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Study of an Implementation Method of Point-to-Multipoint Communication for IoT Data Exchange to Reduce Traffic on an IoT Network

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Abstract - Due to the growing interest in the Internet of Things (IoT) in recent years, platforms for efficiently exchanging IoT data generated by IoT devices such as sensors and actuators among IoT users are being discussed in various areas. In this platform, the interworking among nodal points, which IoT devices and IoT users connect to, is essential to support wide-area and large-scale IoT systems. In addition, it is desirable to share IoT data generated by IoT devices among multiple IoT devices and IoT users in case of notification of alarms, command control to multiple devices, and so on. In address to the above requirements, this paper proposes an implementation method of point-to-multipoint communication to efficiently exchange IoT data among users. The proposed method is characterized by the coordination with multicast control at the application level in order to accommodate various quality of services with IoT data while utilizing Data Distribution Service (DDS). By comparison with the method of using only DDS, it is confirmed that the proposed method reduces the traffic volumes among nodal points and that the transmission latency is suppressed even in an environment where there is a path to a specific node with degraded communication characteristics.

Keywords: Internet of Things, Data Distribution Service, point-to-multipoint communication, IoT Data Exchange.

1 INTRODUCTION

In recent years, there has been growing interest in the Internet of Things (IoT) technology, in which all things are connected to a network. With the expansion and development of IoT-based services and businesses, the number of connected IoT devices is increasing year by year, and IoT devices are expected to exceed 29 billion by 2024[1]. For the increasing number of IoT devices such as sensors and actuators connected to IoT systems, there are many efforts towards developing IoT systems and proposals to efficiently exchange IoT data under wide-area and large-scale IoT networks. For example, there are proposals for monitoring urban transportation systems [2] and research on efficient data collection systems from sensors [3].

In addition, platforms for efficiently sharing data generated by IoT devices (IoT data) among users (IoT users) are also discussed in various places to cope with the growing scale of IoT systems and the increasing number of IoT devices. For example, there is research on providing power-saving IoT services by applying mobile edge computing technology to unmanned aerial vehicles equipped with IoT devices [4]. The IoT data exchange platform (IoT DEP) [5] is another research effort to provide an efficient platform and has been standardized in ISO/IEC 30161 series. In the IoT DEP, IoT end devices, that is, IoT devices and IoT users (servers), access the platform using information centric network (ICN) technologies in order to benefit from high-efficiency communication services. And interoperability among gateways, called nodal points, that accommodate the IoT devices and IoT users is discussed toward the provision of services over wide areas.

Furthermore, in contrast to IoT for consumer fields, applications of IoT in industrial fields have been actively discussed in recent years [6]-[9]. That is, IoT in the industrial fields has strict requirements for reliability and low latency for data, and further research is needed beyond the investigations in IoT for the consumer fields. Also, the short-cycle cyclic communication is a key feature of the industrial applications.

This paper is considering a wide-area and large-scale IoT system for efficient exchanging IoT data among IoT devices and IoT users based on the architecture of the IoT DEP (Fig. 1). That is, our targeted IoT system consists of IoT access networks and an IoT core network. Furthermore, it aims to provide data sharing in point-to-multipoint based communication, such as notification of alarms perceived by IoT devices and command control to multiple devices by IoT users.

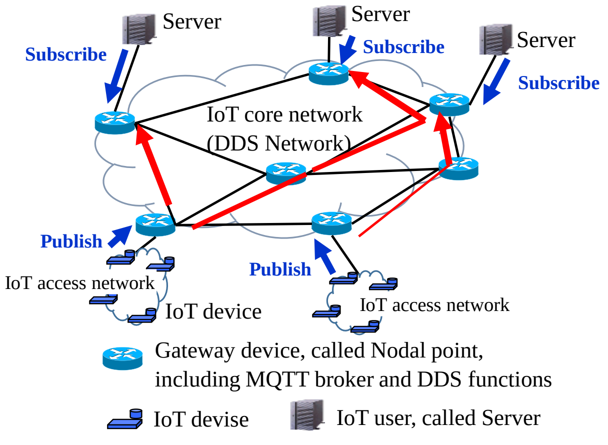


Figure 1: Example of IoT systems.

In the above targeted IoT system, this paper discusses to provide IoT services with various service requirements in terms of point-to-multipoint communications, considering the reliability and low latency data sharing required in the industrial fields. That is, when Data Distribution Service (DDS) is applied to the interconnection among the nodal points on the IoT core network, overheads of control packet by DDS increases, only if the reliable mode provided by DDS is only utilized to achieve interworking among nodal points. On the other hand, interworking based on the best-effort mode provided by DDS is difficult to provide the required service level in the exchange of IoT data with reliability and/or low latency requirements. Therefore, this paper proposes an implementation method which is characterized by the coordination with multicast control at the application level in order to accommodate various quality of services with IoT data while utilizing DDS. It also evaluates the effectiveness of the proposed method.

