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A PEER-ASSISTED SYSTEM INFORMATION ACQUISITION USING FAST SCANNING ALGORITHM IN HETEROGENEOUS NETWORK

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ABSTRACT

Femtocells have become an integral part of mobile heterogeneous network which is now being widely utilized as solution of coverage and bandwidth limitation. Coverage area could be expanded, and enormous volumes of traffic can be relieved from macrocell. Coexistence of numerous femtocells in macrocell coverage area certainly need a robust mechanism to integrate in such scenario. In this paper, simulation of peer-assisted fast scanning handover has been done to assist inbound CSG femtocell users. To enhance the handover procedure, a fast scanning done by evaluating some parameters, network conditions and used intra-frequency measurement scenario with the help of collocated users. The results show that the proposed method able to mitigate the unnecessary handover and lowered the system interruption time better than that of existing method approximately 85%.

Keywords: *Evaluation, Execution, Handover, Heterogeneous, LTE, LTE-A, Peer-Assisted, Signaling*

1. INTRODUCTION

Over the past few decades mobile cellular networks have witnessed a constant improvement in their design. This is due to a rising numbers of mobile devices that require voice, data, plus other services of high quality. To ensure demands provided with improved quality, utilization of femtocells proven to be an effective solution, much better than the existing method of installing macrocell. The conventional practice required high installation and maintenance cost, besides, environmentally unpromising. By offering cost and energy efficient to increase network capacity and coverage area, femtocell with low power requirement offers value added to the network. It helps to enhance signal quality in homes and small workplaces. Home users find femtocells easy to install and manage since they operate in the same macrocell base stations licensed spectrum [1]. Femtocells installed within the coverage of a macrocell forming a two-tiered network and operates in three different modes via: open access mode, close access mode or hybrid access mode. The open mode is suitable for the public since it provides open services to public users. As for closed group, only subscribed group members can access the femtocells [2] resources. The combination of closed group and open group known as Hybrid Subscriber Group. Hybrid mode offers highest priority resources access to the subscribed members and considers the remaining resources to non-subscribed members after traffic transmissions scheduling [3]. Femtocells can co-exist with the macrocell and share or utilized on their own spectrum in heterogeneous network. However, as this situation introduces advantages and possibilities, it will also affect the network system and conditions. To manage interoperability in this heterogeneous network, an efficient handover strategy needs to be considered. The objective of this study is to provide an efficient handover strategy with fast scanning mechanism and improved system information acquisition for a heterogeneous network in LTE/LTE-A. It also aims at reducing unnecessary handover in the LTE/LTE-A network and shorten the length of time during information acquisition. The rest of the content is

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structured as follows. Related work on handover algorithm in the heterogeneous LTE/LTE-A network presented in Section II. Section III discussed on heterogeneous network architecture of LTE/LTE-A whereas the proposed handover mechanism is presented in section IV along with the performance analysis of the proposed mechanism. Finally, section V will conclude the work presented in this paper.

2. LITERATURE REVIEW

2.1 Drawback and Challenges

In LTE system, about 504 range of physical identities (PCI) will be shared among the Hybrid, Open and CSG cells. A restricted range of PCI allocated for CSG cells, the rest of it is dominated by Hybrid and Open cells. Since various number of HeNB located in macro cells, there will be many physical identities to be identified which resulted to PCI confusion when some of them having same identity. Fig. 1 illustrates the deployment of femtocells located under macrocells coverage area in LTE/LTE-A network. Misidentification can occur when eNB try to discover CSG cell to handover. To sort out this problem and avoid HO failure, UE needs to read the system information (SI) of the target cell, to check and compare the cell global identity (CGI) with CSG white list [4], [5]. During this system information acquisition process, data will be dismissed and connection between UE and serving eNB will be released to make way to a process called measurement gap or service interruption. Measurement gap may require specific length of time up to 160ms [6]. Such long interruption may affect or reduce the QoS especially in real time services for example voice over IP or video conferencing. Hence, it would be an advantage if there is a new mechanism introduced to help on avoiding or reducing disruptions on sensitive services. Yet, the 3GPP LTE SI acquisition part and its element still remain open in its technical specifications [7], [8].

