Efficient SON Handover Scheme for Enterprise Femtocell Networks

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***Abstract*—Femtocells are used in indoors to improve the coverage and data rates of the mobile users. In Enterprise building having high deployment of femtocells, users keep moving from place to place inside the building. As a result existing handover schemes lead to a lot of handovers. These handovers are happen to provide seamless connectivity. However, some of the handovers can happen at locations where user mobility is constrained and therefore unnecessary. These unnecessary handovers can even lead to considerable packet loss, decrease in system throughput and high signaling cost. Mitigating these unnecessary handovers requires the notion of location and user mobility in indoor environment. In this paper, we propose an efficient self-organizing network (SON) based handover scheme to mitigate unnecessary handovers with the help of estimated user position information. Simulation carried out in NS-3 show that our proposed scheme achieves 31% improvement in reducing handover delay compared to an existing scheme.**

I. Introduction

In order to provide higher data rates in mobile wireless networks, the 3GPP proposed Long Term Evolution (LTE) standard by enhancing the Universal Terrestrial Radio Access Network (UTRAN). LTE promises to meet bandwidth demands of the emerging new applications such as MMOG (Multimedia Online Gaming), mobile TV, Web 2.0, and video streaming. According to the traffic statistics given by Huawei and Nokia-Siemens [1], [2], more than 70% of the traffic in cellular networks come from indoor environments due to the increased use of smart phones and tablet computers for media consumption. The outdoor macro cell sometimes does not cover the areas within the buildings and as a result the signal strength is very weak inside the building. Further the signal strength falls down due to attenuation factors such as fading and shadowing.

To address the issues regarding the signal coverage within indoors, femtocells have been integrated into LTE cellular network architecture. Femtocell is an example of small cell network installed by end users and it can serve 16 to 32 user equipments (UEs) [3] in case of enterprise Femto deployments. Femtocells are used to provide sufficient wireless access to the indoor UEs. These femtocells are installed by end-users who have broadband Internet connection. But usage of femtocells lead to several issues such as frequent handovers, co-tier and cross-tier interference, PCI (Physical Cell ID) confusion and security issues.

Handover procedure consists of handover measurement report, handover decision, handover execution and handover completion phases. The handover depends on access mode of femtocell. Femtocell provide three types of access: closed, open and hybrid. In closed access mode, femtocell allows only authorized UEs. In open access mode, femtocell serves all UEs upto its maximum capacity. The hybrid access mode is combination of open and closed modes. The open (or hybrid) access can lead to frequent handovers in areas with high density of femtocells. The handovers happening at regions like windows, where user mobility is constrained are unnecessary as user cannot move beyond that position and these handovers can even lead to packet loss, reduced throughput and high signaling cost. The issues arise by these unnecessary handovers in high density of femtocells are studied and solution for optimizing them are presented in this work.

