SYSTEM ARCHITECTURE WITH E-UTRAN -- 3GPP ACCESS NETWORKS

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Abstract - The present Wireless Technology is 3G is implemented by 3GPP Networks. There are many different Technologies in the 3G Networks to implement; here one of the implementation technology is E-UTRAN. E-UTRAN is System Architecture similar to a wireless Network.

In this paper the E-UTRAN Network is implementation is specified by using the 3GPP Access Networks and Non 3GPP Access Networks. This paper also describes the implementation of this issues in various aspects.

Keywords - E-UTRAN, 3GPP, Networks, EPC, UTRAN, Access Networks, Non 3GPP.

I. INTRODUCTION

The 3GPP architecture specifications were split into two tracks:

1) GPRS enhancements for E-UTRAN access: This document describes the architecture and its functions in its native 3GPP environment with E-UTRAN and all the other 3GPP Access Networks (ANs), and defines the inter-working procedures between them. The common nominator for these ANs is the use of GTP (GPRS Tunneling Protocol) as the network mobility protocol.

2) Architecture enhancements for non-3GPP accesses: This document describes the architecture and functions when inter-working with non-3GPP ANs, such as cdma2000® High Rate Packet Data (HRPD), is needed. The mobility functionality in this document is based on IETF protocols, such as MIP (Mobile Internet Protocol) and PMIP (Proxy MIP), and the document also describes E-UTRAN in that protocol environment.

II. SYSTEM ARCHITECTURE CONFIGURATION WITH ONLY E-UTRAN ACCESS NETWORK:

Figure 1 describes the architecture and network elements in the architecture configuration where only the E-UTRAN AN is involved. The logical nodes and connections shown in Figure 1 represent the basic system architecture configuration. These elements and functions are needed in all cases when E-UTRAN is involved. The other system architecture configurations described in the next sections also include some additional functions.

The high level architectural domains are functionally equivalent to those in the existing 3GPP systems. The new architectural development is limited to Radio Access and Core Networks, the E-UTRAN and the EPC respectively. UE and Services domains remain architecturally intact, but functional evolution has also continued in those areas.
UE, E-UTRAN and EPC together represent the Internet Protocol (IP) Connectivity Layer. This part of the system is also called the Evolved Packet System (EPS). The main function of this layer is to provide IP based connectivity, and it is highly optimized for that purpose only. All services will be offered on top of IP, and circuit switched nodes and interfaces seen in earlier 3GPP architectures are not present in E-UTRAN and EPC at all. IP technologies are also dominant in the transport, where everything is designed to be operated on top of IP transport.

The IP Multimedia Sub-System (IMS) is a good example of service machinery that can be used in the Services Connectivity Layer to provide services on top of the IP connectivity provided by the lower layers. For example, to support the voice service, IMS can provide Voice over IP (VoIP) and interconnectivity to legacy circuit switched networks PSTN and ISDN through Media Gateways it controls.

The development in E-UTRAN is concentrated on one node, the evolved Node B (eNodeB). All radio functionality is collapsed there, i.e. the eNodeB is the termination point for all radio related protocols. As a network, E-UTRAN is simply a mesh of eNodeBs connected to neighboring eNodeBs with the X2 interface.

One of the big architectural changes in the core network area is that the EPC does not contain a circuit switched domain, and no direct connectivity to traditional circuit switched networks such as ISDN or PSTN is needed in this layer. Functionally the EPC is equivalent to the packet switched domain of the existing 3GPP networks. There are, however, significant changes in the arrangement of functions and most nodes and the architecture in this part should be considered to be completely new.

III. SYSTEM ARCHITECTURE WITH EUTRAN AND LEGACY 3GPP ACCESS NETWORKS

The E-UTRAN, UTRAN and GERAN all provide very similar connectivity services, especially when looking at the situation from the end user point of view, where the only difference may be the different data rates and improved performance, but architecturally these ANs are quite different, and many things are carried out differently. There are, for example, big differences in how the bearers are managed in the EPS compared to the existing networks with UTRAN or GERAN access.

