Network Technology for a Smart Community

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The concept of a "smart community" is attracting attention as a means of achieving a regional energy management system (EMS) that connects houses and public/commercial facilities along with their air conditioning, lighting, and other electronic devices to a network. However, connecting diverse devices to a network presents two challenging problems. One is the mixture of device/industry-specific communication standards, which makes it difficult to connect the devices to a single network. The other is the lack of a WAN communication protocol that can establish a link to the on-premise LAN that interconnects devices, which makes it difficult to seamlessly connect the server in the cloud to premise devices. In response to these problems, Fujitsu has created a function for normalizing the differences in device communication standards and a gateway function to enable the normalized device data format to be commonly handled in both LANs and WANs. These functions make it possible for service providers to develop services using a uniform and straightforward device control interface without having to worry about different communication standards. Fujitsu has commercialized these functions in the form of a smart sensing platform (SSPF) and has shown them to be effective in simplifying and streamlining the service development process through a home energy management system (HEMS) experiment.

1. Introduction

"Smart community" is often used to describe a social system that makes maximum use of renewable energy such as solar and wind power while minimizing the consumption of energy. For example, the amount of electricity that natural sources of energy like solar and wind power can generate is easily affected by the weather, which means that a smart community will need adjustment functions to absorb such fluctuations in generated power. We thus define the word "smart" in this paper as the ability to

1) understand environmental and human conditions, and
2) perform operations while adjusting to those conditions.

A smart community should therefore be able to determine the present conditions of the residents and to achieve efficient energy use on the basis of those conditions. Moreover, the process of obtaining a detailed understanding of community conditions should lead to services that provide safety and security to the residents. In short, we see technology for achieving a smart community as the next social infrastructure and view energy as the door to that development.

To create a smart community, we need to make the constituent elements of the community "smart." Here, we consider the buildings that make up the community to be its elements (i.e., smallest units). We have been studying smart communities from the viewpoint of giving homes, office complexes, and retail shops as well as public facilities likes schools and hospitals smart characteristics. In this paper, we focus on homes as one example of community buildings and present network technology for achieving a home energy management system (HEMS). We explain why such technology is needed, present requirements to be satisfied and problems to be solved, and describe Fujitsu's approach to developing and implementing this technology.

2. Network technology for HEMS

The need to limit power consumption has become an issue of particular urgency in Japan due to the disastrous earthquake of 2011. Power consumption in the home can be made more efficient through the achievement of an HEMS, which forms a network interconnecting home electronic equipment like air conditioners and lighting, energy-creation devices like solar cells, and energy-storage devices like storage batteries.

An HEMS makes it possible to keep power consumption in the home below a previously set value while the occupants go about their normal daily lives. Moreover, in conjunction with a community energy management system (CEMS), it enables the pooling of power among homes, schools, retail shops, etc., meaning that they can share power with each other whenever one of them lacks sufficient power. As a result of controlling energy use, an HEMS obtains information about the behavior of the occupants and about the indoor environment. It can use this information to control such actions as automatically turning off the air conditioning and lighting after the occupants have left the home.

Achievement of an HEMS requires that premise devices be connected to an energy-management service, which means that two requirements must be satisfied.

1) All devices and fixtures must be connected to the same network.

Home devices of all types (sensors, electrical appliances, energy-creation and energy-storage devices, etc.) and all electrically driven home fixtures must be connected to a single network. Physical connection media and communication protocols, which differ in accordance with device type and vendor, must all be accommodated to achieve seamless connections.

2) The HEMS must be connected to the cloud.

The HEMS must be connected to the cloud so that it can communicate with other systems such as a CEMS. This enables energy usage to be managed at the community level.

When setting out to manage a community's energy usage, the question arises as to how to implement each building's energy management system (EMS) such as an HEMS or building energy management system (BEMS). There are two basic approaches. One is to implement an EMS in each building and to manage them by using a cloud-based CEMS. The other is to have the EMSs run as applications in the cloud and to have each EMS interface with the cloud-based CEMS. We have taken the latter approach because it can be achieved with a single architecture that manages all home devices from the cloud.

