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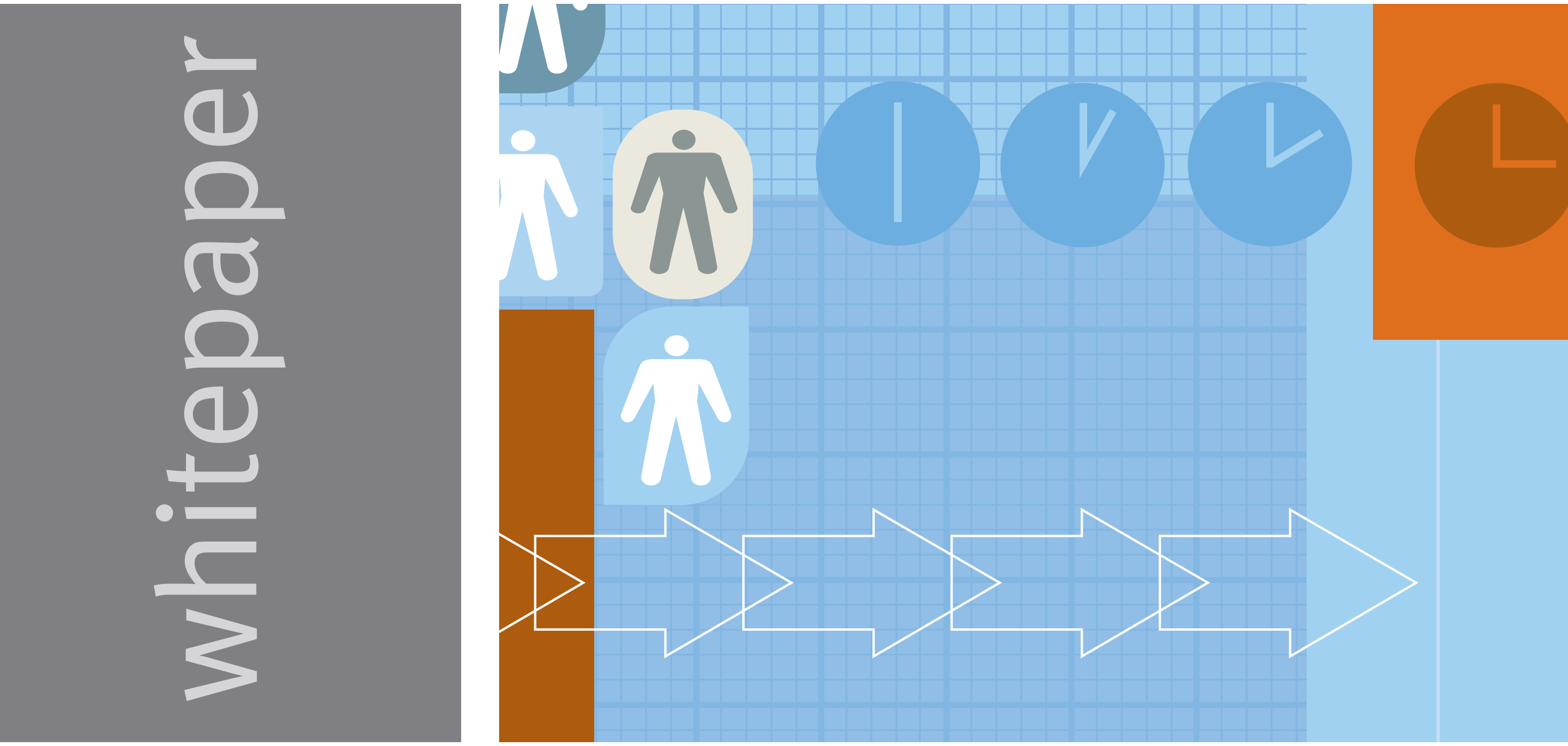

Evolving IP-IP Gateways to Multi-Access Convergence Gateways for LTE/SAE Systems

Table of Contents

Executive Summary

Analysis Research Limited in their report on “Market Potential for 3G LTE”, January 2008, reports that by 2015 Mobile Broadband usage will grow up to a staggering 5 billion users worldwide and Long Term Evolution (LTE) alone will contribute 9% to this number (450 Million users). LTE revenues will account for around 16% of the total mobile revenues by 2015 (EUR 150 billion). As per Universal Mobile Telecommunications Systems (UMTS) Forum Report 41 “The Market Potential for LTE”, a significant portion of these revenues will come from non-voice bandwidth-intensive mobile data traffic, as in Mobile Commerce (M-commerce), data networking, content messaging, games, television, music, browsing, paid information, personalization, peer-to-peer (P2P) messaging etc. Called as the harbinger of the All IP Network (r)evolution, LTE demands a totally new packet core infrastructure that is simple but supports higher data rates and lower latencies and is also optimized for packet traffic.

