Advances in Technology Innovation, vol. 4, no. 1, 2019, pp. 21 - 29

Performance Evaluation of MQTT as a Communication Protocol for IoT and Prototyping

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Received 03 March 2018; received in revised form 05 August 2018; accepted 14 September 2018

Abstract

The hypertext transfer protocol (HTTP) has been widely used as a communication protocol for Internet access. However, for Internet of things (IoT) communication, which is expected to grow in the future, HTTP requires a large overhead and cannot provide efficiency. In order to solve this problem, lightweight communication protocols for IoT have been discussed. In this paper, we clarify some problems of HTTP for IoT and propose MQ telemetry transport (MQTT), which is a promising candidate for the IoT protocol, after conducting a performance comparison with HTTP.

Keywords: IoT, HTTP, MQTT, lightweight protocol, performance evaluation

1. Introduction

In recent times, there have been numerous discussions on the Internet of things (IoT) worldwide [1-2]. A large number of IoT devices are connected to networks, and IoT devices collect data from various sensors. Though the data size of sensor devices is very small, it is communicated in large quantities through the network.

Currently, Internet access requires TCP/UDP/IP and application protocols over these protocols. Amongst the application protocols, hypertext transfer protocol (HTTP) [3] is common. It is applied for general Internet access. In IoT communication, a large number of devices communicate using very small data packets. When HTTP is applied to IoT communication, protocol overhead causes serious degradation of performance. Moreover, the IP address in IoT is thought to depend on the physical location and causes complexity in network control. In order to solve these problems, data aware networking (DAN), [4] e.g., information centric networking (ICN) [5-6], named data networking (NDN) [7], and content centric networking (CCN) [8], is being considered and discussed to be used as the architecture of IoT. MQ telemetry transport (MQTT) [8] is categorized as DAN. MQTT has been developed for IoT. Protocol overhead is reduced, and information is transferred in a name-based system referred to as topical. It is not required that the address in MQTT depends on the physical location as the IP address. Offered traffic in the network is reduced to transfer information.

This paper describes, performance evaluation of IoT communication based on MQTT, and compares the performance of HTTP and MQTT protocol. This paper reports prototyping of IoT devices based on MQTT and HTTP. Finally, it proposes using a combination of MQTT and conventional IP.

2. Related Technologies and Standardization Trends

In order to realize IoT communication, active discussions have been held between the industry, academia, and government. Discussions on various topics such as technology development, international standardization strategy, and

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promotion of demonstration experiments are held by the IoT promotion consortium [10]. In this section, taking these arguments into consideration, we summarize the discussion on environmental in this paper.

2.1. *Communication network for IoT*

The communication network scenario for IoT is reported in [11]. Fig. 1 shows the system configuration required for realizing IoT communication.

In Fig. 1, the area network is introduced for IoT communication. However, wide area network infrastructure coexists with various services of legacy and IoT. An outline of the communication protocol is shown in Fig. 2. In the wide area network infrastructure, IP communication is widely spread. Presently, IoT communication cannot be differentiated from IP communication. However, HTTP has been used for wide Internet access, and every time information is accessed, a need for a three-way handshake with the TCP is required. In case of IoT communication, a large number of small packets are generated because they handle traffic from the sensors. In the case of HTTP, a large communication capacity is required to attach a header to each of them. For this reason, as shown in Fig. 2, lightweight protocol for IoT communication is necessary.