Figure 2: System architecture for 3GPP access networks

However, when UTRAN or GERAN is connected to EPC, they may still operate as before from this perspective, and for this purpose the S-GW simply assumes the role of the Gateway GPRS Support Node (GGSN). Also in optimized inter working with the E-UTRAN, the GERAN and UTRAN ANs behave almost the same way as they behave when inter-working between themselves. The differences become more visible in the EPC, because what used to be the fixed GGSN is now the S-GW that may be changed along with the SGSN change during UE mobility.

All nodes and functions described in the previous section for the Basic System Architecture Configuration are needed here also. The EPC needs the addition of a few new interfaces and functions to connect and inter-work with UTRAN and GERAN. The
corresponding functions will also be required from GERAN and UTRAN. The new interfaces are S3, S4 and S12. The interface from SGSN to HSS can also be updated to Diameter based S6d, but the use of the legacy MAP based Gr is also possible.

Keeping E-UTRAN, i.e. the eNodeB design as focused to, and as optimized for the requirements of the new OFDMA radio interface, and as clean of inter-working functionality as possible, was an important guideline for the inter-working design. Consequently, the eNodeB does not interface directly with the other 3GPP ANs, and the interaction towards the EPC is the same as in other mobility cases that involve EPC. However, optimized inter-working means that the network is in control of mobility events, such as handovers, and provides functionality to hand the communication over with minimal interruption to services.

This means that an eNodeB must be able to coordinate UE measuring UTRAN and GERAN cells, and perform handover decisions based on measurement results, and thus E-UTRAN radio interface protocols have been appended to support the corresponding new functions. Similar additions will be required from UTRAN and GERAN to support handover to E-UTRAN.

IV. ADDITIONAL AND UPDATED LOGICAL ELEMENTS IN 3GPP INTER-WORKING SYSTEM ARCHITECTURE CONFIGURATION

4.1 USER EQUIPMENT

From the UE point of view, inter-working means that it needs to support the radio technologies in question, and the mobility operations defined for moving between them. The optimized inter-working means that the network controls the usage of radio transmitter and receiver in the UE in a way that only one set of them needs to be operating at the same time. This is called single radio operation, and allows UE implementations where only one pair of physical radio transmitter and receiver is implemented.

The standard does not preclude implementing multiple radio transmitters and receivers, and operating them simultaneously in dual radio operation. However, single radio operation is an important mode, because the different ANs often operate in frequencies that are so close to each other that dual radio operation would cause too much interference within the terminal. That, together with the additional power consumption, will decrease the overall performance.

4.2. E-UTRAN

The only addition to E-UTRAN eNodeB compared to the Basic System Architecture Configuration is the mobility to and from other 3GPP ANs. From the eNodeB perspective the functions are very similar irrespective of whether the other 3GPP AN is UTRAN or GERAN.

For the purpose of handover from E-UTRAN to UTRAN or GERAN, the neighboring cells from those networks need to be configured into the eNodeB. The eNodeB may then consider handover for those UEs that indicate corresponding radio capability. The eNodeB requests the UE to measure the signal level of the UTRAN or GERAN cells, and analyses the measurement reports. If the eNodeB decides to start the handover, it signals the need to the MME in the same way that it would signal inter-eNodeB handover when the X2 interface is not available. Subsequently, the eNodeB will receive the information needed for the Handover Command from the target Access System via the MME. The eNodeB will send the Handover Command to the UE without the need for interpreting the content of this information.

In the case of handover from UTRAN or GERAN to E-UTRAN, the eNodeB does not need to make any specific preparations compared to other handovers where the handover preparation request comes through the MME. The eNodeB will allocate the requested resources, and prepare the information for handover command, which it sends to the MME, from where it is delivered to the UE through the other 3GPP Access System that originated the handover.

4.3. UTRAN

In UTRAN, the radio control functionality is handled by the Radio Network Controller (RNC), and under its control the Node B performs Layer 2 bridging between the Uu and Iub interfaces.
UTRAN has evolved from its initial introduction in Release 99 in many ways, including the evolution of architectural aspects. The first such item is Iu fl ex, where the RNC may be connected to many Serving GPRS Support Nodes (SGSNs) instead of just one. Another such concept is I-HSPA, where the essential set of packet data related RNC functions is included with the Node B, and that connects to Iu-PS as a single node.

