the RSSI map around the person containing the path loss variations. We show the RSSI map in Fig. 34. A RSSI map is made from measured data by mobile terminal.

We operated programs for the “measurement of RSSI”, “extraction of RSSI from the image”, “mapping the data on 3D”, “display of the map in the window”, and “controlling of Agent device”. We programmed this agent device as following control sequences. First, the agent device moves to the forward after taking off perpendicularly. Next, the agent device moves to the right or the left. This moving sequence takes three steps, however the steps are fewer than case of using the other algorithms.

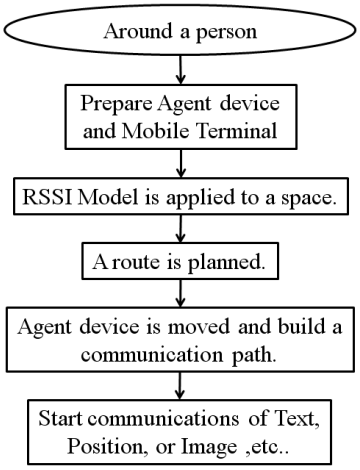



Figure 32: The control flow.

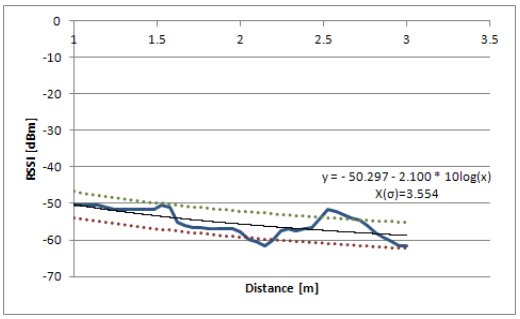



Figure 33: RSSI on a center raw.

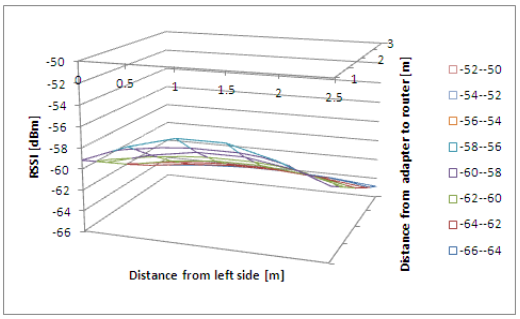



Figure 34: Calculated RSSI map.

We describe more detail about the control. We measured RSSI on a center raw line in order to approximate to the log-normal path loss equation. The terms of n and $X(\sigma)$ in the equation were decided from the measurement. In this case, n was 2.100 and $X(\sigma)$ was 3.554. Then, we made a map by using the approximation from measured data. The map is shown in Fig. 34. The map is displayed on the display of mobile terminal as shown in Fig. 35 by control program. The position of the target was decided from the map. RSSI of this position should be more than -90dBm, and the position should be a nearby window for receiving a GPS signal or cellular phone signal. Therefore, we decided the circle painted red as a goal position shown in Fig. 36. We used to Excel and Processing language [33] on the windows OS for controlling the agent device. The program for controlling the agent device shows the RSSI map in a window. Then, exploration of the communication path is performed. First, the agent device takeoff, then, it aimed at target RSSI value. The trajectory of the device by schematic diagram is shown in Fig. 36. The agent device flew according to the program of the mobile terminal toward this goal. We show the positions relation between Mobile terminal and Agent device in Fig.37. The agent device moved to the forward to this goal after taking off perpendicularly. The contact sheet of the movie is shown in Fig. 38. At last, we succeeded in making a communication path. In this case, it took 13 seconds for the flight to the goal. Almost of the time was spent for the taking off. The remained energy of agent device after this flight was enough to perform the bidirectional communication. We could receive the position data by using GPS. We could receive the image data by using the built-in camera. Then, we could send the message and attached data to iPad set to other distant place by using Pocket WiFi. We could perform telecommunications of information satisfactorily. The text information (a), the house position information (b), and the image of room information (c) are shown in Fig. 39.

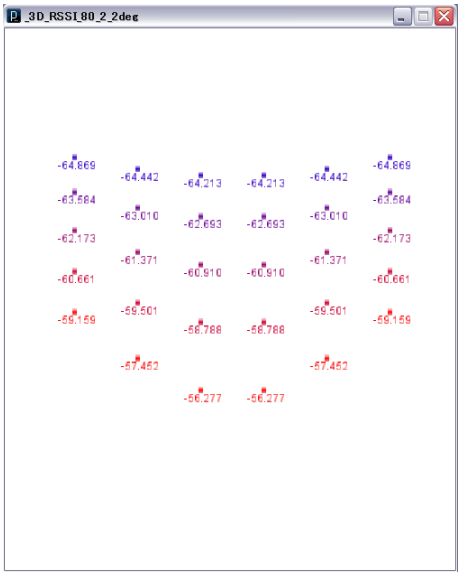



Figure 35: RSSI map in the window.

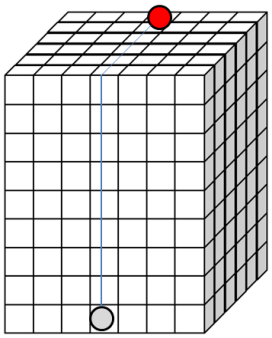


Figure 36: Path and a goal position.

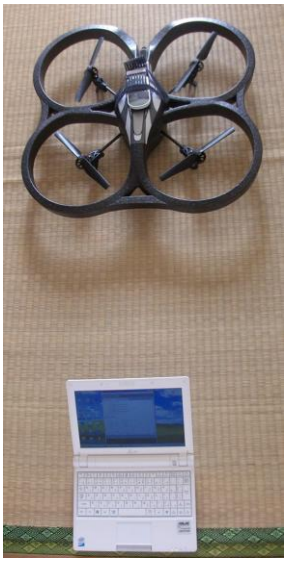
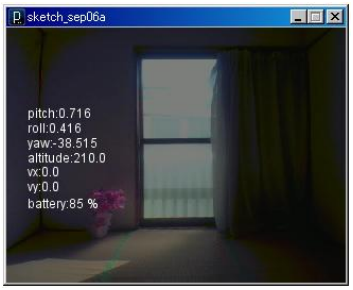


Figure 37: Mobile terminal and the agent device.

Figure 38: The contact sheet of the movie of the agent device.

(a)

(b)




(c)

Figure 39: Information from the agent device. (a): The text information, (b): The house position information, (c): The image of room information

## 5 CONCLUSION

In this study, we proposed various architectures of agent devices. And, we compared of these architectures. Many strong points and issues arise from the architectures of each agent device. These strong points and the issues were summarized. We conducted the some experiments at indoor and outdoor environments. First, we simulated RSSI using the log-distance path loss model. Next, we simulated RSSI using the log-normal path loss model. These simulated results were compared with actual measured RSSI. The measured value showed the same tendency as the simulation value. We assume that the log-normal path loss model can use to explore the route for communications. We proposed the direct routing algorithm by using log-normal path loss model. According to this method, an agent device is able to arrive at the goal in shorter time than case of using other algorithms; an agent device will reduce the energy consumption very much.

As future works, followings research will be made: We will research more applications of an agent device using direct routing algorithm.

## REFERENCES

[1] A. S. Tanenbaum, M. V. Steen, Distributed Systems, Principles and Paradigms, Pearson Education, (2003). T. Mizuno, T. Higashino, Y. Miyanishi, K. Suzuki, S. Nishiyama, F. Satou interpreted to Japanese.

[2] Krco, S., Tsiatsis, V., Matusikova, K., Johansson, M., Cubic, I., Glitho, R., Mobile Network Supported Wireless Sensor Network Services, IEEE Internatonal Conference on Mobile Adhoc and Sensor Systems 2007 (MASS 2007), pp. 1–3, (2007).

[3] Y. Tobe, Sensing Network, Information Processing Society Jounal, Vol. 51, No.9, pp. 1105–1110, (2010).

[4] H. Nakazawa, H. Tokuda, The information processing based on a sensor actuator network, Information Processing Society Jounal, Vol. 51, No.9, pp. 1127–1135, (2010).

[5] HARALD T. FRIIS, A Note. on a Simple Transmission Formula, Proceedings of the I.R.E. and Waves and Electrons, Vol.34, Issue.5, pp. 254-256, (1946).

[6] J.B. Andersen, T.S. Rappaport, S. Yoshida, Propagation measurements and models for wireless communications channels, IEEE Communications Magazine, Vol.52, pp. 42-49, (1995).

[7] T. S. Rappaport, Wireless Communications, Principles & Practices. Prentice Hall, (1996).

[8] D. Puccinelli and M. Haenggi, Multipath Fading in Wireless Sensor Networks: Measurements and Interpretation, In IEEE/ACM International Wireless Communications and Mobile Computing Conference (IWCMC'06), (2006).

[9] M. K. Awad, K. T. Wong, and Z. bin Li., An integrated overview of the open literature's empirical data on the indoor radiowave channel's delay properties, IEEE Trans. Antennas and Propagation, (2008).

[10] S. Y. Seidel, T. S. Rappaport, 914 MHz Path Loss Prediction Models for Indoor Gíreles Communications in Multifloored Buildings, IEEE Trans. Antennas Propagat., Vol. 40, pp. 207-217, (1992).

[11] G. Zhou, T. He, S. Krishnamurthy, and J. A. Stankovic, Impact of Radio Irregularity on Wireless Sensor Networks, MobiSys '04 Proceedings of the 2nd

international conference on Mobile systems, applications, and services, pp. 125-138, (2004).
[12] M. Hidayab, A. H. Ali, K. B. A. Azmi, Wifi Signal Propagation at 2.4 GHz, Microwave Conference 2009 (APMC 2009), Asia Pacific pp. 528 - 531, (2009).
[13] J. A. R. Pacheco de Carvalho, H. Veigal, R. Costa, P. A. J. Gomes, A. D. Reis, A Contribution to Experimental Performance Evaluation of Point-to-Point WiMAX Links, IEEE International Symposium on Signal Processing and Information Technology 2008 (ISSPIT 2008), pp. 150 - 153, (2008).
[14] Ye Wang, Wenjun Lu and Hongbo Zhu, Experimental Study on Indoor Channel Model for Wireless Sensor Networks and Internet of Things, Information Processing Society Trans, Consumer Device & System, Vol.2, No.1, pp. 58 - 66, (2012).
[15] Ye Wang, Wenjun Lu and Hongbo Zhu, Experimental Study on Indoor Channel Model for Wireless Sensor Networks and Internet of Things, IEEE International Conference on Communication Technology (ICCT), 2010 12th, pp. 624 – 627, (2010).
[16] Y. Chen and A. Terzis, On the Implications of the Log-normal Path Loss Model: An Efficient Method to Deploy and Move Sensor Motes, SenSys '11 Proceedings of the 9th ACM Conference on Embedded Networked Sensor Systems, pp. 26-39, (2011).
[17] Dongjin Son, Bhaskar Krishnamachari, and John Heidemann, Experimental Study of Concurrent Transmission, ACM Trans, Antennas and Propagation, (2008).
[18] K. Srinivasan, M. Jain, J. I. Choi, T. Azim, E. S. Kim, P. Levis, and B. Krishnamachari, The κ Factor: Inferring Protocol Performance Using Inter-link Reception Correlation, In Proceedings of the sixteenth annual international conference on Mobile computing and networking (MobiCom '10), pp. 317–328, (2010).
[19] K. Srinivasan, M. Kazandijeva, S. Agarwal, and P. Levis, The $\beta$ -factor: Measuring Wireless Link Burstiness, In Proceedings of the 6th ACM Conference on Embedded Networked Sensor Systems (SenSys), (2008).
[20] O. Tekdas, J. H. Lim, A. Terzis, and V. Isler, Using Mobile Robots to Harvest Data from Sensor Fields, IEEE Wireless Communications Magazine, Vol. 26, pp. 22–28, (2009).
[21] P. Dutta, S. Dawson-Haggerty, Y. Chen, C.-J. M. Liang, and A. Terzis, Design and Evaluation of a Versatile and Efficient Receiver-Initiated Link Layer for Low-Power Wireless, Technical Report CSD-TR 02-0013, University of California, Los Angeles, Computer Science Department, (2003).
[22] O. Yuuki, K. Yamada, T. Mizuno, H. Mineno, M. Nishigaki, Wireless Telecommunication by Using the Sphere Device Wrapped in Adhesives in Blind Zones of Electric Wave, Institute of Electronics, Information and Communication Engineers Technical Report, Vol. 112, No. 67, pp. 27-33, (2012).
[23] O. Yuuki, K. Yamada, T. Mizuno, H. Mineno, M. Nishigaki, Wireless Telecommunication by Using Pocket Agent Device in Blind Zones of Electric Wave, Information Processing Society Trans. Consumer Device & System, Vol.2, No.1, pp. 58-66, (2012).
[24] O. Yuuki, K. Yamada, T. Mizuno, H. Mineno, M. Nishigaki, Wireless Telecommunication by Using a Space Movement Agent Device in Blind Zones of Electric Wave, Consumer Device & System IPSJ SIG Technical Report, Vol.2012-CDS-4, No.13, pp. 1-8, (2012).
[25] O. Yuuki, K. Yamada, T. Mizuno, H. Mineno, M. Nishigaki, Wireless Telecommunication by Using the Smart Agent Robot in Blind Zones of Electric Wave, Institute of Electronics, Information and Communication Engineers Technical Report, Vol. 112, No. 67, pp. 35–40, (2012).
[26] Transystem Inc. (online), available from http://www.transystem.com.tw/ (accessed 2011-11-28).
[27] Three.co.uk (online), available from http://threestore.three.co.uk/broadband/?mifi=1 (accessed 2011-11-28).
[28] google map (online), available from http://maps.google.co.jp/ (accessed 2012-5-13).
[29] Pocket WiFi SoftBank C01HW (online), available from http://mb.softbank.jp/mb/data_com/product/mobilewifi/c01hw/ (accessed 2011-11-28).
[30] Eee PC 900A (online), available from http://www.asus.com/Eee/Eee_PC/Eee_PC_900A/(accessed 2012-9-16).
[31] inSSIDer (online), available from http://www.metageek.net/products/inssider/?utm_expid=1903281&utm_referrer=http%3A%2F%2Fwww.infraexpert.com%2Fstudy%2Fwireless23.html (accessed 2012-5-13).
[32] BNR speed test (online), available from http://www.musen-lan.com/speed/ (accessed 2012-5-13).
[33] processing (online), available from http://processing.org/ (accessed 2012-9-13).

