Parallel Measurement Method of System Information for 3GPP LTE Femtocell

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***Abstract*—In the 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE) system, User Equipments (UEs) have to measure system information of target cells, if the target cells are Closed Subscriber Group (CSG) cells. Home evolved NodeB (HeNB) in the LTE femtocell is CSG cell. Femtocell is one of promising cellular network technologies to enhance both of cell coverage and capacity. This paper introduces six measurement methods of system information in the 3GPP LTE system. And, we also analyzed performance of the proposed measurement methods in aspect of service interruption time and measurement delay. We find out that the autonomous and parallel method shows the smallest measurement delay and the methods which use small gaps have small service interruption time.**

***Keywords*-LTE; Femtocell; System Information Measurement**

I. Introduction

In 3rd Generation Partnership Project, Long Term Evolution release 8 standardization has been finalized [1]. And also, release 9 standard is on the final step. LTE release 10, in other words LTE-Advanced is being discussed actively. One of the key features of LTE/LTE-Advanced system is heterogeneous deployment. Therefore, femto technology is adopted to expand cell coverage and enhance cell capacity, in the 3GPP LTE release 8. HeNB is femtocell eNB of 3GPP LTE network. HeNBs operate only CSG mode in the release 8. Therefore, only authorized users can access the CSG HeNBs. In the LTE release 9, HeNB is extended to be able to operate in open mode. HeNB can operate in hybrid mode in the LTE-Advanced standard. Hybrid mode HeNB operates not only as CSG HeNB, but also as an open HeNB. Therefore, it provides limited service even though the user who tries to access is not a member of its CSG.

UE does not need to measure system information from target cell in general LTE handover procedure [2], [3], [4]. CSG inbound handover technology is essential to support femto technology in LTE/LTE-Advanced system. And, CSG inbound handover requires system information measurement from target HeNBs instead of getting the information from serving eNB. However, there is not detailed description for it in the 3GPP technical specifications. Therefore, we propose four methods to measure the system information of CSG femtocell in 3GPP LTE/LTE-advanced system.

The remainder of the paper is organized as follows. Section II introduces the backgrounds about System Information in 3GPP LTE system. Section III introduces and analyzes System Information Measurement methods which are proposed in [5] . Section IV proposes the Autonomous Measurement with Parallel Small Gaps method. Section V shows the evaluated performance comparison results and section VI concludes this paper.

II. System Information in 3GPP LTE System

The System Information is exchanged in a type of System Information Blocks (SIBs) between eNBs and UEs. SIB messages are kinds of Radio Resource Control (RRC) messages [2]. SIB messages include Master Information Block (MIB), System Information Block Type 1 (SIB1) and System Information message. MIB message contains essential information such as downlink bandwidth, Hybrid Automatic Retransmission Request (HARQ) channel configuration and System Frame Number (SFN) information. SIB1 message contains information related to cell selection and scheduling information of SIB2 - SIB13 [3].

SIBs except SIB1 are not a RRC message but message elements that are carried by SI message. SIB2 is composed of configuration information of common and shared channels. SIB3 contains cell reselection information, mainly related to the serving cell. SIB4 contains information about the serving frequency and intra-frequency neighboring cells relevant for cell reselection including common parameters for a frequency as well as cell specific reselection parameters. SIB5 contains information about other Evolved Universal Terrestrial Radio Access (E-UTRA) frequencies and inter-frequency neighboring cells relevant for cell reselection. SIB6 contains information about UTRA frequencies used in Universal Mobile Telecommunications System (UMTS), and UTRA neighboring cells relevant for cell reselection. SIB7 contains information about GSM/EDGE Radio Access Network (GERAN) frequencies relevant for cell reselection. SIB8 contains information about CDMA2000 frequencies and CDMA2000 neighboring cells relevant for cell reselection.

