WHITE PAPER

Trends in Packet Core Networks

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This white paper contains the findings of independent research and analysis carried out by Informa Telecoms & Media in H2 2008 and early 2009. The research was sponsored by Huawei.

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ABOUT Huawei

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Abstract

With the recent explosive growth and success of mobile broadband services mobile operators are facing a range of new business and technology challenges to ensure sustained profitability and to prepare for an even brighter future for packet data services.

This paper has identified the following principal trends in mobile broadband impacting mobile packet core networks:

- **Driving down the capital cost of delivering mobile broadband to the mass market**
- **Reducing packet core operational costs for increased delivery efficiency**
- **Incorporating functionality in support of new business models using service awareness**
- **Evolving core architectures smoothly and cost effectively towards 4G**
- **Evolving service and transport layer architectures towards All IP and IMS**
- **Evolving core and service layers to support all relevant radio access standards**

Leading mobile packet core vendor Huawei has developed a range of solutions effectively addressing these challenges.

This White Paper has been written with a focus on trends and developments that are expected to impact mobile packet core networks. Some key points pertaining to market drivers, radio access and other systems have been included for the purposes of analysing and discussing their impact on future mobile core networks and business models.

Section A: Introduction - the changing role of packet core networks

Although mobile operators do not advertise the intelligence of their core networks to the public, these are critical components of mobile networks that allow operators to offer innovative services, reduce operational costs and provide support for unforeseeable future services. Packet core networks have been present in mobile networks since the launch of GPRS and are now evolving to more advanced flat-IP architectures to support higher capacity radio interfaces.

The packet core network is becoming increasingly important for mobile and converged broadband operators as a technology enabler of mobile broadband. In the late 1990s mobile packet core technology was introduced into GSM core networks in support of relatively narrowband GPRS-based packet data services, and it has since evolved to support 3G (UMTS) and more recently HSPA mobile broadband services. The packet cores of non-3GPP networks such as CDMA2000 have developed along a parallel evolutionary path.

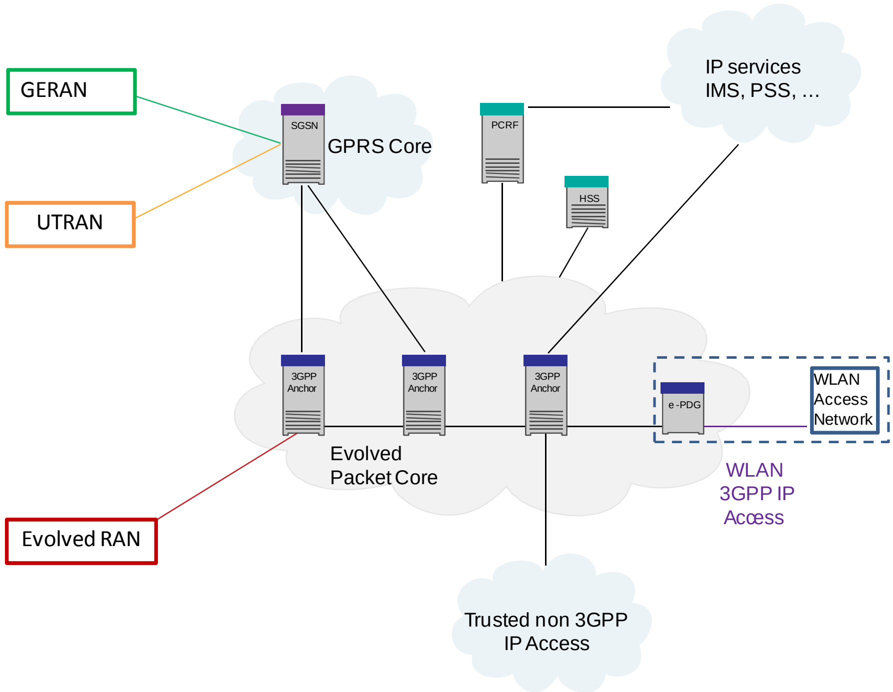
In response to the explosive growth of the mobile broadband market operators and vendors are focusing on accelerating the development and evolution of the mobile packet core.

The most important and business critical packet core trends are:

- Driving down the capital cost of delivering mobile broadband to the mass market
- Reducing packet core operational costs for increased delivery efficiency
- Incorporating functionality in support of new service aware business models
- Evolving core architectures smoothly and cost effectively towards 4G
- Evolving service and transport layer architectures towards All IP and IMS
- Evolving core and service layers to support all relevant radio access standards

This paper examines and discusses the latest business drivers and technical trends in mobile packet core networks, defined here as any part of the core network providing functionality for switching, signalling, transport, and service delivery of mobile packet-based data services.

Figure 1: Conceptual architecture of an evolved packet core

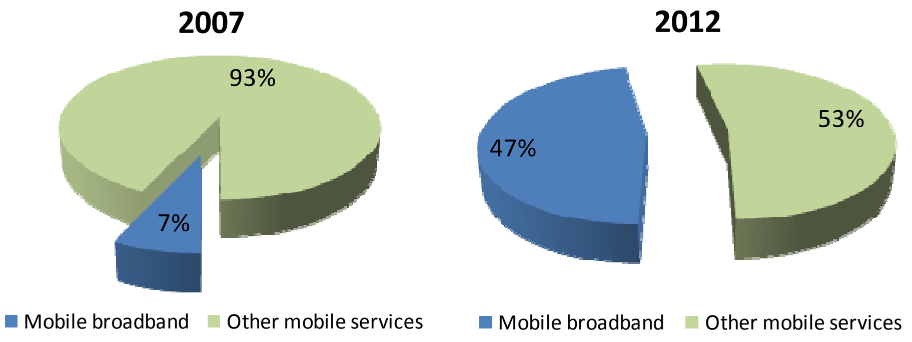


Source: Informa Telecoms & Media

Market overview

An increasing number of developed markets, especially Europe and the developed regions of Asia Pacific, are experiencing a surge of growth in mobile packet data usage largely over UMTS-based mobile networks (supporting the 3GPP suite of standards).

Figure 2: Global mobile broadband vs other mobile service revenues – 2007 & 2012



Source: ITM – Future Mobile Broadband

ITM predicts that by 2012 mobile broadband voice and data (including EV-DO, W-CDMA and HSPA, but excluding WiMAX) will generate US$423bn. Thus packet core will gradually replace the legacy circuit-switched core as the most important, revenue-generating subsystem of the core network.

Drivers for mobile packet data services

New services have been driving mobile broadband usage and these will continue to impact mobile broadband markets. The clear winner and catalyst for growth has been high-speed mobile broadband access for the notebook PC connectivity market as mobile operators in developed markets are now aggressively marketing their broadband product portfolios. But other services are also increasing in popularity. Mobile entertainment is on the rise and multimedia services will grow over the next few years. The resulting growth of packet data services will require greater capacity and change the basic competitive functionality requirements for the packet core itself.

Adoption of flat-rate Internet access

European 3G operators are increasingly offering mobile broadband Internet access services at flat rate or near flat rate monthly tariffs. Many are comparable or even lower than fixed broadband alternatives such as DSL or cable. In the UK monthly tariffs for speeds of up to 2.8Mbps and 2-3GB of data per month cost US$7.50-15.00 (£15-30) and some markets offer lower rates.

Examples of popular flat rate mobile broadband services using USB modems include:

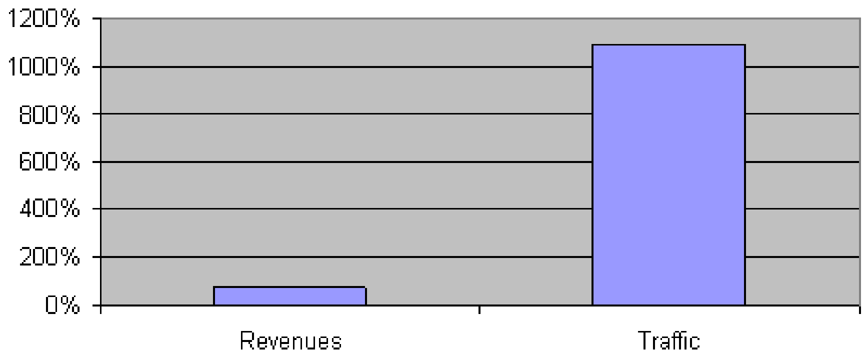
- 3 Sweden: 7.2Mbps data speed with no volume cap for US$30 per month
- 3 UK: 3.6Mbps data speed and a cap of 1GB for US$20 per month
- Maxis of Malaysia: 3.6Mbps data speeds and a cap of 3GB for US$32 per month.

With full mobility, mobile broadband Internet access is an increasingly attractive value proposition for consumers. T-Mobile UK reports that the market is driven by consumers wanting to replace fixed broadband connections with the equivalent mobile service.

Mobile operators and vendors expect growth within this segment to continue but competition is exerting ever-greater downward price pressure on mobile broadband flat-rate fees. ITM's Mobile

Networks Forecasts report anticipates that global mobile data traffic will increase by a factor of more than 10 between 2007 and 2012 while revenues will only rise by 77%. So operators will increasingly aim to minimize packet core infrastructure costs and improve delivery mechanisms.

Figure 3: Global mobile data revenues vs traffic, percent change 2007 & 2012



Source: Informa Telecoms & Media

The flat rate business model encourages ever higher data use without generating additional revenues. Higher data use will require packet core network capacity upgrades & investments disproportionate to modest revenue levels per user. Independent research by the author with leading mobile operators and consultants has shown that capital expenditure (CAPEX) per subscriber for mobile broadband data could reach a level more than 10 times that of voice CAPEX. This stems from mobile broadband subscribers using UMTS and HSPA for generic internet access as a substitute for fixed broadband, where the resulting very high traffic levels require high capacity in both RAN and core networks. Capacity-based charging from leading vendors, particularly with respect to software fees, dramatically drives up CAPEX per mobile broadband subscriber while strong competition drives down tariffs.