# Selecting Advertising Links to Guarantee Detour Paths against Single Node and Link Failure in OLSR

Yohei Yukawa†, Takuya Yoshihiro‡

†Graduate School of Systems Engineering, Wakayama University, Japan
‡Faculty of System Engineering, Wakayama University, Japan
{s111059, tac}@sys.wakayama-u.ac.jp

***Abstract*** - OLSR (Optimized Link State Routing) has been standardized as a routing protocol for MANET. OLSR has a mechanism MPR (Multi Point Relay) , which reduces load of control packets by means of optimizing links to advertise. However, advertised topology of OLSR is not sufficiently redundant so that it cannot always guarantee detour paths for every single link or node failure on the advertised topology. If there is no detour path in case of failure, recovery takes time because the process to update the advertised topology and to recompute the shortest paths are required. On the contrary, if there are detour paths on the advertised topology, immediate path recomputation is possible. In this paper, we propose a new algorithm to select links to advertise in order that every pair of nodes has at least two link- and node-disjoint paths on the advertised topology. Through simulation work, we evaluate the additional load of control messages required to guarantee detour paths.

***Keywords***: Mobile ad hoc networks, Routing protocol, Redundant network, OLSR

## 1 Introduction

Recently, MANET (Mobile Ad-hoc Network) has been studied well as one of the next-generation networks, and several routing protocols has been standardized[1][4][3][2]. Because MANETs do not require physical communication lines, they can provide network infrastructure inexpensively with low restriction of location. Due to these characteristics, various applications of MANETs are considered for the future.

In MANETs, instability of communication is inevitable due to mobility, physical obstacles, radio interference, and so on. To stabilize communications under such nature of MANETs, many routing schemes have been proposed so far. Four routing protocols for MANETs have already been standardized in IETF, and OLSR (Optimized Link State Routing) is one of the most popular routing protocols among them.

As one of the major features of OLSR, MPR (Multi-Point Relay) plays an important role of reducing control messages in MANETs. In order to reduce network load of control messages of OLSR, MPR limits nodes to relay control message of OLSR, while guaranteeing the reachability of control messages for every node in a network. MPR also limits links to advertise also to reduce the load of control messages. However, redundancy of the advertised topology in OLSR is insufficient in terms of robustness of networks. Specifically, the advertised topology only guarantees the shortest paths between every pair of nodes, but it cannot guarantee detour paths against node or link failure even if the network itself has detour paths on the full topology. Consequently, when a path fails due to a link or node failure, routers cannot immediately recalculate an alternative path, and have to wait for advertisements of new links that enable routers to compute the new shortest paths.

Note that, if a detour path exists in the advertised topology, routers can immediately resume communications with the detour paths that are pre-computed as preparation against failure. In this paper, we proposed a new algorithm to select links to advertise in OLSR so that the advertised topology guarantees detour paths against single link or node failure. Because this algorithm guarantees detour paths as long as they exist, routers can immediately resume communications as soon as they detect failure. We also give an evaluation results on the load of control messages required to guarantee the detour paths with our algorithm.

The reminder of this paper is organized as follows. Section 2 gives the overview of OLSR and its mechanisms related to our study. Section 3 describes the related work and clarifies the contribution of this paper. Section 4 explains the proposed algorithm on the selection of advertising links. Section 5 gives the theoretical results over the proposed algorithms that include theorems and proofs that guarantees detour paths in the advertised topology. Section 6 presents the results of computer simulation that compared the message load between the proposed algorithms and the conventional algorithms. Finally, Section 7 gives the conclusion and the future work of this study.

## 2 Advertised Link Selection in OLSR

This section briefly explains the mechanism used in OLSR to reduce the network load due to control messages.

OLSR is a link-state routing protocol. So, each node first exchanges HELLO messages to discover neighbors. Note that Hello messages in OLSR include a list of neighbor nodes so that receivers get to know the nodes within 2-hop distance. We call these nodes of 2-hop distance *2-hop nodes*. Based on the information obtained from Hello messages, each OLSR node selects nodes among neighbors as its MPRs. Because only MPRs relay messages to their neighbor nodes in the flooding procedure, the mechanism of MPR reduces the network overhead of propagating messages. To ensure messages reach all nodes in a network, each node selects its MPR set so that a message is relayed to each of its 2-hop nodes via at least one MPR node.

OLSR can expand the redundancy of MPR to have message propagation more robust by varying the parameter called MPR_COVERAGE. As shown in Fig.1, this parameter controls the number of MPRs to reach messages for each 2-hop neighbor. Although the default value of this parameter is 1, we can use larger values to gain the robustness of propagating messages while keeping the load in a network due to message flooding in allowable level.

OLSR also reduces the network overhead by limiting a set of links to propagate to a network. In OLSR, all the link information advertised into a network is shared by all nodes to form the network topology from which the shortest-paths and consequently the routing tables are computed. MPR again plays an important role in this advertised link selection to exclude redundant links from the advertised topology. Specifically, by default, an OLSR node selects a link $(u, v)$ as an advertised link if the node $v$ selects node $u$ as its MPR. This is possible because HELLO messages include MPR information so that each node $u$ gets to know the neighbors selecting $u$ as their MPR. As we call such neighbors *MPR selector* of $u$, we say that each node selects links that connect to its MPR selectors as the *advertised links*.

Note that, because MPRs are the relay nodes selected to guarantee messages to reach all nodes, OLSR guarantees paths between any pair of nodes in the advertised topology except for the first-hop links. To complement the advertised topology, OLSR uses the neighbor and 2-hop neighbor information obtained from HELLO messages. In other words, each OLSR node computes its routing table from the synthesized topology of the advertised topology and the neighbor information.

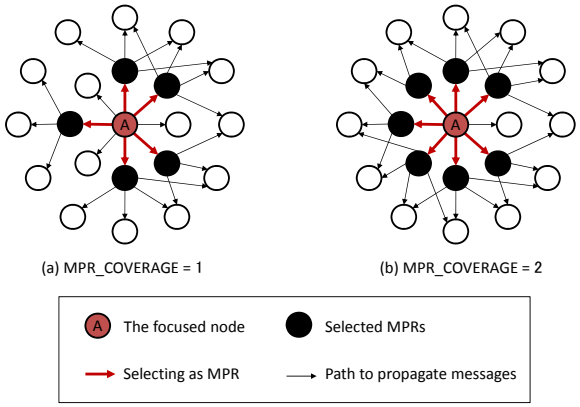



Figure 1: MPR_COVERAGE: If MPR_COVERAGE =1 (a), then, each node selects a set of its MPRs so as to relay messages to each 2-hop neighbors via at least one MPR node. Messages from node $A$ is forwarded to all 2-hop nodes via MPRs. If MPR_COVERAGE =2 (b), then, each node selects a set of its MPRs so as to guarantee two reachable paths (i.e..two neighboring MPRs) for each 2-hop node as long as possible. As a result, the redundancy is expanded whereas the network overhead is increased.

We further note that OLSR has a parameter TC_REDUNDANCY to control the advertised topology. In the following, we show the effect of each value of TC_REDUNDANCY, and also show the example in Fig.2. The default value of TC_REDUNDANCY is 0, which function has been described above.

- TC_REDUNDANCY =0: each node selects directed links from itself to its MPR selectors as its advertised links.
- TC_REDUNDANCY =1: each node selects the both direction links between itself and its MPR selectors as its advertised links.
- TC_REDUNDANCY =2: all links in the network are selected as its advertised links.

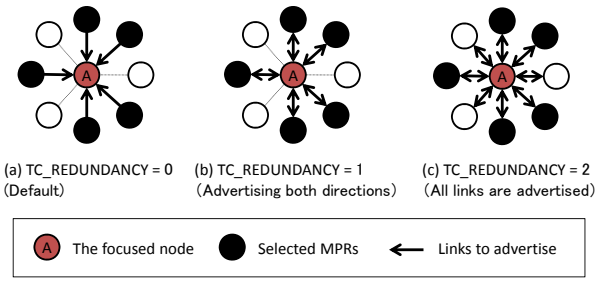



Figure 2: Function of TC_REDUNDANCY parameter.

## 3 Related Work

### 3.1 On Topology Redundancy in OLSR

One of the key characteristics to be considered when we treat proactive routing protocols in MANET is the topology control function described in Sec. 2. There is a few work that investigates the performance of topology control mechanisms of OLSR. Clausen et al. [6] investigated the performance of the two topology control parameters MPR_COVERAGE and TC_REDUNDANCY in mobile scenario, and clarified that the topology redundancy provides better data delivery in high-mobility scenarios. Villanueva-Peña et al.[7] and Huang et al.[8] performed an in-depth evaluation for stationary and mobile networks.

Those results showed that the topology redundancy within the current OLSR protocol performs effectively against mobility and the consequent link failure by providing alternative paths to re-establish the new forwarding paths quickly. However, the current parameters for topology control is not based on any theoretical results and consequently they cannot even guarantee detour paths against single failure.

To make the most of topology redundancy, Yi et al. proposed a multi-path extension to OLSR called MP-OLSR (Multi Path OLSR) [13]. By introducing a multi-path forwarding mechanism, they reduce the risk of link/node failure as well as improving the load balancing performance. However, MP-OLSR includes considerable overhead because it applies source routing to realize multi-path forwarding.

### 3.2 Mechanisms to Treat Failure

Quick re-computation of alternative paths in case of failure is not an special topic in proactive routing schemes, but it is a

common difficulty in mobile and sensor networks. There exist several techniques that improve path re-computation time to improve packet delivery performance. For example, Yamaguchi et al. proposed a method that maintains a degree-bounded spanning tree in a decentralized fashion to be robust against failures [14]. However, most of them assume full knowledge of network topology so that they do not take topology control mechanisms of OLSR into account.

On the other hand, for wired networks, the approach called IP Fast Reroute is well-known[9]–[12], which tries to repair forwarding paths immediately after failure to reduce packet loss until the new shortest paths is computed. IP fast reroute methods repair forwarding paths within 50ms after failure by precomputing detour paths. In many cases, they guarantee to prepare detour paths for every single link/node/component failure. However, they also assume the full topology of networks synchronized with all nodes so that they cannot be applied into OLSR in which only a partial advertised topology is available.

In this paper, we extend the mechanism of generating the advertised topology to guarantee detour paths against every single link/node failure. By guaranteeing detour paths in the advertised topology, our method not only improves path re-computation time in case of failure, but also it is a sufficient preparation to apply IP Fast Reroute techniques into OLSR. Note that this paper only treats the generation of the advertised topology, i.e., the method to construct detour paths is out of scope of this paper.

# 4 Selection of Advertised Links to Guarantee Detour Path

## 4.1 Requirements for Advertised Topology

Our objective in this paper is to provide an advertised topology on which we can guarantee detour paths against any single node/link failure. See Fig. 3 for instance of the current problem in OLSR. We have a few advertised links here as a result of the advertised link selection of OLSR. If we consider a flow from $s$ to $d$ and assume that link $(u, d)$ fails, we have to wait for MPR sets and the advertised topology updated, to have link $(v, d)$ advertised and then the new route $u \rightarrow v \rightarrow d$ becomes available. In contrast, if we have an advertised topology that afford detour paths, we can immediately resume communications using the detour paths by computing them in advance of failure.

We have one more issue to mention related to the advertised topology. The existing method deployed in OLSR guarantees the shortest paths between any pair of nodes. It is, however, not possible only by the advertised topology. To do this, as additional information, OLSR requires the information of neighbor links collected through Hello messages. By using the neighbor link information, OLSR reduces the network load of messages while guaranteeing the shortest paths computation. However, when we consider computing detour paths against failure (e.g., using IP Fast Reroute techniques developed for wired networks[9]–[12]), the problem of inconsistency arises among routing tables of nodes due to the difference of the base information from which those nodes calculate the forwarding paths. Many schemes that pre-compute detour paths against failure assume that all nodes share the same topology information from which they compute the forwarding paths to guarantee consistent detour paths.

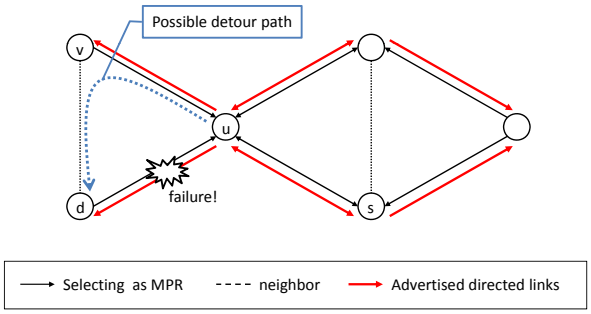



Figure 3: Example of Advertised Topology in OLSR

Therefore, we in this paper aim at providing a redundant advertised topology shared by every node, on which detour paths against every single link/node failure scenario are guaranteed. Specifically, we propose a link selection algorithm to construct the advertised topology, and give a theoretical proof that the advertised topology has two link/node disjoint paths between every pair of nodes. Note that this condition means the existence of detour paths in case of single link/node failure. One naive idea to achieve this is to set a parameter as `MPR_COVERAGE=2`, which extends the redundancy of the advertised topology as we described in Sec.2. This guarantees two disjoint paths between any pair of nodes in combination with the advertised topology and neighbor link information. However, we wish to do this without neighbor link information.

To make the advertised topology guarantee detour paths against any single link/node failure, we have two issues to solve:

(i) Complementing the first-hop links of the forwarding paths.

(ii) Ensuring detour paths to neighbor nodes.

First, we explain the issue (i). Assume `TC_REDANDANCY=0`, which is the default setting, so that each node advertises the directed links to its MPR selectors from itself. If a node is located at the "edge" of a network, the node is not selected as a MPR by any node because any two-hop node is found over edge nodes. Consequently, links from the edge nodes are not advertised as shown in Fig. 4(a). To ensure the first-hop link from such edge nodes is the first task to do.

Next, we explain the issue (ii). Even if (i) was solved, there is a case where no detour path to a neighbor node is provided in the advertised topology. See Fig. 4(b) for instance. We consider the case where nodes $a$, $b$ and $c$ are connected one another and only $c$ is connected to another node. In this case, even if we have advertised links $a \rightarrow c$ and $b \rightarrow c$ as a solution of (i), detour paths from $a$ to $c$ (i.e., $a \rightarrow b \rightarrow c$) is not available because $a$ and $b$ do not select each other as

their MPR. Another type of an example in issue (ii) exists as shown in Fig. 4(c). In this case, because the center node does not have any 2-hop node, the node does not select any MPR, and therefore any path to this node does not exist. We propose an algorithm to solve these two issues so that the advertised topology provides at least two link/node disjoint paths between every pair of nodes.

