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Verification of wireless environment network simulation and reliability

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ABSTRACT

The aim of this paper is to prepare grounds for embodiment of a smart water treatment plant through acquisition of data such as flow, pressure, water level, and water temperature in vertical water treatment facility and real-time monitoring under wireless environment. Zigbee-based sensor node, in the 2.45 GHz band, and gateway were manufactured for this. Data obtained from the sensor was transmitted to the data processing device, and monitoring of the processed data could be performed on operation PC and mobile device. In addition, propagation environment and transfer rate were conducted to analyze applicability and reliability test of wireless data. This study intends to construct a ubiquitous sensor network-based distributed water supply system at low cost and high efficiency by creating a remote monitoring system using communication network analysis and mobile device.

Keywords: Wireless; Gateway; Sensor node; USN; Water treatment plant

1. Introduction

Communication media are becoming diversified and faster with development of communication technology. The most important factor in construction of information society can be regarded as means of communication. Accordingly, embodiment of a system for inexpensive and convenient use of diverse services such as data collection and distribution is demanded [1–3]. Such environment can be embodied using ubiquitous sensor network (USN), a network that obtains and manages information using sensors.

USN is an infrastructure of advanced intellectual society that monitors, stores, processes, and integrates environmental information from sensors attached to objects and living spaces, providing customized knowledge service anywhere and at any time through creation of situation recognition information and knowledge contents. It is a ubiquitous IT with a new paradigm that expands the horizon from human-oriented information to objects. Sensors and wireless devices are combined to allow object–human

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communication and computing. Information about the changing physical environment around objects is obtained to enhance productivity, safety, and living standards [4,5].

On one hand, data-like operation status of pumps and valves, flow, water level, water temperature, and pressure are extremely important factors of water treatment process at industrial sites such as water treatment plants. Such data are generally transmitted through wired network and monitored, which can show excellent stability of transferred data but has difficulty in maintenance and requires large initial investment. Therefore, data can be obtained easily and inexpensively by constructing a wireless network using ubiquitous wireless device. Monitoring and control can be done outside the control room using a mobile device [6–8].

Accordingly, ubiquitous Zigbee sensor node, in the 2.45 GHz band, and gateway were developed in this paper. An experiment was conducted to verify the