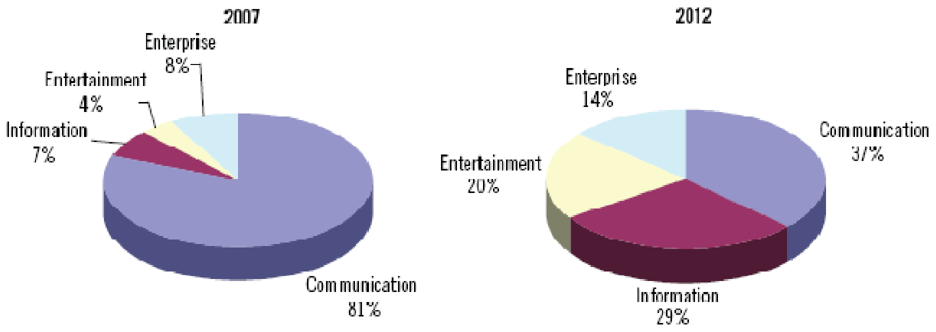
To address this vendors and operators are studying and implementing new packet core solutions for traffic inspection, control, and service-dependent charging.

Mobile entertainment

Until the advent of the *dongle* HSPA modem, music downloads to handheld 3G and HSPA enabled devices were the most important driver of mobile data. Mobile operator 3 Networks ran an early, and successful global marketing push for music downloads from the launch of their 3G networks.

Music and other forms of mobile entertainment download services are still developing rapidly. ITM expects the market for mobile music to reach US$16.7bn by 2012and the market for mobile entertainment services – including music, mobile TV, video, images, gambling, and games – will be US$35.7bn by that time. A recent ITM operator survey has found that full track downloads currently represent around 34% of the mobile music total, while 48% is made up of ring tones and ringback tones.

Figure 4: Global mobile network traffic – market share by application 2007 &2012



Source: ITM – Mobile Network Forecasts report 2008

The mobile industry is still trying to overcome the problem of small screens but with handheld screen sizes increasing, the popularity of some mobile video formats is increasing. Content providers are also studying how to best adapt large screen content to small screens.

Video downloading or streaming to mobile devices is equally being driven by the popularity of video content-sharing site YouTube since the mobile portal in 2007 allowing users access to content via video streaming enabled mobiles. The mobile entertainment segment also includes games and electronic books.

ITM's Future Mobile Networks report forecasts that entertainment traffic volume will grow 20 times between 2007 and 2012, while information traffic volumes (the majority of which is browsing) will multiply by approximately 17 times but from a larger base.

Mobile multimedia services

3G mobile broadband networks are technically well suited to providing mobile multimedia services, such as IP-based rich calls with file sharing, enhanced messaging, video conferencing, etc. IP Multimedia Subsystem (IMS), the core network architecture for such service provision, was standardized in 3GPP Release 5 and has been available from leading infrastructure vendors for several years.

Leading mobile operators Vodafone, Orange and Telefonica and vendors expect mobile multimedia services to become a new source of operator revenue over the next few years.

A cooperative programme called Rich Communications Suite was announced in July 2008 which aims at developing service features, implementation guidelines, and network interoperability for mobile multimedia services. Both vendors and operators are increasingly focused on developing IMS services and eliminating interoperability problems that have so far marred this.

Take-up of mobile multimedia services will impact the services and application layer of mobile packet core networks where a full IMS core will be needed. Depending on future popularity of IMS services, more capacity may also be required on the transport layer. Overall IMS-type services are expected to drive core network architectures more firmly in the direction of All-IP.

Mobile TV over 3G networks

ITM predicts in its Mobile Entertainment report that global mobile TV Revenues will grow from US$763m in 2007 to US$5.1bn in 2012.

Mobile TV is a hotly debated issue. Some infrastructure vendors including Ericsson and Huawei have advocated the unicast (streaming) 3G network technology with Multimedia Broadcast/ Multicast Service (MBMS) as the delivery vehicle, while others have strongly supported Digital Video Broadcast-Handheld (DVB-H) that does not employ mobile network infrastructure. DVB-H seems to be winning for mass market mobile TV with several DVB-H spectrum licenses already allocated in Europe. Italy's 3 Italia is perhaps the most successful to date with 700,000 DVB-H users Nokia recently released the N96 with DVB-H capability.

New 3G and HSPA-capable Mobile Internet devices are another important driver for the take-up 3G mobile TV & video streaming because they facilitate access to a large selection films and TV content over the web. If 3G TV services become popular with consumers, the impact on mobile packet core network capacity is likely to be significant. Even with extensive video compression mobile TV is a bandwidth-hungry application. Ericsson reports that 12 mobile TV channels will require a downlink data rate of 256kbps when using MBMS and HSPA Evolved access technology and 5 MHz of spectrum.

Voice over IP (VoIP)

Although technically viable on most mobile broadband networks, VoIP is perceived by most operators as a marginal business opportunity. For the Vodafone Group VoIP is marred by poor QoS making it less than ideal for quality telephony compared to legacy circuit-switched telephony.

Operators are also reluctant to adopt VoIP because it is a disruptive technology likely to undermine their cash-cow voice business and reduce traditional circuit-switched voice revenues. Some Tier-1European operators have allegedly been blocking VoIP by removing VoIP applications from devices although they have since officially denied these allegations. MTN in South Africa has declared that it intends to either block VoIP or charge for the service at a specific VoIP tariff per MB.

There is no doubt that in the long term voice calls will move to the IP-domain and impact packet core network capacity and architecture. But its impact as a low-bandwidth service will be smaller than more bandwidth-hungry applications such as Internet browsing and video streaming. VoIP development as a fully-fledged, mature service over mobile is closely linked to the maturity of associated service layer network solutions such as IMS and the inclusion of real mobile multimedia applications into mobile operator service portfolios. It is also crucial that mobile packet core networks incorporate service-aware functionality capable of identifying the VoIP service and subscribers that use it in order to control the traffic and bill accordingly.

Internet access for emerging markets

In emerging markets in Africa, Latin America, and parts of Asia basic Internet access is still in great demand and considered by most a necessity for a modern lifestyle and for running a competitive, modern business. At the same time many emerging markets lack well-functioning fixed infrastructure for Internet access.

In large parts of Africa, Asia and Latin America fixed line access infrastructure either does not exist, cannot viably be upgraded to digital technology, or geographical coverage is too limited to meet rising market demands. Mobile packet data services are often the only realistic alternatives for public Internet access. For operators, building mobile or wireless networks is the only financially viable infrastructure solution for providing telecommunications services in general.

Emerging market mobile operators, who until recently focused only on voice services over GSM technology, have experienced a surge in packet data volumes for basic Internet connectivity via GPRS and EDGE. But 3G technology is also becoming important for higher Internet access bandwidths for the general public.

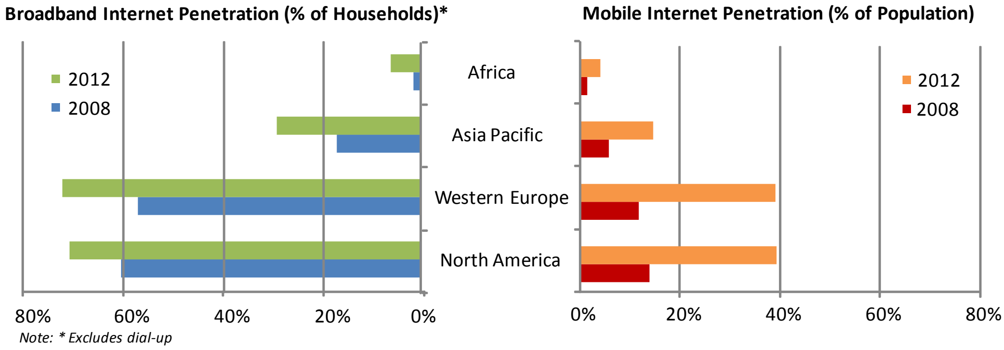
ITM's World Broadband Information Service (WBIS) predicts that Internet penetration will reach 30% by 2012 in emerging markets and average 75% in developed markets. Mobile broadband and wireless networks will carry most of this traffic and packet core networks will need to grow accordingly. Mobile operators in Brazil are under license obligations to provide broadband to at least 80% of the Brazilian population by 2010. Brazil's Claro (part of América Móvil Corp, Mexico) plans to move to evolved HSPA by 2009 and 3GPP LTE around 2011.

In emerging markets it is important to offer packet data services to the mass market at rock bottom prices since emerging economies are characterized by mainly low expendable incomes with few subscribers enjoying appreciable incomes by Western standards.

Annual costs per telecommunications site in these markets are nearly twice those of developed markets. The following are key competitive criteria for success for packet core solution vendors:

- Delivering competitive packet core networks at lowest possible CAPEX
- Ensuring local deployment & support with rapid time-to-market
- Providing innovative solutions to reduce installation site and other operational costs
- Providing cost-effective backhaul & core transport solutions
- In the medium term supporting both legacy 3GPP and non-3GPP access technologies

Figure 5: Broadband & Mobile Internet Penetration to 2012



Source: Informa Telecoms & Media

New devices for mobile broadband

The success of USB-modems with HSPA

The availability of operator-branded, USB dongle-type HSPA mobile broadband modems has had a great impact on the global mobile broadband market. USB data modems are low cost, compact, easy to install and work immediately on a laptop computer. Huawei has been particularly successful in bringing USB modems of this type to the market.

In some markets USB-modems are fully subsidized while other operators offer them at a price of US$100-200 per unit. Either way they are not expensive. The GSMA recently reported the commercial availability of 74 USB HSPA-capable modem devices.

ITM predicts in its 2008 Mobile Broadband Devices report that globally a total of 36.8m portable mobile broadband devices (including ultra portable notebooks, notebooks, dongle modems and cards) will be sold in 2008 and that this figure will rise to 127.9m by 2012. According to Ericsson, in Sweden alone – a mature broadband market of 11 million inhabitants – a total of one million USB-modems were sold in 2007.

Easy-to-use modems give mobile broadband a clear advantage over its fixed rivals. Typical DSL or cable services have longer lead times and on-premise routing equipment can be more difficult to install. Full mobility and "always connected" packet data are a very attractive value proposition.

