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LTE Home Node Bs and its enhancements in Release 9

Mai 2010

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Summary

The following document provides an overview of enhancements for LTE Home Base Stations that have been defined in 3GPP Release 9 specifications. After introducing 3GPP Release 8 Home Node B functionality, we look at the new functionality such as the hybrid cell concept, inbound mobility support, Closed Subscriber Group management as well as newly defined RF requirements to allow for uncoordinated deployment of femto-cells in a mixed carrier deployment.

LTE HeNB Introduction (Release 8)

Femto-cells or Home Node Bs have been a hot topic for quite some time since they offer benefits such as providing:

- Significant offload of traffic from regular base stations;
- Full coverage and high speed transmission at home;
- Better link quality, lower transmit power, higher performance;
- A single mobile device serving all purposes for the customer;
- Improved customer relations for the operator.

In 3GPP terms, LTE femto-cells are called Home Node B's for HSPA and Home eNode B's for LTE. With increasing LTE terminal penetration and fixed-mobile convergence, the expected demand for LTE Home eNodeBs is likely to provide attractive services and data rates in future home environments. In the following, we look at Home eNodeB (HeNB)deployed as small EUTRAN cells in domestic environments, small offices and similar environments. The HeNB functionality and interfaces are basically the same as for regular LTE base stations except few additional functions as described in [1]. There are no additional HeNB interfaces such as the Iuh for HSPA.

The architecture of HeNBs is presented in Figure 1. The HeNB Gateway shown can concentrate a large number of HeNB's and appears as an MME to the HeNB and the EPC. Amongst others it provides the Tracking Area Code (TAC) and network identification (PLMN ID) to the HeNB

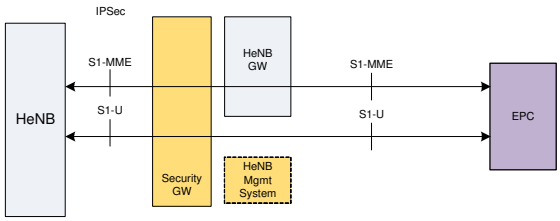

Figure 1: LTE HeNB architecture

HeNBs are typically associated with uncoordinated large scale deployments. Nevertheless due to the licensed spectrum the operator must have complete control to:

- Activate/deactivate HeNBs;
- Verify the identification and geographical location;
- Determine the state and to regulate conformance.

HeNBs as defined in Release 8 have multiple Access Control mechanisms:

1. Closed access (residential deployment): Access is only allowed for the subscribed user. The HeNB is defined as a Closed Subscriber Group cell and Access Control is located in the Gateway (GW)
2. Open access (enterprise deployment): All users are allowed access to the HeNB and receive the offered services.

Access Control is based on a HeNB cell ID, which is called Closed Subscriber Group (CSG) identification (CGI). Release 8 defines basic CSG provisioning and access control. The User Equipment (UE) will need to support Automatic CSG selection in idle mode as well as Manual CSG selection. Autonomous search is performed to find CSG member cells, whereas the algorithms are left completely to UE implementation. The

problem of increased UE power consumption by excessive cell search can be addressed by using the Physical Cell Identification (PCI) to identify a CSG cell. A number of PCIs are reserved to identify CSG cells within the same carrier frequency in case of a mixed deployment (other HsNBs using the same frequency). A non-standardized autonomous cell search, left to UE implementation, was chosen to minimize impact on non-CSG UEs and regular base station.
Mobility of Closed Access HeNBs only supports outbound handover from a HeNB to a macro cell, but not inbound mobility from the macro cell to the HeNB. For outbound mobility the normal HO procedures is used and similar performance figures can be expected.

For in-bound handover to a HeNB, the following issues have not been solved within the Release 8 timeframe:

- PCI Confusion: Determining the target cell when more than one HeNB under macro coverage shares the same Physical Cell Identification. This is a likely scenario in mass deployments of HeNBs in parallel to Macro eNB deployment. The network might thus not be able to do a handover since another cell with the same PCI is being reported.
- Access Control before handover: Determining whether the UE that is handed over to a HeNB is actually allowed to access the target cell. This can lead to dropped or temporarily interrupted calls.