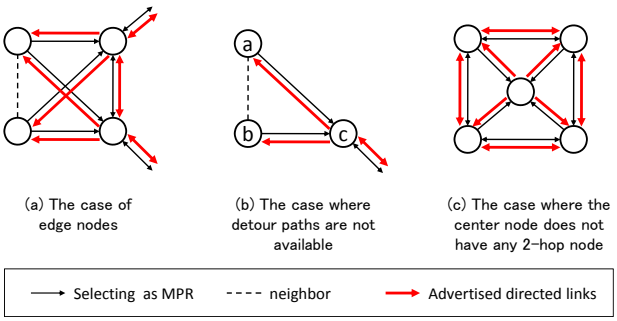



Figure 4: The examples require to solve issue (i) and (ii)

## 4.2 Overview of the Proposed Algorithm

We developed an algorithm to select advertised links to solve two issues (i) and (ii) described in section 3.1 and a few exceptional cases. We assume that `TC_REDUNDANCY=0`, which is the default setting of this parameter.

The proposed algorithm consists of the following three steps:

(a) Setting `MPR_COVERAGE=2` to provide two disjoint paths to every 2-hop node.

(b) Modifying the algorithm to select MPRs to provide detour paths to neighbor nodes.

(c) Modifying the algorithm to select links to advertise to provide the first-hop links.

Step (b) and (c) are our solution for the problems (ii) and (i), respectively, and are described in detail in Section 3.3 and 3.4, respectively.

We propose two algorithms. The first one applies the steps (a) and (c) into OLSR, which guarantees detour paths against any single node failure under a certain condition. The condition is that every node selects at least one MPR. This condition is not strong, because it is satisfied only if the diameter of the network in hop count is larger than 2. We call this algorithm with steps (a) and (c) as *Algo1*.

The second algorithm applies all the steps (a), (b) and (c) into OLSR, which guarantees detour paths against any single link/node failure without any restriction. Note that the algorithm guarantees detour paths not only against node failure, but also against link failure. We call this algorithm with steps (a), (b) and (c) as *Algo2*.

## 4.3 Modifying the Algorithm to Select MPRs

This section explains the detail of step (b) presented in Sec. 3.2. Step (b) modifies the algorithm of OLSR to select MPRs so as to guarantee detour paths to neighbor nodes.

In OLSR, every node selects a set of its MPRs such that each of its two-hop nodes is reachable via at least one MPR. In other words, two-hop nodes should be "covered" by MPRs. If we set `MPR_COVERAGE=2` as we do in step (a), MPRs are selected such that every two-hop node is covered by two MPRs as long as possible.

As step (b) of the proposed algorithm, we changed the algorithm to select MPRs such that every node covers not only 2-hop nodes, but also 1-hop neighbors. Here, we regard that a MPR node covers itself. That is, for instance, node $A$ selects its MPRs such that every two-hop node and every one-hop neighbor of $A$ have at least two $A$'s MPRs within 1-hop distance. This process makes the paths for 1-hop neighbors on the advertised topology redundant and robust. The proof of the correctness is given in Sec. 4.

## 4.4 Modifying the Algorithm to Select Advertised Links

This section explains the detail of step (c) presented in Sec. 3.2. Step (c) modifies the algorithm of OLSR to select advertised links to augment the advertised topology with first-hop links. In combination with step (a), this modification guarantees the existence of a path between any pair of nodes in the advertised topology.

In OLSR, selection of advertised links has a limitation because it fully depends on the selection of MPRs, i.e., only the reverse links to MPRs are advertised under the default setting `TC_REDUNDANCY=0`. In contrast, in our algorithm, a node not only advertises the reverse links to MPRs, but also all links that connect to the nodes that are selected as MPRs by other nodes. With this extension, OLSR nodes can advertise the first-hop links.

See Fig. 5 for example. Fig. 5(a) shows the case of the conventional algorithm with the setting `MPR_COVERAGE=2` (i.e., step (a)). Every node covers each 2-hop node with at least two MPRs, and the advertised links are selected depending on the selection of MPRs as shown in Fig. 5(a). Note that this conventional algorithm does not guarantee a path between every pair of nodes. Therefore, we use step (c). Fig. 5(b) shows the result where step (c) is applied in addition to step (a). You see that the first-hop link on the path between every pair of nodes is advertised. As proved afterwards, this algorithm that we call Algo1 guarantees two node-disjoint paths between every pair of nodes.

Note that we have to modify the format of HELLO messages of OLSR, because it does not include the field to advertise a set of MPR selectors of the sender nodes.

# 5 Theoretical Results

This section presents theoretical results to prove that the proposed algorithms guarantee to provide a detour path on the advertised graph $H$.

We begin with definitions. Let $= (V, E)$ be a directed graph representing the base network, where $V$ is a set of nodes and $E$ is a set of directed links. We assume that is *symmetric*, i.e., $(v, u) \in E$ holds for every link $(u, v) \in E$. We call is *connected* if there is a path from $u$ to $v$ for any

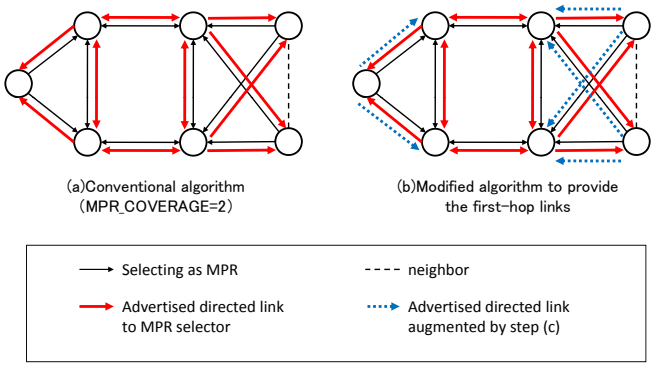



Figure 5: Extension of link adverting by our algorithm

pair of vertices $u, v \in V$. For a set of vertices $C_V \subset V$, if $' = (V - C_V, E)$ is not *connected*, then $C_V$ is called a *vertex-cut* of . Let $|C_V|$ be the size of $C_V$; if $|C_V|$ for any vertex-cut $C_V$ is equal to or larger than k, then is called *k-vertex-connected*. Similarly, for a set of edges $C_E \subset E$, if $' = (V, E - C_E)$ is not connected, then $C_E$ is called an *edge-cut* of . Let $|C_E|$ be the size of $C_E$; if $|C_E|$ for any edge-cut $C_E$ is equal to or larger than $k$, is called *k-edge-connected*. For any pair of vertices $u, v \in V (u \neq v)$, we call a sequence of edges $p = (u = v_1, v_2), (v_2, v_3), \ldots, (v_{n-1}, v_n = v)$ as *u-v path*. If a set of $u-v$ paths $p_1, p_2, \ldots, p_k$ on do not share any node except for $u$ and $v$, then these $k$ paths are called *vertex-disjoint*. Similarly, if such $k$ paths do not share any edge except for $u$ and $v$, then the paths are called *edge-disjoint*.

For a vertex $v \in V$, let $N_1(v)$ be a set of its neighbor vertices, and $N_2(v)$ be a set of its 2-hop neighbor vertices. Let $M_k(v)$ be a set of MPRs selected by $v$ with the parameter `MPR_COVERAGE=k` under the conventional method, i.e., OLSR. We call $M_k(v)$ as the *k-degree* MPR set. Let $\overline{M}_k(v)$ be the corresponding set of *k-degree* MPR selectors of $v$. Also, let $M'_k(v)$ be a set of $v$'s MPRs under the proposed method of step (b) with the parameter `MPR_COVERAGE=k`, and let $\overline{M}'_k(v)$ be the corresponding set of *k-degree* MPR selectors of $v$.

Suppose that *2-degree* MPR set $M_2(v)$ is determined by every vertex $v \in V$. Then, let $F_1$ be the set of directed edges $(v, u)$ where $u \in \overline{M}_2(v) \cup \{u | u \in N_1(v), |\overline{M}_2(u)| \geq 1\}$. Let $H_1 = (V, F_1)$ be the subgraph of called *advertised graph* generated by Algo1, which corresponds to the advertised topology generated by the proposed method with steps (a) and (c). Similarly, let $F_2$ be the set of directed edges $(v, u)$ where $u \in \overline{M}'_2(v) \cup \{u | u \in N_1(v), |\overline{M}_2(u)| \geq 1\}$. Let $H_2 = (V, F_2)$ be the subgraph of called *advertised graph* generated by Algo2, which corresponds to the advertised topology generated by the proposed method with steps (a), (b) and (c).

To guarantee existence of detour paths for any single node/link failure, the advertised graph $H$ should be 2-node/link-connected, and we prove it in this section. In fact, we prove that two node/link disjoint paths exist on $H$. Note that, in the following proposition, existence of two disjoint paths is equivalent

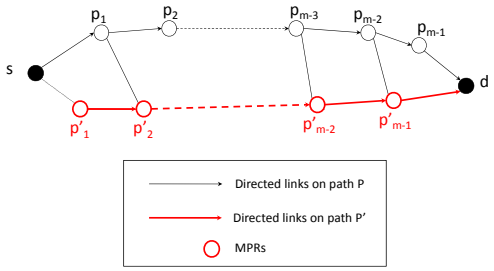



Figure 6: For a path $P = (s = p , p_1, p_2, \ldots, d)$ in , we can obtain the path $P' = (p'_1, p'_2, \ldots, d)$ in $H$, which lays along with $P$, where $p'_{k-1}$ is an MPR of $p'_k$ that covers $p_{k-2}$.

to the two-connectivity.

**Proposition 1 (Menger's Theorem[5] for Node Connectivity)** *A directed graph $= (V, E)$ is k-vertex-connected if and only if there is a set of $k$ vertex-disjoint paths between any pair of vertices $u, v \in V$.*

In the following theorem, we first show the property of the advertised graph $H_1$ generated by the proposed algorithm Algo1.

**Lemma 1** *If is 2-vertex-connected and $M_2(u) \neq \emptyset$ for every vertex $u \in V$, there are two node-disjoint paths on the advertised graph $H_1$ between every pair of nodes $s, d \in V$ where $d \notin N_1(s)$.*

*Proof.* We assume is 2-vertex-connected. From Proposition 1, there are two vertex-disjoint paths $P$ and $Q$ in for every pair of vertices $s, d \in V$. We define that $P = (s = p , p_1), (p_1, p_2), \ldots, (p_{m-1}, p_m = d)$ and $Q = (s = q , q_1), (q_1, q_2), \ldots, (q_{n-1}, q_n = d)$. Assume that a 2-degree MPR set $M_2(v)$ is determined by every vertex $v \in V$.

To prove that $H_1$ is 2-vertex-connected, we have only to show the existence of two vertex-disjoint paths on $H_1$ between every pair of nodes $s, d \in V$ where $s$ and $d$ is not adjacent. Naturally, we suppose two nodes $s$ and $d$ that are not adjacent and show the existence of two vertex-disjoint paths.

Because $p_{m-2}$ is located at 2-hop distance away from $d$ on $P$, $p_{m-2} \in N_2(d)$ holds. Thus, a node $p'_{m-1} \in \{M_2(d) \cap N_1(p_{m-2})\}$ exists because $d$ covers $p_{m-2}$ with its MPRs. Because $F_1$ contains directed edges to MPR selectors, $(p'_{m-1}, d = p_m) \in F_1$ holds. The same operations can be performed along $P$, e.g., for $p_{m-3}$ and $p'_{m-1}$, a node $p'_{m-2}$ with link $(p_{m-2}, p'_{m-1}) \in F_1$ exists in $N_1(p_{m-3})$. By repeating this, we obtain a path $P' = (p'_1, p'_2), (p'_2, p'_3), \ldots, (p'_{m-1}, d)$ on $H_1$, where $p'_1 \in N_1(s)$ on . We obtain a path $Q' = (q'_1, q'_2), (q'_2, q'_3), \ldots, (q'_{n-1}, d)$ on $H_1$ where $q'_1 \in N_1(d)$, with the same operations on $Q$. The process to obtain $P'$ is illustrated in Fig. 6.

We prove that $P'$ and $Q'$ can be constructed to be vertex-disjoint. Assume that $P'$ and $Q'$ are not vertex-disjoint, i.e., there is a vertex included in both $P'$ and $Q'$. We first consider the case where $p'_{m-1}$ and $q'_{n-1}$ are the same vertex. In this case, we can repair $P'$ and $Q'$ to be vertex-disjoint. Let

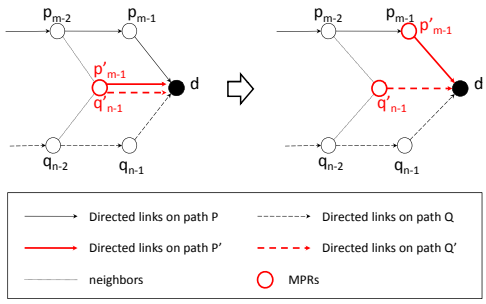



Figure 7: Repairing process to make $P'$ and $Q'$ vertex disjoint. In case of $p_{m-1} = q_{m-1}$, we can re-select different nodes for $p_{m-1}$ and $q_{m-1}$ to repair the paths. Repeating this process for every node included in both $P'$ and $Q'$, we obtain a pair of vertex-disjoint paths $P'$ and $Q'$.

us consider the set of vertices $R = M_2(d) \cap \{N_1(p_{m-2}) \cup N_1(q_{n-2})\}$. Note that $R$ contains $p'_{m-1}$ and $q'_{n-1}$. Because $M_2(d)$ is a 2-degree MPR set, it covers each of $p_{m-2}$ and $q_{n-2}$ with two vertices whenever possible, and it is in fact possible because there are at least two vertices (other than $p'_{m-1}(= q'_{n-1})$) $p_{m-1}$ and $q_{n-1}$ that can cover $p_{m-2}$ and $q_{n-2}$, respectively. This implies that we can re-select different vertices $p'_{m-1}$ and $q'_{n-1}$ to repair $P'$ and $Q'$ to be vertex-disjoint. This repairing process is illustrated in Fig. 7.

