Handover in UMTS Networks with Hybrid Access Femtocells

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***Abstract*— Femtocells enable in-home cell phone coverage and provide access to high speed wireless broadband services. The Femtocell network architecture is very different from the existing based on the UMTS macrocell network architecture. Hence, a modified handover procedure for existing networks is needed to support macrocell/femtocell integrated networks. Voice call services are an essential part of mobile communications and studies of mobile usage show that more than 50 percent of all voice calls are placed indoors. Frequent and unnecessary handovers are another problem of heterogeneous network environments. In this paper, we propose a modified handover procedure for voice call service between 3GPP UMTS-based macrocell and femtocell networks. And Call Admission Control (CAC) to reduce the unnecessary handover in the hybrid access mode is proposed.**

***Keywords*— handover, hybrid access, 3GPP, Macrocell, Femtocell, UMTS.**

1. INTRODUCTION.

One of the main issues for wireless communications is to increase the coverage and capacity of existing cellular networks. Recently, femtocells have come into the spotlight as a solution to improve the quality of services and to increase data rates in residential or enterprise environments. Femtocell base stations are connected to the Internet to access the cellular service [12]. Femtocells can provide a shortcut between a mobile station and a femtocell base station as compared to a path between a mobile station and a macrocell base station for improved capacity. Femtocells are attractive as they increase the coverage of cellular services with low-cost and low-power characteristics. Furthermore they can be simply deployed by users without much intervention [11].

Since the femtocell architecture is very different from the existing cellular networks, there are three issues in order to integrate femtocell/macrocell. First, if there exist many femtocells in a macrocell, they may cause interference [9]. Second, due to many possible target femtocell candidates for macrocell to femtocell handover, communications with many femtocells in a large neighbour list may be required for the pre-handover procedure. Third, some modification of the existing network and protocol architecture is needed for the integration of femtocell networks with the existing macrocell networks. In this paper, we focus on the handover issue. Finding an appropriate solution to this problem can improve the performance of femtocell/macrocell networks [6]. The handover procedure is related to the femtocell access mode. There are three access modes which allow users to access femtocells, i.e., open access mode, closed access mode and hybrid access mode.

The open access mode has no access limits for the users. Since there is no limit, if any User Equipment (UE) receives a higher signal level from a specific femtocell than that from a specific macrocell, it can access the femtocell as long as there is surplus bandwidth. However, frequent and unnecessary handovers are caused by the users near the femtocell area. In the closed access mode, each femtocell has pre-registered users, so only the pre-registered and allowed users can access it. The advantage of this mode is that it reduces the number of unnecessary handovers and the closed subscriber group can have sufficient bandwidth. If, however, an un-registered user comes into the femtocell, the interference from the base station can lower the service quality [4]. In the hybrid access mode, each femtocell has pre-registered users who are able to access it, however, other un-registered users can also gain access in the case that there is surplus bandwidth.

In this paper, to improve the performance of the handover and reduce unnecessary handovers, a new handover procedure and a Call Admission Control (CAC) mechanism for the hybrid access mode is proposed. Studies on mobile usage show that more than 50 percent of all voice calls originate indoors. Hence, in this paper the proposed handover procedure focuses on voice call services. The CAC is related to the time UEs stay in a femtocell area and how to differentiate between the pre-registered users and un-registered users.

This paper is organized as follows. Section 2 describes the femtocell network architecture. The handover procedure for voice call services between the macrocell and the femtocell, and CAC for the hybrid access mode is proposed to minimize unnecessary handovers in Section 3. The simulation results for the proposed mechanism are provided in Section 4. Finally, we conclude in Section 5.

2. FEMTOCELL SYSTEM ARCHITECTURE

The Femtocell Gateway (FGW) enables a Radio Network Controller (RNC) to present itself to the Core Network (CN) as a concentrator of femtocell connections. The Iu interface between the CN and FGW serves the same purpose as the interface between the CN and RNC [3] (See Fig.1).

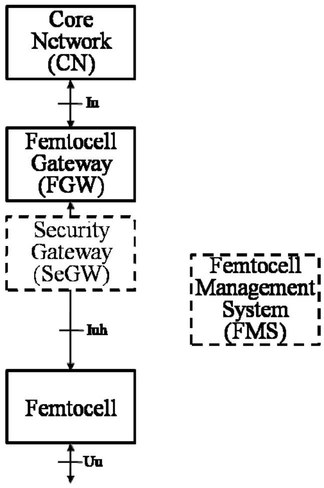

Figure 1. Femtocell system architecture.

