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MQTT-Based Distributed Brokers Internet of Things Platform

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Abstract—

Several different types of services for the Internet of Things across large geographic areas have been set up. Most IoT services need the transmission of a large number of very small data packets across long distance networks. This calls for a simplification of the transfer processes. MQ Telemetry Transport is a viable contender for usage as a transfer mechanism (MQTT). In this work, we suggest a virtual ring design for a distributed MQTT broker. ISO/IEC JTC 1/SC 41 describes an IoT Data Exchange Platform, and this design follows those specifications. This paper describes the functionality of a distributed broker architecture that use a virtual ring network for real-time communication, and it demonstrates the architecture's superiority via a performance study using queuing models.

Key word :

Internet of Things, Internet of Things platform, data exchange platform, MQTT, and standardisation are all terms that may be found in this article's index.

Introduction :

It's no secret that IoT services rely on various forms of communication technology [1]. Networks must provide for the smooth movement of data for IoT services and allow for the coexistence of IoT and any legacy services when they are deployed across a large region. Most Internet of Things services involve sending several small data blocks from the sensors to the actuator through the network. Therefore, it is necessary to define the architecture for low-overhead protocols with straightforward communication sequences. ISO/IEC JTC1/SC41, an international standards group, proposed the IoT Data Exchange Platform (IoT DEP) for this purpose, and its main points have been detailed in a number of papers [2]–[4]. Overlapping networks at service nodes are described in detail in the IoT DEP's ideas for interoperability.

Information Centric Network (ICN) technologies allow the end points, such as end devices and servers, to communicate with one another [5]. These terminals and nodes of interaction are built as a middleware module that uses a socket interface to integrate with standard communication infrastructure. It is expected that the access protocol between an endpoint and an interworking point is MQ Telemetry Transport (MQTT) [5]. As MQTT brokers, interconnection nodes facilitate communication between devices. Using a queuing analysis, the authors of this study suggest and assess procedures using these brokers. Furthermore, cyclic communications based on shared memories are suggested for real-time communication inside these interworking points, as are virtual ring topologies.

IoT Data Extraction and Prediction

ISO/IEC 30161, "Internet of Things (IoT) - Requirements of IoT data exchange platform for different IoT services," whose architecture is shown in Figure 1, was proposed in 2018 and debated as an international standard in ISO/IEC JTC 1/SC 41. The edge of an IoT DEP network is an interworking point that allows end points, including end devices and servers, to access the network. When it comes to providing services for the

Internet of Things, virtualized IoT DEP networks are just an overlay on top of the existing Internet infrastructure. Moreover, interworking stations are linked to standard communication infrastructure, such as IP routers. To facilitate IoT service edge-to-edge communication, a network of virtual pathways is established betweenthe various points of connectivity.

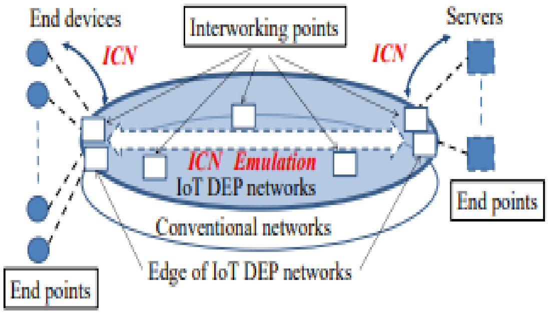

Fig. 1. The architecture of IoT DEP.

ICN technologies include various mechanisms. These mechanisms can be categorized into synchronous and asynchronous mechanisms [5]. In synchronous mechanisms, the request to obtain data and a response corresponding to this request are paired, as represented by a content-centric network (CCN) [6], [7]. In a CCN, a request corresponds to a packet of "interest," and a response corresponds to a packet of "data." By contrast, in an asynchronous mechanism, a request and a response are invoked independently, as represented by MQTT [8], [9]. In MQTT, data are provided by a "publish" packet, and are obtained by a "subscription" packet. These packets are invoked asynchronously. Because ICN technologies do not require complicated communication sequences, e.g., IoT DEP provides lightweight access through such mechanisms as access sequences of a Domain Name System (DNS), three-way-handshake procedures of TCP, or a large protocol overhead, e.g., HTTP.

