International Journal of Control and Automation
Vol.7, No.4 (2014), pp.35-44
http://dx.doi.org/10.14257/ijca.2014.7.4.04

Adaptive Time-to-Trigger Scheme for Optimizing LTE Handover

Juwon Kim, Geunhyung Lee and Hoh Peter In

College of Information and Communications, Korea University
Seoul, Republic of Korea

{xacti2, skypepper, hoh_in}@korea.ac.kr

Abstract

This paper presents a handover optimization scheme in LTE for a variety of velocities. This scheme adjusts the time-to-trigger parameter based on received signal strength. The proposed algorithm demonstrates a more enhanced performance during a data link failure and ping-pong effect than existing algorithms focusing on a user's position.

Keywords: *LTE, Handover, Velocity, Time-to-Trigger*

1. Introduction

LTE (Long Term Evolution) is a new mobile communication technology with improved system capacity, coverage, and user experience through higher data rates, reduced latency, deployment, and operating costs, as well as seamless integration with existing systems.

The number of mobile users is on an upward trend. A recent study forecasted a global shift toward mobile Internet usage. Mobile data traffic will grow about sixty-six percent from 2012 to 2017, as shown in figure 1 [1]. For this reason, a handover is an important topic for user mobility.

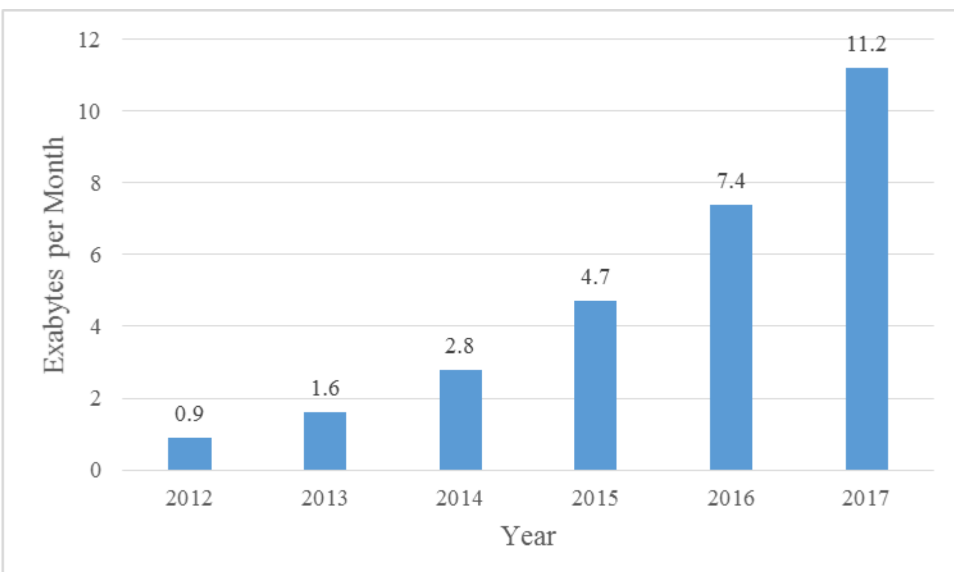


Figure 1. Mobile traffic forecast

ISSN: 2005-4297 IJCA

Several papers have suggested handover methods in an LTE system for a high speed train [2, 3]. However, these methods are focused on the speed and position of the user equipment (UE). While speed and position are good standards for measuring where the user will move in the next phase, this concept generates a great deal of overhead because the UEs have to send their speed and position information periodically to the serving cell. In addition, other methods are required to forecast next user position.

In this paper, a novel handover scheme in variety velocity adjusting time-to-trigger will be proposed. The proposed algorithm changes the time to trigger using received signal strength of the serving cell. In this algorithm, the location and speed of the UE are not important. Radio link failures are therefore decreased.

The remainder of this paper is organized as follows. Section 2 describes the background knowledge relevant to an LTE handover, including the handover procedure. Section 3 describes the proposed handover scheme. Section 4 provides a description of the experiments and results, which illustrate the improvements brought about by the proposed method. Finally, some concluding remarks are given in the final section.

2. Background

2.1. Overview of LTE handover

A measurement configuration is information regarding a connection reconfiguration message sent by a server cell to a UE through an RRC (radio resource control). If any events happen at UE, the measurement configuration reports the received signal strength of serving and neighbor cells. When the collected signal strength meets some conditions of events, a measurement event is triggered and the serving cell is informed. There are several reporting criteria, and especially event A3 is described in particular in Section 2.2.

