An Adaptive Sensor Management System

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Chyi-Ren Dow, Yaun-Zone Wu, Bonnie Lu, Shiow-Fen Hwang, and Fongray Frank Young

Abstract

This paper proposes an adaptive sensor management system which consists of five main components, including the Sensor Web Interface, Request Dispatcher, Publish/ Subscribe Management, Communication Converter and Message Broker. The Request Dispatcher can automatically allocate the tasks of Sensor Web to each module as the service requested. The Communication Converter let the Message Broker handle the operations of Sensor Web, notify sensors and modify the information of sensors through the Sensor Web Interface. Two sensor control methods are defined for publication and subscription. The experimental results by the designed prototype system show that this system can effectively perform sensor management.

Keywords

IoT • SWE • MQTT • Sensor Management

35.1 Introduction

Sensor Web Enablement (SWE) [1] was proposed by Open Geospatial Consortium (OGC). In the sensor management mechanism, SWE only focuses on describing the information of the sensors and monitoring their schedules. SWE emphasizes on collecting data from the sensors, but does not control the behavior of sensors. Message Queue Telemetry Transport (MQTT) [2] is based on TCP/IP and suitable for IoT environments. It is characterized by its header size fixed on two bytes for various types of packets in MQTT. It transmits and receives information using the publish/subscribe mechanism.

The number of sensors is expected to increase in the future. We need a highly scalable sensor environment. These sensors may be lightweight devices which are powerless and have weaker computing capability. It is necessary to use low-powered protocols for these sensor environments. Different sensors have unique specifications, so the system needs to fuse various data that have collected. It is necessary for a centralized management system to manage the sensors. The mechanism of sensors is usually focused on collecting sensor data, but the control sensor state is seldom discussed.

This paper is organized as follows: Section II discusses the related research and technology. Section III presents our system overview and architecture design. Section IV describes the ideas of Sensor Control Management. Section V shows the system prototype. VI provides the system experimental results. Finally, the conclusions are proposed in Section VII.

35.2 Related Work

There are many applications in the sensor network. There are more sensors which are deployed in the environment. The study [3] aimed at sensors integrating. There are many

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different formats for the sensors. Therefore, it is difficult to integrate the sensors into the observed system. The research [4] combined SWE with RESTful to transform the message into different formats. In this method, SWE effectively combines with the other protocols. The alternative sensor network was proposed [5]. This research talks about the social network. People who use smartphones are the best observation nodes.

The Internet raises the performance up with the light-weight packet. The MQTT and CoAP [6] are lightweight protocols. The study [7] compare MQTT with CoAP. CoAP, which is based on UDP, is better for small areas than MQTT, which is based on TCP/IP. All things considered, MQTT has better scalability than CoAP in the IoT environments. There is a special characteristic of MQTT that divides messages into three QoS levels: at most once, at least once, and exactly once. The studies [8] propose the different QoS levels. Based on the advantages of MQTT, the system that handles large events was proposed [9].

Management function in the sensor network is required. The Sensor Web Node Management System was proposed [10] to manage the sensor network. We need a system to fuse the information that is collected from different sensors. To solve this problem, they design the Cloud4sens which uses cloud management in the system. This system fuses different data and provides information to users [11].

35.3 System Architecture

This work proposed a system architecture for sensor management. An overview of this system is shown in Fig. 35.1, including the SWE Server, the Management, the Message Broker, sensors and users.

