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Adaptive ARQ Method for Enhancements of LTE MAC Protocol

Yonghak Jung†, Youngmi Kwon††

ABSTRACT

In layered communication architecture, each layer is designed to service its own functions to higher layer while getting serviced by lower layer. Usually layered architectures are not optimized in a total view of whole services and functions. So cross layer design pursues performance enhancements by optimizing in various ways. In LTE, MAC layer uses HARQ mechanism and RLC layer uses ARQ mechanism for retransmission. According to the 3GPP 36.331 specification, two layers' cooperation may not happen in an optimized way. This paper suggests an adaptive MAC layer approach which RLC layer's function might be initiated in MAC layer in advance to utilize MAC layer's idling wasting time for RLC layer's next decision. This adaptive ARQ method in MAC layer speeds up the next retransmission and reduces the overall transmission time. Emulation shows the improved performance in total retransmission time and retransmission success ratio. In wireless shadow area, the retransmission occurs frequently. Our approach has strong points in this poor wireless condition.

Key words: LTE, HARQ, ARQ, MAC, RLC

1. INTRODUCTION

According to the GSA (Global mobile Suppliers Association), Q3 2015 total LTE (Long Term Evolution) subscriptions worldwide is 908.5 million, and is equivalent to 12.45% share of the global mobile subs base [1]. Compared to the Q2 2015 total [2], it was increased from 10.44% to 12.45 in three months. As the number of subscribers is increasing, the cell radius of base stations is getting shrunk from macro to micro, pico and femto. As the radius is getting shrunk, the handover among base stations happens more frequently. And as a node gets approaching into cell edge, the signal from base station gets weak and the retry to connect to base station is getting increased.

In layered communication architecture, each layer is designed to service its own functions to higher layer while getting serviced by lower layer. Usually layered architectures are not optimized in a total view of whole services and functions. So cross layer design came up pursing performance enhancements by optimizing in various ways. In recent works, V. S. Gandhi and B. Maheswaran showed PHY - MAC ROUTE cross layer approach is the best among another combination of cross layer approaches like PHY-MAC-APP, MAC-ROUTE, etc[3]. N. Bouchemal, et al. worked on resource allocation and MAC scheduling algorithm to propose a QoS guaranteed cross layer scheduling algorithm in LTE system[4]. A. Mukhopadhyay and V. Sudheer changed uplink control methods to achieve higher MAC layer throughput and good fairness among users[5]; whereas S. Brueck, et. al

※ Corresponding Author : Youngmi Kwon, Address: (305-764) 79 Daehangno, Yuseong-gu, Daejeon, Korea, TEL : +82-42-821-6890, FAX : +82-42-823-5586, E-mail : ymkwon@cnu.ac.kr
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† Mobian Co., Ltd.
(E-mail: jyhpan@gmail.com)
†† Dept. of Radio & Information Communications Engineering, Chungnam National University
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improved downlink control for MAC layer throughput enhancements[6].

In this paper, we focus on improvements of MAC protocol in terms of cooperation with RLC (Radio Link Control) layer. In LTE, ARQ (Auto Repeat reQuest) in RLC layer and HARQ (Hybrid ARQ) in MAC (Medium Access Control) layer cooperate to control the retransmission for the loss of data which is usual in a bad air condition.

In this paper, we propose an improved MAC protocol by importing RLC ARQ to use MAC's idle time for retransmission. Emulation shows the better performance than legacy mechanisms.

In chapter 2, we will describe the general overview of LTE, and in chapter 3, we will propose the adaptive ARQ in MAC. We will show the experimental results in chapter 4 and conclude in chapter 5.

2. LTE OVERVIEW

2.1 Protocol Stacks and Architecture

LTE is a standard for high-speed wireless communication for mobile devices. The overall architecture is shown in Fig. 1. Mobile devices (UE: User Equipment) connects to eNodeB in wireless environment, and the E-UTRAN is responsible for all radio-related functions, such as Radio Resource Management (RRM), Header Compression, Security and connectivity to the EPC (core network) [7].