The remainder of the paper is organized as follows: Section 2 explains the targeted IoT system in the paper. In section 3, related works related to the paper are presented. And, section 4 proposes the implementation method of point-to-multipoint communication at the application level, section 5 describes the results of evaluation. Finally, section 6 concludes the work.

2 TARGETD IOT SYSTEM AND ISSUES

In this section, the IoT system that is the research target of this paper is described and DDS applied in the IoT system is explained. It also describes its challenges.

2.1 Targeted IoT System

Figure 1 shows the targeted IoT system. The targeted IoT system consists of IoT access networks and an IoT core network, called DDS network. The IoT access network is an access network to accommodate IoT devices and IoT users, and is connected to the IoT core network via a gateway device called a nodal point. In the IoT access network, Message Queuing Telemetry Transport (MQTT) [10][11] is deployed as a communication protocol for transmitting/receiving IoT data to/from IoT devices and IoT users. MQTT is a candidate communication protocol for IoT systems. Interworking among multiple MQTT brokers, i.e., nodal points, are coordinated in the IoT core network by DDS [12]. That is, the IoT core network is a network for development of a wide-are IoT system, and multiple MQTT broker, which are implemented on nodal points, are interconnected with each other. The interworking among nodal points is deployed by DDS. DDS is a publish/subscribe communication protocol that supports various communication characteristics and is applied in industrial fields where reliability is required.

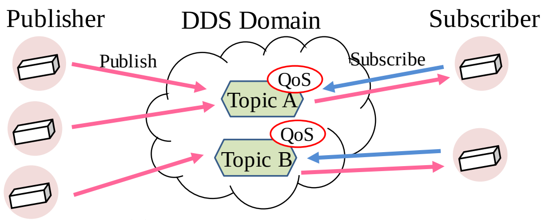
IoT data generated by an IoT device is published to a nodal point, which is an MQTT broker. The published IoT data is shared among multiple MQTT brokers because it is utilized by multiple IoT users. In other words, IoT data is forwarded by multicast manner from the nodal point, which the IoT device connects to, to multiple nodal points. IoT data generated by the IoT device require various QoS requirements, such as best effort, reliable, and low latency.

2.2 Data Distribution Service (DDS)

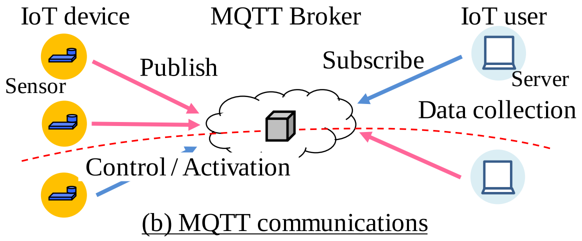
Data Distribution Service (DDS) is data-centric publication and subscription middleware for highly dynamic distributed systems, standardized by OMG (Object Management Group). Data is published to a DDS domain, and subscribers subscribe to share data from that domain without knowing the state of a source node or structure of the information, as shown in (a) of Fig. 2. DDS offers a wide range of Quality of Services (QoS) parameters such as durability, lifetime, presentation, reliability, and delivery time. According to the OMG website, DDS is one of many protocols used in industrial fields such as railway networks, air traffic control, smart energy, medical services, military, and aerospace, and industrial automation.

In a similar way to MQTT, DDS is topic-based publish/subscribe communication, and has in common that the quality control function called QoS can be used to set the guaranteed delivery level and that is implemented by middleware. One difference is that MQTT operates over TCP/IP, while DDS operates over UDP/IP. Another difference in design is that MQTT requires a Broker, whereas DDS does not require a Broker and allows direct communication between Publishers and Subscribers ((b) of Fig. 2). DDS also provides real-time, many-to-many managed connections.

As shown in Fig. 3, the DDS consists of “Real-Time Publish/ Subscribe”, “Minimum Profile” “Durability”, “Ownership”, and Content Subscription”. And the DDS is implemented as an upper layer protocol of UDP/IP, and supports various Quality of Services (QoS) for applications that exchange IoT data through the DDS. A software compliant with the DDS provides application interfaces for transmission and receive of data, such as “DataWriter” and “DataReader” functions. That is, The DataWriter is the application interface and provides a function to transmit data to other nodes. The DataReader is the application interface and provides a function to receive data from other nodes. In the following, the message sequence in providing reliable data exchange is described with reference to Fig. 4. The DataWriter transmits HEARTBEAT packets to support reliable data exchange. That is, The DataWriter transmits a HEARTBEAT to the destination as a packet to confirm the reachability of data with reliable requirements. The DataReader that receives the HEARTBEAT responds with the sequence numbers of the packets it received before receiving the HEARTBEAT. The sender, the DataWriter, confirms that the packet has reached the destination by receiving the response to the HEARTBEAT.



(a) DDS communications



(b) MQTT communications

Figure 2: Comparison of DDS and MQTT communications.