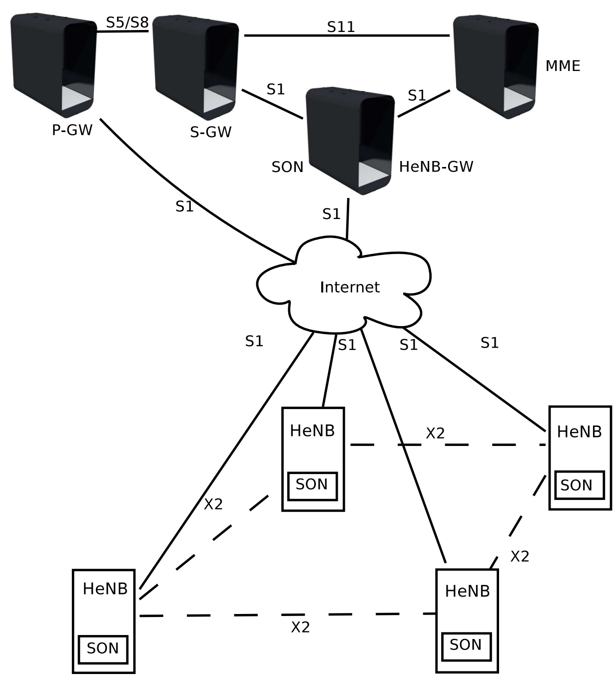

Fig. 1. Architecture of LTE Femtocell Network

II. LTE Femtocell Network Architecture

Fig. 1 shows LTE Femtocell network architecture which comprises of Home eNodeBs (HeNBs), HeNB Gateway, Mobility Management Entity (MME), Serving Gateway (S-GW) and Packet Gateway (P-GW). The terms Femto and HeNB are used interchangeably in the rest of this paper. The HeNBs are connected to the MME/S-GW through HeNB-GW with S1 interface. In 3GPP release 11 [4], X2 interface has been introduced between enterprise Femtos with open/hybrid access. The X2 interface is used for efficient handover management and load balancing.

In Enterprise Femtocell network deployments, Femto can be deployed with Self-Organizing Network (SON) functionalities. SON is an automation technology designed to make the planning, configuration, management, optimization and healing of LTE systems simpler and faster. The plug-and-play feature of SON means the nodes in the network can automatically configure themselves and then quickly establish an optimal network by configuring and adjusting each Femto. Fig. 1 also shows SON equipped Femtos and HeNB Gateway.

Rest of the paper is organized as follows. Section III describes the related work. Section IV discusses the proposed work. Simulation setup and results along with analysis is presented in Section V. Finally, Section VI contains conclusions and future work.

III. Related Work

Our current literature survey includes various unnecessary handover reducing mechanisms [5]–[7]. The authors in [5] based on UE mobility state proposed an optimized handover algorithm for reducing unnecessary handovers and also to improve the performance of LTE femtocell networks. The authors in [6] proposed a dynamic handover hysteresis margin calculation based on the UE position to reduce unnecessary handovers. In [7], the authors proposed a Fuzzy Logic Controller (FLC) that adaptively modifies handover hysteresis margins for reducing handovers. The authors in [8] proposed a simplified handover algorithm based on UE mobility state for reducing unnecessary handovers and signaling overhead in two-tier LTE network. In [9], a mobility management scheme is proposed where the control point of mobility in user plane is shifted from the S-GW to the HeNB-GW to make the handover decision between HeNBs. In highly dense deployed two-tier LTE network, UE mobility produces lot of signaling. Different from the approaches in [5]–[9], our proposed algorithm uses SON module of Femtos for reducing unnecessary handovers in enterprise Femtocell networks.

The authors in [10] proposed an autonomic system that uses Kernel methods. This autonomic system learns about frequent handover happening regions and reduces the frequent handovers. The system proposed requires a region as input from user, which is not fully plug-n-play as required by the SON paradigm. The authors in [11] uses Self Organizing Map for autonomic system. This autonomic system learns about the frequent handover regions using user mobility patterns. The system is fully autonomic with plug-n-play capability of SON. The proposed mechanism works with residential scenario, but in enterprise scenario, the amount of processing require for learning from user mobility involves a lot of overhead. The main objective of this paper is to avoid the unnecessary handovers at indoor regions of enterprise Femtocell network deployments. The paper is concerned with estimating user position and determining the regions where handovers should be permitted for avoiding unnecessary handovers.

IV. Proposed work

A. System description

The LTE Femtocell network architecture shown in Fig 1 is used as the system model. In enterprise buildings, HeNBs are deployed inside the buildings and are connected to HeNB-GW. All HeNBs are assumed to be operating on same frequency band and so there can be co-tier interference. The HeNBs are positioned in a planned manner to reduce this interference. The handover between HeNBs involves UE measurement report, handover decision, handover execution and handover completion phases. Since HeNB and UE reside within the building, the system model incorporates building path loss model [12] for computing path loss between HeNB and UEs.