We next consider the more general case where $P'$ and $Q'$ share vertices other than $p_{m-1}$ and $q_{n-1}$. Let $p'_i$ be one of the shared vertices nearest from $d$ in $P'$, and let $q'_j$ be the same vertex on $Q'$. Because $p'_{i+1}$ is the first vertex that is shared by $Q'$, $p'_{i+1} \neq q'_{j+1}$ holds. Then, let $R_i = \{M_2(p'_{i+1}) \cup M_2(q'_{j+1})\} \cap \{N_1(p_{i-1}) \cup N_1(q_{j-1})\}$ be the set of vertices neighboring to $p'_{i+1}$ or $q'_{j+1}$ to cover $p_{i-1}$ or $q_{j-1}$. If $|R_i| = 1$, then $p_i = q_j$ holds; thus, this case contradict the assumption that $P$ and $Q$ are vertex-disjoint. If $|R_i| \geq$ , with the similar discussion as given above, two different vertices can be re-selected as $p'_i$ or $q'_i$ in $R_i$ to repair $P'$ and $Q'$ to be vertex-disjoint. In this way, by repairing $P'$ sequentially from the shared vertex closer to $d$, we finally obtain two vertex-disjoint paths $P'$ and $Q'$.

Note that $P'$ and $Q'$ do not include the start node $s$. We show that $F_1$ includes two links $(s, p'_1)$ and $(s, q'_1)$ to make $P'$ and $Q'$ connect from $s$ to $d$. We consider the case where $p'_1$ and $q'_1$ are the same vertex. Similarly, we define $R_s = \{M_2(p'_2) \cup M_2(q'_2)\} \cap N_1(s)$. If $|R_s| = 1$, then $p_1 = q_1$ holds, which contradicts the assumption that $P$ and $Q$ is vertex-disjoint. If $|R_s| \geq$ , from the same discussion as above, different $p'_1$ and $q'_1$ can be re-selected. Thus we can assume that $p'_1$ and $q'_1$ differ. Note that $p'_1$ and $q'_1$ are neighbors of $s$, and they are selected as MPRs by $p'_2$ and $q'_2$, respectively. Because Algo1 selects advertised links to nodes that are selected as MPRs by other nodes, $(s, p'_1), (s, q'_1) \in F_1$ holds. As above, existence of two vertex-disjoint paths on $H_1$ is proved in the case $s$ and $d$ are not adjacent. □

**Theorem 1** *If is 2-vertex-conneted and $M_2(v) \neq \emptyset$ for every vertex $v$, then advertised graph $H_1$ is 2-vertex-connected.*

*Proof.* This statement directly holds from Lemma 1 and Proposition 1. □

We next show the characteristics of the advertised graph generated by Algo2. In this case, we can omit a restriction that $M_2(v) \neq \emptyset$ for every vertex $v$, from Theorem 1.

**Theorem 2** *If is 2-vertex-connected, then advertised graph $H_2$ is 2-vertex-connected.*

*Proof.* Because the MPR set of $v$ in Algo1 is included in that of Algo2, i.e., $M_2(v) \in M'_2(v)$, this statement holds if $M_2(v) \neq \emptyset$ for every vertex $v$, from Theorem 1.

When $M_2(v) = \emptyset$ for every vertex $v$, every vertices are neighboring with one another. Because Algo2 includes step (b), $M'_2(v)$ additionally covers every neighbor $w$ with two MPRs as long as possible. With step (c), for every node in MPRs, $w$ advertises the link for it or $w$ is a MPR node to cover $w$ itself. This guarantees $H_2$ to be 2-vertex-connected. □

We further show that a stronger statement holds on $H_2$ that $H_2$ is 2-link-connected. Note that, contrary to the intuition, the condition 2-link-connected in the following Theorem 3 is stronger than 2-node-connected because the condition for is different, i.e., is 2-node-connected in Theorem 2 whereas 2-link-connected in Theorem 3.

**Lemma 2** *If is 2-link-connected, there are two link-disjoint paths on the advertised graph $H_2$ between every pair of nodes $s, d \in V$.*

*Proof.* We follow the similar discussion as Lemma 1. We first consider the case where $d \notin N_1(s)$. We define $P = (s = p\ , p_1), (p_1, p_2), \ldots, (p_{m-1}, p_m = d)$ and $Q = (s = q\ , q_1), (q_1, q_2), \ldots, (q_{n-1}, q_n = d)$ as two link-disjoint paths from $s$ to $d$ on . Suppose that under Algo2 every vertex selects a MPR set, and obtain two paths $P' = (p'_1, p'_2), (p'_2, p'_3), \ldots, (p'_{n-1}, d)$ and $Q' = (q'_1, q'_2), (q'_2, q'_3), \ldots, (q'_{n-1}, d)$ on $H_2$ where $p'_1, q'_1 \in N_1(d)$, with the same operation as in Lemma 1.

Assume that $(p'_{i-1}, p'_i)$ be the link in $P'$ shared with $Q'$ that is nearest to $d$. We denote the same link in $Q'$ by $(q'_{j-1}, q'_j)$. If $p_{i-1} \neq q_{j-1}$, we can repair the paths $P'$ and $Q'$ in the same way as Lemma 1. If $p_{i-1} = q_{j-1}$, $p_i \neq q_j$ must hold because $P$ and $Q$ are edge-disjoint. In this case, $p'_i$ and $q'_j$ can be re-selected to repair $P'$ and $Q'$, from the similar discussion as Lemma 1. By repeating this process, we obtains two edge-disjoint paths $P'$ and $Q'$ in the end.

In the case of $d \in N_1(s)$, $M'_2(d)$ covers $s$ with at least two MPRs. If $s$ itself is not included in the MPR set, the same discussion as above can be applied. Otherwise, link $(s, d)$ is advertised and is a path from $s$ to $d$. Another path from $s$ to $d$ can be taken in the same way of taking a path $P'$ as the above discussion. □

**Proposition 2 (Menger's Theorem[5] for Edge Connectivity)** *A directed graph $= (V, E)$ is $k$-edge-connected if and only if there is a set of $k$ edge-disjoint paths between any pair of vertices $u, v \in V$.*

**Theorem 3** *If is 2-link-connected, then advertised graph $H_2$ is 2-link-connected.*

*Proof.* This statement directly holds from Lemma 2 and Proposition 2. □

# 6 Evaluation

## 6.1 Performance Measurement

In the previous section, we presented a theoretical results that the presented two algorithms (Algo1 and Algo2) guarantee the detour paths on the advertised topology. However, we require additional network load to have advertised links afford to have detour paths. In this section, we evaluate the network load of control messages required in our method, instead of guaranteeing detour paths.

We use the following four measurements to evaluate the overhead of our methods.

**Ratio of MPR selection.** The ratio of the pairs in the relation of MPR among all adjacent pairs. This value is calculated as the sum of the number of MPR nodes among all nodes divided by the sum of the number of neighbor nodes among all nodes. This measurement indicates how many MPRs increased by the proposed methods.

**The number of message transmissions.** The number of transmissions including relays when every node propagates one message throughout the network. This measurement indicates the network load of control messages from the view point of the number of messages sent.

**Ratio of advertising links.** The number of directed links included in the advertised topology divided by the total number of directed links in the network. This measurement indicates the factor of network load coming from the performance of the advertised topology optimization.

**The load of message propagation.** The total sum of the size of transmitted messages in the network, where message size is estimated by the number of including links to be propagated. This measurement indicates the estimated total network load coming from control messages (except for that of HELLO messages).

## 6.2 Simulation Scenario

Through simulation study, we compare the proposed algorithms (i.e., Algo1 and Algo2) with the conventional algorithms using the four measurements described in Sec. 6.1. The main concern of this comparison is how much additional network load is required by the proposed algorithm to guarantee detour paths on the advertised topology. One of the most important feature of the optimization of advertisement in OLSR is to enable us reduce network load especially in dense networks. Therefore, we compare performance with variation of network density. We implement the simulator from scratch using C language, and it is sufficient because we focus on control messages without considering traffic of networks,

In our simulation scenario, we locate 25 nodes at random coordinates in a square field of various side length, i.e., we tried 100, 150, . . . , 950, and 1000 meters of the side length, to vary node density of the network. We set the communication range of wireless links as 200 meters; if two nodes are within the communication range, they have links bi-directionally to connect each other. We simulate exchanging messages in OLSR and compare the proposed algorithms Algo1 and Algo2, with the conventional algorithm of OLSR.

For the two measurements, i.e., the ratio of MPRs and the number of transmissions, we compared the proposed algorithms with the conventional method with `MPR_COVERAGE=1`, which is the default setting. Note that Algo1 and OLSR with the setting `MPR_COVERAGE=2` are equivalent in these measurement. For other two measurements, we added the conventional method with setting `MPR_COVERAGE=2`. We conducted 200 trials for each cases and used the average for comparison.

Note that, in the figure of the results, we just write MC for `MPC_COVERAGE` and TC for `TC_REDUNDANCY`.

## 6.3 Simulation Results

Fig. 8 shows the result for the ratio of MPRs, where the horizontal axis means the node density and the vertical axis means the measurement values. In general, the number of MPR nodes goes higher as the network density goes lower. Consider that if the density is extremely high, in other words, if every node is neighboring most of the nodes, nodes hardly select their MPRs in the conventional algorithms. This is the reason why the load of Algo2 is relatively high when the side of the field is shorter than 250 meters. Further, we found that the load of Algo2 continues to go higher as the side of the field goes longer than 700 meter, while Algo1 suppresses the growth of the load. This effect is due to step (b).

Fig. 9 shows the result for the number of transmitting messages. As network density goes lower, this value firstly raises, and turns to dropping around the side length of 500 meters. When the side length is lower than 250 meters, the same tendency as Fig. 10 is seen in this result. Algo2 takes higher values on the whole because the number of MPRs is large, however, Algo1 takes rather higher values for some values of side length.

Fig. 10 shows the result for the ratio of advertising links. This value has similar tendency to the ratio of MPRs shown in Fig. 8. Note that the Algo1 takes far larger values compared with the conventional case `MC=2`, which are equivalent in the ratio of MPRs. This means that the augmentation of advertised links by step (c) effects significantly on the network load.

Fig. 11 shows the result for the load due to message propagation. The whole curve is similar to the number of message transmissions shown in Fig. 9, but due to the augmentation of advertised links with step (c), the network load increases significantly. Here, note that the most important characteristics of optimizing the advertisement in OLSR is to reduce network load especially in high density cases. From this point of view, our results clearly shows that the most important property is hold in the proposed methods.

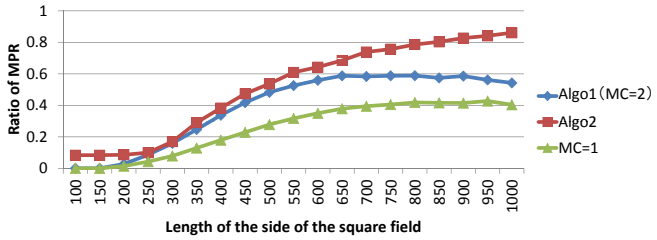



Figure 8: Ratio of MPRs

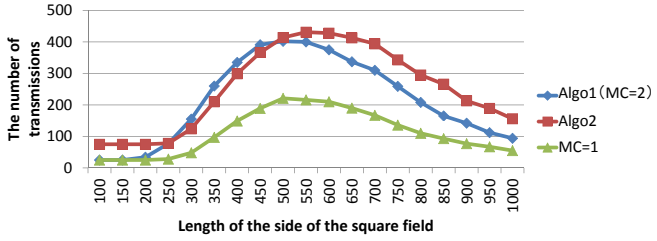



Figure 9: The number of message transmissions

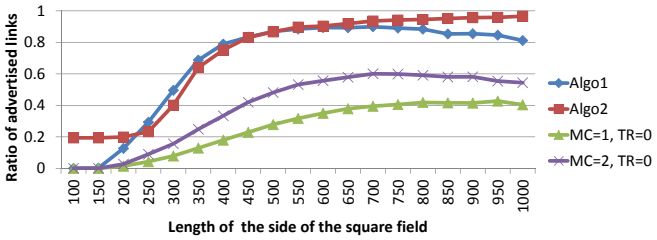



Figure 10: Ratio of advertising links

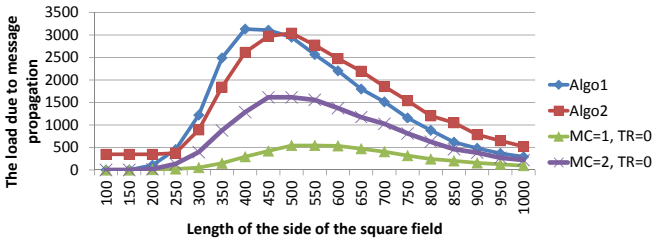



Figure 11: The load due to message propagation

## 6.4 Discussion

The network topologies used in the simulation do not always guarantee two node/link-disjoint paths between every pair of nodes. However, we did confirm that Algo1 provided two node-disjoint paths for every pair of nodes on all the advertised topologies we tried. Also, we confirmed that Algo2 provided two node/link-disjoint paths for every pair of nodes. In contrast, we confirmed that the conventional method did not provide such pair of disjoint paths on any advertised topologies with any combinations of the two parameter values, i.e., `TC_REDUNDANCY=0,1` and `MPR_COVERAGE=1,2`.

Through the simulation, we clarified that the proposed algorithms require considerable amount of additional load. However, in case of dense networks, in other words, in the case where we need to reduce the network load, the proposed algorithms surely reduced the load within the allowable level. The proposed algorithms did not lose the essential characteristic required in ad hoc networks, so that they are still practical enough.

## 7 Conclusion

In this paper, we proposed two algorithms to select advertised links to guarantee the advertised topology 2-link/node-connected. These algorithms enable us to pre-compute detour paths to use in case of failure in order that we can immediately resume user's communications. We gave the theoretical proof of 2-link/node-connectivity of the advertised topology, and evaluated the additional network load of control messages of the proposed algorithms. As a result, it is clarified that the proposed algorithms require considerable load, but they still keep the significant characteristic required in MANET, i.e., they can reduce the network load within the allowable level in case of high-density networks.

## Acknowledgment

This research is partly supported by JSPS KAKENNHI (24700069).

## REFERENCES

[1] T. Clausen and P. Jacquet, "*Optimized Link State Routing*," IETF RFC3626, 2003.

[2] C. Perkins and E. Belding-Royer, "*Ad hoc On-Demand Distance Vector (AODV) Routing*," IETF RFC3561, 2003.

[3] D. Johnson, Y. Hu and D. Maltz, "*The Dynamic Source Routing Protocol (DSR) for Mobile Ad Hoc Networks for IPv4*," IETF RFC4728, 2007.

