

Mobile Broadband Access Gateways: Bridging the Gap Between 3G and 4G Networks



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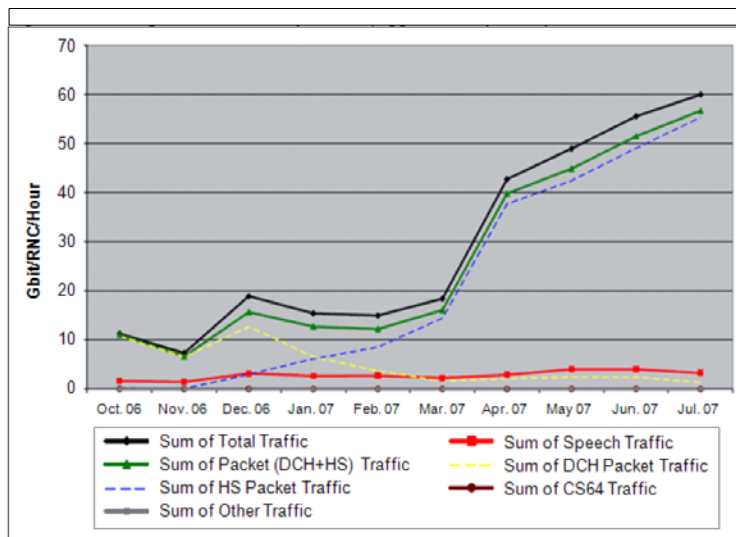
Executive Summary

Mobile networks have emerged as the fastest growing and most profitable sector of the telecommunications industry. Many networks are currently experiencing exponential growth in wireless data traffic (see Figure 1) and, consequently data revenues are also experiencing rapid growth as illustrated by the revenue reported by Verizon Wireless and AT&T Mobility (see Figure 2).

In many developed countries, mobile phone penetration is extremely high. Therefore, continued growth must come from up-selling new wireless data services to existing mobile phone users or stealing users with a more competitive offering. The good news for service providers is that demand for data services is high. AT&T and Apple sold one million 3G iPhones the first weekend it was available and demand for iPhones and other next generation smart phones has continued to grow. The bad news is that the network could be a victim of its own success. Increased demand means that service providers could be forced to upgrade capacity in all parts of the network infrastructure including the:

- Radio Access Network (RAN)
- Back-haul network
- Core Network Data Services elements (SGSN, GGSN, PDSN)

Capacity upgrades mean higher capital and operating expenses. Furthermore, many of these 3G components including the RAN, SGSN, GGSN, and PDSN can not be reused in 4G networks. Therefore service providers are being forced into making capital investments today that will require forklift upgrades when service providers migrate to 4G.



Source: Ericsson Strategy & Technology Summit (London, September 2007)

Figure 1
Average Traffic Volume per RNC (Aggressive Operator)

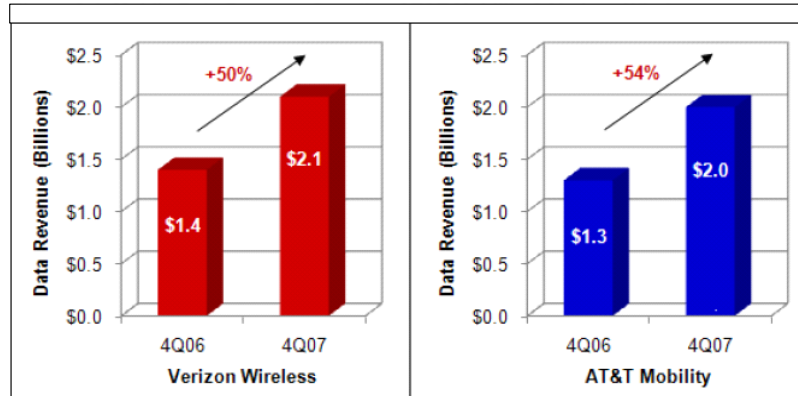


Figure 2
Mobile Data Growth Trends in North America – Verizon Wireless and AT&T Mobility

