Alcatel·Lucent

TECHNOLOGY WHITE PAPER

Interworking LTE EPC with W-CDMA Packet Switched Mobile Cores

As wireless operators begin the process of evolving their existing 2G and 3G networks to Long Term Evolution (LTE), a new all-IP Evolved Packet Core (EPC) will be required to support the network and to deliver the performance, scalability and quality of experience that new wireless broadband services will require.

One of the benefits of the new EPC is the additional flexibility in functional composition of the network elements supporting the control and data planes. This functional flexibility provides the opportunity for the design of new core architectures that can be tailored to meet the service requirements, topologies and organizational models of the wireless operator.

With this transition to LTE, interworking with the existing 2G/3G mobile networks will be required so that seamless handovers occur across the wireless operators' own networks as well as when LTE services roam across both trusted and non-trusted networks.

Alcatel-Lucent has developed a complete, end-to-end LTE solution, including a purpose-built service-aware Evolved Packet Core that can seamlessly interwork with existing 2G/3G networks.

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1. Introduction

The Evolved Packet Core (EPC) is a new, all-IP mobile core network for Long Term Evolution (LTE) — a converged architecture for packet-based real-time and non-real-time services. The EPC provides mobile core functionality that was, in previous mobile generations (2G and 3G), realized through two separate sub-domains: circuit-switched (CS) for voice and packet-switched (PS) for data. It is specified by the 3GtecPP Release 8 set of LTE standards, which were finalized in early 2009.

The EPC (also called System Architecture Evolution or SAE) should not be viewed as yet another incremental step in existing mobile core technology that can be simply implemented with the addition of new processor cards and software upgrades for existing gateway nodes. LTE introduces a radically different and more stringent set of network and service requirements. Many of the existing gateway nodes do not have the architecture or inherent design attributes to support both 2G/3G and LTE requirements. As a result, the EPC should be built upon new, purpose-built platforms that can support LTE and future 4G requirements.

Four logical functional entities are defined for the EPC: the Serving Gateway (SGW), the Packet Data Network Gateway (PGW), the Mobility Management Entity (MME) and the Policy Charging and Rules Function (PCRF). The first two gateway elements are primarily responsible for the user or bearer plane and the latter two are responsible for dynamic mobility management and the policy control plane. By separating user plane functions from control and mobility management functions into individual, purpose-built platforms, the EPC network architecture can be designed more flexibly and with more deployment options than in existing 2G/3G core networks.

With standards being completed and the announcement of several key LTE commercial trials underway, the momentum is clearly behind it as the next generation wireless technology of choice. LTE is being globally adopted as the industry standard to converge existing circuit and packet switched networks. Wireless operators now face the strategic decision of when, where and how fast they should transform their existing networks to LTE. This decision is dependent upon a number of factors including: the existing 2G/3G installed base and the services currently offered; the availability of new or existing spectrum; the maturity of the LTE ecosystem and, in particular, the availability and cost of end-user devices; roaming agreements; and the operators' own time-to-market plans to offer differentiated mobile broadband and/or converged services.

Some operators are choosing to aggressively deploy LTE so as to gain a competitive advantage for delivering the next wave of Web 2.0, multimedia broadband services and applications. Others will add LTE selectively as an overlay network in urban areas where the demand for media-rich data services and the return on the initial investment is high. Still others may take a go-slow approach and defer the decision to add LTE in the near term and instead upgrade their existing EDGE/HSPA networks to HSPA+ to provide greater spectrum efficiencies and higher data speeds for users. Regardless of which approach is taken, LTE is the preferred, next-generation mobile technology of choice for most wireless operators and with it will bring a fundamental change to a new, all-IP, flat network architecture for a variety of new wireless broadband services.

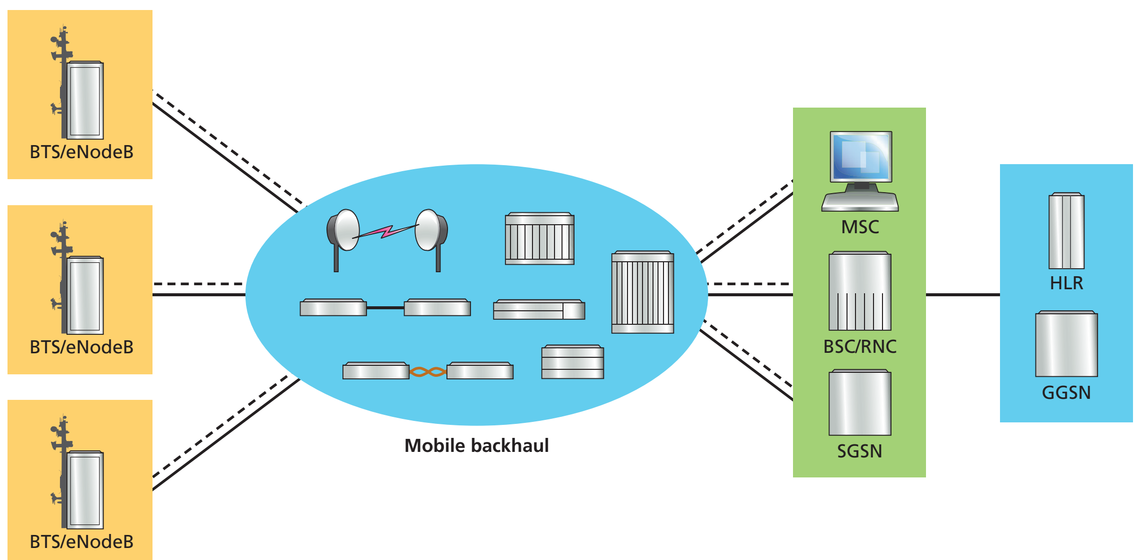
Given that LTE networks are going to be constructed over a period of several years, it will be very important to wireless operators that there is a seamless handover of applications and services between their existing 2G/3G and LTE networks. The industry standards for LTE inter-Radio Access Transport (inter-RAT) for 3GPP and non-3GPP networks are well defined to support these handovers. The standards support LTE interworking options for both 2G/3G Release 8 and pre-Release 8 networks. The decision on which upgrade path to choose is not an easy one as there are pros and cons for interworking with each option. A wireless operator will need to work closely with the vendor to determine which option is best suited to his business model and network evolution plans. A vendor with previous experience in 2G/3G migrations can assist the wireless operator in making this decision and, once made, develop the interworking methods and procedures to make the transformation to an all-IP LTE network as seamless as possible.