[4] R. Ogier, F. Templin and M. Lewis, "*Topology Dissemination Based on Reverse-Path Forwarding (TBRPF)*," IETF RFC3684, 2004.

[5] R. Diestel, "*Graph Theory Second Edition*," Springer-Verlag New York, pp.50, 2000.

[6] T. Clausen, P. Jacquet, andd L. Viennot, "*Investigating the Impact of Partial Topology in Proactive MANET Routing Protocols*," Proc. 5th Int. Symp. on Wireless Personal Multimedia Comm., Oct. 2002, pp. 1374-1378.

[7] P. E. Villanueva-Peña, T. Kunz, and P. Dhakal, "*Extending network knowledge: Making OLSR a Quality of Service Conducive Protocol*," Proc. 2006 Int. Conf. on Comm. and Mobile Computing, Vancouver, Canada, pp. 103-108, July 2006.

[8] Y. Huang, S. Bhatti, and S. Sorensen, "*The Impacts of Spatial Topology Redundancy on Proactive MANET Routing Performance*," Technical Report RN/07/16, UCL (2007).

[9] M. Shand, S. Bryand and S. Previdi, "IP Fast Reroute Using Not-via Addresses," draft-ietf-rtgwg-ipfrr-notvia-addresses-04.txt, 2009.

[10] Z. Zhong, S. Nelakuditi, Y. Yu, S. Lee, J. Wang, and C.N. Chuah, "Failure inferencing based fast rerouting for handling transient link and node failures," in Proceedings of IEEE Global Internet, Mar. 2005.

[11] T. Yoshihiro, "A Single Backup-Table Rerouting Scheme for Fast Failure Protection in OSPF," IEICE Transactions on Communications, Vol. E91-B, No. 9,

pp.2838-2847, 2008.

[12] T. Yoshihiro and M. Jibiki, “Single Node Protection without Bouncing in IP Networks,” IEEE 13th Conference on High Performance Switching and Routing (HPSR2012), pp. 88–95, 2012.

[13] J. Yi, A. Adnane, S. David, B. Parrein, Multipath optimized link state routing for mobile ad hoc networks, Ad Hoc Networks, Volume 9, Issue 1, Pages 28—47, 2011.

[14] H. Yamaguchi, H. Akihito, T. Higashino, K. Taniguchi, “An Autonomous and Decentralized Protocol for Delay Sensitive Overlay Multicast Tree”, Proc. of IEEE ICDCS2004 (24th Int. Conf. on Distributed Computing Systems), pp. 662-669, Mar. 2004

# A Streaming Method with Trick Play on Time Division based Multicast

Yoshitaka Nakamura†, Kazuki Murakoshi‡Yoh Shiraishi and Osamu Takahashi

†School of Systems Information Science, Future University Hakodate, Japan
‡Graduate School of Systems Information Science, Future University Hakodate, Japan
{y-nakamr, g2110045, siraisi, osamu}@fun.ac.jp

***Abstract*** - VoD is a leading service in NGN, which requires a low-load distribution method for network load and the distribution server. In addition, the distribution method must be considered Trick Play in order to respond to user requests. In this paper, we propose a distribution method that combines a number of multicast and unicast to get non-received data, and Fast-Forward algorithm. Then simulation results show an effect of our proposal method on the loads of distribution server and network traffic.

***Keywords***: VoD, NGN, Multicast, Trick Play, Fast-Forward

## 1 INTRODUCTION

In recent years, Next Generation Network (NGN), which provides reliability and stability as the circuit switched network and scalability and low cost as the Internet, has become popular.

In NGN, voice call, broadcasting, and data transmission are integrated with the high speed and broadband IP network, moreover advanced services are provided with Quality of Service (QoS) control and access control. In addition, development of the service by competition among providers is expected because some interfaces to access NGN are provided for many providers to use NGN. Above all, Video on Demand (VoD), which provides the large-scale and high quality content like a movie by using QoS control, is a useful service. In the VoD service, providers need to respond immediately to the user ' s request called Trick-Play such as fast-forward and rewind. Therefore, a technique called True VoD is used in a general VoD service to achieve Trick-Play. In true VoD, content is delivered from the delivery server to the requested user by unicast. However, there is a subject of the increase in cost of equipment in unicast due to a load of delivery servers and network increase proportion to increase the number of users.

In previous research, Content Delivery Network (CDN) and Peer-to-Peer network based VoD (P2P-VoD) provide load balancing by efficient placing cache servers to keep a copy of content. In these approaches, load balancing of the delivery server and load reduction of the network are achieved by delivering from an appropriate server in a geographical or network place. However, content is delivered by unicast to achieve Trick-Play in these approaches, larger load reduction is not expected. On the other hand, there are some approaches using multicast such as Near VoD to deliver content from the beginning at regular intervals, Fusion-Stream and Neighbors-Buffering-Based VoD (NBB-VoD) unified multicast and unicast. As the server delivers with multicast in these approaches, a load on the server and network is decreased greater than True VoD. However, There are some subjects such as corresponding to Trick-Play and definition of the number of channels on multicast, connection stability owing to user ' s action as join or leave P2P network, and a load on network owing to a long time unicast.

In this paper, we propose NBB-VoD based streaming method to decrease a load of delivery servers by limited to three connections, which are a multicast to receive from delivery server, a unicast to receive unbuffered data from a user who joins the multicast just before, and a unicast to send a user who joins the multicast immediately after, on Set Top Box (STB) that is a receiving device. Also, we propose an algorithm for Trick-Play, so we achieve more on-demand content delivery method. Furthermore, we compare our proposal method with CDN and Fusion-Stream by Network Simulator, as a result, this paper shows the usefulness of our proposal method in high-quality content delivery service.

## 2 RELATED WORK

### 2.1 Content Delivery Network

A Content Delivery Network (CDN) consists of two components, the origin server where the content to be distributed over the Internet is originally stored and cache servers where the content is duplicated and delivered. Multiple cache servers placed distributedly on the Internet, contents are deliverd from the cash server which is the nearest to the user who required delivery. For metrics of the distance to the cash server, geographical distance or distance in network topology or delay time from delivery request to deliver is used. In CDN, the traffic amount is reduced by shortening the distance of using unicast communication. And, network load and processing load on the single delivery server are distributed by locating a cash server distributedly. In addition, user authentication and easy accounting management are also characteristics of CDN, because the service provider manages point-to-point communication. However, with the increase of the users, the increase of the equipment cost and the traffic amount become the problem because of using unicast communication.

### 2.2 Fusion-Stream

Fusion-Stream is a contents delivery method that combines multicast communication and unicast communication. The contents are delivered from the begining by multicast, and when a user join the session halfway, the non-acquisition part of contents are delivered by unicast from the user who participated just before. In Fusion-Stream, the network load can

be reduced greatly in comparison with CDN, because the delivery server performs only multicast delivery and management of IP address and the request order of the user who requests to watch contents. The data transmission to the user who joins next is realized by buffering the data which each user terminal already received. Therefore, the time to watch the contents from the request of contents becomes short, and users can playback contents in any timing. However, as much as an elapsed time of the delivery becomes long, the time of unicast communication between users becomes longer, and the network traffic quantity increases. And there are some problems with non-correspondence to Trick-Play and problems with stability at the time of users' frequently participation and secession of the network.

## 2.3 Neighbors-Buffering-Based VoD

NBB-VoD is also a contents delivery method that combines multicast communicationto deliver a content with multiple channels and unicast communication to acquire non-acquisition data from other users like Fusion-Stream. In NBB-VoD, the contents data is delivered from the beginning every period of time by multicast. As much as possible users participating in contents delivery deliver non-acquisition data for the user who requests to watch contents by unicast communication. In NBB-VoD, the load of network bandwidth is reduced, because the long-time unicast communication that becomes the problem in Fusion-Stream is divided into the number of channels. And, there is the advantage that the management of the certification and the charging is easy because NBB-VoD uses each STB as a receiving terminal. However, the load of the delivery server and the load of network bandwidth are in a relation of the trade-off because the load of the delivery server increases by the number of channels. In addition, there are some problems in NBB-VoD, including the number of the channels of effective multicast being unknown, the equitableness of electricity which users incured and the network bandwidth, the correspondence to Trick-Play and the point that unicast communication produces from delivery server when contents are delivered by more than the number of the maximum unicast connection of each user.

# 3 PROPOSED METHOD

In this paper, we propose a delivery method that can reduce the load of delivery servers and network bandwidth in contents delivery than NBB-VoD, by limiting the communication of each STB which is the receiving terminal of users to three. And, we clarify the appropriate number of multicast channels that is not clarified in NBB-VoD by implementing proposed method on a network simulator and evaluating quantity of traffic of the whole network. Furthermore, we propose a control method by the change the communication session of STB from delivery servers and realize Trick-Play.

Fig.1 shows a communication channel between delivery server and STB in the proposed method and NBB-VoD. The delivery server delivers contents using three multicast channels in NBB-VoD(Fig.1(a)). At the same time, multiple unicast channels for the delivery server are necessary in NBB-VoD, because the delivery server delivers non-acquisition part of data which cannot be delivered by the users who had already joined the session to users who joined the session halfway. In addition, multiple unicast channels are also necessary for STB, because STB performs unicast communication as much as possible. On the other hand, the proposed method(Fig.1(b)) is more efficient because the delivery server delivers contents using only three multicast channels and STB also needs only one unicast channel.

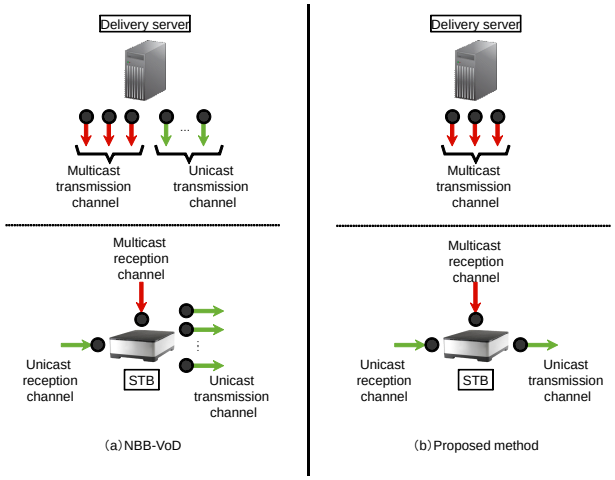



Figure 1: Communication channel of delivery server and STB

## 3.1 Contents Delivery

The proposed method is a contents delivery method. This method sets dividing points in contents at regular intervals. And it combines multiple multicast communication to deliver contents from the beginning in each dividing point and unicast communication to transmit and receive non-acquisition part of data for STB. Each STB buffers all the received data until the multicast delivery that its users join is finished. At this time, STB may buffer the one whole content at most. Therefore the storage which can buffer one whole content at least is necessary for each STB. In addition, two network channels for the reception and one network channels for the transmission are necessary for each STB.

Fig.2 shows a delivery example in the proposed method. In this example, we assume the number of partitions (the number of dividing points) 2, and the contents of 30 minutes are delivered by two multicast channels. Therefore the user who request the delivery by 15 minutes later since the first multicast session is started (until half of the content has been delivered) joins the first multicast session. And the user who requested the contents delivery after 15 minutes by 30 minutes later joins the second multicast session. STB 2 is the terminal which request the delivery 5 minutes later since STB 1 had requested and does not have the data from the begining to 5 minites which had been deliverd before joining the multicast session. Therefore STB 2 acuires the data between 5-30 minutes by multicast communication. At the same time, STB 2 acquires non-acquisition data of 0-5 minutes by unicast communication from STB 1 which joined the multicast session

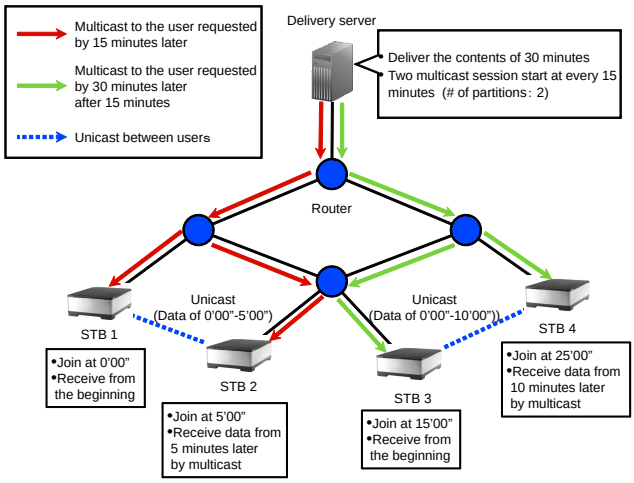



Figure 2: Delivery example in the proposed method

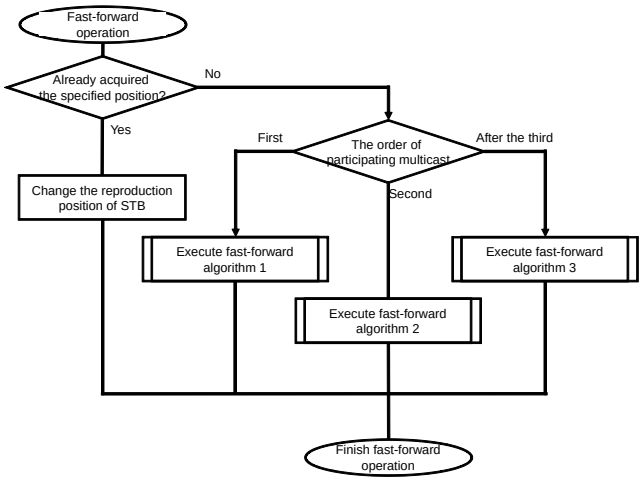



Figure 3: Overview of fast-forward algorithm

just before. Similarly, STB 4 acuires the data between 10-30 minutes by multicast communication, and STB acquires non-acquisition data of 0-10 minutes by unicast communication from STB 3 which joined the session just before. The proposed method uses SIP(Session Initiation Protocol)[4] as delivery requests and reply. And the necessary infromation for the session establishment is described in a form of SDP（Session Description Protocol）[5].

## 3.2 Type of multicast

The proposed method uses two kinds of multicast of static multicast and the dynamic multicast for normal delivery and Trick-Play. This method uses static multicast to deliver the contents from the beginning to the end by multiple channels in the normal delivery. The static multicast is communication to deliver to the user who request the contents by channels assigned every time interval set beforehand.

