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HeNB (LTE Femto) Network Architecture

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- Major infrastructure vendors
- Specialist femtocell vendors
- Vendors of components, subsystems, silicon and software necessary to create femtocells

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1. Executive Summary

LTE Femtocells are low-power cellular base stations that use licensed spectrum and are typically deployed in residential, enterprise, metropolitan hotspot or rural settings. They provide an excellent user experience through enhanced coverage, performance, throughput and services based on location.

Femtocells can also offload traffic from the macrocell network and enable new applications such as location based services.

This paper provides an operator friendly guide to the LTE femtocell architecture options outlined in the 3GPP standard. It concludes that operators' choices will be driven by their existing infrastructure, how quickly they want to roll out femtocells and how widely they plan to deploy them.

The report finds that the three femtocell architecture options outlined in the LTE standard comprehensively support a wide variety of operator deployment scenarios. It details key factors that operators need to consider in order to make the most prudent architecture choice, based on their specific business and technology circumstances.

2. Introduction

The architecture of the HeNB system is discussed and three different options for implementation are listed. The different implementation options are analyzed and a set of pros and cons is given for each option. Additionally the applicability of each variant to different deployment scenarios is discussed.

The communication between the HeNB and the network (HeNB Gateway, when exists, or to the MME) is secured by a mandatory Security Gateway (SeGW) function / logical entity.

Security Gateway logical entity may be implemented either as a separate physical entity or co-located with an existing architectural entity.

3. Deployment Scenarios and Business Drivers

Two types of scenarios: with W-CDMA pre-existing HeNB infrastructure and without it. In both types, following subcases must be considered:

1. Deployment for controlled coverage: according to feedback of customers and measurements of the RAN, the operator defines areas where the coverage should be improved. The HeNBcells are installed in these limited areas.

2. Free deployment for coverage or offloading or “home” services: in addition to scenario 1, HeNBcell offer is made available for customers and marketing actions ensure the customers know it. Customers can decide to buy a HeNB for improving their coverage or for increasing the throughput inside their home. Value of the incentives associated to the offer, if any, is low or moderate.

3. Pushed deployment for offloading or “home” services: on top of scenario 2, HeNBcell cell offer is strongly pushed to customer. Aim is to have a good ratio of customers using the HeNBcell. The offer may be associated with good incentives.

Ideas for Business Drivers in Deployment Scenarios – Good ideas to be selected during plenary and to be developed later:

1. Vendor choice: ability to keep existing vendor for existing equipment and ability to select various vendors for existing equipment or new equipment. An increase of requirements on a type of gears, in addition to mandatory standard requirements, can be considered as reducing the ability to choose the vendor.

2. Cost of the architecture: cost of the equipment of the architecture choice and of any additional equipment it mandates. Impact of the possible reuse of existing equipment, for example from W-CDMA deployment, could be considered.

3. IP infrastructure: ability to match various architectures for IP infrastructure deployment and various number and type of points of concentration. Any constraint on the IP infrastructure is a drawback.

4. Organization of maintenance: ability to match various organisations of maintenance teams.

5. Evolutivity: ability to support possible future, identified features with minimal impact on existing network.

6. Interoperability: ability to be integrated in a deployment with equipment from various providers.

7. Scalability: ability to support any size of deployment, independently of the scalability of the gears of the solution which is vendor dependent.

3.1 LTE HeNB Architecture - Variant 1

Figure 1 shows the agreed architecture in 3GPP for LTE HeNB for Variant 1 (Reference: 3GPP TS 36.300, figure copied from 3GPP TR 23.830):