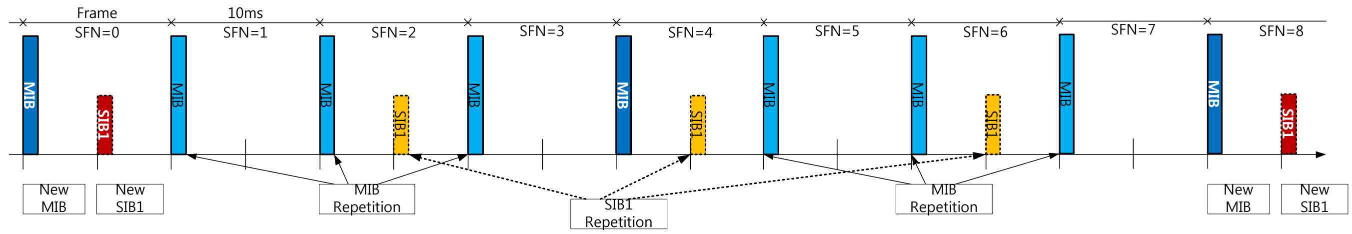

Fig. 1. System Information broadcasting scheduling in time domain

SIB9 contains a home eNB identifier (HNBID). SIB10 contains an Earthquake and Tsunami Warning System (ETWS) primary notification. SIB11 contains an ETWS secondary notification. SIB12 contains a Commercial Mobile Alert System (CMAS) warning notification. SIB13 contains information related to Multimedia Broadcast and Multicast Service (MBMS).

Downlink channel of the 3GPP LTE system uses Orthogonal Frequency Division Multiple Access (OFDMA). Therefore, resources are divided into time and frequency axis. Measurement of MIB and SIB1 is essential steps before handover decision to CSG femtocell. MIB and SIB1 messages are broadcasted from eNBs periodically. System information broadcasting scheduling in time domain is shown in Figure 1. Length of a subframe is 1ms. And, 10 subframes compose a frame. Therefore, length of a frame is 10ms. MIB message packets are generated for every 4 frames (40ms) and replicas are transmitted for every frame (10ms). The packet generation time and transmission duration of SIB1 are double of those of MIB, respectively. Therefore, SIB1 packets are generated for every 8 frames and its replicas are transmitted for every 2 frames. Another system information might be scheduled aperiodically or use other transmission duration. The scheduling information of SIBs in the system information messages is contained in SIB1 messages [6].

III. System Information Measurement in 3GPP LTE System

UE measures system information from neighboring cell after neighboring cell detection. UE has to disconnect the link with serving eNB to measure system information from target eNB. The service interruption time for measurement is called “Measurement Gap”. System information measurement could be performed autonomously or by scheduling from serving eNB. In the autonomous method shown in Figure 2, UE determines the measurement gap by itself. During the measurement gap, packet drop can be occurred since serving eNB cannot know whether the UE is disconnected or not. In the scheduled method shown in Figure 3, UE requests for measurement gap to serving eNB and serving eNB allocate measurement gaps to the UE. Therefore, packet drop does not occur in scheduled methods.