Inter-working with E-UTRAN requires that UTRAN performs the same measurement control and analysis functions as well as the transparent handover information delivery in Handover Command that were described for eNodeB in the earlier section. Also the UTRAN performs similar logic that it already uses with Relocation between RNCs, when the Iur interface is not used.

4.4. GERAN

GSM EDGE Radio AN (GERAN) is the evolved version of GSM AN, which can also be connected to 3G Core Network. It consists of the Base Station Controller (BSC) and the Base Station (BS), and the radio interface functionalities are divided between them.

The GERAN is always connected to the SGSN in both Control and UPs, and this connection is used for all the inter-working functionality. Also the GERAN uses logic similar to that described above for E-UTRAN and UTRAN for inter-working handover.

4.5. EPC

The EPC has a central role for the inter-working system architecture by anchoring the ANs together. In addition to what has been described earlier, the MME and S-GW will support connectivity and functions for inter-working. Also the SGSN, which supports the UTRAN and GERAN access networks, will need to support these functions, and when these additions are supported, it can be considered to belong to the EPC.

The S-GW is the mobility anchor for all 3GPP access systems. In the basic bearer operations and mobility between SGSNs, it behaves like a GGSN towards the SGSN, and also towards the RNC if UP tunnels are set up in Direct Tunnel fashion bypassing the SGSN. Many of the GGSN functions are actually performed in the P-GW, but this is not visible to the SGSN. The S-GW retains its role as a UP Gateway.

To support the inter-working mobility, the MME will need to signal with the SGSN. These operations are essentially the same as between those two MMEs, and have been described earlier in section 3.2. An additional aspect of the MME is that it may need to combine the change of S-GW and the inter-working mobility with SGSN.

The SGSN maintains its role as the controlling node in core network for both UTRAN and GERAN. These functions are defined in. The SGSN has a role very similar to that of the MME. The SGSN needs to be updated to support for S-GW change during mobility between SGSNs or RNCs, because from the legacy SGSN point of view this case looks like GGSN changing, which is not supported. As discussed earlier, the SGSN may direct the UP to be routed directly between the S-GW and UTRAN RNC, or it may remain involved in the UP handling. From the S-GW point of view this does not really make a difference, since it does not need to know which type of node terminates the far end of the UP tunnel.

5. INTERFACES AND PROTOCOLS IN 3GPP INTER-WORKING SYSTEM ARCHITECTURE CONFIGURATION:

Table 1 summarizes the interfaces in the 3GPP Inter-working System Architecture Configuration and the protocols used in them. Interfaces and protocols in legacy 3GPP networks are not listed. Interfaces and protocols listed for Basic System Architecture Configuration are needed in addition to these.

5.1 INTER-WORKING WITH LEGACY 3GPP CS INFRASTRUCTURE:

Table 1 Summary of additional interfaces and protocols in 3GPP Inter-working System Architecture configuration

<table>
<thead>
<tr>
<th>Interface</th>
<th>Protocols</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>S3</td>
<td>GTP-C/UDP/IP</td>
<td>29.274</td>
</tr>
<tr>
<td>S4</td>
<td>GTP/UDP/IP</td>
<td>29.274</td>
</tr>
<tr>
<td>S12</td>
<td>GTP-U/UDP/IP</td>
<td>29.274</td>
</tr>
<tr>
<td>S16</td>
<td>GTP/UDP/IP</td>
<td>29.274</td>
</tr>
<tr>
<td>S6d</td>
<td>Diameter/SCTP/IP</td>
<td>29.272</td>
</tr>
</tbody>
</table>
Inter-working with non-3GPP ANs was one of the key design goals for SAE, and to support it, a completely separate architecture specification was developed in 3GPP. The non-3GPP Inter-working System Architecture includes a set of solutions in two categories. The first category contains a set of generic and loose inter-working solutions that can be used with any other non-3GPP AN. Mobility solutions defined in this category are also called Handovers without Optimizations, and the same procedures are applicable in both connected and idle mode.