This paper discusses the main components of the Evolved Packet Core of LTE, and the possible migration paths that existing IP-IP Gateway vendors can pursue to offer the EPC functions.

IP-IP Gateway vendors can leverage Aricent product consulting, development, and integration testing expertise in datacom and wireless access technologies to evolve their legacy IP Gateways to Multi-Access Convergence Gateways as a possible strategic deployment option.

1 Introduction

The word “Communication” alone is insufficient to express the next generation services expected by the end users. What the end user needs is “Enriched, Interactive and Personalized Experience”. Such experience is an amalgam of multimedia communication, information, location, presence, entertainment, business, and lifestyle applications. Such experience must be consistently and continuously visible, accessible and consumable through any device (personalized or shared), at anytime, from anywhere. Personalized devices include mobile phones, personal digital assistants (PDAs), laptops, office desk phones, while examples of shared devices could be television, home PCs, café PCs, residential phones, and conference phones.

The Internet has shown the power of IP as an underlying transport technology. Today, the Internet is flooded with applications, free or paid, that satisfy, to a great extent, the Enriched, Interactive and Personalized Experience that the user seeks. However, these experiences have been traditionally confined to fixed devices with wireline connection or through wireless connection, such as Wi-Fi, with limited mobility.

Further, in order to increase average revenue per user (ARPU), wireline operators are migrating to All IP Networks (AIPN) so that they can offer triple play services - voice, video and data to end users. They also see this as a way to reduce operational expenses.

Wireless operators are under intense pressure to offer compelling next generation services to provide a personalized user experience for mobile users. They first introduced GPRS/EDGE services that introduced packet switching and connected the mobile device to the Internet over IP. The pursuit for higher data rate, higher capacity, higher throughput, lower latency, better spectrum efficiency and flexibility, diversified mobile speed and greater coverage over cellular, resulted in GPRS/EDGE (2.5/2.75G) evolving to UMTS (3G) to HSPA (3.5G) to HSPA+ (3.75G). Compared to a data rate of 180 kbps in EDGE, HSPA+ promises data rates of 42 Mbps downlink and 22 Mbps uplink. Clearly the trend indicates that the mobile phone will soon support broadband speeds. Now, with the advent of LTE (3.9G or Super 3G), mobile broadband just got broader.

2 The Evolved Packet Core System

3GPP has not only evolved beyond addressing the Universal Terrestrial Radio Access Network (UTRAN) requirements to providing bandwidth intensive services. It has also put in a significant effort to evolve and simplify the packet core network. Branded as System Architecture Evolution (SAE), 3GPP has proposed a framework to evolve the 3GPP system to a higher data rate, lower latency, packet-optimized packet core system (Evolved Packet Core) that supports multiple access technologies, including 3GPP Internet Protocol Connectivity Access Network (IP CANs) like GSM EDGE Radio Access Network (GERAN), UTRAN and Evolved UTRAN (E-UTRAN) and non-3GPP IP CANs like WiFi, WiMAX and even wired technologies. This access independent evolution of the packet core system architecture is the first major step towards the realization of an All IP Network (AIPN).

Figure 1 illustrates the functional decomposition of the Evolved Packet Core for 3GPP and non-3GPP IP CAN. The EPC architecture is guided by the principle of logical separation of the signaling and data transport networks. The fact that some EPC functions reside in the same equipment as some transport functions, does not make the transport functions a part of the EPC. It is also possible that one physical network element in the EPC implements multiple logical nodes.