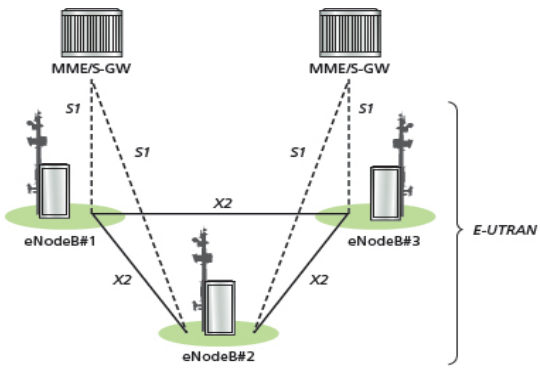

Fig. 1. The Overall Architecture.

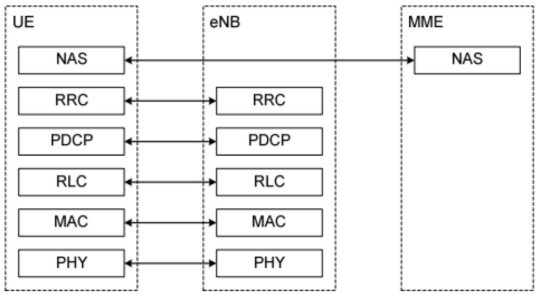

Fig. 2. Protocol Stack in UE and eNodeB.

Protocol stack in UE and eNodeB is shown in Fig. 2. Mobility Management Entity (MME) is an element of core network. Non-Access Stratum (NAS) function is achieved through the interaction between UE and MME.

2.2 Initial Attachment Procedure

When UE initiates the attachment to the LTE network, it follows the procedure shown in Figure 3. UE-side MAC uses contention-based Random Access. MAC sends PRACH (Physical Random Access Channel) preamble and receives RA Response. Finally, MAC gets CR (Contention Resolution) ID which is one of MAC control elements.

2.3 Retransmission Control: ARQ and HARQ

Retransmission in LTE is a cooperation of some layers as shown in Fig. 4. Between UE and eNB, ARQ (Auto Repeat request) in RLC and Hybrid ARQ (HARQ) in MAC are relevant.

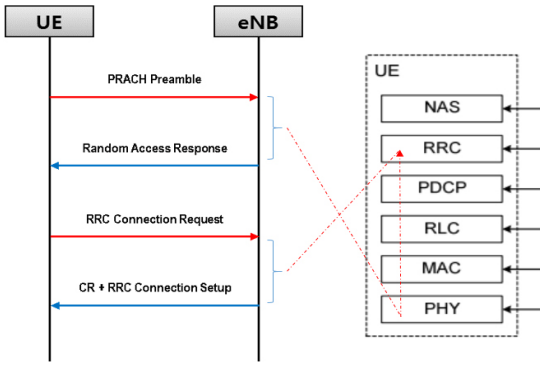

Fig. 3. Initial Attachment Procedure (Part).

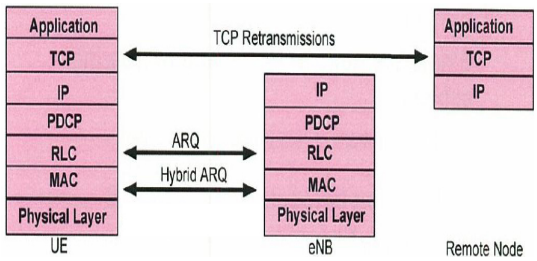

Fig. 4. Retransmission in LTE.

HARQ is only supported for DL/UL-SCH (downlink/uplink shared channel) and HARQ ACK/NACKs are sent to signal if the data transmission was successful or not. ARQ retransmits RLC PDU(s) based on RLC status report which is usually sent from receiver to sender. ARQ is typically a packet with preamble, header, CRC, etc. So, it has higher overhead than HARQ ACK/NACK. In bad channel condition, if ARQ is only used, it produces high latency with extra ARQ status report overhead. Physical HARQ Indicator Channel (PHICH) is a special channel for feedback from eNodeB back to the UE on the HARQ process for the uplink. HARQ is synchronous, with a fixed time of 4 TTI (Transmission Time Interval) from uplink to ACK/NACK on the downlink from the eNodeB. The eNodeB responds back with an opportunity to retransmit which is then scheduled and retransmitted. Fig. 5 and Fig. 6 shows the ACK/NACK processing in uplink and downlink scheduling each other [8, 9].