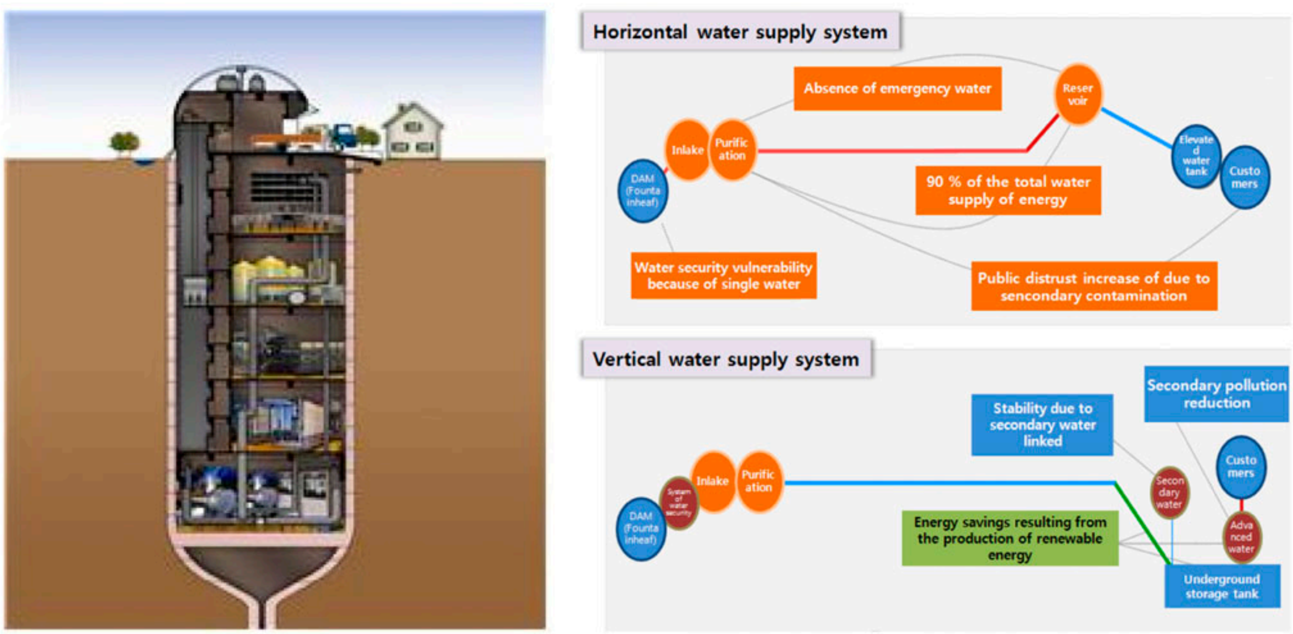


Fig. 1. Compact of vertical type WTP (underground-type) and horizontal/vertical water supply system.

Table 1
Comparison of communication methods

Division	RF	Zigbee	Wi-Fi	W-CDMA
Communication distance	Max. 1.5 km	Max. 300 m	Max. 20 km	R. 3–4 km
Frequency	424 MHz	2.4 GHz	2.4/5.0 GHz	2.1 GHz
Transfer rate	1.2–115 kbps	250 kbps	2–20 Mbps	2.4–14.4 Mbps
Output	10 mW within	0 dBm (1 mW)	Max. 50 mW	Max. 200 mW
Interface	RS232C	HART/ Ethernet	Ethernet	USB
Standard	EIA	IEEE 802.15.4	IEEE 802.11b/g/n	W-CDMA (3GPP)
Application (Water)	Building blocks (flow rate, pressure monitoring)	Purification plant (data)	Dam bureau of alarm (data + video)	WCDMA through the outdoor manager administration
Purpose	Low, middle distance	Low, short distance	High, long distance	High, long distance
Security	–	128 bit AES	Authentication and encryption	USIM card authentication

algorithm using network simulation tool for optimal management. In addition, data transfer path through wireless mesh net was confirmed and a monitoring control screen was prepared to obtain and monitor each data received from the sensor node. They were applied to mobile device to develop a water supply system management technology that reduces transport energy and secures water security.

2. Overview of vertical water treatment facility

Vertical water treatment facility was proposed by constructing a compact-type water treatment facility in order to offer a solution to problems of existing horizontal water treatment facility.

Existing horizontal water treatment facility is showing continuous increase in secondary pollution and maintenance expense caused by long distance of water pipes and aging of pipeline needed to transport treated water. Also, it is necessary to prepare national emergency water security system for emergency situations such as drought. Distributed water supply system that includes decentralization and compaction of treatment facility, minimization of transport process, detention of water security and emergency water, and maximized use of renewable energy was proposed for fundamental settlement of such problem [9]. The conceptual diagram of a vertical water treatment facility which aims to supply water to consumers without interruption is shown in Fig. 1. As a water treatment facility in the existing horizontal form is established as a vertical one, the area cost is reduced and its maintenance becomes easy [10]. The biggest difference between existing water supply system and the distributed water supply system proposed is that water security system can be linked with distributed water supply system, which can secure emergency water using underground detention tank and recover the trust of citizens by preparing for disasters and preventing secondary pollution through distribution [11].

The vertical water treatment system proposed in this study is composed of water intake and supply process in the basement, ozone and active carbon processes on first and second floors, and membrane filtration process on third floor.

3. Selection of the communication method and derived algorithm

3.1. Selection of the communication method

Wired communication methods, including analog transfer, have many disadvantages such as large initial investment, noise, high cost of additional installation, and inconvenience in maintenance [12]. Wireless data

Table 2
Environment of simulation

Division	Contents
Frequency	2.4 GHz band
Network bandwidth	250 Kbps
MAC protocol	802.15.4 MAC
Transport	UDP
Grid	70 × 70 m (100 nodes)
Transmission time of packet	10 s
Maximum communication distance	10 m
Success rate of packet transmission	98%