2.2 Previous Works

Study on heterogeneous network handover have attracted quite a lot of attention recently after being published by the researchers. A work on decision procedure for CSG and non-CSG to avoid unnecessary handover during hand in and hand out in three scenarios was carried out by [9]. Other than that, the paper examined ways to reduce handover failure and eliminate the cross-layer interference. As

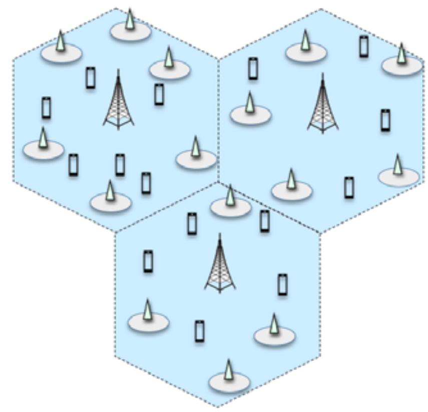

Figure 1: Scenarios of device-to-device Heterogeneous Network

this work only focused on designing the procedure of bound in and bound out for the femtocell users, results on utilizing of simulation software were not available. Writers in [10] focused on the two-tier Femtocells network spectrum access and handover approach. Since the authors concentrated on handover from Macrocell to the Femtocells by considering the Received Signal Strength Indicator (RSSI) and Signal to Interference Level (SINR) level, they introduced a fresh Call Admission Control (CAC) algorithm. Their method managed to reduce and minimize the handover rate and unnecessary handover probability. The authors concluded that the interferences experienced by the users in the Femtocells two-tier network can be reduced by using dynamic spectrum allocation strategy and suggested load switching network algorithm to decrease the network capacity.

While the previous authors introduced a new CAC Algorithm, authors in [11] suggested threshold time for different users to facilitate voice call handover procedure between Macro and Femtocells. Simulation findings for the suggested system showed a reduction in the amount of transfers as the time interval limit increased. The authors demonstrated that the suggested mechanism was effective in preventing unnecessary handover. Following this the authors [12] proposed an algorithm based on speed and QoS to execute handover between femtocell and Macrocell. Users given permission to handoff were divided into 3 categories: low, middle and high speed. User mobiles had to wait for a certain length of time before being allowed to handoff the current services to targeted femtocells. To maintain the QoS, simulations were conducted on both real time and non-real time for different types of services. Next the

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authors compared the results with that of the conventional method. The findings showed better performance for handover numbers. Unfortunately, the authors only considered fixed mobility for mobile users; this does not resemble the actual situation. UEs mobility such as speed and direction of movement differs and varies dynamically. Their optimization technique did not provide the optimum parameter setting for such modifications in the scenario. Therefore, to cope with such realistic modifications, a handover approach must be developed [13]. The authors in [14] focused on and explained important areas and challenges of femtocells in LTE-A. Additionally, they classified the present handover decision algorithms for macrocell-femtocell integration in LTE-A. To obtain a reduction in number of handovers, the authors applied a handover decision policy based on predicting user mobility [15]. The basis for predicting user movement was Markov's chain transition probabilities. Three handover scenarios to consider and analyze were designed: hand-in, hand-out, and inter-FAP handover. Further they introduced reactive and proactive handover strategies to facilitate solutions where validated reactive handover was identified as the mechanism for reducing unnecessary handover. Frequent and unnecessary handover were recorded [16] together with the mobility prediction mechanism proposed in [15]. In their subsequent investigation, the authors focused on horizontal and vertical handovers. Considering hand-in scenario only, they found that the reactive handover strategy was better performing compared with the other handover strategies. Another work [17] introduced a handover mechanism using the HeNB Policy function. The authors used measurement reports and other suitable criteria. So, factors like type of user, femtocell mode, and load were considered in selecting the desired HeNB. Their conclusion was their proposed mechanism could reduce probability of handover failure and unnecessary handovers. Further advantages of the proposed mechanism were also presented. To decrease the total number of hand-in and the Handover Drop Rate (HDR) in the LTE networks, movement direction of mobile devices in addition to users' signal quality were used in [18]. As all the proposed and research done focused on handover mechanism, the system information acquisition (SIA) enhancement also gathers quite a number of attention for the researchers as the mechanism in SIA could prolong the delay of handover and interrupt the current ongoing services which eventually would lead to radio link failure (RLF).

