A Novel Handover Mechanism between Femtocell and Macrocell for LTE based Networks

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***Abstract*—The femtocell networks that use Home eNodeB and existing networks as backhaul connectivity can fulfill the upcoming demand of high data rate for wireless communication system as well as can extend the coverage area. It is also of interest to minimize operational effort by introducing self-optimizing mechanisms, and the optimization of the Home eNodeB involved handover is an important goal of LTE-Advanced. Since the different network architecture and functionality between Home eNodeB and LTE eNodeB, the handover procedure between the femtocell and macrocell should be modified in LTE network. In this paper, modified signaling procedure of handover is presented in the Home eNodeB gateway based femtocell network architecture. A new handover algorithm based on the UE's speed and QoS is proposed. The comparison between the proposed algorithm and the traditional handover algorithm shows that the algorithms proposed in this paper have a better performance in the reducing of unnecessary handovers and the number of handovers.**

Keywords-self-optimization; handover; femtocell; macrocell; QoS; velocity

I. INTRODUCTION

The Long Term Evolution of UMTS is just one of the latest steps in an advancing series of mobile telecommunications systems. Nowadays standards for Universal Terrestrial Radio Access Network The Long Term Evolution(LTE)i.e. Evolved UTRAN are being done as release 9, which aims at reduced delays, increased user data rates , increased cell-edge bit-rate and seamless mobility with deployed Home eNodeB (HeNB) [1]. The 3GPP standard for Home eNodeB, LTE femtocell, which is one of the best approaches to reduce the Operating Expenditures (OPEX) for operators as well as to diverse the load from the LTE macrocell networks. Femtocells are low-power access points, providing wireless voice and broadband services to customers primarily in the home. 3GPP has been carried out the research on Home eNodeB, while the Home eNodeB applications may also introduce some challenges to the work related to LTE-Advanced.

There special care with respect to SON(Self-Organising Networks) shall be taken for mass deployment scenarios like in the case of Home eNodeB, i.e. for In and Outbound Mobility for Home eNodeB and problems caused by incorrect behavior of Home eNodeBs. With the deployment of the Home eNodeB, the handover between femtocell and 3GPP macrocell networks is become more and more important in the LTE based networks. Thousand of femtocells within a macrocell area will create a large neighbor cell list and interference problem. So the modifications of handover procedures for existing networks are needed. The optimization of handover procedure and algorithm will improve the performance of both the femtocell and LTE networks.

UEs with various velocities moving through the femtocell usually lead to performing some unnecessary handovers especially for high speed users. These cause the reduction the system capacity. Conventional handover methods cannot promise a good enough handover performance for multi-service under different mobility in macrocell and femtocell mixed environment. In fact, unnecessary handovers have become a heavy burden and degrade the communications of the overall broadband wireless system; the result is usually a reduction of user's QoS level. Conventional handover decision algorithms for users in mobile vehicles cannot meet current need, which means the unnecessary handovers and quality of service (QoS) problems will get even worse for users' different mobility and states of real-timing service.

A Closed Subscriber Group (CSG) identifies subscribers of an operator who are permitted to access one or more cells of the PLMN but which have restricted access (CSG cells). The UE shall contain a user controlled list of allowed CSG identities (Allowed CSG List). It shall be possible to store the Allowed CSG List in the USIM. When available, the list on the USIM shall be used [1]. Here we only discuss the closed mode.

The rest of this paper is organized as follows: section II provides the concentrator based HeNB network architecture. In section III, Call flow for handovers between macrocell and femtocell are introduced. In section IV, a novel handover optimizing algorithm based on QoS and velocity has been proposed to minimize the unnecessary handover. Analysis of the comparison between handover algorithm proposed and traditional is provided in Section V. Finally, Section VI concludes the paper.

II. LTE FEMTOCELL SYSTEM ARCHITECTURE

For the E-UTRAN HeNB architecture, the discussions for the LTE femtocell standards are undergoing in the Femto Forum, in NGMN Alliance and in 3GPP. While the architecture has not been finalised, there is a strong consensus to keep it as flat as possible, following the principles of 'all-IP' networks adopted in the LTE standards. The debate is still going on as to whether there is a need for a signalling aggregation element or whether the evolved packet core (EPC) itself should be able to support femtocells directly [7]. The reference LTE femtocell architecture is shown in Fig. 2，

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which has a set of S1 interfaces to connect the HeNB to the EPC. With the involved of Home eNB Gateway (HeNB GW), it equivalent to expanding the S1 interface between HeNB and core network, and more HeNB can be deployed. We can assume that the HeNB GW worked at control plane, especially the concentrator of the S1-MME. The HeNB side S1-U interface can be terminated at HeNB GW or the logical connection between HeNB and S-GW by directly user-plane. Logical architecture of HeNB in showed in Fig. 1.

