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A Case Study of Data Acquisition from Field Devices Using OPC UA and MQTT

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Abstract: Data acquisition plays an important role in control (and measurement) systems, especially in the context of IoT. It is required to handle complex or structured data and to transfer data frequently. In this paper, a case study of data acquisition from field devices using OPC UA and MQTT is shown. Not all field devices have interfaces to connect to communication network such as Ethernet and they need help of gateway devices. A SCARA robot designed for studying was used as a field device and it was connected to communication network through a single board computer as gateway device. It is found that the SCARA robot with gateway device can be controlled by the data taken from OPC UA server and that its motion can be monitored by MQTT.

Keywords: OPC UA, MQTT, Field device, Gateway, IoT

1. INTRODUCTION

Data acquisition plays an important role in control (and measurement) systems. Once any problems or troubles have happened, we can neither analyze the cause nor solve the problems without data recorded or monitored.

A control system usually consists of a variety kind of components such as PLCs, computers and sensors. It can be divided into several layers such as MES(Manufacturing Execution System) level, controller level and field device level. Communications between them are very important and it is required to transfer complex or structured data.

In the context of IoT(Internet of Things), data acquisition is an essential part of the systems. Every component or device related to the systems is expected to be connected to some communication networks and to transfer much more data frequently. The field devices without interfaces to connect to communication network have to get help of gateway devices.

As for transferring structured data, OPC UA[1] is one of the most suitable choices. For the purpose to transfer large data frequently, lightweight messaging protocol such as MQTT[2] should be adopted.

The objective of this study is to show a case study of data acquisition from field devices using OPC UA and MQTT through gateway devices.

2. OPC UA AND MQTT

2.1 OPC UA

OPC UA is standardized as IEC 62541 and widely used by many vendors. OPC UA that provides a mechanism for secure communication has an advantage about security and is used for the communication layer of the reference architectural model Industrie 4.0(RAMI 4.0)[3].

Structures of data transferred with OPC UA is specified by address space according to information model[4]. Therefore, it is important to create information models suitable for target systems or business. OPC Foundation, which is the organization for promotion of OPC UA, collaborates with some organizations such as PLCopen and makes related companion specification[5].

2.2 MQTT

MQTT is a lightweight messaging protocol and standardized as an OASIS Standard[6]. It is based on publish/subscribe messaging and suitable for one-to-many messaging. In MQTT, data published by publishers are distributed by broker to subscribers. Three levels for QoS are available as follows: QoS0(at most once), QoS1(at least once) and QoS2(exactly once). In addition, all messages can be set to be retained for new subscription request. Data type for message is not specified and character strings (including JSON) is available for example.

3. CASE STUDY USING SCARA ROBOT

3.1 Field device and gateway

In this study, a SCARA(Selective Compliance Assembly Robot Arm) robot designed for studying as shown in Fig.1 is used as field device. This can be connected to computers by USB and handled as an USB HID device. Five motors are included in it and each of them can be controlled specifying torque mode (On/Off/Brake) and angles via USB.

On the other hand, this provides no means to connect to communication networks. It needs help of some gateway devices in order to communicate with other devices by other means than USB.

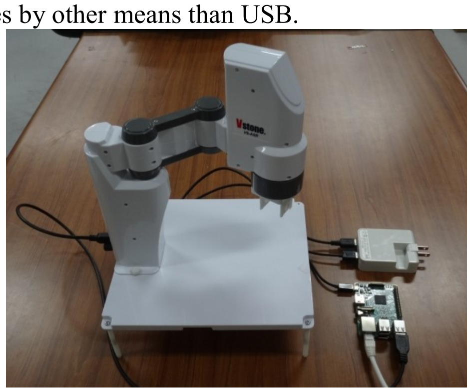

Fig.1 SCARA Robot and Raspberry Pi.

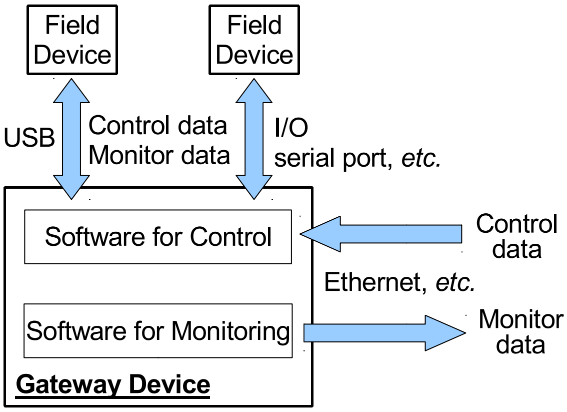

Fig.2 Interfaces of gateway device.

Gateway devices, as a matter of course, have to provides means to connect to communication networks such as Ethernet. In addition, gateway devices have to provide interfaces such as GPIO, USB and serial port to connect to field devices as shown in Fig. 2.

