Apply HIP to Handover Procedures in Hybrid Access Mode LTE Femtocells

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Abstract—Femtocell networks that use Home evolved NodeB (HeNB) and existing networks for backhaul connectivity can fulfill the upcoming demand for high data rates in wireless communication systems as well as extend the coverage area. In this paper we seem handover between femtocell and macrocell as a heterogeneous handover and apply the Host Identity Protocol (HIP) with Media Independent Handover (MIH) to achieve handover execution. It considers handover parameters for, including interference, velocity, RSS and quality of service (QoS) level. We propose a new handover strategy based on HIP between the femtocell and the macrocell for LTE (Long Term Evolution) -based networks in hybrid access mode. This strategy can avoid unnecessary handovers and can reduce handover failure.

Index Terms—Femtocells, Handover, HIP, MIH, Hybrid access mode

I. INTRODUCTION

Femtocells are a popular method to extend mobile network coverage and to enhance the system capacity and are expected to become a mainstream solution. There are many special characteristics for femtocells; for example, femtocells have a small communication range, low power, and low cost. Femtocells can also be used in home based stations and can be set up by both system operators and consumers. The use of femtocells allows for better-quality communication services and data transmission [1-3, 12].

The MIH framework offers a common interface and provides link layer and other related network information to the upper layers. Moreover, mobility management is one of the most important issues in mobile communication, and it affects the efficiency of the whole mobility network. Mobility is achieved through the implementation of handover and mobility management protocols [6-11, 17, 25], including the Session Initiation Protocol (SIP) at the application layer and Mobile IP (MIP)[18, 23] at the network layer. Meanwhile, the protocol can improve the efficiency of integrated heterogeneous wireless networks. However, use of SIP requires a larger handover message. MIP causes communication delays and triangle routings. In response to the shortcomings of SIP and MIP, Host Identity Protocol (HIP) [14, 19], defined by Internet Engineering Task Force (IETF), has emerged as a feasible solution for service mobility. In access control management, there are currently three femtocell access methods. The first method is a closed access mode; if you are not a CSG (Closed Subscriber Group) member, then you cannot access the CSG's femtocell. As an alternative, open access mode is open to let everyone use. Hybrid access mode is similar to closed access mode, but there are some restrictions on users of non-CSGs. How to choose the appropriate access mode and the proper management are also very important. As femtocells emphasize the convenience of building, the exact coverage area planned may not be available (cell planning). The interference between femtocells and macrocells may be very serious. We must have an adaptable self-configuration network, interference cancellation, or a way to control power. Avoiding and/or reducing the interference between two femtocells or between a femtocell and a macrocell is also an important challenge. Femtocells suitable for applying HIP in mobility management because of indoor and small coverage area features. So past research use an idea that utilizes the HIP and MIH to implement the handoff management for femtocells environment [15]. In this paper, we discuss the handover decision strategy and handover procedures more detail in hybrid access mode femtocells. We provide a new reference model for LTE femtocell networks applied HIP with MIH.

The rest of the paper is organized as follows. Section II describes related work. Section III introduces Handover Strategy in HIP-based LTE femtocells Networks with Hybrid Access Mode. Section IV proposes hand-in and...
hand-out handover procedures. Our conclusions and possible future work in Section V.

II. RELATED WORK

A. Review of Femtocells

Femtocells (femto) can provide indoor and small office coverage, substantial capacity, high quality and high transmission, for wireless communications services to balance the loading of a macrocell. Backhaul uses broadband internet, and the installation and configuration of backhaul uses plug and play components. Table I shows related terminology for femtocells.

<table>
<thead>
<tr>
<th>3GPP terminologies</th>
<th>Popular names</th>
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<tr>
<td>HNB (home NodeB)</td>
<td>Femtocell</td>
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<tr>
<td>Called HNB in UMTS</td>
<td>(FAP)</td>
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<td>Called HeNB in LTE</td>
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<td>HNB-GW (HNB Gateway in UMTS)</td>
<td>FAP-GW (FAP Gateway)</td>
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<td>HeNB-GW (HeNB Gateway in LTE)</td>
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<tr>
<td>HMS (HNB management system)</td>
<td>ACS (Auto-Configuration Server)</td>
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Table I. Terminology for femtocells.