The focus of this paper is on the role of broadband mobile access gateways in solving the challenges in 3G today and future 4G networks tomorrow. Gateways enable interconnectivity between multiple types of radio networks, including 3G, 4G, WiFi Hotspots, and WiMAX networks. The key gateway benefits are:

- Providing seamless mobility between alternative radio networks and the RAN
- Reducing the need to upgrade 3G network capacity (RAN, Backhaul, SGSN, GGSN, PDSN) by off-loading traffic to alternative networks
- Improving RF coverage (especially indoors)
- Increasing end user data rates and performance which enhances the customer experience, enables new services and applications, and therefore reduces churn

By mitigating the need to upgrade 3G network capacity, service providers reduce capital investments and reduce on-going operations expenses associated with maintaining and managing equipment. Improving end customer experience decreases churn and better positions service providers to up-sell new, value-added data services.

Mobile broadband access gateways solve a real problem today by off-loading traffic from 3G network infrastructure, providing mobility between 3G, WiFi, and 4G (e.g. WiMAX), improving coverage, and increasing data rates. These Gateways are also an important part of 4G infrastructure standards. For example, the Systems Architecture Evolution Gateway (SAE GW) is a core component of the Evolved Packet Core (EPC) for 4G LTE networks. This gateway provides service and subscriber management as well as interworking functions to legacy 3GPP, 3GPP2, and other mobile networks (WiFi, WiMAX, etc.). Similarly, the Access Service Node Gateway (ASN GW) is essential for deployments of 4G WiMAX networks. Service providers should carefully evaluate the 4G readiness of a gateway before selecting an access gateway for WiFi and Femtocell Interworking.

This paper will provide a brief overview of the 4G network architecture and discuss the roles and technical requirements for mobile broadband access gateways in both 3G and 4G networks.

Blazing a Trail Between 3G and 4G Architectures

The goal of 4G wireless networks is that high speed data networking should be available to mobile users anywhere, any time. Both LTE and WiMAX are generally considered 4G technologies. WiMAX is available today and is being used by service providers worldwide to build competitive broadband wireless networks; \$400 Million was spent on WiMAX equipment in the third quarter of 2008. LTE is a 3GPP standard with the expressed goal of providing a smooth migration path from both 3GPP and 3GPP2 networks to LTE. Some of the key 4G system objectives are:

- Over the air data rates of 10 Mbps to 100 Mbps (100 Mbps downlink and 50 Mbps uplink)
- Wireless and data core network optimized for IP
- Clear separation of the functions and evolution of the data core and RAN networks
- Creation of a flatter, all IP network architecture
- Interworking functions provided between 3GPP and non-3GPP wireless networks

High data rates are needed to support new data services and IP is clearly the technology selected by service providers for next generation networks. The benefit of a flat IP architecture is that data traffic does not need to pass through many expensive network components, it can be routed directly to its destination on the IP network. This concept is best illustrated in Figure 3. There are four levels of hierarchy in a 3G network: the radio base stations (referred to as a NodeB or NB), Radio Network Controllers (RNC), Serving GPRS Support Node (SGSN), and the Gateway GPRS Support Node (GGSN). A 4G network is a flat IP architecture with only two levels of hierarchy: the eNodeB, and a mobile broadband access gateway providing session management, IP routing, mobility, and other data services and control functions.

