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Mobility Management Survey for Home-eNB Based 3GPP LTE Systems

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Abstract: The specification of the Home Evolved NodeB (Home-eNB), which is a small base station designed for use in residential or small business environment, is currently ongoing in 3GPP LTE (Long Term Evolution) systems. One of the key requirements for its feasibility in the LTE system is the mobility management in the deployment of the numerous Home-eNBs and other 3GPP network. In this paper, we overview the characteristic of Home-eNB and also describe the mobility management issues and the related approaches in 3GPP LTE based Home-eNB systems.

Keywords: *Home-eNB, 3GPP LTE (Long Term Evolution), Mobility Management*

1. Introduction

A significant interest within the telecommunications industry has recently focused on the femto-cell which is defined broadly as low-cost, low-power cellular base stations that operate in licensed spectrum to connect conventional, unmodified mobile terminals to a mobile operator's network [1][2][3].

Femto-cell has been actively discussed in 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE) system [4] by the name of Home e-NodeB (HeNB). A HeNB is connected via Ethernet to the home router, and the traffic is backhauled over IP back to the operator's core network using the customer's broadband connection. HeNB is short range about tens of meter, installed by the consumer for better indoor voice and data reception.

Advantages of the deployment of HeNB is that it can satisfy not only the need of customers for the high bandwidth wireless internet access in the home and office but also the need of operators for efficient and cost-effective capacity solution for indoor coverage.

The HeNB deployments however have several challenges. A numerous HeNBs and other 3GPP cells can be deployed in macro cellular network. Also the HeNB is based on self-optimized and self configured in the network [5][6]. Therefore the HeNB is automatically and frequently turned on/off in the macro-cell (e.g. evolved NodeB) coverage with various deployment scenarios. While considering these factors, system should support the continuous mobility when the User Equipment (UE) moves to in/outdoor region of HeNB. From this viewpoint, mobility management of UE is the key requirement for feasibility of HeNB deployment in 3GPP LTE system.

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In this paper, we aim to address the mobility management issues of HeNB in 3GPP LTE systems and related approaches about the issues. In section 2, HeNB based on 3GPP LTE systems is described. In section 3, the issue about the mobility management of HeNB and related approaches are described. Finally, conclusion of this paper is given in section 4.

2. 3GPP LTE based HeNB system

2.1 3GPP LTE system

The network architecture of LTE system consists of eNBs providing both user plane and control plane to the UEs [6]. The eNBs are interconnected with each other by the interface and also connected to the Mobility Management Entity (MME) which the functions is related to handover and the Serving Gateway (S-GW). The S-GW is mobility anchoring for the inter-3GPP mobility and routes and forwards the packets. The Evolved Universal Terrestrial Radio Access Network (E-UTRAN) architecture is depicted in the left side of fig. 1.

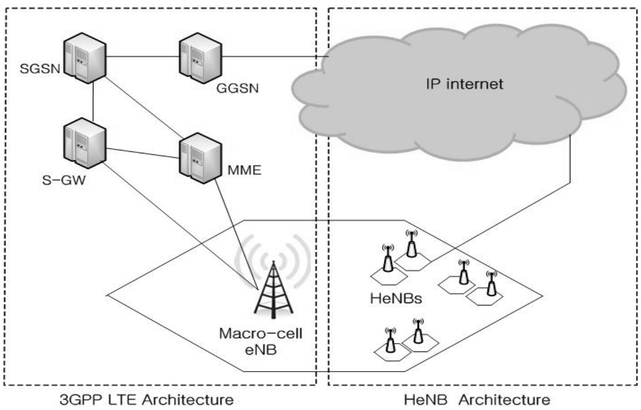


Fig. 1. HeNB deployment with macro-cell

2.2 Mobility support in 3GPP LTE

The UE state for the mobility support in the 3GPP LTE systems is classified in two states: Idle mode and Connected mode [4] [7].

In the idle mode [7], the cell selection and re-selection is done for the mobility management of UE. When a UE is turned on, Public Land Mobile Network (PLMN) is selected. The UE searches for a suitable cell of selected PLMN and chooses the cell to provide available services and tunes to its control channel. This choosing is referred as "camping on the cell". If the UE finds a more suitable cell, according to the cell re-selection criteria, it selects onto that cell again and camp on it and this mechanism is defined as the cell reselection.

When a call is generated, the idle mode is transited to the connected mode. The LTE utilizes a network-controlled and the UE assisted handover procedure for mobility in connected mode [4]: UE measures downlink signal strength and sends the measurement report to the serving eNB. The serving eNB then makes the handover decisions based on the received measurement reports. The message sequence diagram of the LTE handover procedure is shown in fig. 2. The handover procedure consists of 3 parts: Handover Preparation, Handover Execution and Handover Completion.

