Technologies Supporting Smart Meter Networks

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The power crisis that Japan confronted in the wake of the Great East Japan Earthquake in 2011 underscored the need for managing and controlling power consumption, especially in terms of avoiding planned outages caused by insufficient power supply, visualizing power consumption, and conserving power. It also reinforced the importance of using Smart Grids as an effective means of meeting this need. A desire has already been expressed for the early introduction of smart meters in the last one mile of the Smart Grid on the customer side. The smart meter networks that will connect the portions of the power network closest to the smart meters will one day be considered a vital part of the social infrastructure. As such, they must be able to collect information such as power usage, provide for remote control of smart meters by power companies, and support visualization of power consumption. This paper describes the technologies developed by Fujitsu for satisfying these requirements for smart meter networks.

1. Introduction

The introduction of renewable energy and the construction of a new electric power supply system have come to be discussed in recent years in response to environmental and energy problems typified by global warming and a depletion of energy resources. Additionally, the power crisis that Japan experienced in the wake of the Great East Japan Earthquake in March 2011 brought into focus the need for managing and controlling power consumption, particularly avoiding planned outages caused by insufficient power supplies, visualizing power consumption, and conserving power. In light of the above, the idea that a Smart Grid can provide an effective solution to these problems is attracting more adherents. In fact, there is already a call for an early introduction of smart meters to anchor the last one mile of the Smart Grid on the customer side. The smart meter networks that will connect such smart meters on the customer side with the closest power network to achieve a Smart Grid will become a critical social infrastructure, meaning that they will have to be stable and highly reliable with low deployment and operation costs.

In this paper, we provide an overview of the smart meter network, introduce the technical requirements, and describe the mechanism of an effective smart meter network based on those requirements.

2. Smart Grid in Japan

As the name implies, a Smart Grid is an intelligent network that uses information and communications technology (ICT) to enhance power system functions, connect suppliers with customers, collect and exchange various kinds of information such as power usage, rates, and types of electric power, and optimize power demand.

A Smart Grid for Japan is now being studied with a focus on expanding the use of renewable energy. The Basic Energy Plan[1] established in June 2010 states as a specific measure, "Building the world's most advanced next-generation interactive grid network as early as possible in the 2020s to enable, in principle, bidirectional communication between all power suppliers and customers." The plan, therefore, is to construct a Smart Grid in about ten years' time.

Power generated at a power plant run by a power company or other entity is delivered to the customer via a power transmission and power distribution network.

As a next-generation power network, a Smart Grid will provide bidirectional secure exchange of information in addition to connecting customers to the power transmission and power distribution networks and supplying power (**Figure 1**). Smart meter networks will play a crucial role in the widespread deployment of a Smart Grid.

A smart meter network consists of smart meters, i.e., power meters having communication functions. The unstable power supply in Japan since fiscal year 2011 has increased the importance of controlling power demand during peak periods. To do this, we need to visualize power consumption and conserve power whenever possible. An action plan[2] covering the next five years has therefore been established that covers 80% of all demand in this way through the use of smart meters.

3. What is a "smart meter network?"

The smart meters in a smart meter network provide information critical to achieving efficient energy management in addition to displaying cumulative power usage as performed by conventional mechanical meters. As illustrated in **Figure 2**, there are two main functions required of smart meters. The first is transmitting the data collected by the meter (i.e., customer power usage and other data) to the power company. The second is exchanging information with equipment supporting the home energy management system (HEMS).

Information transmitted by the first function flows along route A in Figure 2. This route handles communications between each customer's smart meter and the power company to exchange data on power usage and reverse power flow (the amount of surplus power sent to the power network by a solar power or other type of home generator). The power company will also use this route to transmit additional or processed information based on the above data. There are approximately 78 million[3] electric power meters installed in Japan, meaning that there is an incredibly large network of meters even when considering that power-meter networks are actually formed in units of power companies.

Information transmitted by the latter function flows along route B in Figure 2. This route is used to