Since a gateway device significantly affects the performance of the field devices connected to it, it is important to select a suitable gateway device. In the present study, a single board computer "Raspberry Pi" is adopted as the gateway device for the SCARA robot.

3.2 Configuration to use OPC UA and MQTT

In this case study, OPC UA is used for data transfer related to controlling device and MQTT is used for monitoring. As described before, torque mode and target angles are used as control parameters for SCARA robot. Object "SCARA_Robo1" containing "target_angles" and "torqueOn" as properties is added to OPC UA address space.

As for MQTT, data are published and subscribed according to "Topic" specified. In this study, a topic named as "scalar_robo/angles" is created and simple JSON data like "[300, -300]" are transferred. QoS for subscribing is set to QoS=2.

In the first case, OPC UA server and MQTT broker run in different computers as shown in Fig. 3. The OPC UA client included in Raspberry Pi controls SCARA robot by using the control data taken from the OPC UA server. The other OPC UA client commands the motion of SCARA robot by sending control data to the OPC UA server. The following software is used:

- MQTT broker : moquitte (https://github.com/andsel/moquette),
- MQTT library: Paho(http://www.eclipse.org/paho/),
- OPC UA library: FreeOpcUa Python library (http://freeopcua.github.io/).

Since the OPC UA is constructed by using FreeOpcUa Python library, the object "SCARA_Robo1" containing "target_angles" and "torqueOn" are located in address space of the OPC UA server program by hand. The resulting address space is shown in Fig.4. Monitor data are transferred from the MQTT publisher in Raspberry Pi to MQTT broker and are distributed to MQTT subscribers.

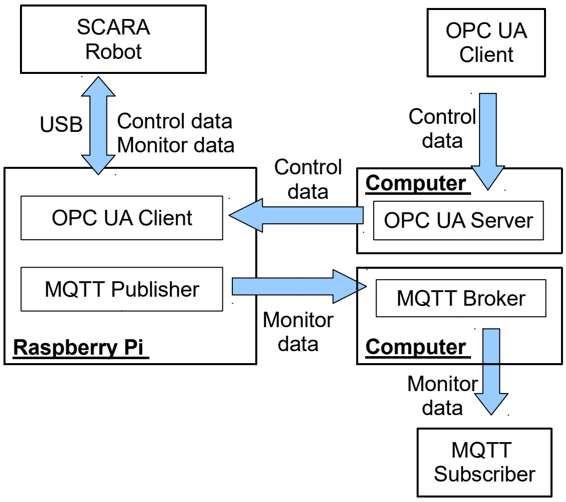

Fig.3 System overview using no PLC.

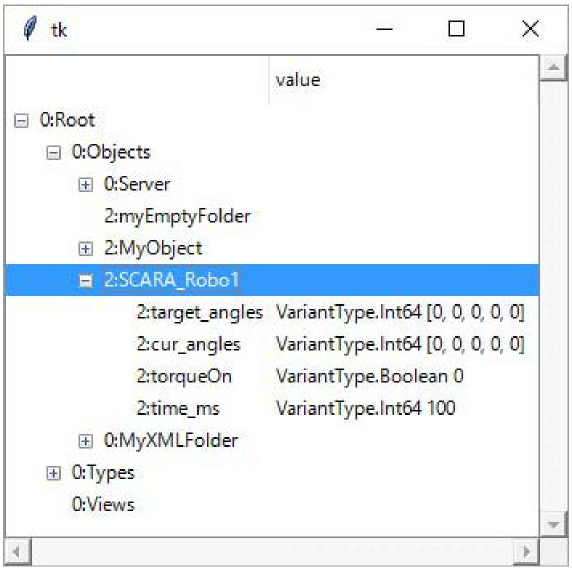

Fig.4 Address space of OPC UA server in Fig.3.

In the second case, we use the OPC UA server built in PLC as shown in Fig. 5. Control data are generated by application program in the PLC or are transferred from OPC UA client illustrated new the top-right corner in Fig. 3. The PLC reflects them automatically to the built-in OPC UA server. Therefore, just one OPC UA client is shown in Fig.5. The address space of OPC UA has to be configured through the manner provided by PLC. The resulting address space shown in Fig.6 is different from one shown in Fig.4.

In both cases, SCARA robot was controlled by the data taken from OPC UA server through the gateway device (Raspberry Pi). It suggests that motion function blocks proposed by PLCopen[7] can be implemented for SCARA robot used here by using OPC UA. The angles of servo motors in SCARA robot were published according to MQTT and distributed to subscribers by the broker. It means that the motion of SCARA robot can be monitored by MQTT.