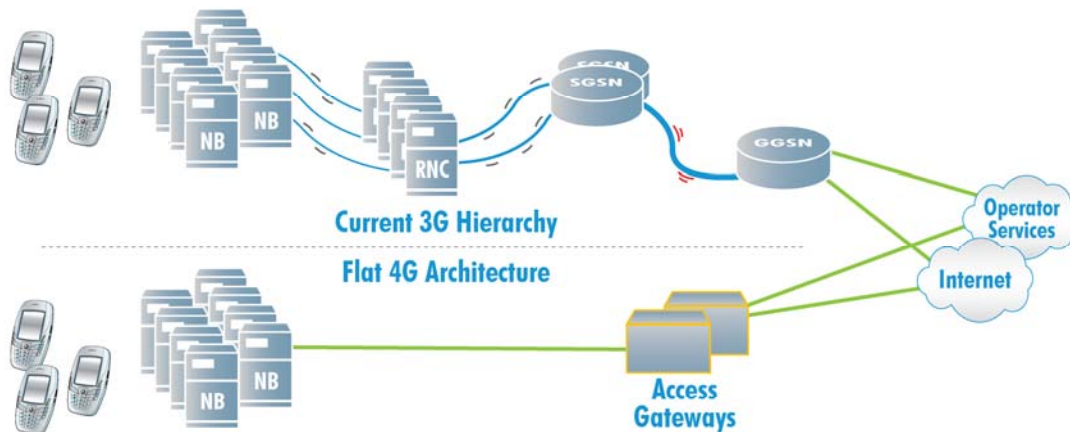


Figure 3
Comparison of 3G hierarchical architecture with a flatter 4G architecture

Broadband Mobile Access Gateway Overview

The broadband mobile access gateway provides important functions in both 3G and 4G networks. In 3G and 4G networks the gateway performs service control, traffic management, and mobility services between multiple networks (LTE, 3GPP, 3GPP2, WiMAX, WiFi). In order to achieve these objectives, the following functions are needed in gateways for 3G and 4G networks are:

- IP routing
- Session and application flow QoS control and policy enforcement
- Flow based charging
- Session and context caching, distribution, & management
- Network based load balancing
- Secure admission control
- Firewall and protection from malicious attacks (DDOS)
- Secure Internet tunneling
- Application layer management using Deep Packet Inspection (DPI)
- Accounting, billing, and reporting on a per subscriber, per service basis
- Interworking functions for interconnection between heterogeneous wireless networks
- Architecture to support high traffic volumes

The functions specified above are necessary to ensure that data services are flexible, services can be rolled out quickly, subscribers can be billed, the network is secure, and network fault and performance management is executed properly.

In the following sections we discuss the role of the gateway in today's 3G networks as well as the evolution to 4G.

The Roles of the Mobile Broadband Access Gateway Today

Gateways enable inter-connectivity between multiple types of radio networks, including 3G, 4G, WiFi Hotspots, and WiMAX networks. In 3G networks today the key gateway benefits are:

Un-Managed vs. Captured Wi-Fi Services Access

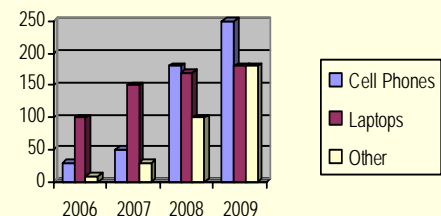
With the advent of the iPhone and other WiFi capable phones and PDAs, users are already starting to enjoy the increased performance of surfing the Internet at high WiFi data rates. This trend is expected to continue with the surge of WiFi enabled devices. WiFi networks are ubiquitous, most businesses and many homes already run WiFi and a myriad of devices are shipped with internal WiFi network interfaces, including laptops, printers, phones, video games, alarm systems, and home video systems. Many subscribers spend a significant portion of their time at work or at home, therefore, given that WiFi is widely available at home and at work, subscribers have easy access to WiFi networks. Given the pervasiveness of WiFi, service providers are faced with two strategic choices:

1. Offer unmanaged WiFi service: Subscribers connect to the Internet independently using WiFi
2. Offer "captured" WiFi service: They can use mobile broadband access gateways to provide monitoring, control, and potentially value added services to enhance their end customer's Internet experience

The risk in letting customers freely access the Internet over WiFi is that service providers could lose control of their customers, thus providing opportunities for large Internet web companies, such as Google, to capture mobile customers with new and innovative service offerings. Alternatively, if service providers route WiFi access traffic to their network (i.e. capture the WiFi traffic), they can monitor use

and provide important security services like parental controls across both network domains. With Captured WiFi service operators are positioned to add value to their customers' wireless Internet experience while also increasing their ability to up-sell value added services in the future. This could be as simple as providing access to walled garden content over 3G and WiFi. Another example of a value added service is a secure VPN access service for business customers that could be offered over either a 3G network connection or a WiFi Hotspot