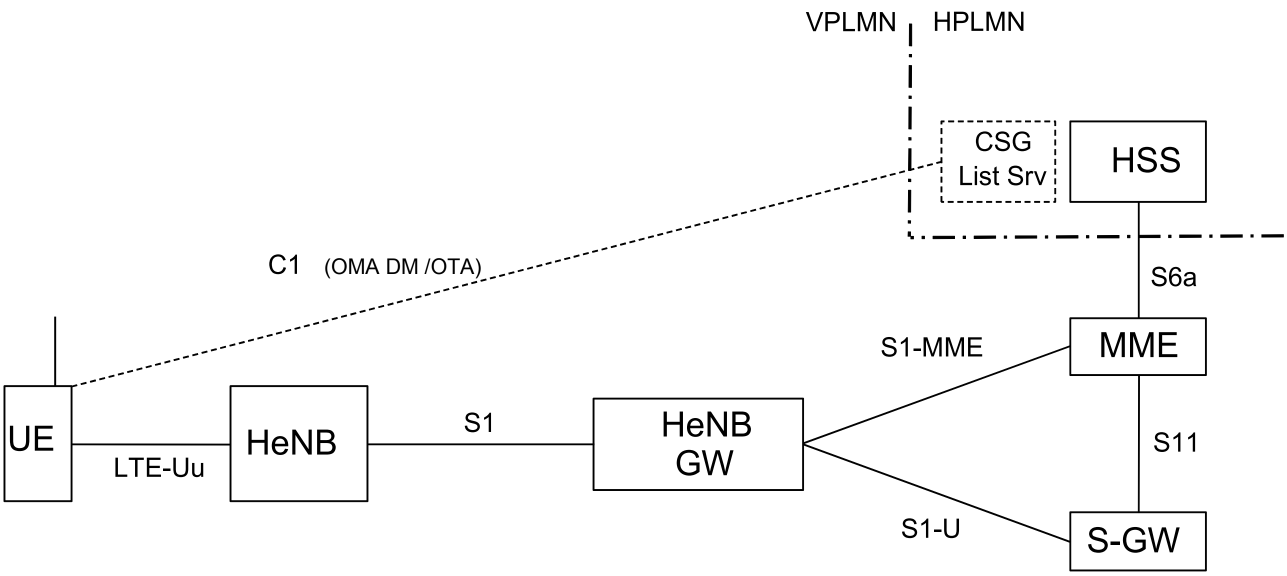

Figure 1: Variant 1: With dedicated HeNB-GW

For variant 1, HeNB-GW serves as a concentrator for the C-Plane and also terminates the user plane towards the HeNB and towards the Serving Gateway.

3.1.1 Advantages

- There is only one SCTP association between HeNB-GW and MME. One SCTP association exists between each HeNB and HeNB-GW. By increasing the number of HeNBs in the network, SCTP association towards MME remains unaffected. This may be beneficial in terms of the following parameters:
  - SCTP heartbeat messages are kept at minimum towards MME. SCTP heartbeat messages (per SCTP association) do not overload MME due to increasing the number of HeNBs in the network
  - The end user may often switch on and off the HeNB causing therefore frequent SCTP association establishments and releases. Maintenance of a large number of SCTP association as well as the frequent establishment and release of the SCTP associations may generate a lot of CPU processing load in MME if the connection between the MME and HeNB is direct.
- Serving Gateway scalability requirements for GTP/UDP/IP connections respectively are reduced comparing to other variants. Number of UDP/IP Paths and the number of GTP Echo messages that S-GW needs to manage remains minimum. Increasing the number of HeNBs does not increase the number of UDP/IP Paths and GTP Echo messages to be managed by S-GW.
- HeNBs do not have to support S1-Flex that will both reduce the overall number of S1 connections and simplify HeNB implementation.
- This variant allows the possibility to implement Paging optimisation mechanism within HeNB-GW.

- IP addresses of MME and S-GW can be hidden from HeNB in this variant. This would result in a more secure architecture as none of the core Network IP addresses / address space is revealed to the home user
- HeNB GW can implement a Denial of Service (DoS) shield to protect the EPC(S-GW and MME). It can detect and filter out the attack traffic while maintaining the QoS of useful traffic.
- This variant allows Traffic offload (SIPTO) to be done at the HeNB-GW. Local S-GW and P-GW functionality for SIPTO may be implemented within the HeNB-GW reducing the need for a new network element.
- [*Forward Looking*] Handover optimization & reduction of Handover related signalling load to MME/S-GW can be realized. User Plane Path switch message exchange between MME and S-GW will be reduced for handover between HeNB Access points (in case core network does not need to know about change of serving cell).
- This variant allows implementing in HeNB-GW a mechanism to avoid overflooding of MME in case of massive failure of HeNB, due for example to a power outage.

