Efficient SON Handover Scheme for Enterprise Femtocell Networks

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***Abstract*—4G Femtocell are used in indoor to improve the performance of the mobile users. In Enterprise buildings there is high deployment of femtocells. As UE keeps moving from place to place within the building, unnecessary handovers are seen prominently and these handovers lead to considerable loss of packets, decrease in throughput and high signaling cost. In this paper, we propose an efficient SON handover scheme to mitigate the unnecessary handovers. The proposed approach uses building information and estimated UE position for making handover decision. Simulation results show that our proposed approach achieves 31.5% improvement in reducing handover delay compared to existing HO scheme.**

***Index Terms*—LTE; Femto Cells; SON; Handovers;**

I. Introduction

In order to provide higher data rates, 3GPP proposed a 4G cellular standard called as Long Term Evolution (LTE) with the aim of enhancing the Universal Terrestrial Radio Access Network (UTRAN) and optimizing the radio access architectures in order to satisfy the recent increase of mobile data usage and the emerging of new applications such as MMOG (Multimedia Online Gaming), mobile TV, Web 2.0, and streaming contents. According to the traffic statistics given by Huawei and Nokia-Siemens [1], [2], 60% of the traffic in cellular networks are from indoor environments due to the increased use of smart phones and social networking sites. The outdoor macro cell sometimes does not cover the areas within the building and as a result the signal strength is very weak inside the building. Further the signal strength is destructed due to attenuation such as fading and shadowing.

To address the issues regarding the signal coverage within indoors, femtocells have been integrated into 4G LTE cellular network architecture. Femtocell is an example of small cell network installed by end users and it can serve 16 to 32 users [3] in case of enterprise scenario. Femtocells are used to provide sufficient wireless access to the mobile users within the building. These femtocells are installed by users who have broadband internet connection. But usage of femtocells lead to several issues such as frequent handover, 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. An enterprise femtocells is configured either in open or closed access modes as in Fig 1. The open (or hybrid) access can lead to frequent handover in areas with high density of femtocells. Frequent handovers in high density of femtocells is a severe issue as it leads to packet loss, reduced throughput and high signaling cost. So, handover issues in high density of femtocells are studied and solution for optimizing them are presented in this paper.

II. LTE HeNB Architecture

Fig 1 shows the LTE HeNB architecture that comprised of HeNBs, HeNB Gateway, Mobility Management Entity (MME), Serving Gateway (S-GW) and Packet Gateway (P-GW). The terms femtocell and HeNB are used interchangeably. The HeNBs are connected to the MME/S-GW through HeNB-GW with S1 interface where as X2 interface is interconnecting between the HeNBs. In release 11 [4], X2 interface has been introduced between enterprise femtocells with open access. The X2 interface exists between neighboring HeNBs for load balancing, packet forwarding etc. The X2 interface is also used on U-plane for temporary UE data forwarding during the inter-HeNB handover.

In Enterprise scenario, HeNB is deployed with SON functionalities. A Self-Organizing Network (SON) is an automation technology designed to make the planning, configuration, management, optimization and healing of mobile radio access networks simpler and faster. The plug-and-play feature of SON means the device will automatically configure itself and then quickly establish an optimal network by configuring and adjusting each HeNB. The SON architecture with X2 interface between HeNBs is shown in Fig 1.

Rest of the paper is organized as follows. Section III describes the related work. Section IV discuss the proposed work. The simulation setup and results along with analysis is

