Sensor/Actuator Management Platform Technology Contributing to Environmental Load Reduction

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Abstract

The recent increase in the deployment of systems consisted of sensors and actuators has raised expectations for services that can contribute by their use to a reduction in the amount of unacceptable environmental loads. For the present, however, systems that can suitably support such services need to be deployed by optimizing each system according to the sensors and actuators that are used. The consequent high cost is tending to hinder the dissemination of such services. To deal with this situation, NEC is advancing R&D of management platform technologies that can reduce the deployment cost of this kind of service. This paper describes the recently developed technologies and their standardization and supporting activities.

In addition, this paper also introduces an outline of a verification experiment demonstration performed at a convenience store chain.

Keywords

environmental load reduction, sensor and actuator, remote management, provisioning

1. Introduction

As various sensors and actuators are recently being deployed for a variety of purposes in houses, offices, factories, public facilities, outdoor fields, etc., it is expected to deploy services which contribute the reduction of environmental loads by making use of such devices.

Nevertheless, the service providers of such environmental services are required to build an optimum system for each individual case according to the functions and communication protocols of the deployed sensors/actuators. This requirement leads to a high cost burden, which is one of the factors hindering the dissemination of this kind of service. This situation could be overcome by developing a system that features standardized functions and interfaces for facilitating the deployment of the various sensors and actuators.

We have defined a management system architecture aimed at reducing the burden of service providers, conducted R&D into management platform technologies that can facilitate the introduction of various sensors/actuators, and are promoting and extracting the standardization of functional elements.

This paper describes the technologies that have been researched and developed up to the present time together with an outline of a verification experiment by selecting a convenience store chain as a suitable site for a demonstration of the environmental load reduction effect. In addition, this paper will also review the standardization trends that are associated with the developed technologies and the associated promotional activities that are being conducted to support them.

2. Management System Architecture

We have defined a management system architecture that aims to reduce the burden for the service providers. **Fig. 1** shows the architecture, which is composed of sensors/actuators, gateway, management platform and service provider. The

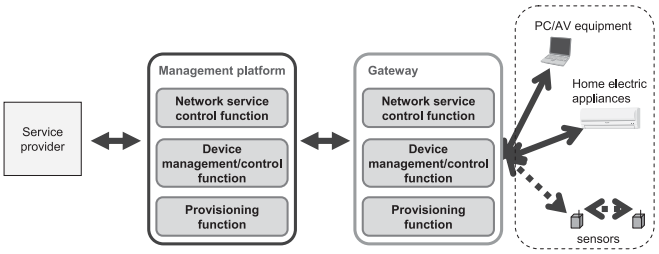

Fig. 1 Management system architecture.

gateway and management platform implements the functions described below based on their linkages.

2.1 Network Service Control Function

This function collects and manages data from the sensors/actuators supporting various communication protocols and distributes the data according to the requirements of the service provider. This function also provides the service providers with the interface to access the sensors/actuators.

2.2 Device Management/Control Function

This function remotely manages the installed sensors/actuators and their networks.

2.3 Provisioning Function

This function deploys only those functions that are necessary for providing services using the sensors/actuators.

3. Technical Issues of the Management System Architecture

The functions of the management system architecture are accompanied by issues associated with the management platform as described below.

3.1 Issues of the Network Service Control Function

The cost of data collection from sensors/actuators would be very high if the service provider deals individually with the differences in data format and communication protocol between sensors/actuators. Therefore, the definition of a universal interface and the selection of a communication protocol become essentially important topics.

Another issue is related to the access from the service provider to the sensors/actuators. If a system is developed considering the communication address of each sensor/actuator, the burden on the service provider becomes a heavy one. To prevent this, it is required to implement an address management system that can facilitate access of the service provider to the sensors/actuators.

Finally, since reception and management of a large amount of data from the sensors/actuators is expected, it is also required to reserve scalability of the data reception process.

3.2 Issues of the Device Management/Control Function

The management information from the sensors/actuators varies because of the differences in their management protocols installed. This means that cost would be increased if the different protocols were dealt with individually in order to achieve the desired functions. To prevent this, it is required to select a common management protocol and to develop a universal model for the management platform.

3.3 Issues of the Provisioning Function

To promote services that accompany the use of sensors/actuators (hereinafter referred to as the device-based services), the gateway that relays communications between the various devices and the service provider should incorporate facilities for supporting a large variety of devices and services. Specifically, this should include driver software for the devices and service software for the service provider.

On the other hand, the gateways that may be purchased by ordinary users would be limited in their computation and memory capabilities due to their low costs, etc. Therefore, it is not desirable to deploy software in the gateway in advance that is aimed at the provision of various device-based services.

Consequently, the issue here becomes how to deploy software dynamically in the gateway according to the connected devices and provided services.

4. Technologies Developed in Association with the Management Platform

Aiming at the dissemination of management system architectures, we have developed technologies for solving the issues related to the management platform described in section 3 above. These technologies are discussed in the following.