If device management functions are implemented in the cloud in this way, the only piece of equipment that need be installed in the home is a gateway (GW) for consolidating the connections to home devices. This eliminates the need for installing high-priced HEMS on-site controller equipment in the home, thereby reducing costs. It also makes for more efficient operations by enabling HEMS applications to be updated and maintained remotely. Finally, it simplifies the development of a mechanism for pooling power between homes as touched upon earlier by enabling power-related information for multiple buildings to be managed from the cloud. For these reasons, the best approach is to implement HEMS services in the cloud and to control home devices from the cloud.

3. Problems in cloud/device connection over a network

In the previous section, we described two requirements for achieving an HEMS, but satisfying these requirements requires that the following problems be solved.

1) Mixture of communication standards among devices

Recent years have seen a proliferation of home devices with all sorts of communication interfaces. This development has fueled an increase in the number of interface products for the purpose of interconnecting and remotely controlling those devices, from home electronic equipment like air conditioners, lighting, and televisions to energy-creation and energy-storage devices like solar cells, storage batteries, and fuel cells. However, while it can be said that these devices follow industry communication standards in a broad sense, they may also include detailed portions that follow proprietary specifications of the device vendors. To therefore connect devices following different communication standards to the same network, a function is needed to convert the communication protocol and data format of each home device to a normalized format. At present, applications are developed to fit device specifications, but doing so each time a new device is added to a system entails additional cost. This cost is an obstacle to market entry for service providers.

Unified specifications that have already been standardized on an industry level include ECHONET Lite[1] for home appliance systems, Continua Healthcare Alliance (CHA)[2] for health device systems, and Digital Living Network Alliance (DLNA)[3] for audio-visual (AV) device systems (**Figure 1**). However, these are industry-specific standards, which means that the problem of establishing mutual connections still remains when connecting multiple devices belonging to different industries to the same network. In short, the fact that communication standards differ from one device to another presents a major problem to connecting home devices to a single network.

2) Seamless connections between cloud and home devices

The plan for controlling home devices from the cloud is to have a server in the cloud connect to those devices via a wide area network (WAN), a GW that consolidates the devices, and a local area network (LAN) in the home (Figure 1). However, the communication standards described for a building network described in 1) above include security settings for routers in that network, which prevents communications from being directly performed with the WAN. It is consequently essential that support be provided for security measures and network address translation (NAT) to enable device information to be exchanged with the WAN.

Premise devices can be managed from the cloud by using a protocol like TR-069 specified by the Broadband Forum or by using the Device Management (DM) protocol specified by the Open Mobile Alliance (OMA). These protocols were created for use over the Internet and were designed to prevent security problems. In addition, these protocols specify a general-purpose data format for transmitting device property information described in Extensible Markup Language (XML), and this data format can support the data formats for the protocols described in 1) above. Since a major objective of these protocols is to change device settings remotely, the communication procedures can be somewhat complicated and numerous. A simple communication method such as HTTP should thus be used in combination with these protocols to convey information from devices and especially sensors installed in a building.

We have described two key problems in connecting home devices to the cloud over a network. In the next section, we present an overview of standardization trends related to these problems.