Wi Fi Enabled Devices (Millions)



- Providing seamless mobility between alternate wireless access networks and the 3GPP/3GPP2 RAN
- Reducing the need to upgrade 3G network capacity (RAN, Backhaul, SGSN, GGSN, PDSN) by off-loading traffic to WiFi hotspots or Femtocells
- Improving RF coverage (especially indoors)
- Increasing end user data rates and performance which enhances the customer experience and enables new services and applications

An example of inter-domain mobility is provided in Figure 4. In this example the mobile broadband access gateway serves as the mobility anchor point for all mobile data network traffic. As users move from 2G/3G RAN to either WiFi or WiMAX network coverage, the data sessions are seamlessly handed off by the gateway. The mobility anchor point is critical for this application because it controls hand-offs between heterogeneous networks. The gateway also maintains control of the subscriber, service, and session security; all necessary functions to deliver and bill for network services.

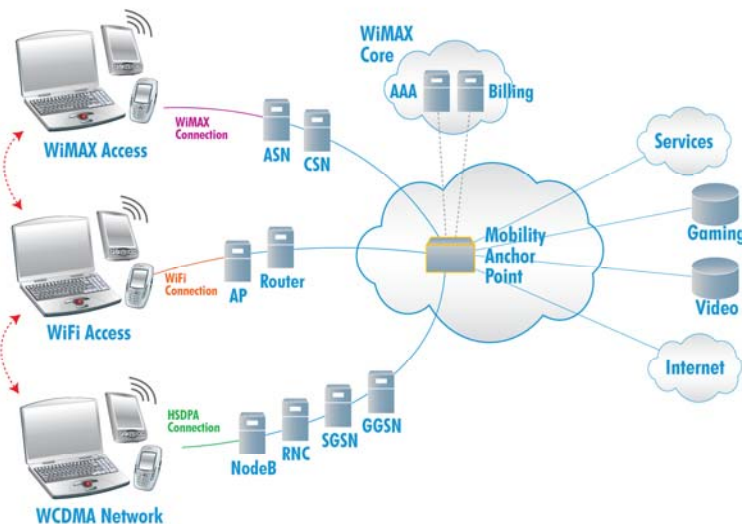


Figure 4

An Example of using a broadband mobile access gateway for inter-domain mobility between 2G/3G RAN, WiFi, and WiMAX Networks

An example of 3G Femtocell deployment is provided in Figure 5 and Figure 6. Using this approach the coverage and performance of the 3G network is improved by using a low cost Femtocell 3G base station to provide 3G radio connectivity to the user. The Femtocell then uses a secure IPSEC tunnel to transport data traffic to the Mobile Broadband Access Gateway across the Internet.

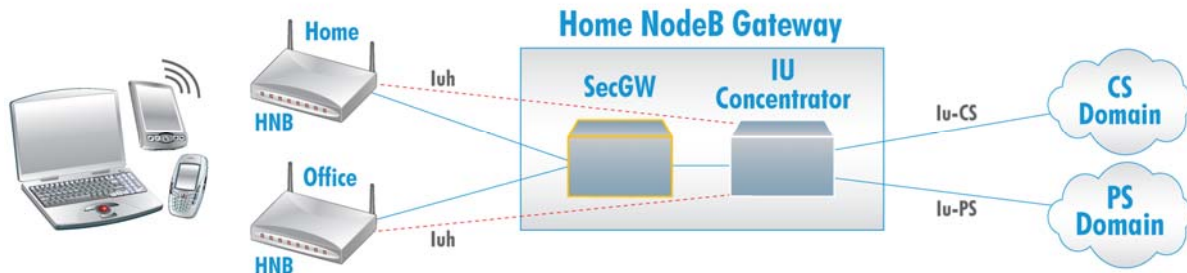


Figure 5

Current 3GPP standard Femtocell deployment can improve service coverage at home or in office buildings. The mobile broadband access gateway performs the role of Security Gateway in this scenario.