In 3GPP LTE, measurement gap may require up to 160 ms long [19] and this long duration may interrupt and degrades the quality of service especially for sensitive services such as video conferencing and voice over IP (VoIP). Therefore, to overcome the interruption of ongoing services and degradation of services provided it is possible for a new mechanism to be introduced to achieve this objective. This is also a possible method as the SI acquisition and its detail is still left open in 3GPP LTE [20], [21]. Two methods proposed previously regarding SI acquisition is known as SALG and SSALG for the second method. SI acquisition will be given in one long measurement 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. 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 must 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. The latter scenario increased the measurement gap, prolonged

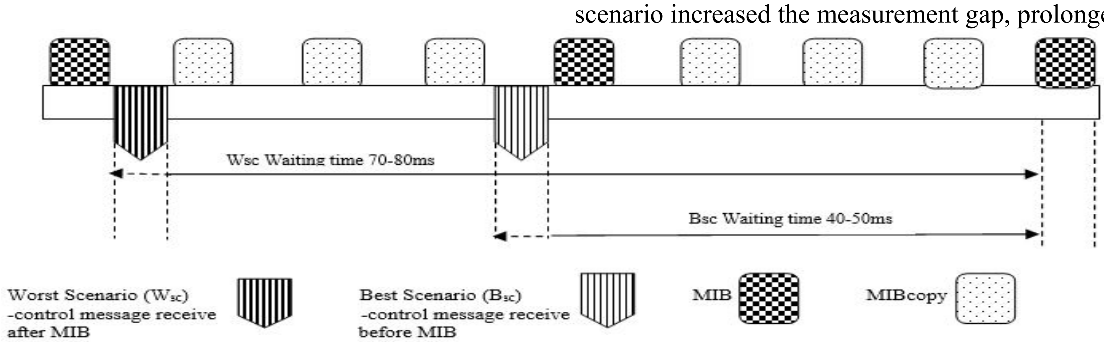

Figure 2: Worst and Best Scenarios of MIB Update

the HO process and caused a drawback of the system performance in terms of quality of service (QoS) [22]. 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 [19]. 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.

3. SYSTEM ARCHITECHTURE

Various features have been added to in LTE-Advanced release 10-12 in order to conform to the requirements by International Telecommunication

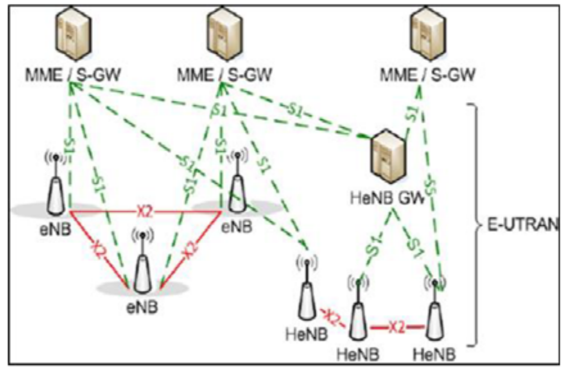

Figure 3: System Architecture in LTE/LTE-A[27]

Union (ITU). Among the feature are heterogeneous networks enhancements, multiple input multiple output for the uplink and the downlink, carrier aggregation enhancements for extending bandwidth, and coordinated multi-cell transmission and reception. These combined features, increased capacity and improved performance in the LTE-A. HetNet enhancements that makes it possible to use small cells like femtocells with smaller coverage within a larger macrocell coverage, can lower the implementing cost and improve the overall system capacity and throughput per-user [23], [24]. The LTE-A system architecture as shown in Fig. 3 represented the eNB and newly added HeNB which supported by the Mobility Management Entity (MME). Other than that, MME also provides assistance for UE mobility and access management, bearer path's creation, security and authentication.