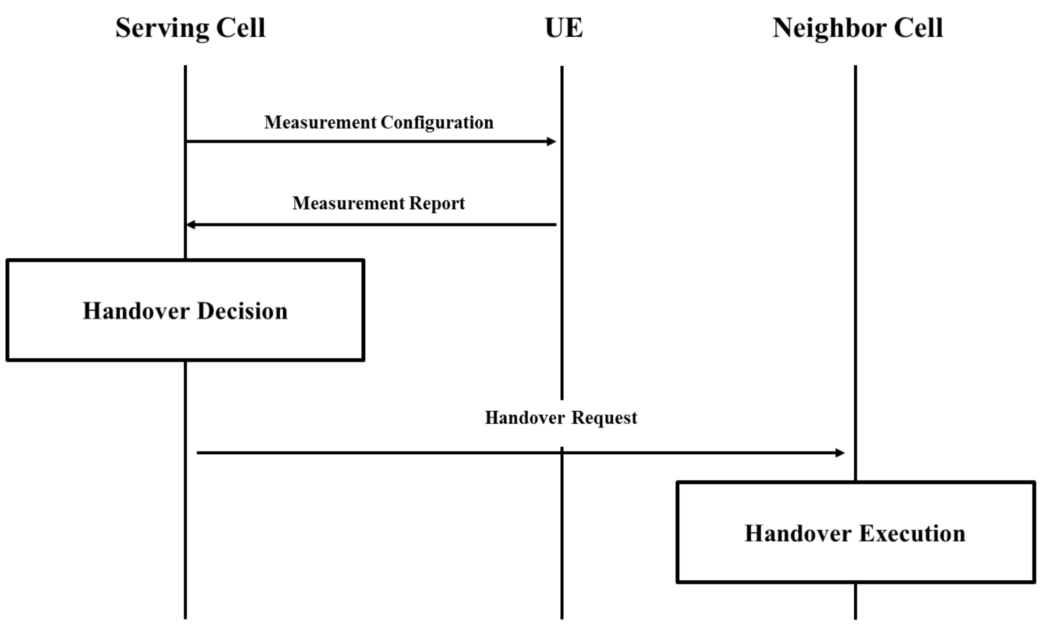


Figure 2. The handover procedure

If an A3 event is reported, the UE determines which neighbor cell and handover is chosen during the handover decision step. Serving cell then forwards a handover request to prepare for a handover to a neighbor cell. A path is created to send a control message and download the packet forwarding.

Handover execution step performs real handover step. UE breaks the wireless link to serving cell and establishes new wireless link to chosen cell. If UE fulfills the connection with new cell successfully, handover is completed.

2.2. Event A3

A UE obtains received signal strengths from the serving and neighbor cells periodically. If the measured values meet the handover event condition, a measurement event is triggered and reports to the serving cell. Event A3 is one of the measurement event reporting criteria to E-UTRA (Evolved Universal Terrestrial Radio Access) [4].

