A White Paper from the UMTS Forum

3G/UMTS Evolution: towards a new generation of broadband mobile services

December 2006

UMTS Forum

Introduction

3G/UMTS has unequivocally delivered on its promise to deliver a compelling mobile multimedia experience with a dazzling array of new services. But this is just the starting point. After examining its market success to date, this paper charts the technological roadmap for 3G/UMTS in the medium and longer term. Backed by an open, transparent standardisation process and a harmonised regulatory environment, continual innovation by operators and manufacturers will drive a new generation of broadband mobile services to benefit consumers and business users into the next decade and beyond.

Section 1

Charting the Landscape: 3G/UMTS Deployments, Services & Operator Strategies

1.1 The making of a mass market phenomenon

Approaching 100 million WCDMA customers worldwide

Five years on from the launch of the first fully commercialised WCDMA network in 2001, Third Generation mobile is unarguably a global mass market phenomenon. During the fourth quarter of 2006, subscriptions to 3G/UMTS networks reached 100 million worldwide, with more than 3 million new customers signing up to WCDMA-based networks each month.

Almost 40 million subscribers in Europe

Japan – the cradle of 3G/UMTS after NTT DoCoMo's pioneering launch of its FOMA mobile multimedia offering in 2001 – makes the single largest contribution to the global base with some 30 million WCDMA customers. Despite a later debut for fully commercialised WCDMA networks than in Japan, Europe is seeing demand for 3G/UMTS growing strongly. With almost 40 million subscribers by mid-2006, Europe as a whole now outstrips Japan in terms of overall connections. Within Europe, Italy maintains pole position as the largest single country in terms of connections, commanding more than 15 million subscribers – or almost a fifth of the world's entire WCDMA base.

Despite high 2G mobile ownership levels in relatively mature markets like Western Europe and Japan, 3G/UMTS is nevertheless experiencing significantly faster growth than GSM did in the first years of its existence.

Faster growth than GSM in the first years of its existence

Just as striking as overall growth in the worldwide base of third generation subscribers is the pace with which customers are turning from second generation GSM to 3G/UMTS. According to mobile market information provider Wireless Intelligence, uptake of WCDMA has now reached a clear 'tipping point'. By the first quarter of 2006, WCMDA already represented no less than 95% of total net subscriber additions (WCDMA+GSM) in Europe. This dominance of WCDMA in the European net additions picture has surprised many industry analysts. While it had been widely anticipated that WCDMA would acquire a greater market share of net additions against GSM during 2006, the speed with which this migration has taken place is remarkable.

By the first quarter of 2006, WCMDA already represented no less than 95% of total net subscriber additions (WCDMA+GSM) in Europe.

Consumers today need little encouragement to pick 3G/UMTS over GSM. They are finding out for themselves that third generation is the only choice to meet their lifestyle needs. There are several reasons for this, including the increasing desirability of WCDMA terminals, improved network coverage… and a greater awareness of 3G/UMTS multimedia service offerings driven by strong marketing by operators.

Another key enabler for rapid growth in subscriptions is the continued increase in commercial 3G/UMTS network launches around the world. By the end of 2006, there were around 140 WCDMA networks operational in more than 50 countries.

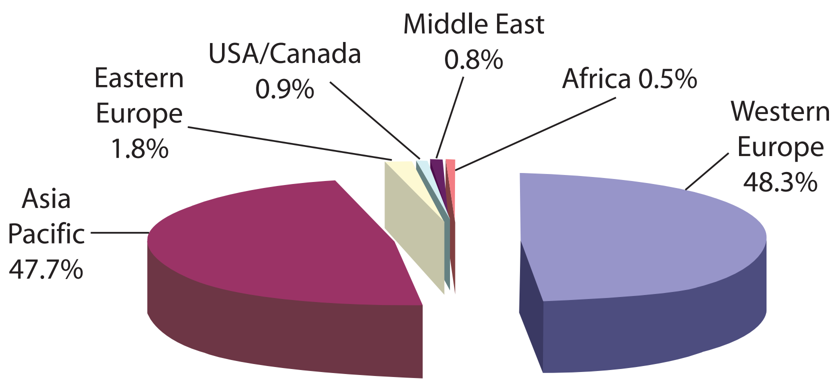
At the end of 2006, the vast majority of WCDMA subscriptions were divided evenly between customers in Western Europe and Asia Pacific. The remainder – less than 4% – was contributed by subscribers in Eastern Europe, North America, the Middle East and Africa. As the pace of network launches slows in 'early adopter' regions, however, we can expect this regional split to change. Growth will occur in these other markets where there is immense potential growth in demand for 3G/UMTS – both as a conduit for consumer-oriented multimedia services and as an alternative to fixed-line access to the Internet in geographical regions that are currently poorly served by access to voice and broadband connectivity.