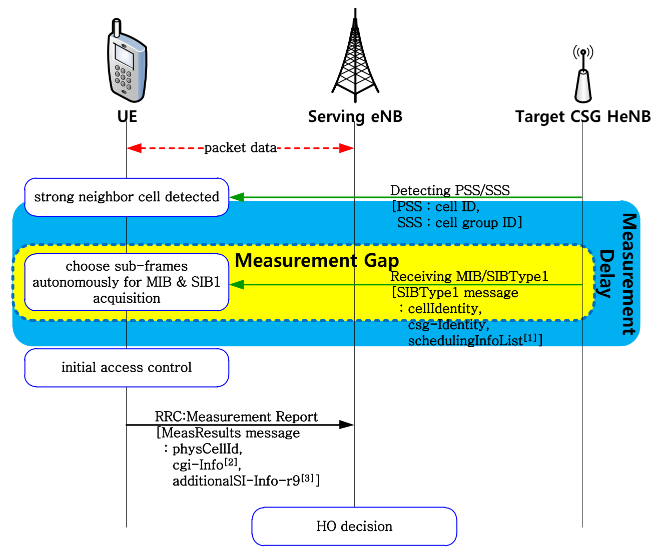

Fig. 2. Message flow of the autonomous measurement with a large gap method

A. Autonomous Measurement with a Large Gap

The Autonomous Measurement with a Large Gap (AMLG) method is shown in Figure 2. In this method, a UE disconnect with serving eNB when candidate neighboring eNBs are detected, and measures MIBs and SIB1s . The UE reconnect with serving eNB after successive MIB and SIB1 measurement. The measurement gap and the measurement delay are given by

$$T_{gap} = T_{MIB+SIB1} \tag{1}$$

and

$$\begin{aligned} T_{delay} &= T_{MIB+SIB1} + T_{RRC} + \cdots \\ &= 6\,(T_{MIB+SIB1} + T_{RRC})\,, \end{aligned} \tag{2}$$

respectively. The measurement delay is the duration from cell detection to measurement completion. And, It is represented as dark (blue) area in Figure 2. The measurement gap is represented dotted (yellow) area. $T_{MIB+SIB1}$ is the service interruption time to receive both of MIB and SIB1 packets of target CSG HeNB at once. $T_{MIB+SIB1}$ is 25ms in the worst case, because maximum time for MIB is 10ms and maximum distance between MIB and SIB1 in time domain is 15ms. And T_{RRC} is the time during a RRC message is transmitted. We assume that T_{RRC} is about 10ms because it is the length of a frame. Figure 4 shows the timing diagram of AMLG.

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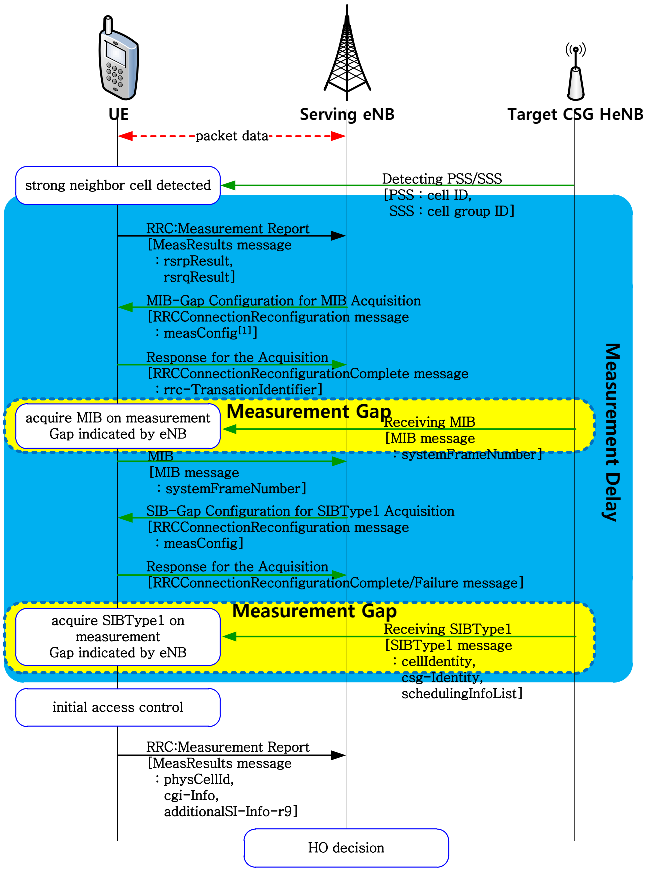

