ICT-Based AMI Network Deployment and Water Information Service Development

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Abstract

This paper aims to enhance efficiency of management through physical, logical consumer channel clustering and reliability on metering reading data, and achieve expandability of wireless metering reading network through channel use that can be identified between proximate clusters, by suggesting channel set-up based on multichannel cluster mixed with network channel and group channel to resolve the problems and implement various services. Further, the article aims to reduce installment time and maintenance repair cost through hierarchical network structure composed with four differentiated devices in wireless AMR systems, and suggest wireless AMR network based on multichannel cluster substantializing various services by supporting various movement modes through quick error recovery and back up functions. The AMI Network is based on multichannel cluster mixed with network channels and group channels, which increases management efficiency through channel clustering of physical, logical consumer, and enhances reliability on meter reading data through channel use which can be identified between geographically proximate clusters.

***Keywords:** Smart water grid, Wireless advanced metering infrastructure, Channel allocation, Data aggregation, Low power consumption*

1. Introduction

Recently, high-efficient, next-generation infrastructure system using information communication technology is increasingly required to overcome limitation of water resource management, and Smart Water Grid is being developed to resolve imbalance by effectively allocating, managing and carrying water resources [1]. From this perspective, the Automatic Meter Reading (AMR) system is a technology automatically reading real-time meter and conveniently searching, printing out, and managing meter detecting data at a control office or where a specific reading meter system is installed, without meter men's visit to households in a remote place to read utility meter of every kind used by consumers such as apartment houses, mixed-use buildings, villas, detached houses [2]. The AMR technology is classified into wired method and wireless method depending on communication systems composed. Typically, a wired method of the technology is using telephony network [3] and power line network [4], whereas a wireless method of the technology is composing low power wireless reading meter network and gathering reading meter data and sending them to remote sites by using CDMA network or wireless LAN [5]. Characteristics of utility serve a major factor to determine a wired/wireless communication method. As electricity, power line communication network is effective to use as power network is already constructed and no additional cost occurs to use. However, utility such as water or gas supply composes wireless communication systems due to difficulty in electricity supply, and recently wireless AMR technology applied to various utilities is widely distributed due to rapid development in wireless technology and decreased price in wireless communication devices. Apart from this meter reading service, wireless AMR service evolves itself into Advanced Metering Infrastructure (AMI) which can offer a wide array of interactive services such as services for the elderly living alone and notification of electricity use according to utility characteristics [6]. As such, for wireless AMR, non-licensed ISM band of 424MHz and 2.4GHz bands is used in South Korea as it can be used free of charge [7]. Currently, as wireless AMR network is composed by using communication channel to the frequency bands specified above to compose low power wireless metering reading network in wireless methods, reliability on wireless communication is lowered as chances of collision between data is higher as the number of consumer is higher. To reduce chances of collision between data, a prerequisite is to limit consumer expandability as the number of consumer node is limited, and a change of metering value cannot be collected between fixed metering periods in schedule-based one way wireless AMR systems. This makes it difficult to expand as various services. Therefore, the article aims to enhance efficiency of management through physical, logical consumer channel clustering and reliability on metering reading data, and achieve expandability of wireless metering reading network through channel use that can be identified between proximate clusters, by suggesting channel set-up based on multichannel cluster mixed with network channel and group channel to resolve the problems stated above and implement various services. Further, the article aims to reduce installment time and maintenance repair cost through hierarchical network structure composed with four differentiated devices in wireless AMR systems, and suggest wireless AMR network based on multichannel cluster substantializing various services by supporting various operation modes through quick error recovery and back up functions.

2. Two-way AMI Network based on Multi-channel Cluster

2.1. AMI Network Composition based on Multi-channel Cluster

The AMI Meter Reading Network herein suggested consists of ED collecting the use from a meter, OHD installed outdoor for users to identify metering values, EDM managing ED and OHD, and NC transmitting data metering through mobile communication network. As the AMI Meter Reading System can install one NC and EDM from 1 to 10 at maximum, and each EDM can collect metering data from 100 consumers at most, a single NC can collect data from 1,000 meters at most, which can reduce metering maintenance cost in an effective manner.