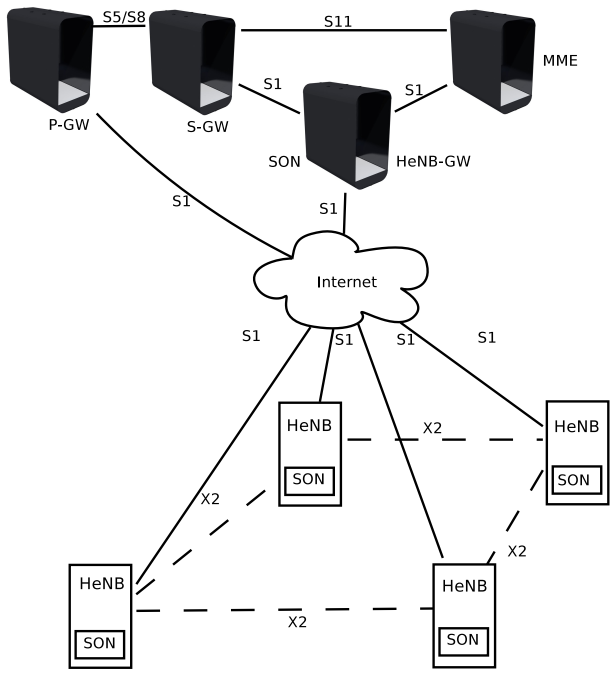

Fig. 1. LTE HeNB Architecture

presented in, Section V. Finally, Section VI contains conclusion 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 handover and also to improve the performance of LTE femtocell network. The authors in [6], proposed a dynamic handover hysteresis margin calculation based on the UE position within cell coverage region. In [7], the authors propose 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 femtocell 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 and HeNB-GW will make the handover decision between HeNBs. In high density of HeNBs and two-tier LTE HeNB network, UE mobility will produce lot of signaling. Different from the approaches in [5]–[9], our proposed algorithm uses SON of femtocells for reducing unnecessary handovers in femtocell network.

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 the region as input from the 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 movement 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 process of learning from user movement involves a lot of overhead.

The main objective of this paper is to avoid the unnecessary handovers at indoor regions. The paper is concerned with the tuning of Hysteresis, with the determination of regions where such tuning should be permitted. The algorithm used for tuning these parameters is presented along with the proposed work.

IV. Proposed work

A. System description

The LTE HeNB architecture shown in Fig 1, is used as System model. In Enterprise buildings, HeNBs are deployed within the building and are connected to HeNB-GW. All HeNBs are operating on same frequency band and so, there will 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. Fig 2 shows typical femtocell placement in Enterprise Building. Since HeNB and UE reside within the building, the system model incorporates building pathloss model [12] for computing pathloss between HeNB and UE.

B. Basic Idea

In LTE, handover has two key aspects, one is the Quality of Service (QoS) and the other is reducing unnecessary handovers. Because of high deployment of HeNBs, there will be frequent handovers in the HeNB network. So, there is a necessity to reduce the unnecessary handovers. The self-organizing functionality of HeNBs can be utilized in mitigating unnecessary handovers. In this paper, we propose a mechanism to mitigate this unnecessary handovers by exploiting building information and estimated UE position. The 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 SON of HeNB optimizes the 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 to estimate the UE position. The proposed algorithm assumes the accuracy of position reference signal to be 0.5 meter [15]. HeNB based on the position reference signal estimates the UE position, which will be perceived by SON. Using the estimated UE position and building information, 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 femtocells are represented as [F1, F2, F3...Fn]. The oval shaped bubbles with cross marks represents regions within the room. 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 is attached to F2 and is continuously moving within the room. When UE has reached region R1, it receives signals from neighbor cells F1, F3 and F4. As there is a window at region R1, the UE receives good signal strength from F1. Because of window, UE cannot cannot move into the region of F1. Based on the UE measurement reports the serving cell F2, makes handover to the target cell F1. As UE is continuously moving within the room, there is a high possibility that UE will reside within the serving cell F2 coverage region. After making handover to F1, if UE immediately moves into the region of F2, there is again a handover from F1 to F2. If there is a window at region R2, similar situation arises between F2 and F3 when UE moves into region R2. But, when UE is at region R3 because of door D5, there is a high possibility that UE is moving out of serving cell region. The handovers happening at the regions R1 and R2 are leading to unnecessary handovers. This unnecessary handovers can be mitigated by using estimated UE position and room information. The proposed algorithm incorporates this information in the handover triggering of femtocell.