On the other hand, S-GW performs routing and forwarding between mobile user equipment, besides charging and accounting. It also serves as a mobility anchor point for different handover types. Combinations of MME and SGW called Evolved Packet Core (EPC) while HeNB-GW, HeNB and eNB known as E-UTRAN. HeNB-GW serves as a concentrator for the control plane and supports many HeNBs. This is where the functions such as user and control plane protocol termination are performed. Besides that, radio resource control, admission control, paging, scheduling and data routing to the S-GW are also performed by the HeNBs and eNBs [25].

3.1 Handovers and System Acquisition in Heterogeneous Networks

Handover procedure and mechanism with various user's mobility support has been specified in 3GPP LTE 4G mobile system [26]. The process divided into 4 parts which are downlink signal Measurement by UE, measurement result processing

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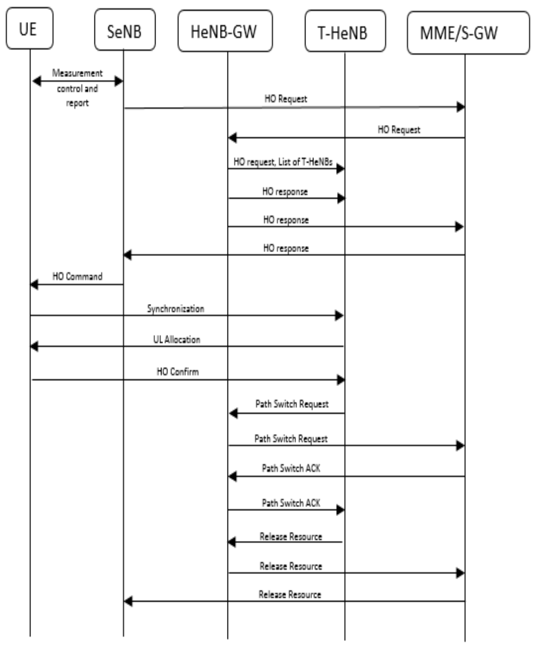

Figure 4: Handover Signaling Process in LTE/LTE-A

processing, report sends to eNB and handover execution based on measurement report. During this stage, the status and information regarding UE, target cell, current ongoing services will be transferred in system information acquisition. System information acquisition will be applied by UE in several situations such as upon initial state after turning the power on, reselecting a cell, after handover completion or receiving the notifications of system information has been changed. UE will search for neighboring cells occasionally even though it still receiving and connected to a serving eNB. This is the stage where UE scans for any possible neighboring cells and select the best and appropriate cell as a new target serving eNB. When it comes to a condition that UE has identified target CSG cell and needs to acquire SI from that cell, UE must disconnect the current service with the serving eNB. Users at this time cannot be provided by or continues to receive any kind of services. This service interruption or measurement gap will also prevent UE to request HO decision from serving eNB until SI is successfully end for all neighboring cells. All these processes happen in initial phase, neighbor networks and resources discovery. Information about bandwidth, channel, frequency will be gathered by UE which will provides multiple metrics such as quality, network coverage and interfaces ready to be used. Some parameters will be used to select the best candidate. In network-controlled mode where the eNB decides to allow and perform handover, RSSI will be the parameter to be compared to perform handover. Still, when CSG is deployed, other parameters such as speed, load balancing, services cost and other has been considered in handover decision. After analyzing network environment and conditions, UE will have to confirms whether a handover is need and possible to be executed. Upon confirmation to handoff, UE will have to release the current connections to eNB and start to receive SI. RRC message is send by the serving eNB to UE to trigger the handover which contains particulars of the target cell, identity and security setting. After this stage, radio random access channel (RACH) process will be executed between UE, eNB and Mobility Management Entity (MME) and should the process successful RRC Connection Configuration will be sent to eNB to end the signaling procedure. Fig. 4 depicted the signaling process of handover in LTE/LTE-A system.