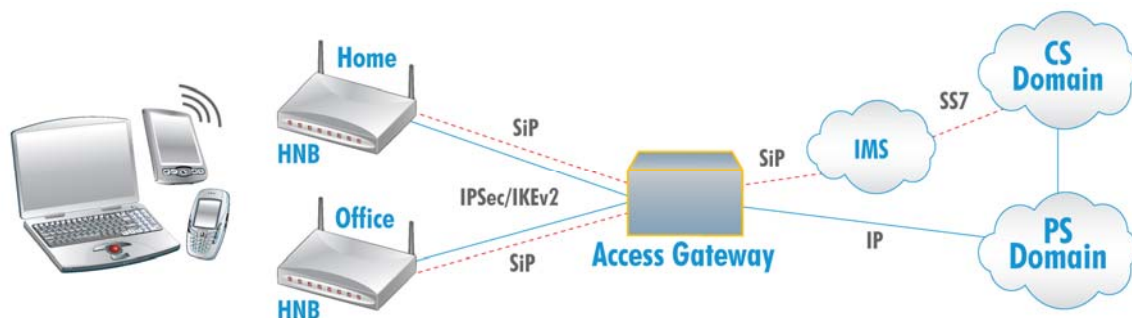


Figure 6

The mobile broadband access gateway should fit into IMS-based Femtocell deployments as well, securing SIP signaling and content traffic between Femtocell and operator network. The gateway also offers a policy enforcement point.

The Role of the Mobile Broadband Access Gateway Tomorrow

The ubiquity of high speed Internet, video, and other multimedia applications has driven a market demand for *mobile* high speed data. In turn, the availability of higher network bandwidth has led to the creation of new services that demand high-speed connectivity such as YouTube, iTunes, AppleTV, and other web based multimedia services. In anticipation of these expected data rate and volume demand increase, the wireless community defined improvements in radio spectrum capacity and efficiency as well as more packet-friendly network architectures in the 4G standards. In response to current market demands operators are planning to upgrade networks from 3G to 4G. As service providers upgrade to 4G, radio data rates will increase dramatically; LTE and WiMAX data rates range between 10 Mbps and 100 Mbps. This will effectively shift the bottleneck in wireless networks from the RAN to the backhaul and data core networks. This shift means that the scalability and flexibility in network transport infrastructure and gateways will become a critical success factor for 4G network deployments.

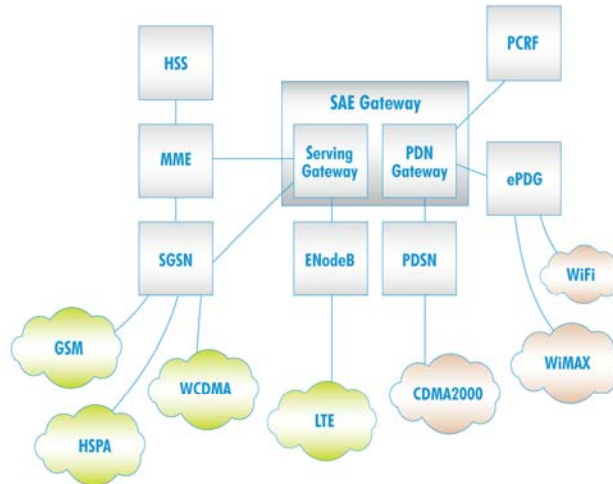


Figure 7
Overview of the 3GPP LTE Architecture including the System Architecture Evolution (SAE) Gateway

