Investigation of applicability of Smart Meter (multifunctional meter for water supply) to the city of Tokyo

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Abstract: On-site experiments (field test) using Smart Meters are conducted by domestic water supply utilities in Japan. We investigated the possibility of utilizing a Smart Meter (multifunction meter for water supply) fitting the circumstances of Tokyo. This investigation verified the communication status and surveyed residents' satisfaction degree with service utilizing the information from communication equipment, by installing devices in homes of subjects living in Tokyo. The results showed the communication success rate was more than 95%, and the satisfaction rating with residents' service was more than 89%. In this survey, we obtained a new assessment on wireless communication performance and residents service as related to Smart Meters.

Keywords: Smart Meter; 920 MHz band radio; visualization / MIMAMORI (monitoring) service; water volume

1. Introduction

In Japan, introduction of Smart Meters is being promoted in electric power companies and gas distribution companies. Field tests using Smart Meters are conducted by domestic water supply utilities and the utilization of data such as water usage obtained from Smart Meters is being studied.

For this study, the Bureau of Waterworks, Tokyo Metropolitan Government conducted on-site experiments assuming the use of Smart Meters in Tokyo. The Smart Meter is defined as having a residents' service function using wireless communication of water usage and accompanying data.

In field tests, we investigated the evaluation of a communication system using the radio frequency 920 MHz and the evaluation by users of residents' service (visualization of usage water volume and abnormality notification) representing the information obtained from the Smart Meter on the display unit in the house.

2. Research materials and research methods

In our field tests, data obtained from water meters is transmitted by a wireless child unit, via a repeater installed when necessary, and sent to a server where the wireless parent unit performs data processing. The 920 MHz band radio permitted by the national government is used for communication between the wireless child unit and wireless parent unit. Wireless child units are installed in pipe spaces (PS) in multi-family houses and in meter boxes (MB) in detached houses.

2.1 Evaluation of communication distance

(1) Communication test at sample house

Prior to our field tests, typical houses (apartment buildings and detached houses) were selected as samples to conduct communication tests. Using information from monitoring the communication state installed in the 920 MHz band radio unit, we installed transmitters (Sa, Sb) and receivers (1 to 8) at expected installation locations for wireless devices, and measured the RSSI (Received Signal Strength Indicator) and PER (Packet Error Rate) between the transmitter and the receiver.

In apartment buildings, because homes are in close contact with each other, sufficient communication could be obtained if wireless repeaters were appropriately arranged (Figure 1) (Table 1). For communication distance on the same floor, radio field intensity is -66.15 dBm (average RSSI) at 11 meters, the distance from the transmission point Sa to reception point 1, while radio field intensity is -91.58 dBm (average RSSI) at 17 meters, the distance from transmission point Sb to the reception point, and there were no errors (PER = 0%). From this result, it can be assumed that a radio repeater installed at a distance about 17 meters away can accommodate a radio child unit on the same floor. On the other hand, regarding communication distance between floors, from test results of reception points 2 to 6, the radio field strength up to three floors away was -77.19 dBm (average RSSI) with no error occurrence (PER = 0 %). From this result, it can be assumed that it is possible to accommodate child units two to three floors away.

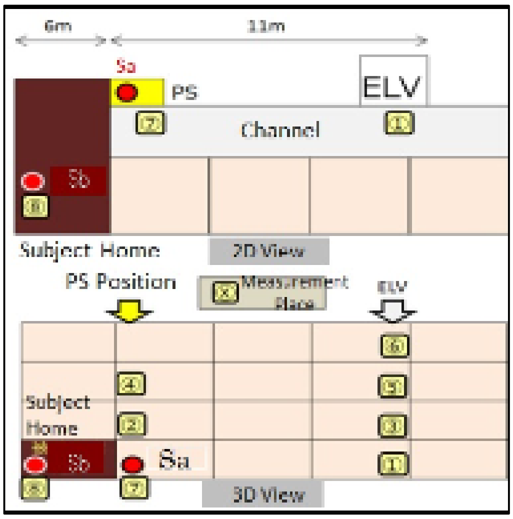

Figure 1. Transmitter & Receiver Installation Locations (Apartments)