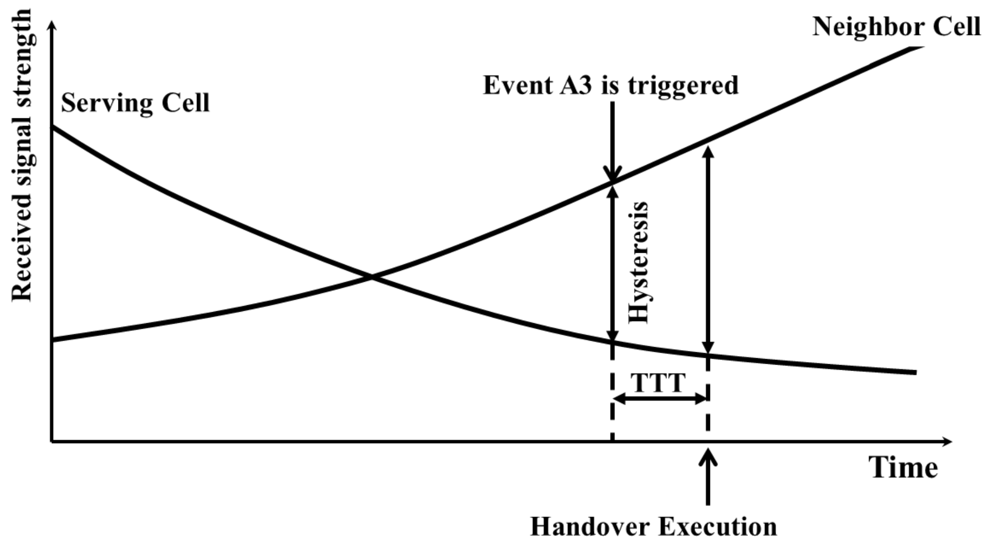


Figure 3. Event A3

Event A3 is triggered when the received signal strength of a neighbor cell becomes better than that of the serving cell. If the received signal strength gap between the serving and neighbor cells is over the hysteresis as shown in figure 2, event A3 is triggered at the UE. Time-to-trigger (TTT) is then required to satisfy event A3. Event A3 can be expressed as follows:

- Event A3 entering condition : $RSS_N > RSS_S + Hysteresis$
- Event A3 leaving condition : $RSS_N > RSS_S - Hysteresis$

where RSS_n and RSS_s are the received signal strength by a UE from the neighbor and target cell, respectively. A TTT is used to avoid a ping-pong effect. Hysteresis and a TTT can be adaptive, and this paper proposes an algorithm that adjusts a TTT to find an appropriate handover time.

3. Handover Scheme by Adjusting TTT

3.1. Parameters

As explained in event A3, a traditional handover is controlled by the hysteresis and TTT parameters. The received signal strength of a neighbor cell is greater than the received signal strength of the serving cell plus the hysteresis value, and this condition should hold for at least the TTT. The TTT is adjusted by proposed algorithm.

The hysteresis and TTT values are specified in [4].

3.1.1. Hysteresis

The hysteresis is a parameter used within the entering and leaving conditions of an event-triggered reporting condition. The actual values vary between 0 and 30dB leaving an interval of 0.5dB. In this paper, we stick to a hysteresis parameter of 6dB.

3.1.2. Time-to-trigger (TTT)

A TTT is the time during which the specific criteria for an event needs to be met in order to trigger a measurement report. The values are 0, 40, 64, 80, 100, 128, 160, 256, 320, 480, 512, 640, 1024, 1280, 2560, and 5120 ms.

3.2. Evaluation of TTT

We evaluated the performance of a traditional handover method using event A3 to determine how the TTT affects the probability of a handover success. The results are given in Figure 4. The velocity of the UE is 120 km/hr.

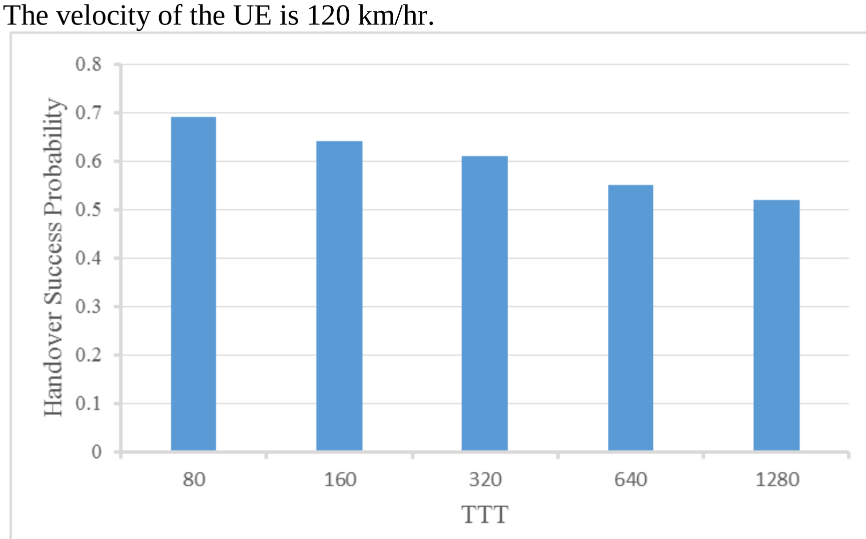


Figure 4. Handover success probability per TTT

When the UE maintains a high speed, the probability of a successful handover decreases as the TTT increases. In addition, we expect a ping-pong effect, which is random mobility near the cell border, to occur in the UE. To solve this problem, we create a criteria that adjusts the TTT inversely to the velocity. This criteria are described in Section 3.3.