2. EPC network design considerations

2.1 Network architecture differences between 2G/3G and LTE

Several key differences in a LTE network enable more flexibility in its architecture than in a 2G/3G network. Figures 1 and 2 provide the key components of these two architectures.

Figure 1. 2G/3G network architecture



A functional representation of 2G/3G network architecture is shown in Figure 1. In this network, the Base Terminal Station (BTS)/NodeBs aggregate the radio access network (RAN) traffic and transport it over a mobile backhaul network to the Radio Network Controllers (RNCs)/Base Station Controller (BSCs). Typically this transport is over T1/E1 copper facilities. If fiber is available at or near the cell site, then the cell traffic is transported over SDH/SONET rings or, more recently, a carrier Ethernet network when the eNodeBs are equipped with IP/Ethernet interfaces. The bearer traffic from a number of RNCs/BSCs is multiplexed at the Mobile Telephone Switching Office (MTSO) and then transported via direct tunneling to the Gateway GPRS Serving Nodes (GGSNs) in the hub data center. This transport is normally over a SDH/SONET ring or a carrier Ethernet network. This tiered aggregation and transport structure lends itself to a point-to-point network topology to minimize both the amount of aggregation equipment required and the transport backhaul expense.

In a 2G/3G pre-Release 8 network, the RNCs and SGSNs are designed to support both the signaling and bearer plane processing and bandwidth requirements. The emphasis in the design for these network elements is in providing the processing necessary to support the high subscriber counts and Packet Data Protocol PDP contexts as the bandwidth requirements for delivery of the initial 2G/3G data services (text and e-mail) were not significant. Since the data services that typically ran over these systems is not real-time neither QoS or latency was an issue. Therefore, the placement of these elements is usually in locations that primarily meet the PDP context and network latency requirements. Thus, the current 2G/3G packet core architecture is typically a centralized network design with the GGSNs deployed in major data centers, and all the data services are backhauled from the SGSNs which are strategically deployed in regional serving offices. Because the aggregate bandwidth for these services did not increase significantly until the past few years, the backhaul transport costs were manageable and could be supported with leased TDM or lower rate OC-n/STM-n interfaces.

Figure 2. LTE network architecture

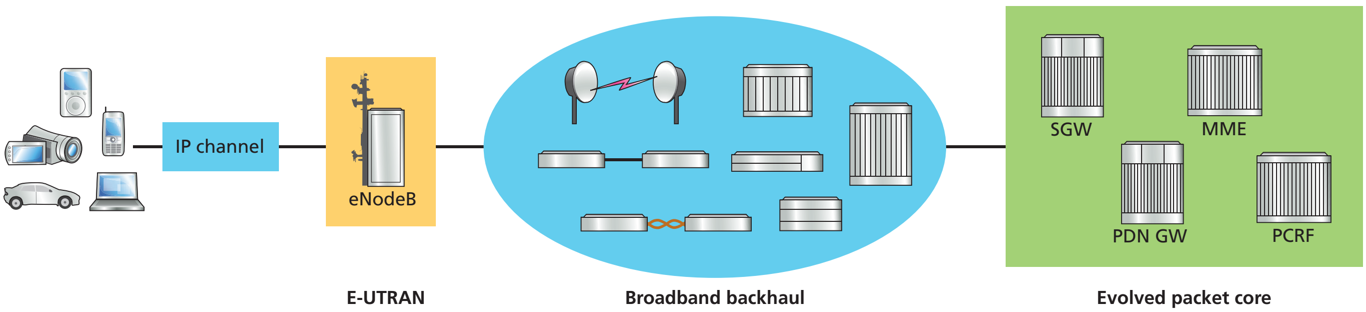


Figure 2 provides a high-level functional representation of a LTE network. This network is composed of three major sub-networks: the Evolved Universal Terrestrial Radio Access Networks (eUTRAN), which provides the air interface and local mobility management of the user equipment (UE), the evolved packet core (EPC), and the broadband backhaul network that provides the aggregation of cell traffic and transport back to the EPC. The 3GPP LTE standards defined the EPC as a set of logical data and control plane functions that can be implemented either as integrated or as separate network elements. The four EPC functions are: the Serving Gateway (SGW), the Packet Data Network Gateway (PGW) that supports the data or bearer traffic; and the Mobility Management Entity (MME) and the Policy Charging and Rules Function (PCRF) which support the dynamic mobility management and policy control traffic. The backhaul network either is owned by the wireless operator or is leased from a third party backhaul access provider. Any number of transport technologies can be used for backhaul including packet microwave, packet optical, Carrier Ethernet, IP/MPLS, GPON and xDSL.

