3GPP LTE: The Relevance of Interworking

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Abstract— **The evolution of digital mobile technology which began from GSM has been very rapid. This evolution is characterized by significant advancements in spectral efficiency, network architectures, data rates, modulation techniques and other parameters. Providing striking advantages, the most recent result of this evolution is Long Term Evolution (LTE), developed by 3GPP – otherwise termed 4G. Widespread adoption of LTE technology begins with interworking (and co-existing) with previously existing access technologies. Interworking ensures seamless connectivity and also enables roaming. This paper provides an overview of LTE interacting with former 3GPP access technologies. Also discussed, is the growing importance of IEEE access – Wi-Fi in LTE Advanced (LTE-A) and beyond network deployments.**

Index Terms— **GSM, Interworking, LTE, LTE-A, UMTS, Wi-Fi**

I. Introduction

LTE was developed and standardized by 3GPP as Release 8. It evolved from GSM/UMTS with an aim to ensure continued competition for the future, to provide higher user data rates and QoS, to provide a fully packet-switched network with low complexity and reduced delays, to enable cost reduction and to avoid unnecessary fragmentation of technologies for paired and unpaired band operation [1]. Using state-of-the-art technology, LTE offers several benefits to the operators and users which were not available with preceding access technologies. Relentless efforts for improvements of access technologies led to the evolving of LTE Release 8 to LTE-Advanced (LTE-A), also known as Release 10 [2]. LTE Release 10 provides higher data cost-effectively, and completely fulfils the ITU requirements for IMT-Advanced. Even with these, there is still on-going work towards evolving LTE to provide more powerful characteristics resulting in further releases (Release 11, 12, 13) [3].

The purpose of any radio telecommunication system is to provide a means for users to communicate with each other with the best possible user experience. LTE provides excellent Quality of Experience (QoE); however, transferring all user traffic to LTE network cannot be automatic. LTE implementation differs from legacy network in its network elements and operations. There must be interoperability between the LTE network and previous mobile networks to foster eventual migration to complete LTE network as well as to support roaming. The Evolved Packet Core network (EPC) of LTE has therefore been designed by 3GPP to be compatible with access technologies provided by itself as well as other bodies [4].

With the increasing billions of interconnected and broadband data-demanding devices – contributing to the Internet of Things (IoT), the place of IEEE access technologies specifically Wi-Fi, cannot be over-emphasized. The most recent Wi-Fi standards, IEEE802.11ac and IEEE802.11ad, offer up to 7Gbps data rate within a channel bandwidth of up to 160MHz and 2.16GHz respectively. In contrast, LTE at its most recent improvement level offers just over 1Gbps in a maximum channel bandwidth of 100MHz through Carrier Aggregation. In order to accommodate the surge in demand for capacity and higher data rates, several efforts have and are being made to extend and improve LTE services through unlicensed spectrum offered by Wi-Fi [5, 6].

Beginning with a brief review of the LTE architecture, this paper discusses the interworking of some common access technologies with LTE as the network operators plan successful migrations to LTE. Also discussed here, is the path to 5G – fostered by the interworking between LTE and Wi-Fi at Millimeter wave (mmwave) frequencies.

II. LTE Architecture

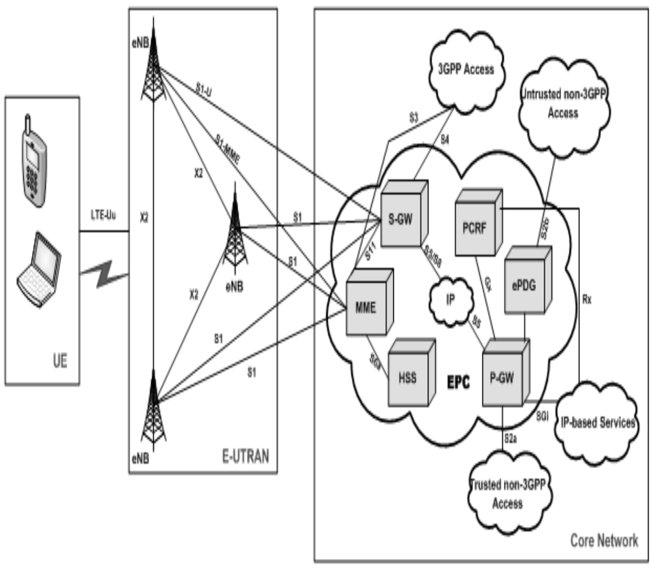

Fig. 1. LTE Network Architecture.