IOT COMMUNICATION USING ICN TECHNOLOGIES

IoT communications are categorized into three types, as shown in Figure 3. End devices, e.g., various sensors, generate data and report to the servers with a notification, as shown in Case 1. The servers are invoked to obtain data and the end response required by the data according to the requests from the servers, as shown in Case 2. Finally, the servers invoke control to the end devices, e.g., actuators, as shown in Case 3.

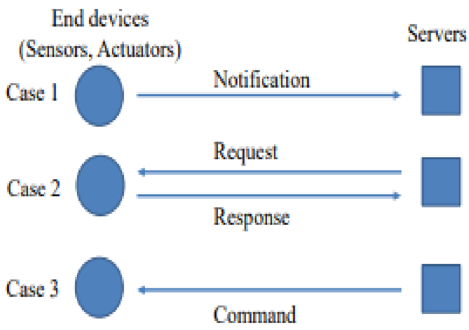

Fig. 2. Communication types among IoT end points.

In IoT services, most communication types are similar to Case 1 because a significant number of sensors should be installed to monitor various situations. Therefore, MQTT provides simpler communication sequences than the sequences of a CCN, because a CCN specifies sequences based on Case 2 [14]. Communication operations among the interworking points in IoT DEP based on MQTT are proposed in the following section.

NEW ARCHITECTURE FOR LARCH-SCALE DEPLOYMENT When IoT services are deployed across wide-area

networks, many interworking points in the IoT DEP networks should cooperate with each other. In the case of MQTT between these points, a problem of cooperation among distributed MQTT brokers occurs. Various approaches have been discussed to solve this problem [10] – [13]. One solution is to broadcast communication among the brokers, which is referred to as a "flooding approach." However, with this approach, the traffic volume may be increased on the networks. Therefore, based on MQTT, a new architecture for large-scale deployment using IoT DEP, referred to as a virtual ring approach, is proposed in this section. In this architecture, interworking points, as shown in Fig. 2, are connected as a logical ring, as shown in Fig. 3. This ring network is virtualized by lower layer protocols, e.g., VLAN. This architecture does not require specific routing protocols and differs from conventional ideas regarding the use of distributed brokers. As shown in Figure 4, the ring network is recognized by a VLAN. Interworking points, e.g., distributed brokers, includes access control and shared memory blocks. An access control block controls data on the ring, such as multiplexing, copying, and terminating. These operations are described in the next section. End points, e.g., end devices and servers, are connected to these interworking points according to the MQTT protocols. Data controlled by the MQTT protocol are referenced among the shared memory in a loop, as shown in Fig. 5. In this figure, two VLANs are provisioned. Each interworking point owns a VLAN, and specifies the initiation and termination points to avoid infinite looping.

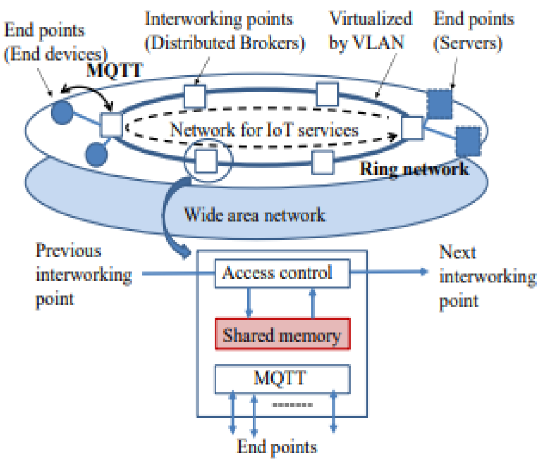

Fig. 3. Architecture of the proposed scheme for distributed brokers.