Figure 3. LTE EPC network architecture

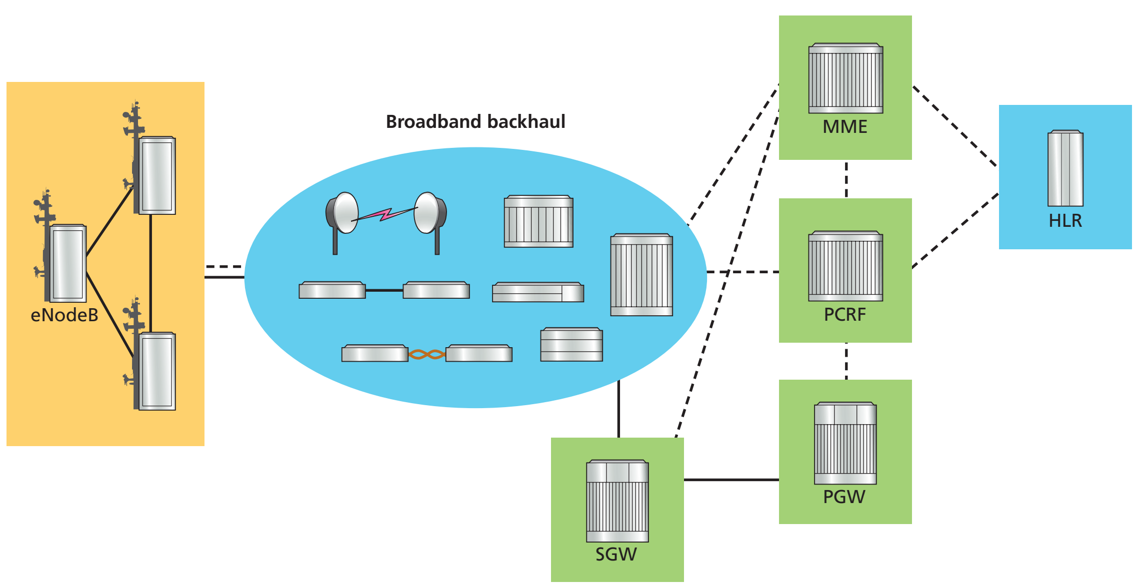


Figure 3 provides additional details of the LTE network architecture, showing the signaling and bearer paths from the eNodeB to each of the EPC functional elements. Adjacent eNodeBs in the LTE E-UTRAN form a partial mesh network by connecting directly with each other for inter-eNodeB handovers rather than through the serving gateway. There are no RNC/BSC network elements in LTE networks. These functions have been distributed to either the eNodeB or MME and so there are fewer layers of aggregation and backhaul required. IP is used as the end-to-end network layer protocol between all LTE network elements. This reduces the levels of hierarchy (and different protocols) that exists in 2G/3G packet networks and simplifies the design and the management of the individual sub-domains (E-UTRAN, backhaul, EPC and backbone networks) as end-to-end IP. Another difference is in the functional decomposition of the LTE packet core elements themselves where the control plane and bearer plane functions are separated into individual network elements, each purpose built and functionally optimized to support its own role in the core network. By taking this building block approach in designing the EPC network, wireless operators can deploy EPC bearer and control plane network elements only where and when they are needed. This flexibility enables them to design their LTE core network in ways that were previously impractical with previous generations of mobile core equipment. This maximizes performance, scalability and operational efficiency of the EPC.

With LTE, new real-time mobile broadband services will be offered. This will require additional levels of QoS to differentiate them from other non-real-time services. The bandwidth for these services will also increase. Backhauling all this high bandwidth traffic to a centralized data center may be cost prohibitive especially when the up take for these high-speed services increase. By distributing the EPC gateways in the network rather than being centralized, the backhaul transport costs associated with these new high bandwidth services can be reduced. For these real-time services QoS and latency will require a more flexible packet core network architecture, one that meets the specific service and geographical needs of the wireless operator while optimizing performance and minimizing transport costs.

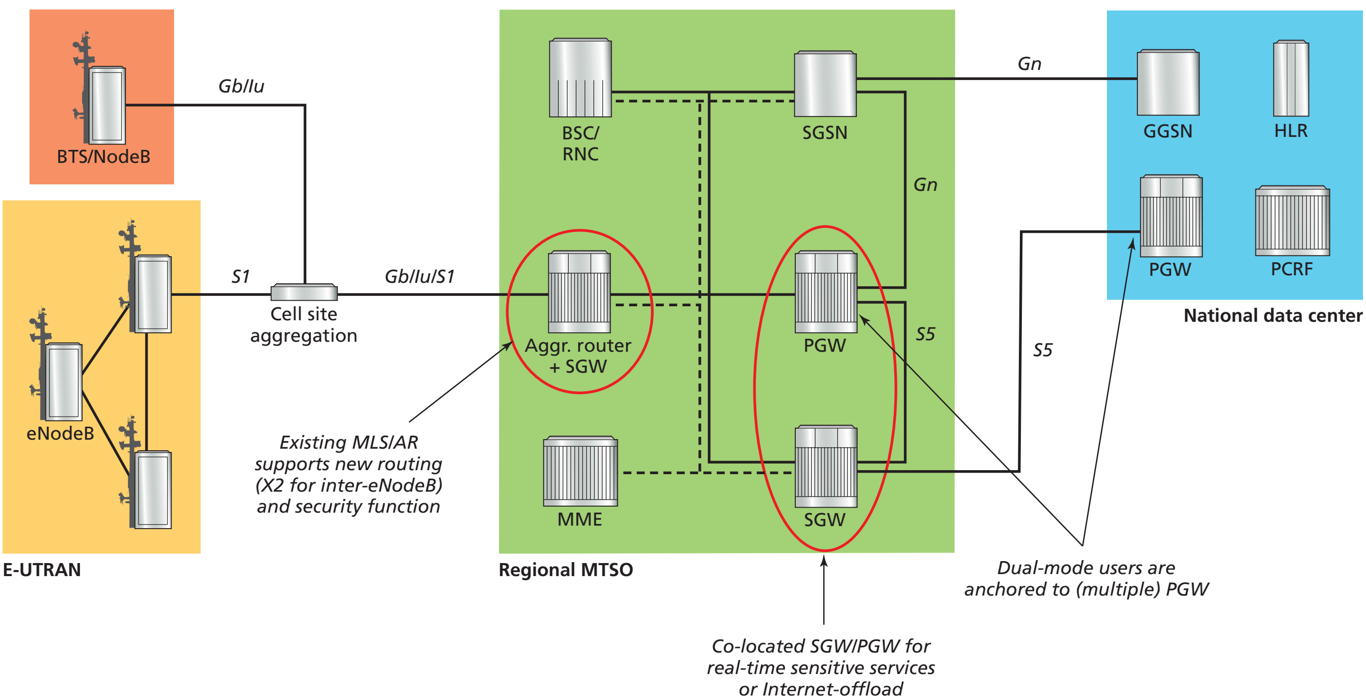
2.2 Combined 2G/3G and LTE packet network architecture

Figure 4 provides an example of a combined 2G/3G and LTE packet network design. It illustrates how a common mobile broadband IP/MPLS backhaul network is used for both 2G/3G and LTE traffic, and how an EPC network can be optimally designed to deliver a range of both real-time and non-real-time broadband services while also supporting the interworking of existing 2G/3G data services.

