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REVIEW OF NETWORK INTEGRATION TECHNIQUES FOR MOBILE BROADBAND SERVICES IN NEXT GENERATION NETWORK

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ABSTRACT
Next Generation Network (NGN) is intended at integrating the existing heterogeneous wireless access networks in order to produce a composite network that provides users with ubiquitous broadband experience. Currently, it has been established that Long Term Evolution (LTE) network, as a backbone network, provides broadband capacity with high efficiency, reduced latency and improved resource provisioning. Resource provisioning on this backbone network is not without its limitation as more mobile broadband services (MBBs) are evolving and users demand for mobility is on the increase. This paper, therefore, reviewed the different integration techniques for the heterogeneous networks that use LTE network as backbone that supports mobile broadband services.

Keywords: *MBB, NGN, LTE, SIP, QoS*

1. INTRODUCTION

Next Generation Network (NGN) evolved in order to provide support to the varied services demanded by present day network users [1]. NGN provides efficient and effective mobility management, resource provisioning and network convergence with guaranteed quality of service (QoS) [2]. It leverages on the overlay of different radio access networks with Long Term Evolution (LTE) as the backbone. As such, the different radio networks needed to be efficiently integrated into a composite network in other to guarantee the quality of service (QoS) required in supporting MBBs. This is actually the basis for the NGN. The resultant network is expected to ensure efficient utilization of overall network resources while maintaining mobility. Heterogeneous networks have different radio access technologies (RATs). Therefore, an appropriate interworking of the wireless access systems is crucial to meet the dynamic mobile users' expectations while also making their coexistence possible [3, 4]. Individually, some of the different `RATs cannot provide reasonable support for MBBs. Therefore, the integration of these radio networks to achieve seamless service delivery is the current issue for researchers in this area. This paper, therefore, reviewed the different integration techniques for the heterogeneous wireless radio access networks that use LTE network as backbone that supports mobile broadband services. The integration techniques with the associated network architectures were presented.

2. INTERWORKING TECHNIQUES IN MOBILE COMMUNICATION NETWORK

Current wireless communication networks are heterogeneous in nature, giving rise to the coexistence of multiple and diverse wireless networks with their corresponding radio access technologies (RATs). Currently, no single RAT is able to optimally cover all the different wireless communications interworking as such, a radio technology optimized to provide outdoor coverage to high mobility users may fail to meet more demanding data rates in low mobility indoor condition and vice versa [3 – 5]. In today's world, user equipments are furnished with the capability to support more than one RAT. In this case, end-user services can either be delivered in an access network specific manner or independent of the involved wireless access networks. In a typical generic

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internetworking situation where the different wireless networks have different RAT as in Figure 1, a common set of services could be offered through both wireless networks, but there could also be some specific services only available when connected to a given wireless network.

Thus, several interworking levels can be envisioned with a different range of interworking requirements. Interworking levels could be based on network architecture or support for specific service and operational capabilities.

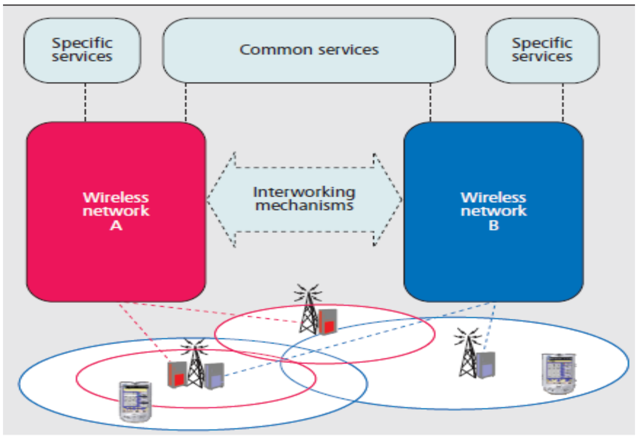

Figure 1: Typical generic internetworking situation [3]

Based on service integration among networks, four interworking levels are distinguished namely:

Level A: Visited Network Service Access- Here a user get access to a set of services available in a visited network while relying on his/her home network credentials. As well, the user could be charged for service usage in the visited network through its own home network billing system. In realizing this level, the mechanisms put in place here aims at extending authorization, authentication, and accounting (AAA) functions among wireless networks, thus allowing users to perform authentication and authorization processes in a visited network attending to security suites and subscription profiles provided by their home networks [6].

Level B: Intersystem Service Access- In this case, a user connected through a visited network would also be able to get access to specific services located in his/her home network. The common approach to enforce user data transfer between networks relies on tunneling protocols such as the Layer 2 Tunneling Protocol (L2TP) defined in RFC 2661 or the IPsec tunnel mode defined in RFC 2401 [6]. Tunnels may be established either directly between mobile terminals and remote network nodes (NDs) or may require additional dedicated network nodes [7].