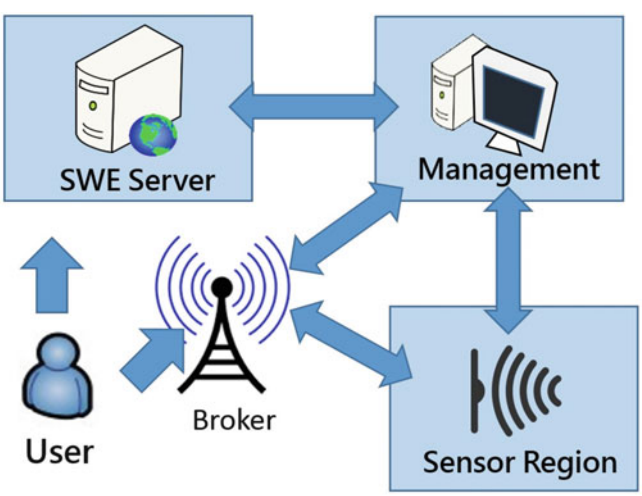

Fig. 35.1 System overview

The broker which relays messages using the MQTT publish/ subscribe mechanism. The SWE Server provides Web Service and standard SWE functions into our platform. The broker transmits messages to the users who in turn subscribes to the topic when the sensors and the management system sends the messages to the topic. The users subscribe to the topic to receive the notification. The management system is responsible for collecting messages and setting the topics. The management system controls the state of all sensors using the publish/subscribe mechanism. Furthermore, the management system can observe the data and control the states of the sensors. The sensors collect information from the environment, traffic and vehicles, and the information is stored in the management system.

The system contains our network management unit, HTTP-to-MQTT broker and converter. In the network management unit, SWE Interface provides the sensor observation service and contains four operational methods, including sensor value insert, sensor value read, service features description and sensor description. It uses XML to exchange the data which collect from the sensors. It also communicates the information and provides the details when a sensor joins the system at the first time. The observation value is stored on the server and accessed by management with this service.

Our system which combines the SWE and MQTT techniques is challenging to provide the real-time service in the sensor network. In the IoT environment, there are many sensors and the system needs scalability. In our system, the traditional SWE standard functions is processed by the SWE interface. We designed a message service that uses the publish/ subscribe mechanism. That is the request dispatcher, publish/ subscribe management, HTTP-MQTT converter and MQTT broker in our system. When the management requests service, the request dispatcher automatically distributes the work to SWE functions. The publish/ subscribe management contains the publish/ subscribe relation between the management and the sensor.

35.4 Sensor Control Management

In the sensor observation and control interface, it has information of the sensors, including the sensor name, the sensor number, latitude and longitude location, grid coordinates, the sensor state, data format, data return frequency, service and communication interface. The sensor has its tag when the sensor registered in the system. We designed a mechanism in which the sensors can exchange the state and control the frequency in the module of the sensor publish/subscribe management, and can also modify the state and frequency with the interface of this mechanism. In the communication interface, we use the platform and have the SWE.

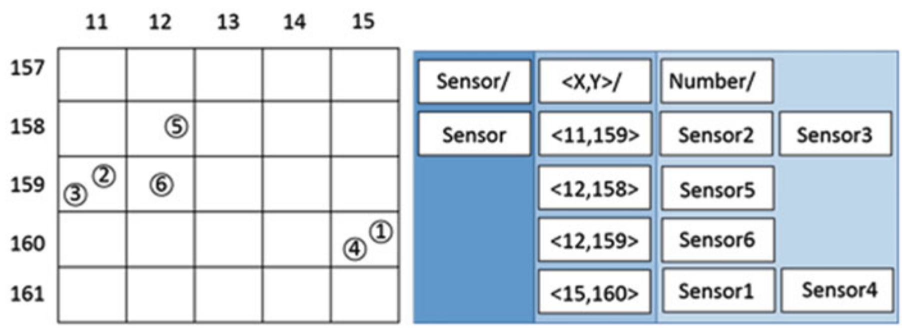

Fig. 35.2 Sensor area example

In the control mechanism, there are two parts: control interface and control module. In the control module, all of the sensors in the system subscribe the control topic. To adjust the sensors, the management sends the message to the control topic. The control topic publishes the message to the sensor correctly. The management can decide the control topic and design the change of strategy to modify the sensors. When the change strategy conforms the parameter, the control center will send the message to assign the sensor. We have two methods based on the sensors area and sensor name to control the sensors. Below is an example in Fig. 35.2.

We use the MQTT mechanism in our method and give the topic “Sensor” to all the sensors in our system, and give the topic “<X, Y>” to a grid with latitude and longitude coordinates X and Y. For example, we have the “Sensor5” in grid “<12, 185>”. In our method, the topic of this “Sensor5” is defined as “Sensor/<12, 158>/Sensor5”. We define all sensors topic in the system with this method. When a new sensor wants to register in the system, the system will give the sensor a number and a topic for this new sensor automatically.