A cell-site switch/router is the device in the broadband backhaul network that aggregates the Gb, Iu and S1 interfaces and emulates the various TDM, ATM, Ethernet and IP services as IP/MPLS pseudowires. These pseudowire services are transported over a common carrier access Ethernet network. The cell-site aggregation switch/router, which is deployed at either an eNodeB or an intermediary hub, can also support the local routing necessary to support the inter-eNodeB X2 interface as well as provide the necessary secure tunnels to transport the cell site traffic through the backhaul network. This is especially important when the backhaul is over a third party provider Ethernet network. At the MTSO, a multi-service edge aggregation router terminates these pseudowires, converts them back to their native protocols and forwards this traffic to the appropriate 2G/3G or LTE network element. By having this edge aggregation/security gateway device perform the pseudowire to native service transformation, the 2G/3G and LTE packet core elements are unaffected and do not have to perform any new service interworking functions. It may also act as a security gateway switch to terminate the IPsec tunnels of backhaul traffic carried over an untrusted carrier access network.

Figure 4 also provides an example of an EPC architecture that is more flexible in its design than an existing 2G/3G packet core. The gateways (SGWs and PGWs) are distributed in multiple locations to deliver the bandwidth and performance requirements of the bearer path, and the mobility and dynamic policy management network elements (MME and PCRF) are strategically positioned deeper in the network to efficiently set-up and process the signaling/control and subscriber policy messaging. This hybrid (centralized/distributed) EPC architecture is appropriate for supporting a mix of real-time and non-real-time broadband services. In this architecture, a mobile subscriber is anchored to several PGWs for access to different PDNs, each providing different services. The real-time applications benefit from lower latencies by having the SGWs and PGWs deployed in serving offices closer to the subscriber while other non-real-time applications (such as e-mail) derive no such performance benefit and, therefore, can be centralized. As noted above, it also reduces the cost of backhaul by off-loading high-bandwidth services at the local office rather than having this traffic backhauled to a larger data center.

Figure 4. Combined 2G/3G and LTE packet network architecture



2.3 EPC deployment considerations

Wireless operators will select an EPC network design that is optimal for their network using at least five key decision criteria:

1. the services and applications that they plan on offering
2. the internal operational management model used to manage their core network
3. the targeted Service Level Agreements (SLAs) they expect to achieve for their services
4. the Operational Expense (OPEX) costs incurred for backhaul of traffic to their packet core
5. the capital cost of the EPC equipment

The type of services offered will significantly influence the network design of the EPC, particularly in the placement of SGWs and PGWs relative to each other. Real-time services such, as video streaming and VoIP that require more stringent performance requirements, will warrant PGWs deployed closer to eNodeBs and therefore favor a more distributed architecture. Other basic, non-real-time sensitive data services such as e-mail, SMS or MMS that are more tolerant to service and performance delays are more suited to centralized architecture with servers in national or regional data centers. Thus, hybrid EPC GW architecture may be the best option for the EPC design where some PGWs are deployed closer to the edge of the network in support of specific real-time services and other PGWs are deployed in hub data centers where performance requirements are less stringent.

The wireless operator's own organizational structure could influence the EPC architecture. Some wireless operators have network OAM responsibilities that are assigned geographically or regionally, while others use a more centralized organizational model. Each wireless operator will have to consider its own organizational structure and operations model to determine the appropriate placement of the EPC functional elements.

Network performance and the wireless operators' own internal metrics for bandwidth availability, latency and jitter will have a significant impact on the EPC architecture. A distributed architecture may provide better overall capacity and performance, but this must be weighed against the increase in capital costs for deployment of more EPC equipment. The type of services again plays a role in the overall network performance objectives.

The cost of backhaul transport also influences the network design architecture. With the increased aggregate bandwidth of services expected in LTE, wireless operators will be increasing the speed and capacity of both their access and network trunks that they lease from their local and carrier providers. A more distributed architecture could off-load data services such as Internet access closer to the user, thus reducing the distances and possibly the capacity of the leased lines that are required.

3. Interworking LTE EPC with packet switched mobile cores

3.1 LTE and 2G/3G packet network interworking options

Given wireless operators' previous experiences and the challenges in evolving their GSM networks to UMTS, there is undoubtedly some trepidation in transforming their network to an all-IP, LTE network. There are certainly many more subscribers than when 3G was introduced and a significantly higher portion of them using data services, which increases the risk of service disruptions and potential revenue or subscriber loss should problems occur. The LTE network will be architected differently with a flatter, all-IP design that will likely use different synchronization and timing mechanisms than existing 2G/3G networks. Operationally, the LTE network will also be managed and maintained differently than in the past using new Ethernet/MPLS OAM tools to troubleshoot and diagnose problems. It is for the above reasons that it is a more likely scenario that wireless operators will first deploy LTE as an overlay network. By introducing LTE as a separate overlay network, wireless operators are able to deploy and test an LTE network while minimizing impact to their existing 2G/3G packet network and potentially disrupt service to their subscribers. This approach enables operators to progressively cap their investment in 2G/3G packet core and fully migrate all their users to LTE over time.

Given the above overlay decision, wireless operators are then faced with a number of options of how they want their existing network and LTE network to co-exist. A wireless operator can select one of three basic 2G/3G/LTE network-interworking options. One option is to keep the networks completely separate and have the multi-mode UE decide when to switch from an existing network to LTE and vice versa. Two additional options are available for operators that leverage standard interworking procedures between existing 2G/3G core network and the EPC to provide service handover support. Each of these options is reviewed along with the advantages and disadvantages of each approach.

3.2 UE selected network handover option

Operationally, the simplest option for wireless operators to implement is to maintain both networks autonomously, where existing services such as voice are supported on the more ubiquitous existing 2G/3G network and new broadband data services are provided on the new LTE network. Each network is maintained and operated independently by the wireless operator. The new UE supports 2G/3G/LTE multi-mode operation and it determines or selects which network provides the best option for delivering the desired service. Each network maintains its own IP addressing scheme and subnets. When the UE detects a network that is better suited for delivering the desired service, the UE drops the existing network connection, registers with the new network, and establishes a new session that provides a better alternative to provide the service. This drop and reselect process can take on the order of tens of seconds where the subscriber has no-service and therefore is generating no revenue.