To integrate with LTE macrocell networks better, the HeNB GW should appears to the MME as an eNB, the HeNB GW appears to the HeNB as an MME between the HeNB and the Core Network though there may be tens of thousands of femtocells in a traditional LTE macrocell, HeNB GW may also have interface to operator's O&M system for configuration and control [1] [13].

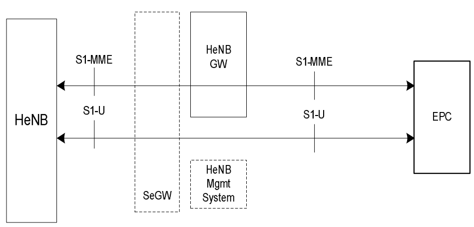

Figure 1. E-UTRAN HeNB logical architecture [1]

The S1 interface between the HeNB and the EPC is the same whether the HeNB is connected to the EPC via a HeNB GW or not. Here we choose the LTE femtocell system architecture based on concentrator.

The overall E-UTRAN architecture with deployed HeNB GW is showed in Fig. 2. The interfaces between the HeNB and the EPC are the standard S1-MME and S1-U, with the HeNB GW optionally providing aggregation function for the S1-MME. The S1-U interface adopts a direct tunnel approach, but optionally also this interface can be aggregated by the HeNB GW. In this case, the HeNB GW may also provide support for user plane multiplexing, for efficient transmissions over limited bandwidth links. The functions supported by the HeNB shall be the same as those supported by an eNB and the procedures run between a HeNB and the EPC shall be the same as those between an eNB and the EPC [1].

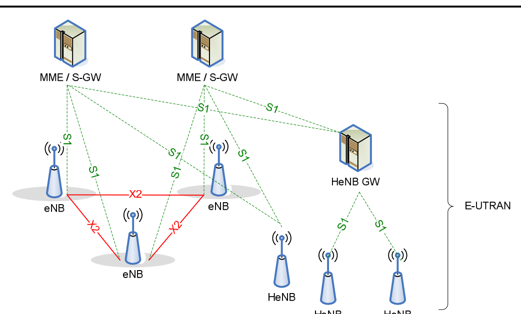

Figure 2. Overall E-UTRAN architecture with deployed HeNB GW. [1]

III. PROPOSED HANDOVER CALL FLOW

Handover between LTE macrocell and Home eNodeB should work smoothly and seamless, for optimization of Home eNodeB related handover is one of the key drivers for LTE-Advanced. The handover procedures between traditional LTE macrocell are presented in [1] and [5]. Here we propose the call flows based on the E-UTRAN architecture shown in Fig. 2.

A handover process can typically be divided into four parts: measurements, processing, reporting, and decision and execution. For handover between eNBs, the procedure is performed without EPC involvement, i.e. preparation information is directly exchanged between the eNBs using X2 interface, but there is no X2 interface between HeNB and LTE eNB. Moreover, not every user can access HeNB but only the user of a restricted group (CSG), while in LTE macrocell users an handover without restrictions. Hence the modified handover call flow is proposed below.

A. *Inbound Mobility for Home ENodeB*

Since there are thousands of possible target HeNBs, inbound handover for Home eNodeB is the most challenging issue for LTE femtocell network. UE is provided for communicating with a serving HeNB, where the UE belongs to a subscriber group (CSG) cell served by a CSG Home eNodeB, only UE belonging to the CSG are permitted to access and receive service from the CSG femtocell. The authentication is checked in preparation phase of handover, thus macrocell to femtocell handover is more complex than existing handover between LTE macrocells. The Fig. 3 depicts the basic handover scenario from macrocell to femtocell (Intra-MME/Serving Gateway).

