International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-4, November 2019

Enhancement of System Information Acquisition for User Based CSG Femtocells in Heterogeneous Network

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Abstract: In LTE/LTE-Advanced networks, system information (SI) acquisition is one of the important parts for accomplishment of handover (HO) to closed subscriber group femtocells. Long measurement gaps and transfer of information during system information (SI) acquisition leads to a degradation of the service quality of the user or radio link failure. In this paper, we run simulations on SI acquisition schemes for user based CSG femtocell inbound using system acquisition from the nearest co-Base station users to avoid interruption ongoing services via intra-frequency measurement scenario and compare with the existing of SI acquisition schemes such as scheduled, semi scheduled and autonomous scheme. Additionally, we propose an improved SI acquisition scheme to reduce measurement gap and minimize the latency of the SI acquisition during the inbound HO evaluation phase with a reduction of time during consideration and valuation of the HO phase. Simulation results show that the performance of the proposed scheme is better than that of the existing SI acquisition schemes by approximately 85%.

Keywords: Heterogeneous, handover, LTE/LTE-A system information acquisition

I. INTRODUCTION

The increasing numbers of mobile broadband data subscribers pose broadening challenges to the operators in terms of providing sufficient radio resources, managing network capacity, traffic loads and maintaining the performance and service quality to various user levels. Several measures are taken to accommodate the increasing number of subscribers including implementation of efficient modulation and coding schemes as well as increasing the radio spectrum. Unfortunately, in the most crowded environments, these measures are not enough to prevent the deterioration of the system performance. One way to overcome this issue is to densify the existing macro networks by adding more sectors which are known as heterogeneous networks. Heterogeneous Networks (HN) scenario with the deployment of the femtocell was adopted for the 3GPP Long Term Evolution (LTE)/LTE-Advanced (LTE-A) systems. Femtocells are small base stations operated under LTE macro cells, also known as evolved Node Bs (eNBs) [1]. This scenario is projected to help the improvement of end user data rate, promote seamless mobility and reduce delays. Evolved Node Bs transmit low powers to cover limited areas and can be accessed in three modes: closed subscriber group (CSG) mode, open mode and hybrid mode. Open Access group is an open service offered to all users regardless of which category the users belong to. This access method is good and suitable to be used at places of interest such as shopping malls, education institutions or public areas. It operates as macro cell to serve all users without any restrictions and any extra charges. Nearby mobile users will receive a stronger signal and can choose to connect with femtocell when the signal from macrocell is deteriorating. This method benefits outdoor users by making use of nearby femtocells in providing indoor coverage where macrocells are unable to provide coverage access. In addition, macrocells can benefit from the traffic offload and improve its performance and capacity especially when providing indoor coverage that requires more power from the macrocells' base station. The subsequent mode is Closed Subscriber Groups mode. In CSG, registered femtocell users have the ability to grant non-registered users' permission to share the femto services. Home Evolved Node B (HeNB) is a 3GPP LTE network femto base station that operates only in the closed subscriber group (CSG). CSG cells have their own unique identifier to facilitate the handover process called CSG Identity (CSG ID). For any registered user, UE will be provided with its core CSG ID and eNodeB ID which is in its CSG whitelist. These ID's will be broadcast in the system information by all femtocells and will be used by UE when there is a need to handover or enable cell reselection. The third and last mode is Hybrid Access Control mode. Hybrid Access mode is divided into two groups namely services provided for the registered users and for unregistered users.

In LTE system, CSG, Hybrid and Open cells will share the range of 504 physical identities (PCI) where Hybrid and Open will get the most numbers to compare with the limited range that is reserved for CSG cells. Since the HeNBs are smaller and cover small areas under macro cells, there will be various numbers of HeNB under one cell and this can lead to PCI confusion when HeNBs have the same identity. This happens when eNB referring to the user equipment report while trying to determine the correct target CSG cell for handover.

Manuscript published on November 30, 2019.
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To resolve the doubt on target cell identity, UE needs to obtain cell global identity (CGI) of CSG cell. This can be done by reading the system information (SI) of the target cell and comparing it with CSG white list [2],[3] to reduce HO failure. UE must release its connection to the serving eNB during the acquisition of SI and prohibited to received or transmitted data packets during this period. This service interruption is called measurement gap. Fig. 1 shows the typical deployment of macrocell and femtocells in LTE network.