3.3 Inter-RAT handover options

The 3GPP standards comprehensively define the mechanisms and procedures for inter-radio access technology (inter-RAT) handovers between 2G/3G packet switched networks and LTE networks. For LTE/W-CDMA interworking, there are two primary inter-RAT (E-UTRAN to UTRAN) options:

- *Option A* – Interworking LTE with a Release 8 W-CDMA network
- *Option B* – Interworking LTE with a pre-Release 8 W-CDMA network

In both cases, there are two phases to the process: a preparation phase and an execution phase. In the preparation phase, the network making the handover decision initiates the relocation request, performs the necessary signaling for resource allocation requests, establishes the bearer path, and sends updates to the affected network elements in the RAN and mobile core. It is in the execution phase where the actual handover between networks takes place and, once completed, the resources and connections are then released from the network making the handover decision.

Also as part of an inter-RAT handover procedure, two data-path forwarding options are defined so that the buffered data, during the handover, can be released to the UE. Direct forwarding is used when the eNodeB forwards buffered data directly to the target SGSN. Indirect forwarding is used when the source SGW forwards the buffered data to the target SGSN. A determination of which forwarding method to use is made during the “handover required” messaging step in the preparation phase.

3.3.1 LTE interworking with W-CDMA Release 8 networks

Figure 5 illustrates an Alcatel-Lucent interworking solution that utilizes network elements from its W-CDMA and from its LTE network portfolio, which includes the UMTS/LTE eNodeB, and the new EPC network elements. The new Alcatel-Lucent LTE EPC network elements are purpose-built, high performance, scalable products dedicated to perform specific functions for either mobility management (9471 MME), dynamic policy management (5780 DSC) and gateway functions (7750SR-SGW and 7750-PGW). The Alcatel-Lucent 9326 Digital 2U provides a cost-effective UMTS NodeB solution that can also support LTE eNodeB functions with additional software. For further details on these products, refer to the referenced web or wiki sites listed in the Resources section of this document.

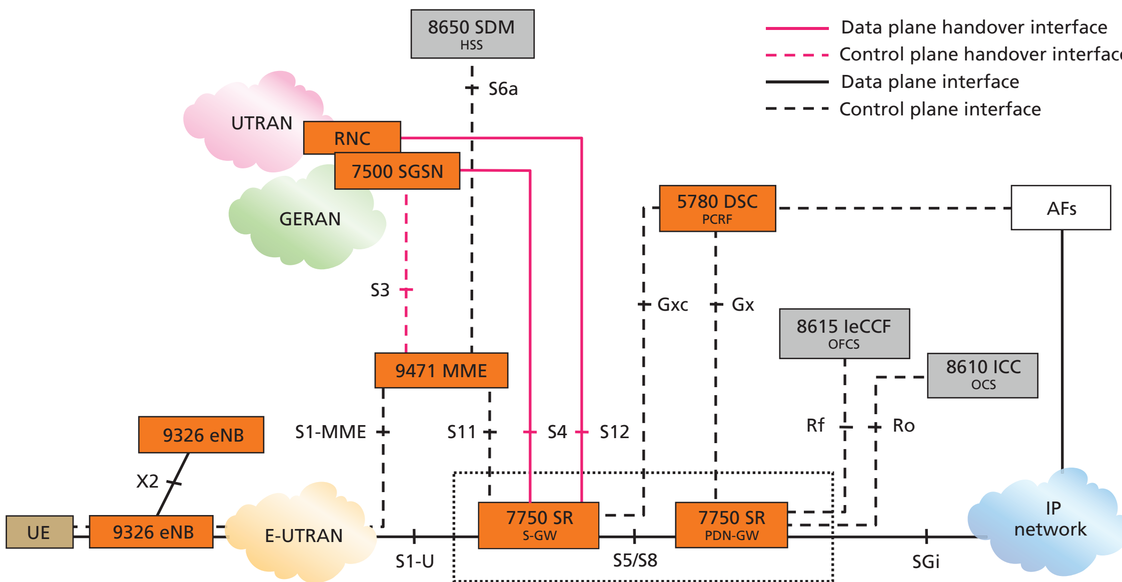
Figure 5 also identifies the key reference points and interfaces within the mobile core networks and radio access networks that are necessary to support inter-RAT handovers between a UMTS/HSPA network on Release 8 and LTE for a non-roaming architecture. They are the S3, which provides signaling message exchange for inter-system mobility support between the SGSN and the MME; the S4, which provides the user plane for inter-system mobility when Direct Tunneling is not established; and the S12 reference point between the UTRAN and SGW when Direct Tunneling is used between the UTRAN and the SGW.

Since UMTS Release 8 is the basis for LTE, the inter-RAT handover mechanisms are relatively straightforward.[1,2] The handover procedures appear from the network to be an intra-E-UTRAN handover with the source MME, the source SGW and the target SGSN. Therefore, the existing 2G/3G packet switched network must be upgraded to Release 8 to support this interworking option.

[1] 3GPP TS23.401, Technical Specification Group Services and System Aspects; GPRS Enhancements for E-UTRAN Access (Release 8)
[2] 3GPP TS36.300, Technical Specification Group Radio Access Network; E-UTRA and E-UTRAN Overall Description; Stage 2 (Release 8)

In the preparation phase, the source eNodeB, MME, SGW and the targeted SGW (if needed) send NAS signaling messages to targeted SGSNs and RNCs for the creation of the PDP contexts (subscriber sessions) and bearer paths to support the relocation procedure, and to determine whether direct forwarding or indirect forwarding applies. Prioritization of the PDP contexts is the responsibility of the target SGSN. Note that the eNodeB continues to receive both uplink and downlink user data over the S1-U interface during this set-up process.

Figure 5. LTE to W-CDMA Release 8 network interworking architecture (non-roaming)



In the execution phase of the handover, the LTE source MME coordinates with the target RNC and SGSN so that the handover of the UE to the UTRAN network can occur. A bearer path is established between the UE, the target RNC, target SGSN, SGW (or target SGW) and PDN-GW, and a new GPRS Tunneling Protocol (GTP) tunnel is established over the S4 interface between the target SGSN and SGW. Once the handover command is initiated eNodeB informs the UE to handover to the target RNC, and the messaging between the target SGSNs, MME, SGW and PGW takes place to complete the handover and forward the buffered data either in direct or indirect mode. Upon completion of the handover, the new network, the old resources and connections from the original (LTE) network are released.

