Unified Management and Control of Heterogeneous Water Quality Measuring Devices via Edge Computing Nodes

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***Abstract*—To integrate different types of devices around Erhai, China, a three layer architecture is introduced. Edge computing nodes are inserted between the server system and the end devices. A metadata model is proposed to unify the representation of devices, measurement and the interactive message between the web services and devices. The edge nodes firstly function as translator between the web services and the end devices. Moreover, smart control functions, such as device starting safety and abnormality detection, are added. One year running demonstrates that the architecture is scalable and relative easy for the new devices to join it.**

***Index Terms*—edge computing; water quality measuring device; metadata; abnormality**

I. INTRODUCTION

The surfaces of a number of lakes and rivers in China have worsened over time [1]. Various types of water quality measuring devices have been produced for water protection [2]. For example, there are six major types of water quality monitoring systems that were deployed around Erhai, Yunnan, China. Each system that consists of data acquisition devices and data servers operates independently. These closed systems block the data to be shared and efficiently used in Erhai water environment monitoring and research. On the demand of the local government, a platform should be built to provide unified data and information services.

The architectures for aggregating data from the distributed nodes can be classified into centralized, distributed and P2P architectures [3]. Considering scalability and efficiency, the distributed architecture is the best choice. The emerging edge computing brings the computing capabilities close to distributed data nodes [4]. Smart controlling and managing end devices, raw data processing can be implemented in the edge computing nodes, named edge nodes. Compared with the cloud centralized architecture, the edge computing not only reduces the dependence on network, but also increases response rate to the emergency close to the end devices.

We propose an architecture for managing and controlling the water quality measuring devices around Erhai in a uniform mode. An edge node was added to a station that contained 3 or 5 devices. The newly added edge nodes act mainly as translator between the web services and the end devices. The uniform data and commands between the web server and the edge nodes are translated into that of the devices. Some function modules, such as detecting the abnormality of devices and the abnormal measuring data, adjusting the sampling period, and avoiding multi-task conflict, have also been added in the edge nodes. In this paper, Section I is introduction. The architecture for integrating heterogeneous water quality measuring devices is presented in Section II. Conclusion is given in Section III.

II. INTEGRATION OF THE DISTRIBUTED WATER QUALITY MEASURING DEVICES BASED ON EDGE NODES

Fig.1 shows a three-layer architecture for unified control and management of the distributed water quality measuring devices by inserting edge nodes. From bottom to top, there are device layer, edge layer and service layer.

A. Function of Each Layer

The water quality measuring devices provided by different manufactories belong to device layer. We divided the devices around Erhai into two categories, controllable and readable. Controllable devices can be operated through the communication channel and the defined communication protocol, such as online analyzers of Hach. So, remote controlling and managing these devices via Internet can be implemented. Readable devices just provide data output. No data input from communication channel is permitted, such as early products of Modi-tech in Hangzhou, China. It is impossible to control these readable devices through Internet.

The edge layer is added between the distributed devices and the web server system that is composed of several servers. The edge nodes of the edge layer not only function as translators, but also have the priority to deal with the device abnormality without the instruction from the web services. A water quality

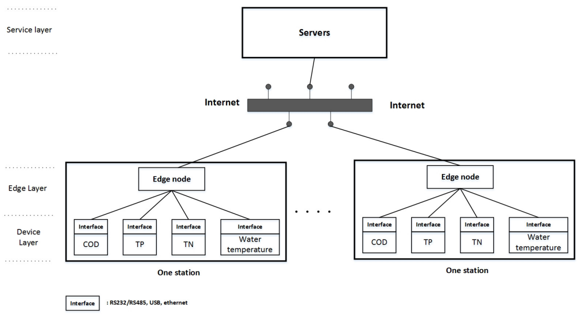

Fig. 1. Architecture for heterogeneous devices integration

measuring device metadata model is proposed to unify the description of the device properties, the device operating state, the measuring data, and the interactive command between the web services and the edge nodes. The data read from the devices are repackaged in JSON format according to the metadata. The command from the web service or from the decision module of the edge node is translated to the command of the device. Applying the edge nodes, no matter how many devices will be deployed, they can be integrated into the web services without changing the data ingestion module and the command module of the service layer.

The service layer consists of a collection of web services, which are built on a cluster of servers. The web services are in charge of receiving data from the distributed edge nodes and sending commands and message to the edge nodes. It also provides unified graphical user interface (GUI) for users to interact with the end devices through edge nodes. The interactive information between the web service system and the edge nodes follows exactly the metadata model.

B. The Metadata Model of Water Quality Measuring Devices

The four metadata components shown in Fig.2 epitomize the common attributes of water quality measuring devices.