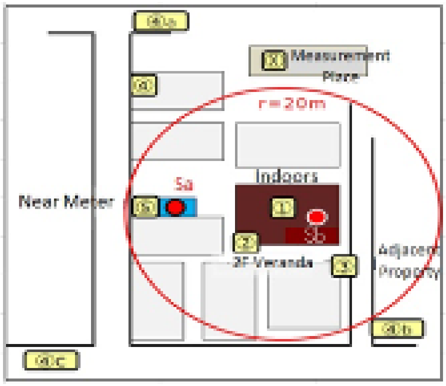

Figure 2. Transmitter & Receiver Installation Locations (Detached House)

In detached houses as well, we installed transmitters (Sa, Sb) and receivers (1 to 5) at assumed installation locations for wireless devices, and measured RSSI value and PER value between the transmitter and the receiver (Figure 2) (Table 2). Good results were obtained, with average RSSI = -59.33 dBm and PER = 0% at 5 MB, about 20 meters away from the representative house parent unit (Sb). Also, at 4 on the road about two houses or 30 meters away, average RSSI = -85.74 dBm, minimum RSSI was 101 dBm, and PER = 7.17%. From these results, it was found that it is possible to accommodate child units in an approximately 20 meter radius, taking into consideration the influence of building walls, cinder block walls and the like.

Table 1. Results of communication tests in apartment buildings

Transmission Point	Reception Point	Max RSSI [dBm]	Min RSSI [dBm]	Avg. RSSI [dBm]	PER [%]	Remarks
Inside PS (Sa) (3rd Floors)	1. Repeater on the same floor (in front of ELV)	-65	-67	-66.15	0	3rd Floor
	2. Meter 1 floor away (up)	-52	-55	-53.65	0	4th Floor
	3. Repeater 1 floor away (up)	-75	-80	-77.19	0	4th Floor
	4. Meter 2 floors away (up)	-67	-69	-68	0	5th Floor
	5. Repeater 2 floors away (up)	-73	-76	-74.42	0	5th Floor
	6. Repeater 3 floors away (up)	-75	-81	-76.74	0	6th Floor
	7. Parent unit (representative home)	-72	-76	-74.03	0	Rep. House Router Position
Parent Unit Estimate (Sb)	8. In front of PS	-69	-88	-74.38	0	3rd Floor
	1. Repeater on the same floor (in front of ELV)	-89	-94	-91.58	0	3rd Floor

Table 2. Results of communication tests in detached houses

Transmission Point	Reception Point	Max RSSI [dBm]	Min RSSI [dBm]	Avg RSSI [dBm]	PER [%]	Remarks
In the meter box (Sa)	1 Center of 1F	-79	-84	-80.72	0	
	2 Veranda of 2F	-84	-101	-89.8	0.99	
	3 Adjacent property	-82	-87	-84.65	0	
	4 On the street (Neighboring house near meter box)	-64	-73	-68.16	0	Good line of sight, about 15 m away
	4a On the A street (1 block away)	-98	-103	-100.24	81.63	Good line of sight, about 60 m away
	4b On the B street (2 houses away)	-93	-101	-95.44	14.74	Poor line of sight, about 20 m away
	4c On the C street (Across the street)	-84	-102	-87.12	0.2	Poor line of sight, about 25 m away
Representative House (Parent Unit: Sb)	5 In front of meter box	-55	-92	-59.33	0	
	4 On the street (2 hourses away: About 30 m)	-80	-101	-85.74	7.17	

(2) Environment in the MB and communication distance

Before the field experiment, we measured the communication distance from the wireless child unit (water meter) in the MB to the wireless parent unit, at the experimental station of the Tokyo Waterworks (Figure 3). In low-rise houses, because the water meter is installed in an iron or plastic box of the same height as the ground, we measured the communication distance for each environment in the MB in each case (Figure 4).