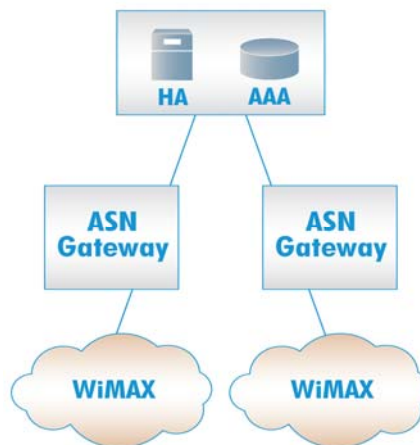


Figure 8
WiMAX Forum WiMAX Reference Model

The mobile broadband access gateway is a critical component for scaling both LTE and WiMAX 4G networks. In LTE networks the Serving GW and PDN GW (SAE GW) perform this role and in WiMAX networks the Access Service Network Gateway (ASN GW) together with CSN network (HA) play this role. Figure 7 depicts the position of the SAE GW in LTE networks. It is a central component of the Evolved Packet Core (EPC) implementing traffic management, service control, and interworking functions at the edge of the network. Clearly, these gateways must be scalable, cost effective, and should be deployed at the service edge of the network to optimize network traffic engineering. The ASN GW and HA (see Figure 8) plays a similar role in 802.16e WiMAX networks supporting mobility, end-to-end QoS, and security.

Technical Requirements for Mobile Broadband Access Gateways

The previous sections of this paper have outlined the roles and high level functions required by mobile broadband access gateways in both 3G and 4G networks. This section of the paper specifies some of the technical requirements for these gateways.

Multiple Access Technology Support

A major problem for service providers is that they need to continue to invest large sums of money to upgrade capacity in their 3G networks today to meet rising demands; however, most of this infrastructure, including the 3G RAN, SGSN, GGSN, and PDSN is not designed for use in the 4G LTE SAE network. Additional, fresh capital investments will be required to build out the 4G, and recent investments in 3G capacity will quickly become stranded as users move to higher speed services. In order to minimize this scenario, mobile broadband access gateways, and all continued 3G CAPEX, must support multiple functions and applications in both 3G and 4G networks.

Interface and Protocol Support

There are multiple applications that run over mobile broadband access gateways and the decision of which applications to run depend on the network infrastructure that is in place and the service objectives. Some of the common gateway roles, interfaces and interworking protocols that must be supported by a gateway are:

Deployment Roles	Interfaces	Protocols
3GPP Packet Data Gateway (PDG), Tunnel Termination Gateway (TTG)	Wu, Wp, Wi, Wm	IKE & IKEv2, IPsec, GTP, IP, DHCP
3GPP2 Packet Data Interworking Function (PDIF)	5, 6, 8	Mobile IP
Femtocell Security Gateway	IuH	IKEv2, IPsec, RANAP
WiMAX ASN-R	R3, R4, R6, R7,	GRE, MobileIP, DHCP
SAE GW	S1, S2, S4, S5, S8, S11	GTP, PMIP, MobileIPv6

Optimized Support for Multimedia Traffic

A key requirement for broadband mobile services is effective delivery of high bandwidth, delay sensitive multimedia traffic. Video is a primary driver for mobile Internet demand, and poor performance will impact customer satisfaction and subscriber retention. Delivering mobile video over broadband means higher data rates, larger traffic volumes, and longer active sessions. A critical requirement is that the gateway effectively forwards multimedia traffic supporting large numbers of sessions while enforcing QoS policies to ensure a quality subscriber experience.

Scalability Requirements

Scalability of gateways is critical as service providers migrate from 3G to 4G networks. In 4G networks user data rates will range between 10 Mbps and 100 Mbps. As the number of wireless broadband subscribers grows, gateways will need to scale from an average of 10s of kbps per user to 100s of kbps per user.

The range of subscriber capacity also has to scale. Services business models must be viable for both high density and low density geographies, requiring network infrastructure to scale from small to large deployments while containing cost.

A few of the key gateway scalability requirements are:

- The system throughput must be greater than 10 Gbps—aggregation rings now operate at 10 Gbps and subscribers transmitting data at 100Mbps will stress aggregation network capacity.
- The gateway must be able to process large numbers of active sessions – greater than 200K sessions are needed to support aggregated data sessions on an aggregation network.
- The gateway should support more than 10 service classes per session to ensure service scalability.

