

Development of Gas Smart Metering System

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Abstract

Gas Smart Metering System in Japan is discussed in this paper. The main components of this system are ultrasonic gas meter with wireless network interface and wireless network system for communication.

Gas utilities in Japan are offering automatic meter reading (AMR) service to their residential customers. The technology for the AMR has been based on the metal telephone line and the diaphragm gas meter. But the recent increase of the customers without metal telephone line at their residential buildings made the market of the existing AMR service smaller, which needs a system applying wireless communication system instead of metal telephone line. The wireless communication system of Gas Smart Metering System is the combination of a multi-hop wireless relay network system called U-bus Air, and wide area network (WAN). U-bus Air establishes a network constituted by multiple gas meters, and WAN connects these networks of gas meters and a gas utility. U-Bus Air and WAN, constituting double-layered network for communication, are essential in wireless communication between each gas meter and a gas utility. In addition, due to the development of ultrasonic gas meter which has no moving parts inside, this ultrasonic gas meter became a good substitute, with improved functions, of the traditional diaphragm type gas meter.

The standardization of wireless communication, as well as the development of the system itself, is the key considering the cost reduction of the communication devices. The wireless network system applied in Gas Smart Metering System is standardized in the three organizations in the world in the field of wireless network.

1. Introduction

This paper discusses the development of “Gas Smart Metering System” in Japan. A joint development team consisting of gas utilities, gas meter manufactures, wireless communication device manufactures, and communication carriers has established the development plan of Gas Smart Metering System and has started its introduction of the system in the customers of gas utilities.

In paper, the use cases, the outline of key technologies, and standardization of the communication system are also discussed.

2. The Overview of Gas Smart Metering System

2.1. Background

An automatic meter reading system based on telephone line as described in Figure 1 is in operation in Japan. We have two main reasons which made gas utilities initiate the development of Gas Smart Metering System instead of the legacy system.

The first reason is reduction of telephone line in the residential buildings in Japan. The increase of the users of cellular phones and broad band network for data communication has decreased the utilization telephone line. As a result, it is often the case that the “traditional” telephone line system is not installed in the residential buildings.

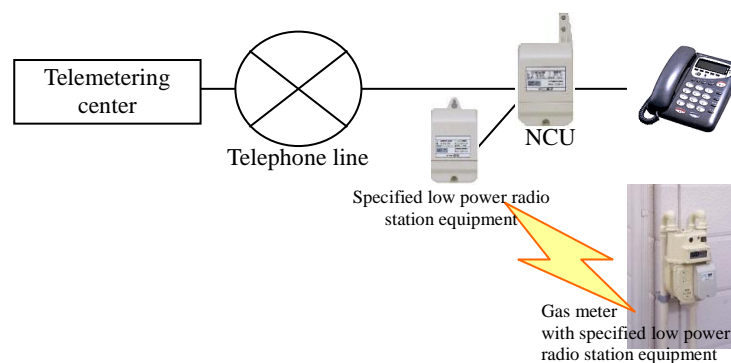


Figure 1 Legacy AMI system

The second reason is the growing needs for remote meter reading on a large scale and new communication services which requires higher performance communication infrastructure.

2.2. Network Composition

Our Gas Smart Metering System is as shown in Figure 2. It consists of ultrasonic gas meter with U-Bus and the wireless communication system. The wireless communication system consists of U-Bus Air Network and Wide Area Network (WAN),

Ultrasonic gas meter with U-Bus is “Gas smart meter” utilizing ultrasonic sensors, and its detailed information is described later.

U-Bus Air is a multi-hop wireless relay network between gas meters or among gas meter and home appliances in the room. U-Bus Air network is standardized in Japan Utility Telemetering Association (JUTA). WAN connects gas utility and ultrasonic gas meters. Any kind of network can be adopted as WAN for Gas Smart Metering System. The choice of network system as WAN depends on the regulation of wireless communication and the already existing communication infrastructure in each country/region. In our Gas Smart Metering System in Japan, PHS is one of candidate networks among the various kinds of WANs. Pu-NCU, the already existing WAN device using PHS network in Japan, is utilized.