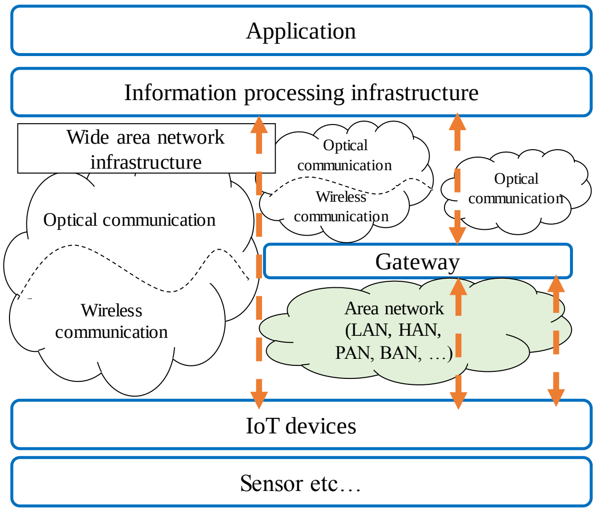

Fig. 1 System configuration of IoT

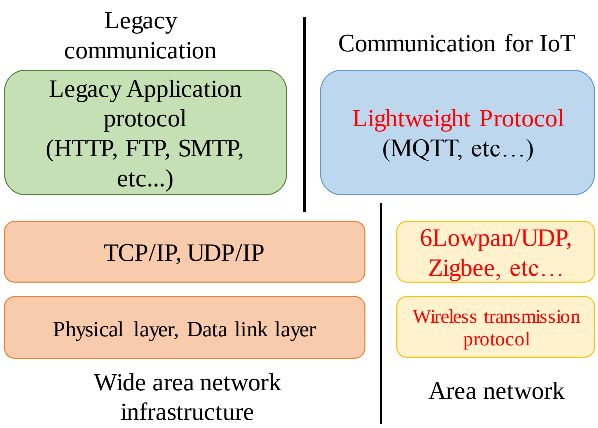

Fig. 2 Outline of communication protocol including for IoT

2.2. *International standardization trend*

The discussion on international standardization of lightweight protocol for IoT is summarized in this section. The IoT standardization can be represented as shown in Fig. 3.

Discussions have been made on the architecture and requirements of communication systems in ISO/IEC, JTC1/SC41, and ITU-T SG13. Among them, there is a need for a lightweight protocol with low overhead. Specifically, instead of using location-dependent information such as IP address, "Name-based access method" that directly accesses information is regarded to be more efficient. These are classified as ICN. For example, [4] defines a framework for it. Discussions have been made on the detailed methods, such as IRTF and oneM2M Forum standards [12-13]. MQTT discussed in this paper is also regarded as an effective method.

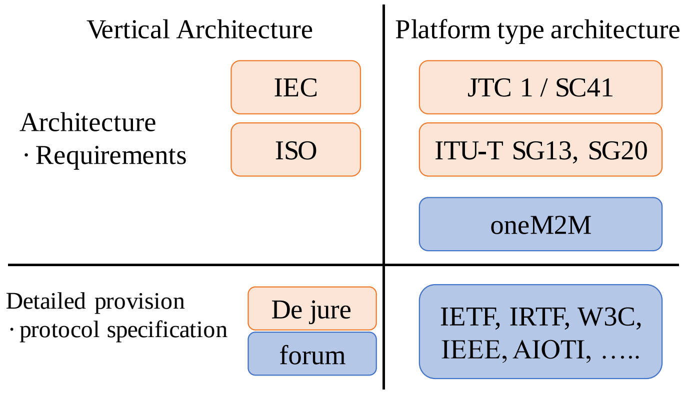

Fig. 3 Standardization overview on IoT

3. Overview of HTTP and MQTT

In this section, HTTP and MQTT are summarized with respect to communication sequences.

3.1. Overview of HTTP

The HTTP protocol is used for the communication of information written in hypertext markup language (HTML). As a feature, in order to obtain information, it is necessary to specify the information location. Uniform resource locator (URL) is used to specify the address of that information. In principle, it conducts stateless communication. Connection/disconnection of a communication session is performed every time information is accessed. However, when HTTP is operated over TCP/IP, reliable communication is provided. HTTP communicates with two responses, HTTP request and HTTP response. The HTTP communication sequence is shown in Fig. 4.

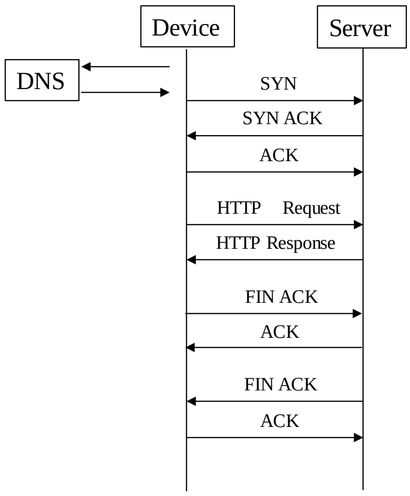

Fig. 4 Communication sequences on HTTP

3.2. Overview of MQTT

MQTT is a communication protocol of the PUBLISH /SUBSCRIBE type, and the client communicates via MQTT broker [14]. As a feature of MQTT, the fixed header of the MQTT packet is a minimum of two bytes. MQTT uses proprietary name-based methods called topics to transfer information. A topic does not depend on the physical location of the IP address. The network load can be reduced by routing. From Fig. 5, topic has a hierarchical structure. There are three types of topic designation methods such as a perfect match, forward match, and partial match. Moreover, MQTT can set three levels of delivery guarantee. Therefore, it can be set according to the importance of communication. From the sequence diagram of Fig. 6, MQTT does not connect/disconnect the session for each communication; however, it keeps a communication session connected. Therefore, the communication session is simplified and communication wastage is reduced. From these features, MQTT applies to IoT communication, small fixed header size, and it is thought that the communication becomes lightweight from retention of communication sessions.