3. ADAPTIVE ARQ IN MAC

3.1 Legacy ARQ and HARQ with Radio Configuration

In [10], default radio parameter values are defined for SRB1, SRB2, MAC, PHY channel, timers and constants. In SRB1, t-PollRetransmit (poll re-

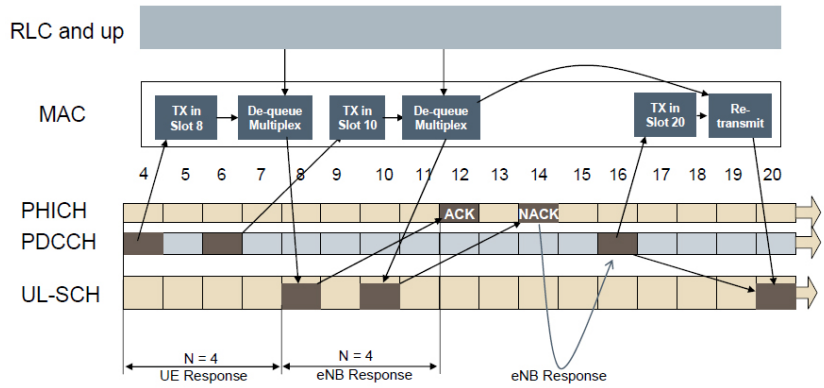

Fig. 5. ACK/NACK Processing in Uplink Scheduling.

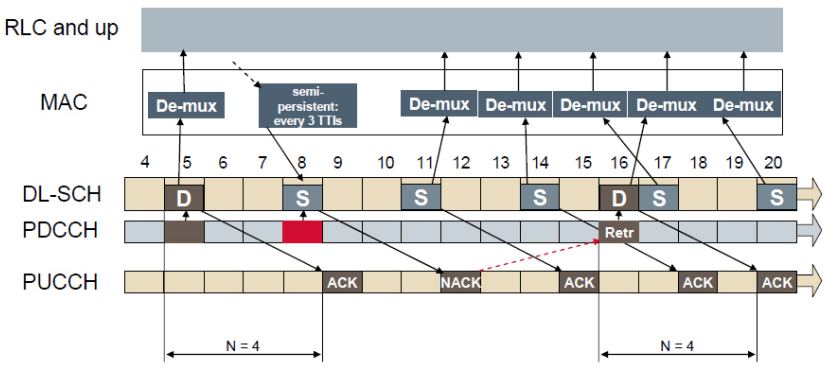

Fig. 6. ACK/NACK Processing in Down Link Scheduling.

transmit timer) is 45 msec and maxRetxThreshold (max retransmission threshold) is 4. For MAC main configuration, maxHARQ-tx (Max HARQ tx) is 5. That is, MAC HARQ is allowed to transmit 5 times at most, including retransmission and RLC ARQ is allowed to retransmit 4 times at most under the condition that polling is used in AM (Acknowledgement Mode) mode [11]. Fig. 7 shows the retransmission flow with these default values.

3.2 Adaptive ARQ combined with MAC HARQ

In Fig. 7, we can see the idle time between MAC finishing time (N+36 subframe) and RLC Timer Expire time (N+45 subframe). During this time, MAC does nothing because it finished the maximum number of transmission specified in parameter. It means that MAC wastes time idling for 9 msec. If the parameters are configured with different values, the idling time could be much larger than this 9 msec. Some telecommunication companies use different values for these parameters, instead of default values, to increase the call connection success ratio and decrease the call setup time even in weak radio condition. One telecommunication company in Korea (say here, Telecom$_A$) configures 100 for t-PollRetransmit, 16 for maxRetransmissionThreshold and 7 for max HARQtx. In this case, MAC idle time is 48 msec.

$$\begin{aligned} MAC\ idle\ time &= RLC\ decision\ time - MAC\ decision\ time \\ &= 100\ msec - (8\ msec \times 6 + 4\ msec) \\ &= 48\ msec \end{aligned} \quad (1)$$

In this paper, we propose Adaptive ARQ so that MAC tries ARQ during the idle time until it waits for RLC's timeout for retransmission. Fig. 8 and 9 show how retransmission may differ in the legacy protocol and in the new proposed protocol. With Telecom$_A$'s parameter values, Fig. 8 is a diagram for legacy ARQ operation and Fig. 9 is for Adaptive ARQ operation. In Adaptive ARQ case, MAC has more opportunity to (re)transmit. In poor radio condition, our Adaptive ARQ in MAC can have higher call setup success ratio and reduced successful data transmission completion time.