B. Basic Idea

In LTE, handover has two key aspects, one is the Quality of Service (QoS) and the other is reducing unnecessary handovers. The self-organizing functionality of HeNBs can be utilized in mitigating unnecessary handovers. Using the SON of HeNB, we exploit regions where UE is moving and estimate UE position within those regions. The mobile telecom operator has to provide the enterprise building information that in turn contains room dimensions with location of doors, windows etc. as input to the SON of HeNB-GW. Based on the dimensions of rooms and estimated UE position, the SONs of HeNB and HeNB-GW perform efficient handover managements and thereby avoids unnecessary handovers.

C. Proposed SON Handover Scheme

The proposed SON handover scheme uses the enterprise system model and has two phases: one is handover triggering and other is handover decision. As proposed in [13] [14], HeNB can use the position reference signal (PRS) to estimate UE position. We can apply the calibration method [15] on the measurement given by PRS to increase the accuracy. The proposed algorithm assumes the accuracy of PRS to be 0.2 meter. HeNB based on the PRS estimates the UE position, which will be perceived by SON. Using the estimated UE position and regions in building, the SON verifies the handover triggering.

A typical enterprise building is shown in Fig. 2. Each room in the building has entry and exit represented with [D1, D2, . . ., Dn] and the deployed Femtos are represented as [F1, F2, F3, . . ., Fn]. The oval shaped regions with cross marks represent sub-regions inside the rooms. The dotted line in the Fig. 2 represents a separation between rooms with window or some open space created because of cubicles. Let us consider an UE that is attached to F2 and is continuously moving within the room. When UE has reached sub-region R1, it receives signals from neighboring Femtos: F1, F3 and F4. As there is a window at sub-region R1, the UE receives good signal strength from F1. Because of window, UE cannot cannot move into the room where F1 is located. Based on the UE measurement reports the serving Femto F2 makes handover to the target Femto F1. As UE is moving inside the same room, there is a high possibility that UE will remain reside within the serving area of Femto F2. If UE is handed over to F1 and then immediately moves away from F1 serving area and moves into F2 serving area, there is again a handover from F1 to F2. If there is a window at sub-region R2, similar situation arises between F2 and F3 when UE moves there. But, when UE is at sub-region R3 because of door D5, there is a possibility that UE is moving out of serving area of Femto F2. The handovers happening at the sub-regions R1 and R2 are leading to unnecessary handovers. This unnecessary handovers can be mitigated by using estimated UE position and building information. The proposed algorithm incorporates this information in the handover triggering of Femto.

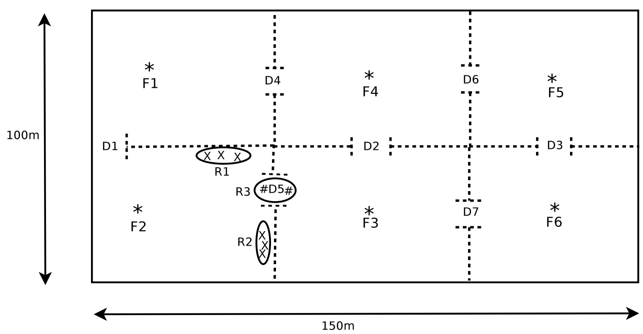

Fig. 2. HeNB deployment in Enterprise Building

D. Algorithm description

Algorithm 1 SON Handover algorithm

Input 1 : *bInfo* $<-$ *Building Information*
Input 2 : *uePos* $<-$ *UE Position from HeNB*
Initialization:

$roomDim$=$GetroomCoords(uePos, bInfo)$;
$entryorExit = GetEntryorExitInfo(roomDim, bInfo)$;
$windows$ = $GetWindowsInfo(roomDim, bInfo)$;
if (uePosition is at entryorExit) **then**
  trigger handover;
else {uePosition is at windows or within room}
  do not trigger handover;
end if

The SON module located at HeNB-GW takes the building information as input from operator and passes this information to the HeNBs' SON modules. The SON module of HeNB can extract the room dimensions from building information and it can get the estimated UE position from the HeNB. Based on the sub-regions in the room and UE position, SON module verifies for handover triggering. After triggering handover, the serving HeNB examines the UE measurement report and performs the handover decision.