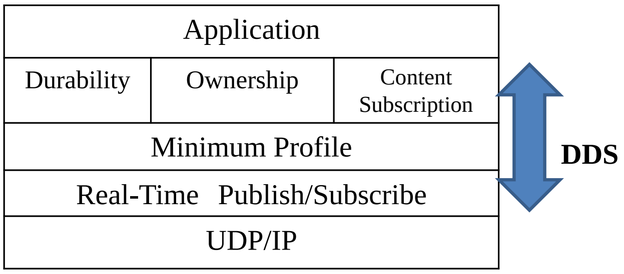


Figure 3: Protocol stack of DDS.

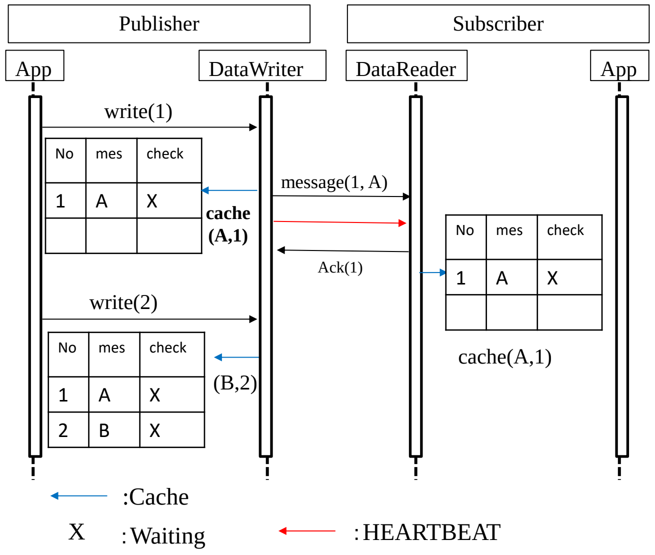


Figure 4: Message sequence of DDS Reliability mode.

2.3 Issues

There are several challenges in developing the targeted IoT systems. In this subsection, several issues related to traffic increase, service level degradation, and information sharing among multiple devices are described. Firstly, the traffic volume forwarded among the nodal points increases as the number of connected IoT devices increases. Secondly, due to the coexistence of IoT data with best-effort requirements on forwarding in the IoT system, there is a degradation of the service level for IoT data with reliable and/or low latency requirements. Lastly, for IoT data that is expected to be shared among multiple IoT devices and IoT users, there is an efficient transfer mechanism to transfer IoT data from a nodal point to other nodal points. Connections between nodal points consist of communication paths with various communication characteristics, and it is necessary to consider the transfer of IoT data to nodal points connected via communication paths with large packet loss and large latency. In other words, in point-to-multipoint communication of IoT data, which requires reliability and low latency, the existing point-to-multipoint communication causes transfer delays due to waiting for arrival confirmation in the worst case, leading to a degradation of the service level. In addition, there is the issue of competition between IoT data requiring low latency and best-effort IoT data at the nodal point.

When DDS is applied in communication among the nodal points, communication services among nodal points depends on DDS functionality. That is, reliability support on DDS is ensured by acknowledgement control from the destination nodes. And, in reliable point-to-multipoint communication on DDS, transmitting of a packet is completed after confirmation of acknowledgements from all destination nodes. Therefore, if there is a nodal point connected via a communication path with large packet loss rate or large latency, point-to-multipoint communication is influenced from the path with large packet loss or large latency. It is necessary to consider a method for ensuring communication methods that does not depend on the DDS functionality and bad communication paths. Based on the above, this paper proposes a multicast control method that considers coordination with DDS by upper-level applications to achieve efficient data communication between DDS functions and IoT data.

3 RELATED WORKS

This section describes the research works related to efforts using MQTT and DDS, and multicast control at the application level.

In [13], several MQTT protocols including the open source “Mosquitto” are evaluated in terms of resource consumption and latency, and the results are shown. In [14], the authors proposed a communication scheme for IoT devices and built a platform for evaluating the system. Evaluations were conducted on a data-by-data basis, showing that the system is efficient in distributing data over a network. In [15], performance evaluation and comparison of communication protocols for IoT such as MQTT and DDS are conducted, and its evaluation shows that MQTT significantly reduces round trip time (RTT) for servers and DDS has high performance in protocol implementation. In [16], data transfer using DDS is implemented, showing that it provides low latency and high throughput, and is an effective communication protocol for communication systems such as those in smart cities.

Regarding the realization of IoT systems using MQTT to deploy large-scale systems, research is being conducted to evaluate the performance and to propose methods of cooperation with multiple brokers. For example, MQTT systems with multiple brokers have been investigated in many studies [17]-[20]. In [17], MQTT with a spanning tree of brokers on the network (MQTT-ST) is proposed for building a distributed network with multiple MQTT brokers. MQTT-ST enables the data collection from a wide area. However, MQTT-ST has issues such as traffic overhead due to the need for periodic information exchange with the broker.