3.3. Handover Optimization Criteria

Table 1. Optimization Critera

Handover Performance Indicator	Parameter Optimization
Radio Link Failure Rate	Increasing TTT
Ping-Pong Handover Rate	Increasing TTT

The optimization criteria were derived from simulations for all valid operating points. The optimization is based on the system performance of the handover operating point. The system performance is calculated individually for every TTT.

3.4. Adaptive TTT scheme based on the RSS of the serving cell

In a mobile network, the received signal strength (RSS) is an important component for determining the service quality. Many existing papers have focused on the position of the UE because if system knows where the UE is, it can calculate when to hand over the UE. However, the serving cell cannot know the exact location and speed of the UE in a traditional LTE system. Sending the speed information of the UE to the serving cell creates an additional step in handover, thereby raising the overhead in the entire system.

Table 2. Algorithm of adaptive TTT

```
// Serving cell becomes better than threshold
if (RSSs – hysteresis > threshold)
        TTT increase;
else if (RSSs + hysteresis > threshold)
        TTT decrease;


// handover start
if (event A3 && adaptive TTT is satisfied)
        Handover occurs;
```

In this paper, we suggest a novel scheme for the RSS of serving cell. In this scheme, the UE does not have to send its information to the serving cell, which reduces needless reporting time.

First, the UE should determine its general location based on the RSS of the serving cell.

$$RSS_s - Hysteresis > Threshold$$

This means the serving cell is better than the threshold. In other words, the UE does not have to undergo handover to a neighbor cell because the serving cell is sufficient to provide service to the UE. In addition, if the RSS of the serving cell is sufficient, radio link failures and the ping-pong rate decrease, which means the serving cell maintains its TTT.

$$RSS_s + Hysteresis < Threshold$$

In contrast the above expression indicates that the serving cell is worse than the threshold. The UE needs to be handed over to another cell to maintain service. In addition, if the RSS of the serving cell is not sufficient, the radio link failures and ping-pong rate increase, which means the serving cell decreases its TTT for conducting an immediate handover to other cells.

4. Experiments

4.1. Experiments settings

For the simulations, we analyzed the handover performance using OPNET Modeler v. 17.5 [5], which is a network simulator. Using OPNET, the delay, packet loss, and throughput performances of an LTE during a handover were determined.