The function of each element in the femtocell system architecture is given as follows.

Femtocell Management System (FMS)
•Based on TR-069 family of standards •Facilitates FGW discovery •Provisions configuration data to the Home NodeB (HNB) •Performs location verification of HNB and assigns appropriate serving elements (FMS, Security Gateway and FGW) [3].
Security Gateway (SeGW)
•Terminates secure tunnelling for TR-069 as well as Iuh •Authentication of femtocell •Provides the femtocell with access to the FMS and FGW
Femtocell Gateway (FGW)
•Terminates Iuh from femtocell. Appears as an RNC to the existing core network using existing Iu interface. •Supports femtocell registration and UE registration over Iuh [3].
Femtocell
•Customer Premise Equipment (CPE) that offers the Uu Interface to the UE •Provides Radio Access Network (RAN) connectivity using the Iuh interface •Supports RNC like functions •Supports femtocell registration and UE registration over Iuh [3].

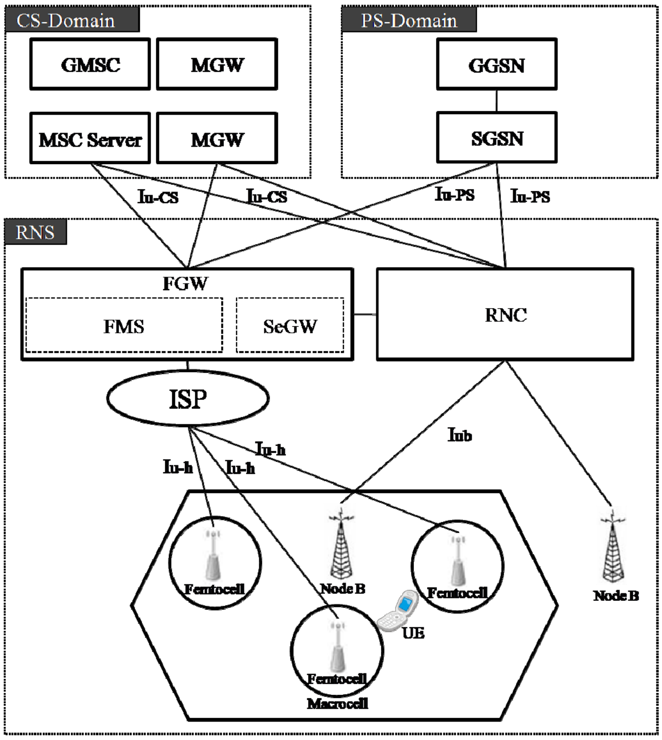

Figure 2. Femtocell users to CN connectivity.

The RNCs aggregate the traffic from the Node B and deliver the aggregated traffic to the mobile core network. The RNC delivers Circuit Switched (CS) traffic for the voice call service to the Mobile Switching Center (MSC) over the Iu-CS interface, while the Packet Switched (PS) traffic for the data service is sent to the Serving GPRS Support Node (SGSN) over the Iu-PS interface [2] (See Fig.2)

3. PROPOSED HANDOVER PROCEDURE BETWEEN MACROCELL AND FEMTOCELL

There are two phases for the proposed handover procedures: handover preparation phase (information gathering, and handover decision), and handover execution phase. During the information gathering phase, the UE collects the information about the handover candidates, and authentications are acquired for security purposes [1]. The best handover candidate is determined in the handover decision. After deciding the best handover candidate, the UE initiates a connection with the new NodeB. For the handover between a macrocell and a femtocell, initial network discovery for the femtocell and initial access information gathering are required. The most important difference between the UMTS-based macrocell networks and the femtocell networks is the radio resource control (RRC) functionalities. Femtocell has RRC functionalities whereas NodeB has no RRC functionalities. Therefore, the proposed handover procedure for macrocell/femtocell integrated networks differs from that of the existing 3GPP-based macrocell networks [1].