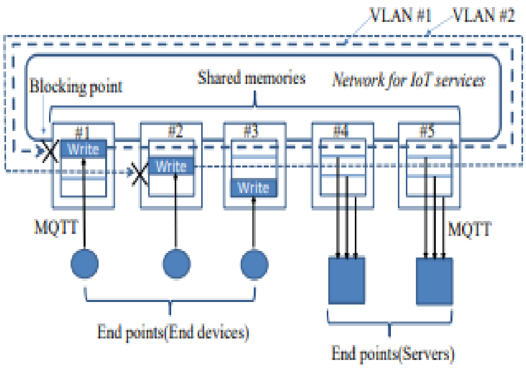

***Fig. 4. Communication among shared memory in distributed brokers*.**

in Fig. 5, end devices generate and transfer data to distributed Brokers according to the MQTT protocol. Data are stored in dedicated areas of the shared memory for each end device, and then transferred to other shared memory in distributed brokers in the ring. The transferred routes are identified using VLAN. In this figure, VLAN #1 is provisioned from Broker #1, and is blocked at the ingress point of this broker. By contrast, servers can refer to all of the areas in their shared memory.

DETAILED OPERATIONS AMONG INTERWORKING POINTS

In the detailed operations among interworking points, distributed brokers of MQTT in the ring network are described as follows. These operations follow the architecture of communication using the shared memory, e.g., [15]. This architecture has been applied to real time communication of the industrial fields [16], [17].

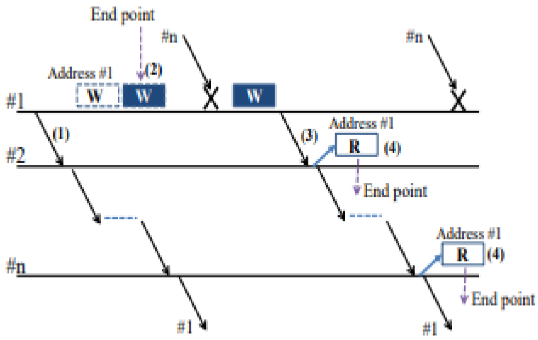

Fig. 6. The transfer mechanism among shared memory.

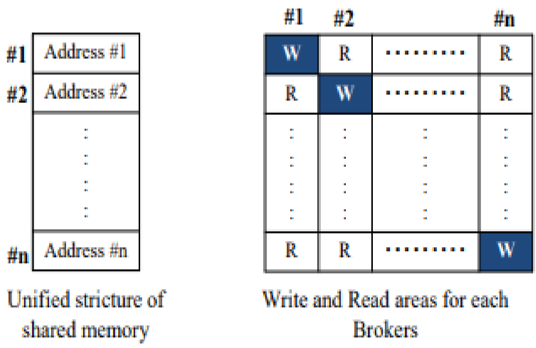

Fig. 7. The structure of the shared memory.

Each end point transfers information according to the MQTT protocols, as shown in Figure 4, to the shared memory in a distributed Broker, which accommodates this end point. The transfer mechanism among the shared memory is shown in Fig. 6. The structure of the shared memory is shown in Fig. 7. The steps shown in Fig. 6 are as follows. In the ring network, frames are transferred at regular intervals among the distributed brokers (Step (1)). These frames are booked at the ingress point of the originating broker, i.e., Broker #1 in Fig. 6. When an end point generates information, this information is written in the dedicated address of the shard memory, shown in Figure 7 (Step (2)), The shared memory is divided into parts, which are identified based on the dedicated address for each broker, as shown in Fig. 7. These parts are categorized into a write or read area. This information istransferred by the next routed frame (Step (3)). This information is written in the read areas in other brokers. The end points accommodated by these brokers can read information stored in these areas (Step (4)). These operations can update information in all parts in the shared memory within a fixed interval.

PERFORMANCE EVALUATION

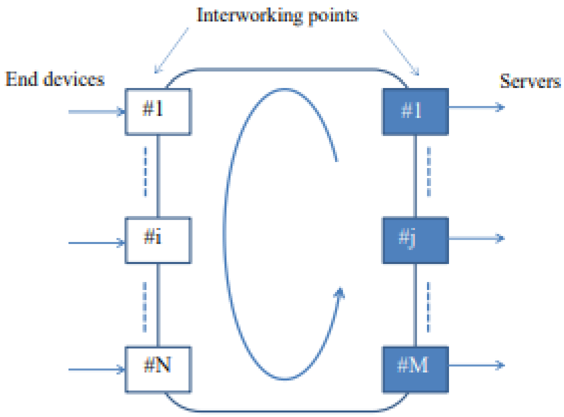

Fig. 8. The model on performance evaluation of the Virtual ring approach.