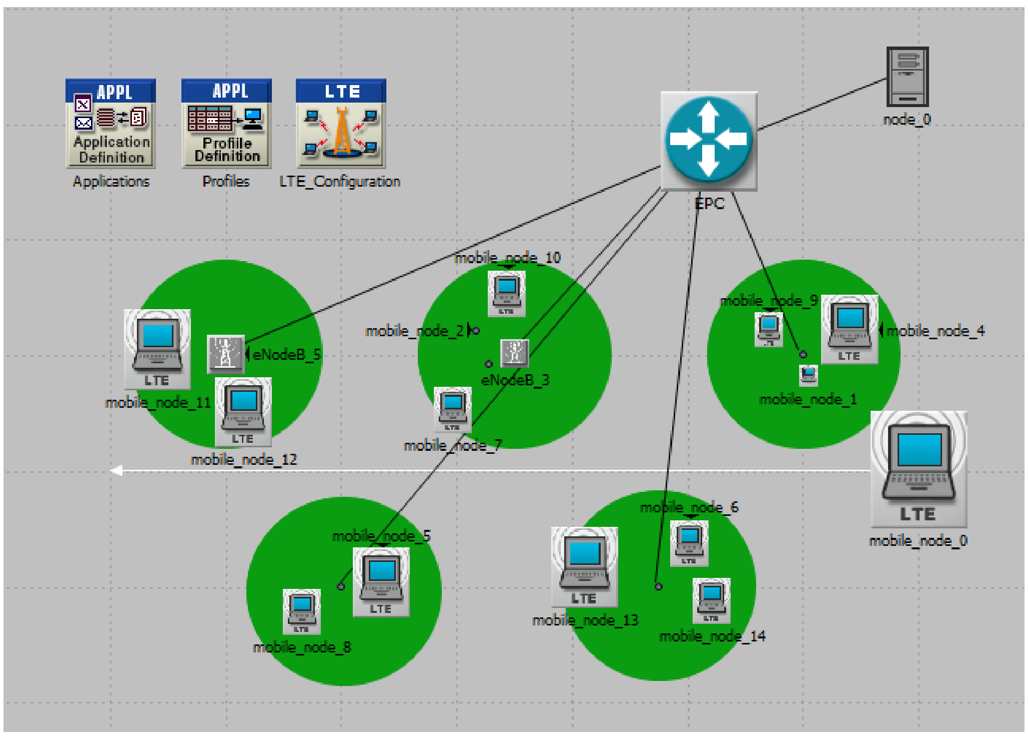


Figure 5. Simulation scenario

The performance was evaluated using a five cells existing side by side. The UEs were uniformly distributed within the area as shown in figure 5. In this simulation, all UEs were constantly moving at random speeds from 0 to 180 km/hr. To bring simulations closer to reality, the UEs assigned their direction to the Random Direction Model (RDM) [6], which is one of the simplest and most widely available mobility models for evaluating a mobile network.

The system parameters used in the simulation are given in Table 3.

Table 3. System parameters

Parameters	Values
Cell Layout	5 cells side by side
Bandwidth	20 MHz
Transmission Power	40 dB
Number of UE	15
UE Position	0 ~ 180 km/hr
UE Direction	Random Direction Model
Simulation Time	10 m
RSRP Sampling Timer Interval	200 ms

4.2. Results

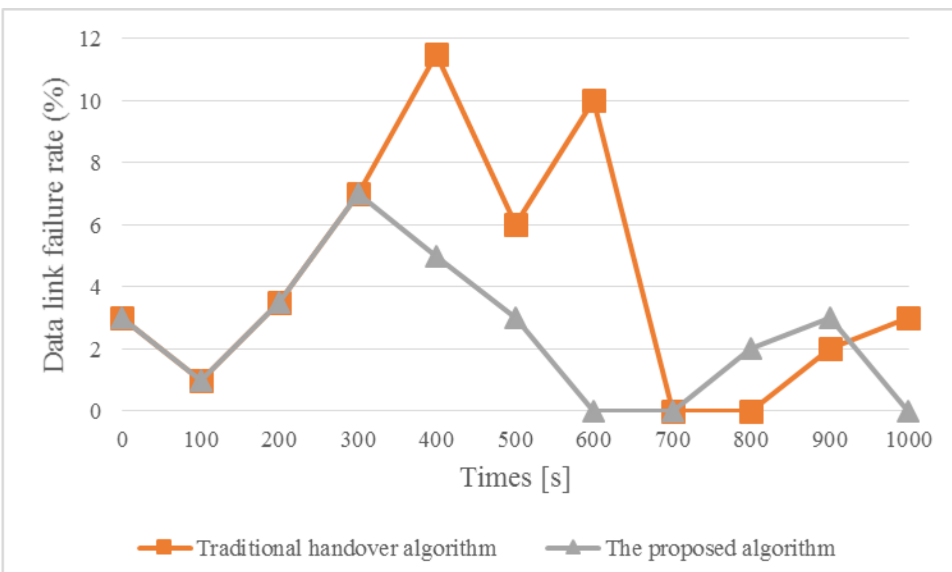


Figure 6. Comparison of data link failure of the proposed handover algorithm with a traditional algorithm per simulation time

Figure 6 shows the date link failure rate based on the simulation time. The data link failures of the traditional handover strategy reach 12% which leads to significant amount of data and packet losses in the network. The proposed algorithm reduces the data link failures that cause data link failures, and an improved performance is shown. The performance is the same up to 4 minutes. After the first phase, data link failure rate reaches almost zero.