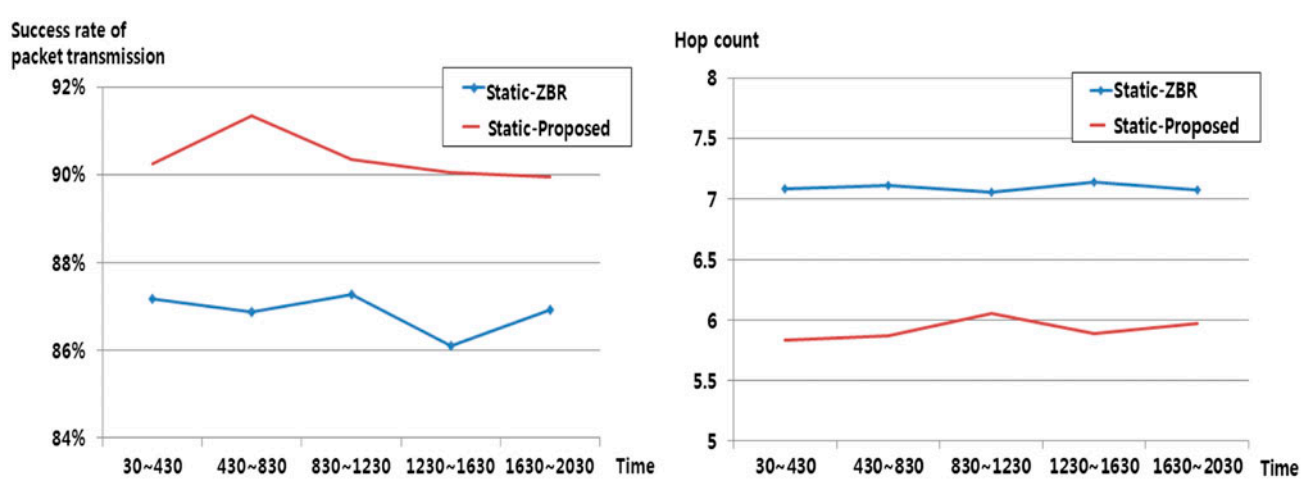


Fig. 2. Success rate of packet transmission and hop count.

acquisition method was selected to resolve such problems of wired communication. Various communication methods applicable to the vertical water treatment facility were compared before construction of the system as shown in Table 1. As a result of comparison based on the fact that the purpose of the vertical water treatment facility is to obtain short distance data and that additional installation of wireless equipment must be taken into consideration, Zigbee method in the 2.4 GHz band was selected. It is appropriate for data transfer in water treatment plants, suitable for low capacity and short distance data transfer, and allows installation of additional devices at low cost [13].

3.2. Derived algorithm

Prior to embodiment of the sensor node, optimal algorithm was deduced using a network simulation

Table 3
Protocol status function and path function

protocol status function	path function

MINT::MINT(nsaddr_t id) : Agent(PT_MINT), htimer(this)
{
index = id
rtable.hop_for_CH = -1;
rtable.hop_for_sink= -1;
rtable.path_for_CH= -1;
rtable.path_for_sink= -1;
 	
for(int i = 0; i < 100; i++)
{
cluster_num = index / 25;
device_type = DEVICE;
 	
if(index % 25 == 0)
device_type = CH;
}
 	
if(index == GW_addr)
{
cluster_num = 5;
device_type = GATEWAY;
}
htimer.sched(10);
}
	void MINT::recv(Packet *p, Handler* h)
	{
	struct hdr_cmn* ch = HDR_CMN(p);
	struct hdr_ip* ih = HDR_IP(p);
	struct hdr_mint *mh = HDR_MINT(p);
	if(mh->data_type == PATH_FROM_CH)
	{
	if(device_type == GATEWAY)
	{
	return;
	}
	if(cluster_num != mh->cluster)
	return ;
	if(mh->seq_no_ > rtable.seq_no)
	recv_path_from_CH(p);
	else if(rtable.hop_for_CH > mh->hop_count || rtable.hop_for_CH == -1)
	recv_path_from_CH(p);
	return;
	}
	if(mh->data_type == PATH_FROM_SINK)
	{
	return;
	}