Level C: Intersystem Service Continuity- Here a user is not required to reestablish active session(s) when moving between networks. However, a temporary QoS degradation can be tolerated during the transition time. The mechanisms proposed for realize this was the Mobile IP (MIP) described in RFC 3344. MIP which is a network layer mobility solution, covers both handover and location management aspects. However, several IP mobility protocols have been proposed over the past several years to complement or enhance MIP over IPv4 networks (e.g., reverse tunneling in RFC 3024) as well as IPv6 networks (e.g., MIPv6 described in RFC 3775 and Hierarchical MIPv6 for localized mobility described in RFC 5380). More recently, network-based IP mobility solutions where the terminal is not directly involved in managing IP mobility (e.g., Proxy MIPv6 defined in RFC 5213) are also being introduced in wireless networks [7, 8].

Level D: Intersystem Seamless service Continuity-This level is aimed to satisfy service requirements also during mobility (i.e. to offer a seamless mobility experience). Seamless service continuity can be achieved by enabling mobile terminals to conduct seamless handovers across diverse access networks. The mechanism for realizing this include: Provision of inter-RAT configuration information about neighboring base station site (BSs), Inter-RAT measurements control and reporting, to improve handover initiation, Inter-RAT resource reservation, Inter-RAT resource availability knowledge [6 – 8].

On the other hand, the interworking architectures between heterogeneous wireless networks can be divided into two main categories: loose and tightly coupled architectures.

2.1 Loosely Coupled Architecture

In a loosely coupled architecture, interconnected wireless networks are relatively independent from each other in terms of handling data flows and signaling messages. There is a common component in all loosely coupled solutions, which is the adoption of Mobile IP as mobility management protocol to integrate multiple wireless networking systems [9]. A typical loosely coupled architecture is shown in Fig. 2.

2.2 Tightly Coupled Architecture

In a tightly coupled architecture, non-cellular wireless networks, such as IEEE802.11 based WLANs, are connected to the core network of cellular networks as access networks to provide cellular radio coverage. There are two common approaches to achieve mobility management in the closely coupled architecture, namely reuse of some functionality in cellular networks as the integration point and adoption of Mobile IP protocols.

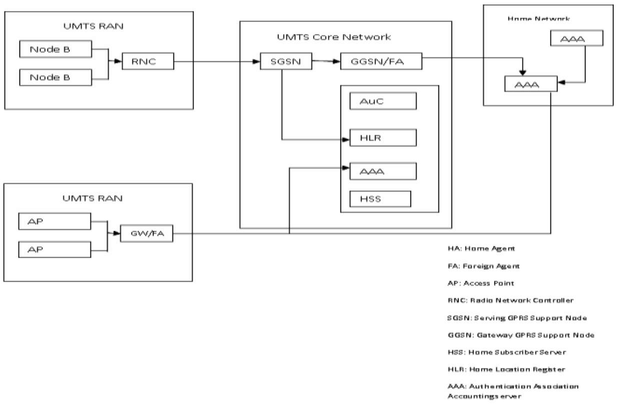

Figure 2: Loss Coupling Architecture

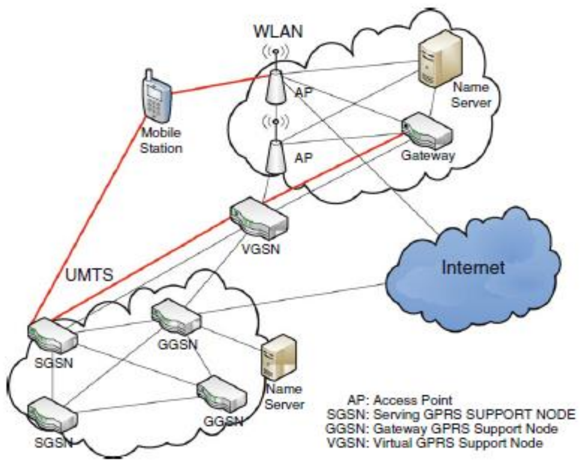

Figure 3: System architecture of GGSN-level coupling approach

In the first approach, some modifications need to be made to facilitate the additional wireless access technologies, while the other approach needs to deploy new network entities to implement Mobile IP functionality. According to different degrees of integration between cellular and non-cellular wireless access networks, solutions for the tightly coupled architecture can be categorized into the following three groups, namely coupling at Gateway GPRS Support node (GGSN) level, coupling at Serving GPRS Support Node (SGSN) level and coupling at Radio Network Controller (RNC) level. Among them, coupling at RNC level requires the tightest relationship between the two networks [10, 11].