By the end of 2006, there were around 130 WCDMA networks operational in more than 50 countries.

WCDMA and EDGE deployments worldwide

Source: SOFRECOM, October 2006

WCDMA subscriber base percentage by region



Source: Wireless Intelligence, November 2006

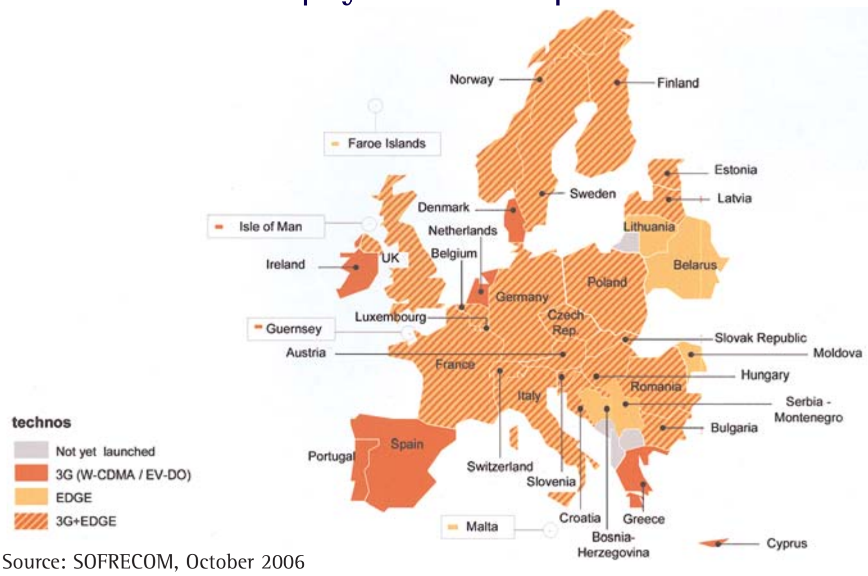
1.2 Gaining an EDGE: a complementary offering for mobile broadband coverage

While its performance in terms of real-world data transfer speeds falls some way short of WCDMA and HSDPA, EDGE offers a cost-effective overlay for operators' GSM networks that gives at least a taste of the 3G user experience.

Over 150 operators have deployed EDGE in more than 90 countries

By the third quarter of 2006, over 150 operators had deployed EDGE in more than 90 countries. Of this total, around a third of all EDGE deployments were in Europe. Significantly, over 50 operators in North America, Europe and Asia had deployed 'mixed' EDGE/WCMDA operations in over 30 countries. In the same timeframe, more than 30 European operators were providing complementary EDGE/WCDMA coverage in over 20 countries. The economics of this strategy are attractive, allowing operators to market broadband mobile services to a larger customer base with wide-area coverage, even when WCDMA networks have not been fully rolled out.

WCDMA and EDGE deployments in Europe



Source: SOFRECOM, October 2006

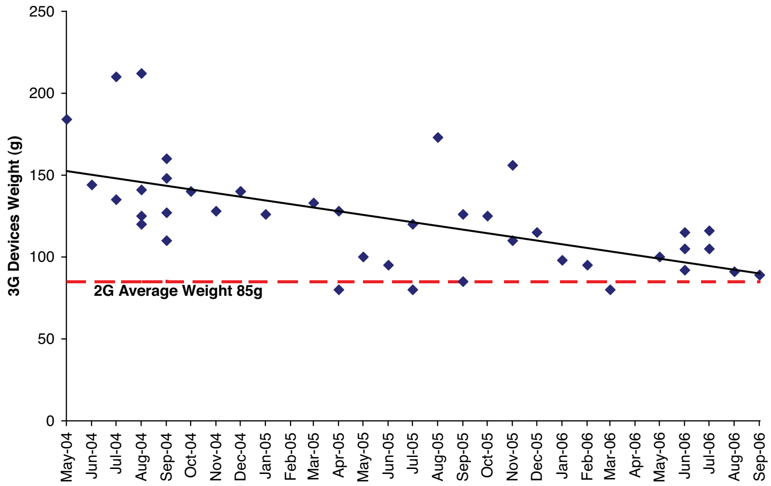
1.3 Terminals: defining the user experience