Fig. 3. Message flow of the scheduled measurement with sevaral small gap

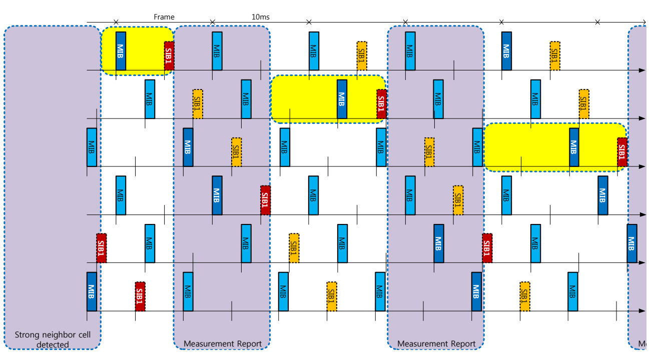

Fig. 4. Measurement Gaps of the Autonomous Measurement with a Large Gap Method

B. Scheduled Measurement with a Large Gap

Figure 5 shows the Scheduled Measurement with a Large Gap (SMLG) method. In the SMLG method, UE request for measurement gap to serving eNB. Then, the serving eNB allocate a large measurement gap to the UE. Therefore, SMLG need more measurement delay than AMLG to exchange scheduling messages. The measurement gap and delay are

$$T_{gap} = T_{MIB+SIB1} \tag{3}$$

and

$$\begin{aligned} T_{delay} &= T_{MIB+SIB1} + 3 \cdot T_{RRC} + T_{MIB+SIB1} \\ &\quad + 3 \cdot T_{RRC} + \cdots + T_{MIB+SIB1} + T_{RRC} \\ &= 6 \cdot T_{MIB+SIB1} + 19 \cdot T_{RRC}. \end{aligned} \tag{4}$$

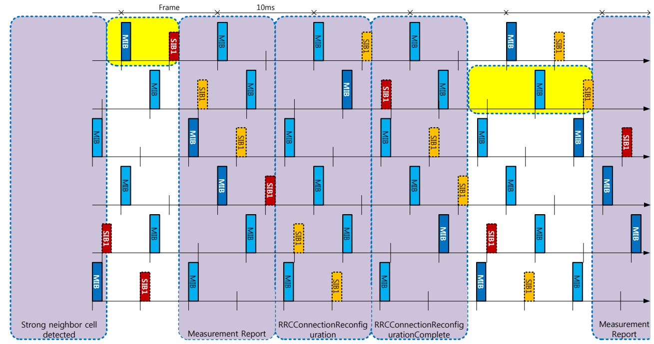

Fig. 5. Measurement Gaps of the Scheduled Measurement with a Large Gap Method

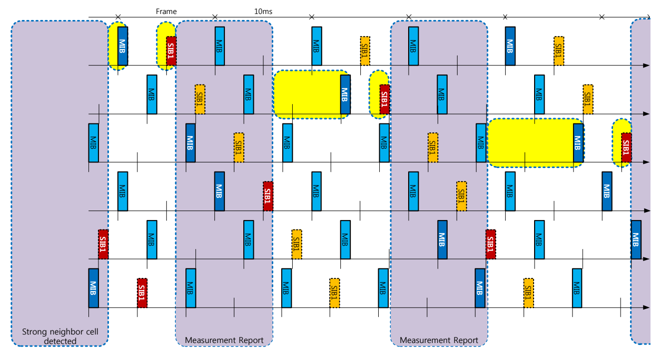

Fig. 6. Measurement Gap of the Autonomous Measurement with several Small Gaps

UE transmits measurement result message to its serving eNB to be assigned a measurement gap. Then, the serving eNB send back RRC connection reconfiguration message to the UE. Finally, the UE acknowledge with RRC connection reconfiguration complete message.