2.2.1 Coupling at the GGSN Level

One of the tightly coupled solutions to support seamless roaming between UMTS and WLAN is presented in [12], which implements coupling at the GGSN level. In this architecture, as illustrated in Fig. 3, a new logical node, called the Virtual GPRS Support Node (VGSN), is designed to interconnect the UMTS and WLAN core networks. VGSN in UMTS networks acts as normal GPRS Support Node (GSN) and is also an access router in WLAN. The main tasks of VGSN are signaling conversion of subscriber/mobility information and data forwarding between the two heterogeneous networks. In this architecture, both networks are independent of each other and handle their own subscribers in coverage separately; VGSN serves as the point of integration to connect two networks. The main advantage of the GGSN-level coupling approach is simplicity, in terms of the interactions between two networks and the introduction of additional functionality.

2.2.2 Coupling at the SGSN Level

The key functional entity in the system is the GPRS Interworking Function (GIF), which is connected to a WLAN and to a serving SGSN as in fig 4. The main function of the GIF is to convert the WLAN functionalities to a unified interface to the core network of cellular networks, and to mask the technology heterogeneity of WLAN technology. From the perspective of cellular networks, WLAN is a special radio access network which consists of only one cell. To achieve this goal, the WLAN adaption function (WAF) is developed to identify the time when the WLAN radio subsystem is enabled and to inform the upper layers, which subsequently redirects signaling and data traffic to the WLAN.

The WAF is deployed in both mobile stations and on top of GIF functionality. WAF functionality includes hardware management service, location management service, QoS support services. The main advantage of this solution is the enhanced mobility support for roaming across two domains, entirely based on cellular mobility management protocols, which guarantee service continuity including authentication, authorization, accounting, billing systems and other data sources. Also by reusing the GPRS core network resources, the network deployment cost can also be reduced in terms of infrastructure [12].

2.2.3 Coupling at the RNC Level

The third type of coupling architecture, implements the integration of UMTS and WLAN networks at the RNC level. A new network entity, called Inter-Working Unit (IWU), is introduced between the RNC and WLAN, as shown in Fig. 5. The IWU functionality is on the network integration and radio access. Some of these modifications imply corresponding modifications of the protocol stack on the mobile terminal.

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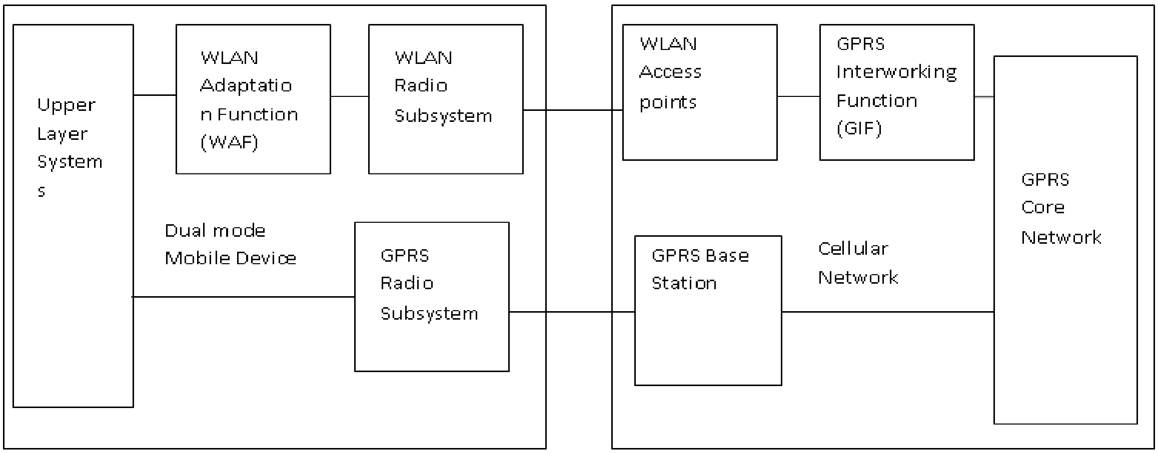

Figure 4: System architecture of SGSN-level coupling approach

The main advantage of this type of architecture is the significant reduction in handover latency, due to the tighter coupling design and functionality reuse in most entities of cellular networks. However, the main drawback is that the architecture is only suitable for network operators deploying both access networks due to the tighter correlation between the two networks. In addition, it requires functionality and protocol modification of both communication systems, which is more complex in system design and implementation [13, 14].