Over 400 WCDMA terminal designs worldwide

There is now a choice of more than 400 WCDMA terminal designs worldwide [source: GSA], representing handsets optimised for voice, video and other multimedia services as well as PC data cards providing Internet access via 3G/UMTS.

While the earliest offerings struggled to capture customers' imaginations, current handsets score strongly on battery life, size, weight and functionality against their 2G peers. In parallel with this, 'must-have' services like mobile TV and music downloads are encouraging consumers to opt for 3G/UMTS when they make their mobile purchasing decisions.

3G vs. 2G: Average terminal weight is converging rapidly



Source: Credit Suisse

3G/UMTS has given manufacturers ample opportunity to engineer a new generation of highly-specified multimedia smartphones, loading their handsets with premium features that would be either impractical or hard to justify on a GSM phone. Fast USB and WiFi connectivity are becoming increasingly commonplace alongside multi-megapixel cameras with quality branded optics, large amounts of removable storage and high-resolution screens with a palette of a quarter of a million colours or more. With 3G, device manufacturers have been able to stretch traditional notions of what functionality a mobile phone should offer – and today's offerings are the surest signs yet of PC/mobile convergence becoming reality.

One area where latest generation terminals are almost unrecognisable from their peers of just a few years ago is storage capacity. High-capacity hard disk drives holding several gigabytes of data underline the credentials of these devices as fully-fledged multimedia appliances. Slots or removable media are also becoming commonplace, allowing customers to store gigabytes worth of pictures, videos and music on compact flash, memory stick and other formats.

While the majority of 3G/UMTS terminal devices offer features aimed at multimedia-literate consumers, a new generation of handsets is appearing for the business market. Loaded with business-oriented operating systems, keyboards for rapid text entry and productivity applications, PDA-style handhelds offer at least a partial replacement for notebook PCs. Against this backdrop of rapid evolution in handheld devices, business users have continued to buy 3G-enabled PC cards for their notebook PCs to allow on-the-move access to e-mail, the web and other corporate resources.

Operators are also using mobile devices as a differentiator to attract a broader range of 3G customers. NTT DoCoMo, for example, has already introduced its first FOMA handsets whose bright colours and styling appeal directly to children.

1.4 3G/UMTS services

1.4.1 Mobile TV: 3G's killer app?

By the end of 2005, Orange France was already proposing more than 50 live 3G mobile TV channels

If there is one service category that epitomises the growing popularity of 3G/UMTS, it is mobile TV. It is a term that is used loosely to cover a range of differentiated services, but Mobile TV typically means offering subscribers access to a choice of themed 'channels', allowing them to watch their favourite shows as well as bespoke content that has been specifically created and optimised for mobile consumption.

A key enabler for the fast-growing popularity of mobile TV has been the viewing experience itself. Mobile screens are getting larger while supporting higher resolutions and larger colour palettes. In parallel with this, improved power management makes it practical to watch a ten-minute clip of a soap opera without flattening the phone's battery.

By the end of 2005, Orange France was already proposing more than 50 live 3G mobile TV channels – at that time the most extensive offering in the market. Orange has also made early moves to grab ownership of the 'mobile cinema' market with its Orange Short Film Festival. Coinciding with the annual film festival in Cannes, the event showcases drama, documentaries and animations specifically created for viewing on mobiles. Spanish operator Amena last year launched the serialisation of hit series Supervillanos via its 3G mobile portal, attracting 200,000 downloads from 80,000 Amena customers between November 2005 and March 2006.

It is unsurprising that television broadcasters are moving to cement strategic relationships with mobile operators. One example of this is the tie-up between Vodafone UK and BSkyB to offer Vodafone Live! customers a 'Sky Mobile' branded package of news, video, weather and other tailored clips.