3.3.2 LTE to W-CDMA pre-Release 8 network interworking

Alternatively, some wireless operators may have an existing pre-Release 8 W-CDMA network that they do not want to upgrade for new data services and simply want to add LTE as an overlay for new broadband services. They would prefer to leave their existing network as is and have the responsibility of interworking with it to fall on the overlay LTE network. In this case, the MMEs and the EPC gateways must develop the pre-Release 8 signaling and bearer interfaces, acting like the existing SGSNs and GGSNs, to support the handovers between the networks. If pre-Release 8 Direct Tunneling is required, then an additional interface is required on the PGW for direct connection to the RNC bypassing the SGSN. Otherwise, if Direct Tunneling is not supported, the bearer path connecting the E-UTRAN and UTRAN networks is between the PGW and the SGSN.

Figure 6. LTE to W-CDMA pre-Release 8 interworking with direct tunnel (non-roaming)

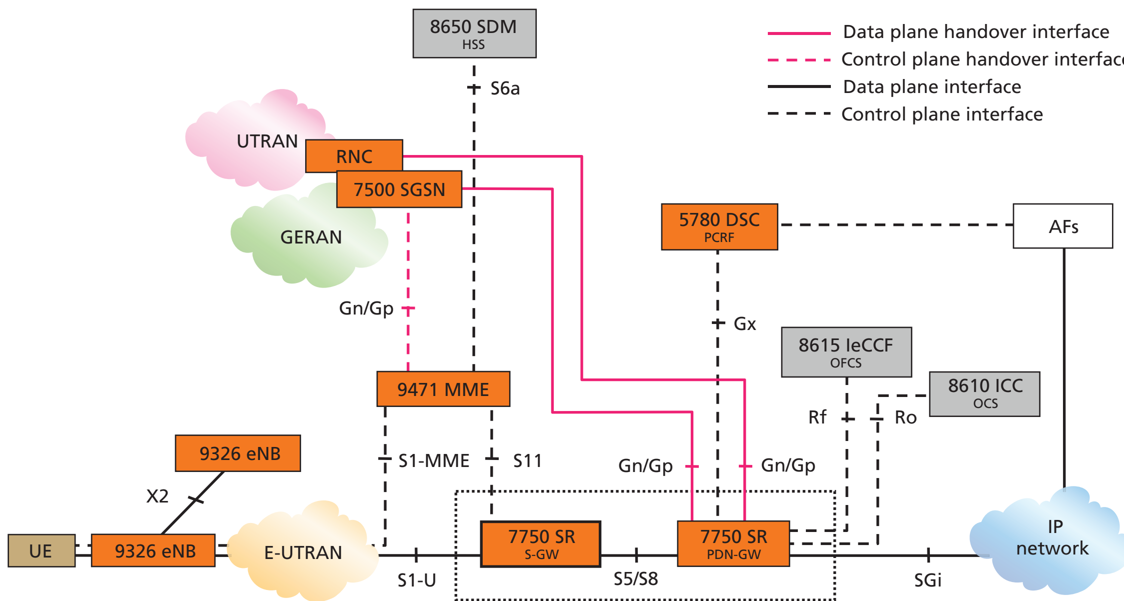


Figure 6 shows the key interfaces that are necessary for inter-RAT handover between a pre-Release 8 W-CDMA network and an LTE network in a non-roaming architecture using Direct Tunneling. The Direct Tunnel specification, or "one tunnel" as it is officially known, is defined in the 3GPP Release 7 standards and enables the user plane data to be directly tunneled between the RNC and the GGSN, by passing the SGSN in the bearer path.[3] With an inter-RAT handover between a LTE network and a W-CDMA network, the Direct Tunnel would be between the LTE PGW and the W-CDMA RNC. For this interworking option, the existing W-CDMA network requires no changes. Rather, the LTE EPC takes on the behavior of a W-CDMA network with the handover appearing to the existing network as an inter-SGSN relocation, and thus provides the necessary "G" interfaces to provide seamless interworking.[4,5] The key interfaces involved in this inter-RAT handover are: the Gn signaling interface between the source MME and the target SGSN, the enhanced Gr authentication interface between the target SGSN and the HSS/HLR, the S6a interface from the HSS/HLR to the MME, the signaling interface between the target SGSN and the source PGW (Gn/Gp), and the Direct Tunnel User Plane interface between the target RNC and the source PGW (Gn/Gp). All of the Gn/GP interfaces utilize GTP. Separate EPS bearers for IPv4 and IPv6 addressing are recommended for the pre-Release 8 W-CDMA network so that both can be maintained when handovers occur.

During the preparation phase of a LTE to W-CDMA pre-Release 8 handover, the eNodeB would initiate the handover by signaling to the source MME that a handover is required to the target UTRAN network. The MME will send the forward relocation request to target SGSN, which will trigger the SGSN to initiate a relocation request with the target RNC, thereby resulting in allocation of resource for the transmission of user data. If indirect data forwarding is used for handover, the source MME will create a temporary bearer between the target SGSN/RNC and PGW.

[3] 3GPP TR23.809: Technical Specification Group Services and System Aspects: One Tunnel Functional Description; (Release 7).
[4] 3GPP TR23.060: Technical Specification Group Services and System Aspects: General Packet Radio Service (GPRS); Service Description, Stage 2.
[5] 3GPP TS23.401 Annex D: Technical Specification Group Services and System Aspects; GPRS Enhancements for E-UTRAN Access (Release 8).