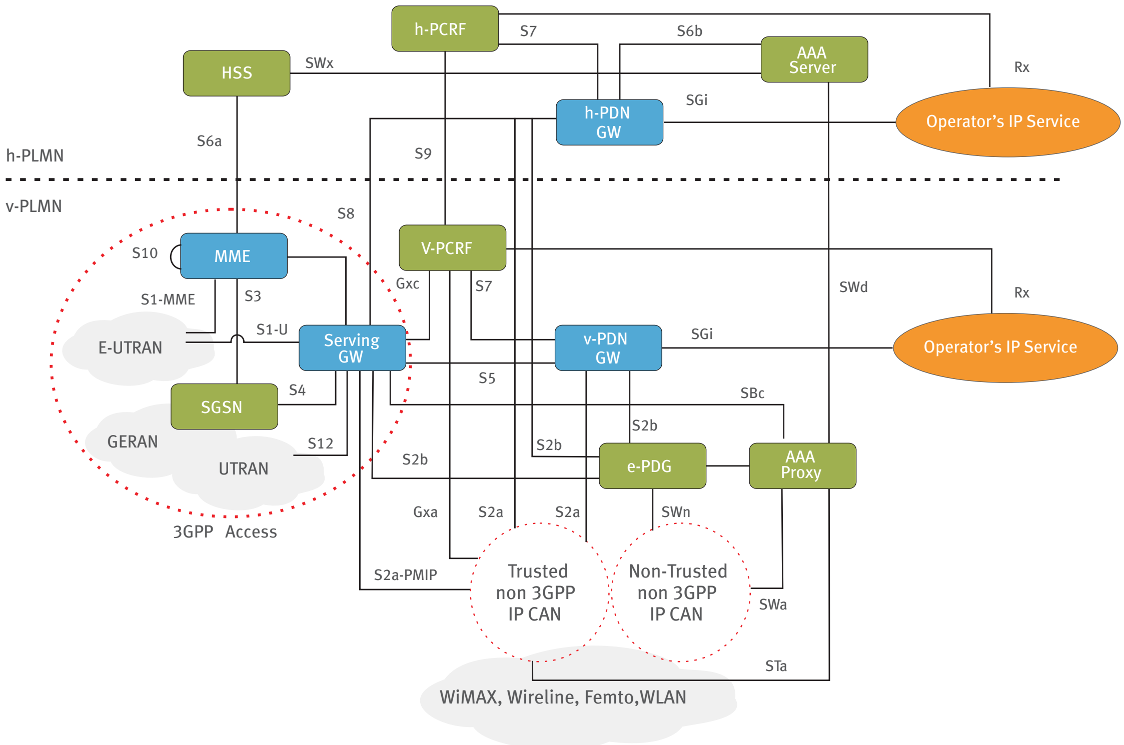

Figure 1: Evolved Packet Core System Architecture

3 Mobility Management Entity

As shown in Figure 1, the Mobility Management Entity (MME) is the control plane function within the EPC that primarily terminates the Non Access Stratum (NAS) signaling messages, including the security of the NAS signaling, from the E-UTRAN access. It is responsible for mobility and session management functions of the E-UTRAN UE.

3.1 EPS Mobility Management (EMM) Functions

The EMM functions include support for:

- Maintenance of the User Equipment's (UE's) mobility management states
- Globally Unique Temporary Identity (GUTI) reallocation procedure
- UE authentication procedure
- NAS security procedure
- UE identification procedure
- Evolved Packet System (EPS) service request procedure
- EPS Mobility Management (EMM) information procedure
- UE attach and detach procedures
- Tracking area list management and tracking area updates
- Paging procedure

3.2 EPS Session Management (ESM) Functions

The ESM functions include support for:

- Maintenance of the UE's bearer context states
- IP address allocation procedure (via NAS signaling, via dynamic host configuration protocol (DHCP))
- Procedures for network initiated default and dedicated bearer context activation, modification and deactivation
- Procedures for UE initiated PDN connect and disconnect; bearer resource allocation and de-allocation