1.4.2 The emergence of mobile video and self-produced content

Mobile phones are not just being used to watch the news: today they are being used to make it. An increasing number of high-profile events have been relayed on the world stage through footage captured on mobile phones. While it may fall far short of broadcast quality, mobile video – enabled by the data throughput of 3G – has become an essential medium in its own right.

The evolution of mobile devices – with video cameras, editing tools and significant amounts of on-board storage space – means that consumers can create and share their own 'mini movies' without the need for a camcorder or any additional hardware or software.

3G has provided much of the impetus for consumer phenomena like YouTube. There are reputedly more than 100 million video downloads served per day from this popular portal that invites contributors to share their own clips. While not exclusively a mobile service, many of these videos have been originated on mobile devices. Similarly, operators are themselves tapping into the groundswell in demand for self-originated content. For example, 3UK partnered with media producer Endemol to offer 'See Me TV' which stimulated 4,000 uploads and 40,000 downloads in its first four months of operation.

Nor have device manufacturers been slow to wake up to this phenomenon. Nokia has created its own 'blogging' portal aimed at users of its Nseries handsets, encouraging them to create, edit, store and share their own video content.

1.4.3 Music on the move: customers flock to mobile music

Mobile music is another service category that is rapidly gaining traction with 3G/UMTS customers. In the early days of 3G, much was made of the technology's ability to deliver full-motion video clips and provide access to the Internet. But while the promise of video-based services captured much initial industry enthusiasm, the importance of music on mobile devices was arguably underestimated in some quarters. To put the appeal of mobile music services in context, downloading a full-length song can take a minute or less via 3G/UMTS. This contrasts with five minutes or more on GRPS.

SFR claims 1.5 million downloads from its catalogue of approaching half a million songs

Audio downloads have revolutionised the way that people browse, purchase and listen to music. While worldwide music sales fell by 3% in 2005, digital music tripled in volume in a similar timeframe. What is more, 40% of this revenue was attributable to mobile phones. Indeed, Japan is the world's biggest market for mobile music revenues, earning no less than 94% of its digital music sales via mobile devices. This new paradigm has re-invented 'music on the move' as a concept to consumers, and it is unsurprising as a consequence that mobile device manufacturers and operators alike have reacted to offer functionality that borrows much from 'the iPod experience'. Approaches to offering music to mobile customers vary. Alongside full-track download services are rental models where the subscriber buys personal listening rights to a copyright piece of content for a limited time.

Operators are already reporting success in this nascent marketplace. By May 2006 Vivendi subsidiary SFR claimed 1.5 million downloads from its catalogue of approaching half a million songs – representing 17% of the French market for legal music downloads. 3UK has also scored significant results in the music download space. Alongside special tariff plans optimised for music lovers, the operator has forged partnerships with several major labels and lured customers with exclusive content offerings. By March 2006, 3 had sold its millionth single download, accounting for more than half of all mobile music downloads in the first quarter of the year. Orange in France has also made music a key element of its mobile broadband offering to consumers. The Orange World Music portal provides 'one click' access to a catalogue of more than 550,000 tracks including several exclusives from major artists. Full-length tracks are complemented by shorter clips and ringtones. Typically priced at €2 or less, downloads can be listened to using the customer's mobile, PC or both. Orange France's offering is further enhanced with a complementary Orange Music Cast service that allows subscribers to listen to a range of themed music channels.

Mobile music currently contributes a relatively small amount to non-voice ARPUs, but this picture may be changing rapidly. Sensitive to the vast potential – still largely untapped – for selling music of all genres through the mobile space, new affiliations are rapidly appearing between record companies and mobile operators in the search for lucrative business models. Handset manufacturers are also playing a key role in shaping this new market, offering devices with high-capacity hard drives and dedicated transport controls.

The future for mobile music undoubtedly lies in tighter interplay between devices and the management of on-line music content libraries. The definition of 'mobile music' will also extend to embrace music video clips, TV clips and other value-added extras. With the commercial interests of record companies and their artists protected by effective rights management schemes, continued growth in operator revenues from this popular, high-value channel looks certain.

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1.5 The price of success: a range of tariff strategies

Pricing remains one of the most volatile elements of the 3G/UMTS customer proposition. In a marketplace that is characterised by intense competition from television and the Internet as well as other mobile services, operators are focusing on innovative pricing strategies and tariff models as a powerful differentiator to lure customers and drive traffic.