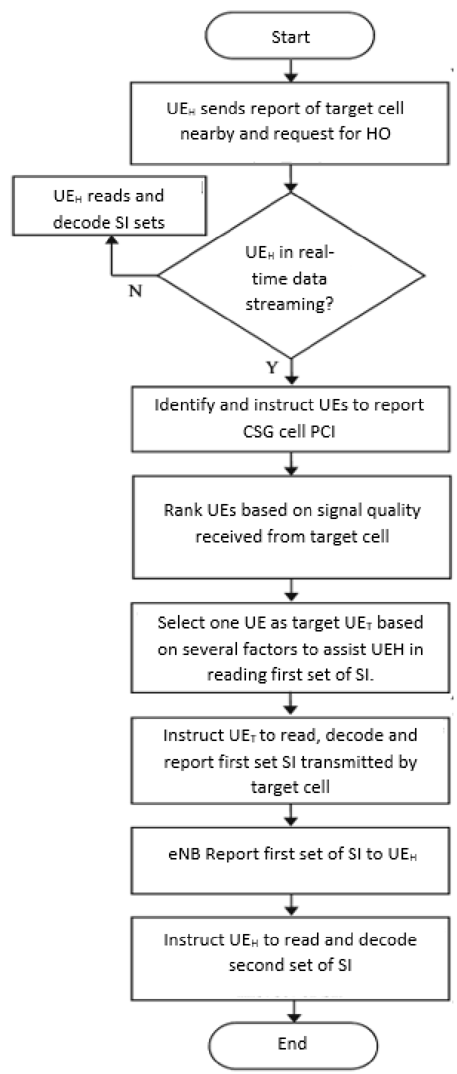

Figure 5: Flowchart of Proposed Scheme

4. PROPOSED ALGORITHM

In this section, we proposed a peer-assisted system information using fast scanning algorithm for inbound CSG cell users. Inbound users to CSG cells will be assess based on the location of the users when they wait for a certain time and will be allowed to handover if still in CSG coverage area. The following stage will acquire assistance from the nearest mobile U_{ET} connected to the same serving eNB in reading the target eNB's MIB packet. This will allow UEh to read the SIB1 concurrently without have to wait for the next cycle of receiving MIB and SIB1. The worst-case scenarios could be avoided using this way and support a faster and accurate handover. Signal strength and available bandwidth are the parameters to be evaluated for selection of femtocells. When identified target CSG cells has been selected, serving eNB will identified nearest UE_T to read the target CSG's MIB packet and send it back to eNB to be shared with UE_H. This is to avoid prolong waiting time to read the SIB1 due to the missed of MIB packet when UE_H need to handover. Fig 5 indicated the proposed mechanism simulation flow chart which was divided into 2 phases. First phase was done when UE request the handover from serving eNB when it senses CSG signal indications. Upon acknowledgement from eNB, selection of a few UEs based on location, speed, and signal strength within the same locality will be done to report PCI of the HeNB. The best UE then will be selected as target UE_T to help UE_H in acquiring SI of target CSG cell or HeNB. In this way will give best opportunities for UEH to read and decode SI set broadcasted by the target cell as fast as possible. Consequently, UE_H will have opportunity to maintain its current ongoing services while obtaining the MIB set from target HeNB. There will be no time allocation needed for UE_H to read MIB set and can directly decode the SIB1 set, in small time gap. In this proposed mechanism, UE_H will obtain the SI of the CSG target cell directly from serving eNB in the form of RRC control message rather than halted the ongoing service to acquire the SI itself. Instead if using inter-frequency SI acquisition procedure, UE_H now will used intra-frequency measurement that will only require small measurement gaps. Measurement gap used is the same as[8], [9] which the delay measurement derived as follow:

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

$Delay_{time}$ is average delay with the summation of $R_{MIB.all}$ and $R_{SIB1.all}$ which are the duration when UE_H received MIB and SIB1 packets from the target UE, UE_T. In the case of UE_T failed to assist in acquiring MIB, the second UET in the list will be chosen to assist the process. $n_{uet} \cdot (½) \cdot (1+10)$ is the mean value for $R_{MIB.all}$ where 1ms and 10 ms represent the minimum and maximum time difference when acquiring MIB. For the SIB1, the mean value will be ½ · (n_{uet} + 20) when the packets broadcasted every 20ms and W_{SIB1}represent the SIB1 packets waiting time with average value ½ · (5 + 15) = 10 ms, for 5 and 15 ms are the interval between MIB and SIB1. Meanwhile rT_{SIB1} is the retransmission of dismissed SIB1 and RR_{time} represent time acquired for RRC message with value of 10ms referred to frame length. Since the proposed method used will detect a few number of UE_T therefore,