There are three types of access control models for femtocells: open, closed, and hybrid. The closed access mode service is only for CSG users. However, the system operator will set a different service level for the needs of CSG users. In this case, management is more complex because femtocells must also be able to know a user's payment level. Under open access mode, any MNs (mobile nodes) can use femtocell services. However, in mixed mode, non-CSG services can get limited service. Of course, the access control mode depends on the management of the system operators. Figure 1 shows the access control management. Using CSG requires having a CSG_id, which gives a user the CSG femtocell service [5]. In an office building, the HeNB is an open cell that can serve any MN (including MN2). The CSG_id of MN2 is “none”; as a result, in this case, service can be only open cell or hybrid cell. CSG_id 2 HeNB in a coffee shop is a hybrid cell that can serve the MN3 and provide restricted service to MN2. The closed cell at home offers normal payment levels. Under open access mode, any MNs (mobile nodes) can use femtocell services. However, in mixed mode, non-CSG users. In this case, management is more complex because femtocells must also be able to know a user's payment level. Under open access mode, any MNs (mobile nodes) can use femtocell services. However, in mixed mode, non-CSG services can get limited service. Of course, the access control mode depends on the management of the system operators. Figure 1 shows the access control management. Using CSG requires having a CSG_id, which gives a user the CSG femtocell service [5]. In an office building, the HeNB is an open cell that can serve any MN (including MN2). The CSG_id of MN2 is “none”; as a result, in this case, service can be only open cell or hybrid cell. CSG_id 2 HeNB in a coffee shop is a hybrid cell that can serve the MN3 and provide restricted service to MN2. The closed cell at home offers normal service to the set of MNs belonging to the CSG_id=1.

For Femtocell and Macrocell network integration, there are some feasible choices. The E-UTRAN (Evolved Universal Terrestrial Radio Access Network) HeNB architecture discussed in LTE femtocell standards has not been finalized. The architecture that we want to have would follow the all-IP principles and would integrate the evolved packet core (EPC) smoothly. The HeNB management system is similar to HMS in UMTS. The reference of the LTE femtocell architecture is shown in Figure 2 [7,13].

3GPP has specified two standard interfaces, which are X2 and S1 for the Evolved Packet System. The X2 interface provides functionality to support mobility and the exchange of information between eNodeBs (macrocells). The S1 interface supports relations between MME (Mobility Management Entity)/SAE GW (System Architecture Evolution Gateway) and eNodeB. Furthermore, S1 is used for communication between HeNB (femtocell) and MME/SAE GW. If HeNB worked at the control plane, it could communicate through S1-MME. Otherwise, the connection between HeNB and MME/SAE GW could use the S1-U interface for the user plane. For a better integration, we could design HeNB-GW as an eNodeB for the S1 interface.

The complete E-UTRAN architecture with HeNB is shown in Figure 3 [3, 7, 13].
also supports handovers between IEEE 802 and non-IEEE 802 technologies. The MIH Function offers three types of services: MIES (Media-Independent Event Service), MICS (Media-Independent Command Service) and MIIS (Media-Independent Information Service). MIH works as follows: when an event occurs in layer 2 of different network technologies (e.g., signal decay), it can be transmitted to the upper layer through MIES. The upper layer (e.g., SIP, MIP, or HIP) can transmit a command (e.g., switching access interfaces) to the lower layer through MICS as well. Additionally, the user device and the network system can offer related information (e.g., network topology) to the lower layer or the upper layer through MIIS.

On the other hand, HIP proposes a new namespace, called the Host Identity namespace. Each Host Identity is unique and distinct from the IP address. It provides a convenient and efficient way to address hosts regardless of their location. In HIP, a pair of self-generated public and private keys provides the Host Identity. There are two main representations of the Host Identity: the full Host Identifier (HI) and the Host Identity Tag (HIT). The HI is a public key and directly represents the identity of the host. Because different public key algorithms have different character lengths, the HI is not good as a packet identifier in HIP. Consequently, HIP uses the HIT, a hash of the HI, as the operational representation. The HIT has the same length as an IPv6 address. Another representation of the Host Identity, the Local Scope Identifier (LSI), has the same length as an IPv4 address. Figure 4 shows the methods of identifying a host.