Performance Requirements

The gateway is in the data forwarding path in both 3G and 4G networks, therefore, the performance is critical. The key performance requirements are:

- Throughput latency less than 1 millisecond
- Wire-speed throughput for multimedia traffic
- Wire-speed throughput for small packet sizes
- Process busy hour session set-up requests which can exceed 1M requests per hour
- Support end-to-end session hand-over delays within budget of 300 milliseconds to meet 3GPP's conversational traffic class requirements

It is also critical that all gateway functions operate at line speed, for example:

- L4-L7 traffic classification, including deep packet inspection (DPI)
- Encryption/Decryption
- Policy Enforcement
- QoS
- Charging and Accounting
- Reporting

Requirements for Operational Efficiency

Gateways must have a high level of operational efficiency to support large and growing 3G and 4G mobile networks. Moreover, as operators ramp up their “Green Operations”, the power and cooling efficiency of network elements should be scrutinized. Operational efficiency helps keep environmental operations expenses in check. Broadband mobile access gateways should minimize power consumption, cooling, and maximize utilization of floor space.

Security Requirements

4G networks are pure IP networks with inevitably higher degrees of openness. While IP presents tremendous flexibility and scalability for new voice and data services, it also presents a plethora of security threats. The gateway is a core component of the 4G network and therefore needs to be designed from the ground up for security. Some key security requirements for gateways are:

- Secure the gateway against Denial of Service (DoS)/Distributed Denial of Service (DDoS) attacks
- Secure the gateway services infrastructure
 - Check that requests for network access are valid
 - Detect protocol anomalies
- Secure subscriber communications and signaling
 - Provide data encryption for both user and signaling tunnels using standard-based mechanism, e.g. IKEv2/IPsec
 - Implement Access Control Lists (ACLs) to control subscriber access to network resources

Traffic Classification and Deep Packet Inspections (DPI) functions

In 3G and 4G network data services, application awareness and controls will be an important driver of service revenue and profitability. For example, some applications will need special accounting and treatment in the network to ensure the right quality-of-experience for end users. Moreover, sessions with community-based applications like Facebook and MySpace encompass traffic from a variety of sources. To properly classify these applications and treat the entire session correctly, access gateways must include flexible traffic classification systems that include inspecting packet payloads, often referred to as DPI. Some mobile broadband access gateways offer this capability today, which can reduce or even obviate the added expense and complexity of a discrete function DPI solution in the access network.

Additionally, end user devices will not always properly mark IP packets with the appropriate QoS settings, it is important that the gateway is able to look deep inside the data packets to classify the applications, classify the traffic, and set the correct IP QoS settings. The gateway must also be able to read QoS settings and treat traffic appropriately. This will ensure that the network provides the right level of service for each value-added application. Some of the requirements for gateway traffic classification and DPI are:

- Traffic classification must be based on L4-L7 session and application headers and data
- Application QoS and policy enforcement should be implemented based on traffic classification
- Optional traffic policing should be implemented for certain traffic classes and to enforce fairness
- All DPI and traffic classification functions must operate at line speed

Accounting and Reporting Requirements

The gateway is a central point of traffic control in 4G networks and provides important interworking functions in 3G networks. Therefore, service accounting and reporting is a critical gateway function. Service accounting must be flexible so that it can support both current and future broadband mobile data services. Some of the requirements are:

- Accounting and reporting must be made on a per subscriber per service basis
- Accounting and reporting must take account of traffic classes, network policies, and network QoS
- All accounting and reporting functions must operate at line speed

Service and Session Continuity Requirements

Subscriber demands for "anywhere" connectivity mandate robust mobility solutions. The gateway session management capabilities must provide session continuity when subscribers move among and between access points and access networks.

Conclusion

The good news for service providers is that revenue and profitability of mobile data services is growing worldwide. Internet, email, and video mobile services are becoming standard features for many subscribers, and future value-added services for both residential and business customers promise future growth.

In order to keep customers satisfied in a competitive wireless market, it is essential that service providers continue to scale their networks to support high performance and RF coverage for customer growth and new service introduction. An effective strategy for scaling 3G networks while making progress towards 4G infrastructures is to embrace WiFi and Femtocells to supplement the 3G RF Network. This helps improve user performance and RF coverage, while significantly reducing operational expenses for backhaul and minimizing capital investment in short-lived 3G network infrastructure. Broadband mobile access gateways allow service providers to offer secure data services across WiFi hotspots or 3G Femtocells access tunnels. These gateways also pave the way for next generation 4G LTE and WiMAX networks.