Figure 3 describes the generic inter-working solution that relies only on loose coupling with generic interfacing means, and without AN level interfaces. Since there are so many different kinds of ANs, they have been categorized to two groups, the trusted and untrusted non-3GPP ANs, depending on whether it can be safely assumed that 3GPP defined authentication can be run by the network, which makes it trusted, or if authentication has to be done in overlay fashion and the AN is untrusted.

![Figure 3: System architecture for 3GPP and non-3GPP access networks](image)

The P-GW will maintain the role of mobility anchor, and the non-3GPP ANs are connected to it either via the S2a or the S2b interface, depending on whether the non-3GPP AN functions as a Trusted or Un-trusted non-3GPP AN. Both use network controlled IP layer mobility with the PMIP protocol. For networks that do not support PMIP, Client MIPv4 Foreign Agent mode is available as an option in S2a. In addition to mobility functions, the architecture includes interfaces for authenticating the UE within and through the non-3GPP ANs, and also allows PCC functionality in them via the Gxa and Gxb interfaces.

In addition to the network controlled mobility solutions, a completely UE centric solution with DSMIPv6 is also included in the inter-working solutions. This scenario is depicted in Figure 4.

![Figure 4: Simplified system architecture showing only S2c](image)

In this configuration the UE may register in any non-3GPP AN, receive an IP address from there, and register that to the Home Agent in P-GW. This solution addresses the mobility as an overlay function. While the UE is served by one of the 3GPP ANs, the UE is considered to be in home link, and thus the overhead caused by additional MIP headers is avoided.

Another inter-working scenario that brings additional flexibility is called the chained S8 and S2a/S2b scenario. In that scenario the non-3GPP AN is connected to S-GW in the visited Public Land Mobile Network (PLMN) through the S2a or S2b interface, while the P-GW is in the home PLMN. This enables the visited network to offer a roaming subscriber the use of non-3GPP ANs that might not be associated with the home operator at all, even in the case where P-GW is in the home PLMN. This scenario requires that S-GW performs functions that normally belong to P-GW in order to behave as the termination point for the S2a or S2b interfaces. In Release 8, this scenario does not support dynamic policies through the PCC infrastructure, i.e. the Gxc interface will not be used. Also, chaining with GTP based S5/S8 is not supported.
VI. ADDITIONAL AND UPDATED LOGICAL ELEMENTS IN 3GPP INTER-WORKING SYSTEM ARCHITECTURE CONFIGURATION

6.1. USER EQUIPMENT

Inter-working between the non-3GPP ANs requires that the UE supports the corresponding radio technologies, and the specified mobility procedures. The mobility procedures and required radio capabilities vary depending on whether optimizations are in place or not. The procedures defined for Handovers without Optimizations do not make any assumption about the UE’s capability to use the radio transmitters and receivers simultaneously, and both single radio and dual radio configurations can use the procedures. However, the handover gap time is expected to be shorter, if preparing the connections towards the target side can start already while data are still flowing through the source side.

This is caused by the fact that Handovers without Optimizations do not have procedures in the network side to assist in handover preparations, and the procedures follow the principle where UE registers to the target network according to the method defined for that network, and then the network switches the flow to the target network. This may be time consuming, since it normally includes procedures such as authentication. Also, the decision to make these handovers is the responsibility of the UE.

6.2. TRUSTED NON-3GPP ACCESS NETWORKS

The term trusted non-3GPP AN refers to networks that can be trusted to run 3GPP defined authentication. 3GPP Release 8 security architecture specification for non-3GPP ANs mandates that the Improved Extensible Authentication Protocol Method for 3rd Generation Authentication and Key Agreement (EAP-AKA’) is performed. The related procedures are performed over the STa interface.

The trusted non-3GPP ANs are typically other mobile networks, such as the cdma2000® HRPD. The STa interface supports also delivery of subscription profile information from Authentication, Authorization and Accounting (AAA)/HSS to the AN, and charging information from the AN to AAA Server, which are typical functions needed in mobile networks. It can also be assumed that such ANs may benefit from connecting to the PCC infrastructure, and therefore the Gx interface may be used to exchange related information with the PCRF.