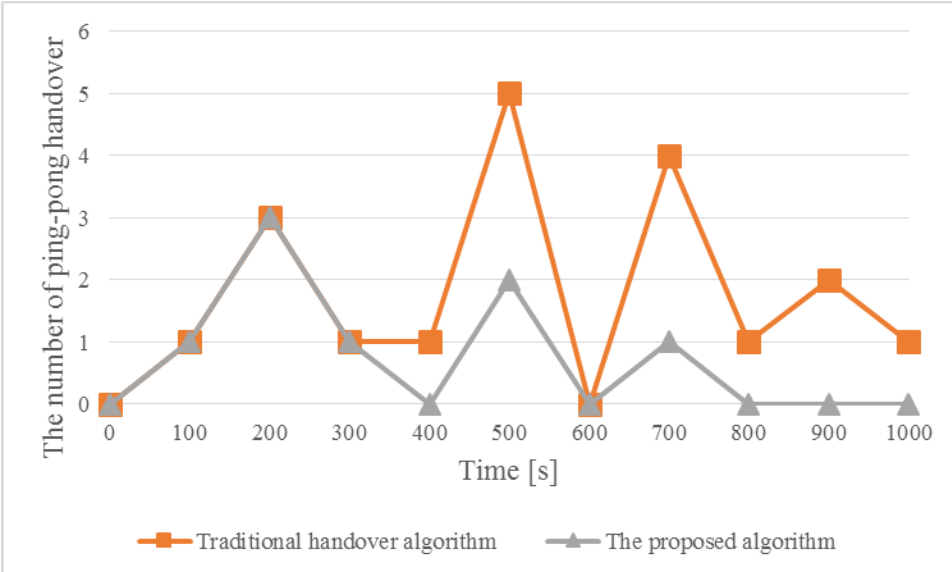


Figure 7. The number of ping-pong handovers of both the traditional and proposed algorithms

In addition, the ping-pong handover rate is enhanced by the proposed algorithm, as shown in figure 7. The reduction in the ping-pong rate is due to the control of the TTT, and thus useless UE handovers near cell border do not happen.

5. Conclusion

As the number of mobile users is increasing, handover is becoming an important topic for user mobility. In an LTE system, existing researches have focused on the user's position when making a handover decision, but this creates additional overhead. In this paper, we proposed adjusting TTT algorithm based on RSS replacing the user's position information. This algorithm demonstrates an enhanced performance in terms of data link failures and the ping-pong effect. As future work, we intend to perform more diverse simulations to prove the effectiveness of the proposed algorithm effectiveness.

Acknowledgements

This research was supported by the R&BD Support Center of the Seoul Development Institute and the South Korean government (WR080951). This research was also supported by the Next-Generation Information Computing Development Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT & Future Planning (2012M3C4A7033345), and Basic Science Research Program through the National Research Foundation of Korea (NRF), which is funded by the Ministry of Education, Science, and Technology (2012R1A1A2009021).

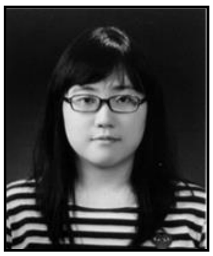
References

[1] Cisco Visual Networking Index: Forecast and Methodology, 2012-2017, Cisco White Papers, **(2013).**

[2] W. Luo, X. Fang, M. Cheng and X. Zhou, "An optimized handover trigger scheme in LTE systems for high-speed railway", In Signal Design and its Applications in Communications (IWSDA), Fifth International Workshop on, **(2011)**, pp. 193-196.

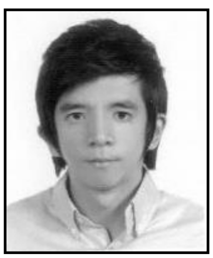
[3] L. Tain, Y. Zhou, J. Li, Y. Huang, J. Shi and J. Zhou, "A novel handover scheme for seamless wireless connectivity in high-speed rail. In Wireless and Mobile Computing", Networking and Communications (WiMob), (2011) IEEE 7th International Conference on, **(2011)**, pp. 230-236.
[4] 3GPP TS 36.331, LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification, vol. 11, no. 40, **(2013)**.
[5] OPNET Technologies, Inc., OPNET Modeler v. 17.5., http://www.opnet.com.
[6] E. M. Royer, P. Melliar-Smith and E. Louise, "An analysis of the optimum node density for ad hoc mobile networks, In Communications, **(2001)**, pp. 857-861.

Authors



Juwon Kim

She is a M.S candidate in the College of Information and Communication, Korea University, Seoul, South Korea. Her research interests are ubiquitous, and embedded system. She received the B.S. degree in computer and information science from Korea University, in 2011.



Geunhyung Lee

He is a M.S candidate in the College of Information and Communication, Korea University, Seoul, South Korea. He received the B.S. degree in computer science from Sangmyung University, in 2011. His research interests are network, and ubiquitous computing.

Hoh Peter In

He is an Associate Professor in the Dept. of Computer Science at Korea University at Seoul, South Korea. His primary research interests are embedded software engineering, social media platform and service, and software security management. He earned the most influential paper award for 10 years in ICRE 2006. He published over 100 research papers. He was an Assistant Professor at Texas A&M University. He received his Ph.D. in Computer Science from University of Southern California (USC).