4. Trends in standardization

Since a variety of service operators will be participating in the operation of a smart community, standardization is an absolute necessity, especially for communication specifications. We thus focus here on the activities of the Focus Group on Smart Grid (FG Smart), which conducted studies from June 2010 to December 2011 under the control of the ITU Telecommunication Standardization Sector (ITU-T).[4]

The studies had a broad scope, ranging from power plants to end users (consumers) and, more specifically, from power transmission, delivery, management, and maintenance to power markets and service providers. This scope reflects well the situation in the United States, where a large number of power companies operate within a single country, and that in Europe, where consumers connect to power networks spanning more than one country. Energy management

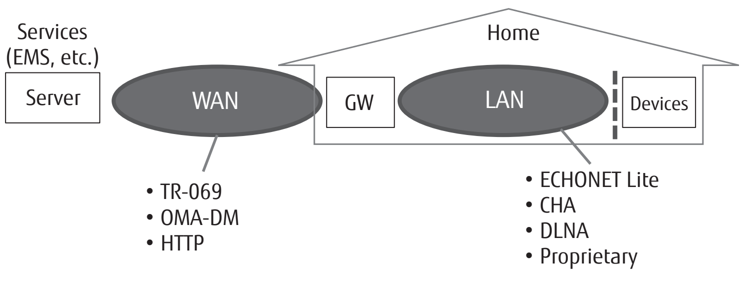

Figure 1
Mixture of communication standards.

on the consumer side as described in this paper deals only with the segment from a service provider to the consumer. However, that segment and its connection to smart meters were central to the discussions of FG Smart and are important from the viewpoint of establishing a communication standard.

Japanese representatives actively participated at FG Smart. Fujitsu, for example, proposed an architecture for achieving cloud-based energy management that reflects the results of discussions with Japanese companies in conjunction with the Network Integrated Control System Standardization Promotion project funded by the Ministry of Internal Affairs and Communications (MIC). A simple image of this architecture is shown in **Figure 2**. It consists of a GW connected to the premise devices, appliances, and sensors, a management platform (PF), and an intermediate PF. The management PF manages the connected devices, appliances, and sensors and provides a service interface for use by the service provider. The intermediate PF, placed between the management PF and service provider, analyzes the information obtained from the devices. Also included are four types of reference points, denoted as IF-1 to IF-4. Fujitsu was given responsibility for IF-3 and was therefore active in developing a method for integrating data formats in a LAN, developing communication schemes for conveying this integrated data over a WAN, and creating a service interface. Fujitsu was also charged with reporting on the FG-Smart deliverables. Fujitsu plans to continue making specific recommendations to the ITU-T.

5. Smart sensing platform (SSPF)

Fujitsu's SSPF[5] product announced in May 2012 consists of middleware functions for solving the two key problems described above and remotely managing and controlling devices installed within a building. Here we describe how we solved these problems.

1) Protocol-difference absorption function

The problem of vendor-specific differences in communication standards among devices was solved by developing a protocol-difference absorption function (**Figure 3**). The device data format in Fujitsu's SSPF conforms to the ECHONET Lite standard, which defines functions for almost all devices that can be installed in a home. Protocol-difference absorption as performed by this function draws a correspondence between originally defined functions found in each device and the functions defined by a single standard, namely, ECHONET Lite. In addition, the GW and management PF function in SSPF were developed in accordance with the Open Services Gateway initiative (OSGi) framework. As a result, difference-absorption rules for each device are implemented as bundles (i.e., Java programs that can be dynamically added or deleted). This approach provides important advantages: a bundle corresponding to a certain device to be connected can be automatically added and supported and the same service can be used even when new devices are purchased to replace older ones.