As Figure 1, the NC directly manages each region, and is connected to entrepreneurs' server with TCP/IP network through exclusive lines. The server requests scheduled-meter reading to the NC in each region, and collects data through respective TCP/IP connection from numerous NCs. Further, all collected data are saved as database in server, and many clients can be offered various services through connection to servers. By supporting mobile client, service can be offered as PC client through exclusive application programs for tablet PC and smartphone, which enables users who have an administrative account to request meter reading and collect data in real time.

Channel allocation and management of AMI network based on multi-channel cluster are as follows. Communication channel between NC and EDM is defined as network channel, and communication channel between EDM and ED or OHD is defined as group channel, which enables EDM to have network channel and group channel set-up. Each EDM uses network channels when it communicates with NC, whereas the EDM uses group channels when it communicates with OHD, a lower layer of it. Meter reading collection through group channel of each EDM can prevent interference between identical channels as it is caused by somewhat overlapped metering reading ranges or close distance. AMR network set-up based on multi-channel can read meter through group channel in each EDM and separate and operate metering reading data through network channel, which enables limited frequency channel resources to be used in an effective manner.

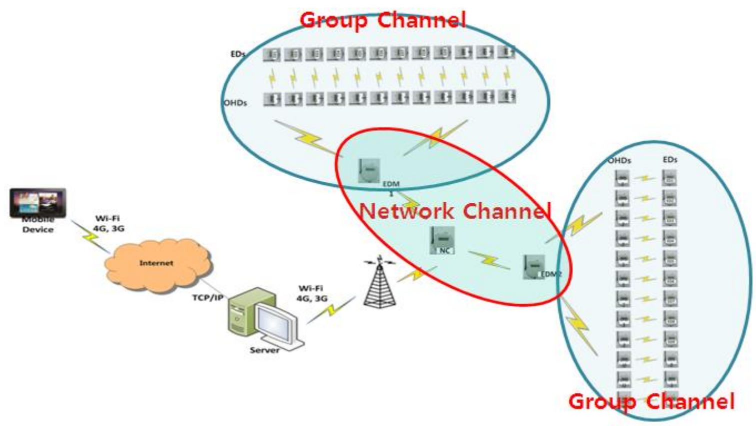

Figure 1. AMI Network Configuration based on Multi-channel Clustered

This multi-channel structure achieves quick data of metering reading data and expandability of AMR network through channel use differentiated between proximate clusters by enhancing efficiency of management through physical, logical consumer channel clustering. Further, wireless AMR systems reduce installment time and maintenance repair cost through hierarchical structures composed of four differentiated wireless devices and substantialize a wide range of services by supporting various operation modes through quick error recovery and back-up functions.

2.2. Each operation of AMI device based on multi-channel cluster

In AMI network based on multi-channel cluster, service operation for each device's AMR can be broadly classified into four parts.

2.2.1. Server ↔ NC ↔ EDM Operation (Regular meter reading)

Regular meter reading is a service conducting meter reading on all consumers of overall AMI networks. When meter reading is required, a command of regular meter reading is transmitted from server to NC. When a command of regular meter reading is received, the NC notifies meter reading by transmitting Request Data from network channel to EDM after transmitting ACK to server. When the EDM receives the request data from NC, it transmits EDM Reply to notify it properly receive them. The NC transmits Reply Confirm to notify that it properly receives the reply. The EDM changes its own group channels and initiates communication with OHD, a lower layer of EDM, after it receives Reply Confirm. Next, the EDM conducts a series of operation. After collecting data from each OHD, the EDM is changed to network channel and confirms whether or not there is communication between other EDM and NC. In case that there is no other communication, the EDM confirms whether or not the NC can receive data by transmitting RTS to the NC. The EDM receiving CTS separately transmits data received from each OHD in accordance with assigned packets. In case there is no error in data received from the EDM, the NC transmits ACK to EDM. The NC transmits data received from the EDM to server.