In [18], a scalable and low-cost MQTT broker clustering system is proposed to handle many IoT devices. In this clustering system, MQTT clients and multiple MQTT brokers are connected by a load balancer to distribute network traffic to the MQTT brokers. Therefore, compared to a single broker, the load on each broker is reduced and the throughput of the entire clustering system is increased, thereby reducing the CPU utilization of each broker.

In [19], MQTT brokers are placed at each network edge to handle data with the characteristic of “edge heavy,” where objects at the network edge of an IoT system generate a large amount of data. To coordinate these multiple MQTT brokers, they propose a new mechanism called the ILDM (Interworking Layer of Distributed MQTT brokers). An ILDM node placed between a broker and a client not only relays MQTT clients and brokers as a proxy but also connects to other ILDM nodes to coordinate multiple brokers. Similarly, [20] proposes, implements, and evaluates countermeasures for interworking among MQTT brokers located at the edges of the network.

As shown in [18]- [20], the deployment of systems with multiple brokers is considered in many places for building large-scale systems. However, there are few studies that consider QoS for data shared among MQTT brokers. Therefore, this study considers the deployment of DDS, a publish/subscribe communication protocol that allows the provision of various services including QoS functions and does not require an intermediate node, for interworking among MQTT brokers.

Next, multicast control at the application level is proposed to improve resource consumption, such as throughput, in the target network to address the issues introduced by conventional communication protocols. For example, latency recovery and fault recovery characteristics have been achieved by drastically reducing control traffic in the bandwidth of stagnation [21]. In [22], a protocol for multicasting at the low-bandwidth application layer is proposed to reduce overhead. Simulation evaluations of the protocols implemented in applications show that the proposed protocols can significantly reduce control traffic. In [23], an algorithm is proposed and evaluated to improve end-to-end throughput at the application level. The evaluation results show that the proposed protocol can significantly improve the throughput.

4 PROPOSAL

In this section, a proposed method for efficient IoT data exchange among DDS nodes in the targeted IoT system is described.

The proposed method does not depend on the QoS functions provided by DDS, but implements transmission control functions at the application layer level to provide reliable point-to-multipoint communication with low latency. Although IoT technologies are expected to be applied in various use cases, the QoS functions provided by DDS alone are not sufficient to satisfy a service level required in each use case. Especially in industrial fields, there are demands for short-period cyclic communication and/or low-latency information sharing, which are difficult to be satisfied only by the QoS functions provided by DDS. For example, in [6], the requirements of two type of industrial applications, process automation and factory automation, are described. It shows that requirement for cycle time in a process automation application is 100ms. And in [8], the reliability requirements for process automation applications vary from 10−3 to 10-4 packet loss rate (PLR), while the latency requirements vary from 50 to 100 ms. There is also a scenario in which information generated by a node is shared and distributed to multiple nodes, such as in emergency notification and command control for multiple nodes in an IoT system. Therefore, the provision of low latency and highly reliable communication in point-to-multipoint communication is also a significant challenge.

In order to flexibly support the required communication characteristics for a variety of use cases, this paper proposes an implementation method that implements a transmission control function that achieves communication control corresponding to the required communication characteristics at the upper application layer of the DDS, while using a best-effort type communication mode for DDS due to its low processing. Figure 5 shows the functional architecture on a nodal point, which is a DDS node. Here, the nodal points are the gateways where IoT devices and IoT users connect to, and Fig. 5 illustrates the flow of IoT data when IoT data from IoT devices and IoT users are transferred to the IoT core network side, as arrowed. And, in Fig. 5, IoT data from IoT devices and IoT users are shown as blue lines, and IoT data to the IoT core network side are shown as red lines. The arrows before and after the forwarding application change color because the forwarding application determines the destination of the IoT data. That is, IoT data transmitted by IoT devices and IoT-users via MQTT are notified to the forwarding application in the nodal point via the broker function in the nodal point. The forwarding application receiving the IoT data forwards the received IoT data (message) to the transmission control function, which forwards it to other nodal points via the API provided by the DDS. This application, that is, the transmission control function, implements a transmission control corresponding to the required communication characteristics according to a use case. This paper then implements the transmission control function for the provision of reliable point-to-multipoint type communication and evaluates its effectiveness.

Figure 6 shows an example of the processing sequence for reliable and low latency transmission to multiple destinations in the transmission control function on the nodal point when forwarding IoT data from the IoT device to other nodal points. IoT data from the IoT device are received on the transmission control function via the MQTT broker and the forwarding application. And the transmission control function forwards received IoT data to other nodal points via DDS protocol by using DDS's API. The communication in DDS is assumed to be a best-effort type service in order to implement QoS control at the application level.