3. LTE BACKBONE FOR INTERWORKING IN A BROADBAND ENVIRONMENT

As user demand for mobile broadband services continues to rise, LTE and its ability to cost effectively provide very fast, highly responsive mobile data services have become ever more important. LTE which represents a significant shift from legacy mobile systems as the first all-Internet Protocol (IP) network technology have impacted the way networks are designed, deployed, and managed [15]. LTE uses Orthogonal Frequency Division Multiple Access (OFDMA) and advanced antenna techniques to maximize the efficient use of radio frequency spectrum with a purely Packet Switch (PS) core network. In addition, the transition to IP has enabled LTE to support Quality of Service (QoS) for real time packet data services like VoIP and video conversation [16]. LTE consists of two networks: the E-UTRAN and the EPC [17]. The result is a flat system characterized by its simplicity, a non-hierarchical structure for increased scalability and efficiency, and a design optimized to support real time IP-based services, higher data rates, and lower latency. It also provides support for interworking with several wireless access technologies. The evolved packet core (EPC) is a flat all-IP system consisting of six nodes: The Mobility Management Entity (MME) , the Serving Gateway (S-GW), the Packet Data Network Gateway (PDGW), the Home Subscriber Server (HSS), the Policy and Charging Control Function (PCRF) and the evolved Packet Data Gateway (ePDG). It allows for interconnections to legacy 3GPP technologies via the S-GW and to non-3GPP technologies via the PDGW to ensure Inter-technology handover and roaming. Thus the overall goal of LTE systems is to provide a converged network compatible (NGN) for broadband capabilities. It's interworking architecture with non 3GPP and 3GPP technologies are presented thus:

3.1 LTE –WLAN Interworking

The interworking of LTE and WLAN is very important to make wireless multimedia and other high data rate services a reality for mobile subscribers. A multimedia LTE/WLAN terminal can access high-bandwidth data services where WLAN coverage is offered, while accessing wide area networks using LTE in other places. To make multi-access solutions effective, we need an integrated solution to provide seamless mobility between these access technologies, allowing continuity of existing sessions. LTE/WLAN integration offers these capabilities seamlessly. The 3GPP has defined an interworking architecture between LTE and non-3GPP, classifying the non-3GPP as trusted and untrusted networks. In the context of LTE/WLAN interworking, the 3GPP considers the WLAN as an untrusted network since it is using unlicensed radio spectrum. This is why when integrating these two technologies, more functional entities have to be added in order to enforce the security mechanism between them. The network elements added to the WLAN network are a WLAN Access Gateway (WAG) and a Packet Data Gateway (PDGW) as in fig 6. [17]. While WAG allows a visited LTE network to generate charging information for users accessing via the WLAN access network, in the roaming case.