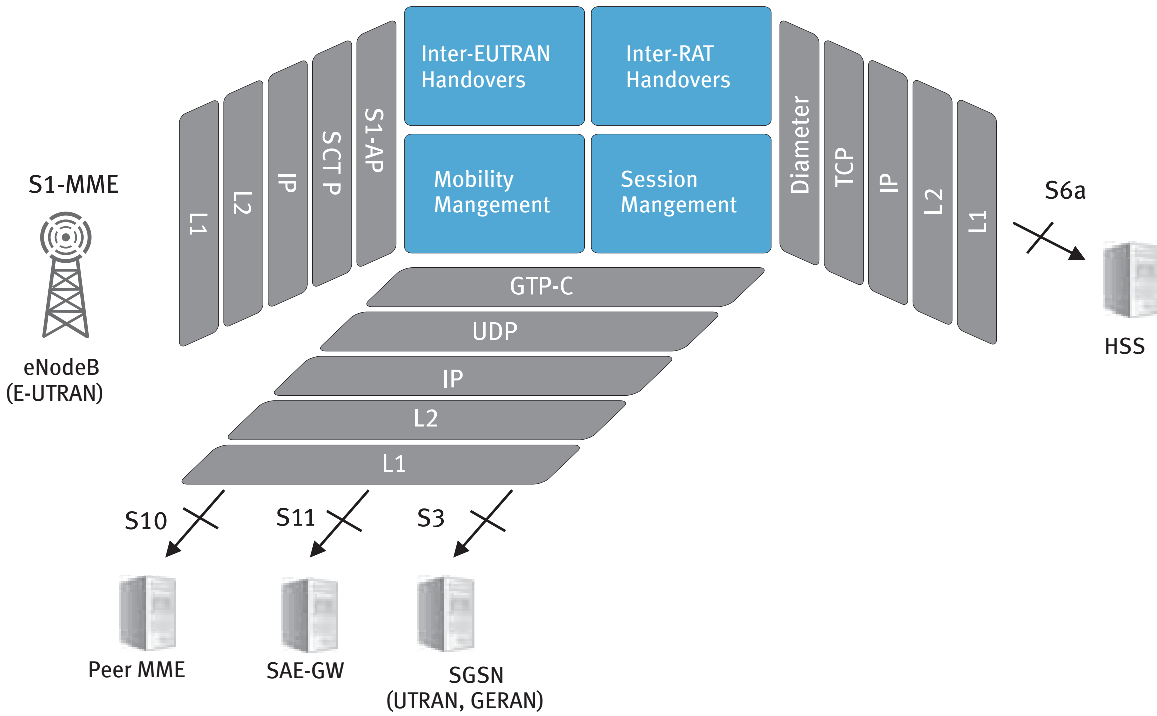

Figure 2: Mobility Management Entity (MME) Architecture

The MME is the signaling focal point for intra-EUTRAN mobility and handovers (as shown in Figure 2). As the LTE and EPS architecture allows an E-UTRAN (essentially eNodeB) to connect to multiple MMEs and Serving Gateways (S-GW), multiple handover schemes are possible namely, Inter-eNodeB handover with and without MME relocation in the control plane, combined with or without relocation of Serving Gateway in the user plane. The MME-MME S10 interface facilitates MME relocation. The MME also acts as the signaling anchor for 3GPP inter-RAT (GERAN and UTRAN) mobility, terminating the S3 interface from the UTRAN/GERAN Serving GPRS Support Node (SGSN).

4 Multi-Access Convergence Gateways

The EPS specifies two types of IP-IP Gateway logical functions for the user plane – the Serving Gateway (S-GW) and the PDN Gateway (P-GW). The S-GW and P-GW are core network functions of the E-UTRAN based access. They may be implemented in one physical node or in separate physical nodes. Early deployments are likely to see a single node implementation of S-GW and P-GW functions with future proof design to decouple these functions such that S-GWs in visited networks can connect to P-GWs of home networks for home PLMN routed IP services.