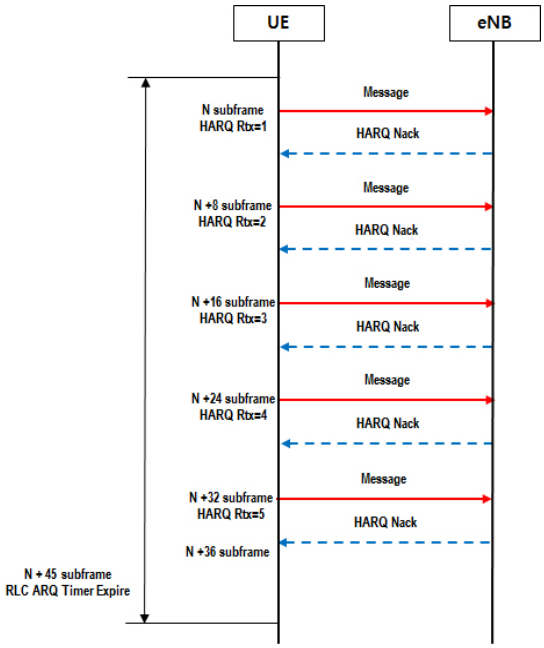

Fig. 7. Transmission Flow with Default Configuration.

4. ADAPTIVE ARQ IN MAC

4.1 Experimental Environment

TTI (Transmission Time Interval) in LTE is 1 msec, which requires high performing CPU. We used TI chip for the experiment. To emulate UE and eNodeB devices, we made two LTE nodes us-

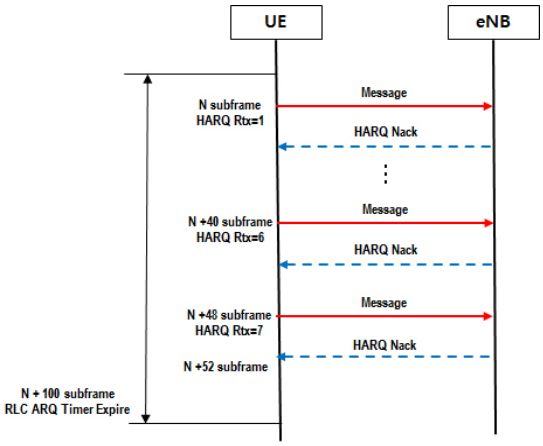

Fig. 8. Legacy ARQ in MAC with TelecomA Configuration.

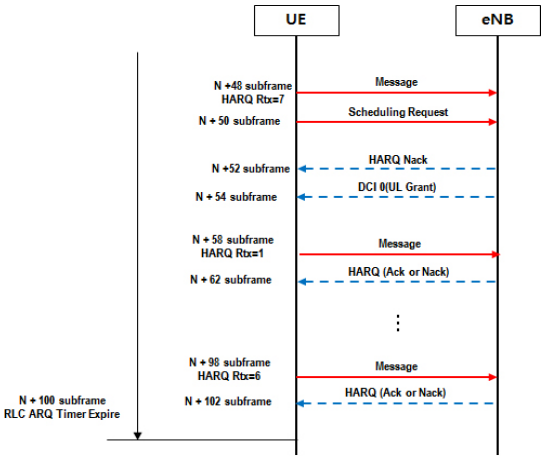

Fig. 9. Adaptive ARQ in MAC with TelecomA Configuration.