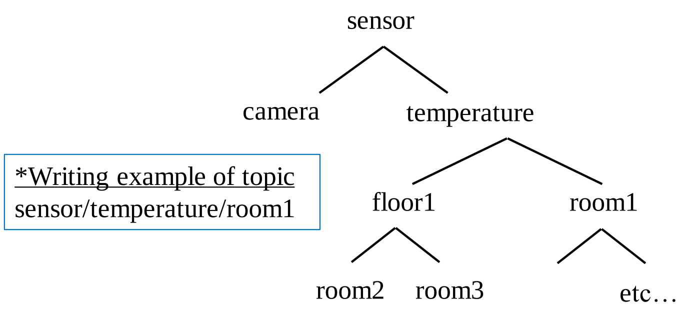

Fig. 5 Structural example of topic

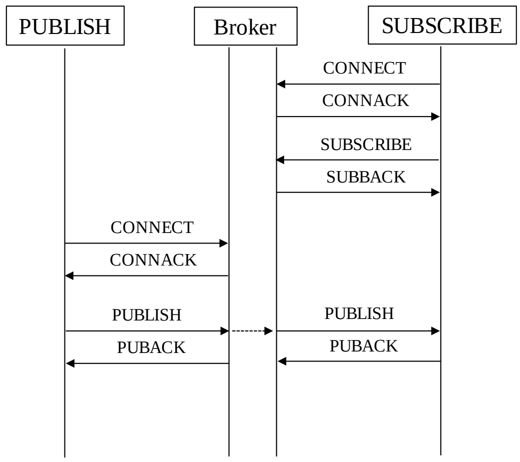

Fig. 6 Communication sequences on MQTT

4. Comparison of HTTP and MQTT Traffic

In IoT communication, when a large number of devices are connected, overhead is caused. It causes problems such as network delay and server load. Therefore, we evaluate their performance from the viewpoint of traffic and examine the suitable protocol for IoT [15-16].

4.1. Definition of the network model

Fig. 7 shows the network model for the comparison with HTTP and MQTT for communication traffic. In Fig. 7, it is assumed that some devices such as sensors are connected to the server. It is a model that receives data from some sensor device via server.

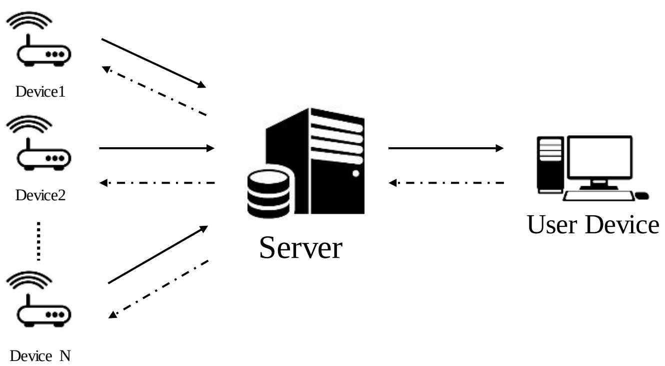

Fig. 7 Network Model

4.2. HTTP traffic

HTTP is applied to the network model of Fig. 7, and traffic in data send/receive is calculated as follows. From the communication sequence of Fig. 4, each communication packet is summed, and the obtained traffic is taken as traffic in one communication. Here, the size of HTTP request/response packets is set to 300 Bytes each. It is assumed that 100 and 1000 sensor devices are connected to the transmitting devices. Its payload size is 0 Bytes.

4.3. MQTT traffic

MQTT is applied to the network model of Fig. 7, and the traffic is calculated [17]. From the communication sequence of MQTT in Fig. 6, the sum of packet sizes of MQTT packets is taken as traffic of one communication. Consider the case of operating on TCP/IP, one communication is from the PUBLISH devices to reception of data on the SUBSCRIBE devices. Table 1 shows each header size of MQTT.