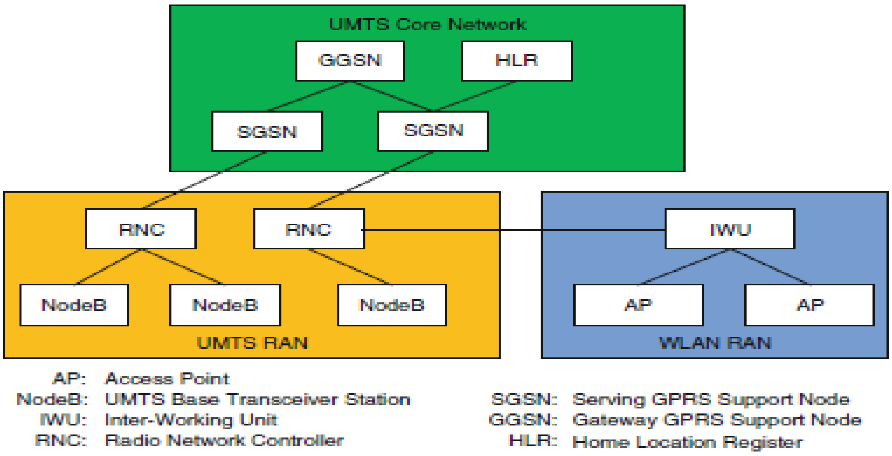

Figure 5: System architecture of RNC-level coupling approach

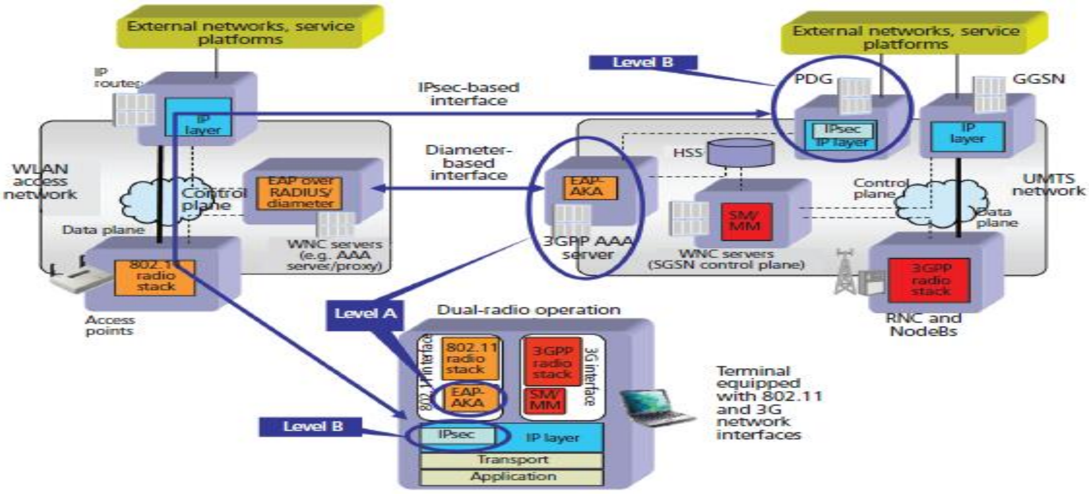

Figure 6: Architecture for WLAN and 3GPP LTE/SAE interworking [3]

It also filters out packets based on unencrypted information in the packets. PDG on the other hand accepts or rejects the requested WLAN access point name (W-APN) according to the decision made by the 3GPP AAA Server. The PDG basically behaves as a Gateway GPRS Support Node (GGSN) for WLAN users. It can use Wi-Fi hotspots to help the interworking between LTE and WLAN [16]. In this case, the interworking can provide better security and mobility but the mobile operators have to invest in a large number of Wi-Fi hotspots, to ensure a good user experience. The UE accesses the P-GW directly through the operator owned Wi-Fi hotspot using the S2a interface. The UE accesses the P-GW through the ePDG using the SWn (toward non-3GPP network) and S2b interfaces. The UE has to setup a secure tunnel with the ePDG through the untrusted WLAN network over the SWu interface (toward the UE) [3, 5, 8].

3.2 LTE –WiMAX Interworking

Mobile WiMAX has excellent capabilities in regard to supporting high data rates, the essential QoS and mobility ability, in addition to offering a wide area of coverage. Interworking between this technology and LTE as in fig 7, is considered as significant towards developing the 4G networks as it provides high data rates, better performance and additional features and services to the subscribers in both wireless networks. 3GPP and mobile WiMAX access are integrated through the EPC; the 3GPP side uses SGW for supporting this interworking while WiMAX uses PGW for the same reason. The SGSN in the legacy network connects to the SGW. A new entity in EPC called the Access Network Discovery Support Function (ANDSF) is used to help E-UTRAN discover the target access. Since the mobile WiMAX and the LTE networks have different protocol architectures and QoS support mechanisms [15], protocol adaptation is required for their interworking. For example, with a Layer 2 approach, adaptation would be required in the Medium Access Control

(MAC) layer for the WiMAX Base Station (BS) and LTE eNodeB. With a Layer 3 approach, the adaptation would be performed at the IP layer, and an LTE user would interact only with the corresponding LTE S-GW. Thus Layer 3 approach is preferred for WiMAX/LTE interworking, since LTE S-GW can fully control bandwidth allocation among the LTE users. The SGW in LTE is responsible for the protocol adaptation up to the IP layer; modifications of LTE User Equipment (UE) and the WiMAX BS are not required. The required LTE access network may be owned either by the WiMAX operator or by any other party, which then requires proper rules and Service Level Agreements (SLAs) set up for smooth interworking on the basis of business and roaming agreements between the LTE and mobile WiMAX operators. The interworking architecture is required to support automatic selection of the appropriate network, based on Mobile Terminal (MT) preferences. The Mobility Management (MM) procedure provides a mechanism to minimize the service interruption time and support service continuity in addition to minimizing the impact on the legacy systems (GERAN, UTRAN) and the UE using the S14 interface. The S2a and S2c are used to control and provide mobility with WiMAX because WiMAX is considered from the 3GPP point of view as a trusted non-3GPP wireless network. The S101 interface also plays an important role by connecting the LTE-MME with the WiMAX Access Service Network (ASN) [3, 8, 9]. LTE –UTRAN/GERAN Interworking: Many of the wireless operators have existing UTRAN/GERAN networks and they want to keep them prior to fully upgrading to LTE.

They prefer to interwork their networks with LTE network so LTE will be an overlay in their current architecture. So MMEs and the EPC gateways need to develop the pre-Release 8 signalling and bearer interfaces, acting like the existing SGSNs and GGSNs, to support handover between the networks. In the case of using Direct Tunnelling, then an additional interface is required from the PGW to the RNC without connecting to the SGSN. The bearer path connecting the E-UTRAN and UTRAN networks as shown in fig. 8 is between the PGW and the SGSN. All of the Gn/GP interfaces utilize GTP.