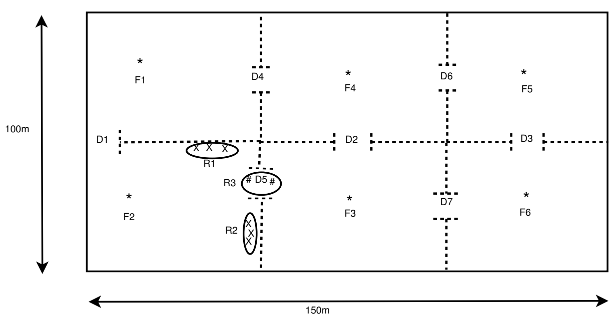

Fig. 2. HeNB deployment in Enterprise Building

D. Algorithm description

The SON, located at HeNB-GW takes the building information as input from operator and passes this information to the SON of HeNBs. The SON within HeNB gets the information of the room and also the estimated UE position from the HeNB. Based on this information SON verifies for handover triggering. After triggering handover, the serving HeNB examines the UE measurement report and performs the handover.

The handover decision scheme in LTE network results in a handover execution, whenever the reference signal received power (RSRP) of an 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. Let L_n be the set of 'n' number of cells. Consider t, 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,

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

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 reduce ping pong effect.

Algorithm 1 SON Handover algorithm

Input 1 : *Building Information*
Input 2 : *UE Position from HeNB*
Initialization:
$roomDim$=$GetroomCoordsFromBuildingInfo()$;
$entryorExit$ = $GetEntryorExitInfo(roomDim)$;
$windows$ = $GetWindowsInfo(roomDim)$;
if (uePosition is at entryorExit) **then**
  trigger handover;
else {(uePosition is at windows or uePosition Within room)}
  don't trigger handover;
end if

The proposed SON handover scheme uses equation 2 for making handover decisions. It uses two handover hysteresis margins (HHM), a static handover hysteresis margin (HHM-Ping Pong) as in equation 1 for reducing ping-pong effect and a dynamic handover hysteresis margin (HHM-Energy) for reducing power consumption.

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

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

where t, s are cells operating in same frequency band and belongs 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 in handover. 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 on UE is yet to be studied.

V. Simulation and Results

We have simulated the Femtocell handover with an enterprise building setup in NS3. We created a scenario where

TABLE I
SIMULATION DETAILS

Parameters	Values
Number of Femto cells	6
Number of UEs per cell	1 - 10
Total number of UEs	6 - 60
UE Deployment	Random
Femto cell coverage	60 m
Velocity For UEs	1 to 3 m/s
Mobility Model	Building Mobility Model

TABLE II
BUILDING DIMENSIONS

Parameters	Values
Simulation dimensions	300 X 200 m
Room dimensions	100 X 100 m
Exit area	4 X 7 m
UE direction change time	0.1sec
UE speed	1 to 3 m/s
Mobility model	Building Mobility Model

femtos are deployed in a building. Building created in the scenario has 6 rooms and 1 floor. UEs are positioned randomly inside the building. The initial phase of network connection of UEs is beyond the scope of this paper, hence we assumed that all UEs are initially connected to the nearest femto cell. Each room has a femto cell. The Random walk mobility was used for movement of UEs inside the building with a velocity of 1 to 3 m/s. Based on the mobility of UEs, number of handovers (necessary and unnecessary ones), handover delay, packet drops and number of signaling messages are measured. The UEs will send the measurement report, which contains the signal strengths of neighboring cells to serving cell. Based on the measurement reports, serving cell takes the decision of handover. The normal HO takes place when target cell RSRP is greater than serving cell RSRP value. The low complexity algorithm in [8] is used as zhangs' algorithm.

In current simulation, SON uses the event triggering mechanism and is responsible for triggering handover. The SON perceives the UE position from HeNB and verifies with the room dimensions for handover triggering. Estimating the UE position using position reference signal has high impact on handover decision. If the error in estimation of UE position is 2 to 3 meters, then the proposed algorithm is more likely behaves as zhangs' algorithm.

The various simulation parameters used in the simulation are given in the table I. The Building dimensions are provided in the Table II.