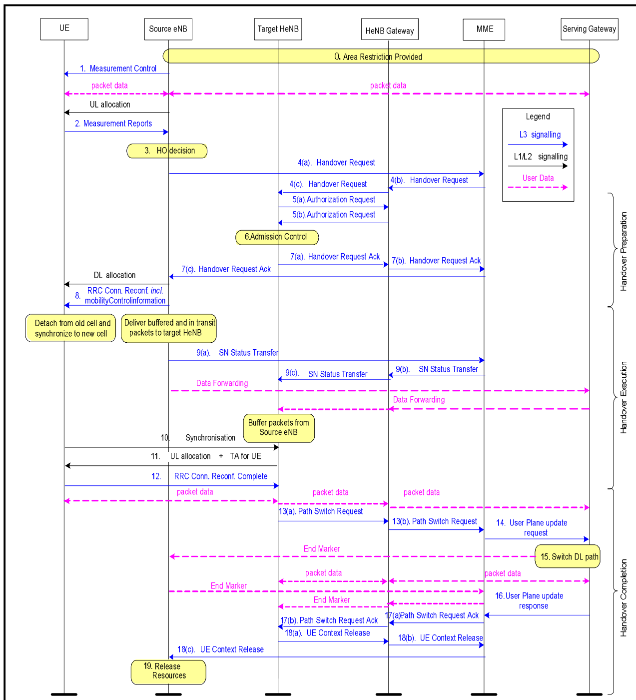

Figure 3. Handover from macrocell to femtocell (Intra-MME/Serving Gateway)

B. *Outbound Mobility for Home ENodeB*

Fig. 4 shows the call flow for the intra MME/Serving Gateway handover outbound handover for Home eNodeB to LTE macrocell network. The outbound handover for Home eNodeB is not so complex like inbound handover for Home eNodeB because whenever a user move out of femtocell network, eNodeB's signal strength may be stronger than Home eNodeB networks in the neighbor cell list, so the selection of target cell is more easily, for no complex interference calculation and authorization check in this handover like that of inbound handover for Home eNodeB [4].

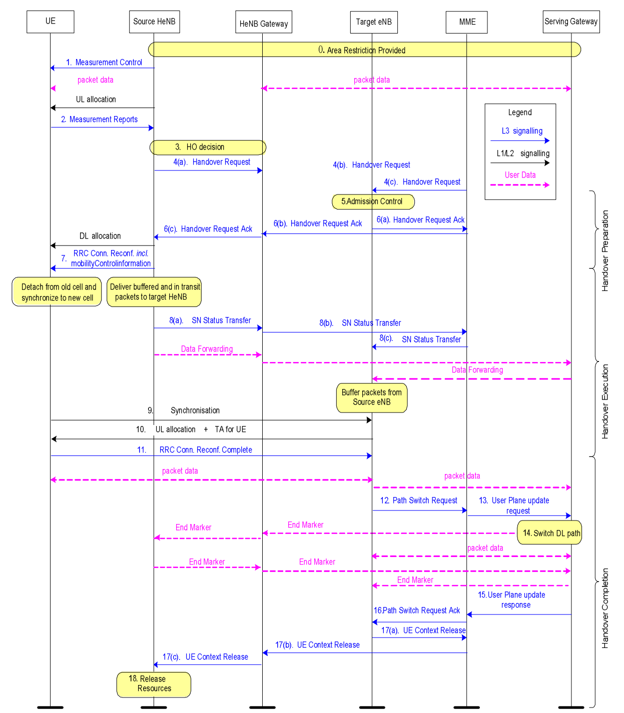

Figure 4. Handover from femtocell to macrocell (Intra-MME/Serving Gateway)

IV. PROPOSED HANDOVER OPTIMIZATION ALGORITHM

Due to the small scale of femtocell's coverage, users with a high velocity will cross the femtocell in a short time, considering the users' QoS, the high speed user may be not necessary to execute handover especially for the non-real-time service. Here we classify the velocity of UEs in the mobility to avoid the situation above. The special velocity environment changes described here include the following scenes:

- Low mobile state: from 0 to 15 km/h, slow walk, stationary.
- Medium mobile state: from 15 to 30 km/h, when ride a bike.
- High mobile state: above 30 km/h, drive a car.

QoS (quality of service) also play an important role in HeNB related handover. Unsuitable handover algorithm may cause QoS degradation for these users by unnecessary handover. For non-real-time applications, delay and packet loss can be tolerated to some extent; however, the long interruption of handover is horrible for delay and packet loss sensitive real-time applications such as IPTV, VoIP, and online games. Sometimes the low speed user wants to move to Home eNodeB as quickly as possible and stay there as long as possible. The detailed pseudo code of UE's state of Speed and QoS based algorithm (SQ Algorithm) is described as follows.

```
1.  INITIALIZATION
2.  Calculate V
3.  IF V>30kmph
          NO handover
4.  ELSE IF  V>15kmph
        IF REAL-TIME
          NEED handover
        ELSE IF NON-REAL-TIME
          NO handover
5.  ELSE
        NEED handover
    RETURN
```

For the femtocell probably has a low distributed density of UE than in LTE macrocell and a low power, moreover, when handover executed based on the measurement value of RSRP/RSRQ of source cell lower than that of target cell with a margin, it may be a little late for the UE will pass the femtocell in a short time, moreover, to consider the load balancing between femtocell and macrocell, we integrate the measurement value, the maximal capacity and the current load of the cell as the input of handover judgment.