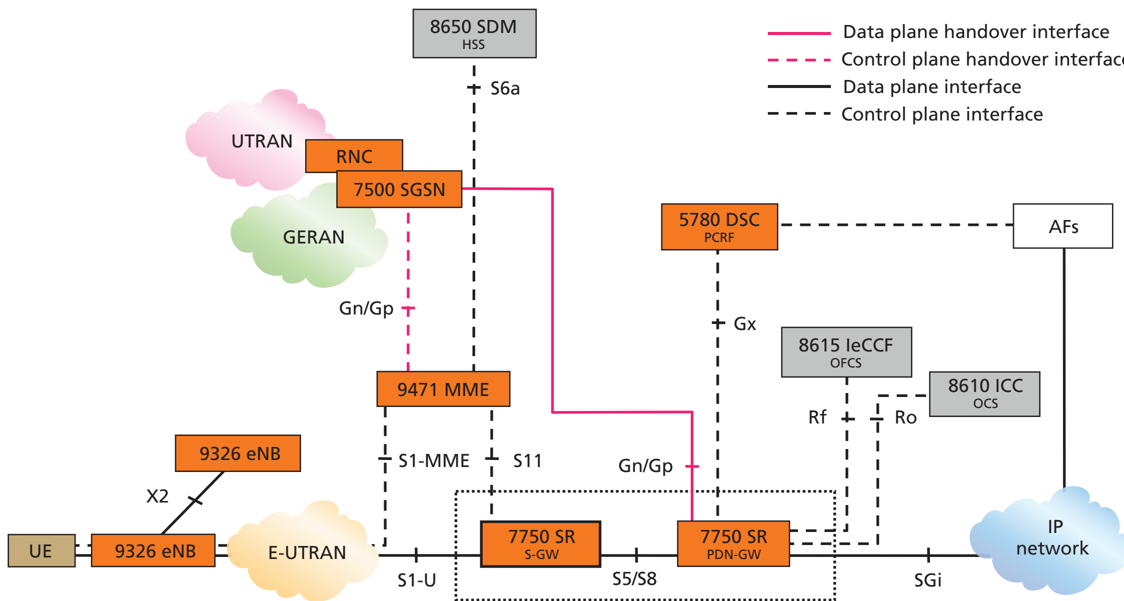
In the execution phase, the eNodeB issues the handover command to the UE and the UE moves to the W-CDMA network target UTRAN. When the UE successfully exchanges data with a new source RNC, a relocation complete message is sent from the target RNC to the target SGSN. Similarly, a relocation complete message is sent by the target SGSN to the source MME, followed by an update PDP context request to the PGW (which appears as a GGSN to the SGSN). The update PDP context request will indicate to the PGW that Direct Tunneling is being used during the switchover of user plane. Upon receipt of the relocation completion message, the MME will then release all related E-UTRAN resources.

The handover mechanisms between a LTE network and a pre-Release 8, GERAN A/Gb network are very similar to the above inter-RAT E-UTRAN to UTRAN procedures since the Gn/Gp SGSN is used to facilitate the handover in both packet networks. From the GERAN network perspective, the I-RAT handover appears as an inter-SGSN relocation with the source eNodeB assuming the role of the source RNC, the MME assuming the role of the "old" SGSN, and the PGW acting as the GGSN. As before in the preparation phase, the source eNodeB determines that a handover to the GERAN A/Gb mode network is required. The eNodeB initiates the handover by sending a message to the source MME requesting a handover and to obtain the necessary resources of the target Base Station System (BSS), new (target) SGSN and S-GW from the Core Network (CN). The source MME determines that the handover is to a GERAN in A/Gb mode and makes a relocation request to the new SGSN over the Gn/Gp interface. The new SGSN determines the ciphering algorithm to use and obtains the necessary access point identifiers from the PDP contexts and makes packet switch handover requests to the target BSS and the BSS determines which packet forwarding containers to assign radio resources. The target BSS creates the BSS transport container and sends acknowledgement to the new SGSN and the new SGSN sends the forward relocation response to the MME acting as the old SGSN, which then makes the decision for the handover to occur. The source MME completes the preparation phase by sending the handover command to the source eNodeB which then initiates the data forwarding for the bearers. The data forwarding goes directly to the target SGSN.

In the execution phase, the eNodeB will give the command to the UE to handover to the GERAN Target Access System which include the parameters received from the target BSS and target SGSN to establish the UE connection to the GERAN. Upon receipt of the handover command, the UE associates its bearers to the GERAN and suspends uplink transmission of the data plane. The UE then executes the handover according to the parameters defined above, synchronizes with the target BSS and sends a signaling message to the target SGSN. The target BSS completes the handover message to the target SGSN when the first block of data is received from the UE. The UE is now associated with a cell within the GERAN. The target SGSN informs the old SGSN (MME) that the handover is complete and sends a PDP context update request to the GGSN (PGW). The GGSN updates the PDP contexts and forwards any new downlink data to the new SGSN. The UE sends a routing area update to the new SGSN and, when the timer expires on the source MME, then sends a message to the source eNodeB releasing the resources from the old network.

Figure 7 shows the key mobile core interfaces that are necessary for inter-RAT handover of a pre-Release 8 GERAN/UMTS network with a LTE network without the use of a Direct Tunnel interface. As with the previous option, this interworking alternative requires no changes to the existing GERAN/UMTS network and the preparation phase and execution phases of the handover procedures are very similar. The key interfaces for handover are the signaling interface between the MME and the SGSN (Gn), as well as the bearer interfaces between the target SGSN and the source PGW (Gn). Without a Direct Tunnel interface, the bearer path connecting the E-UTRAN and the 2G/3G RAN networks is between the PGW and SGSN.

Figure 7. LTE to pre-Release 8.0 UMTS/HSPA network interworking without direct tunnel



3.4 Strategic options for the introduction of LTE

Table 1 summarizes the three strategic options discussed above that are available to a wireless operator in deploying a LTE overlay network and having it interoperate with their existing 2G/3G packet network. The UE selected network option is the simplest to deploy since each network is operated autonomously but it provides the poorest user experience as the IP session is dropped and then must be reestablished when moving between networks. Therefore, providing service session-based billing is difficult at best. This option may be adequate for a trial or if multimode UEs are not available.

The overlay of a LTE network with a pre-Release 8 network improves upon the user experience where the handover gaps in data flow are expected to be less than a second. It also is the least disruptive to the existing 2G/3G network since the responsibility for development of the Gn/Gp interfaces falls to the LTE EPC network elements. Both the 2G/3G packet core and the LTE EPC use the PGW as the IP anchor point for multimode UEs and the GGSN remains to support non-LTE capable UEs. The prime advantage of this option is that there is no cost to upgrade the existing 2G/3G network, but the disadvantages are in its poorer performance (no ISR support) and slower UL and DL speeds.