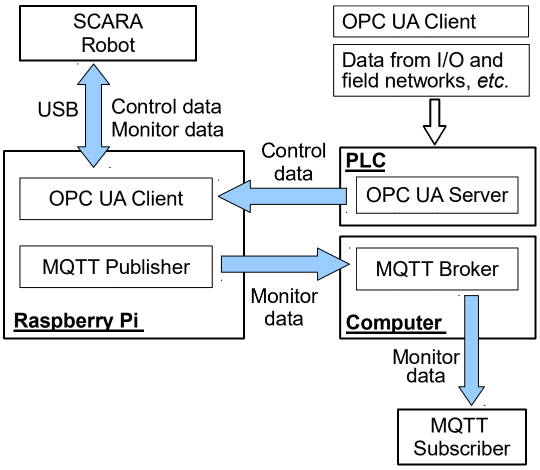

Fig.5 System overview using PLC as OPC UA server.

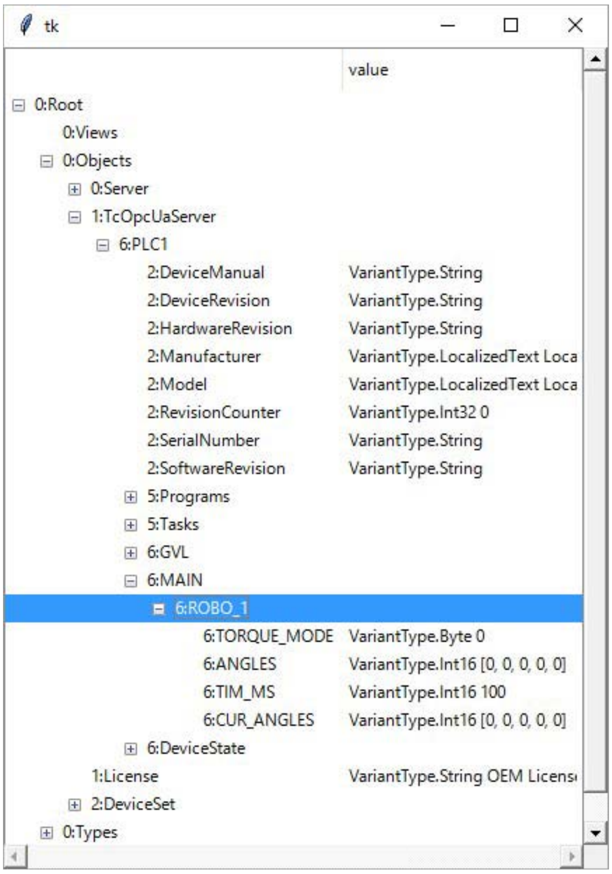

Fig.6 Address space of OPC UA server in Fig.5.

3.3 Data transfer from a field device with a gateway

We will show the results of the data transfer for the configurations shown in Fig. 2 and 4. Control data are sent from OPC UA clients illustrated near the top-right corner in Fig. 3 and 5. Monitor data are subscribed by just one subscriber.

The SCARA robot was controlled to move as shown in Fig. 7. At first, the angles of the two motors are set to zero (labeled as 1). After 0.5 sec, as shown with label 2 in Fig. 7, they are commanded to move until their angles equal to 90 deg and -90 deg, respectively. Then, after 0.5 sec has passed, they are commanded to move to the third position (labeled as 3 in Fig.7) where their angles

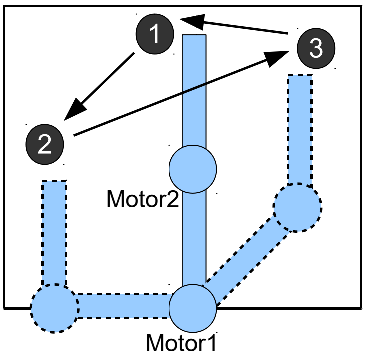

Fig. 7 Top view of the motion of SCARA robot.

Table 1 Results with OPC UA server on PC.

	Subscriber without SSL	Subscriber with SSL
Execution time	20.86[s]	20.91[s]
Count of MQTT publishing	645.2	654.0
Frequency of MQTT publishing	30.9[s^{-1}]	31.3[s^{-1}]

Table 2 Results with OPC UA server on PLC.

	Subscriber without SSL	Subscriber with SSL
Execution time	20.82[s]	20.83[s]
Count of MQTT publishing	699.2	703.0
Frequency of MQTT publishing	33.6[s^{-1}]	33.8[s^{-1}]

are -45 deg and 45 deg, respectively. In addition, after 1.0 sec, they are commanded to return to the first place. The OPC UA clients repeat this cycle (motion of 1 > 2 > 3 > 1 in Fig. 7) 10 times.