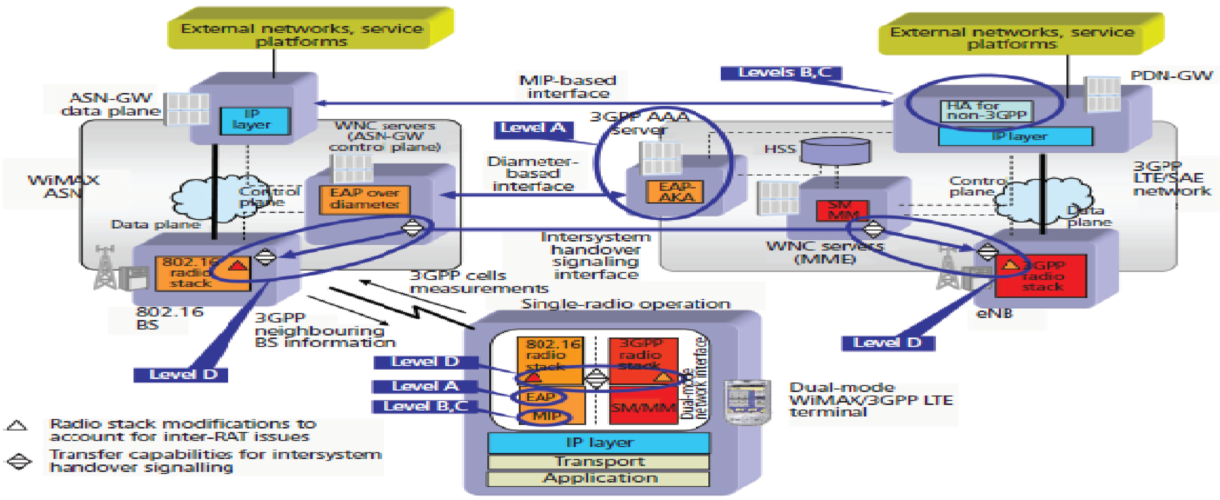

Figure 7: Architecture for WiMAX and 3GPP LTE/SAE interworking [3]

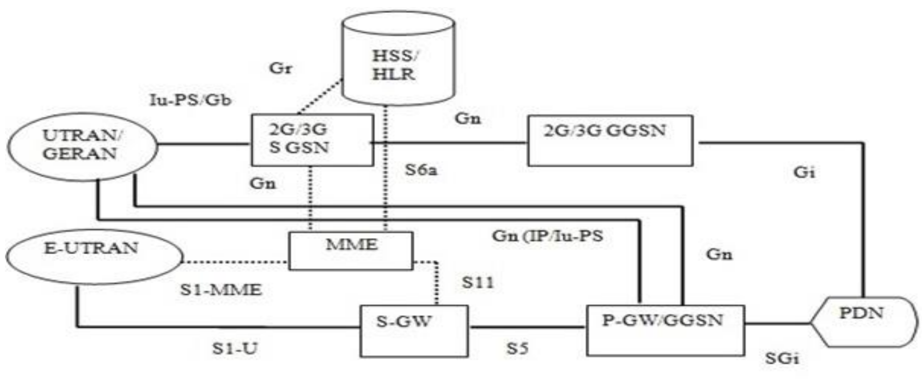

Figure 8: Architecture for E-UTRAN Interworking with GERAN/UTRAN [8]

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 handover occurs. The handover mechanisms between an 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 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 P-GW 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. As with the previous option, this interworking requires no changes to the existing UTRAN/GERAN networks and the preparation phase and execution phases of the handover procedures are very similar. 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.

3.3 LTE –HRPD/ EV-DO Interworking

Seamless transition between 3GPP2 based cdma2000® and LTE is required to provide interworking between them. This interworking provides current subscribers in 3GPP2 based cdma2000® more new features. Here, in order to make the interworking between cdma2000® High Rate Packet Data (HRPD) and LTE, many interfaces are introduced such as S101, S103, and S2a to realize the interworking between them as shown in fig. 9. The Packet Data Serving Node (PDSN) is split into HRPD Serving Gate Way (HS-GW) and PDN-GW. The new required interfaces for this integration are: The S103 bearer interface between EPC S-GW and HS-GW, is used to forward the downlink data, minimizing the packet loss during the transfer from LTE to HRPD. The S101 signaling interface between MME and HPRD AN, allows a UE to tunnel HRPD air interface signaling over the LTE system to make preregistration and exchange handover signaling messages with the target system before the actual handover. The S2a interface, which is between PDN-GW and HS- GW, provides control and mobility support for the user plane. HRPD enables Inter-technology handover between LTE and EV-DO networks based on HRPD. It also enables roaming for LTE subscribers on EV-DO networks and enables common applications to be used across EV-DO and LTE Access.