Table 4
Zigbee sensor node and gateway

Division	Design specification
Frequency	2.4000–2.485 GHz
Transmission output	10 mW
Power	12 Vdc
Current consumption	Transmission mode 270 mA (@3.3 V) Reception mode 55 mA (@3.3 V)
RF data rate	250 Kbps
Receive sensitivity	−100 dBm
Networking topology	Mesh topology
Spread spectrum type	DSSS (direct sequence spread spectrum)
Analog input	2 CH, 4–20 mA input, 16 bit ADC
Interface	10/100 Ethernet interface
Antenna	0 dBi whip antenna

tool called NS-2 (Network Simulator Version 2). NS is a discrete event simulator, written in Otcl and C++ languages, used to evaluate performance of various protocols such as TCP, routing, and multicast protocol in wired and wireless networks [14].

The experimental environment of simulation was formed according to the conditions in Table 2 by creating a 70×70 m topology with packet transfer time of 10 s. NS 2.34 version was used for this.

In addition, protocol status function and path function were embodied as Table 3 and Fig. 2.

Routing protocol proposed for this study was compared with the existing tree-based Zigbee routing protocol. The proposed routing technique is a method in

Table 5
Zigbee sensor node and gateway

Process	IP address of gateway	Name of measuring devices installed
Third floor	192.168.100.72	12 spots including A-series inflow pressure (original water) and A-series outflow pressure (treated water)
First floor	192.168.100.71	8 spots including A-series inflow pressure and A-series outflow pressure
Underground	192.168.100.70	10 spots including PAC water level meter and A/C filter blower pressure gage

Table 6
Wireless data reliability

Name	Deviation of wired data	Deviation of wireless data	Correlation (%)
Pressure transmitter (kgf/cm^2)	0.20	0.20	99.0
Flow transmitter (m^3/h)	2.48	2.48	98.5
Level transmitter (m)	0.03	0.03	98.0
Turbidity (NTU)	0.02	0.03	99.6
O3 Remain (mg/L)	0.01	0.01	99.9
Polyaluminium chloride (m^3/h)	0.00	0.00	99.6
pH	0.01	0.01	100.0

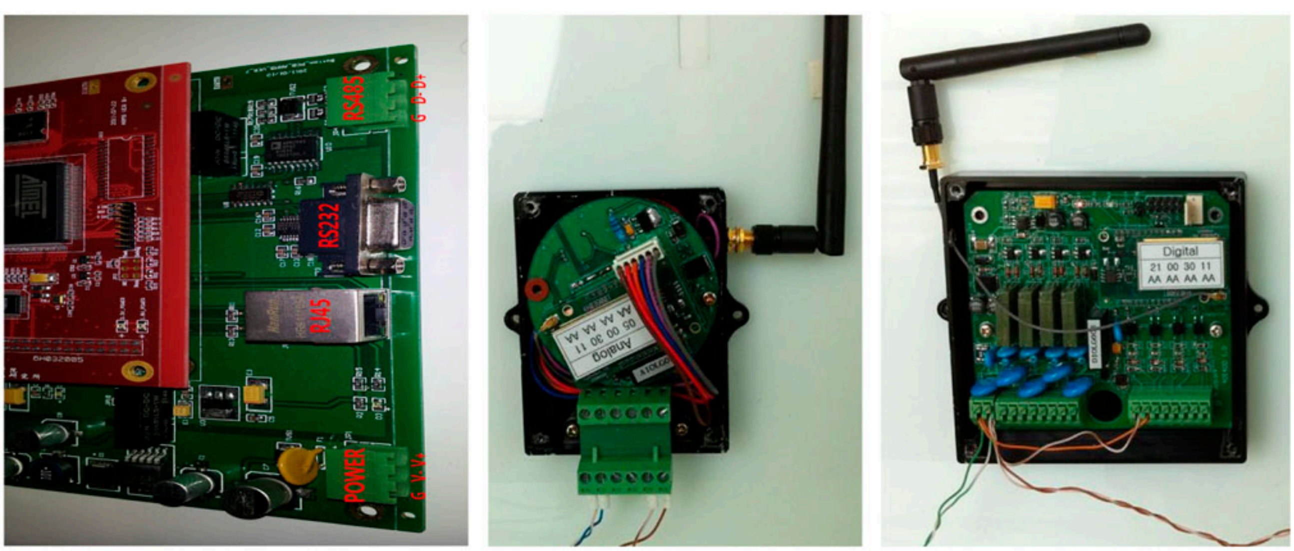


Fig. 3. Comparison of estimate and real travel times.