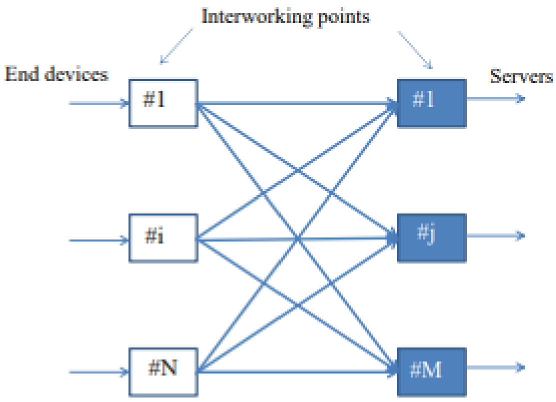

Fig. 9. The model on performance evaluation of the flooding approach.

In these figures, the numbers of interworking points that accommodate end devices and servers are denoted as M and N, respectively. This evaluation, shown in Figure, focuses on Case 1. Each interworking point accommodating the end devices receives data as packets generated randomly by the devices, the receiving rate of which is specified as follows:

$$\lambda_i \ (i = 1, \dots, N)$$

The average transmission time on a packet at this interworking point is as follows.

$$b_i \ (i = 1, \dots, N)$$

In the flooding approach, each transmission capacity

between interworking points, which accommodate the end device and the server, divides the total capacity of the virtual ring approach into sizes of M × N.

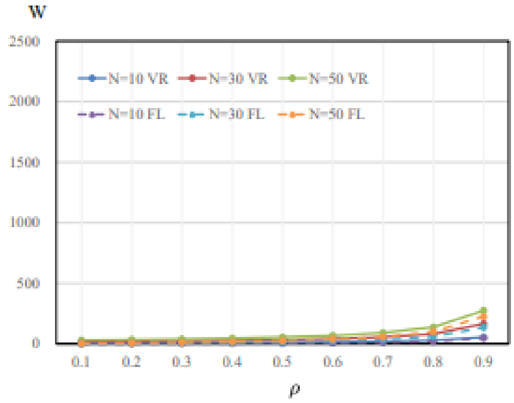

Fig. 10. The average delay in the small-scale case (M=1)

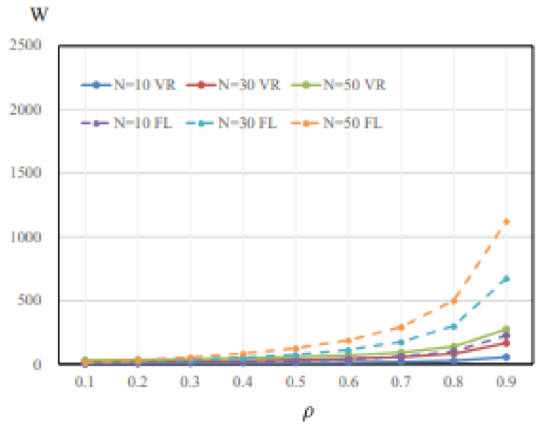

Fig. 12. The average delay in the small-scale case (M=10)

In this section, the average delays between these interworking points when applying these approaches are compared using queueing models. In the virtual ring approach, because packets from an end device can be transferred through the interworking point accommodating this end device, when circulated frames arrive at this interworking point, models with multiple queue access can be applied as token passing mechanisms and polling systems [18]. In this approach, when a frame arrives at the interworking point accommodating the end devices, itis assumed that all information in this interworking point is transferred by this frame, which is referred to as an exhaustive policy. The average delay in a symmetrical case is derived from Eq. (1) [19].

CONCLUSIONS

In this paper, a framework of IoT DEP was introduced, which is a communication platform for various IoT services, and has been standardized in ISO/IEC JTC 1/SC 41 based on the authors' own promotion. In addition, detailed operations in the IoT DEP are proposed. Specifically, a virtual ring approach used to connect the interworking points in this platform was proposed and compared with a flooding approach, which is based on conventional technologies. It was then concluded that a virtual ring approach is superior to a flooding approach based on a queuing analysis. As the next step, the virtual ring approach will be implemented as a prototype system.

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