Table 1 MQTT Packet Type

Message Type	Bytes
CONNECT	14
CONNACK	4
PUBLISH	6 + topic(1Chara/Byte)
PUBACK	4
SUBSCRIBE	7 + topic(1Chara/Byte)
SUBACK	5

4.4. Comparison result of HTTP and MQTT traffic

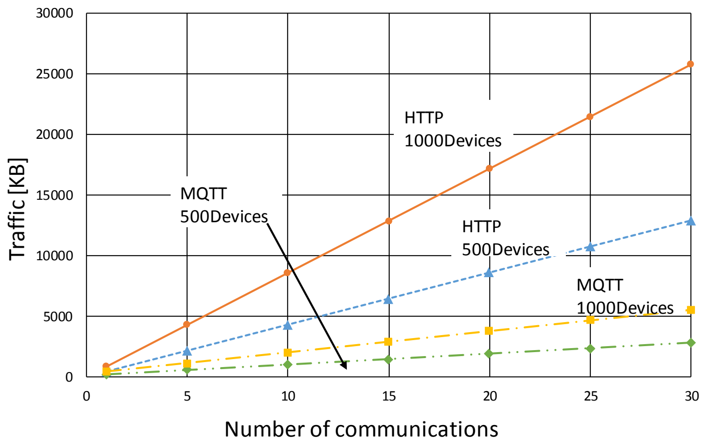

Fig. 8 Traffic volume of HTTP and MQTT

The traffic of HTTP and MQTT as discussed in Section 4-2 and 4-3 are as shown in Fig. 8. From this, compare the traffic on HTTP and MQTT, as the communication increases, difference in traffic between HTTP and MQTT increases, and when communication occurs 30 times, MQTT becomes about 1/5 of the traffic compared to HTTP. As can be seen from Fig. 8, in MQTT, the traffic of both 500 and 1000 devices connected to the server is less than half of the traffic connected with 500 devices by HTTP. Therefore, it can be understood from this that traffic can be reduced using MQTT in IoT communication.

5. Comparison of Network Resources

5.1. Definition of network resources

By comparing the network resources of HTTP and MQTT, we present the definition of network resources. It is defined as the occupation time in server from the start of communication to the end of device (Fig.9).

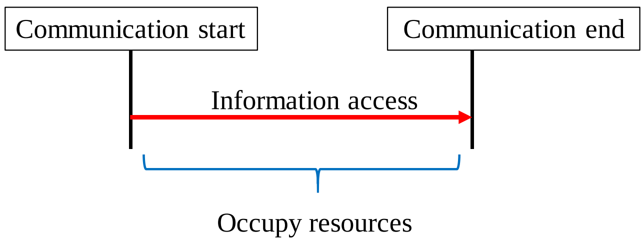

Fig. 9 Definition of network resources

5.2. Measurement of access delay time

In order to calculate network resources, we measure the access delay in actual communication [15] [18]. For verification, we used Raspberry Pi as a device and Wireshark [19] of packet capture software to measure the communication access delay time (Fig. 10).

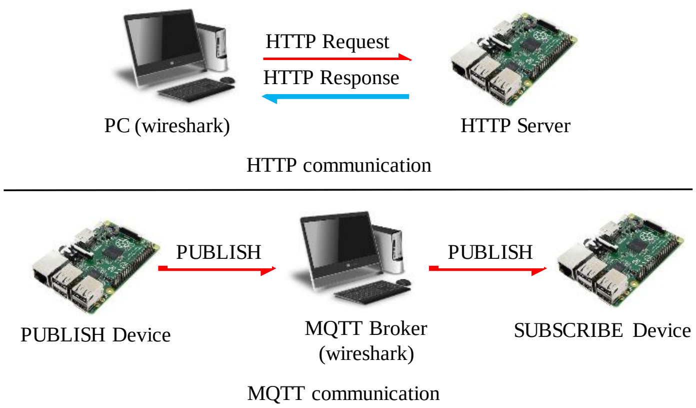

Fig. 10 Network configuration of access delay measurement

In the case of HTTP communication, the access delay time is measured when the server is accessed from the PC to acquire data. In the case of MQTT communication, the access delay time is measured from the PUBLISH device to the SUBSCRIBE device via the MQTT broker.