Finally, the option of adding a LTE overlay network onto a Release 8 network provides the best user experience with seamless mobility across all three radio technologies and gaps in data flows during handovers less than 500 milliseconds. Interoperability between the LTE and the 2G/3G packet networks is straightforward since the existing networks are upgraded to support the required release interfaces to the EPC. One key advantage of upgrading a UMTS/HSPA network to Release 8 is that features such as Idle state Signal Reduction (ISR) can be used, which significantly reduces the signaling to register the UEs location while moving between the LTE and 2G/3G network.

The existing networks performance and bandwidth is optimized to deliver HSPA+ services. With this option, the SGW becomes the mobility anchor for all radio technologies, thereby simplifying the handovers between them.

The prime disadvantage of this option is in the cost for upgrades and the disruption to the existing network. The wireless operator will have to weigh the advantages and disadvantages of each option to determine which is best suited to their own situation and deployment strategy. Whichever option is chosen, a new purpose-built Evolved Packet Core should be considered as the foundation for deployment of LTE. This new EPC provides the scalability and performance needed to offer both new LTE and existing data services and offers the most flexibility in core network designs to deliver them.

Table 1. LTE and W-CDMA packet switch network interworking options

	UE-BASED "DROP-AND-RESELECT"	LTE OVERLAY WITH PRE-RELEASE 8 INTERWORKING	LTE OVERLAY WITH RELEASE 8 INTERWORKING
User experience	Poor – UE (re-)selects network based on signal strength. Results in service discontinuity and poor user experience	Seamless mobility across UMTS and LTE	
Architectural and operational changes	LTE is introduced as a separate overlay network. Seamless (session) based service billing is difficult	LTE elements support legacy pre-Release 8 interfaces Existing charging infrastructure is extended to LTE	Legacy elements need to be upgraded to Release 8 interfaces Use of SGW as mobility anchor for ALL users Existing charging infrastructure is extended to LTE
Advantages	Simple to implement	No changes or upgrades to existing mobile core elements	ISR improves performance Common mobility anchor for all users
Disadvantages	No seamless mobility	No ISR results in more signaling messaging	Require upgrades to existing core elements

4. Conclusion

Wireless operators must answer a number of important questions about their existing 2G/3G packet switch core networks as they begin the planning for LTE. Can the existing packet switch core network efficiently and cost effectively support the more stringent performance, increased capacity and finer grain QoS requirements of the LTE EPC? How should the EPC network be designed to deliver the new media-rich, mobile broadband services enabled by LTE? Since the existing 2G/3G packet switch network will co-exist with the LTE network for some time, which interworking option should be used for Inter-RAT handovers and what upgrades, if any, should be performed on the existing network to facilitate this interworking? Each of these questions were discussed and the results can be summarized as follows:

- The 3GPP Release 8 standard defines a LTE EPC architecture that separates the signaling/control plane from user plane functions. This separation of functions can only be fully leveraged with the deployment of new, purpose-built EPC network elements that offer greater individual scalability, performance and flexibility than in previous packet switch core elements.
- An EPC using purpose-built functional elements provides more flexibility in its design than existing 2G/3G packet cores built with general-purpose computing platforms that provide a combination of bearer and control plane functions. Centralized, distributed or hybrid EPC architectures are all supported using this functional building block approach. Which design to use is highly dependent upon the type of services offered and the performance metrics of each as well as the cost of the backhaul transport and operational/organizational responsibilities.
- The 3GPP standards define inter-RAT interworking options for both pre-Release 8 and Release 8 networks that enable seamless mobility across all three radio technologies.
- Alcatel-Lucent has a complete end-to-end LTE solution and an EPC that supports interworking with both pre-Release 8 and Release 8 networks.

5. Additional Resources

- Alcatel-Lucent End-to-End LTE Solution
http://www1.alcatel-lucent.com/tmp_Static/lte/lte.html
- Alcatel-Lucent Evolved Packet Core Wiki
http://wiki.alcatel-lucent.com/cm/wiki/?id=30181
- Evolved Packet System (EPS): The LTE and SAE Evolution of 3G UMTS (Hardcover) by Pierre Lescuyer (Author), Thierry Lucidarme (Author)
http://www.amazon.com/Evolved-Packet-System-EPS-Evolution/dp/0470059761/ref=pd_bbs_sr_1?ie=UTF8&s=books&qid=1226335030&sr=8-1
- Advanced QoS for Multi-Service IP/MPLS Networks [ILLUSTRATED] (Paperback) by Ram Balakrishnan (Author)
http://www.amazon.com/Advanced-QoS-Multi-Service-MPLS-Networks/dp/0470293691/ref=pd_bbs_sr_5?ie=UTF8&s=books&qid=1226334696&sr=8-5
- External links (organizations, agencies, standards)
3GPP: http://www.3gpp.org/
3GPP2: http://www.3gpp2.org/
NGMN: http://www.ngmn.org/
LSTI: http://lstiforum.org/

6. Abbreviations

BSC	Base Station Controller
BTS	Base Terminal Station
CDMA	Code Division Multiple Access
EPC	Evolved Packet Core
eNodeB	Evolved NodeB
eUTRAN	Evolved Universal Terrestrial Radio Access Networks
EVDO	Enhanced Voice – Data only
GGSN	Gateway GPRS Serving Node
GSM	Global System for Mobile
GTP	GPRS Tunneling Protocol
HRPD	High Rate Packet Data
HSPA	High Speed Packet Access
Inter-RAT	Inter-Radio Access Technology
LTE	Long Term Evolution
MME	Mobility Management Entity
MTSO	Mobile Telephone Switching Office
PCRF	Policy Charging Rules Function
PDP	Packet Data Protocol
PGW	Packet Gateway (also PDN-GW)
RAB	Radio Access Bearer
RNC	Radio Network Controller
SAE	Serving Architecture Evolution
SGSN	Signaling GPRS Serving Node
SGW	Serving Gateway
UE	User Equipment
UMTS	Universal Mobile Terrestrial Service
UTRAN	Universal Terrestrial Radio Access Network

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