In HIP, a new protocol layer is added into the TCP/IP stack (Figure 5): the Host Identity Layer. It is located between the networking layer and the transport layer. The new layer hides IP addresses from the layer above. Applications need not rely on IP addresses but instead depend on HIT or LSI. The new layer transforms the HIT/LSI into an IP address, and vice versa. With this new approach, the application procedures create a socket that consists of the pair of the HIT and the port. In addition, the socket is mapped to a destination IP address. The application process does not involve any destination IP addresses but rather the HIT. If the IP address is changed, the transport layer can still be connected to the HIT because the mapping between IP addresses and the HIT can be retrieved such as the DNS. The HIP Base Exchange establishes a secure association between two hosts. It utilizes the four-way handshake and creates a secure association with IPSec. The Base Exchange is illustrated in Figure 6. The initiator sends the trigger packet (I1) to the responder and starts the Base Exchange. This packet contains the HIT of the initiator and, if known, the HIT of the responder. Upon receiving the I1 packet, the responder immediately replies with a prepared R1 packet. It contains a puzzle (a cryptographic challenge) that the initiator must solve before continuing the exchange. In addition, the R1 contains the initial Diffie-Hellman parameters and a signature; R1 is also used to create a session key and to establish the IPsec Encapsulated Security Payload secure association between the nodes. Then, the initiator sends the I2 packet containing the solution to the received puzzle. Without a correct solution, the I2 message is discarded. Finally, the R2 packet completes the Base Exchange.

To reach a mobile host, a HIP mobile host can change its IP address. The initial IP address must be stored somewhere. The rendezvous server (RVS) [20] is designed to solve this problem. To achieve mobility, each host must register with its own RVS server. This server must be updated with the latest IP addresses of the mobile host. Figure 7 shows a HIP base exchange involving an RVS. As Figure 7 indicates, the initiator sends an I1 packet to the RVS as notification of a change of IP address, and then the RVS forwards this packet to the responder. Later, the responder answers with an R1 packet. Finally, the initiator and responder exchange I2 and R2 packets. The diagram notation and its meanings are listed in Table II. The Diameter Base Protocol [21, 24] defines the same functions used in the various applications and provides basic mechanisms for credible transport message delivery and error handling services. It supports either IPsec (Internet Protocol Security) or TLS (Transport Layer Security) in order to protect the message. On the other hand, the Diameter NAS application describes the details of the authentication procedures on the Diameter servers and network access servers (NAS) [22]. NAS specification defines an AA-request and an AA-answer command that deal with the first two “A”s of AAA: authentication and authorization. AA-request (AAR) is a command sent by an NAS to request the authentication and/or authorization of a given NAS user. All requests must contain information that uniquely identifies the source of the call, such as a user-name or NAS port identifier. If authentication is requested, both the user-name and the related authentication Attribution Value Pair (AVPs) should be
present. AA-answer (AAA) is a command sent in response to an AA-request message. If authorization is requested and processed successfully, the AA-answer will include related authorization AVPs for the service requested and processed successfully, the AA-answer response to an AA-request message. If authorization is present. AA-answer (AAA) is a command sent in

III. HANDOVER STRATEGY IN HIP-BASED LTE FEMTOCELLS NETWORKS WITH HYBRID ACCESS MODE

The handover process in LTE femtocell networks should be modified. In this paper, we consider the received signal strength, the velocity and the QoS level, and we design a new handover scheme for hybrid access modes in femtocell networks. Although there are many related papers, few consider the hybrid access mode. Here, we utilize the interference level as the primary factor with regard to non-CSG users. Our idea can avoid unnecessary handovers and can reduce handover failures. We view femtocell network as a heterogeneous network and utilize the MIH which considering cost and complexity reduction to process handover execution. On the other hand, femtocell serve in local area or indoor, so it is more adaptive for HIP.