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

where 20 is the time needed to receive the missed SIB1 which is 20ms, i , signify the number of SIB1 that need to be retransmitted while $PSIB1(i)$, is the probability that more time needs for UE_H to receive SIB1 packets. This paper will only take in the consideration of successful MIBs and SIB1s transmission with no packets dismissed by UE. Therefore, the probability of time to receive SIB1 can be derived as,

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

Since the SIA done focused on intra-frequency measurements, hence the measurement gap of MIB from the target cell can be overlooked due to the unnecessary of UE tuning away from its current downlink channel. Consequently, referring to [7], service interruption time given as,

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

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

5. PERFORMANCE EVALUATION

Simulation was done using the MATLAB software with the parameters listed in table 1.

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Table 1: 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

Several parameters have been considered during simulation of handover which are SINR, RSSI, bandwidth capacity and UEs velocities. The handover from Macrocell to Femtocells threshold was set at the minimum level required for handover to be executed [10]. Random movement of UEs will approach the Macro and femtocells as represented in fig. 6 as the beginning of the simulation. UEs randomly divided into 3 groups of CSG, non-CSG and Hybrid and set with random speeds at mean 3m/sec. For the purpose of examine the performance, velocity of the UEs that approaching CSG cells with streaming services, was set to be fixed throughout the simulation time. There are 4 types of services randomly set for all UEs which were VoIP, video, data services and best effort services. Fig 7 shows the inbound femtocell UEs type of service. Internet browsing represented by type 2 for 128Kbps was the highest number followed by type 3 for VoIP with 384Kbps. Type 4 and type 1 was in 3rd and 4th positions referring to internet downloading and online video browsing with the smallest number of users that inbound to femtocell.

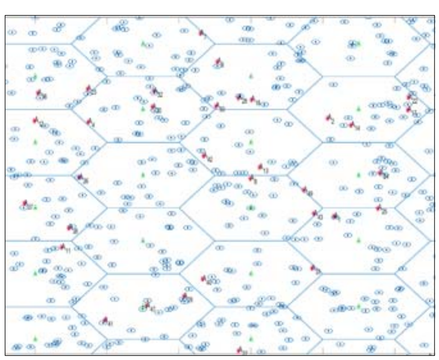

Figure 6: Simulation Scenarios of SSIAS

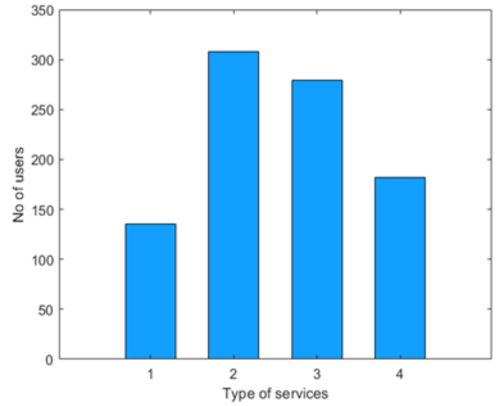

Figure 7: Inbound Femto type of services

Discussion on the further part of this study will focus on VoIP users that approaching femtocells. Simulation time was set at 500 with 2500 users, only 279 users was the CSG femtocell inbound users with VoIP services shown in fig 7. Number of handovers showed in fig. 8 where, CSG users have the lowest number of handovers and trailed by hybrid and open group users. This is due to the open policy for both group and less strict to be compared to CSG users that only give priority registered users to handover to CSG cell. Fig. 9 described the speed of UEs for inbound CSG users with different types of service. For all types of services 50% of users speed was below 2.4(m/s) except for IPTV users. As for internet browsing and video streaming, 69% of the users' speed was below 3.8(m/s). This verified that only appropriate users can handover to CSG femtocell using time stay method. The inbound users were filtered and denied to handovers due to users' high speed which only stay for a while in femto coverage area and resulting ping pong effects [11]. The probability of unnecessary handover can be seen from the CDF graph in figure 10 with respect to total handover. The first 50 seconds of simulation time showed that when UEs was set to stay in the femto