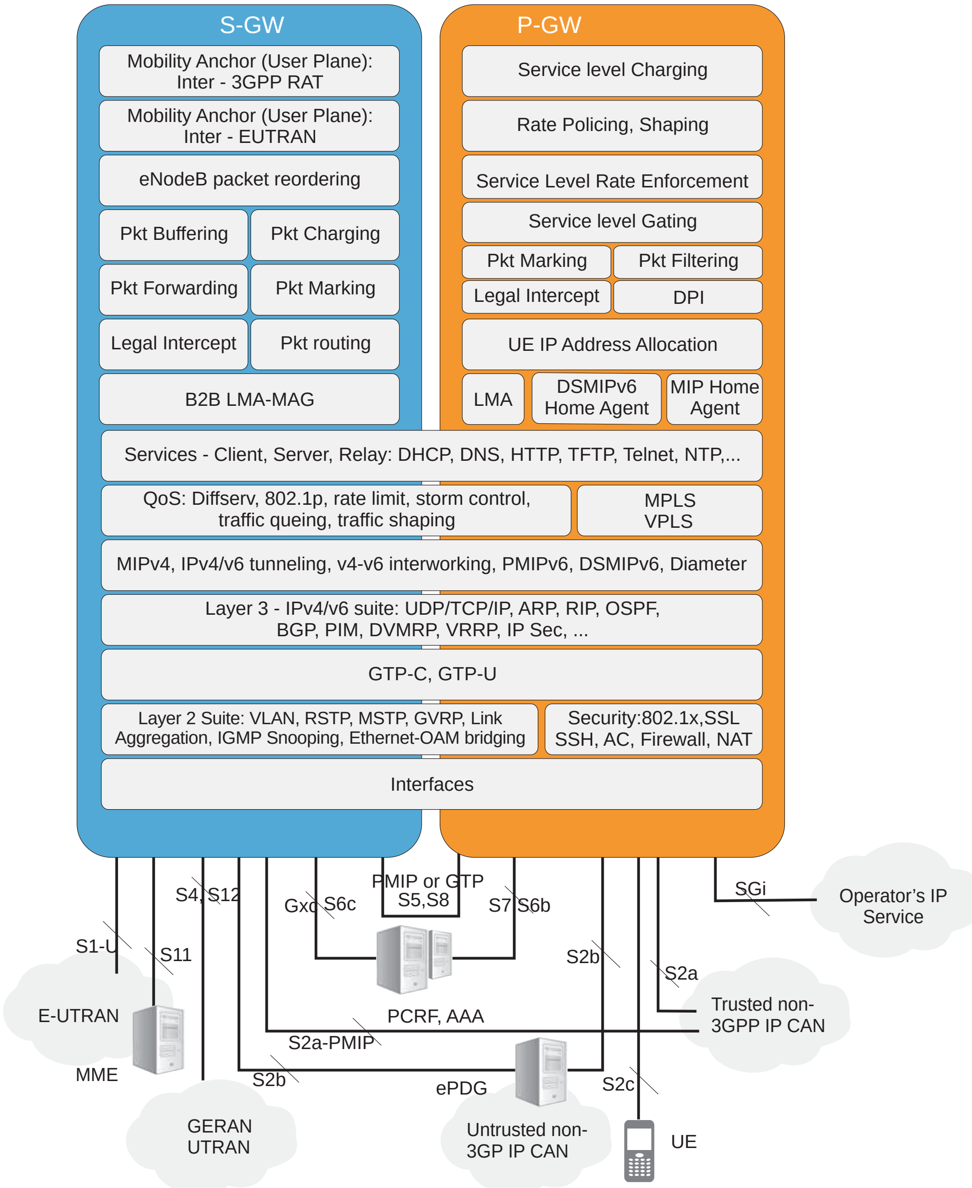

Figure 3: SAE Gateway (S-GW) and PDN Gateway (P-GW) Architecture

As shown in Figure 3, both the S-GW and P-GW are built on core datacom routing and switching technologies supporting the Layer 2 and Layer 3 suite of an All IP Network. Therefore, it is anticipated that the S-GW and P-GW are logical migration and evolution paths for the traditional IP-IP Gateway product lines. Each IP-IP Gateway vendor will have their own hardware and platform USP that supports line-rate switching and packet forwarding with very low latency of high volume IP traffic.

There exists a striking similarity between the S-GW and P-GW functions. Other than the commonality at the core datacom layer, they both act as the Policy Enforcement Points (PEP) for dynamic QoS policies. While the S-GW is dedicated to policy and QoS enforcement at packet level, the P-GW functions as the PEP at the service level. On the charging front, both the S-GW and P-GW have a role to play. While the S-GW is involved in generating charging records at packet level, the P-GW takes up the responsibility for producing charging records at service level. Deep Packet Inspection and Legal Intercept are dedicated functions of the P-GW, but nothing prevents the S-GW from implementing these functions as well.

Given that the S-GW is the direct interface point for E-UTRAN eNodeB (S1-U interface), functions such as inter-E-UTRAN mobility anchoring for the user plane (coordinating with the MME) and eNodeB packet reordering are exclusively meant for S-GW implementation. Since the S-GW directly interfaces with the GERAN and UTRAN networks (S4 and S12 interfaces), it also acts as the anchor point for inter-3GPP RAT mobility.

The P-GW on the other hand is primarily responsible for the IP address allocation of the UE in the AIPN and acts as the anchor point for mobility across the non-3GPP IP-CANs (for both trusted and non-trusted).

For network based mobility, the P-GW acts as the Gateway Local Mobility Anchor (LMA) terminating Proxy Mobile IPv6 (PMIPv6) for the control signaling and IPv4/IPv6 tunneling for the user plane. This corresponds to the S2a and S2b interfaces for the trusted and non-trusted non-3GPP IP-CAN respectively, where the non-3GPP IP-CANs directly terminate into the P-GW, bypassing the S-GW (as in the case of the non roaming architecture for EPS or home routed architecture or the case of local breakout within the visited PLMN). The trusted or non-trusted non-3GPP IP-CAN typically emulates the MAG function of the network based mobility architecture. For deployment architectures where the S-GW is in the path of the chained home routed solution, the S-GW additionally plays the role of a back-to-back Gateway LMA and MAG function. In such scenarios, the S2a and S2b interfaces from the trusted and non-trusted non-3GPP IP-CAN respectively, are routed to the P-GW via the S-GW.

There are two deployment models to address host-based mobility. In the first deployment model, the S2a and S2b interfaces are based on MIPv4 technology. The P-GW acts as a MIPv4 Home Agent and the trusted and non-trusted non-3GPP IP-CAN provide the Foreign Agent function for the Mobile Node (the UE). The user plane is based on the tunneling of end-to-end IPv4 over transport IPv4. The second deployment model assumes that the UE is capable of acting as a DSMIPv6 client and the P-GW is the DSMIPv6 Home Agent. All other nodes in the network are IP Access router systems. This deployment model applies to both 3GPP and non-3GPP IP-CANs (the S2c interface between the UE and the P-GW).

The formal interface between the S-GW and the P-GW is called S5 (where S-GW and P-GW are within the same PLMN) and S8 (where S-GW belongs to visited PLMN and the P-GW to the home PLMN). The S5 and S8 interfaces are otherwise functionally similar. There are two protocol options for these interfaces. The first option is to support GTP tunnels between S-GW and P-GW, GTP-C for control signaling and IP tunneling over GTP-U for the user plane. This typically applies to 3GPP access deployments, where the S-GW acts as a GTP-U relay between the 3GPP access network and the P-GW. If the UE over the 3GPP access network supports DSMIPv6, then it is possible to run the S2c interface over GTP over the P-GW and S-GW connection.