Typical building in enterprise scenario is shown in Fig. 2. Each room in the building will have entry and exit, which are represented as [D1..Dn] and femtocells are deployed in each room. Fig. 3 shows the radio environmental map of femtocells along with UEs. This map has been generated using Ns 3. The UEs are distributed uniformly in all the rooms. Density of UEs varies from 1 to 10 in each room.

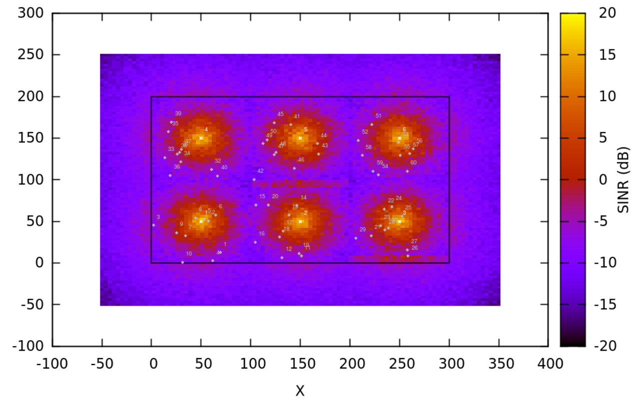

Fig. 3. Femto Placement in Ns-3

The performance of proposed algorithm is measured with the following parameters:

- Number of Handovers (HO): The total number of handovers of UEs.
- Handover Delay (HD): The time period between the handover request sent by serving HeNB to target HeNB and the UE context release signal from target HeNB to serving HeNB.
- Packet Drop Ratio (PDR): The total number of packets dropped to total number of packets transmitted.
- Signaling cost (SC): The total number of signaling messages passing among UE, serving HeNB, target HeNB and HeNB-GW during handovers.

The proposed handover scheme achieved a low HO, low HD, low PDR and low SC. Further, we illustrate our simulation results for number of handovers (HO), Handover Delay (HD), Packet Drop Ratio (PDR) and Signaling Cost (SC) from several aspects.

Fig. 4 shows the simulation results for HO with varying UE density. The simulated result illustrates that our handover scheme significantly reduces the number of handovers. This is because of SON in femtocell. SON triggers the handover whenever necessary. In general, the handover will happen when the UE receives high signal strength from neighbor cell as depicted in Fig. 4, as normalHO, which has more number of handovers. Our proposed approach has achieved lower HO compared to Zhangs' because of SON in femtocells. SON takes building information and estimated UE position as input for reducing unnecessary handovers.

Fig. 5 illustrates the simulation results for HD with varying UE density. From the results, we can see the impact of high handover requests. Lower the number of handovers, lower the handover delay. Fig 5, shows the HD vs density of UE's (varying from 6 to 60). With increase in UE density, congestion in network increases which inturn increases the delay