Mobile Broadband Notebook PCs (MBPCs)

Built-in HSPA and future WiMAX modems in notebook PCs is another important trend. Ericsson and Dell already incorporate HSPA modems in new lines of notebook PCs as do most leading manufacturers. According to Ericsson some 100m HSPA-capable notebook PCs will be shipped annually by 2011, and the GSMA reports 119 notebooks with HSPA capability.

Notebook PCs with embedded HSPA and future 3GPP LTE modems will likely become the equivalent of today's PCs with embedded WiFi connectivity. But with typical 3-year replacement cycles, much longer than handheld devices, the installed base of HSPA-enabled notebook PCs will grow at a slower rate. In the US and some Asian markets notebook PCs with built-in WiMAX modems will also become important as the coverage footprint of WiMAX operators develops.

The increase in the global installed base of notebook PCs equipped with HSPA or future 3GPP LTE is expected to significantly drive up mobile broadband usage and further increase capacity requirements for the packet core.

Attractive smartphones

One of the most important recent developments in the handheld market is Apple's introduction of the iPhone and their popular success which encouraged other vendors' to launch touchscreen mobile internet devices. This marks the beginning of a trend in touchscreen broadband-enabled smartphones with extensive broadband networking capabilities and friendlier user interfaces.

T-Mobile Germany has found that iPhone users transport 30 times more data than others. ITM's Future Mobile Operator Business Models report quotes more such examples from AT&T:

- 95% of iPhone owners regularly surf the web, even though 30% had never done so prior to iPhone ownership
- 51% of iPhone users have viewed videos via YouTube
- Apple's iPhone is responsible for 50 times the number of mobile searches of any rival handset

And from O2 in the UK:

- 60% of O2's iPhone users in the UK are sending and receiving more than 25MB of data per month. By comparison less than 1.8% of other contract customers use comparable amounts of data.

Moreover, some press reports have suggested that Apple could be receiving as much as 40% of the revenues from data usage.

Samsung and LG have launched similar touch-screen products and Google is advocating a new open-source operating system (OS) called Android with touch-screen capability. RIM believes the success of the iPhone has increased the popularity of other smartphones such as the Blackberry.

Nokia is trying to capitalize on this trend by launching Ovi, a simple to use Internet services environment for Nokia smartphones running Symbian OS and offering P2P file sharing and remote access to PCs from the mobile phone.

Main device trends & packet core impact

The most important trends impacting mobile packet core networks as far as user devices are concerned can be summed up as follows:

- High growth of USB-modems of general, unrestricted HSPA broadband Internet access

- Increase in the popularity of smartphones with multiple broadband connectivity including HSPA and WiFi
- Creation of competing Internet service environments for smartphones including one-click services for Web 2.0 applications such as file sharing, social networking, and mobile entertainment.

All these are qualified attempts by vendor and operator communities to develop the mobile broadband market and boost the attractiveness of mobile Internet services, offering similar experience and functionality for handheld devices. As services of these types grow in popularity mobile packet cores will need to accommodate increased data traffic.

Current technology trends in cellular networks

Availability of broadband capacity in 3G networks

A number of prominent mobile operators particularly in Europe adopted and deployed UMTS technology early expecting a surge in the uptake of 3G data services but slow initial growth meant that some operators have had excess packet data capacity. This is only now being used effectively with the introduction of HSPA, flat rate charging, and accelerated market growth.

Continued growth of mobile broadband access services and volumes and increased demand for higher data speeds will mean operators will need to expand and optimize their packet core capacity & functionality extensively over the next few years.

Boosting data speeds with HSDPA technology

The deployment of radio access systems capable of delivering much higher data speeds than standard 3GPP Release 99 networks is a key driver in both developed and emerging markets. The widespread adoption of High Speed Downlink Packet Data (HSDPA) particularly in mature markets stems from the fact that data speeds are comparable to fixed broadband over DSL or cable.

HSDPA builds on existing WCDMA radio technology and requires relatively few network equipment upgrades to WCDMA networks based on 3GPP Release 99, so is relatively simple and cost effective for WCDMA operators to roll out. Many HSDPA operators currently offer packet data speeds at a theoretical maximum of 7.2Mbps in the downlink, a twenty-fold improvement on the initial 3G downlink data speeds of 384kbps. With the evolutionary step High Speed Uplink Packet Data (HSUPA) now available and further enhancements of both technologies on the way, operators continue to improve radio access network data throughput to attract more broadband customers.

HSUPA for improved uplink

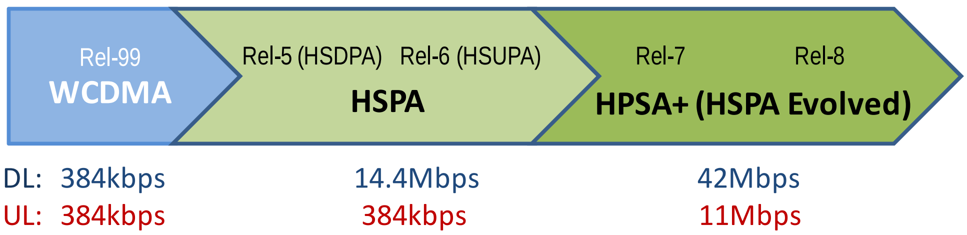
HSPA is a suite of radio interface standards building on existing WCDMA mobile networks. According to the GSMA, close to 200 commercial HSDPA networks are in operation worldwide, capable of boosting downlink data rates. However, with the increased popularity not only of Internet browsing but also P2P data services over the Internet, uplink data speeds are also in need of a boost.

To increase uplink data rates to a maximum theoretical rate of 5.72Mbps the next technology, already commercially available, is HSUPA, part of the 3GPP Release 6 standard and called Enhanced Uplink. The GSMA reports that a total of 44 mobile operators have implemented HSUPA and most current HSDPA operators are expected to implement it within a couple of years.

HSUPA growth will have a strong impact on packet core network capacity such as the SGSN and GGSN network elements in the short term as the volume of uplink data transferred to the packet core network could be increased overall by as much as a factor of 10 depending on the type and popularity of services offered. To ensure sustainable broadband business growth, it is imperative that capacity expansions are implemented at capital expenditure levels, reflecting continued market-driven reductions in end-user tariffs unless other business models prevail.

WCDMA and HSPA data speeds as a function of the 3GPP Release standards are shown in the chart below. Many equipment vendors are already offering Rel-6 functionality with 7.2Mbps downlink and 5.72 uplink data speeds.

Figure 6: 2WCDMA and HSPA data speed evolution



Source: Informa Telecoms & Media

Current technology trends in mobile packet core

Packet Core Deep Packet Inspection (DPI)

Mobile packet core vendors and operators are facing a number of technology challenges to meet the demands of the developing mobile packet data market. Both the transport layer (the physical and logical infrastructure for packet data processing & networking) and the service and control layers will need to evolve cost efficiently to address a growing number of business critical challenges and opportunities.

The popularity of flat-rate tariffs and resulting dramatic increase in mobile packet data traffic, mobile operators are faced with the immediate challenge of controlling usage bandwidth. Many broadband operators find that a small percentage of users consume a disproportionate amount of packet core bandwidth due to extensive use of P2P applications. WCDMA vendor Ericsson reports that P2P applications consume up to 68% of their total mobile packet core bandwidth.

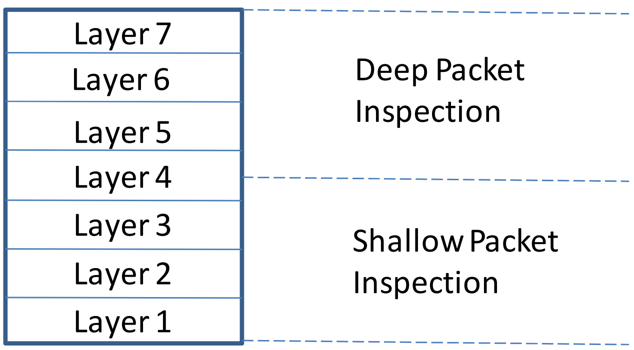
P2P applications are Internet-based services that run between individual users' computers and thus bypass network servers, usually for the purpose of sharing content. Skype and Napster are examples of Internet sites offering P2P-type services.

Dimensioning packet core networks to accommodate a few users of this type is not financially viable, and therefore mechanisms for imposing bandwidth control are becoming increasingly important. The control of P2P packet data traffic is a short term imperative for mobile operators wishing to develop a sustainable mobile broadband business model. The starting point for bandwidth control is deep packet inspection (DPI). DPI technology has been employed for a number of years within IP switching to provide network security with firewall functionality. A number of leading packet core vendors including Huawei offer DPI functionality as an integrated part of the packet core solution.

DPI looks at the content of individual IP data packets to and including layers 4 to 7 of the IP protocol stack and is able to identify the type of service accessed by the user. To identify heavy and encrypted bandwidth-consuming P2P applications, such as those used for Skype, analysis of data patterns is required using heuristic analysis. Other methods for detecting P2P traffic include detection of application signatures and transport layer port identification. Not all DPI detection algorithms are 100% effective as protocols for P2P services are constantly changing.

Deep packet inspection algorithms can be implemented as a part of the functionality of existing or upgraded packet core elements, such as in the Gateway GPRS Support Node (GGSN) or alternatively incorporated at the edge of the core network as an independent element. The latter is relevant for mobile operators offering converged packet data services over both fixed and mobile access networks.

Figure 7: Heuristic Analysis



Source: Informa Telecoms & Media

Once packet contents are known mobile operators can implement policies to control usage or even block certain services, such as unwanted VoIP or heavy P2P traffic. A common method is to implement 3GPP-defined quality of service (QOS) functions allocating restricted bandwidth to some users to avoid overall service degradation. This is known as the fair usage policy.