Inspired to some extent by 'flat-rate' pricing for unlimited broadband Internet access, 3G/UMTS operators have experimented with high-volume offers of their own. Typically these offers bundle 1,000 minutes' talk time or more with video call minute and messaging. Hitherto, 'unlimited' offers have been restricted to same-network calls or non-peak times, but now increased competition is driving more inclusive deals.

There are as many price plans and tariff strategies as there are 3G/UMTS networks and target customer groups. Some operators have used seductive offers to stimulate usage of services like videotelephony. As an example, Orange Switzerland used the 2006 FIFA World Cup as an opportunity for 3G/UMTS subscribers to view live matches free for a month as part of a 'Try mobile Internet' promotion. In Italy, 3 offered a €10 package including goals and a 60-second summary of all 64 matches. Vodafone Italy, meanwhile, provided video highlights of each match for €0.50/day plus video match round-ups for €1.90/day.

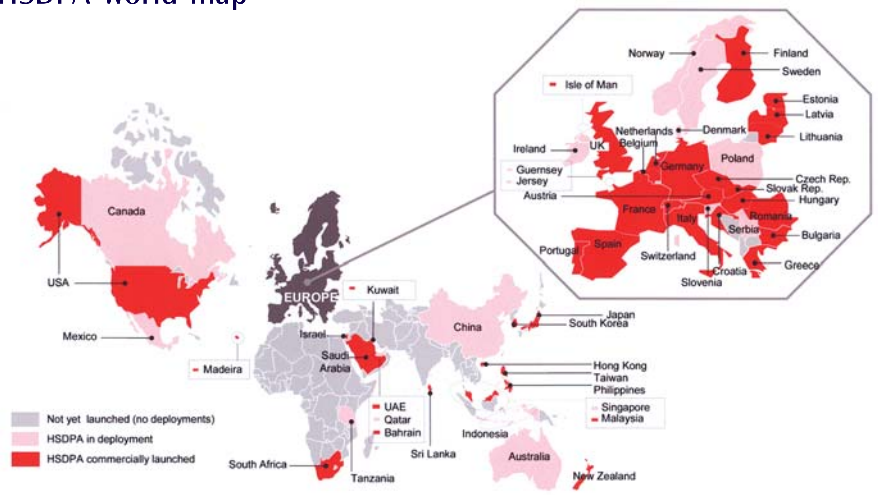
A 'disruptive' influence that potentially threatens 3G pricing models is the emergence of 'free' or unlimited voice calls from the new generation of VoIP providers. Some operators are turning this to their advantage by partnering with VoIP players to offer their 3G customers effectively unlimited low-cost voice calls. Skype, for example, has been accessible to e-plus customers via a 3G PC card since Q4 2005. Whether this strategy will undermine mobile voice revenues in the long term remains to be seen.

Tariff plans are not the only drivers for consumer purchasing behaviour. As operators like NTT DoCoMo have already demonstrated with the successful introduction of entry-level models, handset pricing can have a dramatic effect on take-up of 3G subscriptions.

By Q3 2006, more than 60 HSDPA networks were commercially operational in almost 40 countries.

1.6 More speed, more capacity: the market moves to HSPA

HSDPA world map



Source: SOFRECOM, October 2006

Spurred by the promise of increased revenues from increased usage of mobile data, many operators are now looking to exploit the benefits of HSPA (High Speed Packet Access). By Q3 2006, more than 60 HSDPA networks were commercially operational in almost 40 countries. This first phase of deployments focuses exclusively on HSPDA, enhancing the downlink component of the WCDMA air interface only. In user terms, this means the benefits of HSDPA will be experienced with 'asymmetric' services such as Internet access, live TV, video on demand, MP3 streaming and audio/video file downloads. A full-length music track downloaded as an MP3 file, for example, takes around a minute using 3G/UMTS, while with HSDPA, this time is reduced to fifteen seconds or less. 'Full duplex' applications – like videoconferencing with symmetric up – and downlink traffic requirements – will only benefit with the introduction of HSUPA (High Speed Uplink Packet Access).

Several operators are offering zero-cost upgrades from their current WCDMA/EDGE data cards.