First step is the preparation of handover. In this step, UE, serving eNB and Target eNB make preparation before the UE connect to the new cell. The main message and process

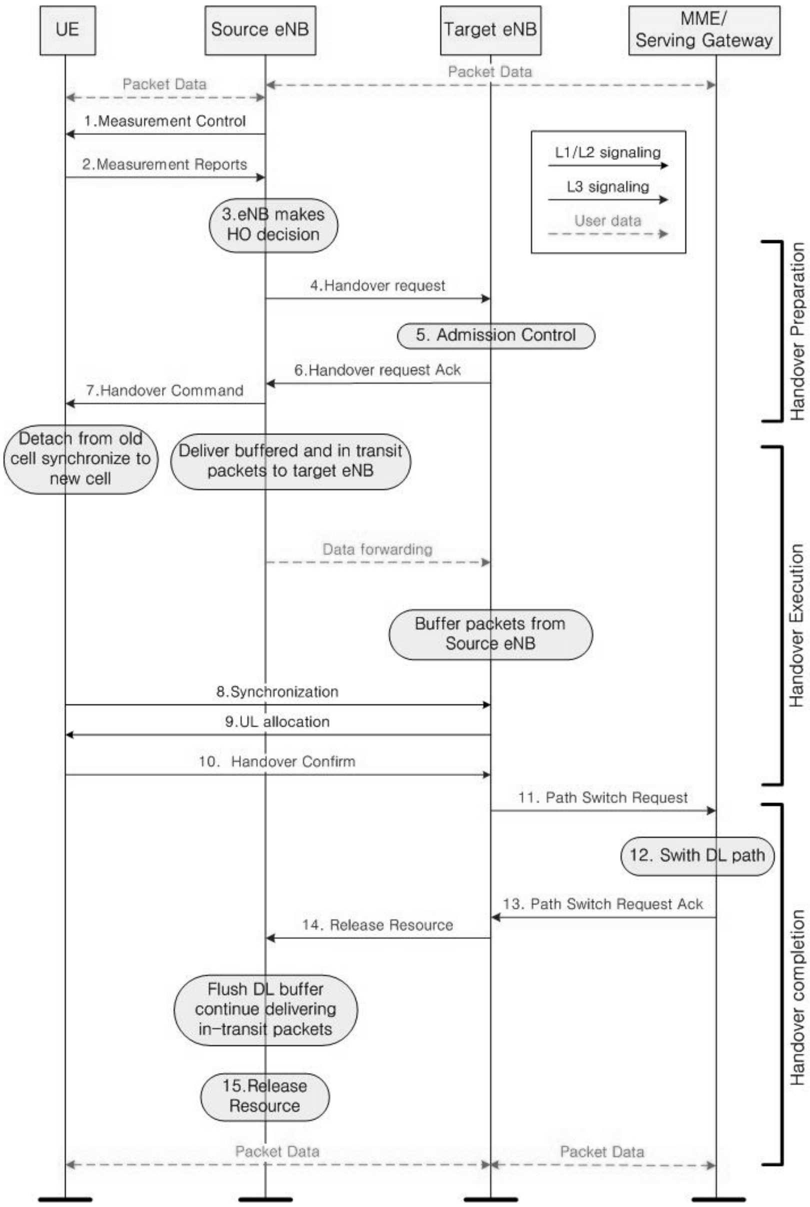


Fig. 2. LTE handover procedure

are described as follows:

1) Measurement Control/Report
The source eNB configures and triggers the UE measurement procedure and UE send Measurement Report message to serving eNB.

2) Handover decision
The source eNB makes the handover decision based on the received measurement report message from UE.

3) Admission Control
The target eNB performs the admission control dependent on the Quality of Service (QoS) information and prepares handover with Layer1/Layer2.

4) Handover Command
The source eNB sends the handover command to UE.

The purpose of the following two steps of handover execution and handover completion is to provide the ways to avoid data loss during handover.

5) Detach from old cell synchronize to the new cell
UE performs the synchronization to the target eNB and accesses the target cell.

6) Path switch
The S-GW switches the path of downlink data to the target side. For this, the S-GW exchanges message with MME.

7) Release resource
Upon reception of the release message, the source eNB can release radio and control related resources. After this time, target eNB can transmit the downlink packet data.