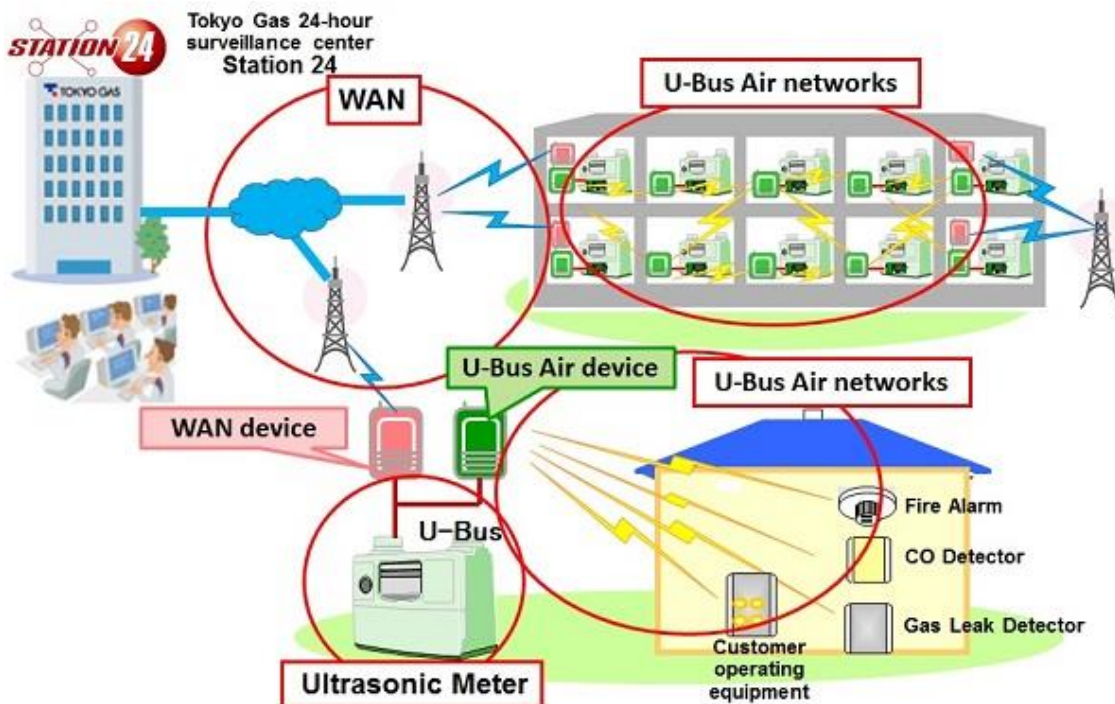


Figure 2 Composition of Gas Smart Metering System

2.3. Advantages of the system

(1) Concentrator-less approach

The feature of the network composition is concentrator-less architecture. All of communication devices are installed in the neighbor of gas meters. It eliminates the difficulty to manage network topology and the asset of concentrator and to get permission to install concentrators on the building from its owners.

(2) Packet switching

This system adopts packet switching. It can reduce power consumption, because gas meters and communication devices can go to sleep after the transmission or reception of a packet.

(3) Non-IP Network

This system basically uses Non-IP communication, even though in some WANs the Non-IP packet is tunneled over the IP. Adopting Non-IP network can shorten the packet header and it reduces the power consumption for the data transmission and reception.

3. Use cases of Gas Smart Metering System application

3.1. Metering in Apartment House

In Japan it is likely that the gas meter is installed around the each entrance of the room in the apartment house. The recent increase of the apartment house with automatically-locked door as its main entrance has

decreased the opportunity of the free entry of a gas meter reader into the apartment house difficult. Gas Smart Metering System is a good solution.

3.2. Remote Monitoring Service

The system is a good solution also in the remote monitoring service. A gas utility in Japan such as Tokyo Gas is providing about four hundred thousand customers with a 24-hour, 365-day remote monitoring service for its residential customers. The legacy system using analogue telephone line as the communication infrastructure is used for this service, but we have been applying Pu-NCU alternatively since 2012. About 40,000 Pu-NCUs have been installed as of end-March, 2014. The introduction of Pu-NCUs as a device of WAN of Gas Smart Metering Systems really works for the remote monitoring service.