On the other hand, in the Trick-Play when some kind of requests of contents such as the fast-foward operation occurred for the data which are not buffered in STB, multicast channels are constructed to deliver the data from the position that user specified to the position buffering in STB. And Trick-Play uses these multicast cannels as dynamic multicast. If the specified position has been already delivered as dynamic multicast, thereare some users who joined the dynamic multicast just before that. In this case, the user who request the contents delivery joins the delivered dynamic multicast session. If there is no participating users and the planned delivery are finished, dynamic multicast session is stopped, because the dynamic multicast is made as a temporary delivery session.

## 3.3 Fast-forward algorithm

The fast-forward operation often specifies a playback position of non-acquisition part of data in Trick-Play. Fig.3 shows the summary of the fast-forward algorithm in the proposed method. It is necessary to consider two cases in the proposed method, because specified position of fast-forward operation has been already acquired or is not acquired. When the specified position has been already acquired, the proposed method only changes the play back position of output from STB to the playback devices, andfast-forward can be operated without any other special processing. Therefore the contents can be played back with continuing transmission of multicast and unicast. When the data of the specified position of fast-forward operation are not acquired, the users who joined the session just before that and the users who have been joined other multicast buffer the data of the part of contents. Therefore we consider three types of cases. At first, there is a case that a user who want to fast-forward join the multicast session which is started first. Next, there is another case that a user who want to fast-forward join the multicast session which is secondly started (only one multicast session has been started). Finally, there is the other case that a user who want to fast-forward join the multicast session which is tarted after the third. (more than two multicast session has been started before).

**The case of participating in the first multicast session** When a user specifies non-acquisition part of data and fast-forwards them, we pay our attention to the data buffered by the user who join just after and just before that. If the user who joined just before that buffers non-acquisition part of data, a user who want to fast-forward can receive non-acquisition data by unicast from the user who joined just before that. Therefore fast-forward is realized by switching from unicast session receiving non-acquisition data to unicast session to receive data after the fast-forwarding from the user who joined just before that. But, the reception of non-acquisition data stops by switching sessions. If there is the user who joined just after that, and the unicast transmission to the user is continuing, the data buffered by the user who want to fast-forward has non-acquisition part of data, and unicast session cannot continue(Fig4).

In the proposed method, if the unicast session cannot continue to the user who join just after or if the user who joins just before does not buffer non-acquisition data, dynamic multicast channel is constructed to deliver the data $D_{before}$ from the position where the user specified to fast-forwarding. And the user who want to fast-forward stops transmission and re-

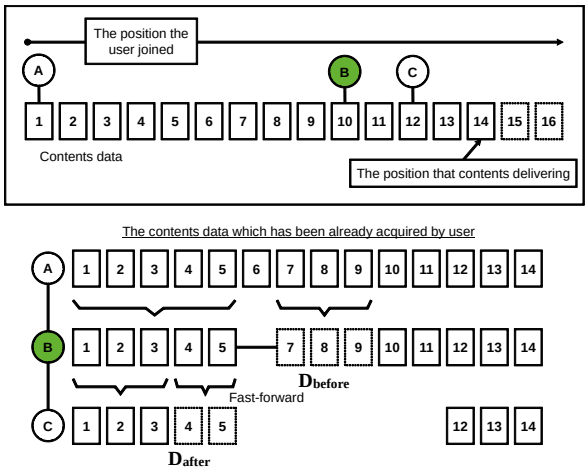



Figure 4: Overview of fast-forward algorithm

ception of unicast channel, and contents data is received from static multicast and dynamic multicast. The user who joined just before that switches a sessions of the unicast, because a user joined just after that transmits non-acquisition part of data $D_{after}$.If there is dynamic multicast including the position which has been already specified, contents data is received by unicast channel from a user participating in the dynamic multicast. By above mentioned processing, fast-forwarding can be realized without stoping the delivery of itself and anteroposterior user. On the other hand, if unicast session can continue or if a user does not exist just after that, a user who want to fast-forward switches receiving unicast sessions, and fast-forwarding is achieved without stopping delivery. The above-mentioned structure is called ”fast-forward algorithm 1”.

**The case of participating in the second multicast session** If a user who want to fast-forward specifies the position of fast-forwarding within multicast session which the user joins, ”fast-forward algorithm 1” is used. On the other hand, if the user specifies the fast-forwarding position across the range of multicast which the user joins, the position may be within the multicast that was started before or in the non-acquisition data range by all the other multicast. If the position is in the non-acquisition data range, the delivery server generates dynamic multicast to deliver from the specified position and switches a session. By the multicast session started before, new participation in multicast does not occur, and unicast sessions between users are finished. If there are the users who have already finished unicast session, the data between the positions that participated in multicast session and the position specified by fast-forwarding is acquired using unicast session from the user who participated in multicast the earliest among those users. If all users continue unicast session, dynamic multicast channel is constructed and the data between the position specified by fast-forwarding and the position where the user who finishes unicast session the earliest finishes the unicast session is delivered. The user leaves the multicast session that the user itself participates in and participates in the multicast session that delivery was started just before that. If the user stopped unicast, the data from the end point of the dynamic multicast to the position that participated in multicast is acquired by unicast. The above-mentioned structure is called ”fast-forward algorithm 2”.

**The case of participating in multicast session after the third** If there is the position specified by fast-forwarding in multicast session started more than two session before, all users participating in the multicast more than two session before finish unicast session of the normal delivery, and each user buffers all the data delivered by the multicast session that each user participates in. Therefore the user who want to fast-forward leaves participating multicast session and identifies the multicast whose position of delivering is the nearest to the position specified by fast-forwarding among the multicast session. And the user searches the user who have unicast session in the multicast session. If there is the user who does not have unicast session, the data is received by unicast from the user who participated in multicast first among the users who do not have unicast channel. If all users continue unicast session, former multicast session are searched. And the user participates in the multicast session that there is the user who does not have unicast channel and receives these data by unicast communication. If there is no multicast session, dynamic multicast channel is constructed between the user who finish the unicast session the earliest among the multicast session whose position of delivering is the nearest to the position specified by fast-forwarding and the data is delivered using this multicast channel. If the user stopped unicast, the data from the end point of the dynamic multicast sesssion to the position that participated in multicast is acquired by unicast. The above-mentioned structure is called ”fast-forward algorithm 3”.

## 4 PERFORMANCE EVALUATION

To show an effect of the proposed method, we implemented each methods of unicast, multicast and Fusion-stream on network simulator ns-2, and evaluated the load of the network and the load of the delivery servers in each method. We measured traffic by adding up packets to flow through the whole network topology every 1 second. And we evaluated the load of the network by this network traffic. We measured amount of transmission data by calculating the sum of packet size that the delivery servers transmitted during simulation time. Each simulation was carried out three times, and we caluculated the mean of them. Table1 shows simulation parameters.

### 4.1 Evaluation about the number of partitions

To show the effective number of partitions in traffic and amount of transmission, the number of partitions are changed in simulation. The number of partitions used 12 of 1, 2, 3, 4, 5, 6, 8, 10, 12, 15, 20, 25. The evaluation items are average traffic, maximum traffic and the amount of transmission data in each simulation time and each number of nodes. Table2 shows simulation results of each number of partitions.

Table2 shows that the average traffic increasing though amount of transmission that is the load of the delivery server increases

Table 1: Simulation parameter

| | |
|---|---|
| Simulation time | $600s$ |
| # of the participation nodes | 4 0 |
| # of the relay nodes | 16 |
| Packet size | $1000byte$ |
| Transmission rate | CBR, $Mbps$ |
| Transmission band of the participation nodes | $100Mbps$ |
| Transmission band of the relay nodes | 1 $bps$ |
| Delay between nodes | $5ms$ $100ms$ |

Table 2: Change of the traffic by the number of partitions

| # of partitions | Ave.[MB/sec] | Max.[MB/sec] | Amount |
|---|---|---|---|
| 1 | 1206.6 | 2373.5 | 572.1 |
| 2 | 1039.1 | 1605.4 | 857.1 |
| 3 | 894.8 | 1410.3 | 1140.7 |
| 4 | 833.7 | 1292.5 | 1425.1 |
| 5 | 788.6 | 1321.2 | 1710.4 |
| 6 | 771.5 | 1302.2 | 1994.0 |
| 8 | 757.9 | 1267.6 | 2565.2 |
| 10 | 745.1 | 1372.6 | 3135.3 |
| 12 | 738.9 | 1393.2 | 3703.6 |
| 15 | 747.3 | 1384.2 | 4558.2 |
| 20 | 750.0 | 1464.1 | 5982.3 |
| 25 | 789.6 | 1506.3 | 7406.8 |

when the number of partitions is more than 15. If the number of partitions is set to 12, the amount of network traffic is minimized, and network is effective in total. However, the performance of the delivery server may be short with the number of partitions 12, because 6.5 times as much as the amount of transmission in comparison with the number of partition 1. In that case, the number of partitions lowered like 10 or 8 as needed.

## 4.2 Evaluation about traffic and amount of transmission

For the evaluation about traffic and the amount of transmission, the number of partitions of the proposed method is decided with 12 that was effective number of partitions. The evaluation items are average traffic, maximum traffic and the amount of transmission data in each simulation time and each number of nodes. Table3 shows the simulation result of each method. And Fig.5 shows the change of the traffic in the elapsed time of the simulation.

From the result of table2, the proposed method reduces 40.9% of average traffic in comparison with unicast and reduces 38.8% of average traffic in comparison with Fusion-Stream. And from Fig.5, the proposed method, Fusion-Stream and unicast are seen to change in the same way until 50 seconds. However, the degree of leaning becomes small after 50 seconds, because the number of partitions is set to 12 by

Table 3: Result of the traffic and the amount of transmission data

| | Ave.[MB/sec] | Max.[MB/sec] | Amount |
|---|---|---|---|
| Proposed method | 738.9 | 1393.2 | 3703.6 |
| Fusion-Stream | 1206.6 | 2373.5 | 572.1 |
| Unicast | 1250.5 | 2454.6 | 136550.4 |

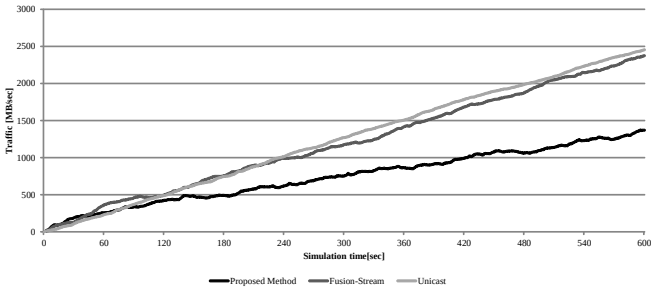



Figure 5: Change of the traffic

proposed method and the second multicast is started at 50 seconds, and the unicast that occurred by 50 seconds is finished. On the other hand, traffic increases in proportion to increase of the number of the participation nodes by the unicast. The change of Fusion-stream becomes similar to unicast, because time for unicast becomes long so that participation in delivery is the latter half. The proposed method reduces 43.2% of maximum traffic in comparison with unicast and reduces 41.3% of maximum traffic in comparison with Fusion-Stream. This result shouw that the proposed method could reduce greatly the peak load of network. In addition, the load of the delivery server is greatly reduced, because the proposed method reduces 97.7% of transmission in comparison with unicast. However, as for the amount of transmission increase 6.5 times in comparison with Fusion-Stream. This is unavoidable in a property of proposed method delivering using multiple multicast.

# 5 CONCLUSION

We proposed a distribution method to reduce network load by limiting the communication of STB by three based on NBB-VoD system in VoD service over NGN. We made Trick Play possible in this method using the algorithm in consideration of the situation assumed especially about fast-forward. We implemented the proposed method on network simulator, and evaluated performance with the existing methods about the number of multicasting division, the amount of traffic and the amount of transmission. The evaluation shows that our proposed method can reduce the load to network bandwidth or distribution server greatly compared with the existing method.

For future work, we plan to implement Trick-Play algorithm on network simulator, and evaluate in more realistic environment. We also make improvements of the algorithm

considering the delay time from making the request of the trick play until switching sessions and receiving the content data.

## REFERENCES

[1] B.Krishnamurthy, C.Wills, and Y.Zhang, On the Use and Performance of Content Distribution Networks, Proc. of ACM SIGCOMM Internet Measurement Workshop 2001, pp. 169–182 (2001).
[2] V.Janardhan, and H.Schulzrinne, Peer assisted VoD for set-top box based IP network, Proc. of ACM Peer-to-Peer Streaming and IP-TV Workshop 2007, pp. 335–339 (2007).
[3] T.Taleb, N.Kato, and Y.Nemoto, Neighbors-Buffering-Based Video-on-Demand Architecture, Signal Processing: Image Communication, Vol.18, Issue 7, pp. 515–526 (2003).
[4] J.Rosenberg, H.Schulzrinne, G.Camarillo, A.Johnston, J.Peterson, R.Sparks, M.Handley and E.Schooler, SIP: Session Initiation Protocol, RFC3261 (2002).
[5] M.Handley, V.Jacobson, and C.Perkins, SDP: Session Description Protocol, RFC4566 (2006).

# Metadata Generation for Digital Photograph by using Smartphone's Sensors

Yoh Shiraishi*, Yuki Kato*, Yoshitaka Nakamura* and Osamu Takahashi*

* School of Systems Information Science, Future University Hakodate, Japan
{siraisi, y-nakamr, osamu}@fun.ac.jp

***Abstract*** - Recently, taking photographs by using camera function of a smartphone for many purpose as well as a digital camera only for photo shooting becomes common. Metadata of digital photographs are add to the photographs at the shooting behavior. There are various kinds of services using these metadata. The existing photographs shot by a digital camera and smartphone's camera function include many metadata based on the Exif format. By using smartphone's sensors, it is possible to generate new kind of metadata for a photograph. For the purpose of sightseeing, persons such as photographers and travelers browse and share many photographs and the metadata.

This paper proposes a method for generating photograph's metadata by using multiple sensors equipped with a smartphone such as an acceleration sensor, direction sensor and camera function. In this study, we focus on sightseeing applications, and consider metadata available for the purpose. Our method uses an acceleration sensor, a direction and a face recognition function for generating metadata: a photographer's action, direction and number of persons in a photograph respectively. We implemented the prototype system on a smartphone and conducted the preliminary experiments.

***Keywords***: metadata, digital photograph, smartphone, sensor and action estimation.

## 1 INTRODUCTION

Many people use photographs to leave with memories. Recently, we often take photographs by smartphones as well as digital cameras. A smartphone has not only a camera function but also various functions. Meta data such as shooting data, shooting model, resolution and location are recorded in a digital photograph data by exchangeable image file format (Exif). There are many social networking services (SNSs) and applications that use the Exif metadata.