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The LTE network is an all-IP network where the Mobility Management Entity (MME) serves as the hub of the network – it controls most of the functionalities for the User Equipment (UE). As seen in the core network in Fig. 1, 3GPP specification provides the opportunity for LTE to interact with other access technologies through its MME/S-GW, P-GW and ePDG elements over the appropriate interfaces. Details on the functionalities of each element can be found in [7-9].

III. LTE Interworking Architectures

As illustrated in the architecture of LTE, mobile communication systems have been grouped by 3GPP into three categories; where LTE interworks with each based on defined standards. These include 3GPP access technologies, trusted non-3GPP access technologies and untrusted non-3GPP access technologies. However, the categorization of non-3GPP accesses into trusted and non-trusted is based on each operator's decision. Presented in this paper, is the interworking of 2G/3G 3GPP access technologies with LTE as well as IEEE access (Wi-Fi).

A. 3GPP Access – GSM/UMTS Interworking with LTE

Recall that GSM is entirely circuit-switched (CS) to provide CS voice and SMS services; the introduction of GPRS, EDGE, UMTS and subsequent 3GPP access technology evolutions up to HSPA+ added a packet-switched (PS) core network to the system to provide data (IP) services. In this PS core network, the SGSN serves as the hub of the network controlling the data-centric functionalities for the UE and network. Full description of the network elements of GSM/UMTS/HSPA can be found in [10, 11]. Three modes of operation have been proposed for LTE deployment [12]:

- LTE Data Only – This may be regarded as the first stage/option for network operators. It is safe as it allows testing of the LTE network without affecting the 2G/3G network operations. This option is targeted at devices such as computers and wireless dongles which only require mobile broadband service and not a circuit-switched connection. This option allows for speedy deployment and evolution to LTE since the need for voice solution is not necessary for these devices. A further stage of this solution is to enable a fallback to 2G/3G data to allow for constant connectivity when the device is out of LTE coverage.
- Simultaneous 2G/3G and LTE networks – This option is relevant to user equipment (UE) such as mobile phones. Here, the operators run two separate networks simultaneously; 2G/3G networks are used for voice and data, and the LTE network is used for voice (via IMS) and data as well. In this case, the mobile phones must be multimode/multiband and should be able to choose the best connection to use at every point in time.
- 2G/3G Voice and LTE Data Only – This method is otherwise known as Circuit Switched (CS) Fallback, described fully in [13]. Here, the legacy GSM/UMTS/HSPA networks with the circuit switch connection for voice and SMS is used for this purpose only while LTE is used to support data only. As seen in figure 2, a UE is connected to a GPRS/EDGE RAN (GERAN) or UMTS RAN (UTRAN) for voice and SMS services while data service is directed to the EUTRAN. The fallback is achieved through the SGs interface between the MSC (Mobile Switching Center) and the MME.

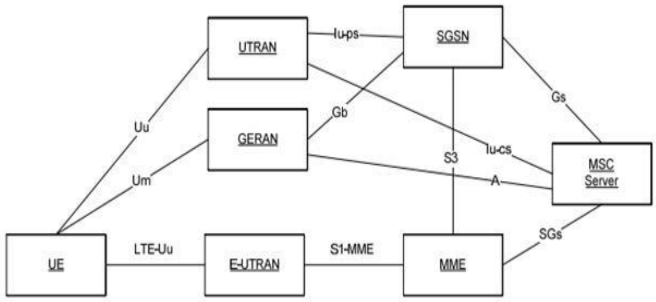

Fig. 2. EPS Architecture for CS Fallback.