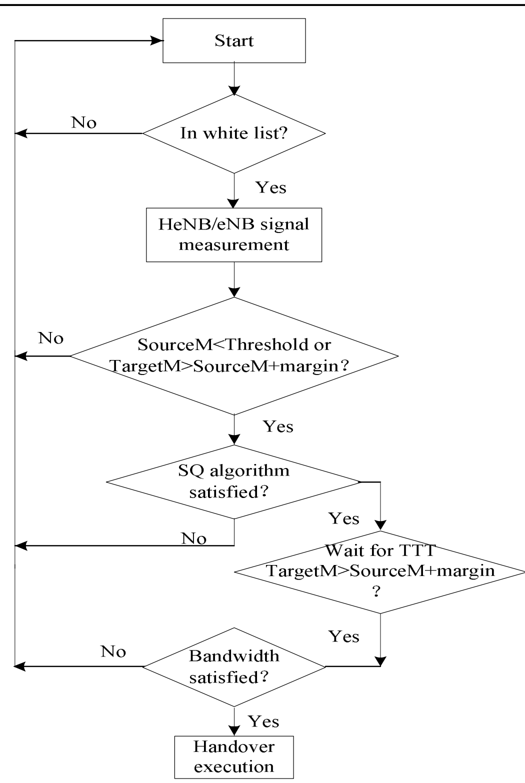

Figure 5. The flowchart of handover algorithm

To optimize the handover algorithm, we use the variable M (in equation (1)) instead of RSRP and RSRQ for evaluating the best macrocell/femtocell and making the handover decisions.

$$M = \frac{M_o}{\log(e * k + n)} * N * G \qquad (2)$$

Mo is the value of traditional measurement such as RSRP and RSRQ, e=2.7182818284590, n is the number of UEs which camp on the LTE/LTE-Advanced cell or femtocell, k is the adjustment factor of different type of the cell, N is the maximal capacity of macrocell or femtocell, G is the G factor which used to adjust the value of M. The flowchart of the optimized handover algorithm is described in Fig. 5

V. ANALYSIS OF COMPARISON WITH TRADITIONAL ALGORITHM

To validate the performance of the algorithms proposed in this paper, we compare the algorithm proposed this paper with traditional handover scheme in three theory aspects such as the rate of unnecessary handover, number of handovers, system performance, and signaling overhead.

In traditional UMTS femtocell handover algorithm, the high speed users and low speed users can not have the same QoS when performing the femtocell involved handover especially the handover from macrocell to femtocell. In the algorithm proposed in this paper, we do not allow the high speed users handover from macrocell to femtocell while low speed users will be allowed. At the same time, the algorithms proposed are also making a difference in real-time users and non-real-time users in mediate speed while traditional handover scheme treat them with the same methods, therefore, the algorithm proposed in this paper will reduce the unnecessary handover especially for the high speed users and non-real-time users.

As the reducing of the number of unnecessary handovers, the total number of handover is reduced at the same time. The system performance is measured by the number of unnecessary handovers and total number of handovers. As the other KPIs such as throughput, data rate, have small difference with traditional algorithm, the system performance of proposed algorithm will be better than the traditional.

As we can see in the call flow for the intra MME/Serving Gateway handover outbound and inbound handover for Home eNodeB in LTE macrocell network showed in the Fig. 3 and Fig. 4, the signaling in the call flow is a little more complex than traditional handover algorithm, so the delay and signaling overhead will affect the performance. At higher speeds there are higher number of unnecessary handovers due to lower correlation in log-normal shadowing samples. To sum up, the proposed algorithms have lower rate of unnecessary handovers than the traditional algorithm for a negligible penalty of signaling overhead.

VI. CONCLUTION

In this paper, modified signaling procedure of handover is presented in the Home eNodeB gateway based femtocell network architecture. A novel handover mechanism based on the UE's velocity and QoS have been studied. The comparison with the traditional algorithm shows that the algorithms proposed in this paper have a better performance in the rate of unnecessary handovers and the average number of handovers, especially in Medium and High mobile speed, for a small penalty of signaling overhead. In the future, we plan to investigate the quantitative effect of different handover algorithms on the signaling overhead.

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