C. Autonomous Measurement with several Small Gaps

Measurement gap of the Autonomous Measurement with several Small Gaps (AMSG) method is not a single large gap, but two or more small gaps shown in Figure 6. UE interrupts connection with its serving eNB until successive

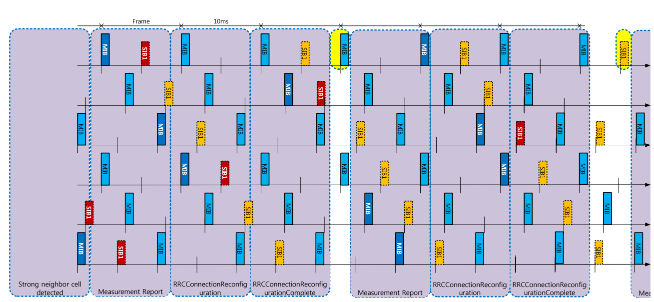

Fig. 7. Measurement Gap of the Scheduled Measurement with several Small Gaps method I

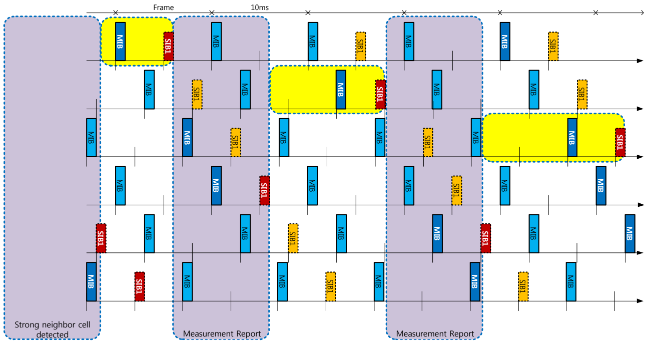

Fig. 8. Measurement Gap of the Scheduled Measurement with several Small Gaps method II

measurement of MIB after detect strong neighboring cell. The UE can predict the time when the target cell transmit a SIB1, because the UE get SFN information from MIB measurement. Therefore, the UE need only one more tiny measurement gap to measure SIB1. The measurement gap and delay are

$$T_{gap} = T_{MIB} \text{ or } T_{SIB1}, \tag{5}$$

and

$$\begin{aligned} T_{delay} &= T_{MIB} + W_{SIB1} + T_{SIB1} + T_{RRC} \\ &\quad + T_{MIB} + W_{SIB1} + T_{SIB1} + T_{RRC} + \cdots \\ &= 6\,(T_{MIB} + W_{SIB1} + T_{SIB1} + T_{RRC}) \end{aligned} \tag{6}$$

where T_{MIB} is time to measure MIB and T_{SIB1} is time to measure SIB1. T_{MIB} is less than 10ms and T_{SIB1} is about 1ms without channel error. W_{SIB1} is waiting time until the SIB1 packet is transmitted.

D. Scheduled Measurement with several Small Gaps I

The Scheduled Measurement with several Small Gaps I (SMSG1) method is almost same with AMSG method except the part of exchanging RRC messages to schedule the measurement gaps. The flow chart and timing diagram are shown in Figure 3 and Figure 7, respectively. The measurement gap and delay are given by

$$T_{gap} = T_{MIB} \text{ or } T_{SIB1}, \tag{7}$$

and

$$\begin{aligned} T_{delay} &= 3 \cdot T_{RRC} + T_{MIB} + 3 \cdot T_{RRC} + W_{SIB1} \\ &\quad + T_{SIB1} + 3 \cdot T_{RRC} + \cdots + W_{SIB1} \\ &\quad + T_{SIB1} + T_{RRC} \\ &= 6\,(T_{MIB} + W_{SIB1} + T_{SIB1}) + 37 \cdot T_{RRC} \end{aligned} \tag{8}$$

respectively. The SMSG1 method naturally has hybrid characteristic of scheduled methods and methods those use several small gaps.