3.1.2 Disadvantages

- HeNB-GW needs to forward GTP-U T-PDU by switching the tunnel from HeNB-GW – S-GW tunnel to HeNB-GW – HeNB tunnel and vice versa. Processing load as regards U-plane is proportional to traffic.
- HeNB connects to a single HeNB-GW at one time. It reduces redundancy and load sharing possibilities in comparison with variant 2.

3.1.3 Applicability for deployment scenarios of variant 1

The variant 1 provides benefits for the operators that already have a 3G HeNB solution and wish to migrate towards LTE HeNB. This architectural variant is similar to 3G Home Node B architecture terminating both control plane and user plane in the Gateway. In case HNB-GW and HeNB-GW are based on same hardware, it allows reusing the existing GW infrastructure components (Platform/ Hardware Reuse, User plane handling / GTP functionality reuse), therefore ensuring a fast and cost efficient migration to LTE HeNB network deployment. For this scenario (existing 3G HeNB deployment), the variant 1 can be a good choice in all the subcases listed in the section 2. That is, given the reuse of the existing GW infrastructure it would be convenient to use the HeNB-GW for all three deployment scenarios presented in section 2.

For the operators who want to deploy the HeNB network starting directly with the LTE HeNB cells, this variant can be beneficial in the subcases 2 and 3. In these scenarios the number of HeNBs in the network is expected to be large or very large, which will be reflected in a large number of SCTP associations and UDP/IP paths resulting in huge scalability requirements on MME and S-GW. Additionally the operators would want to minimize the impact to the EPC network as much as possible when the number of HeNBs increases beyond a certain number in the overall network.

As number of paging could hugely increase in case density of HeNB in an area is high, as for scenario 2 and 3, paging optimisation could be necessary. In this case, variant 1 allows implementing various optimization techniques in HeNB-GW without impacting MME.

In addition, the customers may often switch off and on the HeNBs causing therefore frequent SCTP association releases and reestablishments. All this can create unnecessary overload in the EPC and can be solved by introducing HeNB-GW which performs the concentration function on S1 interface.

3.2 LTE HeNB Architecture - Variant 2

Figure 2 shows the agreed architecture in 3GPP for LTE HeNB for Variant 2 (Reference: 3GPP TS 36.300, figure copied from 3GPP TR 23.830):