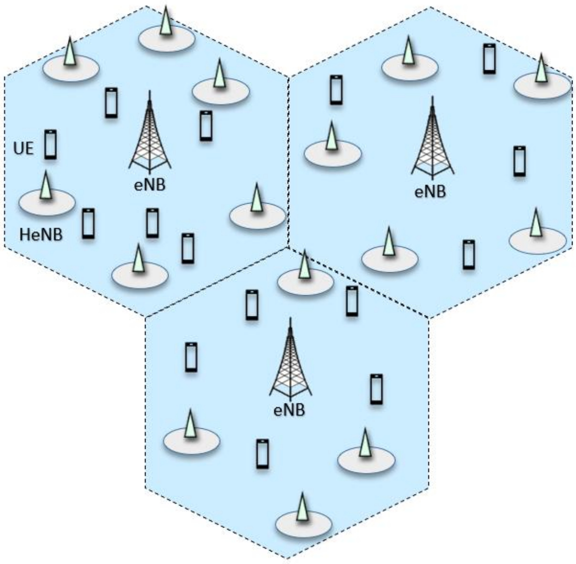

Fig. 1.Heterogeneous network in LTE/LTE-A

In 3GPP LTE, the acquisition of SI may require a measurement gap of up to 160 ms long [4]. Long gaps may degrade quality of services specifically for real time services such as video conferencing or voice over IP. Therefore, the introduction of a new mechanism that could help to avoid or reduce interruptions on real time services would be an advantage to the system. Still, the part of SI acquisition and its detail is left open in technical specifications of 3GPP LTE [5[,[6]. In this paper, we propose a mechanism requiring SI that helps to reduce the measurement gap and minimise service interruption for appropriate CSG users. The proposed algorithm will determine eligible inbound users to be granted services and assisted them by selected nearest UE to share system information during SI acquisition process. This specific UE that is served by eNB will be selected to read the first SI set. The SI set will then be shared to the UE_h via eNB thus enabling the UE_h to read the following SI set in short measurement gaps. This technique can reduce time during HO procedures and shorten the service interruption time for real time services while maintaining the ongoing services of $UE_{h.}$

II. SYSTEM INFORMATION ACQUISITION METHODS IN 3GPP LTE/LTE-A

In 3GPP LTE System, UE that is in connected mode will report to its serving eNB whenever it senses there is a CSG located near its current location. The eNB then will ask the UE to acquire CSG ID of the target cell for checking purposes during preliminary access to avoid confusion due to reuse of PCIs. System Acquisition (SI) in LTE System is divided into two parts. The first part is built-in in the master information block (MIB) and the second is in the system information block type I (SIB1). MIB contains basic information of a target cell such as bandwidth, antenna configuration, frame number and so on, while SIB1 contains CSG ID, cell selection criteria and scheduling information of other SIBs [7]. CSG ID of a cell transmitted on SIB1 uses a physical downlink shared channel (PDSCH) while MIB uses the physical broadcast channel (PBCH). PBCH will broadcast MIB in four transmissions interleaved throughout 40 ms transmission time. The MIB contents can change every 40 ms and UE is not allowed to combine the transmission across 40 ms PBCH inter leaving boundary. Meanwhile, the SIB1 is broadcasted in four identical data blocks over a period of 80 ms. Its repetition will be done in every 20 ms period. This will allow UE to combine the received blocks and improve decoding performance. The combination of these blocks can only be done in this limited time due to the changeable content of SIB1 after the period of 80 ms. UE may need to receive multiple transmissions of a SI message to successfully decode the message [5].

There are two methods proposed in 3GPP LTE regarding the SI acquisition; scheduled method and suspension of the eNB connections method. In the scheduled method, eNB will negotiate the occurrence of measurement gaps and acquire the
SI [8]. SI acquisition will be given in one long measurement gap to read both MIB and SIB1 sets or different small measurement gaps separately reading both sets. During this process of SI acquisition UE will be disconnected from the serving eNB and no transmission or reception will be allowed.