which a random node among nodes of each cluster is operated as cluster header. As shown in Fig. 2, random setting of the cluster header yields about 5% improvement in packet transfer success rate in comparison to cluster head selection using the formula existing in tree-based Zigbee routing protocol. Hop count was confirmed to be within 6 hop. It is viewed that efficient packets can be transmitted because the routing protocol suggesting this used less energy consumption than the existing method and transmitted a large amount of packets.

The optimal management system for the vertical water treatment facility was embodied based on such simulation results.

Fig. 4. Installed sensor nodes.

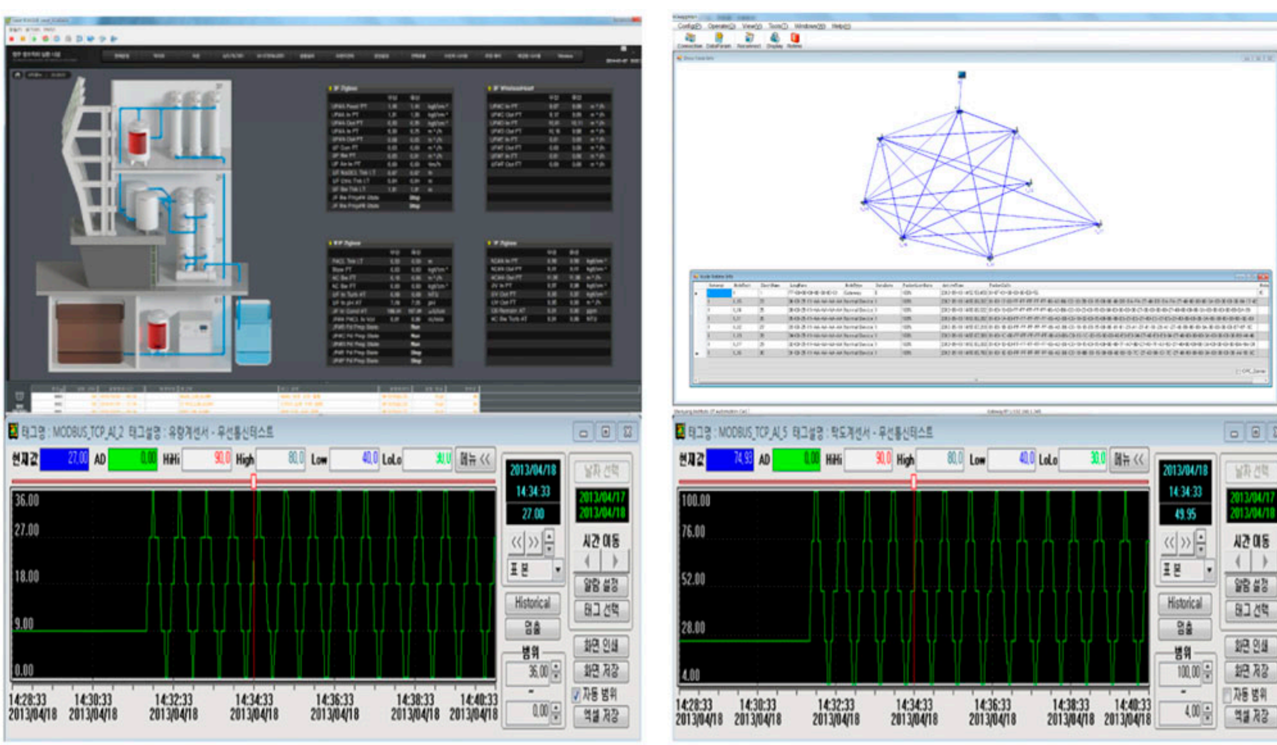


Fig. 5. PC HMI, mesh network and trend value.