4. NEXT GENERATION NETWORK ARCHITECTURE AND CONVERGENCE OF HETEROGENEOUS NETWORKS

Next Generation Network (NGN) aims at integrating several heterogeneous networks in a bid to provide users with ubiquitous broadband experience. NGN has been built up on the heterogeneity concept in the presence of multiple traditional networks such as the fixed PSTN/ISDN, 3.9G, 3.5G, 2G mobile networks and the internet. The motivation for NGN is to provide a central platform through convergence of multiple networks. NGN, which is envisioned to reshape the present communication systems structure by, transformed the present structure of vertically independent, although interconnected, networks into a horizontal structure of networks based on IP. The aim is to bring all existing networks with different transport and control technologies into a unique, unified and multi service platform based on an IP [13]. The growing trends of telecommunication de-regulation and rapid convergence of distributed computing and communication are the two main factors for the development of this future network. The overall purpose of this network is to cut costs, create new income sources and provide ubiquitous of next generation broadband services experience to users [14].

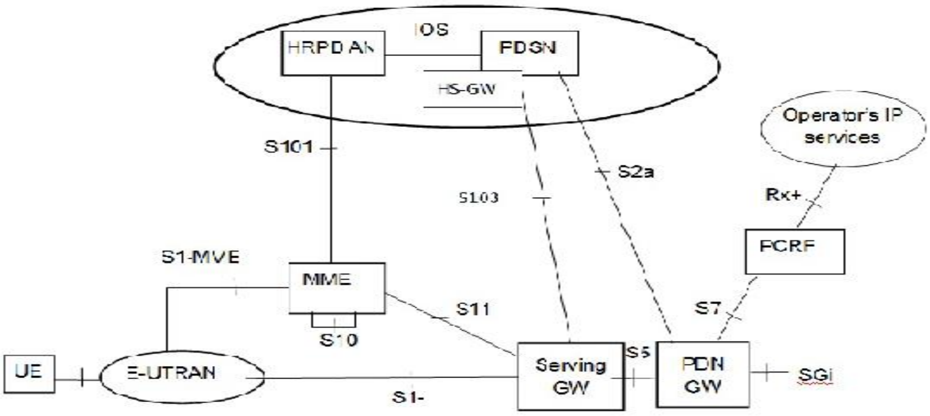

Figure 9: Architecture for E-UTRAN-HRPD Interworking and Mobility [8]

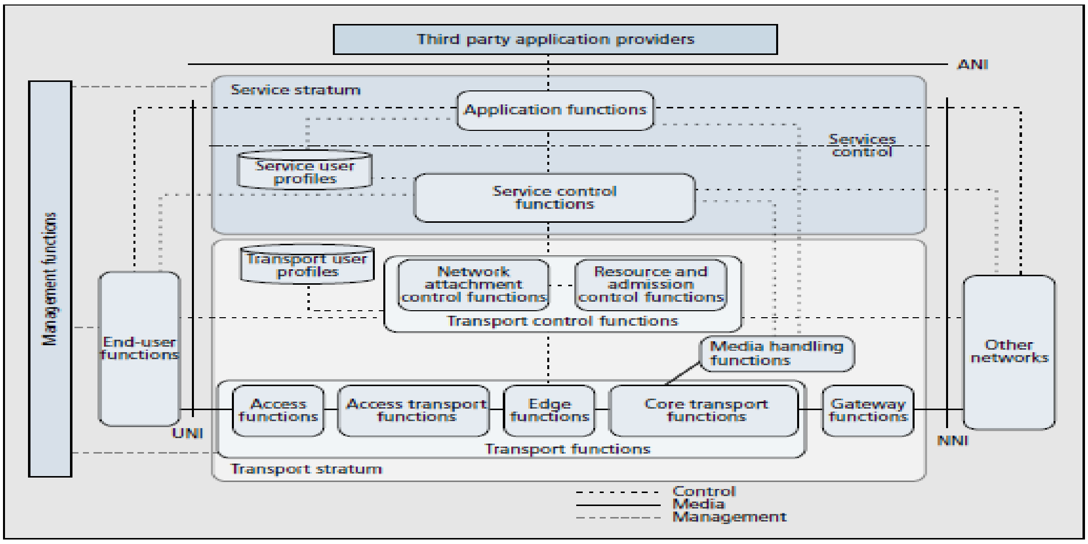

Figure 10: NGN architecture overview at ITU-T [17].