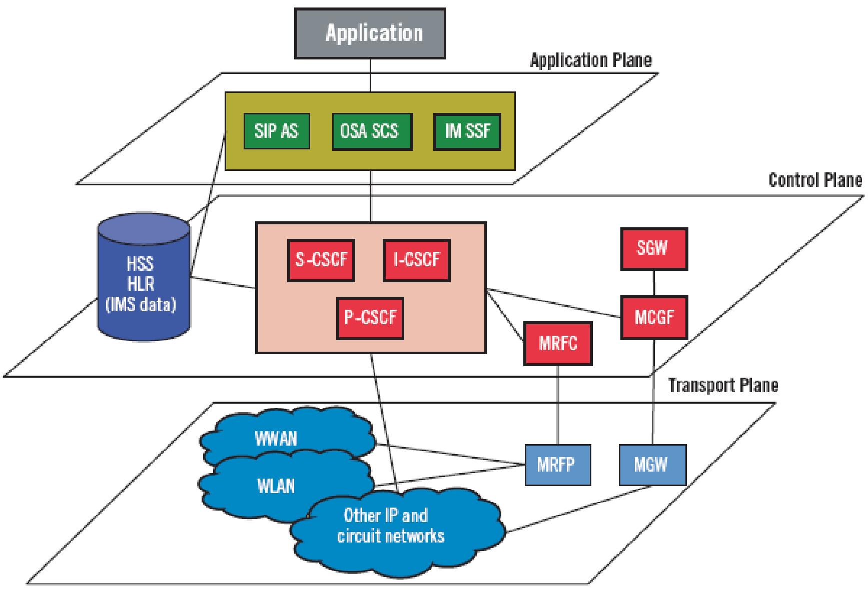
Most leading operators recognize that the implementation of deep packet inspection, heuristic and other types of analysis, and usage policies including packet core QoS is a must in the short term. It is also imperative that the QOS and capacity of the packet core network is not degraded by the introduction of deep packet inspection functionality.

The growth of the IP Multimedia Subsystem (IMS)

IMS was standardized in 3GPP Release 5 but has only recently started receiving attention from leading mobile operators. The Vodafone Group recently announced its intention to implement IMS into its core network infrastructure and start offering IMS services. Other major operators are expected to follow and Ericsson has announced 50 contracts for commercial IMS systems.

IMS requires implementation of an IMS core architecture at the service and signalling level. IMS allows seamless integration of multiple access technologies – including fixed and mobile – into the service portfolio.

Figure 8:Traditional and IMS Network Layers IMS Architecture



Source: Informa Telecoms & Media

IMS aims to create a technical environment for new revenue sources, namely IP-based multimedia services for the mobile broadband device market. It is also intended to facilitate service continuity over converged fixed-mobile broadband networks and to ease the deployment of indoor convergent solutions such as femtocells. IMS is closely related to other key infrastructure trends such as service awareness as IMS systems are inherently service aware and enable charging based on content, application, and QoS.

IMS is a complex industry issue. Its success will depend on the development of an IMS industry ecosystem of operators, network vendors, application developers, Internet companies, content providers, and not least regulatory bodies. Interoperability (the seamless availability and continuity of IMS services across any network) is critical for the IMS industry and requires strong cooperation between all members of the ecosystem. Drivers for mobile operator implementation of IMS include:

- Faster service creation and delivery despite more complexity suite of services
- More efficient bundling and convergence of services
- Reduced complexity of the network infrastructure.
- Reduced load and complexity of the billing process
- Delivery of new services from innovative applications using the IMS platform.

IMS requires implementation of a family of servers for subscriber, mobility, and service management on the service layer of the core network. It also requires implementation of Session Initiation Protocol (SIP) for IP-based signalling between IMS-enabled devices and the network.

Vendors and operators recognize that IMS will impact transport core infrastructures over the next few years but the extent to which it will happen will depend on the popularity of new IMS-based multimedia services and other such as further developments in fixed-mobile convergence.

The drive towards Fixed-Mobile Convergence (FMC)

Many operators in mature and deregulated markets offer packet data and voice services across a variety of access media including fixed lines, wireless and mobile broadband. The aim of convergent broadband operators is to offer a competitive suite of services over the same packet core network architecture ensuring continuity of services for the end user regardless of the access method employed.

An aspect of FMC is the emergence of dual-mode Generic Access Network (GAN) devices supporting both short-range wireless access (WiFi) and mobile access over 2G and 3G technologies. Although a few mobile operators have launched such devices and associated services, notably early entrant TeliaSonera's Home Free and BT's BT Fusion, the concept has not so far been a market success perhaps because of the limited availability of suitable handsets.

The goal of operators wishing to evolve to a fully converged core network is to transform existing transport architectures and service platforms such as those supporting legacy PSTN and 2G mobile telephony into a single core network infrastructure. The business benefits of this transformation are many and include:

- Reduced complexity of the core network and thus reduced CAPEX and OPEX
- Reduced time-to-market for new services and rapid adaptation to changing needs

- New revenue development opportunities through bundling and new service creation

The transformation of packet core architectures towards convergence is usually performed in a number of steps and is a relatively complex process of introducing new architecture while still supporting systems that carry legacy circuit-switched traffic.

Most operators and vendors agree that the following are useful steps on the road to fully converged core networks:

- Complete the transformation to two-tiered (soft-switch) architecture separating user and control planes of the core network
- Implement IMS for a flexible, IP-based multimedia services environment
- Gradual introduction of IP transport on network element interfaces
- Gradual change from legacy TDM transport to carrier IP transport.

Capacity demands for packet core network elements

Industry consensus suggests a doubling of capacity demand in the mobile packet core every 18 months. This means that mobile operators are faced with a real practical challenge in building and expanding packet core capacity at an unprecedented rate.

The main core network elements requiring increased packet handling capability are SGSN and GGSN nodes to support increased traffic from HSPA and WCDMA packet data services. The greater the capacity of these individual elements, the more efficiently the mobile operator is able to operate the packet core, and potentially also reduce CAPEX for upgrades.

Section B: Operator packet core business issues

Impact of various emerging technologies

A number of emerging technologies for mobile and fixed network infrastructure will in the short to medium term impact the operator packet core business case. Each emerging technology will affect core architectures and also change the way in which mobile operators conduct their business and revamp existing business models.

IP Multimedia Subsystem (IMS)

IMS was standardized by the 3GPP in Release 5 and has since gone through a number of revisions. IMS is in principle a new service-layer network architecture with standardized interfaces and protocols enabling easier integration of IP-based services into the mobile packet core. IMS is designed to enable the fast creation and service delivery of high-end, IP-based mobile multimedia services to the end user, such as rich calls, videoconferencing, and the like.

The technical impact of IMS on the mobile operator packet core network can be summarized as follows (the cost impact of the introduction of IMS into the network is assessed in a subsequent section):

- **Implementation of new network elements on the service layer:** A number of new network elements need to be implemented on the service layer according to the IMS architecture and interface specification. The number and type of new servers depends on the IMS vendor's chosen implementation, but will usually at least require a Home Subscriber Server (HSS) to manage basic subscriber information. The HSS is the logical IMS equivalent to the HLR (Home Location Register), which manages subscriber information for circuit-switched calls in GSM and UMTS. A number of application servers (AS) will also be required depending on the number and type of IMS-based services the operator is expected to launch.
- **Preferred implementation of All-IP on packet core network elements:** Because IMS is a service-layer technology, IMS does not from a functionality point of view require changes in the transport layer. That means that existing GGSN and SGSN core network elements generally can be reused, although they will need to support SIP signalling. It is preferred, however, that IP interfacing is introduced on packet core network elements in order to receive the full benefit of a transparent IP transport network and for ease of integration.
- **Implementation of SIP signalling instead of or complementary to SS7:** Nearly all mobile operators today use legacy SS7 signalling systems for controlling and switching circuit switched traffic, such as voice. Some have also chosen to implement a variant of SS7 known as SIGTRAN, where SS7 messages are carried over an All-IP transport layer. In IMS control-plane functionality is carried by a natively IP-based signalling protocol called Session Initiation Protocol (SIP), which is fundamental to the implementation of IMS. So all involved network elements, such as the GGSN and SGSN, need to support SIP signalling functionality. In addition IMS implementation

requires a number of SIP services to be deployed on the service layer, including the Proxy Call Session Control Function server (P-CSCF).

IMS will clearly have an impact on the operator business case for packet core networks. The following are the main cost elements that need to be considered in building the IMS business case. For the overall business case to be profitable, the network operator needs to evaluate the extent to which the IMS services offered will generate enough revenue to offset the CAPEX and OPEX of deploying IMS.

- **Service layer CAPEX:** An IMS service layer deployment represents a significant investment for any mobile or fixed network operator. CAPEX components include the cost and implementation of server hardware, but typically the software employed to enable IMS functionality is the predominant cost component. Service layer network components are usually deployed at operator's main hub site and may be collocated with other core network elements, but may also require switching room expansions and civil works. Implementation costs depend widely on the choice of supplier and the size and architecture of the IMS service layer required.

- **CAPEX and OPEX for gradually moving to All-IP as a part of IMS:** A number of operators consider the deployment of IMS a part of a network wide evolution towards All-IP. To deploy IP interfaces on core network elements as a part of an IMS project may therefore be considered part of the overall CAPEX and OPEX for the IMS business case. As the GGSN is typically already operating with IP interfaces, the most relevant network element to upgrade to IP-interfacing is the SGSN. Operators generally incur costs for both software and hardware when the SGSN is upgraded to All-IP. OPEX costs include the software maintenance fees from vendors & additional support staff to maintain the All-IP traffic layer, if required.[1]

- **Upgrade of existing elements to SIP (CAPEX & OPEX):** As already mentioned, the full implementation of IMS requires packet core network elements to be capable of handling SIP signalling. This functionality is normally supplied in the form of software updates to existing network nodes, but also represents a CAPEX. It is estimated that the implementation costs in some cases may exceed the equipment CAPEX due to the complexity of implementing SIP with minimized disruption of existing traffic on the network.

- **Capacity upgrades in the packet core networks - CAPEX:** The introduction of IMS services will also to a greater or lesser degree impact packet core traffic in the network. If the mobile operator is successful in launching popular IMS services, the operator may need to upgrade the packet and subscriber handling capacity of GGSN

[1] If All-IP is implemented across the network and existing TDM systems are dismantled, there may be a savings in operating an All-IP network. But most existing operators are faced with having to operate a TDM transport network to support legacy services. In most cases it is therefore likely that the cost of taking a first step towards All-IP in the short to medium cost will introduce additional OPEX.

and SGSN network elements, IP interfaces, IP switches, and associated elements. The CAPEX may include both hardware and software components.