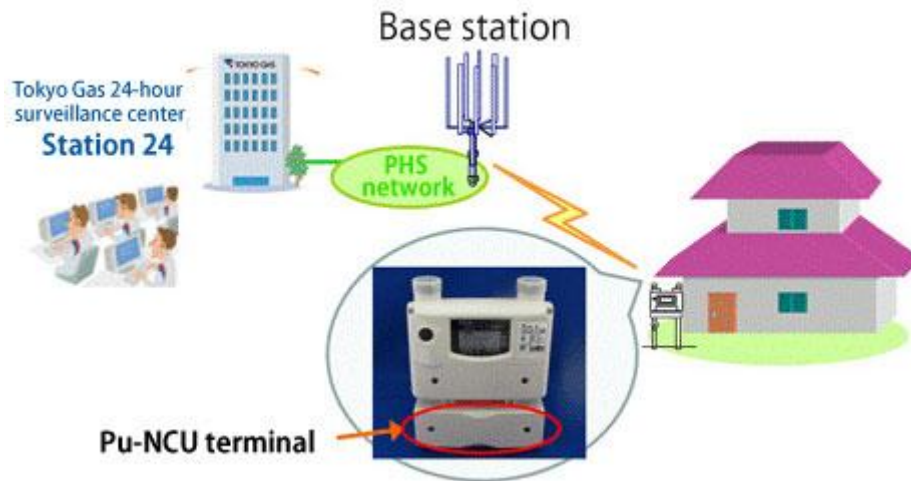


Figure 3 Network composition for Remote Monitoring Service

4. Technologies

4.1. Ultrasonic Gas Meter

4.1.1. Overview

Yazaki, Toyo Gas Meter, Panasonic, Tokyo Gas, Osaka Gas and Toho Gas developed the ultrasonic gas meter with U-Bus Interface as a gas smart meter. There are two implementations of the ultrasonic gas meter so far as in Figure 4 and Figure 5.



Figure 4 Yazaki's ultrasonic gas meter



Figure 5 Toyo Gas Meter's ultrasonic gas

The city gas utilities in Japan have started using ultrasonic gas meter since 2005, and have installed about 350,000 ultrasonic gas meters as of end-March, 2014. The ultrasonic gas meter is installed also by LPG utilities in Japan since 2009, and the total number of installation leached to about 330,000 as of end-March, 2014.

Figure 6 describes the architecture of the ultrasonic gas meter. The major components including ultrasonic sensor, pressure sensor, shut off valve and controller unit are communalized to both the ultrasonic gas meter for city gas and the one for LPG.

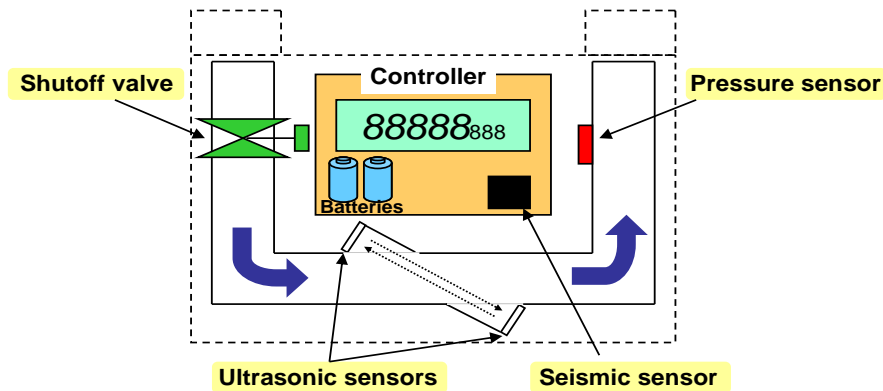


Figure 6 Architecture of the ultrasonic gas meter

Table 1 Specifications of ultrasonic gas meters

Maximum flow rate	1.6, 2.5, 4, 6 m ³ /h
Minimum flow rate	80 L/h
Detectable minimum leak	3 L/h within a month
Operating temperature	From -30 to 60 °C
Operating pressure	0 – 3.5 kPa
Shutoff valve	Open/close 2-way valve driven by stepping motor
Self-diagnostics functions	<ul style="list-style-type: none"> • Low battery • Ultrasonic sensor error • Valve leakage
Logging function	<ul style="list-style-type: none"> • Hourly gas consumption or gas pressure profile

4.1.2. Safety Function

The ultrasonic gas meter has automatic shutting off function. It has several triggers of the shutting off, such as gas leakage, reduction of pressure, detection of an earthquake. In addition, the ultrasonic meter has remote shutting off function. Alarming is another safety function of ultrasonic gas meter. In case the ultrasonic gas meter should recognize the long continuous usage of gas, which could be due to the gas leakage, it can initiate the alarm of the information system so as to avoid the potential accident.

4.2. U-Bus Interface

This system adopts U-Bus interface for wired communication between devices including gas smart meter. U-Bus is very simple and easy to implement. Additionally, U-Bus has other merits as described in Table 2.