The trusted non-3GPP AN connects to the P-GW with the S2a interface, with either PMIP or MIPv4 Foreign Agent mode. The switching of UP flows in P-GW is therefore the responsibility of the trusted non-3GPP AN when UE moves into the ANs service area.

6.3. UN-TRUSTED NON-3GPP ACCESS NETWORKS

To a large extent, the architectural concepts that apply for un-trusted non-3GPP ANs are inherited from the Wireless Local Area Network Inter-Working (WLAN IW) defined originally in Release 6. The Release 8 functionality for connecting un-trusted non-3GPP ANs to EPC is specified fully in with references to the earlier WLAN IW specifications when applicable.

The main principle is that the AN is not assumed to perform any other functions besides delivery of packets. A secure tunnel is established between UE and a special node called the Enhanced Packet Data Gateway (EPDG) via the SWu interface, and the data delivery takes place through that tunnel. Furthermore, the P-GW has a trust relationship with the EPDG connected to it via the S2b interface, and neither node needs to have secure association with the un-trusted non-3GPP AN itself.

As an optional feature, the un-trusted non-3GPP AN may be connected to the AAA Server with the SWa interface, and this interface may be used to authenticate the UE already in the non-3GPP AN level. This can be done only in addition to authentication and authorization with the EPDG.

6.4. EPC

The EPC includes quite a few additional functions for the support of non-3GPP ANs, when compared to the previously introduced architecture configurations. The main changes are in the P-GW, PCRF and HSS, and also in S-GW for the chained S8 and S2a/S2b scenario. In
addition, completely new elements, such as the EPDG (Evolved Packet Data Gateway) and the AAA are introduced. The AAA infrastructure contains the AAA Server, and it may also contain separate AAA proxies in roaming situations. Figure 5 highlights the AAA connections and functions for non-3GPP ANs.

The P-GW is the mobility anchor for the non-3GPP ANs. For PMIP based S2a and S2b interfaces, the P-GW hosts the Local Mobility Anchor (LMA) function in a manner similar to that for the S5/S8 PMIP interfaces. Also the Home Agent (HA) function for the Client MIPv4 Foreign Agent mode in S2a is located in P-GW. The relation between P-GWs and non-3GPP ANs is many to many. The P-GW will also interface with the AAA Server, which subsequently connects to HSS. This interface is used for reporting the selected P-GW to the HSS so that it is available in mobility between non-3GPP ANs, and to authenticate and authorize users connecting with S2c mode. Each P-GW may connect to more than one AAA server.

The EPDG is a dedicated node for controlling the UE and inter-network connection, when an un-trusted non-3GPP AN is connected to EPC. Since the AN is not trusted, the main function is to secure the connection, as defined in . The EPDG establishes an IPsec tunnel to the UE through the un-trusted non-3GPP AN with IKEv2 signaling over the SWu interface. During the same signaling transaction the EAP-AKA authentication is run, and for that the EPDG signals with the AAA Server through the SWm interface. While the SWm interface is logically between UE and the EPDG, the SWm interface represents the interface on a lower layer between the EPDG and the un-trusted non-3GPP AN. The Release 8 specifications do not assume that EPDG would signal with PCRF for any PCC functions, but the architecture already contains the Gxb interface for that purpose.

The 3GPP AAA Server, and possibly a AAA Proxy in the visited network, performs a 3GPP defined set of AAA functions. These functions are a subset of what the standard IETF defined AAA infrastructure includes, and do not necessarily map with the way other networks use AAA infrastructure. The AAA Server acts between the ANs and the HSS, and in doing so creates a context for the UEs it serves, and may store some of their information for further use. Thus, the 3GPP AAA Server consolidates the signalling from different types of ANs into a single SWx interface towards the HSS, and terminates the access specific interfaces S6b, STa, SWm and SWa. Most importantly the AAA Server performs as the authenticator for the EAP-AKA authentication through the non-3GPP ANs. It checks the authenticity of the user, and informs the AN about the outcome.