A smartphone has an acceleration sensor and a direction sensor. These sensors is not built-in the existing digital camera. There is a possibility that we can generate new kinds of metadata by using these smartphone's sensor.

Meta data are not data itself but are the related information with the data. When we take a photograph by digital camera, metadata such as shooting date, time and models are annotated to the digital photograph with Exif format. There are famous social networking services such as Facebook [1] and 4travel [2]. The Facebook supports uploading and sharing photographs and movies among people all over the world. The uploaded contents are arranged and classified by using metadata such as location information (geo-tagged contents) and keywords annotated manually by users. The 4travel is a service for supporting travels. Travelers are users of the service and can post photographs, the location information and the related comments. The users can evaluate and share the contents in the portal site for supporting travel. In this way, many social networking services (especially, ones of travel supporting) have many photographs and use the related metadata for sharing and communication of the uploaded contents. Generating new kinds of metadata promotes the popularization and expansion of the services, and develops new kinds of services with digital photographs.

This paper organizes as follows. In section 2, we refer to the related works and point out some problems. In section 3, we mention to our approach for the problems, and describe a new method for generating metadata for digital photographs by using smartphone's sensors. In section 4, we show the results of the preliminary experiments. Finally, we conclude in section 5.

## 2 RELATED WORK

Digital cameras support many kinds of Exif formats, but smartphones don't support some of camera parameters such as shutter speed, aperture of the lens, ISO sensitivity, focal length and color space. A digital camera for only shooting is superior to a smartphone for multiple functions (including shooting) in order to grasp the camera state.

On the contrary, equipping new kinds of sensors with a camera provides the potential for using these sensor data as metadata of the digital photographs. Watanabe at al. use some sensors that are not equipped in the existing digital cameras and acquire new kinds of metadata that are not included in the Exif format [3]. These metadata are provided for the browsing users to support understanding of the content of the photograph such as where the photograph was taken. However, this related work does not discuss concrete application examples that use such metadata.

There are many situations for sightseeing and traveling that use metadata acquired at shooting. Location information (namely, latitude and longitude) are often used for such applications. Kurata et al. developed the prototype system to support action planning of travelers [4]. The system can plot the POI (point of interested) uploaded from many travelers and visualize a distribution map of points with frequent shooting.

There are other studies that use location information as photograph's metadata [5]. These studies pay attention to the shooting points, classifies the points to some categories for visualization and extracts high spots for sightseeing.

There are lots of studies for action estimation by using an acceleration sensor and a smartphone in the field of ubiquitous and mobile computing. By using an acceleration sensor, we can estimate various kinds of actions: walking,

running, stopping, standing and so on. A smartphone has not only an acceleration sensor but also other sensors including a direction sensor, GPS, microphone and camera. A smartphone with these sensors has a great potential to estimate various kinds of user actions.

We can acquire time series data from an acceleration sensor of smartphone's sensor, and estimate the user state by using such sensor value. A microphone and camera can be used for grasping visually the state. Acquiring new kinds of metadata from smartphone's sensors when a photographer takes a photograph may cause the state and condition of the photographer.

Metadata about digital photographs are often used to support sightseeing. However, the existing works cannot estimate what is the aim of the tour (what is the aim of shooting) by using photograph's metadata. Realizing of estimating the shooting aim by using photograph's metadata is a challenge for effective sightseeing support.

Therefore, we propose a method for generating new kinds of metadata of digital photographs by using smartphone sensors in order to estimate what is the aim of a photographer at shooting. We target sightseeing as a concrete application of the proposed method.

# 3 PROPOSED METHOD

## 3.1 Approach

Digital camera is superior to a smartphone in grasping the camera state at shooting. However, we can use various kinds of sensor data from multiple sensors of a smartphone. For example, we can acquire time series of sensor data from smartphone's sensor such as an acceleration and direction sensor, and extract maximum and minimum values of such sensor data. It is a possibility to estimate typical actions of a photographer by using these smartphone sensors because these sensors are often used for action estimation in the existing works.

Table 1: Metadata of digital camera and smartphone

| Meta data | Digital camera | Smartphone |
|---|---|---|
| Shooting date / time | supported | supported |
| Shooting point | supported | supported |
| Focal length | supported | not supported |
| Diaphragm | supported | not supported |
| Max/min of acceleration sensor | not available | available |
| Shooting direction | not available | available |
| Time series of acceleration data | not available | available |
| Time series of direction sensor data | not available | available |
| Number of times of continuous shooting | not available | available |
| Time to shoot | not available | available |
| Face recognition | available | available |

Our research aims at generating new kinds of metadata of photographs to support sightseeing. In this study, we consider photograph's metadata for grasping the following situations:

(a). The target of a photographer at shooting
(b). Feeling of a photographer at shooting
(c). Location of a photographer at shooting

In order to grasp the target at shooting, we classify photographs into some categories. Each category represents the type of the photograph. The type of a photograph is metadata to estimate what kinds of the photograph and the shooting situation. If we can arrange photographs by using the type of the photograph (namely, sightseeing), a user (not the photographer) to browse these photographs grasp the aim of sightseeing of the photographer based on the type of the photograph.

A survey report by Net Mile suggests that "who goes together", "what to do in the tour", "what cost of travel" and "what a traveler wants in the tour" are important when sightseeing. We pay attention to "who goes together" and "what to do" in the tour. In order to estimate such situations, we assume four categories ("person", "group", "landscape" and "dish") as the photograph types.

"Person" indicates a travel alone or in two some. "Group" indicates a travel that more than three persons go on such as family, school and company trip. "Landscape" indicates a travel that a traveler goes around sightseeing spots and takes photographs many times. "Food" indicates a travel for visiting famous restaurants and gourmet tour. We classify a photograph shoot by a smartphone into each of these four categories. In realistic situation, these photographs cannot be classified in such simple way. As the first step of our research, we try to make rough classification by using multiple sensors of a smartphone.

We consider two kinds of metadata ("the number of times of continuous shooting" and "time to shoot from starting the camera application") to express feeling (for example, "fan", "surprise") of a traveler at shooting.

The number of times of continuous shooting is how many times a traveler take photographs continuously with running the camera application. When a traveler finds a famous sight and spot, he or she will take photographs of the sight and spot not once or twice. The proposed system starts to count the number of times of continuous shooting after activated, and resets the number to zero when it is stopped. The time to shoot is the time from activating the camera function to shooting. When a traveler is surprised at the sight, he or she will start shooting once activating the camera function. These metadata may inform the feeling of the photographer to other travelers on a web site for traveling. Currently, a user for such site posts his or her comments and evaluation points for recommendation manually. Generating such metadata automatically will reduce the posting cost after traveling.

By recording location information of a photographer at shooting, it can display these points on a map. It can show the type of photographs, the number of times of continuous shooting and the time to shoot related to the shooting point.

These metadata will be useful for realizing a service with good quality. If we can know type of a photograph at the shooting point, we will estimate the target of the shooting and selects the photographs with the specific target. If we can know the number of times of shooting and the time to shoot, we will estimate the feeling of the photographer and use these metadata as materials for travel planning.

### 3.2 Acquisition of sensor data

In the proposed system, metadata are generated at different phases as follows:

- Phase 1: time from invoking the application to first shooting
- Phase 2: time at each shooting
- Phase 3: time after shooting (off-line processing)

In phase 1, the system acquires 3-axis acceleration data by using the built-in acceleration sensor, direction data such as azimuth, roll and pitch by using the direction sensor and time to shoot. In phase 2, it acquires roll value of direction sensor data at each shooting, the number of times to push the shooting button and whether the macro mode is on or not. We use the macro function to shoot nearby object such as dishes and flowers. In phase 3, it detects whether persons are in the photograph, and not and counts the number of the persons in the photograph by using face recognition as an image processing technique.

### 3.3 Generation of metadata by using sensor data

We use actions of a photographer, camera direction at shooting and the number of faces in a photograph to generate the type of the photograph. We use the time to shoot and the number of times of continuous shooting to generate metadata related with the feeling of the photographer.

Our system classifies the shooting photograph into the following group: “person”, “group”, “landscape”, “dish”. In this paper, we define “person” as one person or two or three person, and define “group” as more than four persons.

Our system executes the following steps for classifying photographs:

- Step [1]
  It examines whether persons (faces) are in the photograph by using face recognition. If it detects persons, go to the step [2]. Otherwise, go to the step [3].
- Step [2]
  It counts the number of the faces in the photograph. If the number is one or two, it classifies the photograph into “person”. Otherwise (namely, more than three faces), it classifies the photograph to “group”.
- Step [3]
  It examines the camera direction. If the direction is downward, go to the step [4]. Otherwise, it classifies the photograph into “landscape”.
- Step [4]
  It checks the macro mode. If the mode is on, go to the step [5]. Otherwise, it classifies the photograph into “landscape”.
- Step [5]
  It estimates the photographer’s action by using the acceleration and direction sensor of the smartphone. If the estimated action is included in action patterns that a user does not take at shooting dishes (for example, squatting down, looking over from side to side, rising the camera), it classifies the photograph into “landscape”. Otherwise, it classifies the photograph into “dish”.

We use the acceleration sensor for estimating “squatting down” and “rising the camera” and the direction sensor for estimating “looking over from side to side”. In the latter case, we examine the difference of directions between at starting the application and at shooting.

## 4 EXPERIMENTS

### 4.1 Implementation of the prototype system of the proposed method

We implemented the proposed method as the prototype system on a smartphone (Xperia acro, Android 2.3.4). Fig.1 shows the interface of the prototype system.


Figure 1: The interface of the prototype system

### 4.2 Experimental results

First, we examined typical actions at shooting. We gave an examinee the instruction to do the following actions: (1) move the smartphone forward, (2) move it backward (return to initial position), (3) move it to left, (4) move it to right (return to initial position), (5) move it backward, (6) move it forward (return to initial position), (7) move it to right and (8) move it to left (return to initial position). Fig.2 shows time series data of 3-axis acceleration sensor when the examinee acting along the instruction.

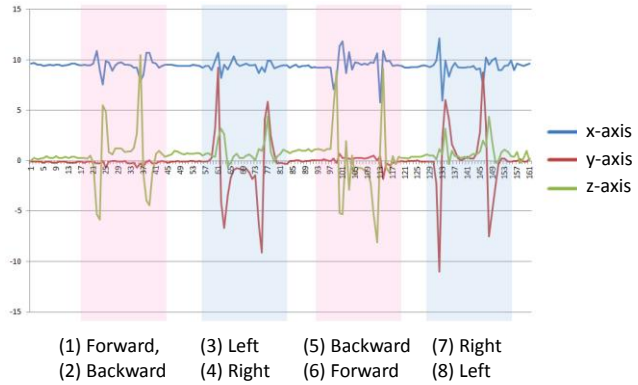



Figure 2: The change of 3-axis acceleration sensor

Fig.2 suggests that y-axis data are highly changed when an examinee move the smartphone from side to side (left to right or right to left), and z-axis data are highly changed when moving it forward and backward. These actions have typical pattern of change of time series data. If we extract such pattern, we can estimate the actions: move from side to side, and move forward or backward.

Figure 3 shows time series data of a direction sensor on a smartphone. An examinee makes the following action: (1) turn the smartphone upper, (2) turn it to left, (3) turn it down and (4) turn it to right. After doing each action, he returns it to initial direction.

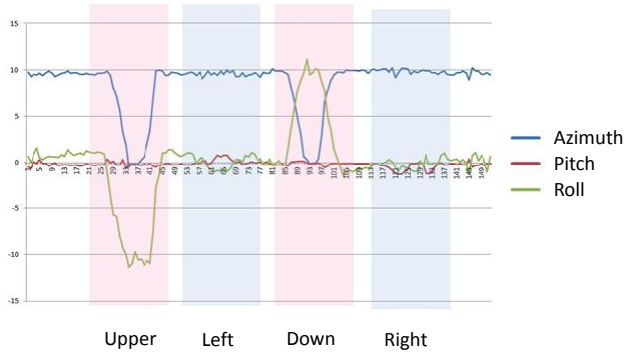



Figure 3: Time series data of a direction sensor

In this study, we use y-axis and z-axis acceleration sensor data for estimating actions that a user does not make when shooting a dish, and use roll value of a direction sensor for estimating the camera direction at shooting.

## 5 CONCLUSION

In this paper, we proposed a method for generating photograph's metadata by using sensors equipped with a smartphone such as an acceleration sensor and camera function. In this study, we focus on sightseeing, and consider metadata available for the purpose. This method generates some kinds of metadata such as photographer's behavior, direction and number of persons in a photograph for classifying photographs shot by a smartphone. Our method uses an acceleration sensor, a direction sensor and a face recognition function for generating metadata: a photographer's action, direction and number of persons in a photograph respectively. We implemented a prototype system of the proposed method on a smartphone and conducted the preliminary experiments.

## REFERENCES

[1] Facebook, http://www.facebook.com/facebook.
[2] 4travel, 4travel, Inc., http://4travel.jp (*in Japanese*).
[3] K. Watanabe and K. Tsukada, "WillCam: a digital camera visualizing users' interest," Information Processing Society of Japan, Interaction 2008, pp.193-194, 2008 (*in Japanese*).
[4] Y. Kurata, K. Sugimoto and N. Yabe, "Onsite Tourist Guide without Detail Information: Extraction and Application of Point-of-Interest Data," Annual Conference on GIS Association of Japan, 2010 (*in Japanese*).
[5] K. Miwa, K. Oku and F. Hattori, "Extraction of a Viewable Point from the Photograph Data with Location Information for Route Recommendation," The 2nd Forum on Data Engineering and Information Management (DEIM), I-9, 2010 (*in Japanese*).

# Panel Discussion

# Green Computing Based on ICT "Current Status and Its Perspective"

Teruhisa Ichikawa*
* Faculty of Informatics, Shizuoka University, Japan

## Contents



2

## 1. Introduction

- Definition of Green Computing
  - U.S. Environmental Protection Agency defines as "the comprehensive view for reducing the load to the environment during introducing, using and disposing of IT equipment.
  - It is also called Green IT and Green ICT.
- Green Computing in the wide sense
  - Green by IT (The measure against an environmental impact of the society by IT)
  - Comparative evaluation of the influence of plus which use of IT has to global environment, and the influence of minus is carried out, the usage is devised or suitable decision-making to IT introduction and implementation is performed.
- Green Computing in the narrow sense
  - Green of IT (The measure against an environmental impact of IT apparatus itself)
  - The measure which reduces environmental impacts in the product life cycle (from a design and manufacture of IT apparatus to introduction, use, abandonment, and reuse).