Table 2 the specification of U-Bus (wired communication)

Layer	Specification	Description
Physical layer	Bus connection	Allows shared use of various devices.
	High transmission speed (9600 bps)	Wider application and higher service level as a result of high-speed transmission (approx. 30 times faster than the legacy device)
Data link layer	Packet communication	<ul style="list-style-type: none"> - Improved bi-directional communication between devices with different transmission speeds - More efficient use of communication links - Improved resistance against faults
	Fixed packet length (104 characters per packet)	<ul style="list-style-type: none"> - Improved efficiency of data processing by devices - Faster response (0.12 s with each packet)
Security	Encryption as a standard	- Improved access control and security protection

4.3. U-Bus Air

U-Bus Air is the specification for short-distance wireless mesh network. It is used for multi-hop relaying of metering data from a gas meter which is outside WAN service area, to another gas meter connected with WAN device inside WAN service area. Data transfer in U-Bus Air network is highly reliable. The data packet is automatically rerouted, should not the data transmission work due to the failure of U-Bus Air device or the change of the transmission conditions of radio waves. Automated network configuration greatly simplifies device installation. Table 3 shows outline specifications of U-Bus Air.

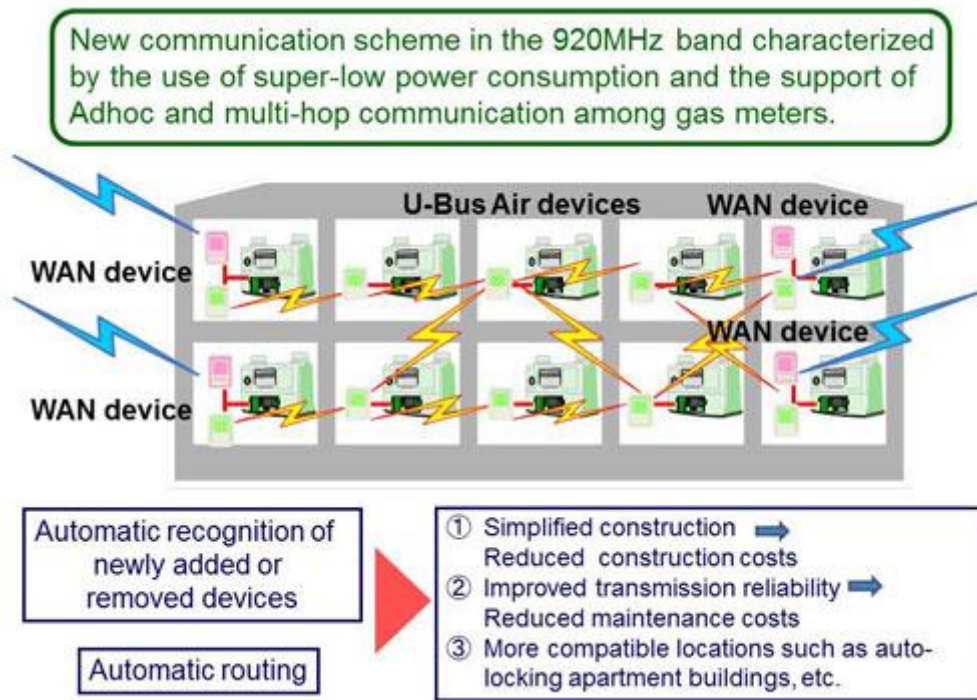


Figure 7 Overview of U-Bus Air

Table 3 Outline specification of U-Bus Air

Device	Frequency band	920 MHz (Japan) or other Sub-GHz (other countries)
	Standards	ARIB STD-T108 * IEEE802.15.4g
	Output power	20 mW / 10 mW / 1 mW
	Data rate	100 kbps
	Life span	10 years
	Power supply	Lithium battery
Network	Network topology	Mesh structure
	Communication direction	Two-way
	Number of relays	Average: 5 hops, Max.: 15 hops
	Number of nodes	Max. 50
	Number of meters	Max. 50 (1/node)
Others	Routing features	Automatic routing, route diversity
	Network construction	Easy association with magnetic reed switch

* ARIB : Association of Radio Industries and Business

4.4. Pu-NCU

Pu-NCU is a WAN device for Gas Smart Metering System using PHS network. Toho Gas, Osaka Gas, Tokyo Gas and Ymobile Corporation, the communication carrier of PHS network in Japan, co-developed Pu-NCU in 2012.