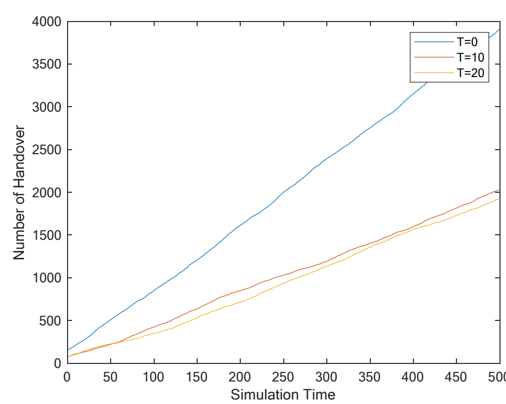

Figure 8: Number of Handovers

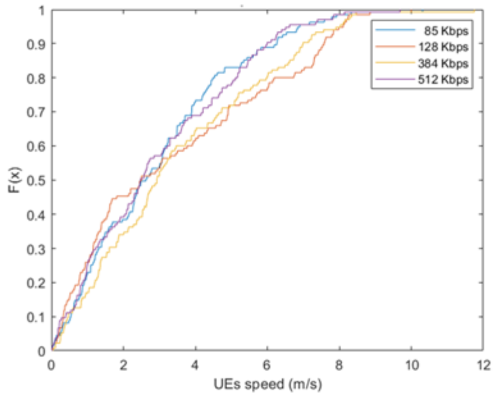

Figure 9: UEs speed throughout simulation time

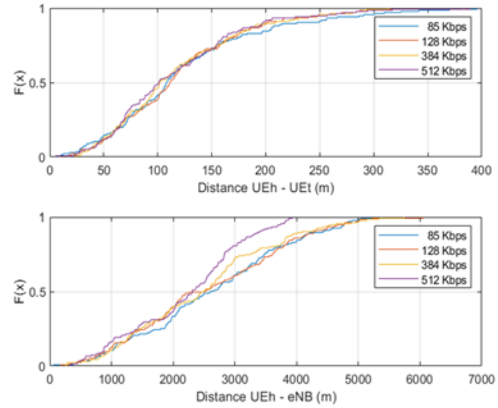

Figure 11: Distance of UE_T and eNB

coverage area until 10 seconds before giving permission to transfer the ongoing services from Macro to Femto, the number of unnecessary handovers was reduced to 0.27 % compared to conventional method at 0.3 % of unnecessary handover. Unlikely for the UEs that must wait for 20 seconds, the unnecessary handovers rate was quite a number which is at 0.32 %. This might be due to the UEs current ongoing services that need to be continue forcing UEs to find an alternative when they was denied to handoff immediately to the femto. 10 seconds stay time to access eligibility of UEs to be served by femtocells showing a better performance compared to 20 seconds stay time as the result showed the number of unnecessary handovers are still high at certain time and remain the same as conventional method. Fig 11 showed the distance of inbound users to serving eNB and target femtocells. In this simulation, the nearest mobile located near the target cell will assist inbound UE_H.

From the CDF graph, 67% distance of UET to target HeNB is less than 125 meters meanwhile 67% distance of UET to eNB were less than 125 meters showing the reason of execution of handover. Service interruption and acquisition delay were analysed in fig. 12. Since we only considered the successful of MIB and SIB1 transmission, the delay time calculated does not consider retransmission of SIB1. Fig. 9 illustrate the comparison of time gap in proposed and conventional method. By scheduling only one gap to read MIB, SSALG method has reduced 55% compared to the conventional method. As the proposed method, the results show that 85 % time gap reduced from the original method and improved 25% compared to SSALG method. Service interruption time was graphed in fig. 13 which indicates that the highest factor that contributes to HO delay were from the system acquisition time gap. Compared to the conventional methods, proposed mechanism shows the lowest service interruption time.