The handover decision scheme in LTE system results in a handover execution, whenever the reference signal received power (RSRP) of a target cell exceeds over the reference signal received power of the serving cell plus a handover hysteresis margin (HHM). The HHM is used to mitigate the ping-pong oscillations. Let L_n be the set of 'n' number of cells. Consider t and s belongs to a set of cells L_n, where t is the target cell and s is the serving cell. The equation for handover decision is,

$$RSRP(t) > RSRP(s) + HHM_{PingPong}, \tag{1}$$

where RSRP(t) is received power signal strength of the target cell and RSRP(s) is received power signal strength of serving cell. The $HHM_{PingPong}$ is to used to reduce ping pong effect.

The proposed SON handover scheme uses Eqn(2) for making handover decisions. It uses two HHMs: a static handover hysteresis margin ($HHM_{PingPong}$) as in Eqn(1) for reducing ping-pong effects and a dynamic handover hysteresis margin (HHM_{Energy}) for reducing power consumption.

$$RSRP(t) > RSRP(s) + HHM_{PingPong} + HHM_{Energy} \tag{2}$$

$$HHM_{Energy} = 10 * log(\frac{P_t * (I_t - P_u * h_u)}{P_s * I_s})$$

where t and s are cells operating on same frequency band and belong to L_n, P_t is the Power of the target HeNB, I_t is the interference power of target HeNB, P_s is the power of the serving HeNB, I_s is the interference power of serving HeNB, P_u is the power of UE attached to s and h_u is the channel gain of UE.

The dynamic HHM [16] is calculated using the interference power of neighboring HeNBs and its significance in taking handover decision is to reduce the UE power consumption during handovers. Impact of dynamic HHM is minimal for current handover algorithm because of lower interference. Current work, focuses on reducing number of handovers rather than saving power of UE. The energy consumption at UEs will be studied as part of the future work.

V. Simulation and Results

We have carried out experiments using NS-3 [12] simulator with the parameters given in Table I to study the performance of proposed SON handover scheme. As part of simulations, we created a scenario where enterprise building has six rooms on the same floor with one Femto deployed in each of the rooms as shown in Fig. 2. We let Femtos communicate with each other through X2-interface. Each room has an entry door and an exit door, which are represented as [D1, ..., Dn]. The UEs are distributed uniformly in all the rooms and total number of UEs in the network is varied from 6 to 60. The Random walk mobility was used for movement of UEs inside the building and they move with a velocity of 1 to 3 kmph. For UE position estimation, since NS-3 does not support position reference signal of LTE, we simulate it by randomly adding or subtracting 0.2 meters to the absolute UE position given by NS-3. The radio environmental map (REM) of six Femtos which are placed inside the building is shown in Fig. 3. From