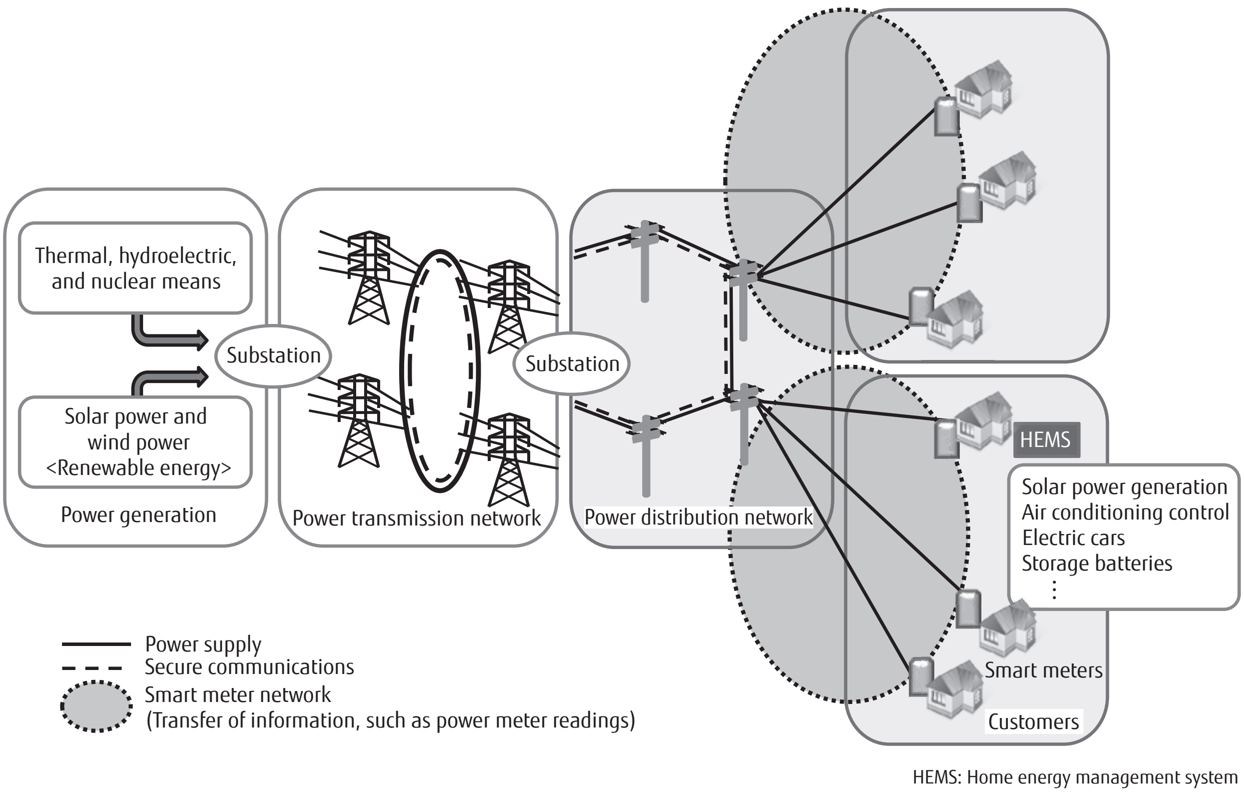

Figure 1
Configuration of Smart Grid.

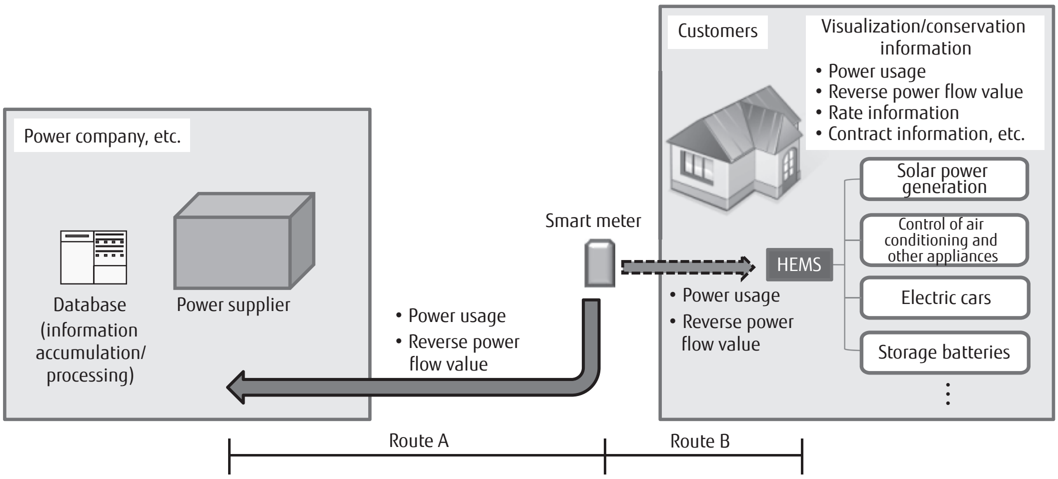

Figure 2
Communication flow using smart meters.

exchange data on power usage and reverse power flow directly between the smart meter and HEMS equipment within the home. This information is used as a basis for visualizing power consumption on the HEMS side as well as to provide demand-response services such as time-of-use (TOU) pricing, critical peak pricing, and peak time rebates to promote demand shifting based on power rates with the aim of conserving power.

Technical standards for each route are now being prepared. Expectations are high that the spread of power networks with standard interfaces will enable demand control during peak periods.