The following describes the operation of the transmission control function. First, the QoS level required by the received IoT data is verified. If the required QoS level is a best-effort service, the received IoT data is forwarded using DDS's API. For IoT data that requires reliability and low latency, the IoT data is copied to the queue corresponding to the destination of the IoT data, and is transferred from each queue in turn. If IoT data remains in the queue, the lifetime of the queued IoT data is confirmed and IoT data that exists exceeding its lifetime is discarded from the queue, and the latest IoT data is queued. When the lifetime of the queued IoT data has not expired, the latest IoT data is queued after the IoT data above. The queued IoT data is discarded when a response is received from the destination.

This enables reliable and low-latency transfer of IoT data to other destinations even when there is a delay or loss in the exchange of IoT data due to a communication path failure with the destination.

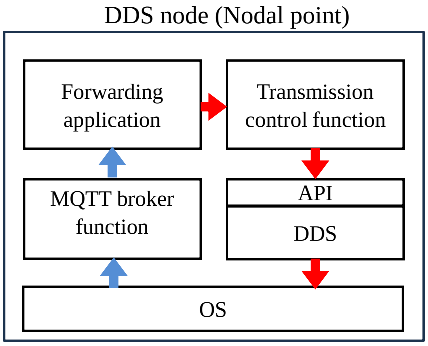


Figure 5: Functional architecture on a DDS node.

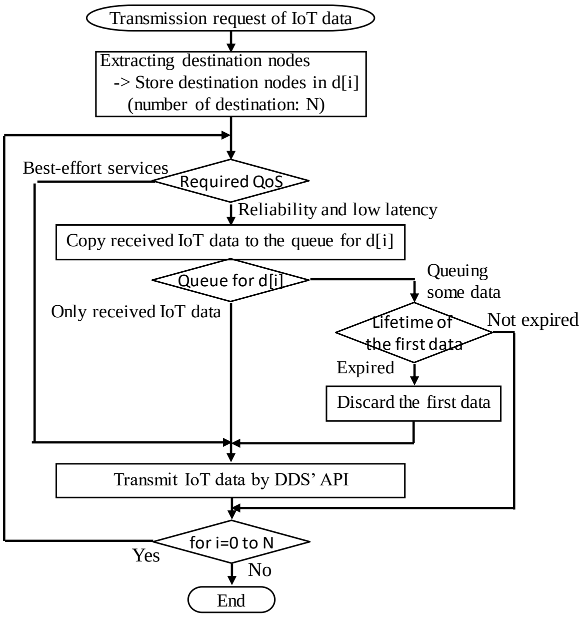


Figure 6: Example of a processing sequence for the transmission control function.

5 EVALUATION

To verify the effectiveness of the proposed method, especially the transmission control function, an experimental network with multiple DDS nodes which is located on nodal points is constructed (Fig. 7). That is, for evaluation, we have developed the experimental environment shown in Fig. 7. In the experimental environment, a Raspberry Pi 4 is used as each DDS node, and the DDS software released by RTI is implemented on the DDS nodes. And the traffic volume between DDS nodes, that is traffic volume on the IoT core network and transmission latency to other nodes are evaluated. In order to emphasize the evaluation of the transmission function, the experimental network consists only of DDS nodes, without IoT devices and IoT-users. In the experimental network, we evaluate the traffic volume when transferring IoT data via the proposed method and via DDS reliability service, called “using only DDS”. The traffic volume according to the generation probability of IoT data with reliable and/or low latency requirements are compared with. And, the paper clarifies the effects on transmission latency which is measured from stating of transmission of an IoT data on the publisher side to receiving time of the IoT data on the subscriber sides, to estimate the effect of the degradation of communication characteristics at a specific destination in point-to-multipoint communication on the DDS protocol.

In evaluation of traffic volume on the IoT core network, Node#1 transmits IoT data to other DDS nodes at 1 packet/second in 1000 seconds. And the data transmitted and received on Node#1 are counted. Ratio of IoT data with reliable and/or low latency requirements varied from 10% to 0.5 % (Table 1). It is noted that packet loss of IoT data is generated at uniformly random at a transmission point.

Figure 8 shows the traffic volume when IoT data is transmitted by using the proposed method and by DDS reliability service, called “using only DDS”. In Fig. 8, the number of receiving DDS nodes varies from 1 to 5, and ratio of number of IoT data with reliable and/or low latency requirements is configured to be 10%. When “Using only DDS” is applied, the overall traffic volume increased because the traffic of acknowledgment control for confirmation to guarantee the reliability is required for transmitting all IoT data. In the proposed method, the traffic volume is suppressed because acknowledgement is performed at the application level only for IoT data with reliable and/or low latency requirements.