HeNB Enhancements (Release 9)

LTE Release 9 provides further functionality to support more efficiently HeNBs operation and to provide a better user experience.

The key functionality added the Radio Access Network for HeNBs in Release 9 are:

- A novel Hybrid Cell concept
- Management of out-of-date CSG info
- Inbound Mobility (including proximity reports)
- Access Control
- Operation, Administration and Maintenance for HeNB
- Operator controlled CSG list
- RF Requirements for TDD and FDD HeNBs

Hybrid Cell Concept

Hybrid access is a new access concept introduced with Release 9 in addition to Closed Access and Open Access. Basically the cell provides open access to all users but still acts like a CSG cell. Subscribed users can be prioritized compared to unsubscribed users and can be charged differently. According to the specification a hybrid cell is defined as a cell that has the CSG indicator set to false and yet broadcasts a CGI (Closed Subscriber Group ID). [3] [7] clarifies the difference between a hybrid cell and a CSG cell.

UEs perform cell selection and reselection in order to find an appropriate cell to camp on in Idle mode. Cell reselection had to be modified to support hybrid cells. The UEs treat the hybrid cell as a CSG cell in cases where the ID is in the allowed Whitelist and like a normal cell in the other cases. In the latter case, the UE will use autonomous search functions in order to select hybrid cells.

Management of Out-of-Date CSG Info

This new Rel.9 feature clarifies the handling of a change in the CSG membership status. If a UE is no longer a member of a CSG group, the MME can signal its membership status to the HeNB. In that case, the HeNB should try to hand the UE over to an non-CSG cell. If the HeNB is a hybrid cell, the UE's Quality of Service can be handled like non-CSG members from that point of time.

Inbound Mobility (including proximity reports)

In contrast to cell selection for Idle UEs, network-controlled handover functionality is required for UEs in RRC Connected state with an established connection to the network. As described before, the inbound handover from a Macro eNB to an HeNB is not supported in Release 8. Before making a handover decision to a HeNB, the Macro eNB needs to acquire UE measurement information related to the so-called target CSG cell. Nevertheless, UEs cannot continuously make measurements and read the system information of lots of CSG cells in cases of large scale HeNB deployments. In order to allow the UE to make those measurements efficiently, a newly defined proximity report can be configured within the RRC Reconfiguration message. This proximity report will allow the UE to send a so-called "proximity indication" to the source eNB in the uplink

whenever it is entering or leaving the proximity of one or more cells with CSG IDs that the UEs has in its CSG Whitelist.

A UE that is able to determine that it is near its CSG cell can thus inform the network to take the necessary actions for handover preparation. The detection of proximity is based on an autonomous search function.

The source eNB, upon receiving the proximity indication, might ask the UE to perform measurements of the CSG cell, to read the System Information (SI) or, in case it already has all required information, it might already start the handover procedure. PCI confusion as described previously is resolved in Release 9. The eNB will ask the UE to report the global cell identity. As usual the UE reporting is using the RRC measurement procedures. The ovell procedure is illustrated in Figure 2 [2].

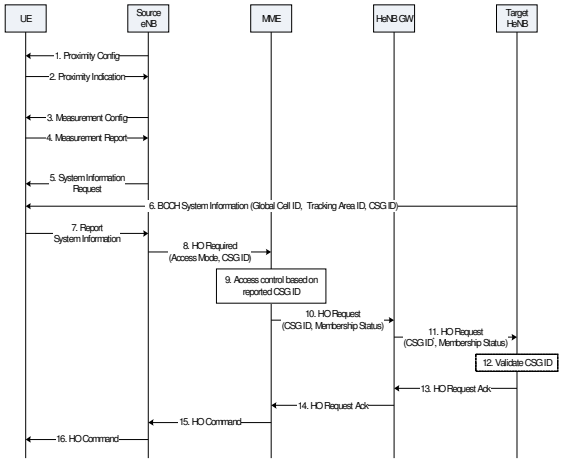

Figure 2: Inbound Mobility to HeNB CSG and hybrid Cells

In summary five basic steps can be identified:

1. Proximity configuration/reporting
2. HO measurement configuration/reporting
3. Resolution of PCI confusion by requesting and reporting System Information
4. Access Control in the network
5. HO execution

Since the CSG search can be very slow there are no strict requirements on the inbound handover performance, which can range from one to several 10's of seconds.