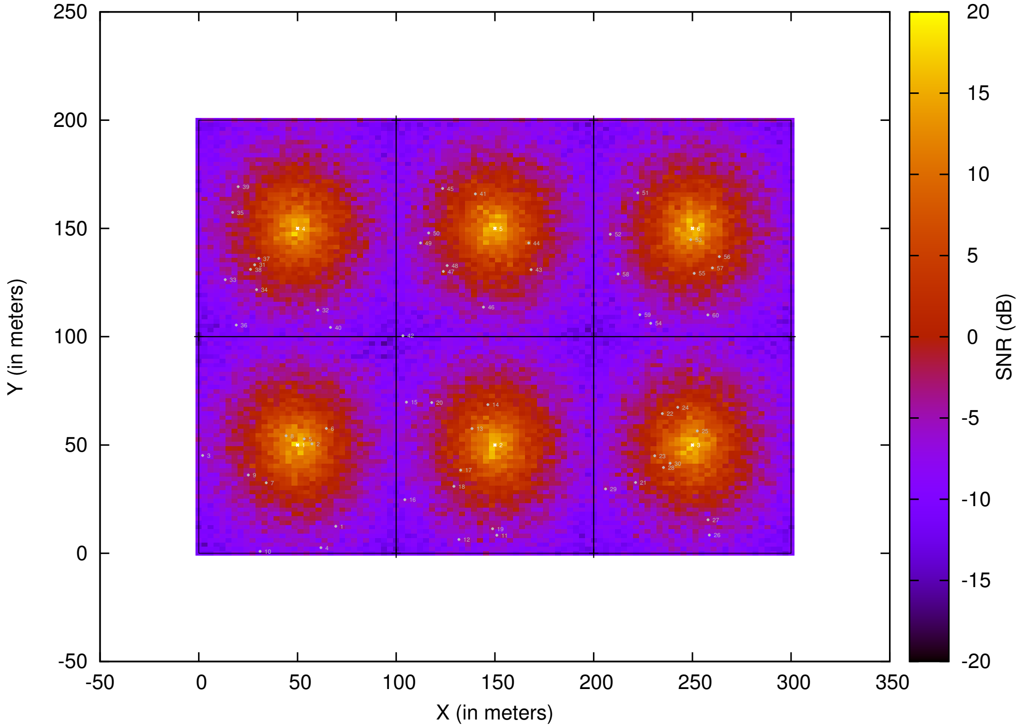

Fig. 3. Femto Placement in NS-3

TABLE I
SIMULATION PARAMETERS

Parameters	Values
Number of Femtocells	6
Number of UEs per cell	1 - 10
Total number of UEs	6 - 60
Femtocell coverage	60 m
Velocity For UEs	1 to 3 kmph
Mobility Model	Random walk
Building dimensions	300 x 200 m^2
Room dimensions	100 x 100 m^2
Exit area	4 x 7 m^2
Simulation time	50 Seconds

the REM, we can observe variation in received signal strength of UEs as they move away from Femto. In simulation setup, signal to noise ratio (SNR) is varying from -20 db to +20 dB.

We have kept one flow running at each UE and generating either TCP or UDP data in our experiments. For each UDP flow, the constant bit rate (CBR) application running at the remote host sends data packets of size 1 KB to UE at an interval of one second. These UDP flows continue to generate packets till the end of simulation. For generating TCP flows, we have used bulk send application at the remote host. The bulk send application keeps sending data packets till the end of simulation.

Initially all UEs are connected to their respective nearest Femtos. We compare the performance of proposed SON handover scheme with two existing handover schemes:

- NormalHO: The normal handover takes place when target Femto RSRP is greater than serving Femto RSRP value. Along with RSRP of target Femto, handover hysteresis margin was used to avoid ping pong oscillations.
- ZhangHO: It is a low complexity algorithm [8]. This algorithm considers the user mobility state for making handovers. The user mobility states are classified as low, stationary and high. Based on the user mobility, the handover to the target Femto takes place. In our simulations, as users reside within the building, we consider only low and stationary states. In case of low state, user moves with a velocity of 1 to 3 kmph, where as in stationary state, user velocity is kept as 0 kmph.

The performance of proposed algorithm is measured by using the following metrics:

- Number of Handovers (HO): The total number of handovers made by UEs at the end of simulation time.
- Handover Delay (HD): The time elapsed from the time the handover request sent by serving HeNB to target HeNB to the time the UE context release signal sent by target HeNB to serving HeNB.
- Packet Drop Ratio (PDR): The total number of packets lost due to handovers to total number of packets transmitted in the case of UDP based flows.
- Signaling Cost (SC): The total number of signaling messages passing among UE, serving HeNB, target HeNB and HeNB-GW during handovers in the simulation experiment.