HSDPA mirrors the first phase of WCDMA launches with the range of differing coverage strategies. By Q2 2006, Tre (H3G) had already reached some 35% of the Italian population, with the objective of reaching 60% POP by the year end. Other European players have made more cautious predictions about the coverage they will be offering in the same timeframe.

The choice of HSDPA-enabled terminals is growing fast – and, as with WCDMA, there is a range of different pricing plans for HSDPA. South Africa operator Vodacom, for instance, offers a choice of 6-month contract periods as well as data bundles stretching up to 10GB per month. For many existing 3G/UMTS customers, the transition to HSDPA is relatively painless since several operators are offering zero-cost upgrades from their current WCDMA/EDGE data cards.

Some operators have opted to differentiate HSDPA services with their own distinctive branding. For example, Vodafone in Germany selected the name 'UMTS Broadband' for its service. Vodafone Portugal, in contrast, has commercialised its service as '3.5G'. Czech operator Eurotel has badged its own offering as 'Internet Speed', supported by flat-rate pricing plans for business customers. In France, Orange has used the brand name '3G+' for the launch of its own HSDPA service. In Asia, South Korea's SKT introduced its consumer-oriented HSDPA service in 25 major cities under the same '3G+' brand, supported by handsets from Samsung, then LG and other vendors.

Section 2

HSPA: Speed & Capacity to Support New Services

2.1 In pursuit of the wireline experience: HSPA introduced

One of the key objectives of third generation technology has been to deliver an improved end-user experience for mobile data applications while ensuring the costs of delivery make the service economic to both end-user and service provider. As wireline broadband services based on Digital Subscriber Line (DSL) and cable technologies become more prevalent, mobile data connectivity must offer a comparable end-user experience if the service is to be attractive in the marketplace. A major development in the improvement of end-user experience is now available through High Speed Packet Access (HSPA). HSPA will be launched to the market in two phases, the first offering improvements in the downlink (HSDPA) while in a second phase the uplink will offer an improved uplink performance (HSUPA).

HSPA is a step along the path of technology evolution which UMTS offers. Improvements to HSPA are already being proposed, these are known as HSPA+, while a proposal for Long Term Evolution (LTE) is currently making its way through standards. Each of these steps will be discussed in this paper. However, at this point it is worthwhile to compare the different steps in the UMTS evolution path in terms of technical characteristics, performance and cost.

2.2 HSPA market strengths and features

The strong level of interest in this technology is driven by some key end-user advantages, some key technical advances, and a common understanding in the industry of the strong market potential for wireless broadband services.

2.2.1 Key end-user advantages

A tenfold increase in maximum throughput compared with 3G/UMTS today

There are two significant improvements that will be perceptible to the end-user with the launch of HSPA: improved throughput and improved latency. In addition, operators will benefit from a significant increase in network capacity for data services.

Improved throughput

UMTS networks deployed based on the 3GPP Release 99 standard offer a maximum theoretical data throughput per user of 384 kbps. With HSDPA there is the possibility to offer the end-user up to 14.4 Mbps in the downlink. How often or how many users will be able to achieve this throughput will obviously depend on network and radio conditions as well as the type of terminal being used. A more reasonable scenario will see a large number of users with a category 6 HSDPA terminal allowing them to communicate at data speeds up to 3.6 Mbps. This is already almost a factor of 10 increase from the maximum throughput available to 3G/UMTS users today. This will bring new applications such as high quality video streaming as well as faster music and entertainment downloads, and improved time savings for ubiquitous corporate e-mail services. Category 6 devices have been part of the early HSPA launches announced in recent months.

First deployments of HSDPA indicate a round trip delay of as low as 60ms

The data capacity available in the standard UMTS carrier bandwidth of 5MHz is increased by a factor of 5

Improved latency

One of the major improvements with HSPA technology is the improvement in network latency or round trip delay for data applications. First deployments of HSDPA indicate a round trip delay of as low as 60ms, meaning that many real-time interactive services can be delivered over HSDPA. This will be true for Voice and Video but also for applications such as multi-user gaming where immediate real-time interaction with other users is key to stimulate high levels of game usage. This will be the key enabler for the beginning of a new era of mobile multimedia over UMTS networks and terminals.