4.1 Network Service Control Function

In order to handle variations, we defined the message formats including the device types of the sensors/actuators. Considering that the IETF (Internet Engineering Task Force) and ETSI (European Telecommunications Standards Institute) are researching http protocol-based technologies for the M2M communications to which the sensors/actuators belong, we decided to adopt the http protocol for the communications between the gateway and management platform.

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With regard to the address management system used in accessing the sensors/actuators, we developed a function for managing the collection of information. This includes the address information that is requested by the service provider in the management platform and the address information of devices that is acquired for the remote management of the sensors/actuators. It is this function that allows the service provider to access the sensors/actuators.

For the data collection from a large quantity of sensors/actuators, we developed a data collection function based on distributed parallel processing to support the efficient reception of the large amount of sensor data transmitted from several gateways while at the same time ensuring scalability.

4.2 Device Management/Control Function

For the remote management technology, the BBF (Broadband Forum) has defined the TR-069 protocol [1] for the remote management of devices including gateways. In the remote management system based on TR-069, the server installed outside the network, called the ACS (Auto-Configuration Server), manages the gateways and other devices remotely.

Additionally, in order to enable the remote management of devices that do not support TR-069 (non TR-069 devices), the BBF is also promoting standardization of a remote management function that uses TR-069 supporting devices as relays. The non TR-069 devices include those equipped with ZigBee and Z-Wave that are well known as standard protocols used by sensor devices.

As the ZigBee devices are expected to disseminate widely in the future, we developed the technology for the ZigBee device management/control function. **Fig. 2** shows an outline of the developed technology and the scheme for the remote management of the ZigBee devices by the ACS.

The developed gateway uses a management function called "ZDO" of the ZigBee devices to exchange management messages with ZigBee devices and perform conversion between the management messages of the ZDO and those of TR-069. The ZigBee driver incorporated in the gateway detects the connection of a ZigBee device and acquires the device information using the ZDO function. The acquired device information is handed to the proxy function that incorporates the message conversion function and the message is converted from the ZDO format to the TR-069 format. The converted message is handed to the TR-069 client that performs actual communication with the ACS and is then sent to the ACS. The message handling and conversion are processed

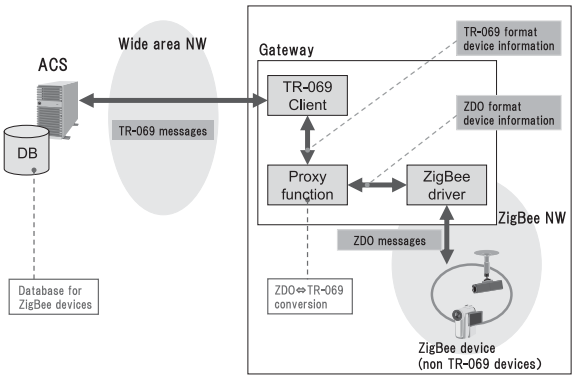

Fig. 2 Outline of the device management/control function.

bi-directionally so that bi-directional communications are possible between the ACS and ZigBee devices.

The message conversion function of the gateway allows the ACS to remotely manage the ZigBee devices. For instance, the ACS can acquire the routing information, manufacturer codes, remaining battery power and radio wave intensities of the ZigBee devices. Particularly, the routing information can be used to manage information on the topology of the ZigBee network.

4.3 Provisioning Function

The OSGi Alliance defined the "bundle," which is the plug-in software running on the Java platform, and the platform for the bundles. The bundles can activate their own functions as required.

With reference to the features mentioned above, we developed a provisioning function that can activate bundles automatically at the time of a device connection. Since the bundles can be plugged in, they are optimum for use as software on the gateway. An example of operation in which a service is automatically made available by the connection of a device is shown in **Fig. 3** .

When a device is connected, the provisioning function in the gateway selects the bundles required by the device and requests the bundle manager of the provisioning function in the management platform to distribute the bundles. This process adopts the following steps.

(1) The device management/control function in the gateway detects the connection of a device and acquires the device information.

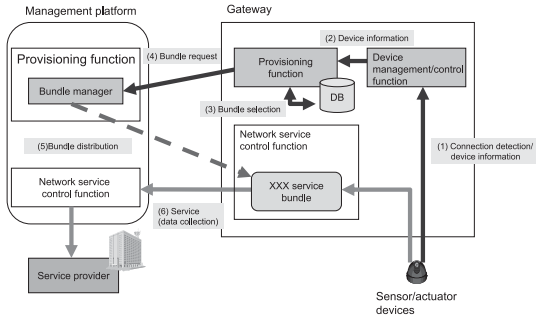

Fig. 3 Example of a provisioning operation.

(2) The same device management/control function notifies the provisioning function in the gateway of the acquired device information.

(3) The same provisioning function selects the required bundles from the database consisted of the device information.