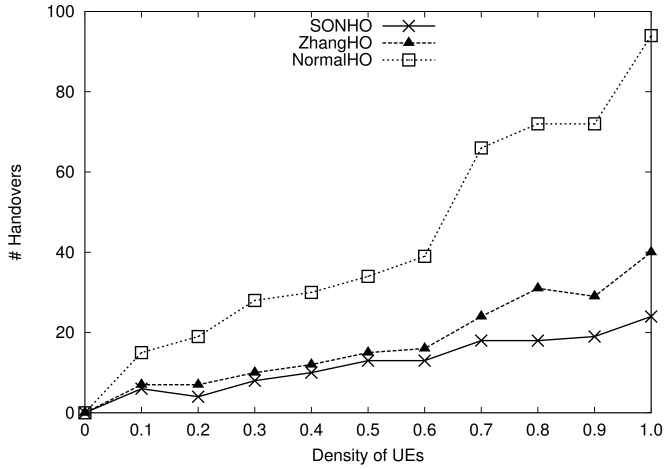

Fig. 4. Handovers vs Density of UEs

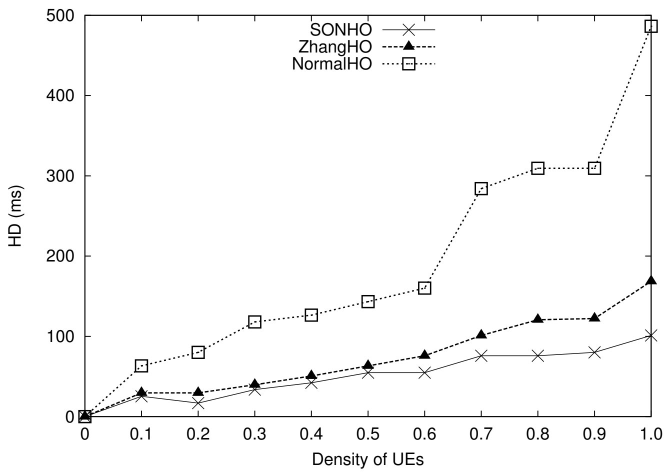

Fig. 5. HD vs Density of UEs

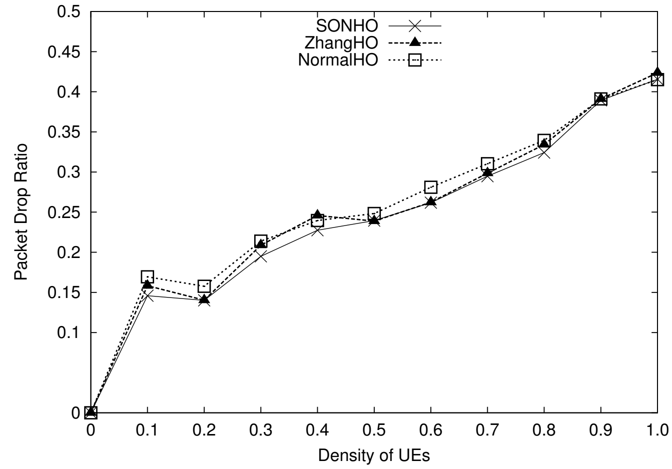

Fig. 6. Packet Drop Ratio vs Density of UEs

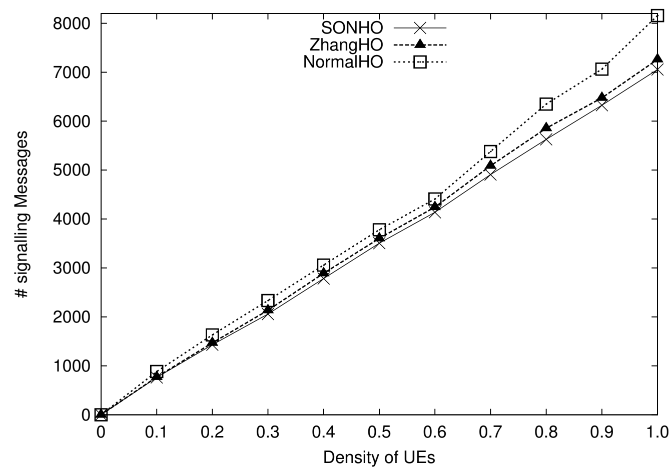

Fig. 7. Signaling Messages vs Density of UEs

for handover. HD is low for proposed approach compared to zhangs' approach because of lower number of handovers.

The simulation results of the packet Drop Ratio (PDR) with different schemes are depicted in Fig 6. The packet drop increases with the increase in traffic of the femtocell. Our proposed approach has less packet drops compared to other approaches, because of mitigating unnecessary handovers that inturn reduces unnecessary traffic.

Fig. 7 shows the simulation results of the signaling cost of handover (SC). Higher the number of handovers, higher the signaling cost. The SC indicates the number of information exchanges between UE and femtocells during handover. The SC of our proposed scheme is lower than Zhangs because of reduction in number of the undesired handover events.

VI. Conclusion and Future work

In this paper, we have developed an algorithm to improve the efficiency of handovers in femtocells. The proposed scheme uses SON in femtocells, which intelligently reduces the handovers with building information. Further 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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