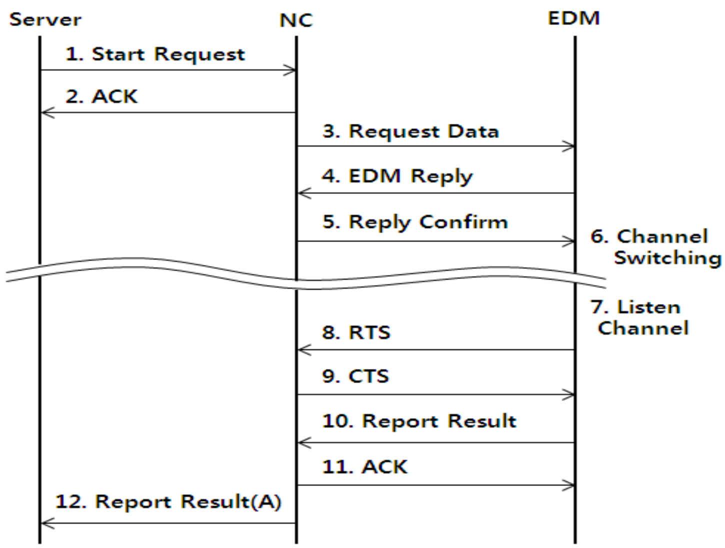

Figure 2. Device Operation of Network Channel

2.2.2. EDM ↔ OHD ↔ ED Operation

The EDM is turned into group channels, transmitting Request Data received from the NC to the OHD in a Broad Casting manner. The OHD calculates time to transmit by analyzing Request Data received from the EDM. When it is time for the OHD to transmit, it transmits Request Data to the ED. When the ED receives Request Data from other devices, it can identify its operation time, and when it is time to move, the ED receives Request Data from the OHD, and the ED transmits Request Data of its own to the OHD after the ED receives Request Data. The OHD receives Request Data from the ED, and saves them to transmit them to the EDM. The EDM saves data received from the OHD.

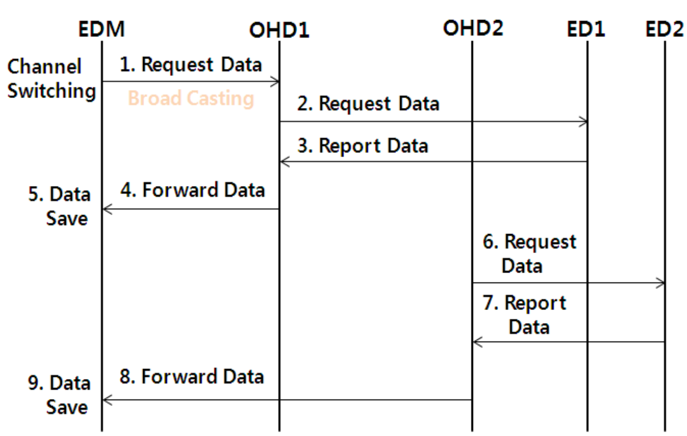

Figure 3. Device Operation of Group Channel

2.3. Low Power Scheduling

As Figure 4, each device in the AMI system stands for Transition Specification Periodic (TSP) to minimize power consumption, repeating transition between Sleep Status (Ts) and Active Status (Ta). Before transition to Sleep Ts, the system lifts all resources except for RTC timer to minimize current consumption. When a specific time period is passed and RTC interrupt occurs, the OHD is transited to Active Ta. Together with this transition, judged is whether or not there is a command required for the OHD by detecting preamble command signals transmitted from devices in a higher layer. As preamble command signals consist of certain IDs reserved in advance, in case of certain IDs the system maintains Active Ta, but otherwise, it is transited to Sleep Ts. It takes a very short time to judge preamble command signals. This is a core algorithm that minimizes power consumed of low power scheduling. A lower layer device judges command signals through preamble command signals from the EDM, a higher device, and maintains Active Ta to wait for Request Data. Lower-layer devices recognizing Request Data transit a current status to Sleep Ts again, shortly wake to Time Slot fixed at each lower-layer device beforehand, transmit result data by required commands to a higher-layer device, and is transited again to Sleep Ts. Afterwards, as only to complete communication in all other devices on the same layer to go back to transition specification periodic between Sleep Ts and Active Ta, there is Time Slot fixed to autonomously protect devices not to interrupt communication by transmitting preamble command signals from other devices or causing interference.