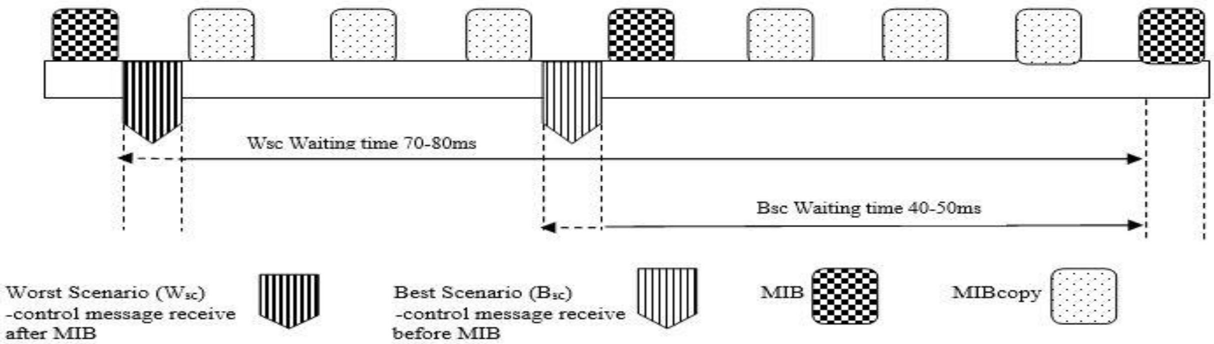

Fig. 2.Worst and best scenarios of MIB Update [7]

To read and decode SIB1, UE must verify the basic information of target cells that are contained in MIB. To read both MIB and SIB1, UE has to disconnect from eNB, and this is known as service interruption time. SIB1 is transmitted in 20 ms periodically whilst MIB interleaved over 40ms. The worst scenario comes when UE misses the information of MIB packet which contains the control message from eNB thus leading to the long waiting time for the cycle repetition to read the MIB again. Fig. 2 depicts the best and worst scenarios. The latter scenario increased the measurement gap, prolonged the HO process and caused a drawback of the system performance in terms of quality of service (QoS) [7]. What happens in worst scenario is UE missed the MIB set and needed to wait for the second transmission of the subsequent MIB set in order to have permission to read the SIB1. This resulted in the long waiting time from 30-40ms.On the other hand, best scenario showed that message control was received slightly before the MIB packet and the waiting time was only 1-10 ms. There are several SI acquisition approaches introduced in 3GPP LTE. The first approach is known as SALG scheduled method with SI packet replicated at 40 ms for MIB and 80 ms for SIB1. In this approach, for UE_H to successfully receive and decode the SI message, it may need multiple transmissions which can prolong the measurement gap to 160 ms. Such long gaps occurring can affect the quality of services especially streaming services as in VoIP communications. HO procedures also will be affected due to the long waiting time and may lead to dropped calls [4]. The second mechanism SSALG will read MIB when granted with a certain scheduled gap and continued with small gaps of SIB1 based on the SFN received. This approach is better than SALG in terms of reducing the measurement gap required to read the SIB1. In the meantime, the gaps to read MIB remain at 80 ms. The third method is called Autonomous Acquisition method (AASG) which allocates a long measurement gap to read MIB and small gaps to read SIB1 as in SSALG, but at the same time detaches the current service with eNB. Unfortunately, this method has not been proven to reduce the measurement gap when UE waits for occurrence of MIB and henceforth to read the SIB1. This is considered as a radio link failure (RLF) because by the time UE is active it might be prohibited to inbound HO to the target CSG cell when it failed to read the SIB1. The existing SI acquisition methods from these 3 techniques clearly aimed at improvement by reducing the measurement gap of SIB1, but not in the case of MIB packets when it could delay the measurement gaps until 80 ms. Consequently, it is significant to enhance the MIB acquisition packets and reduce the overall SI acquisition as proposed in this paper. Our technique was targeted at minimizing the time of evaluation phase and maintaining the QoS during the SI acquisition.