Since the proximity information is based on UE signaling, the network might be receiving a lot of proximity indications, increasing the network load. Therefore, it was agreed to limit proximity indications a UE can send within a certain time frame. A timer, called the prohibit proximity timer, was introduced.

Additionally, the UE complexity was increased in that there are now two methods to report the SI from another cell. The UEs use DRX/measurement gaps for the reports supporting the Automatic Neighbor Relation function and use autonomous gaps measurements for inbound mobility to a CSG cell.

Access Control

The UE reports its membership status in the target cell along with CGI that has been read on SIB1. Access control will be performed by the MME based on the CSG ID and the membership status of the UE. CSG Handling is done at the target cell. If the target cell is a hybrid cell, prioritization will be done based on the UE membership status reported by the MME.

Operation, Administration Maintenance for HeNB

The number of the HeNBs may be very large and located at a private residence which is not accessible for onsite maintenance. Therefore, it is essential that management functionality is defined, including considerations for multi-vendor environments. The HeNB will be managed by the Home eNodeB Management System (HeMS) through the so-called type 1 interface [4], based on TR-069, as defined by Broadband Forum. Figure 3 introduces the HeNB management architecture. The Integration Reference Point (IRP) Manager will manage HeNBs via the type 2 interface to the HeMS.

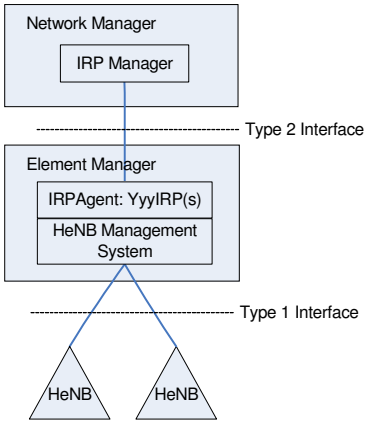

Figure 3: HeNB Management Architecture

The Element Manager handles various IRPs supporting different functions as described below.

Configuration Management: The HeMS configures the HeNBs using the TR-069 CPE WAN Management Protocol (CWMP). HeMS is able to reboot the HeNB and start/stop transmissions on certain frequencies. The HeNB shall also be allowed to download software.

Requirements for Performance, Fault and Security Management were defined.

Performance Management: The HeNB can collect performance data and send it to the HeMS.

Fault management: The HeNB will support fault management, enabling the operator to monitor and manage it. The HeNB will also provide alarm-related information on demand or based on HeMS policy.

Security Management: The HeNB must protect itself against attacks via interface type 1.

Operator controlled CSG lists

CSG IDs and Whitelists were already introduced in Release 8 to make the UEs aware of the CSG cells and to prevent the UEs from trying to access every CSG cell wasting their battery life. CSG related parameters are stored on the SIM card (USIM) of the UE.

Release 9 introduces an additional operator-controlled CSG list on the UE. The operator CSG list is provided to the UE based on procedures for a Release 9 USIM as defined in TS 31.102.

CSG entries on the USIM consist of:

- PLMN Identifier
- CSG Identifier
- Home eNodeB Name
- CSG Type

A UE camped on a CSG or hybrid cell will display the CSG Type (if available) or the HNB Name.

HeNB RF requirements for TDD and FDD

Due to the expected uncoordinated, large scale deployment, new requirements have been introduced which resulted in modifications to the RF specifications. The outcome of work done in Release 8 was captured in a technical report TR 25.820. In Release 9 significant work was done to define HeNB specific RF requirements. UE RF specifications, on the other hand, were not affected, thus limiting complexity of UE implementation and testing.

In some scenarios, the HeNB output power can cause interference from/to macro cells and from/to other CSG cells. Means are therfore provided to allow the operator to reduce the interference caused by the HeNBs to the macro cell or to other HeNBs.