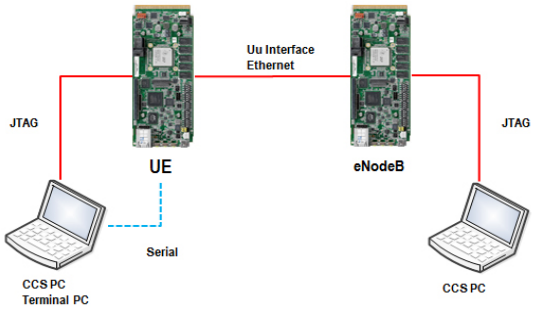

Fig. 10. Experimental Configuration.

ing TI TMS320C6670 DSP EVM board. TMS 320C6670 is a multicore processor which has 4 DSP core subsystem operating in 1.0GHz~1.2GHz clock. This processor supports turbo encoding/decoding, bit rate coprocessor, RSA (Rake Search Accelerator), packet accelerator, RoHC, Air Ciphering, SHA-1/2, MD5, HMAC and etc[12]. Fig. 10 shows the experimental configuration and environment. As for the parameter configuration, we used 3GPP TS 36.331 default values and Telecom$_A$ values. We experimented 1,000 times for each BER condition and measured the completion rate, average completion time and maximum completion time.

4.2 RRC Connection Setup Complete Ratio

We measured RRC connection setup completion ratio with default configuration values and Telecom$_A$ configuration values. As Fig. 11 shows, Telecom$_A$ environment shows higher success ratio than default values environment. Telecom$_A$ setting aims to get higher success ratio for call connection than 3GPP default value. So this is natural result. With default parameter values, in a poor radio condition, the connection setup ratio went under 100%, but still Adaptive ARQ method shows better completion ratio than non-Adaptive ARQ method.

4.3 Average Time for RRC Connection Setup

Average time for the successful RRC connection is shown in Fig. 12. With default parameter values, there is no big difference between Adaptive ARQ

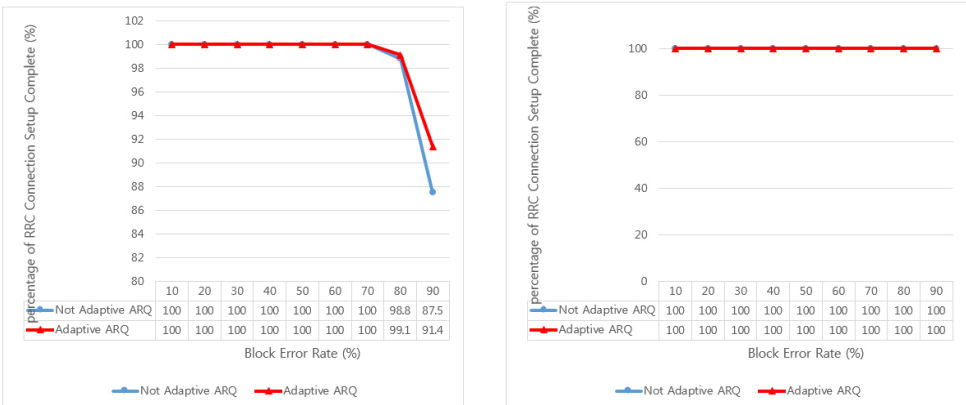

Fig. 11. RRC Connection Setup Completion Ratio.

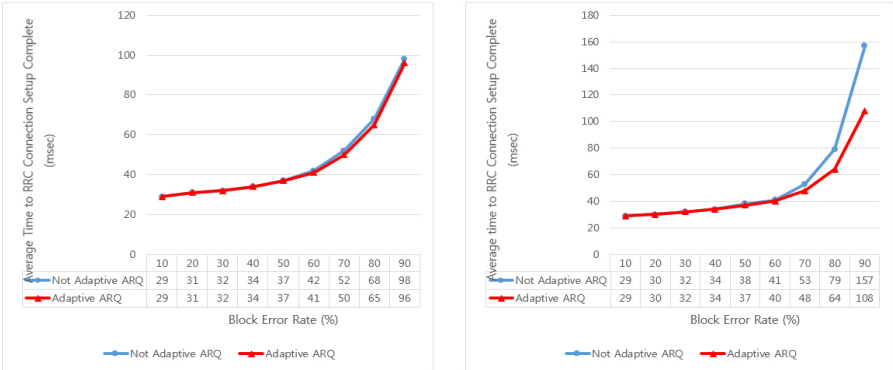

Fig. 12. Average Time for RRC Connection Setup Completion.