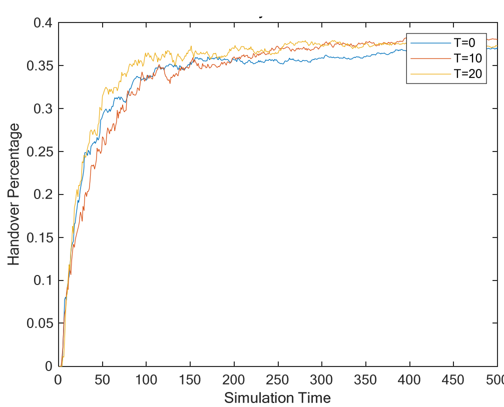

Figure 10: Unnecessary Handovers

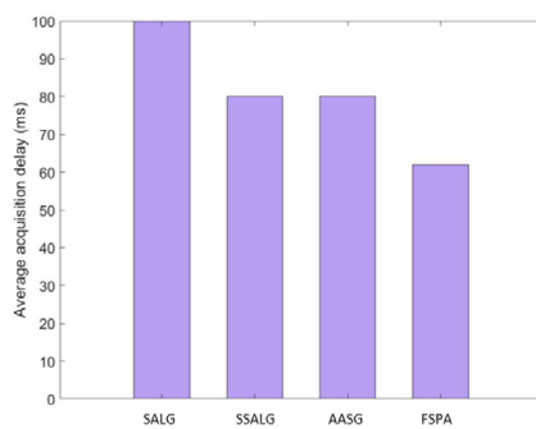

Figure 12: Acquisition Delay

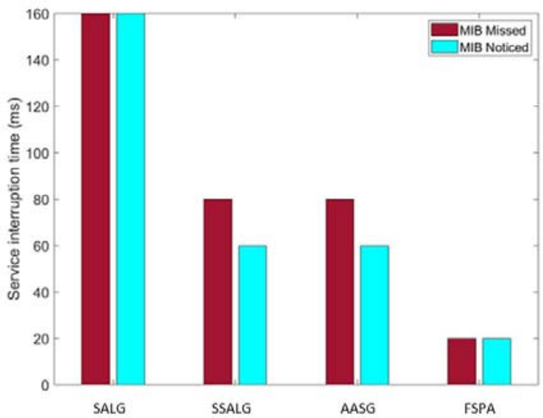

Figure 13: Service interruption time

6. CONCLUSION

In this paper we simulated HO process using peer-assisted fast scanning SI acquisition for inbound CSG Femtocells UEs with VoIP service in heterogeneous mobile network scenario. Hand-in or inbound scenarios from Macro to femto are more demanding since there are many femtocells existed in Macro coverage area in heterogeneous network. Selection of femtocells to handover is quite a challenging issue due to its identities and different groups operation. Results shown that the proposed method accomplished to reduce the unnecessary handover for the inbound CSG femtocell users. In terms of average acquisition delay, the proposed method managed to lower down the delay, helps to improve the handover process and enhanced the quality of service for the CSG femtocells inbound users.

Existing methods are best suited for users who receive or engaging with non real-time services. However, this is not possible for real-time services where users unavoidably will experience prolonged HO procedures. Previous methods introduced indicates a reduction in time but unfortunately will result to radio link failure during the measurement and acquisition of the information system. Thus, it is a necessity to ensure avoidance of unnecessary HO, short acquisition delay and clearly identified cell ID, during the process to avoid service interruption especially the worst-case scenario. The proposed method capable to avoid unnecessary handover for inbound CSG femtocell users and reduced the service interruption time when users need to handover due to network condition or its location. Additionally, users have advantage to continue maintaining ongoing services as a result of intra-frequency transmission that allows SI acquisition done without interrupting the current ongoing service. This mechanism also requires small measurement gaps and suggests better possibility in providing improved quality of service. Handover and its essential is major importance in providing better and reliable services to consumers especially to the users with sensitive data transferring. Hence, it is vital for any network provider to maintain and perform in this part, to avoid service degradation and provide best quality of services to consumers.

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