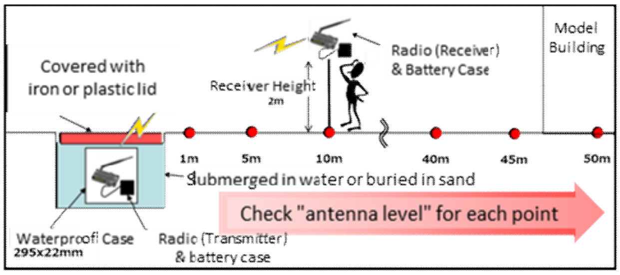

Figure 3. Overview of communication distance measurement

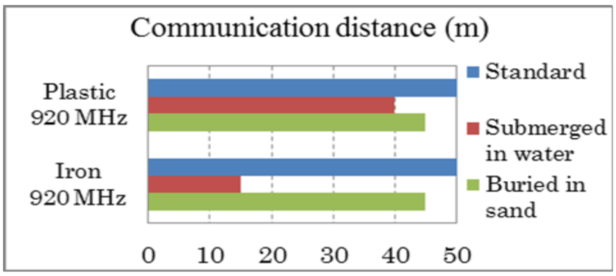

Figure 4. Comparison of communication distance

A trend was seen that the communication distance was shorter when the wireless handset was stored in an iron box than a plastic box. Also, cases where the radio handset is submerged in water or buried in the earth, the communication distance is shortened in both cases in the standard environment (without inclusions), but it was observed that communication distance tends to be shorter in submerged environments.

2.2 Outline of Field tests

We selected collaborators living in Tokyo as subjects to conduct field tests (Figure 5). The implementation period was about 3 months, starting in August 2015.

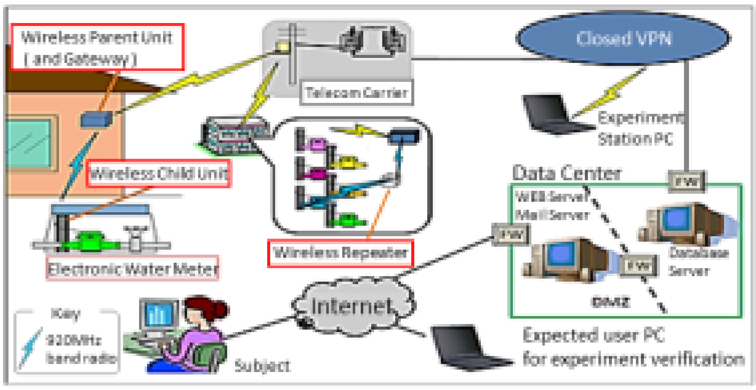

Fig. 5 Field Experiment Image Diagram

Communication between the wireless child unit (water meter) and wireless parent unit (gateway) used 920 MHz band radio, and beyond that, the devices were connected to the communication network of existing domestic telecommunications carriers.

After finding and processing the accumulated amount of used water (1 hour unit) acquired from the water meter on servers, we provided residents' services such as sending email to the subjects.

2.3 Subject classification and data transmission method

The survey covered 58 subjects, which included 32 middle-class apartments, and 26 low-rise detached houses (Table 4). For apartments, data from each home was transmitted to the server through a wireless parent unit installed in each building. For 20 of the detached houses, we installed wireless parent units and wireless child units one by one in each home and transmitted data individually. In the remaining detached houses, data from multiple houses was transmitted through one wireless parent unit in the vicinity. We classified the former case where data is transmitted individually from each home as individual-type, and we classified the latter case where data from several houses are aggregated and transmitted to the server as aggregate-type (Table 4).

Table 3. Subject categories and data transmission methods

Category	Area	Subjects	Total
Apartment Building	A	10	32
	B	11	
	C	11	
Detached Houses (Aggregate)	P Area	2	6
	Q Area	4	
Detached Houses (Individual)	Locations in Tokyo	20	20

2.4 Verification Items

We conducted verification of wireless communication performance by measuring the communication success rate (communications per hour) of the installed communication device etc. was measured.

We surveyed residents' services (visualization of usage water volume, notification of abnormal usage water volume) with questionnaires for the subjects about (1) changes in lifestyle when water usage is visualized, (2) the relationship degree of interest in water usage and usage of water, and (3) requests for residents' services (degree of satisfaction, ease of use, payment, etc.).

From the results of this questionnaire, we examined the depth of interest in the use of water, the evaluation of specifications of each service (graphical representation, notification, etc.), and the desired price to receive services.