Service Awareness and Intelligent Edge

Service awareness and Intelligent Edge are aggregate level terms for a variety of functionality usually implemented in the packet core but in some cases (such as bandwidth management) may extend to the radio access system. The following set of functionality is generally a prerequisite and most often implied when the term service awareness is used:

- Deep packet inspection (DPI) up to and including layers 4-7 of the IP protocol stack. For the mobile operator to be aware of the service accessed by the end user IP packets need to be inspected on all levels including the application level.
- Functionality for heuristic, application signatures, and transport layer types of P2P identification algorithms within the GGSN or a dedicated network element. DPI alone is not enough for the network to be service aware. The special algorithms mentioned accurately analyze packet data streams and determine what services are accessed by individual users.
- Access method, location, and roaming awareness to control and enable services based on the location of the subscriber. This functionality allows operators to implement new services according to the output of the service aware network node.
- Functionality for service bandwidth allocation for bandwidth management on subscriber and aggregate service levels. This functionality may or may not be a part of the service aware platform but is usually associated with it.

The technical impact of deploying service awareness and intelligent edge systems can be summarized as the following network evolution steps:

- **Deploying DPI into existing (GGSN) or new packet core network nodes:** DPI can be implemented either in a dedicated packet core node element, such as a high capacity IP router/firewall element, or in a GGSN. If a dedicated solution is chosen one or more DPI-capable elements need to be deployed depending on the size and configuration of the operator’s network. Some vendors including Huawei advocate incorporating DPI functionality in the GGSN as this reduces the total number of network nodes and thus simplifies the network. As DPI is often critical for successful network operations, incorporating DPI into at least two interconnected DPI network nodes of the same capacity and functionality should ensure the redundancy of DPI functionality. Implementing DPI often involves only a software upgrade if existing routing platform hardware already supports adequate processing power.
- **Deploying service aware analysis methods into the packet core:** Most vendors package service aware analysis methods with the DPI software and include it in the overall functionality of the intelligent edge. This is therefore not likely to impact the packet core significantly. Some suppliers may however choose to commercially market this functionality as an optional feature and thus CAPEX may be incurred.

- **Deploying service aware billing functionality and interfacing to existing billing systems:** Once the service aware packet core is in place the mobile operator needs to pass on the real-time service awareness results for each subscriber to the billing system for further processing. Billing systems need to manage a range of new information and billing schemes, such as billing based on location, service type, access point, individual service events, and more, according the mobile operators chosen service strategy.

The following are the main CAPEX and OPEX issues that need to be considered when implementing a service aware / intelligent edge packet core network solution. As such solutions do not usually represent major architectural changes or the introduction of many new network nodes, the CAPEX and OPEX impact is usually limited. But the operator still needs to analyze the extent to which the additional cost is offset by increased revenues from new aware services:

- **Service aware / intelligent edge network node CAPEX& OPEX:** If a stand-alone network node solution is chosen to implement service awareness2, the operator will incur hardware and software CAPEX for the given node. If redundancy is required, two or more nodes will be needed, and even more nodes may result if the geographical scope and topology of the core network is extensive (to equip regional packet core centres with replicated equipment).

  If the chosen vendor provides solutions that can be incorporated into an existing high-capacity GGSN, this solution is less CAPEX intensive as, theoretically at least, it will result in software CAPEX only. The implementation of a service aware node usually only amounts to a relatively simple installation and configuration of the routing hardware and is thus not prohibitive. The OPEX component of the cost is limited to vendor software maintenance fees, and any additional staff needed for maintenance and configuration support.
- **Implementing service aware billing and new interfaces CAPEX & OPEX:** The implementation of new billing mechanisms in support of new aware services is a complex task for which CAPEX and OPEX greatly depends on the extent and complexity of the services offered.

  Some billing systems may relatively readily support sophisticated charging mechanisms and policies, while others may require both hardware and software upgrades and thus incur significant CAPEX. However, the implementation cost (IMPEX) for deploying service aware billing can often exceed equipment and operational costs. Operators should also expect to incur significant OPEX on additional staff to manage, support, and update aware services as the service aware business proposition evolves.

[2] Stand-alone service aware / intelligent edge solution are usually only chosen by operators running converged fixed-mobile networks. In this case service awareness in the GGSN is not enough, as this does not offer awareness of fixed-line traffic from technologies such as DSL or WLAN

Standardization and regulatory issues relating to packet core networks

Standardisation and regulatory issues could impact the mobile operator business case in the medium to long term. The following are key areas the development of which should be carefully observed by mobile operators and vendors alike:

- **Inclusion of WiMAX into the scope of 3GPP standards:** The 3GPP has adopted a standardization approach where mobile WiMAX access networks can be interfaced to 3GPP packet core networks including those of 3GPP LTE under the heading "non-3GPP" interfacing. This means that the mobile packet core networks of the future may need to support much more capacity and functionality than thus far.
- **Long-term threat of network neutrality regulation:** Network neutrality is a complex issue pertaining to what extent network operators are allowed to change, block, or modify Internet (packet data) content and services. Thus far regulation in this area has not been implemented, but it is not unlikely that some regulatory measures could be imposed on operators in the long term. This issue is treated in more detail in Section C.
- **Packet data roaming regulation:** Particularly the EU Commission has recently commented on the issue of high tariffs for packet data international roaming. Some believe that the often very high tariffs on packet data while roaming should be reduced by regulation. This may mean increased packet data traffic for roaming subscribers but may also decrease mobile operator revenues depending on to what extent data roaming traffic will be affected.

Section C: Operator analysis – Market trends and business models

Innovating the broadband business model

The near demise of the walled garden

In the walled garden business model, operators build a closed data services environment for the end user and usually employ operator-branded access portals for a variety of services. They thus fully control access to value-added services (VAS) and charge accordingly. Examples of walled gardens are Vodafone Live or MTNLoaded, where users can access music, ring tones, news, games, and other forms of content for their mobile device. However, the limited success of services running under the walled garden model has also forced operators to look elsewhere for new sources of revenue.

But it is important to note that in the broader IT market space a few walled gardens are still proving successful, for example Apple's iTunes download portal, which has transformed the music download market and may do the same with video and other forms of entertainment content.

The flat rate business model

The rapidly growing flat rate (or near flat rate) mobile broadband services model is almost the direct opposite of the walled garden approach.

This model is built on revenue almost exclusively from monthly access fees (and in some markets additional volume fees when exceeding caps on data volume). The mobile broadband operator then effectively becomes a bit-pipe for unspecified broadband Internet access.

The flat rate business model has been instrumental in developing the mobile broadband market and is likely to dominate for years to come. But it is also susceptible to market pressures from fixed operators or other mobile competitors competing purely on price.

Mobile broadband operators are rethinking their value proposition in the face of eroding revenues. A number of opportunities exist, but it is both costly and difficult for operators to compete purely on overall service quality and raw data rates.

New business models using service awareness

The next major trend in the mobile broadband business will be to build new revenue models based on service awareness, where the mobile operator is aware of Internet services and sites the end user is accessing. This is usually done in the mobile packet core through deep packet inspection, data logging, and analysis of the packet data patterns of individual broadband users.

Typically at least the following packet core functionality needs to be introduced to enable service aware business models:

- Service control including traffic analysis, access point redirection, and authorization
- Bandwidth management including QoS control
- Flexible charging based on content, events, volume, and time consumption.

The emergence of new service-aware business models is speculative since it depends on a number of complex issues in the marketplace including content rights, legislation, and market behaviour. The following examples are likely to be relevant in the medium term:

- **Premium data services:** With broadband usage exploding and some packet core networks overloading one possibility is to offer resource allocation priority to premium broadband users, such as corporate users or high-end consumers, who are willing to pay more for a guaranteed minimum grade of service.

  Service awareness and bandwidth control allow mobile operators to favour subscribers who pay more with a better QoS including guaranteed bit rates. Conversely, low-paying subscribers consuming high bandwidth can be downgraded and allowed to use only limited network resources. This model is attractive in that it reintroduces market segmentation and allows mobile operators to capitalize on differentiated services. Packet core vendors offering effective means of service awareness and bandwidth quality control are well positioned to take advantage of this.

- **Service-based charging:** Service awareness enables the mobile operator to gauge which Internet services are important and valued by the end user, enabling service-based broadband charging. In this business model high-value Internet sites and services are accessed at a premium tariff.

  Service-based charging through service awareness also offers new opportunities for revenue-sharing agreements between operators and third parties, such as Internet-based companies providing popular or business critical services. Mobile operators with large customer bases are well-positioned to negotiate revenue sharing agreements from which 3rd parties will also benefit.

  On the down side service-based business models can present the challenge of managing a large number of complex business agreements as well keeping track of subscriber service preferences.

  To be successful, this business model needs transparent and easily understandable service-based charging plans to avoid alienating a market flooded with mobile broadband service offerings.

- **The potential for advertising revenue:** Understanding the behaviour and preferences of individual users is key to developing effective advertising and marketing schemes. Through DPI and analysis, operators have the tools to understand in detail what individual subscribers are looking for.

  This information can be used (and possibly abused) for marketing and advertising purposes. Push messages, emails, or other tailored media with advertising messages can be precisely targeted towards subscribers known preferences. Highly effective and accurate advertising can then become a source of additional revenue, as illustrated by the success of ad-funded UK MVNO Blyk. According to recent research by 4th Screen, more than 80% of young users would accept mobile advertising in return for free access to video content.

- **Loyalty programmes:** The airline industry has been particularly successful in using loyalty programmes to secure customer retention. Airmiles have been effective in encouraging passengers to use only one airline or an alliance of carriers, an instrumental strategy for conserving and even increasing market share.

The telecommunications industry has not yet adopted this business model, but with falling ARPU and increased broadband competition, loyalty programmes will become more prevalent. Schemes could take the form of free services such as video downloads or free access to popular content sites in return for use of paid services for a certain time duration or volume.

Packet core technical and business issues, including risk assessment

Mobile broadband technical and business risks

As packet data usage grows and networks evolve, mobile operators are faced with a number of technical and business challenges. Associated with these are risk factors that may or may not be under the control of the operator and vendor communities.