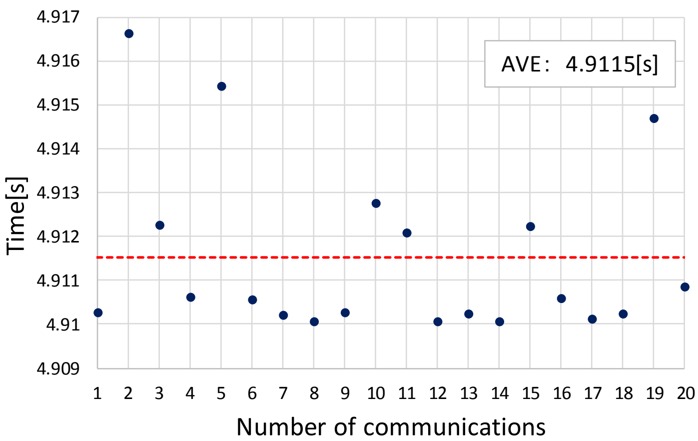

Fig. 11 HTTP access delay time

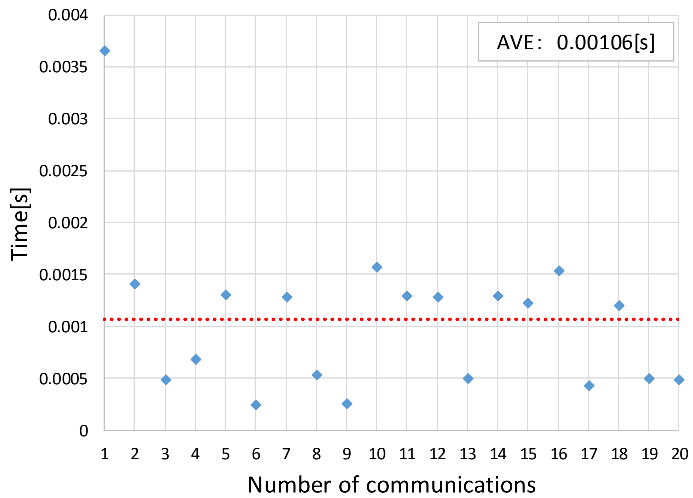

Fig. 12 MQTT access delay time

The results of the access delay time measurement of HTTP and MQTT are shown in Fig. 11 and 12. Communication was carried out 20 times each, and the average was calculated. In HTTP (Fig. 11), the access delay was about 4.91 s on an average. In MQTT (Fig. 12), the average was about 0.00106 s. In the first instance of communication for the MQTT, access delay is large in order to establish a communication session.

Because of looking at each sequence, in HTTP, a delay of about 4.8 to 4.9 s occurs when a FINACK packet of a session disconnection request from a server is sent. This delay is considered to be a processing delay or keep time by using the server software. That does not mean that such delays will occur in all HTTP communications. However, even if we subtract about 4.9 seconds from the measured HTTP access delay time, we found that there is about 10 times short access delay time of MQTT communication. There are differences in the size of each protocol, in the case of HTTP, it seems that there was a big difference in the access delay time owing to differences such as connection/disconnection of communication sessions.

5.3. Required network resources

Next, network resources shown in Fig. 9 are evaluated. We assume that access to information follows Poisson distribution and time required for access follows an exponential distribution of average access time obtained in Section 5-2. In addition, capacity of network resources is assumed to be sufficiently large. In this case, if the device generating information is K, it is represented by M/M/∞//K (finite population model). Equilibrium state probability in this model is Pk, the arrival rate of the information is λ, assuming that the average processing time is h, necessary network resource N is expressed by Eq (1).

$$N = \sum_{k=0}^{k} k \cdot p_k = \frac{\sum_{k=0}^{k} k \cdot (\lambda h)^k \binom{k}{k}}{(1+\lambda h)^k} = \frac{k \cdot \lambda h}{1+\lambda h} \tag{1}$$

Fig. 13 shows the numerical calculation using arrival rate λ as a parameter with respect to Equation (1). As can be seen from Fig. 13, the MQTT requires less network resources for HTTP.