4. Results and discussion

The most basic role of this study is to efficiently collect data from measuring devices installed on the vertical water treatment facility through gateway, and devices installed on the USN network include Zigbee gateway and analog/digital sensor nodes. In this study, standard IEEE 802.15.4 Zigbee chip in the 2.4 GHz band was selected to apply the sensor node and gateway. As shown as Table 4, Optimized Zigbee stack was used to promote smooth data communication between wireless sensor nodes.

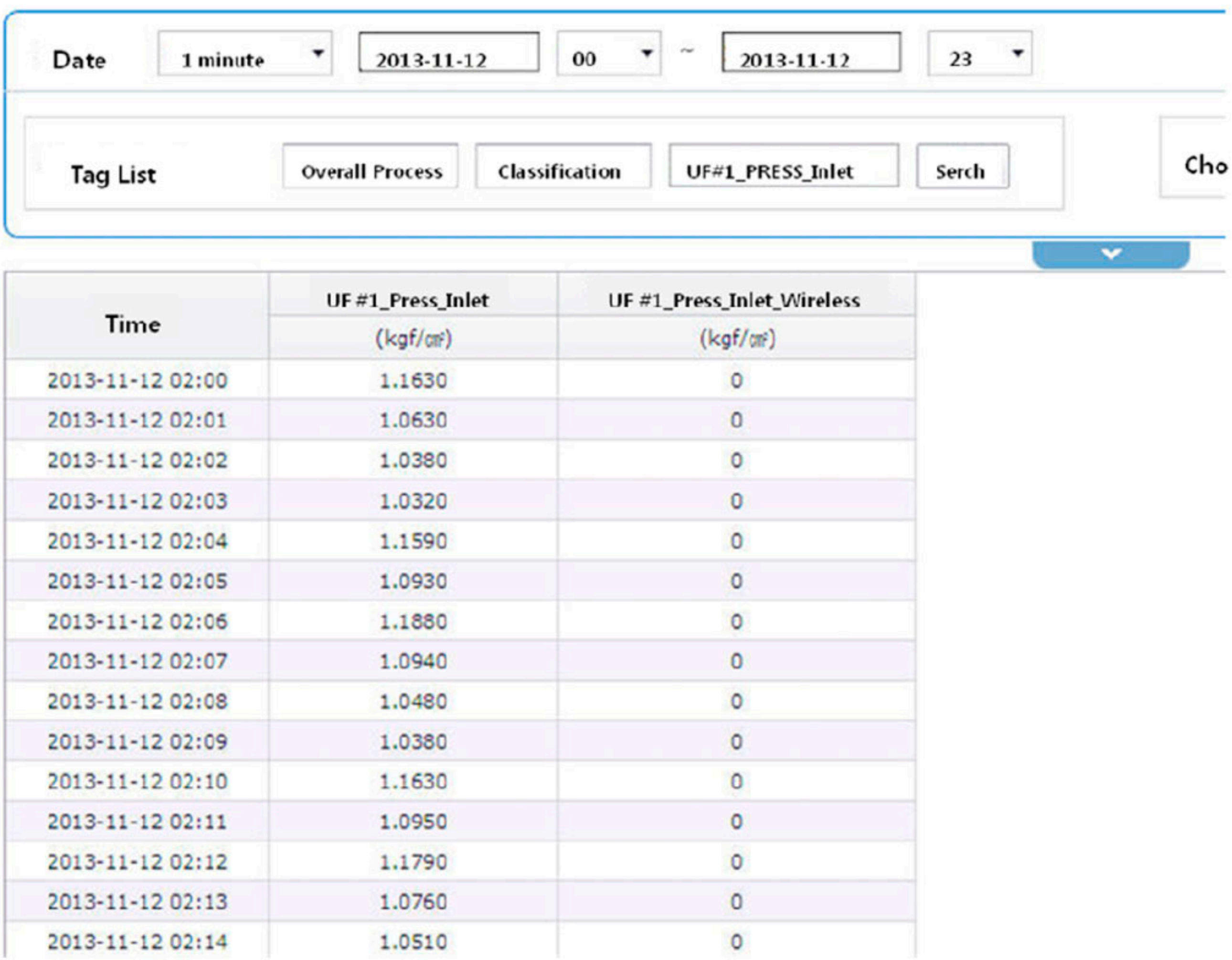
The gateway is in charge of interconnecting a network with another network. It is needed to transfer data measured by sensor node to operation PC. WIA program was used in this study. Interior of the gateway is composed of AT91RM9200 and Ethernet interface communication is used.