A. Proposed System Information Acquisition Scheme

In this section, we proposed user-based network access to avoid unnecessary handover and simultaneous SI acquisition scheme (SSIAS) for inbound user that needs to handoff to CSG cells. The method used is to approve appropriate inbound users based on time limitation or time stay and detect before rank the nearest mobile (UE_t) to acquire assistance request MIB packets from the identified target mobile by eNB. UE_h acquires the MIB of the target cells in stipulated amounts of time and reads the SIB1 concurrently. Therefore, the worst-case scenarios could be avoided, and the overall process of HO will be faster and more precise. The selection of the femtocells is based on signal strength and bandwidth factor. The SSIAS scheme uses different methods of SI acquisition by different mobile equipment. In the case of missing MIB, the SIB1 that is received will be retransmitted after MIB successfully arrive. In other words, all SIB1s will be received but not in the right order. The detailed simulation process is depicted in the flow chart in figure 3. The proposed mechanism is divided into 2 phases. The first phase is when UE requests for HO as it senses CSG signals indications and gets acknowledgement from eNB after revising the current ongoing services of UE. The eNB will select a few UEs within the same locality to report PCI from the target cell (HeNB). These UEs will then be ranked based on signal strength, speed and location. The best UE will then be the target UE (UE_T) to assist the UE_H based on several factors that might empower the UE to acquire the SI of the HeNB. These factors will give best opportunities to read and decode the SI set that is broadcasted by the target cell in a short time and then report back to the eNB. This will enable the UE_H to obtain the first SI set from eNB rather than waiting from the target cell in the second phase. Thus, UE_H does not need to interrupt its current ongoing services or to disconnect from the serving eNB to obtain the MIB set of CSG target cell, HeNB. Therefore, there is no time allocation needed to read the MIB set from the serving eNB and UE_H can directly read the second set of SIBI inter-frequency in small time gap using either scheduled mode or autonomous mode. In this proposed mechanism, the first set of SI of the target CSG cell will be obtained by the UE_H in the form of RRC control message directly from its current serving eNB rather than acquiring the set from the target cell itself. This means that the UE_H is using intra-frequency measurement instead of inter-frequency SI acquisition procedure where UE_H need to suspend the current ongoing data services to read the MIB set. Thus, the determination of the subsequent SIB1 of the target cell can be done only in small measurement gaps.

B. Selection of target UE (UE_T)

Selection of the target UE_T starts when eNB receives the proximity indication report from the UE_H and the following process will depend on the status of $UE_{H,}$ whether it is engaging with the activity that will prevent it from processing the target cell SI. If the status is clear and available, eNB will identify a number of connected UE which has close vicinity to the target cell and instruct all to report the physical cell identity (PCI) of the target cell back to eNB. Based on the radio resource controller (RRC) and reference signal received power reported by the selected UEs, eNB will then rank the UEs based on the signal strength received and quality indicated that measured by the UEs.

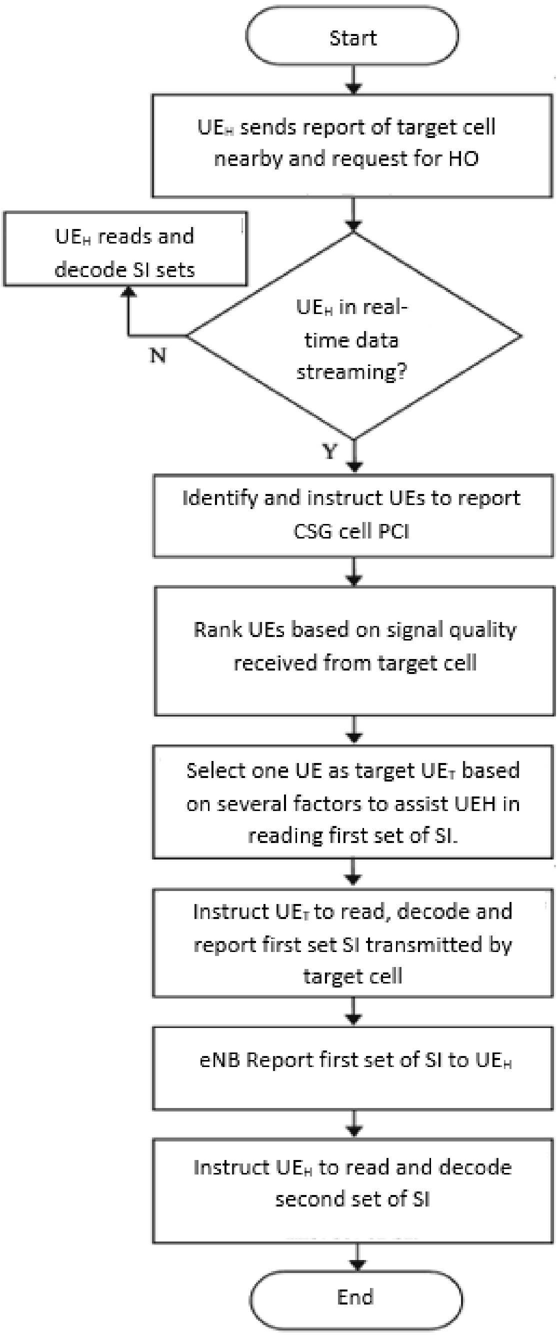

Fig. 3.Flowchart of Proposed Scheme

The best candidates with the highest potential to read and decode in the shortest time span will then be the target UE (UE_T). Measurement gap used in this paper is the same as [8], [9] for SSIAS, where delay can be derived as below:

$$Delay_{time} = R_{MIB.all} + R_{SIB1.all} + W_{SIB1} \ldots + rT_{SIB1} + RR_{time} \quad (1)$$