2.3 HeNB requirements in 3GPP LTE

The requirements [8] of HeNB in LTE are summarized as follows:

1) Compatibility
The HeNB should not degrade significantly the performance of network deployed in other channels. Also, the HeNB configuration intended for deployment in the same channel as an existing E-UTRAN network should guarantee their combined performance is not significantly worse than that of the legacy networks. The HeNB must support existing E-UTRAN UEs.

2) Performance
HeNB should provide reasonable performance in the both case that it is deployed in separation and that multiple HeNBs are deployed in the same area.

3) Mobility
The HeNB must support the UE speeds up to 30km/h and above.

In this paper, we will mainly focus on the issues of the HeNB related to mobility requirement.

2.4 Deployment scenario of Home-eNB

The possible cases of different deployment configurations have been considered for HeNB in 3GPP LTE system [9].

HeNB can be deployed in E-UTRAN as depicted in the right side of Fig. 1. The aspects which classify deployment configurations are as follows: Access type, Channel allocation type and Transmit power

1) Open Access and Closed Subscriber Group (CSG)
Open access deployment enables the HeNBs to serve any UE in the same way as a normal eNB. CSG however only serve limited UEs which are a member of particular group or HeNB.

2) Dedicated channel or co-channel
In the dedicated channel deployment, HeNBs operate in their separate channel. In the case of co-channel, HeNB shares a channel with an existing EUTRAN network. The comparison of each case is described in Table 1.

Table1. Comparison of deployment channel scenario

	Dedicated Channel	Co-channel
Pros.	- Mitigation of interference from eNB	- High frequency efficiency - Easy Handover between eNB and HeNB - Low complexity of UE
Cons.	- Low frequency efficiency - UE should support different frequencies - Service discontinuity during handover	- Interference between eNB and HeNB

3) Fixed or adaptive maximum transmit power
The HeNB have a set fixed maximum transmit power and can also adjust maximum transmit power according to interference in network.

In the next section, we will discuss the mobility management issue of HeNB in the LTE systems considering the CSG deployment.

3. Mobility Management Issues

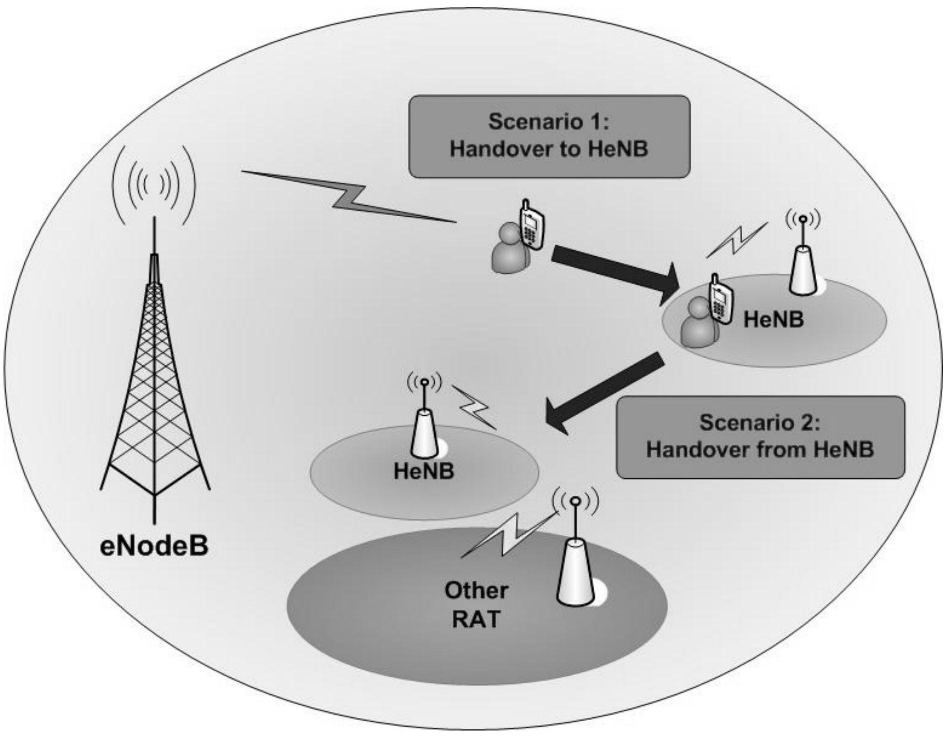
3.1 Handover Scenario

Considering deployment of the HeNB in 3GPP LTE systems, the possible handover scenario could be classified into 2 cases as depicted in the fig. 3. Also each handover scenario has both the idle and connected state.