2.5 Content of field test (residents' service)

In the test, we visualized the amount of water used and abnormality detection for the subjects, as resident services.

By visualizing the amount of water used, we made it possible for subjects to check their own water usage from various perspectives (Figure 6). Specifically, subjects can view the amount of water used by day and the amount of water used by month on the Internet, and compare it with past water usage (comparing amount of water used on two specified days or the amount of water used for two specified two months) can be carried out. Also, subjects can receive notifications of the amount of water used every hour for the most recent 24 hours at a set time of their choosing, with a pre-registered e-mail address.

Fig.6 Examples of water usage visualization display

Information from Bureau of Waterworks, Tokyo Metropolitan Government

Dear abc@yxz.co.jp

MIMAMORI (Monitoring) Service   Please contact [redacted] urgently.

Current Monitoring Settings
Water nonuse elapsed time period: 3 hours
Time Zone: 10:00 AM to 22:00 PM

Please check the monitoring settings from the following URL.
https://xxx.xxx.xxx.xxx/Waterworks/Waterworks.html

Fig.7 Examples of water usage abnormality notification

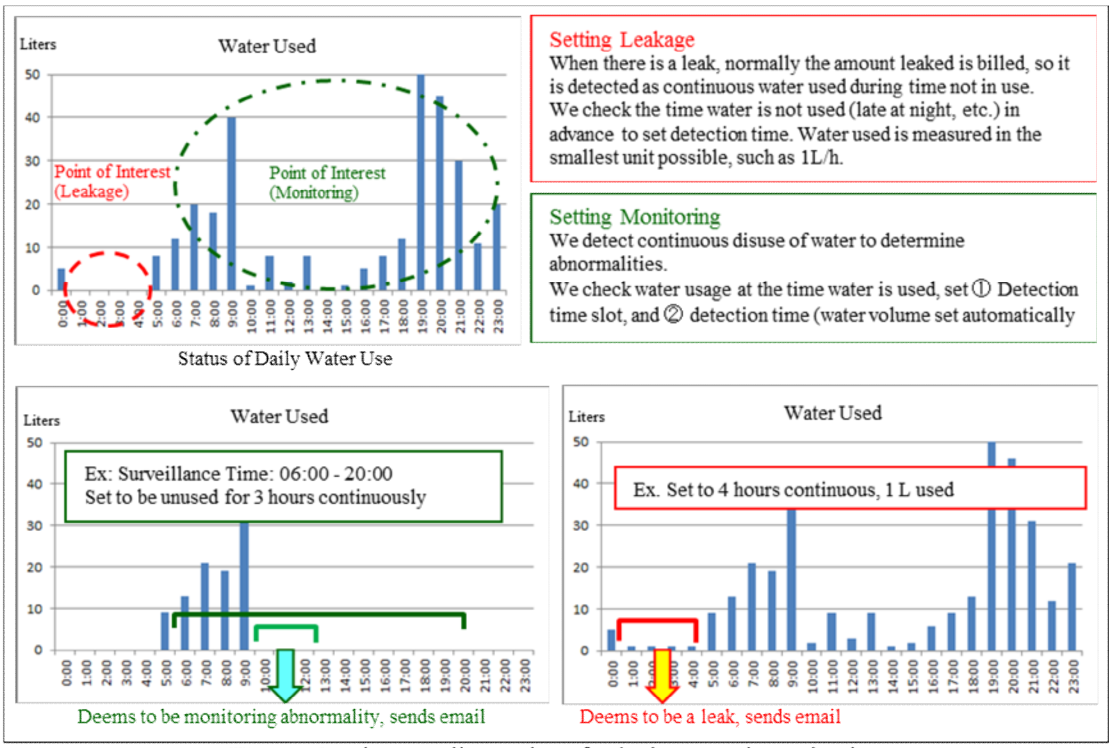

Figure 8. Abnormality notices for leakage and monitoring

Abnormality detection is a function that notifies the subject by email when their water use is judged to be abnormal, so that subjects can detect abnormalities as soon as they occur (Figure 7). There are two different situations which will be determined to be abnormal water use. One case is when water uses late at night and other times are determined to be a water leak, while the other is when water is not used during a time of day it normally is used and determined to be an abnormality (Figure 8).