4. Requirements for a smart meter network

Achieving a smart meter network connecting the last one mile of the power network to the home will entail the construction of a large-scale network, the operation of a stable network, and the provision of a secure network. These requirements are described below.

4.1 Construction of a large-scale smart meter network

The question is whether smart meters in a huge number of customer locations can be efficiently and speedily accommodated in the power network without inconveniencing customers and incurring high network construction costs.

Smart meters must be installed in all sorts of environments including urban and suburban areas, high-rise apartment buildings, and underground shopping complexes. Considering that the meters will be installed in accordance with their effective period of power measurement (5–10 years depending on the type of meter) as specified by government regulations, we can expect the number of smart meters accommodated by the power network to increase in stages.

Furthermore, it must be kept in mind that HEMS equipment communicating with a smart meter along route B will typically be installed indoors while many smart meters will be installed outdoors. Some means of securing communications between indoor HEMS equipment and outdoor smart meters will therefore be necessary.

4.2 Operation of a stable smart meter network

The operation of a smart meter network as a critical social infrastructure must first and foremost be stable. The failure of some units in the network must not be allowed to affect the entire network, and its impact must be minimized.

The smart meter network must also be able to accommodate the regular addition and removal of smart meters without disrupting operations and be able to reduce the operation and management loads.

The need for remote program updating of equipment within the smart meter network must also be supported to facilitate network maintenance and deal with service expansion during peak periods.

4.3 Provision of a secure smart meter network

Smart meters handle private customer information such as amount of power usage, and that information flows through the smart meter network to the internal network of the power company. This situation requires the establishment of a secure network robust against such menaces as information interception, information tampering, and unauthorized access.

5. Smart meter network technologies

The main communication methods available for use in smart meter networks are radio frequency (RF) mesh networking using radio signals to transmit data to target equipment by a multi-hop communication system, power line communication (PLC) using power lines as a communication circuit, and 1:N networking using a mobile carrier network such as a third-generation mobile phone system.

The PLC and 1:N networking methods make use of existing resources such as power lines and mobile phone networks of public wireless carriers. This means that they can minimize the cost of constructing a core network such as an optical transmission network using concentrators[note)] to connect with a power company (part of route A in Figure 2) at the time of deployment in comparison with the cost of constructing an RF mesh network. At the same time, post-deployment support must be provided for the following situations regardless of the communication method used.

- New operation costs appear due to changes in the density and environmental conditions of installed smart meters.
- The need arises for real-time access control of smart meters and HEMS equipment.
- Traffic volumes increase owing to addition of new demand-response services.

With the above in mind, Fujitsu has determined that the most effective of the above communication methods for constructing a smart meter network is RF-mesh networking making use of the 920-MHz low-power radio band (released for use on July 25, 2012) and wireless LAN in the Industrial, Scientific, and Medical (ISM) band as transmission media. The following describes the features of multi-hop communications in the RF mesh network and the transmission media adopted by Fujitsu.

5.1 Multi-hop communications

A key feature of an RF mesh network is that individual nodes communicating with each other construct a network. Thus, applying this scheme to a smart meter network means that individual smart meters communicating with each other form a network. Hence, providing smart meters (communication nodes) with intelligent functions for autonomously selecting communication partners and forming stable communication paths will enable a distributed network to perform multi-hop communications. The final result is an extremely effective communication network for efficiently passing on information such as power usage to target equipment using the bucket-brigade system. Fujitsu has optimized the volume of control packets in multi-hop communications, thereby making it possible for a single concentrator to accommodate up to 1000 smart meters. This technology can deal with situations in which a failure occurs on a communication path because of physical obstacles or electromagnetic interference or faults in some smart meters in the network. It does this by enabling each smart meter to search for and establish communication paths in an autonomous manner without any instructions or operations from upper-level equipment and to forward information to target equipment by avoiding that portion of the radio network affected by those failures (**Figure 3**). Another feature of an RF mesh network is that a communication path from the concentrator can be constructed even with a smart meter that is not in direct communication range of the concentrator by using other smart meters as a repeater or next hop to create a path, that is, by multi-hopping. This makes it possible to achieve wide-area communications using the specified low-power radio band.