Results for both configurations are shown in Table 1 and 2. Each value in the tables is averaged one over 5 executions. As to SSL/TLS tunneling for subscribers, Python library is used. These result shows performance of the gateway device ("Raspberry Pi") are not affected by OPC UA servers. The current gateway is able to publish MQTT message about 30 times in a second. It means also that the gateway can get and set data in OPC UA server 30 times in a second, since each MQTT message are usually published after getting and setting data in the OPC UA server.

The performance of the gateway is not affected by using SSL/TLS tunneling for subscriber messaging. It is considered to be because the number of subscriber is small (just one) and SSL/TLS use symmetric encryption after secure session is established.

4. DATA TRANSFER WITH MULTIPULE DEVICES

The results shown in the previous section are based on a small control system including one field device, one gateway and one controller (OPC UA client) and one monitor (MQTT subscriber). It may be usual that some devices, controllers and monitors are contained,

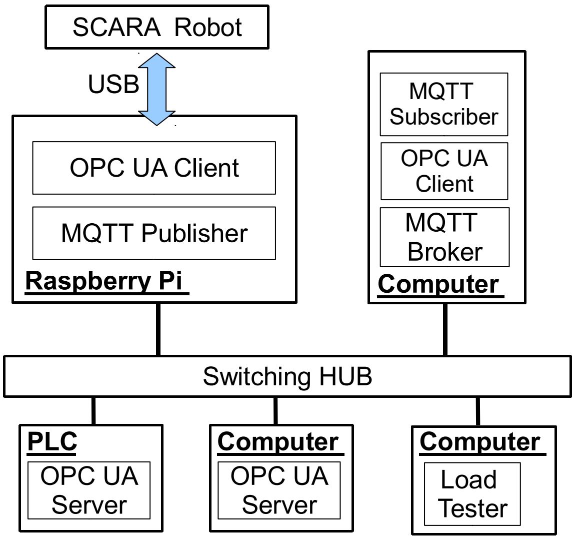

Fig. 8 Overview of load testing.

and it is important to evaluate data transfer of such systems.

For this purpose, load testing is adopted. By using load testing for MQTT broker, many monitored devices and monitors are simulated. On the other hand, load testing for OPC UA server simulate many field devices or many controllers. Fig. 8 shows the overview of the current load testing. The SCARA robot is controlled in the same manner as described in the previous section.

In this study, we used a load testing tool 'Locust' (http://locust.io/), because it is easy to configure test cases for protocols including MQTT and OPC UA.

Table 3 shows the results of MQTT load testing. MQTT broker received about 250 requests (QoS=2) in a second when 5 users for load were used. Loading test by 10 users for load could not be executed. It is found that load testing for MQTT broker did not give significant affect on performance of the gateway up to the load of 250 requests in a second. It seems because MQTT is a lightweight publish/subscribe messaging protocol.

Table 4 shows the result of OPC UA load testing. Loading test by 30 users to the OPC UA server on the PLC could not be executed because of the upper limit of the number of accessing users. The performance of the gateway is affected by the number of the user for load. As users for load increase, its performance gets lower significantly (Table 4(a)). Since this means that the performance of control is affected, it is important to conduct load testing to systems where OPC UA server plays some role in control.

Table 3 Results under MQTT load testing.

(a) Results with OPC UA server on PC.

	5 users without SSL	5 users with SSL
Execution time	20.90[s]	20.89[s]
Count of MQTT publishing	668.2	652.6
Frequency of MQTT publishing	32.0[s^{-1}]	31.2[s^{-1}]

(b) Results with OPC UA server on PLC.

	5 users without SSL	5 users with SSL
Execution time	20.85[s]	20.85[s]
Count of MQTT publishing	709.2	718.8
Frequency of MQTT publishing	34.0[s^{-1}]	34.5[s^{-1}]

Table 4 Results under OPC UA load testing.

(a) Results with OPC UA server on PC.

	10 users	20 users	30 users
Execution time	20.87[s]	21.02[s]	21.30[s]
Count of MQTT publishing	639.8	588.4	412.4
Frequency of MQTT publishing	33.1[s^{-1}]	28.0[s^{-1}]	19.4[s^{-1}]

(b) Results with OPC UA server on PLC.

	10 users	20 users	30 users
Execution time	20.85[s]	20.90[s]	--
Count of MQTT publishing	661.0	610.0	--
Frequency of MQTT publishing	31.7[s^{-1}]	29.2[s^{-1}]	--

5. CONCLUSION

In this paper, a case study of data acquisition from field devices using OPC UA and MQTT through gateway device is shown.

In the first case, OPC UA server and MQTT broker run in different computers. In the second case, we use the OPC UA server built in PLC and MQTT broker run in a computer different from PLC.

From both cases, it is found that SCARA robot can be controlled by the data taken through a gateway device from OPC UA server. The angles of servo motors in SCARA robot were published by MQTT and distributed to subscribers by the broker. It means that the motion of SCARA robot can be monitored by MQTT.

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