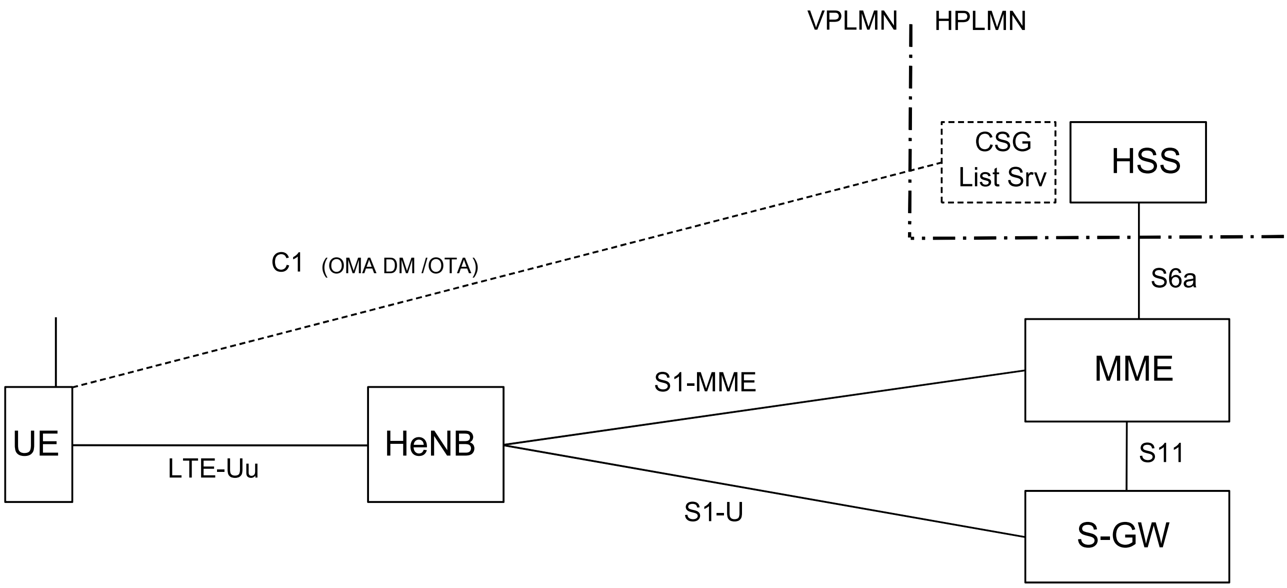

Figure 2: Variant 2: without HeNB-GW

For variant 2, the S1-U interface of HeNB is terminated in S-GW and S1-C interface in MME, as per eNB. The HeNB may have connection to multiple MME/S-GW, i.e. may support S1-flex.

3.2.1 Advantages

- There are less failure points in the system and no additional single point of failure.
  - If one HeNB network element fails below the MME/S-GW, the other HeNBs are not affected like in case of HeNB-GW failure.
- Simple flat architecture of this variant has less network elements to be operated and is consistent with macro architecture (e.g. S1 flex support on HeNB).
- Lower latency and reduced system level processing is achieved, because the S1 C-plane and U-plane are directly connected from the HeNBs to the MME and S-GW without protocol termination at the HeNB-GW.
- [forward looking] There are less upgrade and compatibility issues in supporting new feature in later releases since there is no HeNB-GW to be upgraded to ensure that new S1 IEs or messages are processed correctly.
- In case gateways are deployed for SIPTO in a distributed manner, variant 3 does not require, unlike variant 1, the deployment of HeNB GW co-localized with SIPTO gateways.

3.2.2 Disadvantages

- This variant does not provide SCTP/GTP-U connection concentration.
  - In case of increasing number of HeNBs in the network, the SCTP heartbeat messages (per SCTP association) might cause an overload situation in MME.
  - In residential scenario, the end user may often switch on and off the HeNB causing therefore frequent SCTP association establishments and releases. Maintenance of a

large number of SCTP association as well as the frequent establishment and release of the SCTP associations may generate a lot of CPU processing load in MME if the connection between the MME and HeNB is direct.
  - In case of increasing number of HeNBs in the network, the UDP/IP contexts might cause an overload situation in S-GW.
  - In case of increasing number of HeNBs in the network, the period for GTP-echo messages might need to be increased to avoid an overload situation in S-GW.
  - Dedicated MME/S-GW might be required to solve the possible over load situation. In case dedicated S-GW are deployed, additional GW relocation load may occur for macro-HeNB and HeNB-macro handovers.

  Remark: The capability to manage and to maintain high number of HeNBs in this variant is depending on the MME capacity and is therefore a product related topic.
- Support of S1 flex (optional) will introduce additional complexity in HeNB implementation.

3.2.3 Applicability for deployment scenarios of variant 2

The variant 2 provides the main benefit in deployment scenarios where the number of HeNBs is rather limited or scattered within the network with reduced cost effect, so that the number of the HeNBs per MME is not causing any scalability issues, as mentioned in section 2.2.2, with SCTP/GTP-U connections maintenance.

From the deployment scenarios described in section 2, the scenarios 1 and 2 are the typical deployment scenarios with architecture variant 2. The feasibility of the variant 2 for scenario 3 will depend on the capacity and deployment of the MMEs (shared MME between macros and HeNBs or dedicated MMEs for HeNBs).
Remark: The possible HeNB dedicated MMEs will cause MME relocations in case of macro-HeNB mobility.

In scenario 1 the number of the HeNBs can be first rather low and therefore the additional investment of HeNB-GW for such a scenario seems not feasible. The HeNBs are operated in this scenario part of the controlled manner deployed mobile network and therefore it can be assumed the HeNBs remain switched on and there are no issues of frequent SCTP association establishments and releases.

The scenario 2 may appear as an evolution step towards scenario 3. With this assumption the number of the HeNBs per MME in scenario 2 can be assumed to remain still decent and the potential overload issues are not relevant. The break point in the number of HeNBs requiring the HeNB GW as a concentration entity will depend on the capacity of the MME (product implementation issue) and on the amount of the HeNBs, which are switched on/off frequently and uncontrolled manner.