Where $Delay_{time}$ is the average delay for proposed method, $R_{MIB.all}$ and $R_{SIB1.all}$ are the time duration while receiving the MIB and SIB1 packets from the list of UE_T. Presuming that the selected UE_T unsuccessful to assist the MIB acquisition, the next nearest UE_T will then be chosen to assist UE_H. The mean value of $R_{MIB.all}$ is n_{uet} · (½) · (1+10) for minimum and maximum time difference of MIB which is 1ms and 10 ms, respectively. As for SIB1 packets that broadcast every 20ms the mean value will be ½ · (n_{uet} + 20). W_{SIB1} is the waiting time for SIB1 packets with average value ½ · (5 + 15) = 10 ms for 5 and 15 ms are the possible intervals between an MIB and a SIB1 packet, while rT_{SIB1} and RR_{time} respectively are retransmission of dismissed SIB1 and time acquired for radio resource control message. RR_{time} value is considered 10ms for it is referring to the length of frame. Since we simulate to detect a number of UE_T and choose the best to HO, the analyse of,

$$rT_{SIB1} = 20.i \; PSIB1\,(i) \quad (2)$$

where 20 is 20ms, the time needed to receive the missed SIB1 and *i*, is the number of SIB1 to be retransmitted and *PSIB1*(*i*), probability that UE_H needs more time to receive SIB1 packets. In this paper we will only consider the successful MIBs and SIB1s transmission without referring to packets dismissed by the UE. Since we only consider successful transmission,

$$PSIB1\,(i) = \binom{n_{uet}}{2}\left(\frac{1}{20}\right)^2\left(\frac{19}{20}\right)^{n_{uet}-2} \quad (3)$$

Simulation done focused on intra-frequency measurements which mean that it is unnecessary for UE tuning away from its current downlink channel, thus the measurement gap of MIB from the target cell can be overlooked. Hence, the service interruption time can be derived as [7],

$$SIT = TRRC\_processing + (4 \, x \, TSIB1) \quad (4)$$

Where $T_{RRC\_processing}$ is assumed to be 15 ms for time of UE to process the RRC control message [8].

III. PERFORMANCE EVALUATION

In this section we ran the simulation to evaluate the SSIAS performance to be compared with the existing methods. Simulation was done using the MATLAB software with the parameters listed in table 1. Handover decision in simulation considered parameters such as RSSI, UEs velocities, SINR and bandwidth capacity. The threshold set was at the minimum level required for the handover from Macrocell to Femtocells [10]. Simulation would start with the movement of UEs, moving randomly approaching the Macro and femtocells as represented in figure 4. UEs were set with random speeds at mean 3m/sec and randomly divided into 3 groups of CSG, non-CSG and Hybrid. Velocity of UEs in this study was set to be fixed throughout the simulation time so we could investigate the performance of the UEs, especially those CSG inbound users with streaming services that currently connected to the Macrocell, eNB. The scenario was designed to simulate the macro to femto handover since the CSG cells were amongst the eNB cells. Threshold was set to the base level required for handover from macro to femto to happen. These UE_H were assisted by the best UE_T that were ranked by the eNB based on several parameters such as current

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DOI:10.35940/ijrte.D9523.118419
Journal Website: www.ijrte.org

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International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-4, November 2019