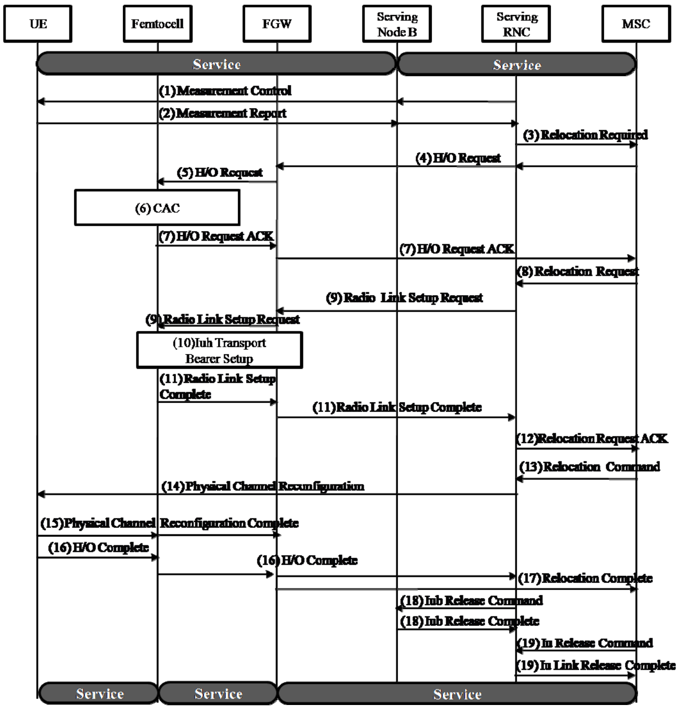

Figure 3. Macrocell to Femtocell handover procedure.

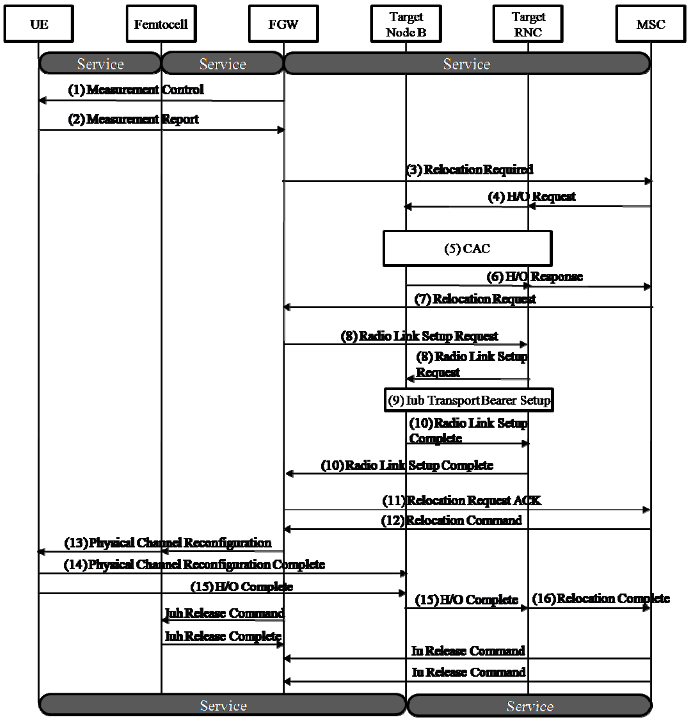

Figure 4. Femtocell to Macrocell handover procedure.

3.1 Proposed Macrocell to Femtocell Handover

Fig. 3 shows the macrocell to femtocell handover procedure with the proposed CAC for the intra MSC. Macrocell to femtocell handover is more complicated than femtocell to macrocell handover. The second-generation (2G) and the third generation (3G) systems broadcast a neighbor list used by a mobile station attached to the current cell to learn where to search for the potential handover cells. Such a handoff protocol causes complexity because of many femtocells to make a neighbor list, since there exist a number of femtocells in a macrocell. Serving NodeB needs to select an appropriate one from many femtocells. Thus the MAC overhead becomes significant due to the increased size of the neighbor cell list message. Also interference should be considered in handover decision since a UE scans many femtocells. So we propose a new CAC mechanism in the proposed handover procedure. When a femtocell receives handover request from FGW, the femtocell makes a decision to allow the handover according to the proposed CAC. The proposed CAC is described in Section 3.3

3.2. Proposed Femtocell to Macrocell Handover

The handover from femtocell to macrocell is not so complex compared to the macrocell to femtocell handover because whenever a UE moves away from a femtocell network, there is no option other than a macrocell network. The most important issue of this handover is that, the handover time should be maintained small. Fig. 4 shows the handover procedure for the intra MSN handover from femtocell to UMTS-based macrocell.