The support of scenario 3 with variant 2 will depend on the capacity of the MME(s) in the network to face the frequent SCTP establishment and releases caused by the customers' actions to switch on/off their HeNBs.

The Variant 2 based deployments can re-use from the pre-existing W-CDMA HeNB infrastructure the Security GWs and transport infrastructure.

3.3 LTE HeNB Architecture - Variant 3

Figure 3 shows the agreed architecture in 3GPP for LTE HeNB for Variant 3 (Reference: 3GPP TS 36.300, figure copied from 3GPP TR 23.830):

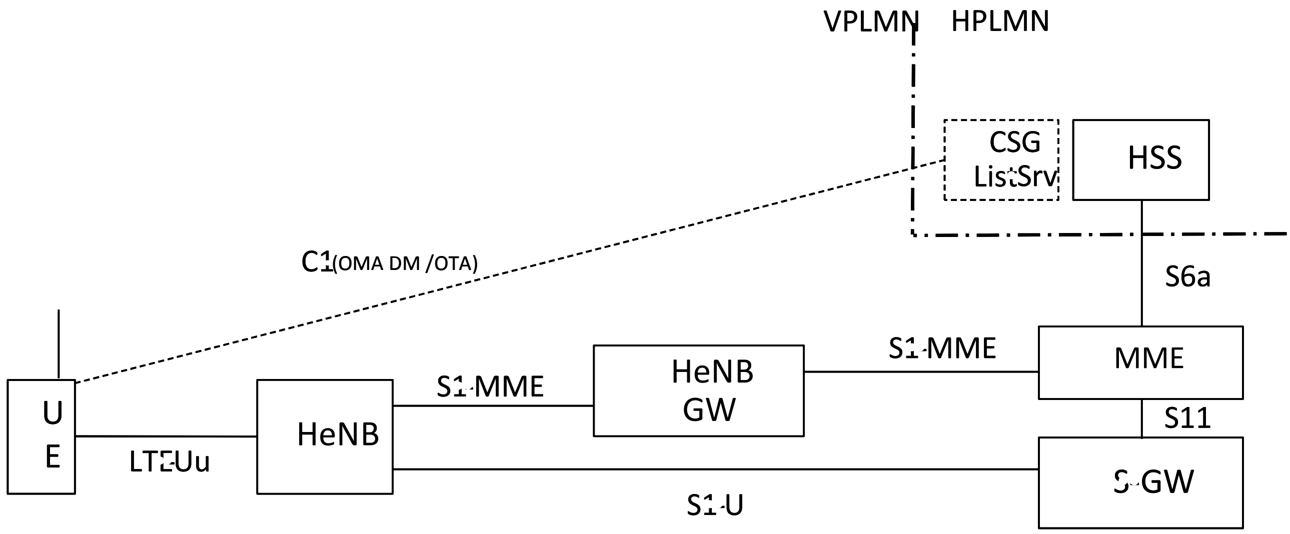

Figure 3: Variant 3: With dedicated HeNB-GW in C-Plane only

For variant 3, HeNB-GW is deployed and serves as a concentrator for the C-Plane. The S1-U interface of HeNB is terminated in S-GW, as per eNB.

3.3.1 Advantages

- There is only one SCTP association between HeNB-GW and MME. One SCTP association exists between each HeNB and HeNB-GW. By increasing the number of HeNBs in the network, SCTP association towards MME remains unaffected. This may be beneficial in terms of the following parameters:
  - SCTP heartbeat messages are kept at minimum towards MME. SCTP heartbeat messages (per SCTP association) do not overload MME due to increasing the number of HeNBs in the network
  - The end user may often switch on and off the HeNB causing therefore frequent SCTP association establishments and releases. Maintenance of a large number of SCTP association as well as the frequent establishment and release of the SCTP associations may generate a lot of CPU processing load in MME if the connection between the MME and HeNB is direct.
- HeNBs do not have to support S1-Flex on C-plane that will both reduce the overall number of S1 C-plane connections and simplify HeNB implementation.
- This variant allows the possibility to implement Paging optimisation mechanism within HeNB-GW.
- In U-Plane, there are less failure points in the system and no additional single point of failure.
- Lower latency and reduced system level processing is achieved in U-Plane, because the S1 U-plane is directly connected from the HeNBs to S-GW without protocol termination at the HeNB-GW,