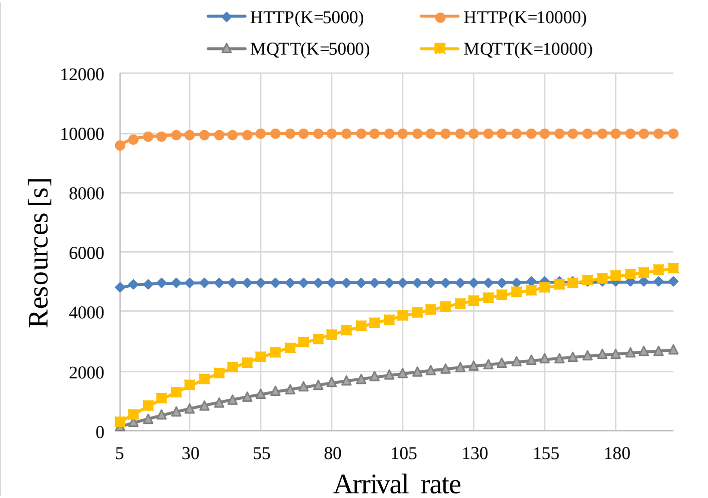

Fig. 13 Comparison of network resources

6. Affinity with IP

The Internet is currently based on IP communication. However, the movement of devices frequently occurs in IoT communication. Assuming this, since IP communication depends on the location, smooth communication cannot be obtained. Therefore, network architectures such as DAN attract attention [4] [20].

We consider the relationship of MQTT with IP when applied to a wide area network. It is assumed that MQTT is applied to a wide area network, as shown in Fig. 14. It is assumed that there are multiple MQTT brokers in many devices.

In this scenario, there are two possible routing problems. Case 1, the PUBLISH devices connected to the MQTT broker and the SUBSCRIBE devices communicate. If devices that want to obtain data are connected to another MQTT broker, the connection needs to be changed. However, PUBLISH devices do not know to which MQTT broker the SUBSCRIBE device is connected.

Case 2, the PUBLISH device has multiple sensors. For each sensor data, the PUBLISH device sends data to the MQTT broker. At this time, it is unknown where the SUBSCRIBE device is divided for each sensor data is connected.

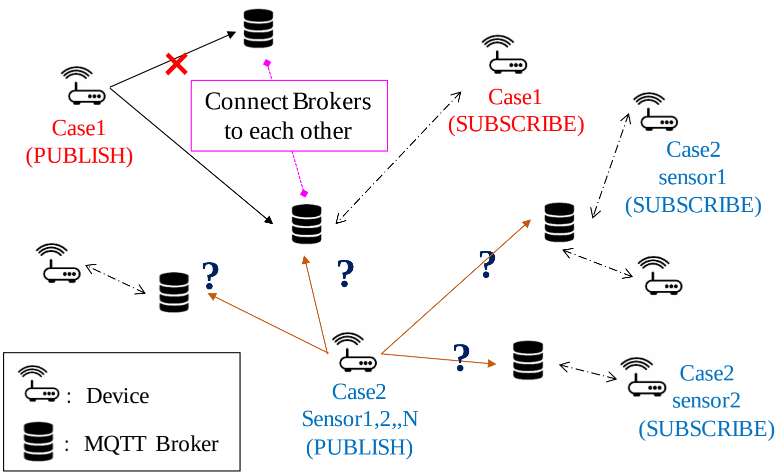

Fig. 14 Wide-Area Network configuration of MQTT

As a solution to these problems, there is a method of connecting the MQTT broker in a ring shape. Alternatively, data may be sent to all adjacent MQTT brokers. In this case a large overhead will occur. Therefore, it may be possible to link topic and IP and perform routing using a mechanism like DNS. Therefore, when MQTT is used assuming a wide area network, it is difficult to communicate with only name-based routing that is independent of IP [21] [22].

It is similar to the above routing mechanism, and MQTT has another version for wireless sensor network MQTT-SN (MQTT for sensor networks). For routing, a predefined topic ID and short topic are introduced. Therefore, there is a feature where mapping is done automatically by informing the topic ID and topic to the client, gateway, and broker in advance without setting it.

It has already been thought that when a name and address are attached independently, it can be further simplified or linked to another ID or the likes. This idea is not limited to MQTT; it can be said that it is common to name-based protocols. As a more sophisticated mechanism, it is conceivable that a name is automatically allocated in name-based routing.

7. Conclusions

TU-T Y. 3033 defines four goals and twelve design goals that reflect the new requirements of future network, which specifies the framework of DAN [4]. The essence of DAN is name-based communication that routes data objects in the network by name or identifier, and the name-based communication allows DAN to locate data objects irrespective of the location. Name-based communication has received considerable attention as it guarantees the continuation of communication without being interrupted by the change of data object position [23].

In this paper, we evaluate the performance from a viewpoint of traffic volume, access delay, and network resources on overhead with both the HTTP and the MQTT protocols applied to the IoT platform and compare them. From this, it is found that MQTT is superior to HTTP when applied to IoT. However, for this network model, as shown in Fig. 7, and in wide area IoT networks, as discussed in Section 6, it is necessary to study the problem caused by transfer of name-based information future works.

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