- DeviceInfo information describes the attributes of water quality measuring devices. DeviceNum is the device type number that corresponds to the MeasureParameter. For example, if the device measures the total phosphorus (TP), then, MeasureParameter is TP, and DeviceNum is 1. DeviceInterface denotes the physical interface between edge node and the devices. DeviceProtocol descrbes the communication protocol.
- LocationInfo represents the geographical position of the water quality measuring station. ZoneCode is the code of administrative region in China. StationNum is the number of a station in a region. ZoneCode, StationNum, plus DeviceNum denotes a device within China, and they form DeviceID. GeoLocation is composed of LongiDirection, Longitude, LatiDirection, Latitude, and Elevation, which denotes geolocation.
- Measurement represents one measurement information. Each item of Measurement, plus DeviceID and GeoLocation are stored in the database of the edge node for one month. MeasureTime and ResultTime are set to represent the start-time and stop-time of one measurement respectively. As soon as the edge node gets MeasureValue, it reads GeoLocation from GPS receiver. If MeasureValue is out of MeasureRange, IsOutRange is true. If the Internet connection between the edge node and the server system is normal, the record which IsTransmitted is false will be sent to the server system.
- DeviceState describes the device state. The state is divided into two types, DevState and DevWorkState. DevState includes five type states, such as normality, error, alarm, debugging, checking. DevWorkState includes five working states, such as not working, measuring, calibrating, cleaning, initializing. The edge node reads DevState from device. If DevState is normality, IsDevOk is set as true. If DevState is alarm, IsAlarm is set as true. Then, the edge node sends a request to the device to get the AlarmNum. The edge node translates AlarmNum into AlarmName according the product instruction. DeviceState is the important information for smart control of the devices and efficient device maintenance.

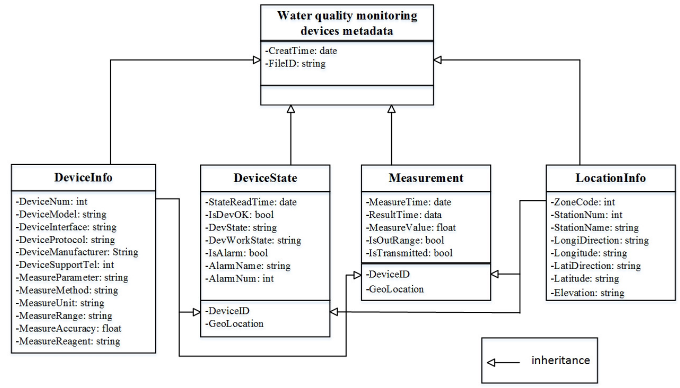

Fig. 2. Metadata model

C. Smart Controlling Devices Through Edge Nodes

The edge node has three major functions. First, the data defined by the manufacturer are reorganized in terms of the metadata model. DeviceInfo mainly comes from the product instruction. DeviceState and Measurement information are obtained through the online interaction with the device. The physical interface between the edge node and a device may be RS485, RS 232, or network interface.

Second, security scheme is built to assure starting measurement successfully. When the measurement time is up, IsDevOk is read. If IsDevOk is true, then, DevWorkState is read. If DevWorkState is not working, the command to start measurement will be sent from the edge node to the device.

Third, one month measurement results are stored in the edge nodes. The stored data are not only used as a backup of the server system, but also used to detect abnormality. When a measurement is started, the mean and deviation of the previous data will be computed. If the difference between the new generated value and the mean exceeds three times

(a) edge node

(b) TP, TN and COD monitoring devices of one station

Fig. 3. Edge node and devices picture

(a) Device state on web page

(b) Measurement data on web page

Fig. 4. Web page of device state and measurement

of deviation, the new value is labeled abnormality. Then, the cycles of water quality measurement will be doubled.

D. Case Study

We used a development board named super Raspberry Pi to construct the edge node. The CPU of the development board is I.MX6Q which is produced by Freescale Semiconductor. Ubuntu 12.04 is the operating system. The GUI, API and all the function modules are developed based on QT/embedded-4.5. The database is created using SQLite.

The server system is composed of two server. One server is used to ingest the information that come from the distributed edge nodes, and it also functions as data warehouse. The other provides web page for users scanning the measurement data and the device state.

We have set six edge nodes around Erhai, one edge node for one station. Each station has three water quality measuring devices which measure TP, TN and COD respectively. The devices of four stations were produced by Raiking Corporation, Suzhou, Jiangsu. The devices of the other two stations were made by Modi-tech in Hangzhou, Zhejiang, China. Fig.3 shows an edge node and three devices. Fig.4 is the web page. The measurements and device states can be seen from the web site (http://202.114.107.177:9005/Wsnyn/login.jsp).

III. Conclusion

We have introduced a three-layer architecture to integrate different kinds of water quality measuring devices. Edge nodes are inserted between the server layer and device layer. A metadata model is proposed for unified description of devices, measurement and interactive message between the server system and the devices. Heterogeneous expression related to the devices is translated into a uniform mode by the edge nodes. Moreover, smart control functions, such as device starting safety and abnormality detection, are also added to the edge nodes. The architecture has been run for one year. The proposed technical solution has been accepted by the local government. Further, the devices of other thirty-one stations will be integrated into our framework.

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