- [Forward Looking] Further control plane optimization could be implemented in the HeNB-GW. For example, the HeNB GW may act as an X2 concentrator, reducing the number of interfaces towards HeNB to be supported by eNB.
- [Forward Looking] Handover optimization & reduction of Handover related signalling load to MME/S-GW can be realized, when X2 is used for U-Plane between HeNB connected to the same HeNB-GW. In this case, User Plane Path switch message exchange between MME and S-GW will be reduced for handover between HeNB Access.
- This variant allows to implement in HeNB-GW a mechanism to avoid overflooding of MME in case of massive failure of HeNB, due for example to a power outage.
- In case gateways are deployed for SIPTO in a distributed manner, variant 3 does not require, unlike variant 1, the deployment of HeNB GW co-localized with SIPTO gateways.

3.3.2 Disadvantages

- This variant does not provide GTP-U connection concentration.
  - In case of increasing number of HeNBs in the network, the UDP/IP contexts might cause an overload situation in S-GW.
  - In case of increasing number of HeNBs in the network, the period for GTP-echo messages might need to be increased to avoid an overload situation in S-GW.
  - Additional or dedicated S-GW might be required to solve the possible over load situation. In case dedicated S-GW are deployed, additional GW relocation load may occur for macro-HeNB and HeNB-macro handovers.
- In C-Plane, HeNB connects to a single HeNB-GW at one time. It reduces redundancy and load sharing possibilities in comparison with variant 2.

3.3.3 Applicability for deployment scenarios of variant 3

When total number of HeNB increases, as from scenario 1 to scenario 2 or from scenario 2 to scenario 3, an obvious impact with variant 3 is the increased requirement on scalability of S-GW. The highest resource requirement on S-GW to manage large number of HeNBs comes from processing of GTP-echo mechanism, but the impact of additional UDP and GTP contexts must also be considered. Fair evaluation of this impact should consider following points:

Minimum period between successive GTP echo messages from one HeNB is 60 seconds.
The rhythm of transmission of GTP-echo messages can be configured and can be increased.
GTP-echo messages can be disabled at the expense of having no end-to-end link control mechanism in the U-plane.

As number of paging could hugely increase in case density of HeNB in an area is high, as for scenario 2 and 3, paging optimisation could be necessary. In this case, variant 3 allows implementing various optimization techniques in HeNB-GW without impacting MME.

In addition, the customers may often switch off and on the HeNBs causing therefore frequent SCTP association releases and reestablishments. All this can create unnecessary overload in the EPC and can be solved by introducing HeNB-GW which performs the concentration function on S1 interface.

The Variant 3 based deployments can re-use from the pre-existing W-CDMA HeNB infrastructure the Security GWs and transport infrastructure.

4. Conclusions

In this document, three possible variant options of network architecture for HeNB have been analysed and the advantages and disadvantages of each variant option have been listed.
The variant options differ in terms of whether a HeNB-GW is part of the deployment or not, and if a HeNB-GW is deployed whether it terminates the C-plane only or the C-Plane and U-Plane both.
It is assumed that these options could become implementation options for the vendor, catering to the requirements for the operator deployment scenario.

5. References

- 3GPP TS 36.300: " Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall Description; Stage 2".
- 3GPP TR 23.830: " Architecture aspects of Home NodeB and Home eNodeB".

6. Abbreviations

- CSG: Closed Subscriber Group
- HNB: Home Node B (over UTRAN)
- HeNB: Home Node B (over E-UTRAN)
- HeMS: Home(e)NodeB Management System
- HNB GW: Home Node B Gateway
- HeNB-GW: Home (e)Node B Gateway
- HSS: Home Subscriber Server
- MME: Mobility Management Entity
- SCTP: Stream Control Transmission Protocol
- SeGW: Security Gateway
- S-GW: Serving Gateway
- UE: User Equipment