In Fig. 4 we plot number of handovers vs UE density

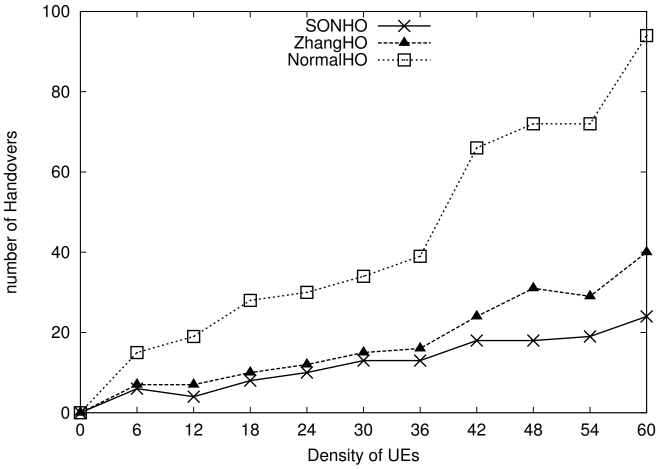

Fig. 4. Handovers vs Density of UEs

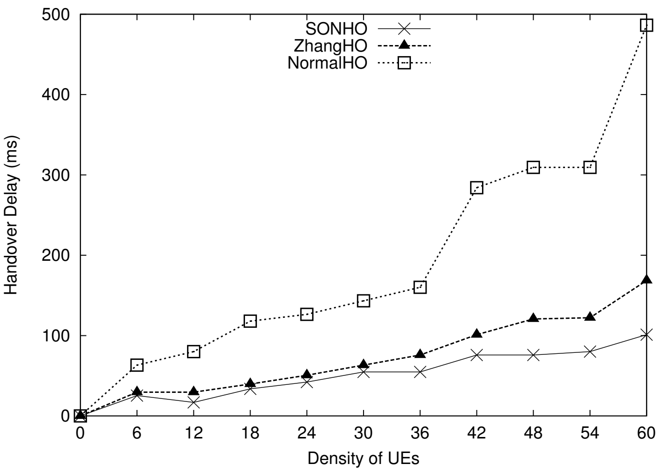

Fig. 5. HD vs Density of UEs

for all three handover schemes. It can be observed that the proposed handover scheme significantly reduces the number of handovers compared to other existing schemes. This is due to presence of SON module in Femtos. SON module triggers the handover whenever it is necessary. In case of NormalHO, number of handovers are much higher. As ZhangHO algorithm considers user mobility state, its performance is better than NormalHO. The proposed scheme has achieved lower number of handovers compared to ZhangHO because of optimizing the unnecessary handovers using SON modules at Femtos and HeNB-GW.

Fig. 5 plots the handover delay (HD) with varying UE density. From the results, we can see negative impact of more number of handover requests. The delay in serving the handover request will increase with increase in number of handover requests. With increase in UE density, the NormalHO has performed more number of handovers, which increased the handover delay. The proposed scheme gives lower handover delay compared to other two schemes by reducing number of unnecessary handovers.