3.3 Proposed CAC In Hybrid Access Mode to Reduce Unnecessary Handover

Fig. 5 and Fig. 6 show the hybrid access mode of a femtocell within the macrocell coverage area and the proposed CAC respectively. In the hybrid access mode, there are two types of users, pre-registered users and un-registered users. Pre-registered users have the priority to use the femtocell services [10]. Un-registered users are able to use the Femtocell services when there is surplus bandwidth. The hybrid access mode is more flexible than the open access mode and the closed access mode, and allows the number of unnecessary handovers to be reduced.

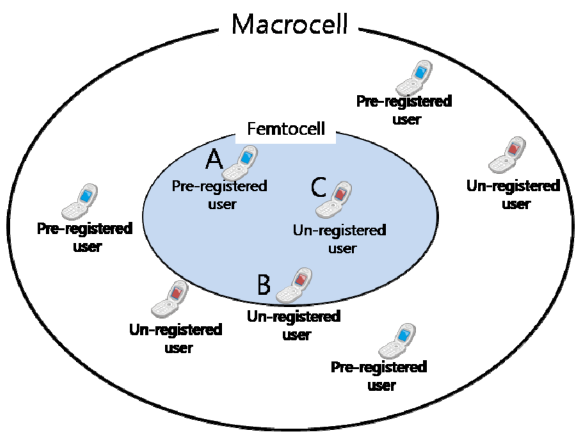

Figure 5. Hybrid access mode of femtocell within macrocell coverage area.

Since the coverage of a femtocell is very small, if a UE moves with high speed, the time duration it stays in the femtocell zone is very short [13], which causes two unnecessary handovers. In a wireless communication system, frequent and unnecessary handovers lower the service quality and decreases the capacity of the system. Therefore it is essential to minimize the number of unnecessary handovers to improve the service level of the users in a macrocell network coexisting with femtocells. To minimize the number of unnecessary handovers, a modified CAC is considered in the hybrid access mode [5].

We propose a new CAC mechanism taking into consideration of residence time in a cell. We consider the user type, the received signal level, the duration a UE maintains the signal level above the threshold level, the signal to interference level and the capacity (bandwidth) that one femtocell can accept. The threshold is the minimum level required for the handover from macrocell to femtocell. If the received signal level from the femtocell is higher than the threshold, the FGW checks whether the UE is pre-registered. If the UE is pre-registered, the next handover procedure is performed. If the UE is not pre-registered, UE must stay in the femtocell area for the threshold time interval (T) during which a signal level is higher than the threshold signal level before continuing to the next handover procedure. Thus the threshold time interval can reduce the number of unnecessary handovers.

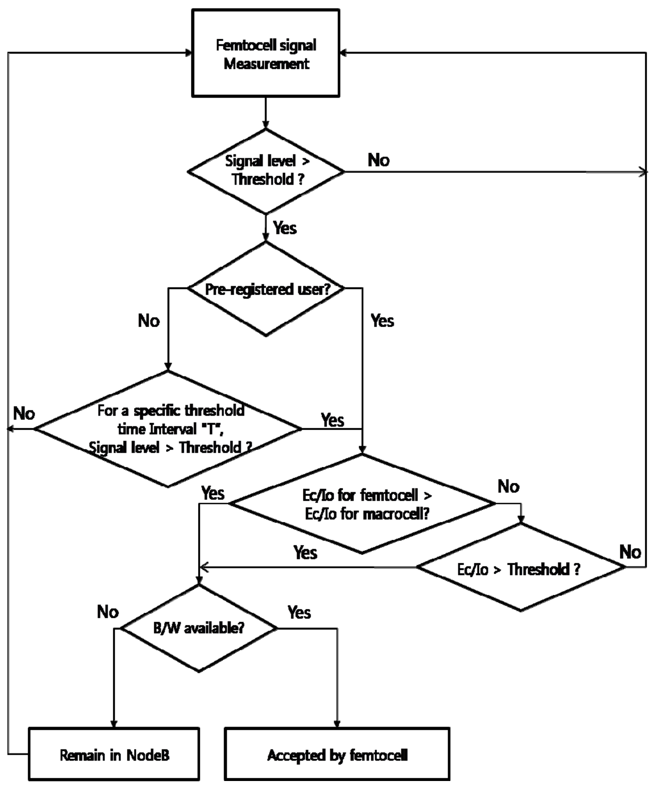

Figure 6. CAC to accept a handover call by femtocell in the hybrid access mode.

Table 1. Simulation Parameters.