The first handover scenario is inbound handover (HO) from macro-cell to HeNB and this scenario is the frequently facing handover scenario for the UE and also complex one. In the second handover scenario, UE is currently connected with HeNB and it is important which entity i.e. eNB and HeNB decide the handover from HeNB to target cell because it affect the handover procedure. Both scenarios have the following problems. First, a large number of HeNBs could be deployed in macro-cell, so it needs the method to identify the HeNB and also check the UE's accessible HeNB in the CSG deployment. The quantity of measurements for non-allowed CSG cell should be also avoided. If the UE measures all the HeNBs and reports the measurement to the eNB, it causes the much power consumption of UE and handover delay. Next, handling of the neighboring cell for handover is also complex to manage. The neighboring cell is the group of candidate of target cell for handover. In LTE system, 'X2' interface is defined and directly connected between the eNBs. Hence the managing the neighboring relation referred as Automatic Neighbor Relation (ANR) is possible [4], but HeNBs and eNBs are not directly connected and also HeNB is frequently turned on/off. Therefore managing the neighboring list which consists of both HeNBs and eNBs is complex problem. Interference between the HeNB and the eNB is a common problem to solve for support of mobility management of UE in both handover scenarios.

3.2 Searching HeNB in CSG case

During Handover procedure as we discuss in the section 2.2, after serving eNB controls the measurement, UE should send measurement report which contains the information of target cell to make handover decision. And also the target



- ✓ Scenario 1 : Handover from Macro-cell to HeNB
- ✓ Scenario 2 : Handover from HeNB to Macro-cell, HeNB, other Radio Access Technology(RAT)

Fig. 3. Handover Scenario

cell consists of both the eNBs and HeNBs.

In case of CSG deployment for HeNB for the target cell which the limited UEs can access the cell, for support of mobility, first problem is that how the UE can find out that the target cell is the CSG cell or not. And next problem is to identify target CSG cell as the UE's own accessible HeNB among the lots of HeNBs in the macro-cells. The solution of this problem is necessary to manage the mobility in both idle mode and connected mode.

3.2.1 Identification of CSG cell

In the mixed deployment of the eNB/CSG (e.g. HeNB) cell, as we discussed, first problem is that the UE need to identify whether the measured cell at physical layer is macro-cell or a HeNB. For this, the CSG indication or flag is included in System Information Block (SIB) in broadcast channel is basically discussed in [10] [11]. However in this case, UE should read the CSG cell flag for all the identified cells and it results in consumption of battery power in the UE.

Some mechanisms are discussed in the 3GPP Working Group (WG) meeting to avoid this problem. First mechanism [11] is the identification based on the CSG cell specific physical cell identity (PCI) [12]. Advantage of this method is making it possible for the UE to identify a CSG cell during the cell identification at physical layer and also can reduce the latency of mobility procedure. In idle mode, lower power consumption can be expected due to not having to read system information from neighboring cells. For example, reservation of PCI for CSG cell which its number is fixed value is suggested in [13]. However CSG cell specific PCI reservation approach is assuming the mixed carrier scenario where interference control is inevitable and it would affect the number of available PCIs for non-CSG cell. Extension of PCI space only for CSG cell is also suggested in [13], but the extension of PCI has the problem for change of physical layer specification.

Another discussed method is based on a CSG cell specific frequency layer. This method is suitable for the scenario that the frequency layer would be dedicated to CSG cell. This method does not need to reserve the PCI and also other possible interference issues.

3.2.2 CSG identity acquisition

After the UE identifies the target cell as the CSG cell, next step is to acquire the CSG identity of the target cell. The CSG identity is checked against the whitelist which contains the identity information of UE's own accessible HeNBs. Considering the deployment of multiple CSG cells with the same PCI within a macro-cell, when UE finds a CSG cell and PCI of CSG cell corresponds to a cell in whitelist, there can be ambiguity to identify the accessible CSG of UE. In order to remove the ambiguity, the possible candidates of CSG identity for the whitelist of UE are discussed in LTE. UE need to check unique information to identify the accessible HeNB. Basically, CSG Identity (ID) is discussed for checking the UE's own accessible HeNB. Also [11] suggests that UE needs to obtain the cell's global ID which is unique and compares it to the global cell IDs of the cells in the CSG whitelist. In order to read the global cell ID, UE has to read the system information of the target CSG cell and UE needs a considerably longer interval which is called "gap" during the connection with the current serving eNB to receive the global cell ID.