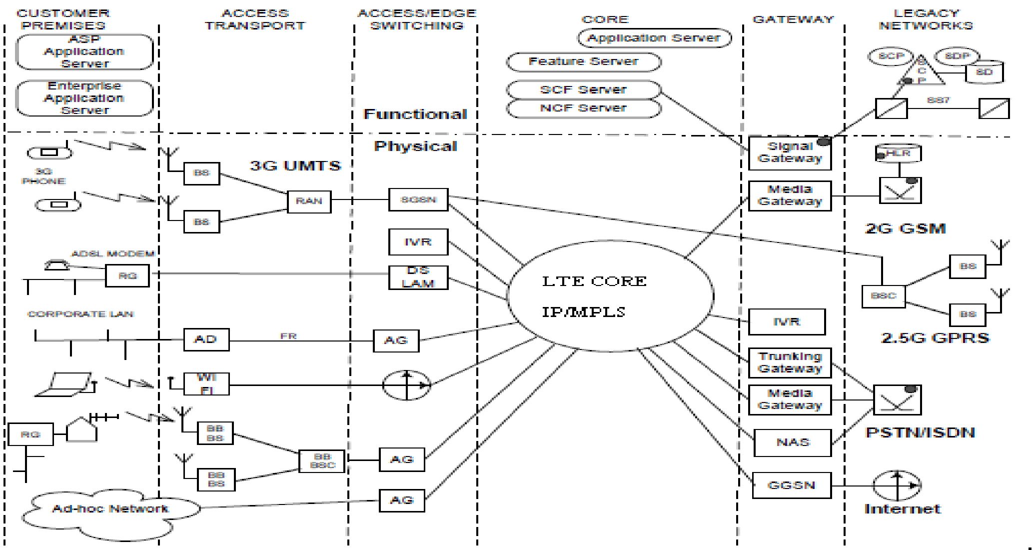

Figure 11: Heterogeneity environment of NGN and relation with LTE as core backbone network [14]

It is able to provide telecommunication services and use multiple broadband QoS enabled transport technologies. It enables unfettered access for users to networks and competes for service providers and or services of their choice. Also, it supports generalized mobility that will allow consistent and ubiquitous provision of services to users [15]. Figure 10 shows an overview of the NGN architecture. Its functions are divided into service and transport strata according to Recommendation Y.2011 [16]. IP is recognized as the most promising transport technology for NGN. The transport stratum will provide IP connectivity for both end-user equipment outside the NGN, and controllers and enablers that usually reside on servers inside the NGN.

It is also responsible for providing end-to-end QoS, which is a desirable feature of the NGN. The transport stratum is divided into access networks and the core network, with a function linking the two portions. Brief descriptions of the transport function are given as follows:

4.1 Access Functions\

This is a sub function of transport functions in the transport layer connecting with end user functions. This function depending on the access technology supported by the transport layer is used to manage end user access to an NGN network. The Access transport functions lie in the category of transport functions in transport layer. It deals with QoS control mechanisms such as buffer management, queuing, scheduling, packet filtering, traffic classification, marking, policing and traffic shaping having direct relation with user traffic [15, 17].

4.2 Core Transport Functions

The core transport functions are responsible for information transportation through the core network in the transport layer. Different parameters are used for differentiation of quality of transport through the interaction with transport control functions. It also handles user traffic directly on the basis of QoS mechanisms such as buffer management, queuing, scheduling, packet filtering, gate control and firewalls etc. [15, 16, 17]. In Figure 11, multiple networks with different services have converged on the single platform called core network or NGN. The NGN infrastructure is divided into different categories such as legacy networks like 2G GSM, 2.5G GPRS, 3G, 3.5G, 3.9G, 4G and PSTN/ISDN. Gateways such as signal gateway, media gateway, IVR, trunking gateway, NAS, and GGSN are used for connection establishment between legacy networks and core network. The core network is responsible for the provision of multiple services with the quality of service (QoS) in the presence of packet transport network. The transport layer separates the service and connection control implemented in a soft switch. Currently, the existing traditional networks are in the transition phase of transforming their infrastructure to adopt new innovative services with a better quality of service and lower cost. There are many services linked with the existing next generation network platform but some require its advanced control and management features. The unified, converged NGN services are linked with access, transport and routing services [18 - 22]. LTE suits as the appropriate backbone network for the core of NGN as it provides efficient ubiquitous broadband support all converged network (i.e. legacy and non-legacy network).

5. CONCLUSION

This paper has been able to give an overview of Interworking in wireless communication network. It was also able to identify the different interworking levels: based on network architecture and operational capabilities. Also, we were able to carry out a critical review of interworking in a broadband driven environment. We were able to establish that LTE currently serves as the most efficient backbone or Core network for integration of other heterogeneous network in a broadband driven environment. We identify different interworking architecture between LTE and other networks i.e. 3GPP and non 3GPP (trusted and untrusted). Furthermore a broader review was done on NGN, which is an architecture aimed at integration of several heterogeneous networks in a bid to provide users with ubiquitous broadband experience. We further establish that LTE best provide the capacity for backbone support for this overlay of networks, as it provides broadband capacity with high efficiency, reduced latency improved capacity and seamless mobility management and resource provisioning.

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