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Implementation of DDS Cloud Platform for Real-time Data Acquisition of Sensors

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***Abstract*—The Industry 4.0 (I4.0) is a multi-disciplinary engineering by combing the IoT, big data, and cloud computing to cope well with the dynamic changing industry. In this paper, the DDS (Data distribution service) communication protocol is employed to implement a cloud platform for data acquisition of various sensors including accelerometer, sound, temperature, brightness, and humility, etc. The sensor signals acquired by the ESP32 microcontroller (MCU) are collected by the Raspberry Pi serving as the edge device and then published with the DDS application to the cloud and stored to the MySQL database. With the Django web server, the sensor signals acquired are real-time shown on the webpage. It is expected that the proposed DDS cloud platform can be applied to a legacy machine to enable sensing and communication abilities such that the development of smart machine is achievable.**

***Keywords*—DDS, MQTT, IoT, Cloud Computing, Monitoring**

I. Introduction

The Industry 4.0 (I4.0) that can cope well with the dynamic changing production is believed with a revolutionist impact to the manufacture industry. In factory, to meet the requirement of the I4.0 production, one of the fundamental tasks is to employ smart machines to achieve smart manufacturing. Currently, however, most legacy machines have been already equipped for usual productions, the legacy machine having additional sensing and communication abilities raises much interests in practical applications.

To enable communication ability among various brands of legacy machines, a common communication protocol is required. A suitable protocol can improve the overall flexibility and adaptability of the production line equipped with different smart machines. Profanter et al. compared the transmission performances among different protocols of OPC UA (OPC Unified Architecture), DDS, ROS(Robot operating system), and MQTT(Message queuing telemetry transport [1, 2019]. Trunzer et al. proposed five characteristic indexes (R1-R5) for evaluating different protocols [2, 2020], in which the DDS features comparable performance to the OPC UA but with higher configurability (R5).

In this paper, the DDS communication protocol is employed to implement a cloud platform for data acquisition of various sensors, which can be mounted to a legacy machine to develop a smart machine.

II. Platform Design

A. DDS

The DDS is a decentralized messaging protocol. It uses the concept of the global data space or domain for data transmission. The DDS domain is implemented by various DDS applications, which can communicate with each other if they share the same domain. Every node in the domain can publish and subscribe a specific topic for message exchange. During exchanging process, the node and its topic can be specified by their own QoS (Quality of service) according to the characteristics of the message or data. Through the use of the QoS, we can alter the attribute of the message transmission. Fig. 1 depicts a typical diagram for the concept of messages exchanges via the DDS protocol.

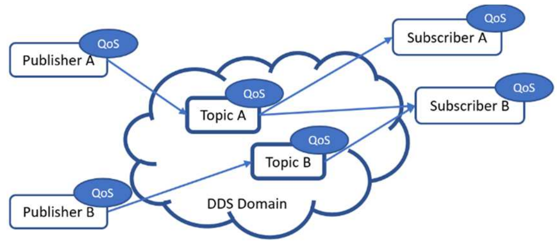

Fig. 1. The logic of DDS protocol for messaging

In the proposed DDS framework, the DDS applications are executed on both the edge device and web server in the same DDS domain. Benefiting from the DDS advantages on decentralized and real-time characteristics, the proposed system features flexible, distributable, and reconfigurable. It is suitable for the applications to the production lines and factories for real-time monitoring the sensors.

B. Platform Architecture

Fig. 2 shows the proposed cloud platform mainly consisting of the Sensing module (SM), DDS domain, Database (DB), and Monitoring server (MS). The control panel in the MS is implemented by the Django web framework with async channels techniques. The website provides the web socket protocol for real-time monitoring the data from the SM. It also provides an interface for querying the historical data stored in the DB.

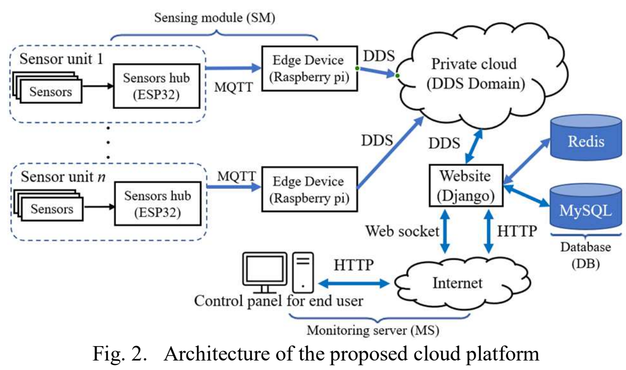

Fig. 2. Architecture of the proposed cloud platform

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C. Sensing module (SM)

The SM is an independent unit including the sensor group (SG), a sensor hub (SH) and an edge device. It can be freely joined or removed from the DDS domain. Once it is joined, the DDS application being executed on the edge device will acquire the data from the SH via the MQTT, filter the data, and then publish the filtered data to the DDS domain with specific topics. The edge device connected to the wireless LAN are not accessible from the Internet.