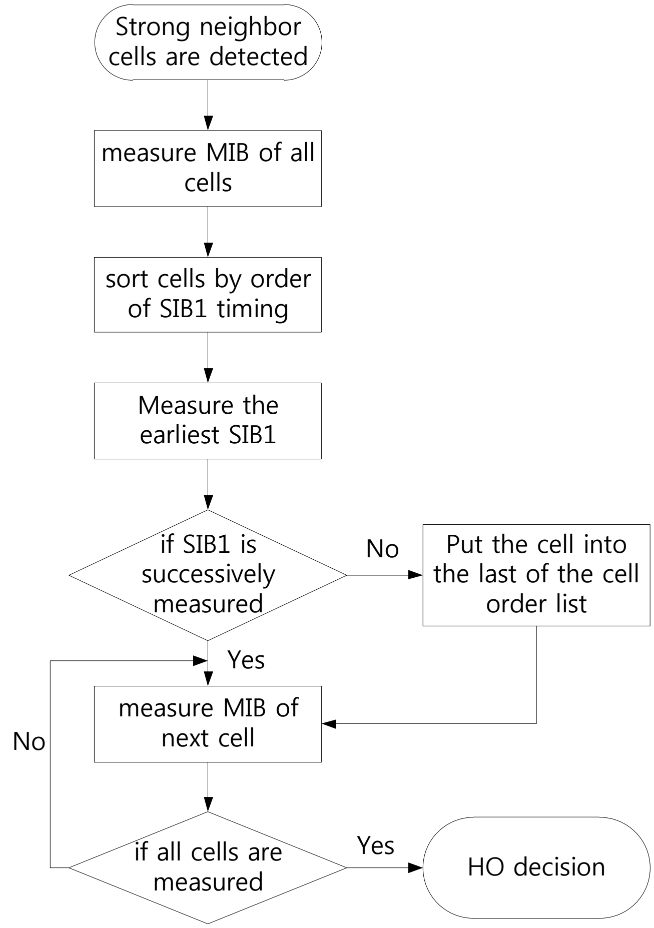

Fig. 9. Flow chart of the Autonomous Measurement with Parallel Small Gaps method

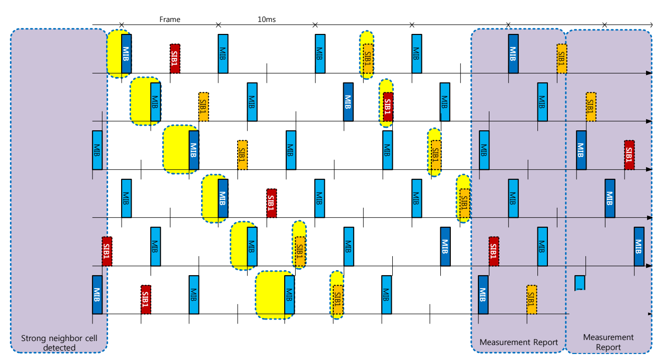

Fig. 10. Measurement Gap of the Autonomous Measurement with Parallel Small Gaps method

E. Scheduled Measurement with several Small Gaps II

The SMSG2 method is hybrid method. UE which uses this method, request measurement gap for MIB to serving eNB. After the UE measure MIB, the UE measure SIB1 autonomously, because the UE knows the timeslot when the SIB1 packet will be transmit and the serving eNB knows the maximum measurement gap for a single cell is 25ms. The timing diagram are shown in Figure 8. The measurement delay and gap are given by

$$T_{gap} = T_{MIB} \text{ or } T_{SIB1}, \quad (9)$$

and

$$\begin{aligned} T_{delay} &= 3 \cdot T_{RRC} + T_{MIB} + W_{SIB1} + T_{SIB1} \\ &\quad +3 \cdot T_{RRC} + \cdots + W_{SIB1} + T_{SIB1} + T_{RRC} \\ &= 6\left(T_{MIB} + W_{SIB1} + T_{SIB1}\right) + 19 \cdot T_{RRC} \quad (10) \end{aligned}$$

respectively.