3 Results and Discussion

3.1 Communication success rate and issues in wireless communication technology

In our field experiment, we measured radio waves in advance for each home, and referenced the results to decide the arrangement of wireless devices (Figure 9) (Figure 10). Items we measured beforehand include the RSSI and the PER between the transmitter and the receiver, which were based on a value of -90 dBm or more and a PER of less than 0.1%, respectively. The communication success rate over the entire field experiment was 95% or higher for many subjects, but lower for others.

Figure 9. Apartment Buildings and Wireless Devices Placement

In apartment buildings, all 32 subjects showed a communication success rate of 97% or higher, generally better than that of detached houses (Figure 11). This suggests that the wireless repeater can be installed in an appropriate place based on the preliminary radio wave measurement result, and that the wireless child unit could be installed above ground (Figure 12).

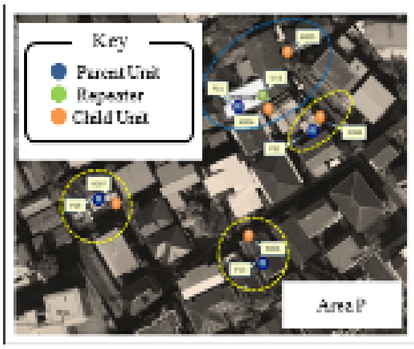

Figure 10. Detached Houses and Wireless Devices Placement

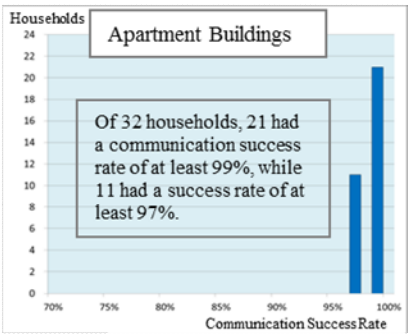

Figure 11. Communication Success Rate Distribution (Apartment Buildings)

Figure 12. Hanging Wireless Child Unit

In detached houses (aggregated type), 5 out of 6 test subjects had a communication success rate of 95% or more, with 1 unit relatively low at about 85% (Figure 13). The aggregated-type transmission method has an advantage in areas where detached houses are densely clustered, as it is possible to communicate using fewer communication devices. Yet, one challenge is the need to organize the conditions of aggregation when it is actually introduced. For detached houses (individual type), 17 out of 20 test subjects had a communication success rate of 96% or more, but 3 houses were relatively low, at a level of 71% to 86%). As a result of verification, we believe that this is caused by deterioration of reception due to physical environmental change such as opening or closing shutters or how cars are parked.

The degree of change in reception varies depending on the installation environment, making it difficult to predict. It is of great importance how much margin can be given in the standard of wireless settings when actually introducing it. In areas with poor reception, redundancy in transmission is considered to be effective, such as temporarily holding data including water usage when there is a communication error and transmitting aggregated data in the next transmission.

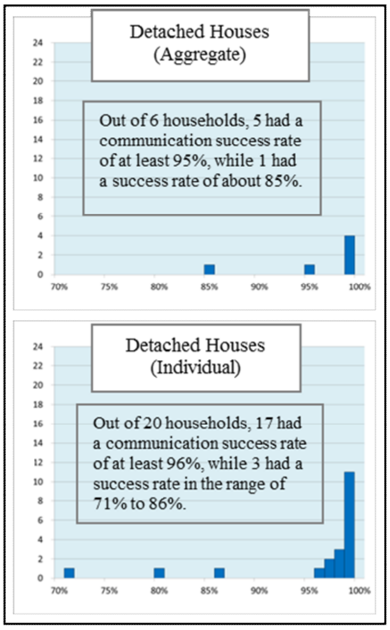

Figure 13. Communication Success Rate Distribution (Detached Houses)

3.2 Evaluation of residents' services

After conducting field tests, we tabulated questionnaires given to subjects and evaluated visualization of the amount of water used and detection of abnormal water usage. The questionnaire collection rate was 84.5%.