Figure 9 shows the traffic volume depending on the ratio of IoT data with reliable and/or low latency requirements. The number of receiving DDS nodes is configured to be 5 nodes. Ratio of IoT data with reliable and/or low latency requirements varies from 0.5 to 10 %. The traffic volume of the proposed method increases, as the ratio of IoT data with reliable and/or low latency requirements increases. Because in the proposed method, IoT data with reliable and/or low latency requirements require only acknowledgement message. On the other hand, when “using only DDS” is applied, the traffic volume remains constant regardless of the ratio of IoT data with reliable and/or low latency requirements because reliability service in DDS always checks for transmission acknowledgement.

Next, to evaluate the effect of communication characteristics on the communication path to a specific node, the transmission latency depending on the communication characteristics, such as packet loss ratio, are evaluated. The transmission latency, which is shown in Fig. 12, is defined as the period between the time when a transmission request is issued by the sending node (DDS Node#1 in Fig. 12) and the time when an acknowledgement is received from the receiving nodes (DDS Node#2 to #4 in Fig. 12). It is noted that, in Fig. 12, an case in which an packet loss occurs when transmitting a message to Node #4 is illustrated in order to show the effect on transmission latency when packet loss occurs. Figure 10 and Figure 11 show the transmission latency depending on the communication characteristics (packet loss ratio in the communication path) for the cases 1 and 2 of “2.Transmission latency due to communication characteristics” shown in Table 1. Figure 10 shows the variation of the transmission latency without packet loss in the communication path, i.e., Case 1 of “2.Transmission latency due to communication characteristics” in Table 1. In a stable communication path, the proposed method is not significantly different from the case with using only DDS, even though messages are forwarded to multiple destinations at the application level (Fig. 10). It is assumed that there is a slight delay in DDS due to the "HEARTBEAT" message used to confirm the response.

On the other hand, Fig.11 shows the variation of the transmission latency when packet loss in the communication path to a specific node is observed, i.e., Case 2 of “2.Transmission latency due to communication characteristics” in Table 1. In this figure, IoT data is notified every 50 ms, and the timeout period for the response from the destination node is 50 ms. In Fig. 11, the blue dot when the sequence number of IoT data is 6 indicates the transmission latency between #1 and #2 on the proposed method due to the timeout for the response. The latency is significantly larger than 50msec. However, the latency of the next IoT data, i.e., IoT data with the sequence number of 7, is less than 10 ms, which indicates no effect of the timeout for the IoT data with Sequence number 6. On the other hand, the X dot, when the sequence number of IoT data is 11, indicates the transmission latency between #1 and #2 on the using only DDS due to the timeout for the response. In the case of using only DDS, the latency of the next IoT data with the sequence number of 12 is also affected due to the timeout of the IoT data with the sequence number of 11, which is about 20ms. So, from this figure, it is confirmed that the forwarding in DDS is affected by packet loss in forwarding next IoT data to all destinations. In contrast, since the proposed implementation method implements destination-based retransmission control at the application level, it is possible to confirm that the impact of packet loss is limited to a specific node.

Finally, in order to verify the results of Fig. 8, Fig. 9 and Fig. 11, it clarifies to behavior of message sequences on point-to-multipoint communication under DDS reliability mode. Figure 13 shows the captured message sequences of point-to-multipoint communication from Node#1 (IP address: 192.168.1.1) to Node#2 (IP address: 192.168.1.2) and Node#3 (IP address: 192.168.1.3). It is noted that queue size is configured to be 1 assuming a latency critical application. In Fig. 13, due to the loss of acknowledgements from Node#2, the message requesting an acknowledgement from Node#1, described as “HEARTBEAT” in Fig. 13, continues to be retransmitted. Figure 14 shows the acknowledgement retransmission sequence in point-to-multipoint communications on DDS reliable mode. In this case, since data queue size for retransmission is configure to be 1, the data queue is filled with data to be transmitted to Node#2 and Node#3 by multicast manner due to the packet loss of acknowledgement from Node#2. And the queueing of the next data is blocked. That is, in communications that require an acknowledgement to provide reliability, the delay or loss of response from the specific destination nodes affects the transmission of subsequent packets. This influences the provision of service levels for data with low latency requirements when conflicting with data with various quality requirements.

As described above, the effectiveness of the implementation method for a multicast control coordination scheme in conjunction with DDS has been confirmed through experiments using the experimental environment shown in Fig. 7. In other words, we have evaluated the effectiveness of implementing the reliable control function as a proprietary application for services that require specific reliable and low latency services, as opposed to a general-purpose DDS that supports a wide quality of services. It is noted that there are concerns that implementing a proprietary application outside of the general-purpose DDS imposes an increased processing load and increased latency. However, Fig. 10 shows that the implementation of the reliable control function in a proprietary application does not cause significant processing delays, since the DDS also operates in user space, and latency with the reliable control function is reduced due to the simplification of processing in the DDS. On the other hand, since the implementation of reliable control as a proprietary application is service-specific, there are challenges of adaptability to devices in which a variety of services are required, optimization, and so on.