An important consideration for service providers implementing gateways is that they choose products that support their migration to 4G. This will mitigate the need for a forklift upgrade of network infrastructure. Refer to the capabilities checklist in Appendix A to help guide your mobile broadband access gateway evaluations. Our paper has outlined the high level functionality and detailed technical requirements of gateways to help service providers and systems vendors create a roadmap for next generation mobile broadband access gateway implementations.

Appendix A: Mobile Broadband Access Gateway Requirements Checklist

Key Access Gateway Requirements	Availability	Vendor Response
Multiple access technologies supported (e.g. WiFi, WiMAX, LTE, HSPA, etc.)		
Key 3G and 4G roles supported (functions, interfaces and protocols)		
Performs multiple roles concurrently		
Scalability:		
~ 50,000 subscribers per rack unit		
100s of kbps per subscriber at peak subscriber capacity		
Services, throughput, and subscriber capacity scale in lock step		
Performance:		
Line Rate Encryption/Decryption		
Line Rate Traffic Classification		
Line Rate Charging & Reporting		
Design optimized for multimedia services and traffic		
Environmental / Operations		
Compact form factor		
Low Power consumption		
Rack space economy		
Simple troubleshooting and operations		

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**Appendix A:
Mobile Broadband Access Gateway Requirements Checklist Cont'd.**

Key Access Gateway Requirements	Availability	Vendor Response
System and Session Security		
Capability to protect against Denial of Service attacks on itself and other core network elements		
Strong Authentication to prevent identity theft and theft of service		
Strong, full session encryption for confidentiality and integrity		
Flexible Traffic Classification		
Deep Packet Inspection available to ensure application awareness		
Flexible service classes definition to accommodate complex and identify over-the-top services		
Policy enforcement and QoS available per application per subscriber		
Accounting and reporting		
Accurate, per subscriber statistics and charging records		
Service and session continuity functions		

Appendix B: Glossary

SAE Gateway: The SAE Gateway is a central component of LTE/SAE and the EPS. It provides a central point of traffic management, accounting, and application layer control for bearer services. It is primarily responsible for packet forwarding and control (signaling and control is the responsibility of the MME). There are two main components of the SAE Gateway: the Serving Gateway and the PDN Gateway.

Serving Gateway: The serving gateway provides traffic management and interworking between different generations of 3GPP networks including LTE, WCDMA, HSPA, and GSM.

PDN Gateway: The PDN Gateway provides traffic management and interworking between non-3GPP networks and 3GPP networks. The PDN Gateway provides interconnection services to CDMA2000, and other non-3GPP networks such as WiMax and WiFi.

MME: The Mobility Management Entity (MME) manages mobility, user device identities, and security parameters. The MME is primarily responsible for signaling control (packet forwarding and bearer services are the responsibility of the SAE Gateway).

HSS: The Home Subscriber Service (HSS) is the master database in 3GPP 3G and 4G networks, it provides a superset of the traditional Home Location Register (HLR) and Authentication Center functions and manages the subscriber's mobility between the Circuit Switch domain, Packet Switch domain and IP Multi-media functions.

PCRF: The Policy and Charging Rules Function (PCRF) implements IP flow based charging based on service and subscriber policies. The PCRF interfaces with the PDN Gateway to control QoS and other parameters of IP flows based on the service policies.

eNodeB: The eNodeB is the LTE radio base station controller which provides radio resource control, encryption, and QoS.

SGSN: The Serving GPRS Support Node (SGSN) performs mobility management, security, packet traffic management, and access control in 3GPP networks. The SGSN is no longer needed in LTE networks but is necessary to support GSM, GPRS, WCDMA, and HSPA.

PDSN: The Packet Data Serving Node (PDSN) provides functions similar to the SGSN in CDMA2000 networks. Its functions are mobility management, security, packet traffic management, and access control.