As described above, for a smart meter network to be constructed by multi-hop communications, the smart meters must be able to communicate with each other wirelessly. As a consequence, a high density of installed smart meters as may be found in an urban area means that a smart meter may have many other smart meters as a repeater candidate. In other words,

note) Equipment consolidating data from multiple smart meters

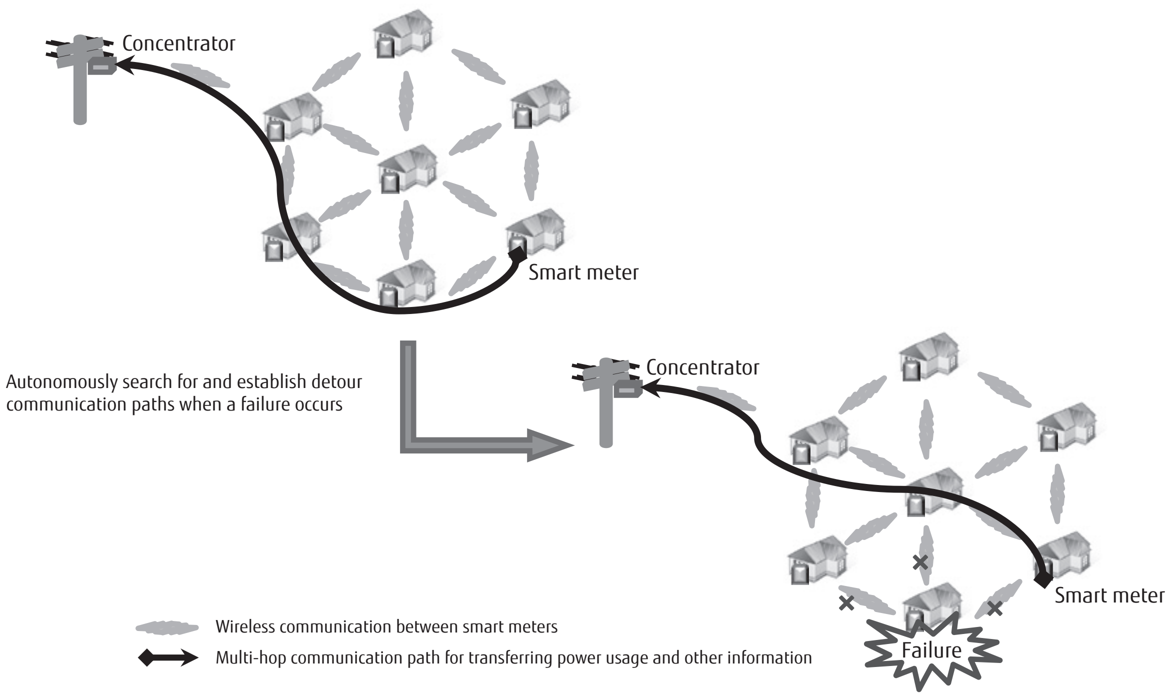

Figure 3
Smart meter network constructed by multi-hop communications.

multi-hop communications enables the construction of a network with redundancy characteristics. However, as the radio bandwidth is not infinite, there is naturally an upper limit on the number of smart meters within a certain area. Nevertheless, it will be possible to deal with a high-density installation environment by considering the smart meter density and effective use of the radio band. Meanwhile, for locations having a low density of smart meters such as less populous areas, mountainous regions, and other outlying areas, Fujitsu can provide low-cost equipment for relaying signals. Installing such relay equipment can lower initial investment in the construction of a network.

5.2 Transmission media

Wireless LAN is a form of communication using the 2.4-GHz band. It is capable of a transmission bit rate of 1 Mb/s or higher, which is high compared with what can be set with the 920-MHz low-power radio band. Wireless LAN is therefore superior in terms of the amount of information that can be transmitted.

At the same time, revisions in Japan's Radio Law enacted in December 2011 reorganized the 900-MHz band envisioning the introduction of smart meters. This revision extended the existing 5-MHz bandwidth in the 920-MHz low-power radio band to the frequency range of 915–928 MHz. It also increased the transmission power of specified low-power radio signals from 10 to 20 mW. We can expect these frequencies to become widely used in the future. Furthermore, given that 920-MHz low-power radio has a lower frequency band than that of wireless LAN, we can expect, on the basis of radio-wave characteristics, its radio signals to wrap around shielding obstacles like buildings. Additionally, the high reachability characteristics of radio signals in the 920-MHz low-power radio band can promote low power consumption.

The 920-MHz low-power radio band also allows for bit rates of 100, 200, and 400 kb/s depending on the number of radio channels used, which means that system specifications can be selected so as to save power on the basis of the volume of traffic generated by demand-response services. Another advantage is that radio wave interference from other equipment is less than with wireless LAN using the ISM band, the use of which has been expanding.

Looking forward, we can expect an expansion of standardization activities related to communication methods and equipment interfaces for smart meter networks. The standards created should enable the implementation of stable, highly reliable, low-cost smart meter networks.

6. Conclusion

Focusing on the last one mile of the future Smart Grid that will connect the power network to customers, we described the technologies Fujitsu has developed for meeting the requirements for smart meter networks, which are destined to become a vital social infrastructure. Looking to the future, Fujitsu is developing basic technologies for a smart meter network using the 920-MHz low-power radio band and wireless LAN. These technologies will be combined with management solutions for data collection and with management and network-monitoring functions using information collected from smart meter networks.

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