Another discussed issue is how the acquisition of CSG cell identity is executed. The CSG identity will be included in the system information, and consequently it requires gap. The possible methods of gap request are discussed in [14]. First discussed method is the no separate gap request. UE relies on available natural gap from Discontinuous Reception (DRX) operation for CSG identity acquisition. In this option, UE can obtain CSG identity only when there are enough natural gaps. Also [15] suggests that the existing measurement method be used for acquiring the CSG identity by tuning of event criteria of parameters. Another discussed method is a separate gap request procedure for the CSG identity acquisition. A UE tries to obtain CSG identity using assigned measurement gap. This method allows the fast identification of target CSG cell. However, it is complex than method of using only natural gap and it affects the user traffic and service perception due to measurement gap.

3.2.3 Measurements on CSG cell

A requirement about CSG cell measurement in [4], states that it is necessary for the UE to avoid measurements of HeNBs which UE does not belong to the HeNB. To minimize the measurements loads related to signaling message need for searching the non-allowed neighbor CSG cells, [16] proposes the use of threshold in terms of radio condition. For example, the parameter '$S_{measure}$' is already defined to limit the measurements and reporting about non-CSG cell in LTE system [10]. Therefore parameter such as $S_{measure}$ can also be utilized for the UE to minimize measurements for inaccessible HeNBs in the CSG deployment scenario.

3.3 Cell reselection

In the idle mode, after UE selects the cell, UE camps on that cell and reselects another cell by the cell reselection criteria. Issues about cell reselection considering the HeNB deployment are also discussed in the 3GPP LTE systems. Reselection of the UE's accessible CSG is necessary to satisfy the purpose of HeNB deployment for improving the network coverage, network capacity and providing the low cost service.

In the requirement of CSG about cell reselection [4], one requirement is that the UE in the coverage of accessible CSG cells should have priority for camping towards the CSG cells because user billing could be dependent on whether the UE is using the HeNB. So, it is important for UE to camp on the HeNB when it is in the range of HeNB. For satisfying this requirement, [18] suggests the use of implicit CSG priority, i.e. CSG cell should have higher priority with regard to the high priority macro-cell in the different frequency scenario.

Another requirement is that the system should avoid excessive signaling and processing load from a UE frequently reselecting the cell in LTE idle between CSG cells and non-CSG cell, i.e. situation that UE move frequently between the macro-cell and accessible CSG cell.

Cell reselection method from macro-cell to CSG cell is discussed in 3GPP WG. For the criteria of cell reselection in the different frequency deployment, [19] suggests that macro cell reception level is not taken into account for inbound CSG reselection. Otherwise, the UE does not reselect to CSG cell if the macro-cell is well received.

3.4 Handover decision parameters

Basically, the serving eNB decides handover to target cell by comparing received signal strength indicator (RSSI) which UE received from the serving eNB and the HeNB. However, when we are considering the CSG deployment for HeNB, other handover parameters which also influence on handover decision should be considered for mobility management: Service cost, Load balancing, Speed status of UE.

HeNB offers the different billing models. The user billing is decided by whether user is using the HeNB. Therefore it is important for UE to handover to accessible HeNB fast.

In viewpoint of load balancing, when a large number of active UEs are located in a given cell, available resources may be insufficient to meet the QoS for the real time service and offer the good performance for the best effort service [20]. Especially in the HeNB case, the available user for HeNB is limited. If the available resource is short for UE to handover to CSG cell, it needs to handover to another accessible HeNB or macro-cell.

Mobility state of UE also effects the handover decision. To reduce the frequent handover trigger, i.e. ping-ponging effect, the states of UE speed should be considered to manage the mobility. In [7], idle mode mobility state is defined by 3 cases: high mobility state, medium mobility state and normal mobility state. These parameters are sent in the system information broadcast of serving cell. Such speed dependent parameter also needs to be considered for handover in the Home-eNB scenario.

As we discussed, during handover procedure, following parameters also affect the handover performance i.e. Service cost, Load balancing and Speed status of UE. The serving cell should decide the handover to target cell considering these multiple parameters and the method to optimize these parameters is the open issue to solve.

4. Conclusion

Femto-cell which is referred as the HeNB in 3GPP LTE systems has the chance to provide high quality network access to indoor users at low cost, while mitigating the mobile operator's concern about coverage extension. This paper overviews the technical challenges in mobility management of Home-eNB which is a key requirement of its feasibility in 3GPP LTE systems. We also describe the discussed solution for mobility management issues. Key technical challenges are the ways a UE searches the own accessible Home-eNB for handover and ways by which a UE reselects the cell for camping in idle mode when the HeNB is deployed for limited users. Also, multiple parameters for handover decision should be optimized for mobility management in HeNB based 3GPP LTE systems.

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