Table- I: Simulation Parameters

Simulation Parameters	
Parameters	***Scenarios***
Cell	51 Hexagon cells 51 Macrocell BS 1000 Femtocells BS (randomly deployed)
Macrocell Radius	1 km
Femtocell Radius	20 m
Macro Tx Power Femto Tx Power	46dBm 20dBm
Propagation model	Same cluster: $L = 127 + 30 \log10 R$ Others: $L = 128.1 + 37.6 \log10 R$
System frequency	2Ghz

ongoing services and distance from the UE_H. All UEs were set randomly with 4 types of services which were: best effort service, data services, video and VoIP. Figure 5 illustrates 4 type of services for all inbound femtocell UEs. The highest service used was type 2 which is 128Kbps for internet browsing and seconded by type 3 which is 384Kbps for VoIP services. Consequently, type 4 came before type 1 which represents the downloading and video online with the least users that inbound to the femtocells. Next the discussion will focus on the inbound femtocell users currently on VoIP services.From the simulation of 2500 users, 279 inbound CSG femtocell handover users were on VoIP services which is represented in figure 5. Simulation time was set at 500 and number of handovers can be seen in figure 6. CSG users with given priority have the lowest number of handovers; followed by hybrid and open groups of users with the highest number of handovers due to the femtocell openness that accepts any group of users. The speed of UEs for inbound CSG with different types of service is shown in figure 7.

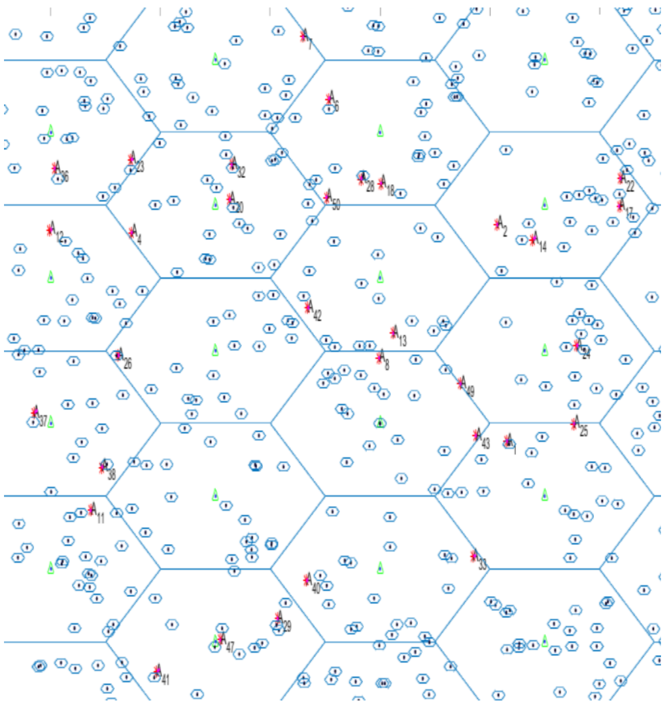

Fig. 4.SSIAS Simulation Scenario

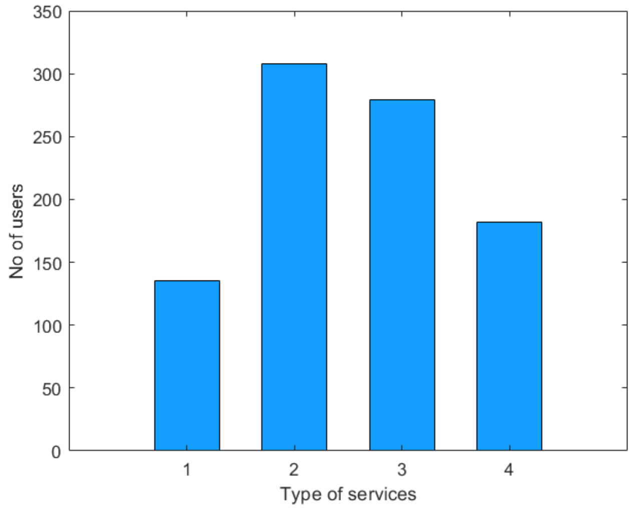

Fig. 5.Inbound femtocell type of services

50% speed of UEs for all types of services except IPTV was below 2.4 (m/s). 69% of users' speed for internet browsing and video streaming was below 3.8 (m/s). These proved that the time stay method used to filter the inbound users was able to determine the appropriate candidates and overcome the unnecessary handovers for users with high speed as UEs will not stay long in femto and produce ping-pong effect [11]. Distance of serving eNB and target cell to the inbound users is shown in figure 8. The inbound UE_H will be assisted by the nearest mobiles encompassing the target cell. Observing the CDF of UE_T to target femtocell, 67% of the target UEs to assist is less than 125 meters to the target cell while 67% current distance of femtocell inbound UEs to eNB were less than 2.5 km showing the basis of handover to be executed. Acquisition delay and service interruption for each group can be analysed in following figure. Notably, the delay time calculated in this paper did not consider the retransmission of SIB1which will be our focus in future work.