35.5 System Prototype

Our system is implemented through SWE and MQTT. We focused on sensor control, adaptive sensor and sensor management. In order to make these functions easily used by the user, we collected various sensors’ information in this platform. We used the tabular form and listed the sensors in the system. It can search and use the sensors more conveniently for users. In the publish/subscribe management, the relation of the manager and the sensors is presented with visualization. We can easily find the publisher and the subscriber through a management system. When we need to control the sensors, it can define and connect the sensors first with visualization.

We accomplished the remote control using the publish/subscribe mechanism with the Sensor Web enablement module. For adaptive sensor control, we made the users control the sensors directly, and the management system accessed the information from the sensor observation module with the time parameter. Moreover, we provided a function to let the user be able to control the frequency for sensors to transmit the data with the MQTT publish/subscribe mechanism. Finally, we combined SWE with the management platform and the observation platform. There is the system prototype shown in the Fig. 35.3.

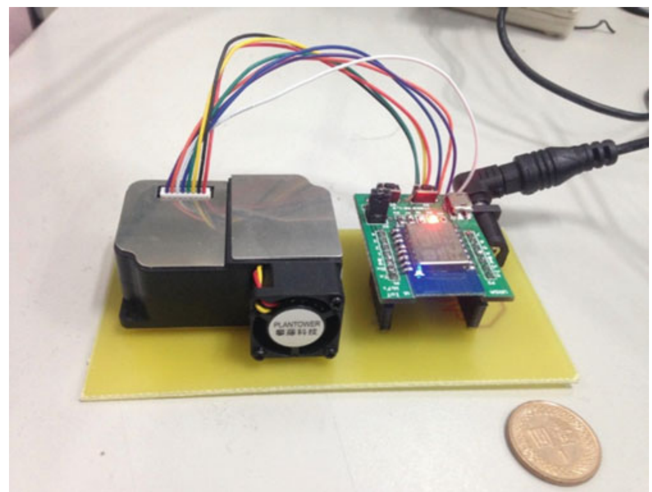

Fig. 35.3 System prototype

Our server was implemented on the Ubuntu system and the Mosquitto [12] was used to build the broker. After we built the broker, we defined the IP address and the topic name of the broker. It can use the IP address and the topic name to exchange the information with the MQTT publish/subscribe mechanism. The user can get the information from the control center and the sensors can receive the control message from the management. The control center is implemented on the Window system by using C#. For the communication between the user and the broker, the system can be used to connect to the broker on 4G (LTE). The broker connects to the server with the Ethernet and wireless network.

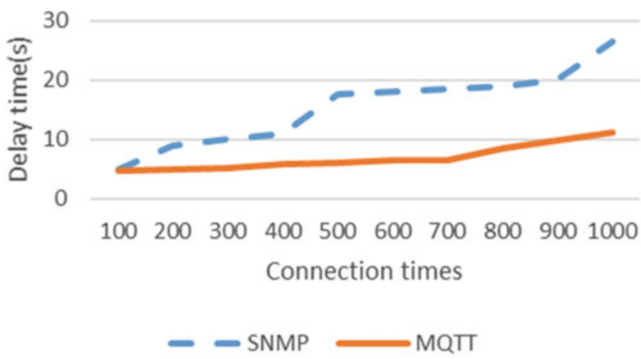

Fig. 35.4 Delay time

35.6 Experimental Results

In order to evaluate the performance of our sensor management system, we design the experimental environment and compare SNMP with MQTT. The management system connects with the sensor by using Wi-Fi is implemented on the Window system. The sensor is a smartphone device.

The management system and sensor use the same device in this experiment. The management system builds on the notebook and the sensor is smartphone. The broker is implemented on the Mosquitto. We use the management to send the control packet with our control method.

Figure 35.4 shows the delay time for SNMP and MQTT. The dash line shows delay time from SNMP. The solid line shows delay time from MQTT. The horizontal axis is the number of times that the management send the packet to sensor. Because the MQTT mechanism only has two-bytes header, we can observe the delay time that MQTT is better than SNMP.

35.7 Conclusions

We proposed a sensor management system which was based on SWE and MQTT. MQTT is the lightweight, low-cost and low-power protocol based on the publish/subscribe mechanism. We used SWE to collect the data from the sensor and provide the sensor control function with MQTT. It can adjust sensors' state and frequency effectively. With our sensor management system, we not only can control the single sensor, but also control the sensor in the group. For the future work, we will implement a SOS which is based on MQTT. It may increase the performance of sensors for collecting the data from environments.

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