A. A Reference Architecture for LTE Femtocell

Figure 9 shows the reference architecture for femtocell network. We view E-TRAN and femtocell network as two heterogeneous network environments. Mobile node (MN) and Correspondent node (CN) are have MIH function to support MIH service. The common core network (the EPC) is based on IP technology. All data paths from the access networks are combined at the P-GW, which incorporates functionality such as packet filtering, QoS policing, interception, charging, IP address allocation, and traffic control routing. Additionally, EPC also contains network control entities for keeping user subscription information (home subscriber server [HSS]), determining the identity and privileges of a user and tracking his/her activities (authentication, authorization, and accounting [AAA] server), and enforcing charging and QoS policies using a policy and charging rules function (PCRF). In order to achieve a seamless handover of the architecture, many extra functionality based on the IEEE 802.21
protocol are needed in each network component. The MIH functionality is placed at the mobile node (MN), the wireless access networks (MIH PoSs), and the operator’s IP network (MIIS server). Moreover, due to mobility management based on HIP, the rendezvous server (RVS) is placed at the operator’s IP network for handling the IP address of an MN.

The handover between the LTE macrocell and the HeNB should operate seamlessly and smoothly. This goal is a big challenge for the LTE, including the femtocell network. In Figure 10, we describe several cases for handover scenarios in femtocell networks utilizing the hybrid access mode. The first case is hand-in. The hand-in type of handover is from a macrocell service to an HeNB. Accordingly, for the CSG or non-CSG user, we can divide two subcases in the hand-in case, which are hand-in (CSG) and hand-in (non-CSG). The second case is hand-out. The hand-out case represents a handover from the HeNB service to a macrocell. The third case is an inter-HeNB-HO (handover). This case describes the handover between two HeNBs. However, our handover decision strategy does not consider the inter-HeNB-HO.

In the femtocell network, interference is divided into the following: Cross-layer - femtocell interference; macrocell users interfering with each other; Co-layer - femtocell interference; and femtocell users interfering with each other. To cope with interference, recommendations in [16] are given for the use of power control in CDMA systems and intelligent subchannel allocation in OFDM systems. Co-layer interference always occurs in two close femtocells without obstruction. The Cross-layer interference often occurs with macrocell users in a femtocell service area, and both the uplink and the download have occurrences of interference. Assume that our LTE is based on an OFDM, as shown in Figure 11 and Figure 12; these figures describe the interference scenarios for downlink (Figure 11) and uplink (Figure 12). The M-user was serviced by a macrocell (eNodeB) and the F-user was serviced by a femtocell (HeNB). In the case of downlink, if the M-user and the F-user use the same subchannels, then this sharing of subchannels will cause interference, as shown in Figure 11. If the signal is strong enough to satisfy the user, then the signal can cause interference easily. This scenario is similar to the case of uplink (Figure 12) [1, 4, 8].