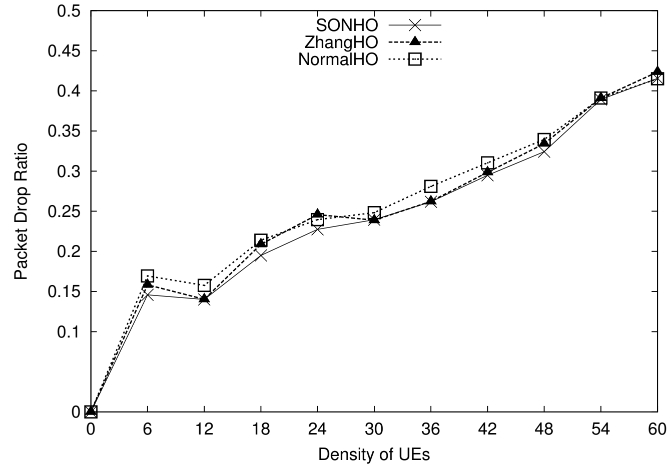

Fig. 6. Packet Drop Ratio vs Density of UEs

In Fig. 6 Packet Drop Ratio (PDR) vs UE density for different schemes is depicted by considering UDP flows. The proposed SON handover scheme has low packet loss compared with other schemes by mitigating number of unnecessary handovers. In Fig. 7, with increase in density of UEs, signaling cost also increases. The Signaling cost of proposed SON handover scheme is lower than ZhangHO because of reduction in the number of unnecessary handovers, which in turn reduces the total signaling cost.

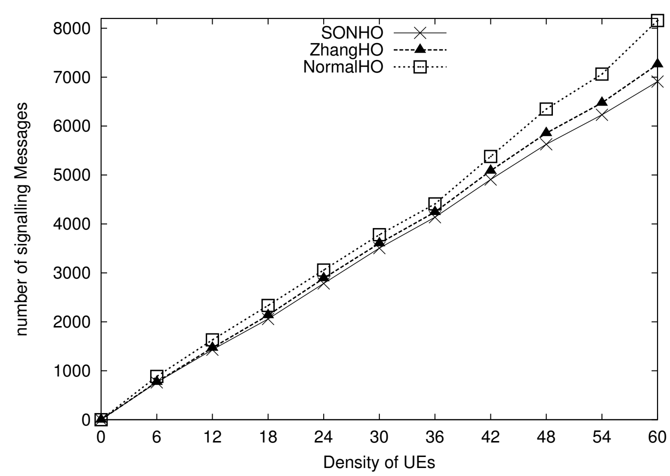

Fig. 7. Signaling Messages vs Density of UEs

To study the impact of the proposed SON handover algorithm on UEs throughput, we have conducted simulations with TCP flows. We have created TCP flows with one bulk send application for each UE, where an application is running at the remote host that will continuously send data of size 512 bytes. Fig. 8 shows the variation of aggregate downlink (DL) throughput of UEs with varying density of UEs. The proposed

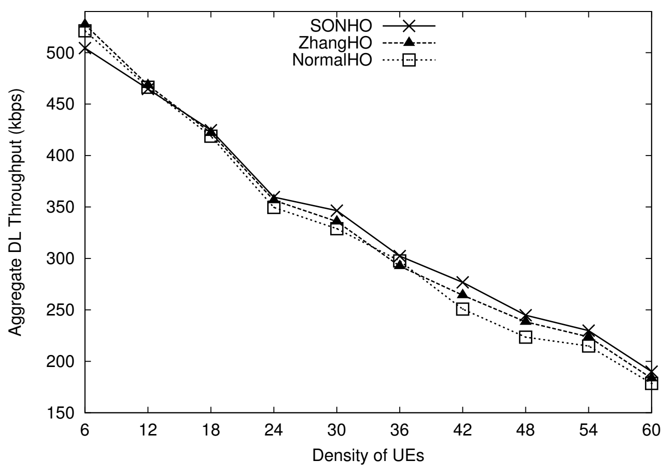

Fig. 8. Aggragate DL Throughput vs Density of UEs

SON algorithm shows an improvement of 2% in throughput compared to ZhangHO by reducing unnecessary handovers.

VI. Conclusion and Future work

In this paper, we proposed a SON handover scheme to improve the efficiency of handovers in enterprise Femtocell networks. The proposed SON handover scheme uses UE positions and sub-regional information inside the building to intelligently reduce the unnecessary handovers. In comparison with ZhangHO scheme, the proposed algorithm shows an improvement of 2% in throughput of UEs. Future work will be focused on considering load balancing factor for handover decision and achieving energy efficiency in UE during handovers.

VII. ACKNOWLEDGMENT

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