Parameter	Value
Radius of femtocell coverage area	10m
Number of pre-registered users	4users/femtocell
Average velocity of UE in the femtocell coverage	0.25m/sec
Average call life time after handover from macrocell to femtocell	90 sec
Call life time and user velocity	Exponential distribution
Number of femtocells within macrocell	50

4. PERFORMANCE EVALUATION

The performance evaluation of the proposed handover minimization procedure is performed. Table 1 shows the basic simulation parameters. The time a UE stays in a femtocell is calculated based on the random angle and speed [7]. We assume that there are 50 femtocells in a macrocell, and when four pre-registered users move into the femtocells from the macrocells, the threshold time interval (T) for handover is set to 0. Un-registered users must stay in the femtocell area for the threshold time interval to go on to the next handover procedure.

Fig. 7 shows the number of handovers between the macrocell and the femtocell. As shown in Fig. 7, the number of handovers is reduced in the proposed mechanism. As the threshold time interval increases from T=10sec to T=30sec, the number of handovers is further reduced. Thus the differentiated treatment of the threshold time between the pre-registered and the un-registered users reduces the amount of unnecessary handovers and provides better service qualtity and flexibility compared to the open access mode and the closed access mode

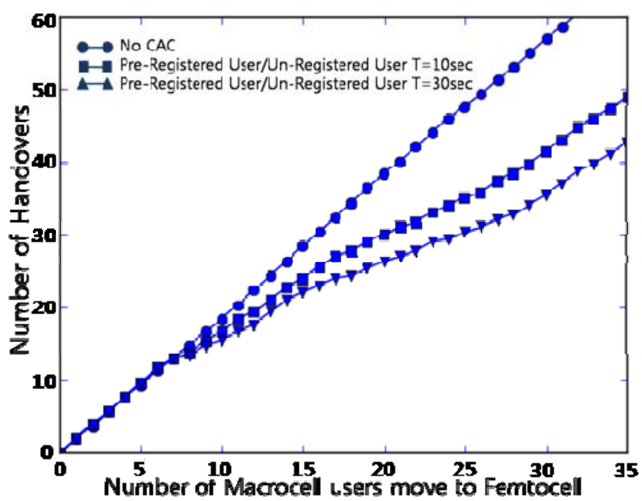

Figure 7. The number of handovers for users moving from the macrocell to the femtocell coverage area.

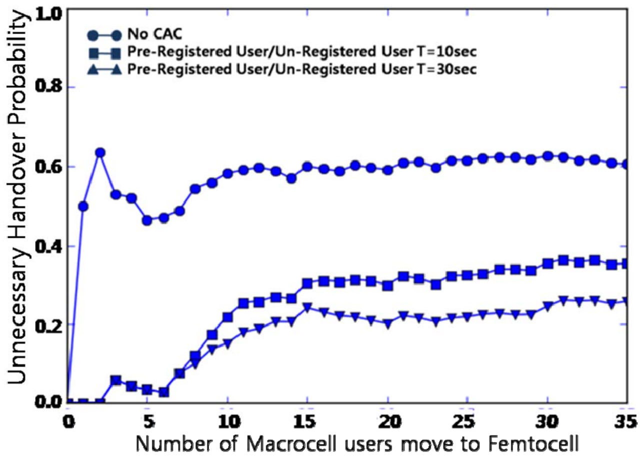

Figure 8. Unnecessary handover probability.

Fig. 8 shows the minimization of the probability of unnecessary handovers due to the proposed handover procedure. We regard a handover as an unnecessary handover when a UE first moves from the macrocell to the femtocell and within 50 seconds it moves to the macrocell again or within 10 seconds it terminates the call. As shown in Fig. 8 the probability of unnecessary handovers for un-registered users with no CAC is about 50~60% and it is reduced to around 30% and 20% at 'T=10sec' and 'T=30sec,' respectively.

5. CONCLUSION

Femtocells present mobile service providers with the opportunity to reduce the total cost of ownership of their voice and data services which can improve the customer loyalty and provide new revenue opportunities [9]. However from a technical standpoint, operators face challenges for integrating 3GPP UMTS-based macrocell and femtocell networks and maintaining scalability. Due to the small area of femtocell, there may be some unnecessary handovers. In this paper, we have proposed a new handover procedure between macrocell and femtocell for UMTS network and CAC in the hybrid access mode to minimize the number of unnecessary handovers. Our performance evaluation results show the number of unnecessary handover can be reduced by the proposed hybrid access mode CAC. Thus efficient and reliable core connectivity for circuit switched traffic of femtocell is possible with the proposed handover procedure.

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