IV. Autonomous Measurement with Parallel Small Gaps

We propose the Autonomous Measurement with Parallel Small Gaps (AMPSG) method to reduce measurement delay. All methods which are proposed in section III, are serial methods. 'Serial methods' means that the UE measures system informations of target cells cell-by-cell in order of Reference Signal Received Power (RSRP). First, the UE which operates with AMPSG method, measures MIB packets of target cells cell-by-cell in order of RSRP. Then, the UE sorts the target cells in order of distance in time domain. Second, the UE measures the earliest SIB1 packet of target cells and next SIB1 packets until all the SIB1 packets of target cells are received. Figure 9 is the flowchart of the proposed AMPSG method. The measurement delay and gap are given by

$$T_{gap} = T_{MIB} \text{ or } T_{SIB1}, \quad (11)$$

and

$$T_{meas} = 6 \cdot T_{MIB} + 6 \cdot T_{SIB1} + T_{RRC} \quad (12)$$

respectively.

V. Performance Evaluation

In this section, we present the results of mathematical analysis and simulation. In the mathematical analysis, we analyze the maximum measurement delay of measurement methods in worst case. The equations which are used in mathematical analysis, are equation 1-12. In the simulation we use OPNET simulation tool and the parameters which are used, are presented in Table I. And, the network deployment in the simulation is shown in Figure 11. The UE perform system information measurements of 6 target HeNB in a simulation execution. We repeated simulation 200 times with different random seed value for each measurement method.

Figure 12 and 13 show numerical results of mathematical analysis and simulation. In the graph, the x axis represents four methods those are proposed in this paper, and the y axis represents time in the unit of milliseconds. In the mathematical analysis, the maximum service interruption time of both the AMLG and the SMLG methods is about 25ms, while that of the AMSG, SMSG1, SMSG2 and the AMPSG methods is about 10ms. And, the maximum measurement delay of the autonomous methods is 210ms, while the scheduled methods have extra delays about 30ms or 60ms for scheduling message exchange. The AMPSG method shows the shortest measurement delay compared with other methods. In the simulation results, the graph shows similar trend with that of mathematical analysis but, the scale is not exactly matched. The differences between two graphs are due to that the mathematical analysis performed with assumption of worst case. And, the AMPSG shows more delay compared with worst case analysis because overlapping of system information broadcast can occur in the simulation.

As a result, the methods with several small gaps show better performance in aspect of service interruption time. But, all of four methods have smaller than 25ms service interruption time. Therefore, the measurement does not influence on video or VoIP services critically, if the channel quality is properly good to prevent errors in system information message packets. And, autonomous methods show much better performance than that of scheduled methods in the aspect of measurement

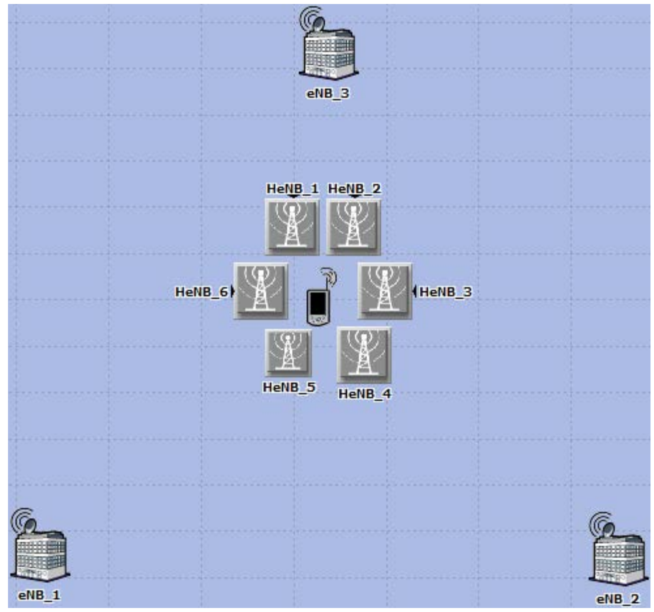

Fig. 11. Network deploy model of simulation

TABLE I
SIMULATION PARAMETERS

Number of macro cell	3 eNBs
Number of HeNB	6
Number of UE	1
Inter-site distance	500 m
System frequency	2GHz
System bandwidth	FDD:10+10MHz
Propagation loss model	Inside the same cluster $L = 127 + 30 \log_{10} R$ For other link $L = 128.1 + 37.6 \log_{10} R$
Shadowing model	Lognormal shadowing
Shadowing standard deviation	10dB for Link between HeNB and HeNB UE 8dB for other links
Penetration Loss	Inside the same cluster: 0dB All other links: 20dB