CAPEX and OPEX issues pertaining to the points below are covered elsewhere in this document.

Technical & business issues

The most important and business critical packet core issues are:

- **Driving down the capital cost of delivering mobile broadband to the mass market:** The cost of delivering a bit of information on a mobile packet core network is perhaps 3-4 times higher than delivering the same information over fixed networks. This means that mobile operators are faced with very high CAPEX cost pressures when in direct competition with for example ADSL broadband providers. To make sure that mobile operators can sustain a profitable broadband business, packet core vendors should provide packet core solutions at the most competitive commercial prices while ensuring that the equipment is technically capable of providing high capacity.
- **Reducing packet core operational costs for increased delivery efficiency:** Many operators place a strong business focus on reducing operational costs, as these directly impact their bottom line annual earnings. To achieve this, packet core vendors need to provide low-maintenance, high capacity, and flexible packet core solutions, which minimize requirements for additional staff and site costs. Maintenance prices (typically SW maintenance) offered by core vendors in support of their solutions also need to be minimized.
- **Incorporating functionality in support of new business models using service awareness:** With broadband bit pipe tariffs under pressure mobile operators need to develop innovative new business models for mobile broadband. This means that packet core equipment will be required to support a range of new functionality including DPI, service awareness, as well as new charging mechanisms.
- **Evolving core architectures smoothly and cost effectively towards 4G:** 3GPP LTE – or 4G – is by many operators considered to be only a few years away. This means that current or any new packet core solutions should be able to evolve

smoothly to support the new architecture and standards of 4G. The smoothness of this evolution is critical for the reduction of unnecessary CAPEX and OPEX spending on the transition to 4G.

- **Evolving service and transport layer architectures towards All IP and IMS:** Most operators agree that an All-IP network is essential. All-IP architecture reduces operational costs and allows for easy scaling of network and transport nodes. It also simplifies service provisioning and speeds up the time to market of new services – including those of IMS. Packet core networks should support IP-interfaces for all network nodes and enable the smooth introduction of IP on backbone and backhaul transport links.
- **Evolving core and service layers to support all relevant radio access standards:** Packet core networks already need to support a number of radio access standards including 2G, GPRS, UMTS, and HSPA. In the future even more radio access standards will be introduced including HSPA Evolved and 3GPP LTE. It is imperative that transport and service layer nodes in the core evolve cost-effectively to support the new functionality required by these standards.

Risk assessment

The following are key risk areas that need to be addressed by operators with packet core networks:

- **Backhaul bottlenecks:** With the dramatic growth in packet data traffic, a number of operators are facing the challenge of providing enough transmission capacity on their backhaul networks (from the radio access subsystem to the packet core). If such capacity requirements for transport are not met in time, the backhaul network may become a bottleneck and reduce the operator's capability of providing a competitive broadband packet data service. Packet core vendors should thus provide effective transport solutions with flexible means for operators to boost transport capacity to the packet core.
- **Uncontrolled & heavy packet data usage:** Some packet core operators claim that 80% of the volume of traffic on their packet network comes from less than 10% of the users. A few percent of the subscriber base typically uses many so-called peer-to-peer services (file sharing and the like) that consume large amounts of bandwidth on the packet core network. If these users are – as in most cases – on flat-rate tariff plans the heavy usage is not reflected in the mobile operator's revenues, and can even block or reduce the quality of service for other packet data users. The risk of service degradation because of excessive usage under flat-rate tariff plans is thus considerable. To counter this, operators need to incorporate mechanisms to cap packet data volumes and control bandwidth.
- **Network security:** With more and more parts of the packet core network moving towards IP, mobile operators also become more susceptible to attacks on their security. The motivations of individuals who would want to break into IP and network systems of a mobile

operator are many and varied, and the risk of such activities is ever increasing. Mobile operators with packet core networks must therefore make sure that proper and effective security mechanisms are incorporated at all interfacing points between the packet core and any external networks, such as the public Internet. Enabling technologies for improved security include deep packet inspection and effective firewall functionality, preferable for inclusion in existing network nodes, such as the GGSN.

- **Packet core capacity deployment speed:**

  The load on packet core networks for mobile broadband is growing nearly exponentially and is expected to continue this trend in the short term. Mobile operators must have technical means of scaling their packet core networks effectively and quickly to meet new capacity demands. Packet core vendors should thus provide flexible, modular, and easily scalable solutions that allow operators to adapt quickly to the growing market to stay competitive.

- **Increasing cost pressures:**

  The cost of delivery packet data over mobile networks is much higher than that of their fixed counterparts. To be competitive in the market mobile broadband operators need to provide low-cost service. In order for the business case to be profitable, mobile operators need to extract significantly lowered packet core prices from the vendors otherwise the business case will in the medium term become much less profitable. Another possible solution to the cost pressures is introducing technologies and architectures that deliver more bandwidth with less infrastructure such as HSPA Evolved, direct tunnelling, and 3GPP LTE.

- **Legislative risks: regulation enforcing network neutrality:**

  Many operators are considering a long-term move towards service awareness in the packet core. This means that operators may chose to impose control on bit-pipe services that have so far largely been transparent for the end users. The risk of enforced net neutrality by national regulators is a serious threat facing mobile broadband operators trying to adopt new service-aware business models in a move away from the bit-pipe model. If such types of legislation are put in place, packet core operators may be inhibited from freely choosing the new business models that suit their business best and provide the highest revenues.

CAPEX and OPEX issues relating to packet core network selection

The solution is a service aware packet core node (Gateway GPRS Service Node - GGSN) including features for service aware billing & DPI.

The cost model below refers to the CAPEX and OPEX items paid out by a typical (theoretical) mobile broadband operator.

CAPEX costs:

- GGSN platform hardware (router)
- Interface modules (Fast Ethernet or Gigabit Ethernet depending on needs)
- Number of GGSN nodes required (depends on capacity requirements, PDP context numbers, simultaneous number of attached users, topology of operator network)
- Alternatively hardware upgrade costs from existing GGSN routing platform & new interface cards
- If needed, capacity expansion units for Ethernet switch (may also be done by upgrade depending on existing equipment), DNS, Border Gateways, Firewalls.
- Software feature costs: Deep Packet Inspection, Firewall SW, service aware charging optional software (for this we need to see the list of optional features from Huawei)
- Other costs: mediation device / modification of Charge Detail Record (CDR) interface to existing billing platform if required
- Upgrades of SGSN(s) and (probably) RNC software features for inclusion of bandwidth control mechanisms
- Implementation of GGSN and solutions above (anywhere from 2 man-weeks to a man-year or more depending on size of the existing mobile network, topologies, geographical distribution)

OPEX costs:

- Software / hardware yearly maintenance fees (typically 20% of SW CAPEX, HW maintenance at typically 10% of total HW costs)
- Additional leased line or IP-capacity on interconnect from GGSN to public Internet (if needed - depending on capacity & traffic) and between geographically dispersed nodes (depending on topology)
- Headcount increase (operations staff) for maintenance, troubleshooting, new or changed billing system.

In addition to this there are the commercial costs (marketing, pricing strategy, distribution, partnerships management, etc) of launching new packet data services based on service awareness.

Other CAPEX and OPEX issues have been covered throughout the earlier pages of this section.

Section D: Technology trends in packet core

Future technology trends

HSPA Evolved

The next phase of the evolution of the HSPA standard – HSPA Evolved – is specified in 3GPP Release 7 and represents a further increase in broadband data speeds. Commercial network solutions from leading infrastructure vendors are expected to be available in late 2008 and 2009.

HSPA Evolved promises up to 42Mbps downlink data rates and 11Mbps in the uplink but is more technically complex than its predecessor as improved data rates require further advancements in antenna array technology, such as beam forming and multiple-input-multiple-output (MIMO) transceivers. On the radio interface the modulation scheme employed is 64QAM boosting data rates by a factor of 4 compared to standard HSDPA.

Some infrastructure vendors, including Huawei and NSN, offer HSPA Evolved together with direct tunnelling between the BTS and the GGSN. NSN suggests this offers an increase of 40-75% in the number of mobile broadband subscribers served within the radio coverage area. Corresponding savings in CAPEX and OPEX are significant through an increase in the inherent capacity of the network and simplification of architecture.

As HSPA Evolved becomes available and is deployed it is expected to increase peak packet core throughput requirements in the medium term by a factor of four.

Next generation radio access with 3GPP LTE

The 3GPP Long Term Evolution (LTE), the informal name given to Release 8 of the 3GPP family of standards, is widely expected to become the next great leap forward in mobile technology .

While the evolution of HSPA builds on the WCDMA air interface specification, LTE requires the deployment of a new radio access system. The 3GPP LTE radio interface uses Orthogonal Frequency Division Multiple Access (OFDMA) and also relies on the deployment of a much simplified packet core network architecture. Most mobile operators and vendors expect LTE to be implemented commercially within a time frame of 2 - 5 years.

3GPP LTE comprises several development phases and will eventually enable downlink data rates of more than 300Mbps. The first phase is expected to deliver broadband rates of more than 100Mbps in the downlink and 50Mbps in the uplink. LTE also vastly reduces signal latency or delay, making it a better medium for VoIP, video, and other real time applications.

LTE technology development is currently in an early phase and iprincipally driven by early adopters such as Ericsson and Japan's NTT DoCoMo. All major infrastructure vendors including Huawei are active in industry-wide cooperation for the rapid development of LTE.

If the mobile broadband market continues to develop at the current rate, the introduction of LTE will require packet core throughput capacities to be expanded by at least an order of magnitude compared to HSPA Evolved. The ability to offer a smooth and minimal-cost evolution towards LTE architecture with minimal impact on existing HSPA and WCDMA services is of critical importance to packet core network vendors.

Direct tunnelling solutions

Over the next few years mobile operators need to gradually change packet core architectures in preparation for LTE & SAE. While these changes are implemented, core networks must still support legacy services, so existing packet core network elements such as the GGSN and SGSN nodes will have to evolve smoothly to incorporate the new functionality needed for SAE.