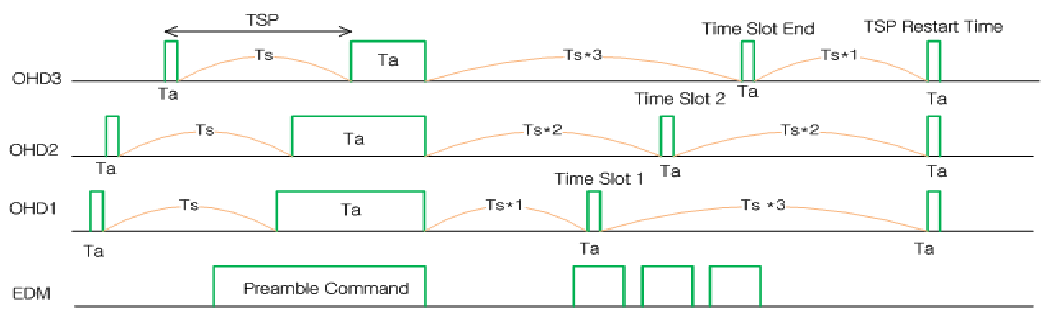

Figure 4. Low-power Scheduling Structure

3. Performance Evaluation and Consideration

3.1. Experiment Environment

To evaluate the existing AMR system, time for collecting meter reading data of the AMI system based on multi-channel cluster, and battery life expectancy, developed was a self-simulator by using C language and C++. The simulator developed has parameters as Table 1, receiving RF transfer rate, the number of consumer, length of meter reading data, Transition Specification Periodic (TSP), power consumed, and a meter reading cycle as input, and causes CC and MC topology composing communication network of lower-layer device based on NC. The CC mode conducts collection and management on meter reading data resulting from the number of consumer on the same channel with existing one NC, the MC mode manages 10 EDMs at most based on multi-channel cluster suggested with a single NC, and a single EDM analyzed life expectancy by printing out the amount of battery consumed resulting from data collected time and transmitting and receiving time of each device by collecting and managing meter reading data from 100 consumers.

Table 1. Simulation Condition

Parameter	Value
RF data rate	250Kbps
No. of consumer	100, 200, 300, 400, 500, 600, 700, 800, 900, 1000
Length of inspection data	128byte
TSP(Ta+Ts)	2, 3, 4, 5, 6, 7(sec)
Inspection cycle	1, 2, 3, 4(hour)
NC network configuration	CC : An existing co-channel configuration of the NC network
	MC : The proposed multi-channel configuration of the NC network
Battery capacity	1cell : 3.6V, 19A

3.2. Analysis on meter reading time and battery life expectancy

As Figure 5, time for collecting meter reading data is proportionate to the number of consumer and length of TSP between Sleep Ts and Active Ta. As the number of consumer is higher, and length of TSP is higher, response time is slower; this is a case from a perspective of EDM. For the AMI system based on multi-channel cluster herein suggested, each EDM has its own group channels, making it possible to conduct concurrent data meter reading on every consumer. Therefore, as Figure 5, in case that a single EDM is 2 for specification periodic, data aggregation time is similarly about 15 minutes for both when meter reading is conducted on 100 consumers and meter reading is conducted on 1,000 consumers by composing them to 10 EDMs.

Further, aggregation time for meter reading data is drastically reduced by 10 times, compared to meter reading for 1,000 consumers with existing channels in Figure 6.