About 89% of the service users were satisfied or very satisfied with visualization of the amount of water used, so it was generally well received (Figure 14). There was a tendency seen that the subjects use this service less frequently in the second half compared with the first half of the experiment period (Figure 15). We believe that the frequency of use decreases due to the sense of security gained from knowing it that can be displayed at any time. It is also important that residents' services are not just well received, but continue to be used. There were also issues with display, as some subjects say that the time display was confusing.

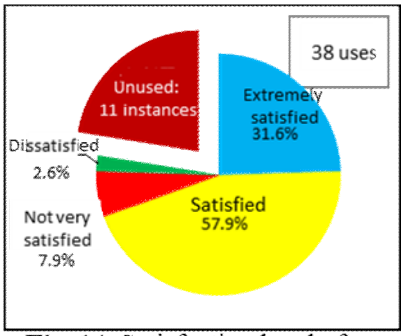

Fig. 14. Satisfaction level of water usage visualization

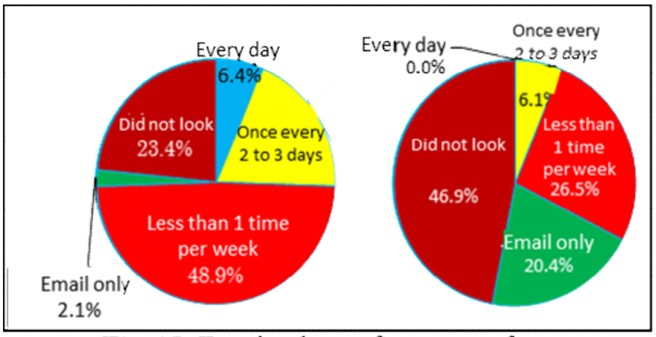

Fig. 15. Trend to lower frequency of use (Left: 1st Half, Right: 2nd Half)

For abnormality detection (not using water), there were less than 10 subjects, which was fewer than visualization of water usage, but about 92% of service users were satisfied or very satisfied (Figure 16). While the time span can be set freely, some subjects complained that it was difficult to set the time. It was clear that improving ease of use is a critical task in increasing the number of users.

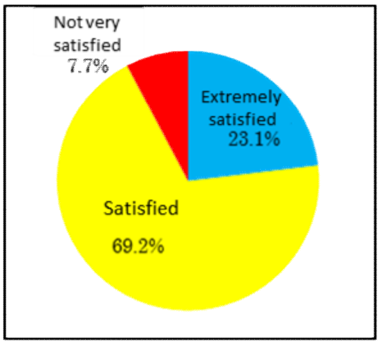

Fig. 16. Satisfaction with abnormality detection (water not used)

A questionnaire survey was conducted about fees (monthly fee) considered to be reasonable for use of services, for both visualization of the amount of water used and abnormality notifications, and a majority of respondents answered that they would like the monthly fee to be 100 yen or less (Figure 17) (Figure 18). We calculated the earnings and expenses of service with this fee, and found that it would be difficult to operate the service.

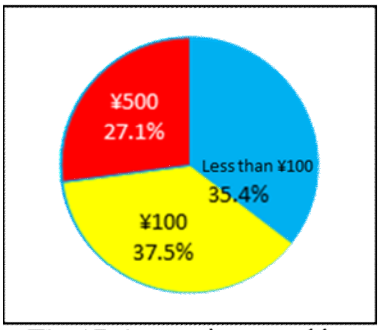

Fig. 17. Appropriate monthly price of visualization

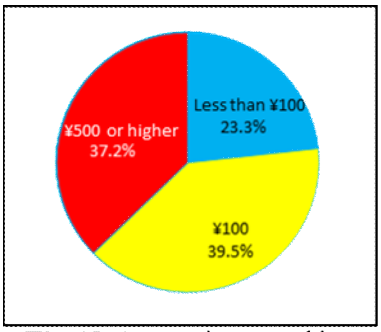

Fig. 18. Appropriate monthly price of abnormality notices

4. Conclusion

In this survey about the Smart Meter, we confirmed that 920 MHz band radio is effective for wireless communication performance. There was strong evaluation of residents' services, as over 89% was satisfied. In order to disseminate Smart Meters in Tokyo, we concluded that it is necessary to develop the technology to ensure the required communication success rate, to improve the quality of residents' services further, and resolve issues such as cost reduction.

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