(4) The same provisioning function requests the bundle manager in the management platform to distribute the selected bundles.

(5) The bundle manager above distributes the bundles to the gateway.

(6) The service provider communicates with the device by means of the network service control function and the distributed bundles, and provides the service for the user.

The provisioning function can solve issues related to gateway resources and those related to the support of various device-based services. Furthermore, it also enables general users to use the various device-based services automatically after the device connection. For example, when a sensor device is connected to the gateway, the sensor data is delivered automatically to the optimum data analysis service provider and the results of data analysis may then be received from this source.

5. Verification Demonstration of a Convenience Store Chain

We are currently verifying the developed functions and monitoring the resulting environmental load of a convenience store chain.

5.1 Verification System Configuration

In conducting the test for verifying the developed technologies and their environmental load reduction effects, we

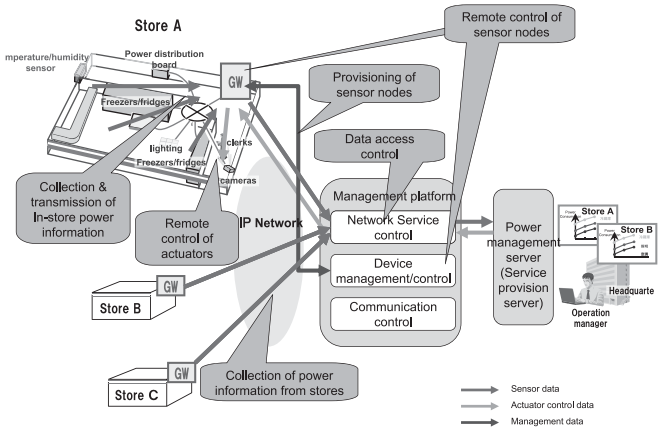

Fig. 4 Test bed system configuration.

selected a convenience store chain as a suitable test environment. This was because the recent increase in the number of such stores has made it necessary for the chain management to decrease the environmental load of the stores by improving their operations (**Fig. 4**).

The test system installs sensors and cameras in the stores and collects data on the temperature/humidity measurements and power consumption of the store equipment such as refrigerators and air conditioners as well as data compiled based on the clerks' actions and equipment operating status of the management platform. The collected data is sent to the power management server of the service provider. The power management server provides a service that makes it possible to confirm the power consumption situation in each store based on the integrated management of the power consumption and operating status of store equipment. In addition, the power management server is also capable of remote control of cameras and similar equipment in the stores via the management platform as may be required.

5.2 Verification Details

We are thus able to verify the possibility of reducing the environmental load by improving the store operations based on the integrated operations of the developed functions. More specifically, we can confirm that a service that collects the power consumption measurements and temperature/humidity information of stores and enables monitoring from a remote location such as the franchise headquarters can effectively reduce the environmental load. At the same time, the test result also verifies the operational quality of the developed func-

tions. The details of the verifications are as follows.

- **Network service control function**

The efficient collection of the various data that deals with the temperature/humidity and power consumption and the transmission of the collected data to the power management server.

- **Device management/control function**

Management of the topology status, etc. of the sensor devices, and the possibilities of checking the service continuity and adopting countermeasures to deal with issues arising during service.

- **Provisioning function**

Distribution and deployment in the gateway of the bundles required for remote control according to the connection of equipment such as cameras.

6. Standardization of Verification Technologies

- **Device management/control function**

The BBF has started discussions on energy saving and is currently studying standardizations related to various sensors/actuators. In this study, we are proposing the adoption of the ZigBee device-compatible management message conversion technology that we have developed in the PD-174 standard.

We have also begun proposals for the ZigBee data models.

- **Provisioning function**

As for standardization of the provisioning function, we are proposing an API for accessing ZigBee devices as one of standardized bundle APIs to the OSGi Alliance.

7. Conclusion

With regard to the R&D described above, we have elaborated a system management architecture aimed at promoting the dissemination of environmental services using sensors/actuators. We have also proposed management platform technologies equipped with functions and interfaces for facilitating introduction of various sensors/actuators. The proposed technologies have been implemented and we are currently performing a verification experiment demonstration at a convenience store chain. In this experiment, we also analyze the power consumption and temperature/humidity information acquired from the tested stores in order to verify the environmental load reduction effects of the system. We are also verifying the management platform technologies and advancing studies for standardization of a remote sensor/actuator management technology and a provisioning technology.

The technologies proposed above are capable of providing a wide range of environmental services at low cost. Therefore, it is expected that they will contribute effectively to the dissemination of environmental services in the future.

8. Acknowledgement

R&D presented in this paper is partially supported by the project of "Promotion of standardization of integrated network management system" funded by the Japanese Ministry of Internal Affairs and Communications.

*ZigBee is a registered trademark of ZigBee Alliance.

*Z-Wave is a registered trademark of Sigma Designs, Inc.

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