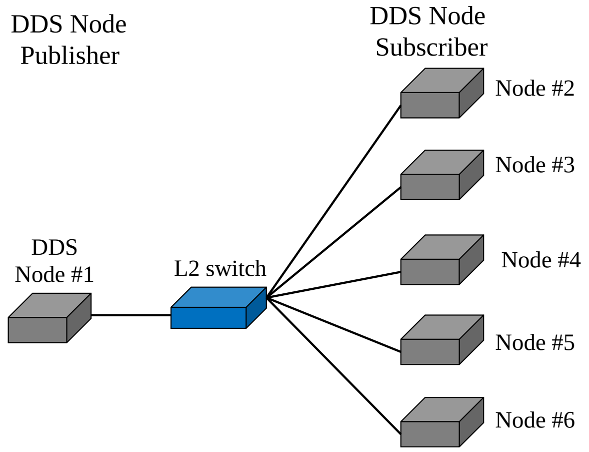


Figure 7: Experimental network for evaluation.

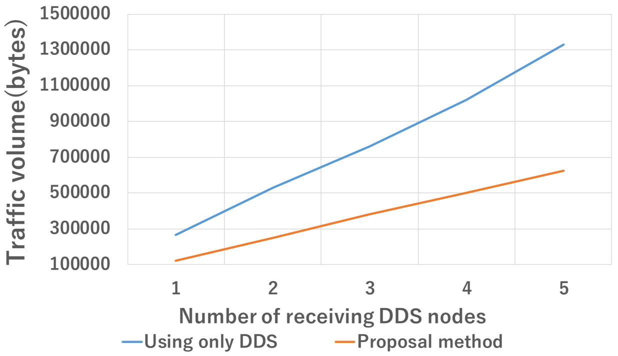


Figure 8: Comparison of traffic on the IoT core network.

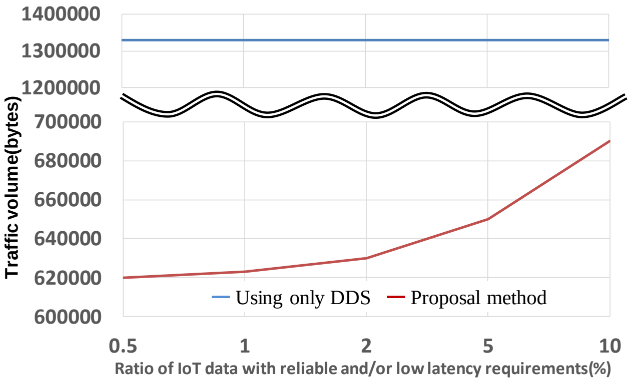


Figure 9: Traffic volume according to ratio of IoT data with reliability and low latency.

Table 1: Evaluation Patterns and Parameters

1. Traffic volume on the IoT core network			
	Case 1	Number of sending nodes	1 (node)
		Number of receiving nodes	1 to 5 (nodes)
		Ratio of IoT data with reliable and/or low latency requirements	10 (%)
	Case 2	Number of sending nodes	1 (node)
		Number of receiving nodes	5 (nodes)
		Ratio of IoT data with reliable and/or low latency requirements	0.5 to 10 (%)
2. Transmission latency due to communication characteristics			
	Case 1	Number of sending nodes	1 (node)
		Number of receiving nodes	1 to 5 (nodes)
		Communication Characteristics (Packet loss ratio)	0.0 (%)
	Case 2	Number of sending nodes	1 (node)
		Number of receiving nodes	1 to 5 (nodes)
		Communication Characteristics (Packet loss ratio)	0.0 to 1.0 (%)

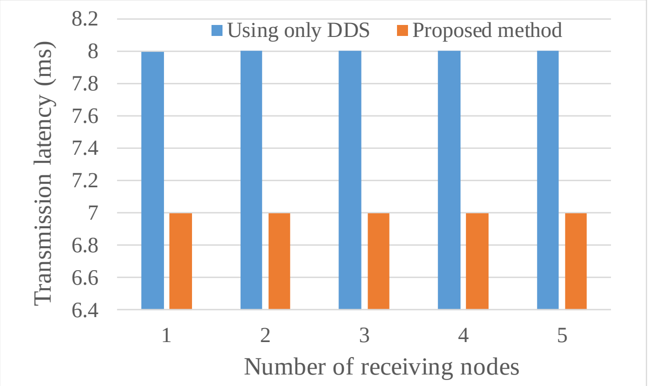


Figure 10: Transmission latency on the proposed method according to number of receiving nodes.