Table 4 Specification of Pu-NCU

Item		Specifications
Wireless Interface	Standards	ARIB STD-28
	Protocol	PIAFS
	Modulation Scheme	$\pi/4$ QPSK
	Output Power	Average : 10mW (Peak : 80mW)
	Frequency Band	1.895~1.918GHz
	Bit Rate	32kbps
Wired Interface		U-Bus

The most important technical feature of Pu-NCU is its low energy consumption. Pu-NCU reduces its power consumption by adopting highly sophisticated intermittent reception and ultra-low energy chipset provided by Ymobile Corporation. The power consumption of the chipset is almost one fourth of the previous chipset for PHS system. Pu-NCU can be operated for more than 10 years with Latium battery.

5. Standardization of U-Bus

5.1. The procedure of standardization activity

U-Bus system is standardized in IEEE, Japan Utility Telemetering Association (JUTA) and Wi-SUN alliance. Figure 8 shows the procedure of standardization efforts. The detail of individual activity is described in the following sections.

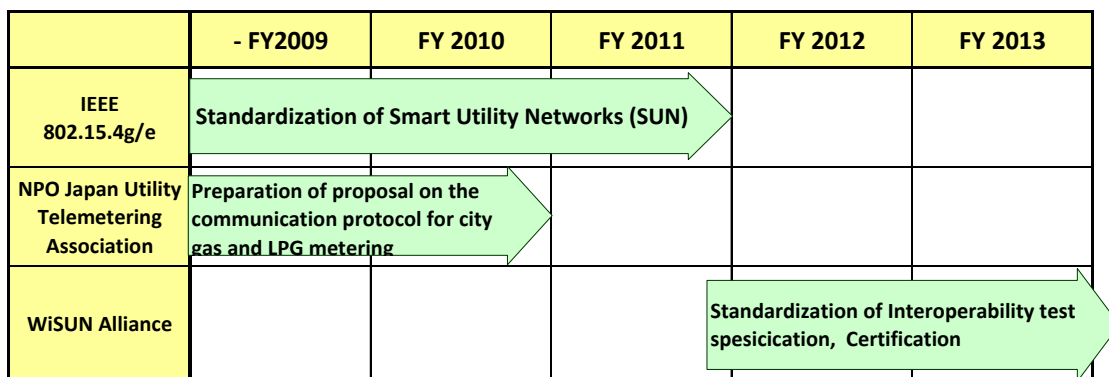


Figure 8 Procedure of standardization efforts

5.2. IEEE 802.15.4g/e

IEEE 802.15.4g is the international PHY standard for smart utility network, such as relay network for smart meters. That is the de facto standard of PHY specification for metering system. The development team of U-Bus Air proposed that in the application of IEEE 802.15.4g in Japan 920MHz should be designated and that low energy specifications should be included in IEEE 802.15.4g. U-Bus Air is satisfying IEEE 802.15.4g. IEEE 802.15.4e is the standard which defines the enhanced specifications of IEEE 802.15.4 MAC. The development team of U-Bus Air proposed its link method for IEEE 802.15.4e as one of the low energy mode. The link method is called RIT (Receiver Initiated Transmission)

5.3. Japan Utility Telemetering Association (JUTA)

JUTA is the association to drive forward the widespread of telemetering system and related services. JUTA has a membership of 75 companies including city gas utilities, LPG utilities, gas meter makers, electric manufacturers, service providers of metering.

JUTA standardized the specifications of gas meter and communication devices for Gas Smart Metering System and posted the specifications on their web site. The specification documents can be downloaded from there.

5.4. Wi-SUN Alliance

Wi-SUN Alliance is an international organization for the certification of wireless communication based on IEEE 802.15.4g. Wi-SUN Alliance provides the test specifications and test environment to certify the compliance with standards.

Wi-SUN Alliance treats multiple specifications including FAN and ECHONET Lite. FAN is the specifications for the field area network of smart grid in United States. ECHONET Lite is the specifications for HAN (Home Area Network) which enables to manage home energy consumption.

JUTA is proposing to adopt U-Bus Air as another standard specification of Wi-SUN. JUTA is planning to finish the preparation of the specification document for U-Bus Air in this year, and will start the discussion to decide test specifications for its certification.

6. Conclusion

This paper shows the status of the development of Gas Smart Metering System. Implementation and test phase are already finished, and the system has been used for some application. The Standardization activities are making progress and will leads to spread of Gas Smart Metering System. We have no doubt that the introduction of this system in our customers increases their satisfaction to our service.