The authorization to use the AN in question will also be performed during this step. Depending on the AN type in question, the AAA Server may also relay subscription profile information to the AN, which the AN may further use to better serve the UE. When the UE is no longer served by a given non-3GPP AN, the AAA Server participates in removing the UE’s association from the HSS.

The HSS performs functions similar to those for the 3GPP ANs. It stores the main copy of the subscription profile as well as the secret security key in the AuC portion of it, and when requested, it provides the profile data and
authentication vectors to be used in UEs connecting through non-3GPP ANs. One addition compared to 3GPP ANs is that since the non-3GPP ANs do not interface on the AN level, the selected P-GW needs to be stored in the HSS, and retrieved from there when the UE mobility involves a non-3GPP AN. The variety of different AN types are mostly hidden from the HSS, since the AAA Server terminates the interfaces that are specific to them, and HSS only sees a single SWx interface. On the other hand, the subscription profile stored in the HSS must reflect the needs of all the different types of ANs that are valid for that operator.

VII. INTERFACES AND PROTOCOLS IN NON-3GPP INTER-WORKING SYSTEM ARCHITECTURE CONFIGURATION

Connecting the non-3GPP ANs to EPC and operating them with it requires additional interfaces to those introduced in earlier sections. Table 2 lists the new interfaces.

Table 2 Summary of additional interfaces and protocols in non-3GPP Inter-working System Architecture configuration

<table>
<thead>
<tr>
<th>Interface</th>
<th>Protocols</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>S2a</td>
<td>PMIP/IP, or MIPv4/UDP/IP</td>
<td>29.275</td>
</tr>
<tr>
<td>S2b</td>
<td>PMIP/IP</td>
<td>29.275</td>
</tr>
<tr>
<td>S2c</td>
<td>DSMIPv6, IKEv2</td>
<td>24.303</td>
</tr>
<tr>
<td>S6b</td>
<td>Diameter/SCTP/IP</td>
<td>29.273</td>
</tr>
<tr>
<td>Gxa</td>
<td>Diameter/SCTP/IP</td>
<td>29.212</td>
</tr>
<tr>
<td>Gxb</td>
<td>Not defined in Release 8</td>
<td>N.A.</td>
</tr>
<tr>
<td>STa</td>
<td>Diameter/SCTP/IP</td>
<td>29.273</td>
</tr>
<tr>
<td>SWa</td>
<td>Diameter/SCTP/IP</td>
<td>29.273</td>
</tr>
</tbody>
</table>

7.1. ROAMING IN NON-3GPP INTER-WORKING SYSTEM ARCHITECTURE CONFIGURATION:

The principles for roaming with non-3GPP accesses are equivalent to those described in section 3.2.4 for 3GPP ANs. Both home routed and local breakout scenarios are supported and the main variations in the architecture relate to the PCC arrangement, which depends on where the services are consumed.

The additional consideration that non-3GPP ANs bring to roaming is related to the case where the user is roaming to a visited 3GPP network in Home Routed model, and it would be beneficial to use a local non-3GPP that is affiliated with the visited network, but there is no association between that network and the home operator. For this scenario, the 3GPP Release 8 includes a so-called chained case, where the S-GW may behave as the anchor for the non-3GPP ANs also, i.e. it terminates the S2a or S2b interface, and routes the traffic via the S8 interface to the P-GW in the home network.

VIII. SUMMARY

E-UTRAN is the air interface of 3GPPs Long Term Evolution (LTE) upgrade path for mobile networks. It is the abbreviation for evolved UMTS Terrestrial Radio Access Network, also referred to as the 3GPP work item on the Long Term Evolution (LTE) also known as the Evolved Universal Terrestrial Radio Access (E-UTRA) in early drafts of the 3GPP LTE specification.

It is a radio access network standard meant to be a replacement of the UMTS, HSDPA and HSUPA technologies specified in 3GPP releases 5 and beyond. Unlike HSPA, LTE’s E-UTRA is an entirely new air interface system, unrelated to and incompatible with W-CDMA. It provides higher data rates, lower latency and is optimized for packet data. It uses OFDMA radio-access for the downlink and SC-FDMA on the uplink.

REFERENCES


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