The analog and digital sensor nodes were installed for wireless measurement at the site. Each node is composed 2/8 input/output channels. Also, WIA-M1800 antenna with omni-directional gain was used to settle poor communication caused by complex indoor environment and long distance transfer [15]. Fig. 3 shows the used gateway, analog and digital sensor node.

5. Implementation and experiment

In order to connect the manufactured devices with the demonstration facility, IP address was allocated to each gateway connected to the measuring devices on each floor. As shown as Table 5, Sensor nodes were installed on 30 spots including 10 spots underground, 8 spots on first floor, and 12 spots on third floor. In addition, Installed sensor nodes are shown in Fig. 4.

A monitoring control screen for integrated management of data was configured to handle the received data. As shown in Fig. 5, wireless mesh



Time	UF #1_Press_Inlet (kgf/㎠)	UF #1_Press_Inlet_Wireless (kgf/㎠)
2013-11-12 02:00	1.1630	0
2013-11-12 02:01	1.0630	0
2013-11-12 02:02	1.0380	0
2013-11-12 02:03	1.0320	0
2013-11-12 02:04	1.1590	0
2013-11-12 02:05	1.0930	0
2013-11-12 02:06	1.1880	0
2013-11-12 02:07	1.0940	0
2013-11-12 02:08	1.0480	0
2013-11-12 02:09	1.0380	0
2013-11-12 02:10	1.1630	0
2013-11-12 02:11	1.0950	0
2013-11-12 02:12	1.1790	0
2013-11-12 02:13	1.0760	0
2013-11-12 02:14	1.0510	0

Fig. 6. Output chlorine rate by present controller.

network can be confirmed and monitoring of measuring device operation status and data can be performed. Trend values can be checked for each item on a real-time basis. Also, remote monitoring program screen was created for tablet PC to allow remote relay monitoring. All data can be analyzed and verified by creating log files for each second as in Fig. 6.

Correlation was analyzed to verify the suitability of the installed wireless data. The deviation of wired and wireless data coming into the sensor node installed on each floor was averaged as the difference in average values. As a result, it was identified that the correlation of a wireless and wired network was about 98% or higher in Table 6.

6. Conclusions

In this paper, a 2.45 GHz Zigbee net was used to construct a wireless mesh net and to embody an optimal management system that obtains data from flow and pressure sensors and monitors status of pumps and valves. The Zigbee net was intended to compose a complex USN network within the distributed water supply system implemented on vertical water treatment facility.

The optimal algorithm was drawn for efficient communication using NS-2 before realization. As cluster heads were randomly selected in comparison with the existing Zigbee routing protocol, which selects a cluster head through a formula to communicate, the efficient packet with less energy consumption than the existing one can be transferred with the high success rate of packet transmission and less packet transmission.

A wireless sensor network was established through the algorithm drawn in this way. As a result of embodiment, monitoring control screen of the wireless mesh net sensor node was confirmed to allow data path and communication settings. Remote relay monitoring of the system was made possible by permitting data monitoring and control on mobile devices in addition to operation PC. Wireless mesh net can be constructed using 2.45 GHz Zigbee net on the basement, first floor, and third floor of the distributed water supply system in vertical water treatment facility. Wireless meth net is used to confirm data transfer path and received values. Moreover, the suitability was identified through a data reliability analysis.

A system that helps decision-making required during operation and maintenance can be constructed to predict and monitor water quality of the underground detention tank and distributed water treatment system. The research outcome has secured diversified water resources used as water in emergency water facilities, offering an ability to cope with terrorism using water and accident in water intake or supply pipe.

In addition, optimal construction of status monitoring and remote management system is expected to result in ripple effects such as reduced rate of death and accident through disaster prevention, to create added values at reduced cost, and to create effects on happiness and life satisfaction of citizens.

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