The second deployment model allows PMIPv6 to run as the control signaling protocol on the S5 and S8 interfaces. For 3GPP access, this implies that the S-GW terminates the GTP-U tunnels and tunnels user IP over transport IP towards P-GW. Initial deployments will possibly start with non-roaming architectures, with the S-GW and P-GW interface being initially S5 focused. Additionally, equipment vendors will be looking into collapsed S-GW and P-GW functions within a single physical node. Hence, vendors are likely to start implementing the S5 interface as proprietary lightweight implementations. However, the interface design must be future proof to make a way for the more formal S5 interface and to evolve to the S8 interface for decoupled S-GW and P-GW solutions, as operators start insisting on roaming architectures and home PLMN routed IP services.

Both the S-GW and P-GW will have Diameter interfaces towards network hosted Policy and Charging Rules Functions (PCRFs) and Service-based Policy Decision Functions (SPDFs)/Radio Access Control Functions (RACFs). The Diameter based Gxc and S7 interfaces control the Policy and Charging Enforcement Function (PCEF) within the S-GW and P-GW functions. It is also likely that the operator network may not have a centralized Policy Decision Point – in this case the S-GW and P-GW must be in a position to accept dynamic policy and QoS decisions from distributed PDPs in the network after implementing a local PDP within the Gateway for resolving policy conflicts. The Gateways must also realize the Diameter interfaces (S6b and S6c) towards external AAA functions for non-3GPP accesses.

5 Evolving IP-IP Gateways to Multi-Access Convergence Gateways

Next Generation Multi-Access Convergence Gateways will play a very important role in the next generation networks. Multi-Access Convergence Gateways will pave the way for operators to increase ARPU with a simplified network architecture and a single point of control for multi-access mobility, charging, policy and QoS. Hence, it can be expected that the legacy IP-IP Gateway vendors will evolve their platforms to such Multi-Access Convergence Gateway solutions. This evolution poses challenges around supporting diverse packet path functions while honoring the platform scalability, feature flexibility, solution availability and stringent performance requirements. The IP-IP Gateway vendors will want to leverage their existing core Intellectual Property Rights (IPRs) in the IP Gateway space to evolve their IP-IP Gateway product lines for multi-access solutions.

5.1 Leveraging Existing IP-IP Gateway IPRs

Today's IP-IP Gateways already have the base infrastructure to evolve to a Multi-Access Convergence Gateway. Firstly, there is a high likelihood that the gateways are already equipped with the hardware and horsepower to route, switch and forward IP traffic. Such platforms already have the redundant, highly available and scalable middleware. They have the entire Layer 2 and Layer 3 suite, along with security and QoS features that are essential components to develop a Multi-Access Convergence Gateway. They also have the generic IP services built in functions such as the client, server and/or relay/proxy functions for DNS, DHCP, NTP, HTTP, TFTP, Telnet etc. Legal Intercept (or Lawful Intercept), a regulatory feature, is expected to be a standard feature of the IP-IP Gateways. Most of the IP-IP Gateways have already started offering some form of Deep Packet Inspection – essential for rolling out operator specific policies. In addition, there is the entire manageability framework for FCAPS. Some IP-IP Gateway platforms already support Mobile IP (Foreign Agent and/or Home Agent function) and IP tunneling. Diameter support is also expected on these IP-IP Gateway platforms.