B. A New Handover Strategy

In the femtocell network, interference is divided into the following: Cross-layer - femtocell interference; macrocell users interfering with each other; Co-layer - femtocell interference; and femtocell users interfering with each other. To cope with interference, recommendations in [16] are given for the use of power control in CDMA systems and intelligent subchannel allocation in OFDM systems. Co-layer interference always occurs in two close femtocells without obstruction. The Cross-layer interference often occurs with macrocell users in a femtocell service area, and both the uplink and the download have occurrences of interference. [1, 4, 8].
We propose a simple handover strategy in Figure 13, which operates under an LTE-based network between a femtocell and a macrocell under the Hybrid access mode. The handover strategy considers the received signal strength (RSS), the velocity (V), the available bandwidth, the QoS, and the interference level. Our algorithm can decrease the interference and reduce unnecessary handover. This algorithm is divided into two parts: Handover from HeNBs to macrocells (hand-out) and Handover from macrocells to HeNBs (hand-in). We did not discuss the handover between one HeNB and another HeNB (inter HeNB-HO). In this case, the hand-in has two sub-components: one sub-component is for CSG users and the other sub-component is for non-CSG users. We design two velocity levels, \(V_t^1\) and \(V_t^2\), for which \(V_t^1>V_t^2\). (For example \(V_t^1=30\) kmph and \(V_t^2=15\) kmph.) The system operator can set up this configuration by himself, using professional judgment. In the case of hand-out, the considerations are simple but the management is more complex. As a result, both CSG and non-CSG users need to perform handover into macrocell service when they experience bad communications. Therefore, we first consider \(V\) of MS (mobile station). We check whether \(V\) is over \(V_t^1\), and we check the availability of the bandwidth, then we perform handover into a macrocell. If the MS is lower than \(V_t^1\), then we use RSS to decide whether to perform handover or not. The HeNB physical layer cannot be a high-speed service. In the case of a hand-in from a hybrid access mode, first we check whether the user is CSG or not. If the MS is CSG, then we see whether the RSS is lower than a threshold and we check whether the velocity is over \(V_t^1\) or not. If \(V>V_t^1\), then there is no handover. If \(V^1>V>V_t^2\), then we see whether there is real-time service or not. If the answer is yes, then the handover will be executed in the bandwidth that is available. If \(V<V_t^2\), then the handover will also be executed in the bandwidth that is available. If the MS does not belong in the CSG, then in a normal situation the HeNB does not need to provide service. However, if the MS causes too much interference, then we hope that the MS can perform handover to the HeNB, to reduce interference. When \(V>V_t^2\), then handover is not allowed because we believe that this interference will pass soon. While \(V<V_t^2\) and achieves an interference level, handover will be requested. This handover is different from a normal situation, where handover is initiated by the HeNB.

IV. HANOVER EXECUTIONS

A. Hand-in Procedures

The handover procedures between traditional LTE macrocell are presented in [13] and [17], and we modify the handover mechanisms include femtocells. The handover from a macrocell to a femtocell has two kinds of procedures. The first procedure is for the CSG. Normally, the MS should choose the most appropriate target for the HeNB. This scenario is shown in Figure 14. For the non-CSG, the handover procedure has some differences from the normal situation. The initialization of the handover is triggered by the HeNB, to avoid interference, as can be seen in Figure 15. On the other hand, we utilize the MIH to process the handover executions because of cost and complexity reduction. According to the characteristics of femtocell networks, it is more suitable for HIP.

MIH_Get_Information which is MIH user of the MN querying the information of neighboring networks. MIH_MN_HO_Commit (MN to network) and MIH_N2N_HO_Commit (network to network), once the MIH user of the MN decides which target network will receive the handover, it confirms that the handover will be executed. The resources of the target network will be reserved. The MIH_HN_HO_Commit that is responsible for negotiation triggered from HeNB. And the authentication procedure is performed. Once the MN establishes the connection with the target PoS, the MN updates its IP address to the RVS located on the operation network to keep its contact information accurate. Then, the RVS notifies the CN that the IP address of the MN has changed. MIH_MN_Complete and MIH_N2N_Complete are responsible for the handover completed.

B. Hand-out Procedures

The hand-out procedures are not complicated shown in Figure 16. The UE has no option to select the target cell because there is only the macrocell eNodeB. If the UE has a high velocity or the RSS is decreasing continuously, then either condition will trigger the hand-out procedure.

V. CONCLUSIONS

In this paper, we propose a simple and effective handover algorithm and a new handover executions mechanism for LTE-based femtocell networks. We offer a new idea in which, according to an interference level trigger, a handover procedure is performed for a non-CSG user. This algorithm could reduce unnecessary handover initialization and could eliminate cross-layer interference. In handover executions, we apply the HIP with MIH to suit the femtocell networks properties and reduce the handover complexity. However, we do not consider co-layer interference and inter-HeNB HO. In addition, we do not discuss the inter-HeNB-HO that involves handover between HeNB and HeNB. But this issue is easily to achieved by HIP. In the future, we hope to add co-layer interference consideration and to perform simulations to compare other handover strategies.
REFERENCES