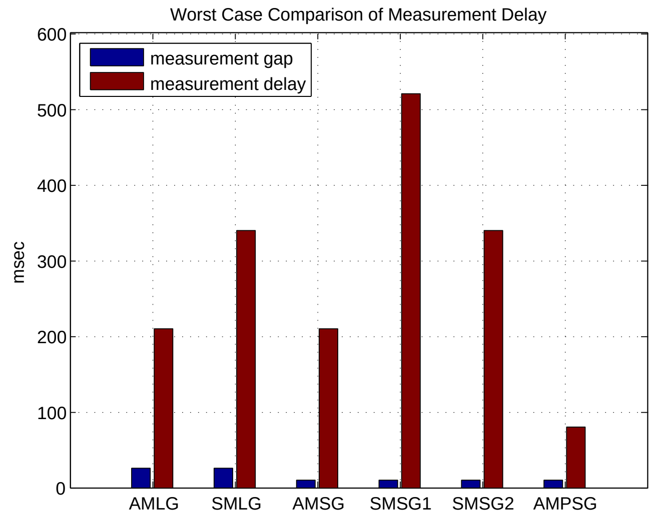

Fig. 12. Worst Case Anlysis Results of Measurement Gaps and Measurement Delay

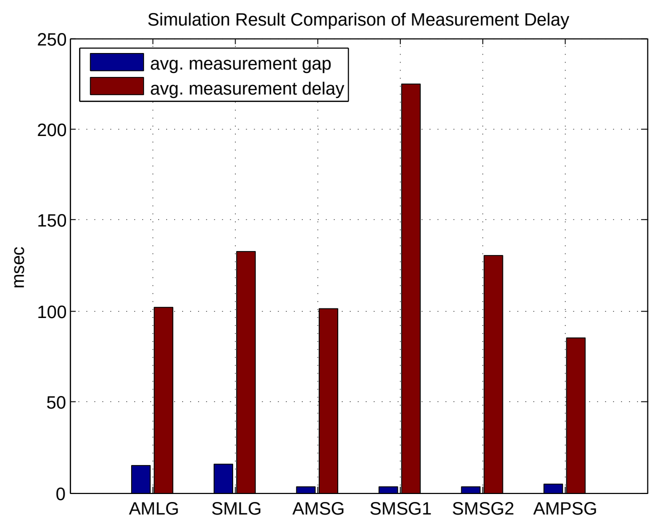

Fig. 13. Simulation Results of Measurement Gaps and Measurement Delay

delay. However, autonomous methods have possibility of packet drop, because the serving cell cannot know whether the UE is disconnected or not. If we want to use the AMLG, AMSG or AMPSG method, we need extra mechanism to prevent possible packet drops. Moreover, parallel method shows better measurement delay performance than that of serial methods. Consequently, the AMPSG method is best solution when the system requires small measurement delay.

VI. Conclustion

In this paper, we propose for system information measurement methods for the 3GPP LTE CSG cell. And we evaluated the performance of those methods in the terms of service interruption time (measurement gap) and measurement delay by mathematical analysis and simulation. As a result, the measurement gaps of methods with a large gap are larger than those of methods with several small gaps. And, the measurement delays of autonomous methods are much shorter than those of scheduled methods. Also, the parallel method shows best performance in aspect of measurement delay.

Acknowledgment

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