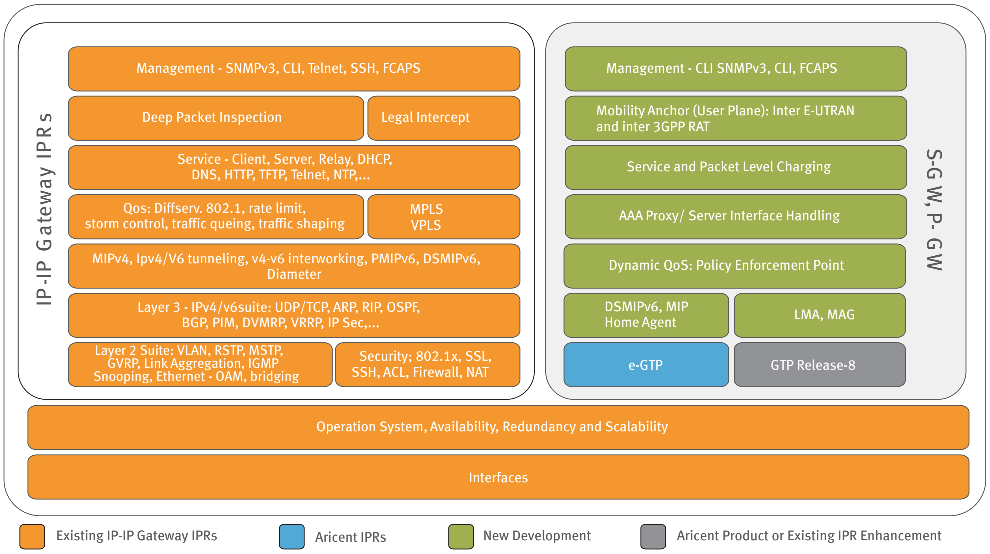

Figure 4: Migrating IP-IP Gateway to S-GW/P-GW

5.2 S-GW/P-GW as 3GPP E-UTRAN Access

The S-GW/P-GW can be positioned exclusively as the E-UTRAN/LTE access. For example, a pure wireline operator planning to offer mobile broadband services to its subscribers can deploy S-GW/P-GW as an E-UTRAN/LTE access.

In addition to leveraging all existing IPRs within the IP-IP Gateway, the GPRS Tunneling Protocol (GTP) feature is necessary to satisfy the LTE access gateway positioning. 3GPP defines two kinds of GTP interfaces for the S-GW/P-GW – the Enhanced GTP or eGTP and GTP Release-8. The support for eGTP for the control plane (GTP-C) is necessary to satisfy the interface requirements between the MME and S-GW (S11 interface) and between S-GW and P-GW (S5 and S8 interfaces). The support for eGTP for the user plane (GTP-U) is necessary to meet the interface requirements between the eNodeB and the S-GW (S1-U interface) and between the S-GW and P-GW (S5 and S8 interfaces).

In a collapsed S-GW/P-GW implementation, the S5/S8 interfaces are inside the LTE access gateway. Hence, the S5/S8 eGTP interface and procedures, including the GTP-U relay procedures of the S-GW function, are not exposed to the LTE access gateway. Therefore, implementation is needed (Inter E-UTRAN Mobility Anchor for User Plane, Figure 4) to terminate the session/bearer management procedures instructed by the MME (S-GW behavior) and to terminate GTP-U user plane tunnels (P-GW behavior).

The IP-IP Gateway platform has all the ingredients for dynamic QoS and policy realization – uplink/downlink bandwidth control, burst size control, next hop forwarding rules, packet marking, traffic shaping, gate/rate/flow control, source filtering, transcoding/transrating etc. It collects charging records at packet and service level. It also supports Diameter interface. The missing elements are the Policy and Charging Enforcement Function (Dynamic QoS: Policy Enforcement Point and Service and Packet Level Charging, Figure 4) within the access gateway and the compliance to the corresponding Diameter based interfaces namely, the Gxc interface between the PCRF and S-GW for packet level QoS/charging and the S7 interface between the PCRF and P-GW for service level QoS/charging.

The entire S-GW/P-GW solution can be designed in such a way that it easily adapts to the IP-IP Gateway platform's availability, redundancy, scalability and manageability infrastructure.

5.3 S-GW/P-GW as 3GPP UTRAN/GERAN Access

Besides being positioned as an E-UTRAN access, the S-GW/P-GW can also act as an access gateway for GERAN/UTRAN accesses. For instance, the S-GW/P-GW can act as an access gateway to provide seamless mobility to subscribers across all the 3GPP accesses when a 3GPP GERAN/UTRAN operator migrates towards LTE.

The additional feature that is required in the S-GW/P-GW is the support for the eGTP based S4 and GTP Release 8 based S12 interface and procedures towards GERAN/UTRAN (Inter 3GPP RAT Mobility Anchor for User Plane, Figure 4).

5.4 S-GW/P-GW for non-3GPP Trusted and Non-Trusted Access

The positioning as an access gateway for non-3GPP accesses (WiFi, Wireline, WiMAX, Femto, etc.) truly makes the S-GW/P-GW a Multi-Access Convergence Gateway. The additional features that are required are Mobile IP and authentication/QoS profile retrieval from the external AAA Proxy/Server for non-3GPP accesses (S6c and S6b interfaces).

In a collapsed P-GW/S-GW implementation, the PMIP based S5-S8 interface is internal and is not exposed outside the gateway solution. It can be a proprietary implementation, for early deployments, but must be architected to evolve to the formal PMIP implementation.

The features that are externally exposed and need additional implementation are the support for P-GW specific Gateway LMA function for PMIPv6 (the back-to-back LMA-MAG function can be deferred, considering a collapsed S-GW/P-GW solution) and P-GW specific Gateway Home Agent behavior for MIPv4 and DSMIPv6. These enhancements will satisfy the S2a, S2b and S2c interface compliance, respectively, to the trusted non-3GPP IP CAN, non-trusted non-3GPP IP CAN (through ePDG), and host based mobility of the UE.