For example, recommendations are given to measure the signals from the macro cell or other cells, and guidance is given on how to reduce the expected output power in relevant scenarios.

Two Release 9 technical reports were published for LTE FDD [5] and TDD [6] respectively. The documents themselves are informative, providing guidance to the manufacturer and operators. Interference reduction techniques for uplink and downlink scenarios and required measurements are described.

Some of the possible measurements are:

- Measurements from all cells: The HeNB could use the Received Interference Power measurement of its own receiver to monitor uplink interference e.g. interference from a closely located UE, connected to a Macro eNB.
- Measurements from macro cells: The HeNB can obtain useful information from its surrounding macro cells for purposes such as interference management.
- Measurements to identify surrounding cell layers: The HeNB can obtain useful information to identify the layer of its surrounding cells for purposes of mobility handling.
- Measurements of other HeNB cells: The HeNB can obtain useful information from its adjacent HeNBs for purposes such as interference management.

The latter three measurement types would require an additional downlink receiver within the HeNB to measure the signal from the surrounding base stations: a so called Network Listening Module or a HeNB Sniffer.

Several techniques have been identified for downlink interference reduction, e.g. Control Channel Interference Protection, Data Protection and Power Control are suggested and analyzed. Control Channel Protection and Power Control is suggested for uplink interference reduction.

As a result of the work done above, a new BS classification was added to TS36.104 [8]. The new Base Station classes in this specification are called Wide Area Base Station and Home Base Station. First of all, the allowed output power of the Home BS was limited to

< + 20 dBm for 1 transmit antenna
< + 17 dBm for 2 transmit antennas
< + 14dBm for 4 transmit antennas

As can be expected, the output power is significantly lower than the power of a regular base station. Note that the maximum output power is even lower than that of a LTE terminal. Other defined RF requirements for the Home BS include lower maximum output power and dynamic range, larger unwanted and spurious emission levels, intermodulation requirements, as well as more relaxed frequency error and sensitivity levels. Those changes also have an impact on the conformance testing. New conformance test cases were added to TS 36.141.

Furthermore, it was specified that the Home BS shall be capable of adjusting transmit power in order to minimize interference on adjacent channels which may be licensed to other operators in the same geographical area. Of course, this will have some impact on the Home BS coverage, the other optimization criteria. As described previously, only recommendations for the algorithms are given, whereas detailed RF requirements are specified in [8]. Basically, the HeNB must also be able to measure the downlink of an adjacent UMTS or LTE carrier based on the Common Pilot Channel or the Cell Specific Reference Signal.

Summary

The paper introduced Release 9 functionality related to LTE Femto-cells/Home eNodeBs. Examples of this new functionality include Hybrid Cells, Inbound Mobility support, HeNB Operation, Administration and Maintenance as well as RF requirements for TDD and FDD HeNBs. Significant work has led to a more consistent framework to efficiently and reliably deploy LTE Home Base Stations and provide a satisfying user experience.

References

[1] TS 36.300 E-UTRA and E-UTRAN; Overall description; Stage 2; Release 8

[2] R2-100960 CR to TS 36.300 CR0187 Rev to V9.2.0; 3GPP TSG-RAN WG2 Meeting #69

[3] RP-100222 for Rel-9 WI Home NodeB and Home eNB enhancements; 3GPP TSG RAN meeting #47

[4] 3GPP TS 32.571 Home Node B (HNB) and Home eNode B (HeNB) management; Type 2 interface concepts and requirements; Release 9

[5] TR 36.921 Evolved Universal Terrestrial Radio Access (E-UTRA); FDD Home eNode B (HeNB) Radio Frequency (RF) requirements analysis; Release 9 .

[6] TR 36.922 Evolved Universal Terrestrial Radio Access (E-UTRA); TDD Home eNode B (HeNB) Radio Frequency (RF) requirements analysis; Release 9

[7] R2-097408 Stage3 CR for LTE hybrid cell Idle Mode Mobility Vodafona, Motorola, Deutsche Telekom, NEC, ST Ericsson, Qualcomm Europe, Huawei, Telecom Italia CR 36.304 (0106)

[8] TS 36.104 Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception; Release 9

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