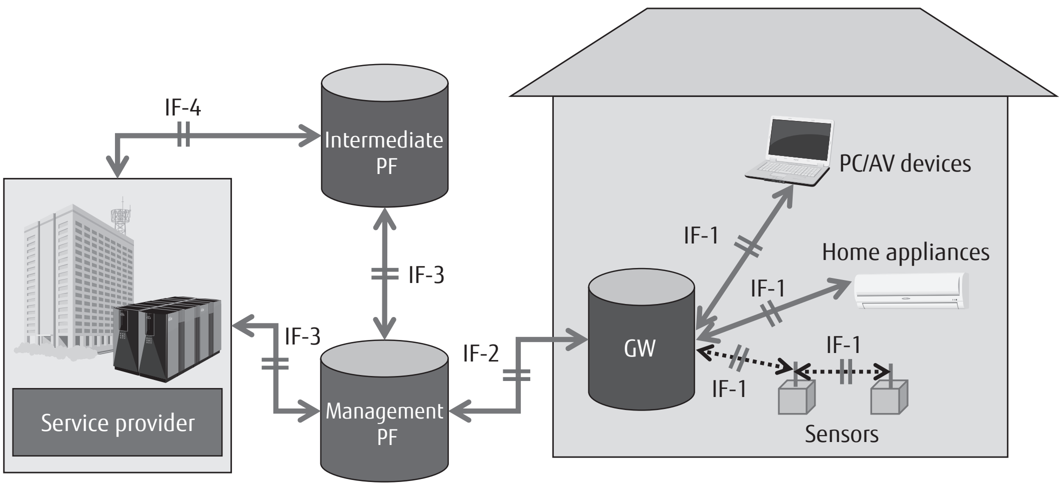

Figure 2
Architecture proposed for achieving cloud-based energy management.

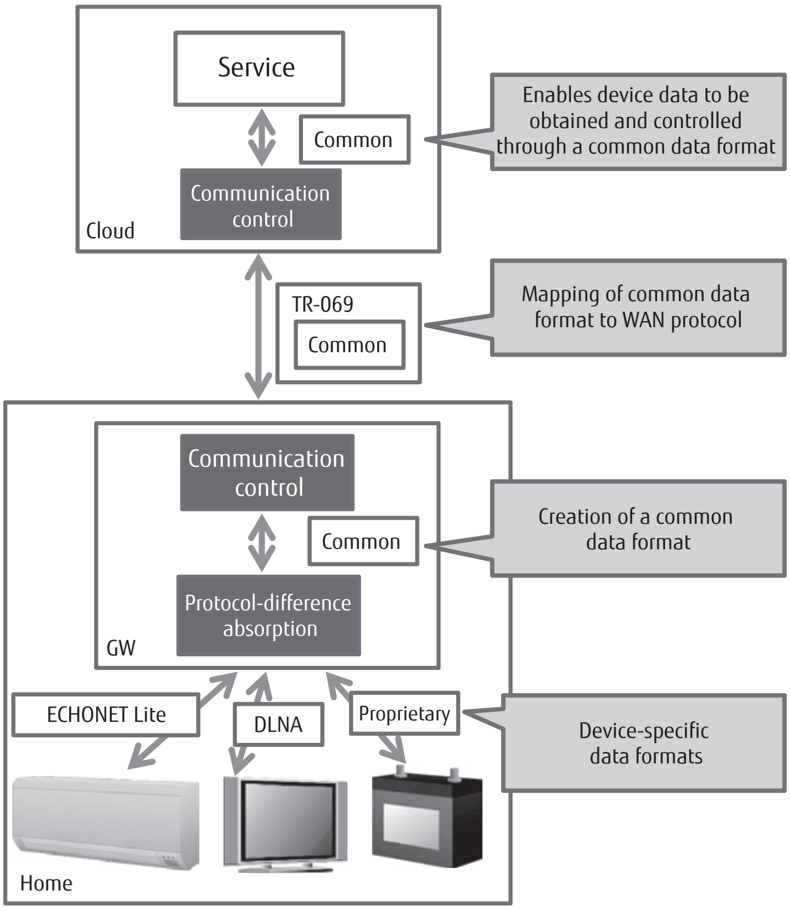

Figure 3
Protocol-difference absorption and communication control functions.