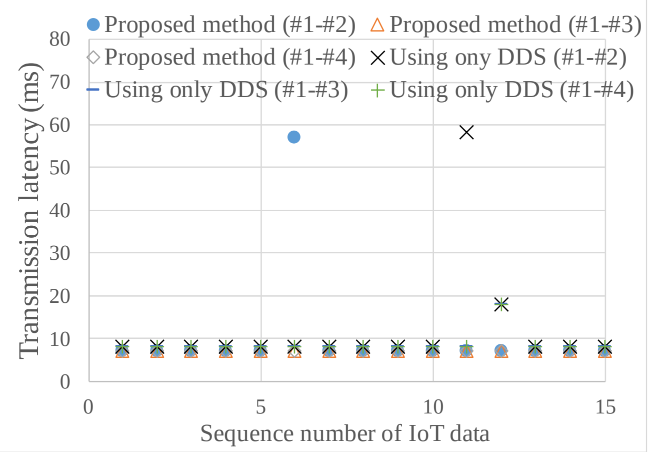


Figure 11: Transmission latency on the proposed method due to packet loss in the communication path to a specific node.

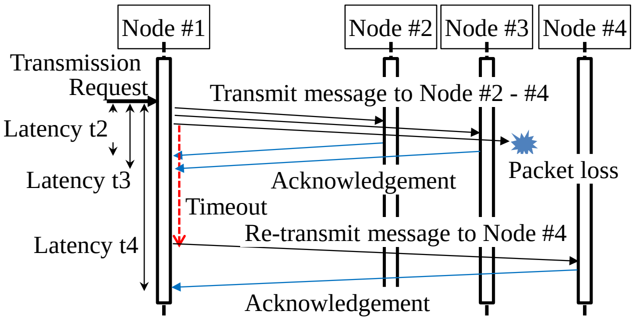
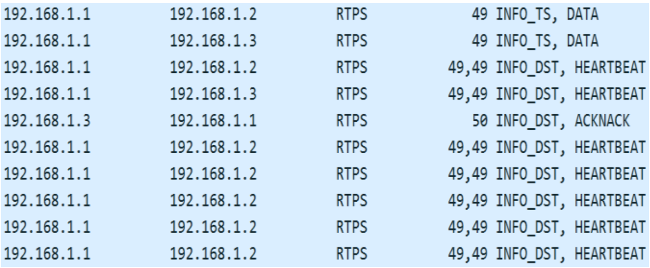


Figure 12: Definition of transmission latency.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192.168.1.1        192.168.1.2        RTPS              49 INFO_TS, DATA
192.168.1.1        192.168.1.3        RTPS              49 INFO_TS, DATA
192.168.1.1        192.168.1.2        RTPS           49,49 INFO_DST, HEARTBEAT
192.168.1.1        192.168.1.3        RTPS           49,49 INFO_DST, HEARTBEAT
192.168.1.3        192.168.1.1        RTPS              50 INFO_DST, ACKNACK
192.168.1.1        192.168.1.2        RTPS           49,49 INFO_DST, HEARTBEAT
192.168.1.1        192.168.1.2        RTPS           49,49 INFO_DST, HEARTBEAT
192.168.1.1        192.168.1.2        RTPS           49,49 INFO_DST, HEARTBEAT
192.168.1.1        192.168.1.2        RTPS           49,49 INFO_DST, HEARTBEAT
192.168.1.1        192.168.1.2        RTPS           49,49 INFO_DST, HEARTBEAT
```

192.168.1.1: IP address of Node #1
192.168.1.2: IP address of Node #2
192.168.1.3: IP address of Node #3

Figure 13: Packet sequence on DDS reliability mode.

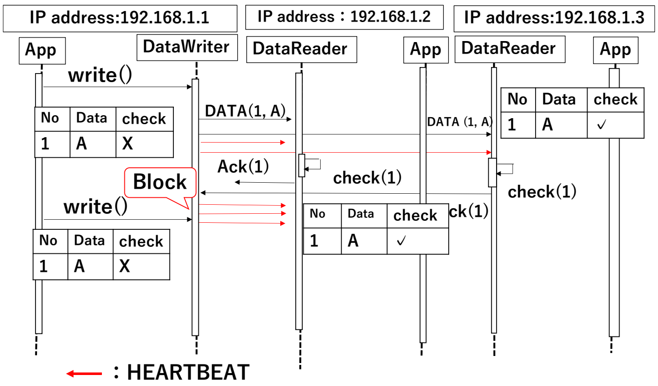

Figure 14: Acknowledgment retransmission sequence in point-to-multipoint communication.

6 CONCLUSION

In this paper, we propose the implementation method for a multicast control coordination scheme in conjunction with DDS as an efficient method of transferring IoT data in IoT systems. We also compared with the data transfer capability of the proposed method and the data transfer using only the DDS function. As results of the evaluation, we confirmed that the proposed method is effective in reducing the traffic volume compared to the communication method using only the DDS function. In addition, we verified the operation in point-to-multipoint in DDS reliability mode. We confirmed that in DDS reliability mode, retransmission for acknowledgement affects transmission of subsequent packets.

In an actual IoT system, various communication characteristics such as packet loss and latency on the communication paths between nodal points are assumed. Therefore, it is necessary to further evaluate the proposed method by considering the communication characteristics of each path in the target IoT system, such as packet loss rate and latency.

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