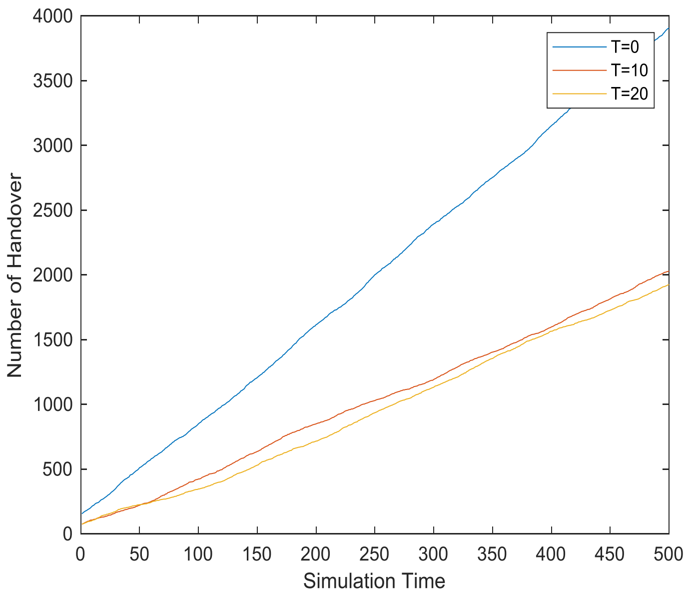

Fig. 6.Number of inbound CSG Femtocell Handovers

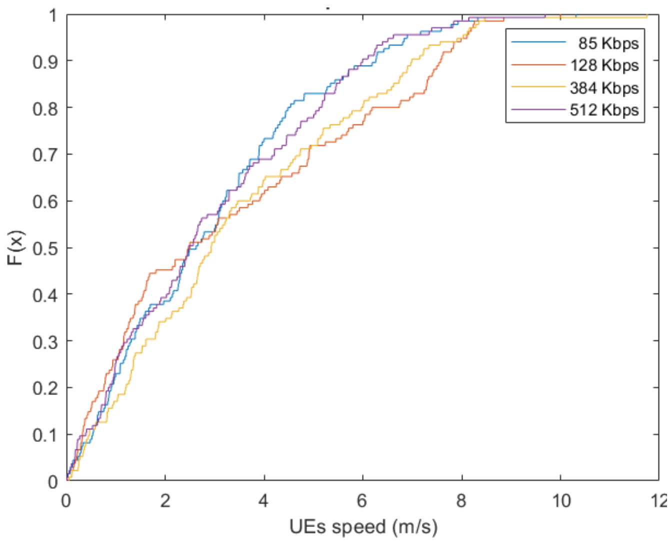

Fig. 7.UEs speed throughout simulation time

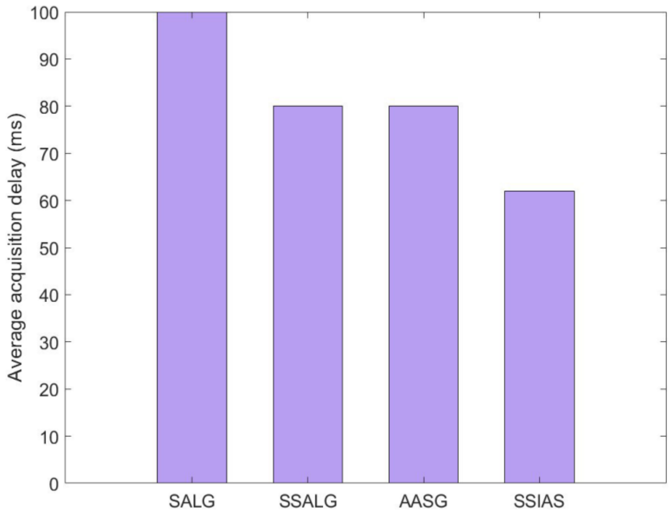

Fig. 9.Average acquisition delay

Fig 9. shows the measurement time gap in conventional and proposed method. SSALG reduced 55% of the gap when scheduled only one gap to read MIB, meanwhile proposed method reduced 25% compared to SSALG and 85% reduced from conventional method SALG. Figure 10 indicates on average acquisition delay when a UE started the HO mechanism. Acquisition delay is the highest factor that contributes to the HO delay. The proposed SSIAS method shows the lowest acquisition delay compared previous scheme.