- 2G/3G and LTE Packet Core Interworking – There are two options in this case.

  The Gn/Gp method – the 2G/3G systems view MMEs as SGSNs, while P-GWs are viewed as GGSNs. This method introduces delay in the network. This method is summarized in figure 3 and more details can be found in [14].

  The Idle-mode Signalling Reduction (ISR) – As network operators overlay 2G/3G networks with LTE networks, this will be a gradual process – resulting in limited coverage for LTE. When the UE moves from a 2G/3G network to LTE and from LTE to 2G/3G, it performs TAU (Tracking Area Update) and RAU (Routing Area Update) respectively. Due to coverage limitations, the UE performs TAU and RAU frequently, leading to ping-pong effect. The purpose of the ISR method is to reduce the frequency of TAUs and RAUs, resulting in reduced network signalling. Legacy SGSN elements must be upgraded to support S3, S4 and S6d interfaces to support this method. Even when the ISR is not activated reduced network signalling still occurs, because the MM contexts (constructed for the UE by the MME) are stored in UE, MME and SGSN when ISR is not active. This functionality is not supported for Gn/Gp method, thereby increasing signalling traffic.

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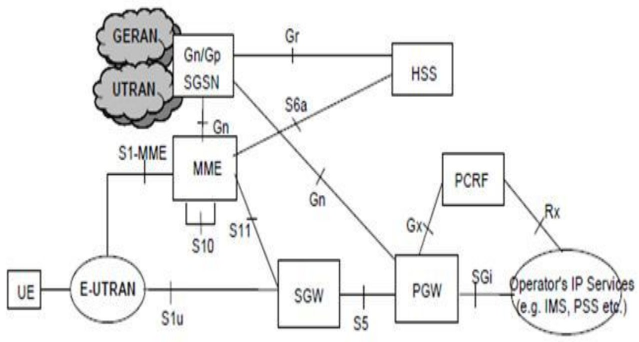

Fig. 3. LTE Interworking using Gn/Gp Interfaces.

B. IEEE Access – LTE and Wi-Fi Interworking

As network operators prepare for the IoT and surge in demand for mobile broadband capabilities offering gigabit speeds and virtually zero latencies, more attention is being given to the converging of LTE and Wi-Fi. Wi-Fi represents the IEEE802.11 WLAN standard. Since 1997, when its first standard was released offering maximum data rate of 2Mbps, there have been tremendous improvements on subsequent standards as highlighted in [15]. Today, using the unlicensed spectrum, this standard (referred to as Wi-Gig) is able to offer up to 7Gbps data rate which is an excellent complement to LTE [16]. LTE and Wi-Fi interworking already existed and has been in operation but this was at the core network level. In order to increase support of higher speeds and more capacity by enabling smaller cells, operators have considered traffic offload to unlicensed spectrum through Wi-Fi. To ensure further continuity in seamless and uniform user experience and operations, there is a need to enable LTE-Wi-Fi interworking on the Radio Access Network (RAN) level – providing the operators with more control over selection of Wi-Fi. Consequently, 3GPP has added LTE and Wi-Fi interworking at the RAN level in their LTE-A Release 12 specifications [17]. As a result, there are many considerations as to the implementation of this integration [18].

IV. Current Status Of LTE Deployment

As at January 2015, according to the Evolution to LTE report by the Global mobile Suppliers Association (GSA) [19], there are 364 commercially launched LTE networks in 124 countries. This number was forecasted to reach 350+ by end of 2014. United States has the most LTE deployments while many other countries are trying to catch up with the evolution. Also, there are 49 commercially launched LTE-Advanced networks worldwide (in 31 countries).

V. Conclusion

As mobile networks mature to enable and ensure broadband connectivity access, emphasis must be placed on interworking between the evolving technologies. This is to ensure compatibility across networks, as the network operators work towards full-scale adoption and deployment of the newer technologies. This is also very necessary to support international roaming.

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