3

## 2. Origin of Green Computing

- It is around 1990 that global warming became a problem and the environmental program started.
  - In 1992, the U.S. Environmental Protection Agency launched the logo mark of Energy Star, and has allowed the notation the apparatus which fulfilled the environmental standard.
- After the Kyoto Protocol went into effect in 2005, IT industry also set about the measure.
  - In March, 2006, the Japanese eco-efficiency forum released "the eco-efficiency evaluation guideline of ICT".
  - In March, 2007, the Ministry of Internal Affairs and Communications released the investigation report "Environment-Friendly ICT use".
  - In December, 2007, the Minister of Economy, Trade and Industry-sponsored "Green IT initiative meeting" was held, and establishment of "Green IT Promotion Council" was expressed. In February, 2008, Green IT Promotion Council was founded. "The collection of best practice" 2010 editions and 2011 editions were distributed.
  - In April, 2011, Waseda University founded the "green computing system research organization" supported by the Ministry of Economy, Trade and Industry. Research and development of the green ICT technology which made the highly efficient many core processor the core with super-low power consumption are promoted.

4

## 3. Classification of Green Computing

**of IT** (energy saving of IT equipment)

Improving energy efficiency of IT equipment and electronics

| Category | Examples |
|---|---|
| IT equipment | PC, Server, Storage |
| Electronics | TV, DVD, Refrigerator |
| Datacenter | Datacenter |
| Parts | Semiconductor |

**by IT** (society's energy saving by IT)

Improving energy efficiency of the society by utilizing IT solutions

| Sectors | Examples |
|---|---|
| Industry | Improving efficiency of a production process |
| Business | Telework, TV/web meeting |
| Household | On-line shopping |
| Transportation | Eco-drive |

Source: Green IT the best practices collection 2011

5

## Projection of the quantity of $CO_2$ emission reduction in 2020

Unit: million t-$CO_2$ / year

| Categories | of IT | by IT |
|---|---|---|
| Industry | — | 7 ～ 14 |
| Household | 4.4 ～ 8.9 | 16 ～ 32 ※ |
| Business | 17.0 ～ 33.9 ※ | 9 ～ 18 ※ |
| Transportation | — | 36 ～ 73 |
| Total | 21.4 ～ 42.8 | 68 ～ 137 |

※ Including the energy saving effect of IT facility.

Source: Green IT the best practices collection 2011

6

## 4. The formula of the amount of cuts in energy consumption by ICT

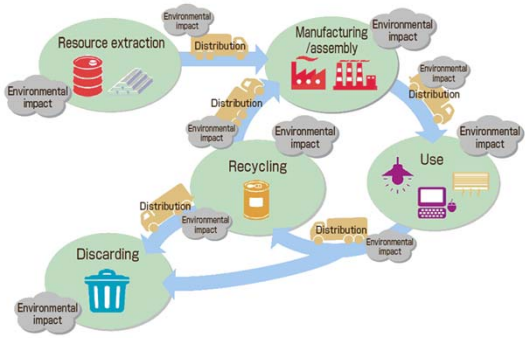
①The amount of cuts in energy consumption = ②The amount of cut effects in energy consumption by ICT use − ③Energy consumed by ICT use

②The amount of cut effects in energy consumption by ICT use = The amount of consumption of the goods and service given to environment × Energy consumption unit when one unit of goods and service are consumed

③Energy consumed by ICT use = The amount of apparatus and the network used × An energy consumption unit when one unit of apparatus and networks are used

7

## Environmental impacts of a product in all its life cycles




出典：Eco-Leaf overview:JEMAI

8

## 5. Potential positive environmental impacts from the effective use of ICT systems

1. Improved energy efficiency
   - Improved efficiency of resource and energy use during production and distribution processes reduces resource and energy consumption, CO2 emissions, and waste production.
2. Reduced consumption of resources by streamlining production and distribution of goods
   - Streamlined business operations reduces the amount of resources, including paper, and energy used by offices, such as for lighting and air-conditioning.
   - Effective use of storage space also reduces the amount of resources and energy required for lighting and air-conditioning.
3. Reduced transportation requirements
   - Streamlined and reduced movement of people and goods reduces the resources and energy consumption required for transportation.

Source：Environment-Friendly ICT use (Mnistry of Internal Affairs and Communications, Japan)

9

## Key points of environmentally friendly ICT use

1. Use ICT systems in a way which reduces the negative environmental impacts and enhances the positive ones.
2. Use your purchasing power to raise the environmental awareness of companies that may have a direct impact on the environment during the manufacturing, disposal or recycling of ICT systems.

Source：Environment-Friendly ICT use (Mnistry of Internal Affairs and Communications, Japan)

10

## Hints for curbing negative impacts and enhancing positive impacts

- Telework (Movement of people, Effective use of office space, Streamlined operations)
- Free address office (Effective use of office space)
- Paperless process management (Consumption of goods, Movement of goods, Storage of goods Streamlined operations)
- Network software delivery (Consumption of goods, Movement of goods)
- Integration of multiple functions (Electricity consumption, Effective use of office space, Waste production)
- Thin client systems (Electricity consumption, Effective use of office space, Waste production)
- Server integration (Electricity consumption, Effective use of office space, Streamlined operations)
- Data center (Electricity consumption, Effective use of office space, Streamlined operations)
- Optical connection service (Electricity consumption, Streamlined operations)

Source：Environment-Friendly ICT use (Mnistry of Internal Affairs and Communications, Japan)

11

## Guidelines for choosing eco-friendly ICT devices

| ICT device | Labels and other guidelines for choosing ICT devices | | | | |
|---|---|---|---|---|---|
| | Energy conservation | | Harmful substances | reduce, reuse, recycle | Comprehensive assessment |
| | Energy Conservation Label | Energy Star | J-Moss Content Mark | PC Green Label | Eco Mark |
| Personal computer |  |  |  |  |  |
| Monitor | | ○ | ● | ○ | ○ |
| Printer | | ○ | | | ○ |
| Server | ○ | | | | |
| storage device | ○ | | | | |
| Network device | △ | | | | |

●Statutory ○Voluntary registration △Considering

Source：Environment-Friendly ICT use (Mnistry of Internal Affairs and Communications, Japan)

12

## The Echo label in the world


13

## Hints for using ICT systems in an eco-friendly way

- **Keeping track of electricity consumption of ICT systems**
- **Devices to reduce standby power consumption**
- **Paperless process management**
- **Reducing power consumption of ICT devices**

## Guidelines for eco-friendly disposal or recycling of ICT devices

- **Reuse of ICT devices**
- **Personal computer collection or recycling**

Source: Environment-Friendly ICT use (Mnistry of Internal Affairs and Communications, Japan)

14

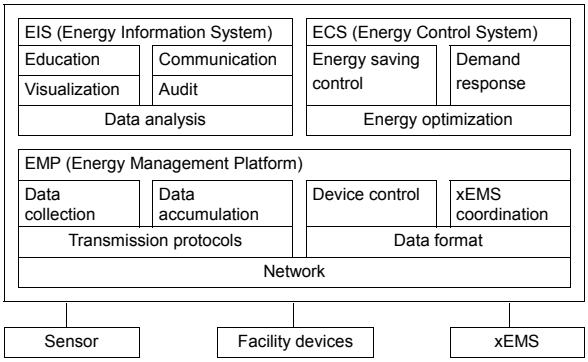
## 6. Method of computing energy consumption reducing effect by IT solution

| Components | Subject of component | Formula of components |
|---|---|---|
| ① Consumption of goods | Paper, CD, Books, etc. | (Reduced consumption of goods) × (Basic unit of goods consumption) |
| ② Travel of people | Airplane, Automobile, Train, etc. | (Reduced travel of people) × (Basic unit of travel) |
| ③ Travel of goods | Track, Railroads, Cargos | (Reduced travel distance of goods) × (Basic unit of travel) |
| ④ Office space | Space occupied by men (including working efficiency), space occupied by IT equip.,etc. | (Reduced space) × (Basic unit of energy consumption per space) |
| ⑤ Warehouse space | Warehouse, Cold storage, etc. | (Reduced space) × (Basic unit of energy consumption per space) |
| ⑥ Power / energy consumption (ICT) | Energy consumption of server, PC, etc. | (Power consumption variation) × (Basic unit of system power) |
| ⑦ NW data communication | NW data communication | (Data communication variation) × (Basic unit of communication) |
| ⑧ Others | Activities other than the above | (Variation by activity) × (Basic unit concerning variation) |

Source: Green IT the best practices collection 2011

15

## Enterprise Energy Management System (EEMS)




Source: Green IT the best practices collection 2011

16

## Datacenter Performance Per Energy (DPPE)

DPPE = ITEU × ITEE × 1 / PUE × 1 / (1-GEC)

| DPPE Sub-metrics | Formula | Responding activities |
|---|---|---|
| ITEU（IT Equipment Utilization） | = Operational Utilization of IT Equipment of datacenter | Effective operation of IT equipment |
| ITEE（ IT Equipment Energy Efficiency） | = total rated capacity of IT equipment ÷total rated energy consumption of IT equipment | Introduction of energy-saving IT equipment |
| PUE（ Power Usage Effectiveness） | = Total energy consumption of datacenter ÷Total energy consumption of IT equipment | Energy saving of facility |
| GEC（ Green Energy Coefficient） | =Green (natural energy) power ÷total energy consumption of datacenter | Use of green power |

Source: Green IT the best practices collection 2011

17

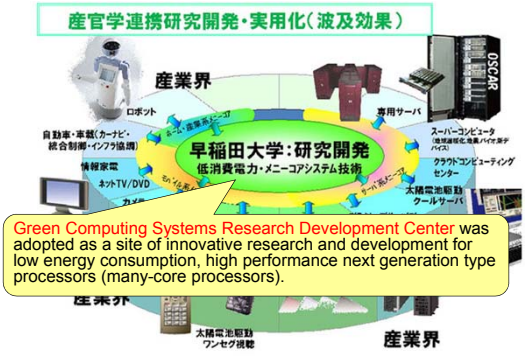
## 7. Education and certification

- Green computing program
  - Degree and postgraduate programs that provide training in a range of information technology concentrations along with sustainable strategies in an effort to educate students how to build and maintain systems while reducing its negative impact on the environment.
  - In the Australia, Australian National University offers “ICT Sustainability” as part of its information technology and engineering masters programs. Athabasca University offer a similar course “Green ICT Strategies”.
  - In the UK, Leeds Metropolitan University offers an MSc Green Computing program.
- Green computing certifications
  - Some certifications demonstrate that an individual has specific green computing knowledge.
  - CGCUS (Certified Green Computing User Specialist)
  - CGCA (Certified Green Computing Architect)
  - CGCP (Certified Green Computing Professional)

Source: Green Computing Initiative

18

## Waseda University
### Green Computing Systems Research Organization




Green Computing Systems Research Development Center was adopted as a site of innovative research and development for low energy consumption, high performance next generation type processors (many-core processors).

Source: Homepage of Waseda University

## Nagoya Institute of Technology
### Center for GREEN COMPUTING

**環境社会最適化シミュレーションを可能にする**
**社会最適化アルゴリズム創出とその応用**
［ マルチエージェント技術による社会の最適化 ］

Green IT and Sustainable Society researchers is needed with intelligent technology. Intelligent agent technology solve new types of issues and also contribute a design on optimal society.

マッチングメカニズム

**社会メカニズムの最適化による環境にやさしい社会の再構築**

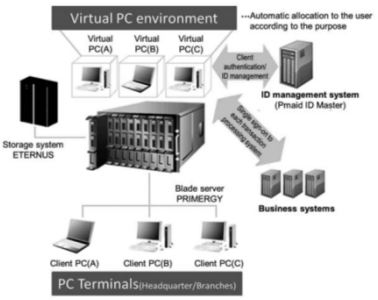
出典：http://www.itolab.nitech.ac.jp/next/



## 8. Green Computing Best Practices —Hokuriku Bank Ltd.

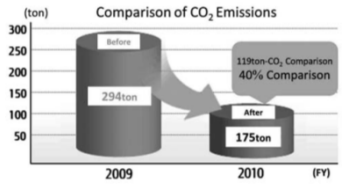
Creating an Environmentally Friendly System to Reduce $CO_2$ by about 40% Through Client Virtualization

Point1:Achieving efficient system operation and maintenance by center integration
Point2:Flexible system which ensures highly safe security based on the virtual PC method
Point3:Contributing to environmental operation




Source: Green IT the best practices collection 2011






Comparison of $CO_2$ Emissions Before and After Introduction

| Category | Before | After | Effect |
|---|---|---|---|
| Work Space | 23.9 | 1.0 | -23.0 |
| Space of ICT equipment | 160.6 | 87.0 | -73.6 |
| Electrical Power of IT-NW equipment | 107.1 | 87.0 | -20.1 |

Source: Green IT the best practices collection 2011



## High energy efficiency mobile PC

- R Series PC of Toshiba has high energy efficiency (40-50% better than ENERGY STAR criteria).
- It has many unique features: "Peak Shift" to help mains power, "Quick Start" to encourage the use of low power mode, "eco Utility" to help low power setting.

- Energy-Saving Effect
  1. Energy saving: More than 50 % energy saving for R731, and more than 40 % energy saving for R741/R751 compared with latest energy criteria of ENERGY STAR V5.2 (TEC value)
  2. Off power: More than 50 % power saving compared with EU ErP Off /Standby power criteria (1.0W)
  3. Power reduction during peak demand time: Power can be less than 1W using a peak shift function.

Source: Green IT the best practices collection 2011



## Outpatient guide dissolution

- We have used electronic paper that can maintain its display without electric power and our unique star-shaped radio network technology to create the world's first electronic card holder, NAVIT.
- This solution gives detailed information to individual out-patients at check-in, calls them when the doctor can see them, and gives payment information.

- Energy-Saving Effect

Average model hospital (average number of outpatients: 180/day, annual hours of examinations: 2,300hours)

1. Conventional system: 35 display devices (LCD), 3 return reception machines, 1 server: annual electric power consumption of 12,397kWh
   1. Newly proposed system: 180 NAVIT units, 17 NAVI Ports, 2 servers: annual electric power consumption of 1,665kWh (down 10,700kWh, or 87%)

Source: Green IT the best practices collection 2011