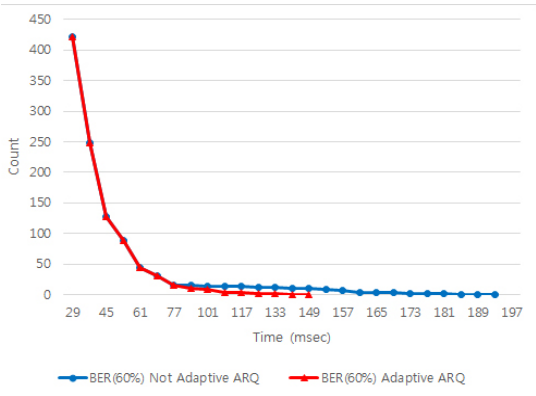

Fig. 13. Distribution of RRC Connection Setup Time when BER is 60%.

and non-Adaptive ARQ. But with Telecom$_A$ values, connection setup time for Adaptive ARQ is shorter than non-Adaptive ARQ.

Because MAC tries another retransmission method rather than idling and waiting for RLC's retransmission, Adaptive ARQ method reduced the overall completion time.

Fig. 13 shows the number of successful RRC connection setups in the 60% BER environment (poor radio condition) with Telecom$_A$ values. For the Adaptive ARQ method, it made the connection successful within 149 msec, whereas non-Adaptive ARQ method took time up to 197 msec. This ratio is roughly 3/4 (75%).

4.4 Maximum Time for RRC Connection

Maximum time for the successful RRC connection is shown in Fig. 14. With default parameter values, there is slight difference between Adaptive ARQ and non-Adaptive ARQ. But with Telecom$_A$

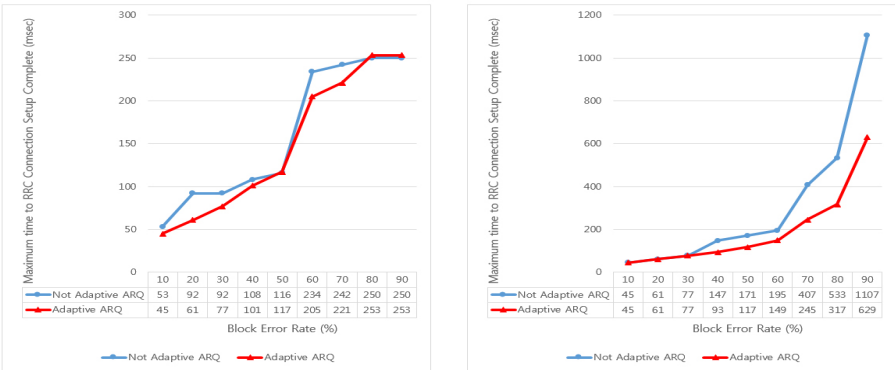

Fig. 14. Max Time for RRC Connection Setup Completion.

values, connection setup time for Adaptive ARQ is apparently shorter than non-Adaptive ARQ.

4. CONCLUSION

HARQ in LTE MAC is called incremental redundancy HARQ scheme because it assembles several incomplete packets into a complete packet. As a sender side gets more chances to retransmit packets in fluctuating poor channel conditions, a receiver can get a packet assembled in shorter time. ARQ in RLC can get a new better link to avoid poor channel resources by a base station for retransmission. In this paper, we proposed the method for MAC to get more opportunities to resend NACK-ed messages by adopting ARQ with HARQ. Instead of idling until RLC decides for retransmission, MAC tries ARQ-like retransmission after HARQ retransmission. Experiment shows that the proposed method completes connection in a shorter time than the normal method does. With Adaptive ARQ method, telecommunication companies can provide user with higher connection successful ratio in shorter connection completion time.

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Yonghak Jung

received the B.S. degrees in Information Communication Engineering from Mokwon University in 2007 and MS. degrees in Information Communication Engineering from Chungnam National University in 2016. During 2007-2013, he stayed in Onnet Technologies Co., Ltd., Daejeon, Korea. Now he is with Mobian Co., Ltd., Korea. Interest areas are Wireless and Mobile Communications.

Youngmi Kwon

received the B.S., M.S. and Ph. D. degrees in Computer Engineering from Seoul National University in 1986, 1988 and 1996, respectively. During 1993-1995, she worked in Electronic Telecommu-nications Research Institute (ETRI), Daejeon, Korea and during 1996-2002, she worked in Mokwon University, Daejeon, Korea. Now she is with Chungnam National University, Korea. Interest areas are Internet Protocols, Mobile Communications, WSN, Embedded System and Cloud Computing.