2) Communication control function

The problem of achieving seamless connections between the cloud and home devices was solved by developing a communication control function. It enables the protocol used for connecting devices within a building to be conveyed over the WAN. It does this by transforming the device data into XML format on the basis of the TR-069 protocol and then transferring that data to the management PF using HTTP/SOAP (Figure 3). We took into account that data formats defined for different devices usually consist of a combination of device function names and values assigned to those names. We thus designed the function so that it describes this combination of function names and values in XML format and uses the standard function names defined in ECHONET Lite. The base protocol is not limited to TR-069; OMA-DM or another Internet protocol can be used as well. This is because the function was implemented as an OSGi bundle, which supports diverse WAN communication protocols.

As a result, a service provider intent on creating services for controlling home devices from the cloud need not worry about the WAN communication standard in use, which had heretofore been a matter of concern.

6. Verification experiment

We conducted an experiment to assess the energy savings effect of an HEMS by using an experimental "iHouse" (**Figure 4**). This two-story wooden house was constructed in accordance with a standard specified by the Architectural Institute of Japan and was equipped with about 210 sensors and controllable devices.[6),7)] We implemented an environment within the house to enable us to connect those sensors and devices to an energy-saving service in the cloud via a

Figure 4
Experimental "iHouse."

GW function so that the devices could be controlled from the cloud. We then evaluated the energy-savings effect on the basis of three types of factors and determined whether sufficient performance could be obtained from the implemented functions.

1) Natural environment factors

We evaluated the effect of controlling ventilation during the summertime. The system was able to turn off air-conditioning equipment by automatically opening windows in accordance with wind direction during the night when outdoor temperatures dropped, enabling cool air to enter the house. The result was a reduction in air-conditioning power consumption of about 15% per day.

2) House factors

We evaluated the effect of letting in sunlight during the wintertime by having the system automatically open the curtains during the day. The result was an increase in room temperature of about 3°C.

3) Device factors

We evaluated the operating characteristics of home appliances and observed that power consumption tended to spike when air conditioning equipment was activated. We compared the effect of turning off the air conditioning for one hour with that of letting it run continuously and found that total power consumption was lower for the latter condition. On the basis of this result, we estimated that air conditioning power consumption can be reduced by about 5% provided that the behavior of the occupants is accurately reflected.

These energy-saving effects demonstrate that a well-functioning HEMS can be achieved by collecting information on the natural environment, the target household, the connected devices, and the occupant's behavior and then coordinating device operation accordingly.

7. Conclusion

We have described a network technology for achieving cloud-based energy management for a smart community. Since devices targeted for connection in a building have a wide variety of interfaces, referencing or controlling them from the cloud requires that data formats within the building's network be integrated and that seamless connections be achieved between the LAN and WAN communication systems to facilitate communication with the cloud. To this end, we proposed a uniform data format based on device functions (properties) specified by the ECHONET Lite standard and applied this format to the TR-069 protocol to achieve WAN communications. Experiments that we have been performing since 2010 have shown that the proposed system can perform a number of control functions that save energy.

Fujitsu's SSPF incorporates several of these experimentally verified control functions. In our experiments, the system was connected not only to home appliances but also to a variety of sensors, energy-creation and energy-storage devices, and home fixtures like electrically driven windows and curtains. Such a system can also absorb protocol differences within a retail shop by handling commercial air-conditioning and lighting devices as ECHONET Lite standard devices. This means that the same energy-saving service can be provided to both homes and retail shops.

The network technology described in this paper is applicable to a variety of fields including healthcare and security in addition to HEMS. The plan is to achieve a total smart community by making use of this wide applicability.

This technology was a result of research and development conducted as part of the "Standardization of Intermediate and Management Platform Interfaces for the Popularization of Services that Contribute to a Reduction in Environmental Load" project funded by the Ministry of Internal Affairs and Communications of Japan. Some of the technology resulting from this project is used in SSPF.

We would like to express our deep appreciation to Professor Yasuo Tan of the Japan Advanced Institute of Science and Technology for his help in developing this technology and to the Ishikawa Sunrise Industries Creation Organization, Ishikawa Information System Association, and all concerned for their assistance in setting up and managing the experimental "iHouse."

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