6 Conclusion

With Multi-Access Convergence Gateways set to play a vital role in Next Generation Networks, there are many challenges faced by the existing IP-IP Gateway platform vendors. However, with the advent of LTE, that promises simplified network architecture, the IP-IP Gateway vendors can turn these challenges into opportunities. They can leverage their intellectual property to evolve the IP-IP Gateways into Multi-Access solutions and become a strategic part of LTE.

7 Aricent as a Partner for LTE and Multi-Access Convergence Gateway Development

Aricent's professional services experience, both in datacom and wireless access technologies, uniquely positions us as the partner of choice for co-creating and evolving traditional IP Gateway platforms to Multi-Access Convergence Gateways for 3GPP (namely, LTE and back ward compatibility with GERAN and UTRAN) and eventually to non-3GPP (WLAN, WiMAX, Wireline Broadband) accesses.

Aricent has rich and varied experience in co-creating products and delivering projects in layer 2 and layer 3 routing/switching markets. We understand the packet forwarding plane challenges of Network Processors and multi-core chipsets. Aricent has vast experience in working with Deep Packet Inspection technologies. We have consistently delivered solutions to wireless access product vendors, whether it is for GERAN/UTRAN SGSN/GGSN/PCUs or WiMAX ASN Gateways or Packet Data Gateways for WLANs. Aricent also has significant experience in delivering products around Voice Gateways which establishes its credibility in dealing with QoS sensitive services on IP networks.

Aricent has implemented regulatory features such as Legal Intercept and Emergency Services for multimedia in both the wireless and wireline space. We have also integrated Mobile IP solutions (Foreign Agent and Home Agent) in context of the Bearer Manager function for Advanced-IMS architectures. Aricent's recent experience in delivering eNodeB solutions puts us in the league of a few leading technology companies exposed to LTE. Our experience positions us well to help you deliver Multi-Access Convergence Gateway solutions.

Aricent offers a comprehensive suite of design and integration services for evolving IP-IP Gateway platforms towards Multi-Access Convergence Gateway solutions. IP-IP Gateway OEMs can leverage all or select services to co -develop their Multi-Access Gateways.

Glossary

3GPP: 3rd Generation Partnership Project
AAA: Authentication, Authorization and Accounting
AIPN: All IP Network
ARPU: Average Revenue Per User
ASN: Access Service Network
DHCP: Dynamic Host Configuration Protocol
DSMIP: Dual Stack Mobile IP
(e)PDG: (evolved) Packet Data Gateway
EDGE: Enhanced Data Rate for GSM Evolution
EMM: EPS Mobility Management
ESM: EPS Session Management
EPC: Evolved Packet Core
EPS: Evolved Packet System
E-UTRAN: Evolved Universal Terrestrial Radio Access Network
GERAN: GSM EDGE Radio Access Network
GPRS: General Packet Radio Service
GGSN: Gateway GPRS Support Node
(e)GTP: (evolved) GPRS Tunneling Protocol
GUTI: Globally Unique Temporary UE Identity
HSPA: High Speed Packet Access
HSPA+: Evolved HSPA
IMS: IP Multimedia Subsystem
IP: Internet Protocol
IP-CAN: IP Connectivity Access Network
IPR: Intellectual Property Rights
ISP: Internet Service Provider
LMA: Local Mobility Anchor
LTE: Long Term Evolution
Mbps: Mega bits per second
MAG: Mobile Access Gateway
MIP: Mobile IP
MME: Mobility Management Entity
NAS: Non Access Stratum
OEM: Original Equipment Manufacturer
P2P: Peer-to-Peer
PC: Personal Computer
PCEF: Policy and Charging Enforcement Function
PCRF: Policy and Charging Rules Function
PCU: Packet Control Unit
PDN: Packet Data Network
PDP: Policy Decision Point
PEP: Policy Enforcement Point
P-GW: PDN Gateway
PLMN: Public Land Mobile Network
QoS: Quality of Service
RAT: Radio Access Technology
SAE: System Architecture Evolution
SGSN: Serving GPRS Support Node
S-GW: SAE Gateway
UE: User Equipment
UMTS: Universal Mobile Telecommunications System
USP: Unique Selling Proposition
UTRAN: UMTS Terrestrial Radio Access Network
WiFi: Wireless Fidelity (IEEE 802.11wireless networking)
WLAN: Wireless Local Area Network

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About Aricent

Aricent is a global innovation, technology and outsourcing company focused exclusively on communications. Aricent is a strategic supplier to the world's leading application, infrastructure and service providers, with operation in 19 countries worldwide.

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