IV. CONCLUSION

In this paper we simulated a user based CSG Femtocells inbound by acquiring system information from the nearest co-Base Station users via inter-frequency measurement scenario. Results shown that the proposed method managed to avoid unnecessary handover and reduced the service interruption time for inbound users when effecting handoff to CSG cells.

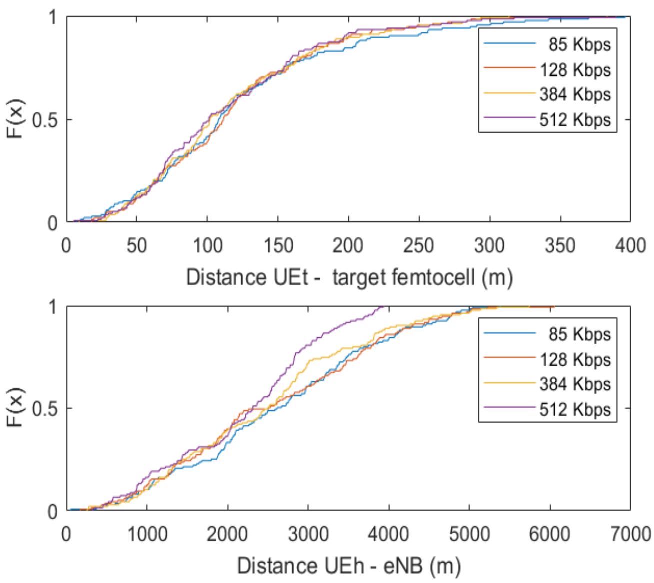

Fig. 8.Distance of UE_T and eNB

The comparison of the proposed algorithm with the existing algorithm in terms of average acquisition delay also showed that the proposed mechanism can lower down the delay while users pursuing handover at a certain region. This will introduce more efficient and seamless handover as well as maintaining and improved the quality of services for the users specifically the CSG femtocells inbound users. Current existing methods are suitable mostly for users receiving or engaging with non-real time services. Unfortunately, this is not possible for real time services in which users will inevitably encounter service interruptions and prolonged HO procedure. Several methods introduced and used showed time reduction but unfortunately will caused radio link failure during the system acquisition process and measurement. Thus, it is important that the average acquisition time is short, so that radio link failure could be avoided. During HO it is important that the cell ID of target cells be clearly identified, to avoid misidentification and unsuccessful HO.

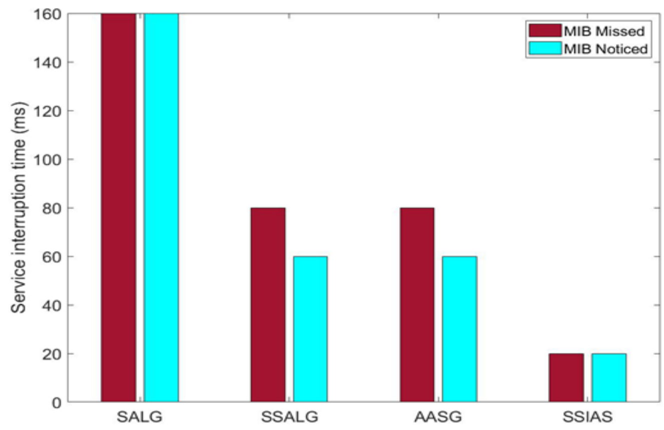

Fig. 10. Service interruption time

Important parameters such as cell ID or PCI that embedded in MIB and SIB1 transmitted and exchanged during RRC process in SI acquisition. In existing SI acquisition methods, the service interruption time is considerably reduced and improved but this acquisition method can lead to RLF during the measurement of the first set of SI [7].

Retrieval Number: D9523118419/2019©BEIESP
DOI:10.35940/ijrte.D9523.118419
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Result shown that the proposed method is suitable for users that involved in real-time streaming communication services such as VoIP especially when users required to handoff its current services due to its location or network conditions. The proposed SSIAS method suggests better possibilities to assist the HO process while maintaining the ongoing services of the inbound UE. This reduction of HO time is very important because it is now possible to provide a better and more reliable service to users besides the assurance of improvement in overall service performance.

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