As a first intermediate step between the flat-IP architecture of SAE and current HSPA-based networks, several leading vendors are offering a direct tunnelling solution for increased efficiency in delivering mobile broadband. This relatively new system tunnels packet data directly from the radio network controller (RNC) to the GGSN and thus bypasses the SGSN for payload traffic. The SGSN is still used for mobility and subscriber management.

Direct tunnelling enables mobile operators save on both OPEX and CAPEX. NSN, for example, claims it can save 30% or more in networks with heavy traffic. Most mobile broadband operators agree that direct tunnelling is a key enabler to lowering the cost of delivering mobile broadband.

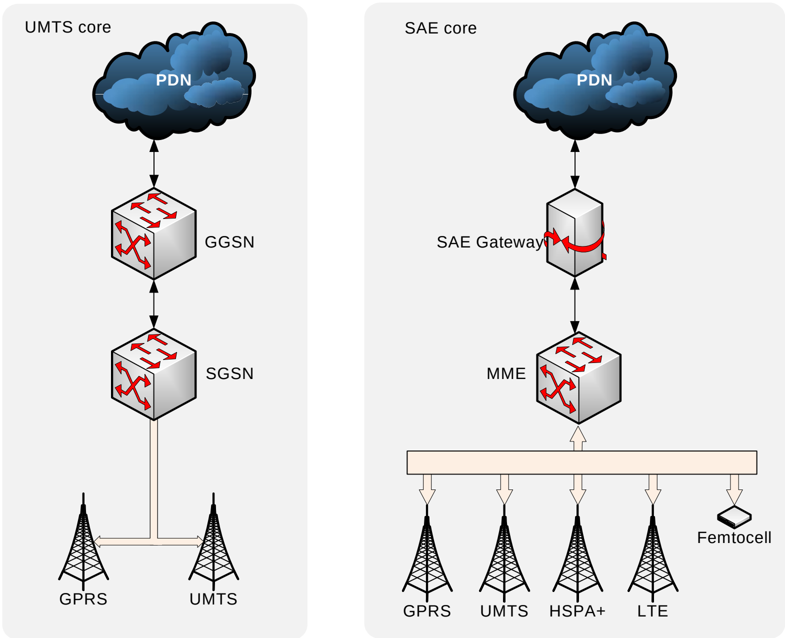
A further step to full implementation of flat IP architecture in 3GPP networks is the introduction of direct tunnelling between the WCDMA/HSPA base station and the GGSN. This method, which also bypasses the RNC and delivers IP data streams directly to the core – is offered by NSN among others. The NSN solution uses evolved HSPA radio access with up to 14Mbps data rates together with direct tunnelling to the GGSN to greatly increase the mobile broadband subscriber and data capacity of a single HSPA base station.

An important selling point of the above solution is that the system is in compliance with the flat-IP specifications of 3GPP Release 7 leading to a smooth implementation of future LTE & SAE in 3GPP Release 8.

Core network evolution towards SAE

The next major architectural development for packet core networks will be the introduction of 3GPP System Architecture Evolution (SAE) in support of the 3GPP LTE radio access standard specified in 3GPP Release 8. SAE is a fully IP-based flat packet core architecture for mobile and wireless networks. Most major mobile operators are currently studying how to migrate packet core architectures smoothly to SAE in the most cost-efficient and least disruptive manner.

Figure 9:Core network evolution from UMTS to SAE



Source: Informa Telecoms & Media

The most important aspect of SAE is the simplification of the packet core network compared to that of current 2G and 3G networks. Instead of the RNC, GGSN, and SGSN nodes much of the required processing will reside in the radio access system (eNodeB base stations), which in turn will connect directly to a common anchor point – a gateway in the packet core. This will result in significant savings both in CAPEX and OPEX for mobile operators, and consequently reduce the cost of delivering a packet data bit.

Most infrastructure vendors are advocating a step-by-step approach to evolving to the full LTE & SAE architecture. Huawei offers an effective evolution path where existing SGSN and GGSN network nodes supporting GPRS and WCDMA services evolve smoothly into the anchor-gateway (Universal Access Gateway (UAG)) and Mobile Management Entity (MME) network nodes needed for full SAE and multi-standard capability.

On the control plane new functionality will be required for mobility and subscriber management including the Mobile Management Entity (MME), User Plane Entity (UPE), and Home Subscriber Server (HSS is also a part of the IMS standard). Vendors may choose to implement this functionality into existing hardware platforms (such as the SGSN) in order to offer a multi-standard compatible core solution and to minimize the amount of new equipment.

Another key feature of SAE is the intended ability of the packet core network to support non-3GPP standards such as WiMAX, WiFi, and CDMA. This means that current CDMA operators such as Verizon Wireless in the USA who have announced their intention to deploy LTE for 4G services will be able to migrate relatively smoothly to 3GPP LTE & SAE. It also means that future WiMAX operators may be able to interoperate with existing LTE networks.

It is not known at this time to what extent complete service continuity including seamless handovers of all services will be available between radio access standards although both Ericsson and Huawei have stated that CDMA1xEVDO to LTE handovers will be supported.

The following are key technical criteria for infrastructure vendors wishing to offer a competitive and business-focused evolution to SAE packet core architecture:

- Developing a comprehensive step-by-step evolutionary approach towards SAE
- Offering upgrades to existing SGSN & GGSN packet core elements to support new SAE functionality such as MME and SAE Anchor Gateway for CAPEX saving
- Incorporating critical service layer functionality (such as *service awareness*) into SAE nodes to reduce network complexity as well as OPEX.

Move to All-IP core networks

Mobile operators are under constant pressure, particularly in mature markets, to cut operational costs and increase efficiency. Operators also want flexible and scalable transport architectures capable of meeting future packet core capacity demands without major changes or upgrades.

A key enabling technology for improving transmission efficiency and capacity in the long term is carrier-class IP. Implementing a carrier-class IP core network is also a fundamental step on the way to fully-fledged SAE for 4G mobile packet data services and will allow greatly simplified and more transparent service provisioning capability.

Most mobile operators today have transport networks comprising both traditional TDM-based and packet data transport over IP and ATM. The former is needed to support legacy voice services while the latter is employed in support of mobile packet data services.

The trend towards all-IP core networks is marked by a number of phases where traditional network element interfaces, such as the SGSN's Frame Relay interface and high-capacity SDH of the RNC, are being replaced by IP-interfaces. This development is already underway for a number of leading operators. For complete all-IP transport, new signalling systems such as Session Initiation Protocol (SIP) for VoIP and mobile multimedia need to be implemented across the entire packet core with the possible intermediate step of using SS7 signalling over IP (SIGTRAN).

On the switching side most mobile operators are now completing their move towards two-tiered soft-switch architecture with separate planes for control and switching. Soft-switch architecture is a further prerequisite for the move towards a complete all-IP network. Infrastructure vendors like Huawei who offer a clear, cost-effective, and operationally optimized path to All-IP packet core networks are in a strong position to capture a part of this infrastructure market.

Mobile WiMAX

Although mobile WiMAX is receives a lot of media attention many operators and vendors perceive it as a relatively immature radio access technology for the time being, at least compared to the widely successful HSDPA. On a positive note mobile WiMAX is specified to deliver mobile broadband data rates as high as 70Mbps over short distances, comparable to data rates of the first phase of 3GPP LTE, but 10Mbps downlink and uplink over average distances is more realistic.

Only a small handful mobile WiMAX networks are currently operational, and the time to market of mobile WiMAX has been much longer than initially expected. However, Worldmax in the Netherlands launched Europe's first mobile WiMAX network in Europe in June 2008 promising unlimited laptop broadband connectivity for only US$13.55 (€20 EUR) per month.

If WiMAX is successful, its impact on mobile packet core networks will be twofold:

- Firstly, it is expected that future packet core networks such as 3GPP LTE & SAE will need to support WiMAX radio access systems, which means that the architecture and services of competitive packet core solutions will have to be transparent to the type of radio access method employed, and
- Secondly, a further boost in the throughput capacity of packet core networks will be needed to support any additional packet data traffic introduced by WiMAX access.

Access agnostic core network support

One clear industry trend is the emergence of an increasing number of radio access standards on the path to greater packet data speeds and improved broadband performance, creating technological fragmentation with a profusion of radio access technologies. With access networks evolving from 3GPP Release 99 to Release 8 (UMTS to 3GPP LTE) mobile operators are expected to support more packet data capable devices across a variety of radio access networks and into the same core network. Add to this mobile WiMAX, ubiquitous WiFi, and access types belonging to the CDMA2000 family, and the range of access standards becomes even more extensive.

Mobile packet core networks will in the medium to long term be required to process an increasing volume of data arising from a variety of new devices operating over a multitude of radio access standards. On the service and application level, core networks will need to manage all elements of mobility, provisioning, service awareness, charging, and rapid service development in support of an increasing number of packet data services delivered over the air.

The evolution of a single IP-based packet core network architecture to support a wide range radio access standards is critical for the future success of mobile operators and is a clear long-term target for most vendors and mobile operators worldwide.

Service aware packet core networks

DPI is not only a tool for controlling usage and implementing fair usage policies, it also gives mobile operators the opportunity to monitor and manage packet data services on their network.

One result of DPI is that packet data service usage can be analyzed, and the results effectively employed in support of new business opportunities.

More and more mobile operators are facing the threat of becoming simply a bit-pipe for generic mobile and wireless IP traffic. If this were to happen, operators would receive revenues based on the amount and possibly the speed of the data transferred, and would be relegated to the lowest level of the value chain. With mobile broadband tariffs under pressure such developments could be detrimental to sustaining sound revenues.

Service awareness enables bandwidth management, security, and new forms of charging. With DPI and service awareness mobile operators can potentially advance their position in the value chain by forming partnerships with content providers. This would pave the way towards revenue shares from a variety of current and future Internet-based services. Ericsson claims 50% of mobile broadband operators have now implemented service awareness in the packet cores.

Service aware packet core networks also empower mobile operators to implement sophisticated charging strategies for mobile broadband services.