D. Messaging between SM and Server via DDS

In practical, the platform may have more than one SM. In this study, the SM is based on a Raspberry Pi. Each Raspberry Pi runs the DDS application serving as the Sensor Publish Agent for publishing the acquired data, and the MS executes another DDS application serving as a Subscribe Agent for subscription.

The Sensor Publish Agent is to use the MQTT-DDS mediate application. It acquires the sensor data via the MQTT topics and publishes the specified topics to the DDS domain. On the other hand, the Subscribe Agent of MS is another DDS application for receiving the data with the specified DDS topics. The received information is then stored into MySQL databases, and the web's charts are updated accordingly.

III. System Implementation and Results

A. Implemented Platform

Fig. 3 shows the data flow of the implemented cloud platform including the sensors' input signals, the transmission protocols of MQTT, DDS, MySQL database, and browser, etc. The DDS's framework used is the RTI's Connext. A microcontroller (MCU) having the 802.11 Wi-Fi connectivity and UART/GPIO/ADC/I2C for I/O communication abilities was responsible for collecting the data from the sensors and publishing the data with specified topics via the MQTT. A Raspberry Pi 3B+ was used as the edge device of the SM.

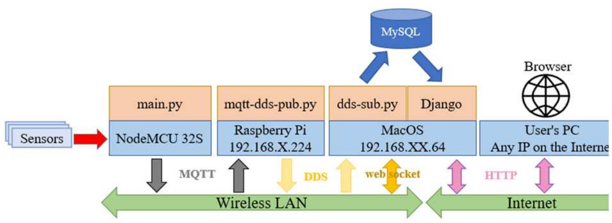

Fig. 3. Data flow and main components of the implemented system

B. Sensor Group

Fig. 4 shows the main components of the SG. Four different sensors were used to demonstrate the function of the implemented platform. A ESP32 based MCU NodeMCU 32S was used to connect to the sensors. The programming language executed on the NodeMCU is MicroPython v1.15.

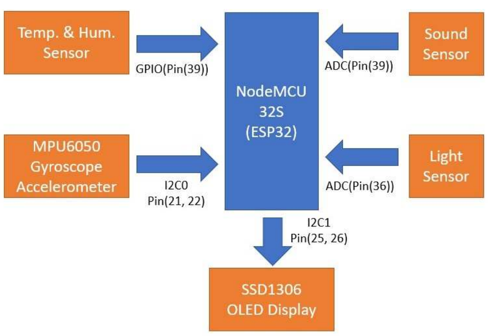

Fig. 4. The connections between NodeMCU and sensors

C. DDS Topic

To implement the DDS applications, it is required to assign the type of topic and specify the related domain settings, which are the XML based documents. A part of the settings in the sensor.xml is shown in Fig. 5 as the follows:

```
<types>
  <struct name="SensorType" extensibility="extensible">
    <member name="station" stringMaxLength="20" type="string" key="true"/>
    <member name="temperature" type="float64"/>
    <member name="humidity" type="float64"/>
    <member name="sound" type="long"/>
    <member name="light" type="long"/>
    <member name='acx' type="long"/>
     <member name='acy' type="long"/>
    <member name='acz' type="long"/>
  </struct>
</types>
```

Fig. 5. The topics expressed in sensor.xml

As appeared in the sensor.xml, the "station" is used to represent the SM, which is expected to be integrated to a production line or a smart machine. The other expressions indicate the names of sensors and types of data.

D. Acquired Information of Sensors

Fig. 6 shows the real-time monitoring charts captured from the DDS topics, including the sound and the signals of the X, Y, Z-axis from the accelerometer. However, actual physical quantities and units are to be determined in later approaches, also, the signals of temperature, humility, and light are not shown in the figure. Through the charts, the function of the implemented cloud platform has been demonstrated.

Fig. 6. Screen shot of monitoring charts from the implemented web site

IV. Conclusion

In this study, a cloud platform based on the DDS protocol was implemented. Several sensors were used to demonstrate the function of real-time data acquisition. Future works are to examine the transmission performances, and actual applications to legacy machines to enable communication abilities are expected.

References

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