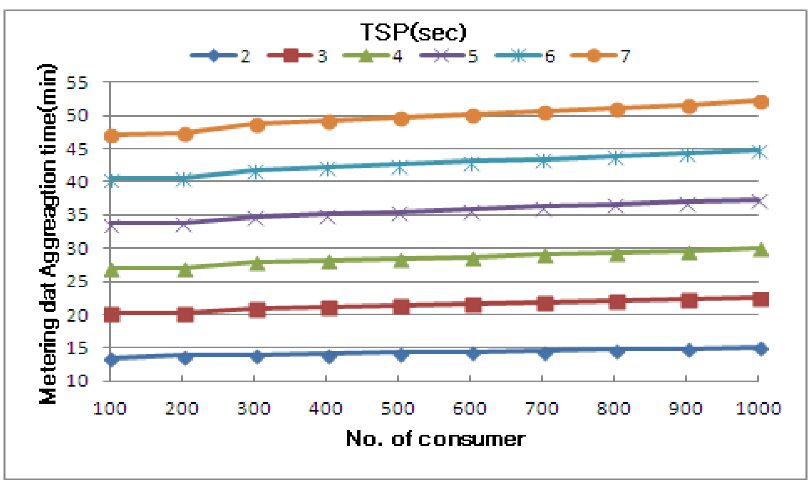

Figure 5. Metering Data Aggregation Time

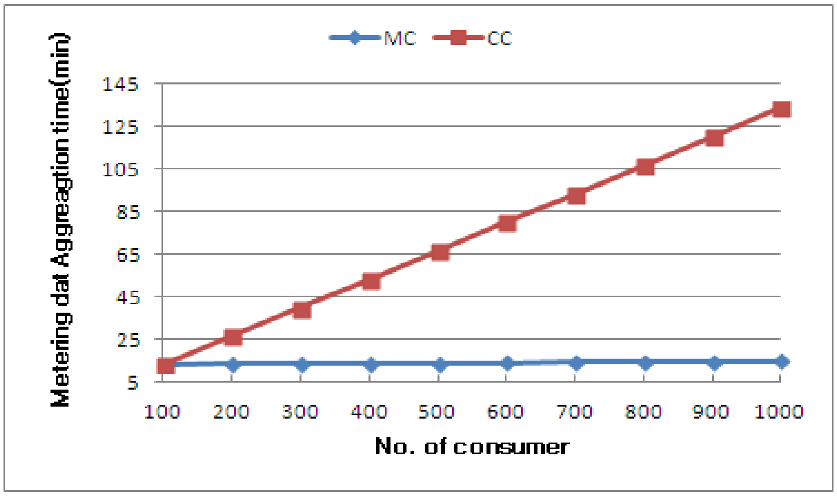

Figure 6. Metering Data Aggregation Time (MC Vs. CC)

Definitely, the EDM transmits meter reading data to the NC in a competitive manner, considering consumed time caused by dividing data in quantity and transmitting them to server. However, this is not an important issue to determine temporal performance. Further, if length of TSP between Sleep Ts and Active Ta is reduced, response time is shorter but current consumed is increased as Active Ta is lengthened of each device. Therefore, as selection on Specification Periodic leads to performance and cost issues, a prerequisite is to select proper specification periodic resulting from the number of consumers on the process of installing and initializing AMI system.

To obtain life expectancy that satisfies users, achieved can be a method increasing the number of battery cell consumed for the EDM. For the life expectancy herein, the AMI device installed is moving for a period of a meter replacement cycle (*e.g.*, 8 years for water meter) without exchanging batteries. As Table 2, the number of consumer is close to 100, which represents analysis on EDM life expectancy on battery cell composition by meter reading cycle, used for the EDM.

Table 2. Life Time Analysis of EDM(unit:year)

No. of consumer	Inspection cycle[1hour]				Inspection cycle[2hour]			
	Cell 1	Cell 5	Cell 10	Cell 20	Ce11 1	Cell 5	Cell 10	Cell 20
10	1	12	24	48	4	22	45	90
50	1	3	6	12	1	6	12	24
100	0	1	3	6	1	3	6	13
No. of consumer	Inspection cycle[3hour]				Inspection cycle[4hour]			
	Cell 1	Cell 5	Cell 10	Cell 20	Ce11 1	Cell 5	Cell 10	Cell 20
10	6	32	63	126	8	40	79	158
50	2	9	18	36	2	12	24	47
100	1	5	10	19	1	6	13	25

To guarantee EDM's battery life expectancy for 10 years, meter reading cycles at two-hour intervals require 20 battery cells, whereas meter reading cycles at three-hour or four-hour intervals can require 10 battery cells. Therefore, in accordance with user requirement and installment environment, it can serve as material selectively using battery cells, and although the number of EDM increases, and if considered is the number of consumer for meter reading is 1,000 at most, managed as a single NC, the cost would not drastically increase.

4. Conclusion

The article herein is about channel set-up and scheduling methods for network allocation of meter reading network in the AMI system, suggesting wireless AMR structure based on multi-channel cluster making it possible for channel set-up and active connection based on multi-channel cluster mixed with network channels between NC and EDM as channel set-up methods for the AMI system's network allocation, and group channels between EDM, OHD, and ED. By setting up channels based on multi-channel cluster mixed with network channels and group channels, efficiency in management can be maximized through physical, logical consumer channel clustering. Further, channel use differentiated between proximate clusters achieves prompt collection on meter reading data and expandability of AMR network.

In conclusion, the AMI system can reduce installment time and maintenance repair cost through hierarchical network structure consisting of four differentiated devices, substantialize a wide array of services by supporting various operation mode through prompt error recovery and back-up functions, and offer various services through increased battery life expectancy and server-based service requests by presenting efficient power management techniques

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