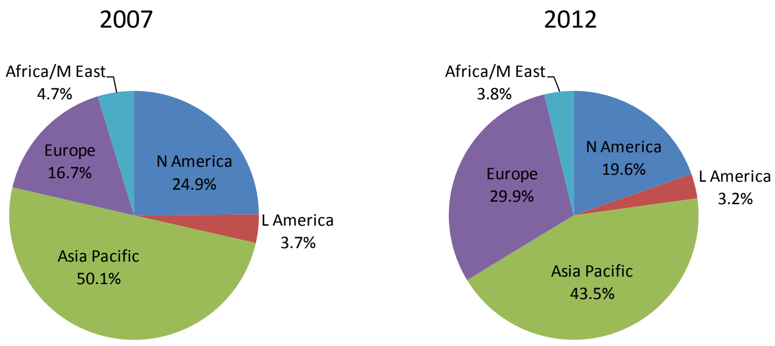
The key functionality requirements for a quality packet core system based on DPI are:

- Functionality for heuristic, application signatures, and transport layer types of P2P identification algorithms within the GGSN or dedicated network element
- The DPI-enabled network element should have access to subscriber profile information to offer differentiated services on a per subscriber basis
- Access method, location, and roaming awareness to control and enable services based on the location of the subscriber
- Functionality for service bandwidth allocation for bandwidth management on subscriber and aggregate service levels
- Smooth implementation of these functions into existing GGSN network elements
- Little or no degradation of processing capacity when DPI and service awareness is introduced into existing elements.

Section E: Forecasts and data

Mobile traffic through the packet core

Figure 10: Global mobile network traffic – market share by region 2007 & 2012



Source: Informa Telecoms & Media – Mobile Network Forecasts report 2008

Packet switch subscriber and traffic growth 2007-2012

In the mobile broadband era the average traffic per subscriber will nearly triple from 2007 to 2012, and mobile operators are already reporting the some mobile broadband subscribers (typically using notebooks with mobile broadband USB dongles) are already generating traffic of more than 2GB per month.

WCDMA subscribers will increase at a compound average growth rate (CAGR) of 30% during the period 2007-2012, compared with 80% for HSDPA, 73% for WiMAX and 470% for LTE (after 2010).

GPRS/EDGE traffic will see a 12% CAGR during this period compared to 37% for WCDMA, 102% for HSDPA and 114% for WiMAX, demonstrating the extent to which more advanced technologies are driving higher data usage and traffic.

Busy hour traffic on average worldwide is assumed to be around 10% of total daily traffic.

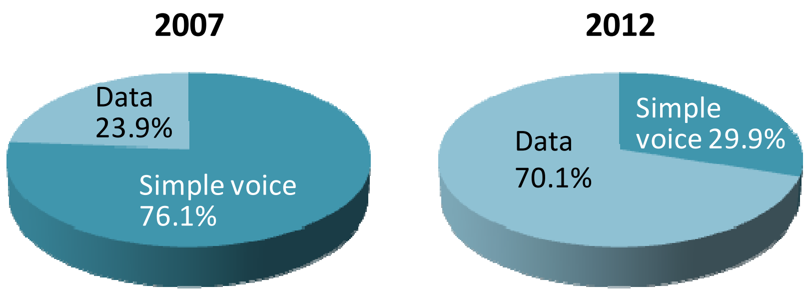
Mobile data services

Mobile data services are taking off across all regions, driving a mobile traffic boom that will lead mobile network traffic to increase in North America at a CAGR of 26% from 2007-2012. In Latin America CAGR will reach 20% during this period, while in Asia Pacific it will reach 29%, in Europe 49% and in Africa/Middle East 27%.

Traffic by application type

The dominance of voice in the mobile industry is well established, and that is particularly clear in the realm of mobile network traffic.

Figure 11: Global mobile network traffic – voice vs data 2007 & 2012



Note: Simple voice excludes VoIP

Source: Informa Telecoms & Media – Mobile Network Forecasts report 2008

Simple voice, also known as circuit-switched voice services, generated 517PB of traffic on mobile networks worldwide in 2007, account for 76.1% of the total traffic that year. The next largest application, internet browsing, generated 47PB, or around 11 times less than simple voice. Browsing accounted for 6.7% of total global mobile network traffic in 2007. Other applications generating significant traffic on mobile networks worldwide in 2007 included mobile office & workforce, business email, consumer email, consumer email and SMS.

By 2012, browsing is still the top application after voice, well ahead of mobile video streaming. Mobile office & workforce, business email and music streaming round out the top five applications after voice in 2012 for generating network traffic.

Although simple voice will still be the top single application generating network traffic, data traffic – that is, all traffic apart from simple voice – will overtake simple voice traffic in 2011, which will be a watershed for the mobile industry.

However, the dominance of simple voice early in the forecast period, plus the strength of consumer email and SMS, account for the dominance of the communication segment, which accounted for 81% of global mobile network traffic in 2007, ahead of enterprise, information and entertainment. Communication will still be the top segment in 2012, followed by information, entertainment and enterprise.

The main driver of the information segment will be browsing, which is expected to increase rapidly by 2012. The other applications in the category will see strong growth but from a very low base, with location-based services and m-commerce services combined generating less than 10PB of global traffic on mobile networks in 2012.

Traffic share by broadband technology

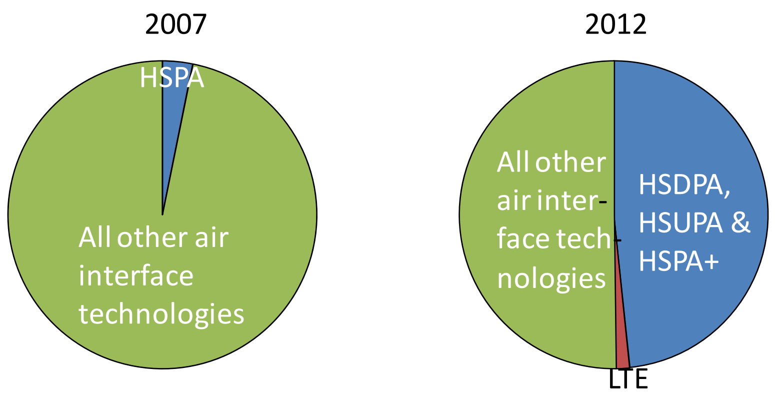
While demand for broadband data will see a continuing strong rise between 2007 and 2011, operator revenues from data traffic will continue to be under pressure from strong competition as users seek flat-rate subscriptions and unlimited usage policies, similar to those they experience on fixed broadband networks. This pressure will continue throughout the next five years, with data traffic growing at more than ten times the rate of revenues.

Many mobile operators, and especially HSDPA operators, can cope with the mobile broadband traffic boom in the short to medium term because there is some spare capacity due to the slower than anticipated early take up of 3G services and the technical characteristics of WCDMA.

However, 2011 will be a watershed – the year in which global mobile data traffic overtakes voice traffic. The transition from voice to data-driven networks will mean coping with the de-coupling of service revenues and network traffic, which in turn means dramatic network cost reductions. Operators are already testing a range of strategies to address this, including new flat IP-based network architectures, and will continue to do so over the next few years.

The chart below shows the HSDPA share of total network traffic in 2007 and the share of HSPA & LTE network traffic anticipated in 2012.

Figure 12: Global mobile network traffic - HSPA and LTE traffic share in 2007 & 2012



Source: Informa Telecoms & Media – Mobile Network Forecasts report 2008

Conclusions

The role of the packet data network is increasing in importance as a key enabling technology of both mobile and fixed telecommunications networks. Not only is packet data Internet traffic increasing dramatically, but voice services will also migrate to packet data networks in the medium term as voice over IP, and mobile operators will gradually phase out legacy circuit switched core subsystems, such as GSM and UMTS CS cores.

A dramatic rise in demand for broadband traffic is being driven by mobile computing, increasingly sophisticated smartphone devices and user desire to access multimedia services on the move. The trend to flat rate fees, along the lines of fixed broadband services, is causing traffic volumes to rise rapidly. Over the next five years, information, entertainment and enterprise data applications will see a strong increase in market share. As a result, mobile operators need to minimise costs and improve delivery mechanisms with packet core solutions for traffic inspection, control and service dependent charging.

The increasing take-up of mobile multimedia services will impact the services and applications level of the mobile packet core networks, where the added intelligence of a full IMS core will be needed. More capacity may also be required on the transport layer.

With high growth of USB modems and HSPA access, due to the fact that HSPA speeds are now comparable to fixed broadband, much of the rise in internet penetration will be due to traffic over mobile broadband and wireless networks and packet core networks will need to grow accordingly. DPI can be incorporated at the edge of the network. Together with heuristic analysis, this allows mobile operators offering converged packet data services over fixed and mobile access networks to control usage.

IMS core architecture at the service and signalling level allows seamless integration of multiple access technologies, including fixed and mobile, into the service portfolio. This enables IP based multimedia services and facilitates service continuity over converged fixed-mobile broadband networks. Drivers include faster service creation and delivery, more efficient bundling of services, reduced complexity of network infrastructure, reduced load and complexity of the billing process. New, innovative applications can also be created using IMS platforms.

Business benefits of a fully converged core network include reduced complexity and therefore reduced CAPEX and OPEX, reduced time to market for new services and rapid adaptation to changing needs, and new revenue development opportunities from bundling and new service creation.

Challenges include driving down capital costs of delivering mobile broadband and reduced packet core OPEX, incorporating new functionality such as DPI, service awareness and new charging mechanisms, evolving core architecture smoothly towards 4G, evolving service and transport layer architecture towards All IP and IMS, as well as core and service layers to support all relevant radio access standards.

Mobile operators will need to address backhaul bottlenecks, look at ways of controlling heavy packet data usage, maintain network security, ensure packet core capacity deployment speeds, manage increasing cost pressures, and potentially face legislative risks such as regulation enforcing network neutrality.

The issues and solutions highlighted in this paper are the main trends and challenges facing mobile packet core operators today and within the foreseeable future. The extent to which mobile operators will be able to react cost-effectively to market and business trends and implement the right changes in packet core networks will also determine the success of the mobile operator businesss in the medium to long term.

A number of packet core vendors including Huawei are well positioned to empower mobile operators to face new challenges and adapt their businesses to a rapidly changing mobile data market environment.