Improved capacity

With the introduction of new improved coding and modulation with HSPA, the spectral efficiency of the access network is much improved. Early tests and measurements indicate that the data capacity available in the standard UMTS carrier bandwidth of 5MHz is increased by a factor of 5 with the upgrade to HSDPA. This will offer the operator a much improved cost structure for offering data services with the cost per bit reducing significantly. This should help drive adoption rates of mobile data services as the cost to deliver the services to a wider audience will be significantly decreased.

2.3 Services & market potential

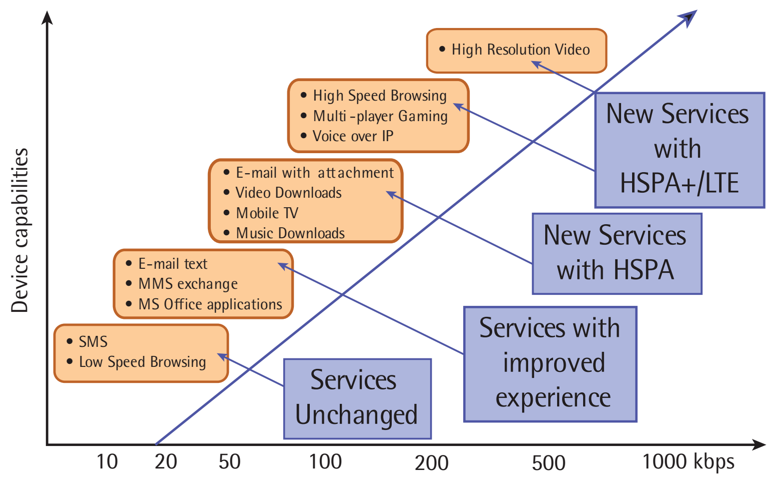
HSPA offers the opportunity of a new service experience for 3G users. In understanding the impact of HSPA on the service offering, the UMTS Forum categorises services into three categories:

1) Services unchanged user experience
2) Services with improved user experience
3) New services enabled by HSPA.

Services such as SMS or low speed browsing are unlikely to see a significant end-user improvement, although the capacity for offering these services will be significantly improved.

The improved speed and latency of HSPA will offer a much improved end-user experience for services such as Multimedia Messaging, Mobile TV, e-mail and music downloads. This improved facility of usage can be expected in turn to stimulate usage levels.

HSPA delivers new services and an enhanced user experience



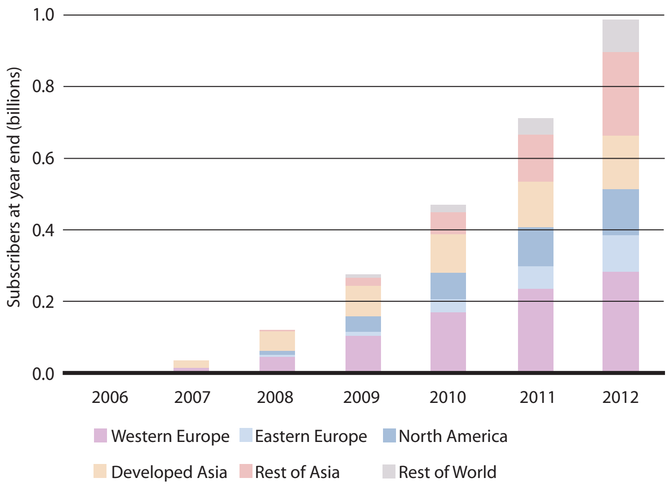
Source: Nortel

By 2012, there will be almost 1 billion users of HSPA technology globally

Among the new services expected to be enabled by HSPA and the evolution to HSPA+ and LTE will be Voice over IP, multi-user gaming and high resolution video. HSPA has the opportunity to become the world's leading 3G technology within the next few years. In Market Report 39, "The Global Market for High Speed Packet Access (HSPA): Quantitative and Qualitative analysis", the UMTS Forum forecasts that, by 2012, there will be almost 1 billion users of HSPA technology globally.

The report also forecasts that HSPA will make a significant impact on the revenues from mobile data services. The report forecasts that mobile data revenues will increase from €17bn in 2006 to €120bn in 2012.

HSPA users will approach 1 billion by 2012



Source: Analysys/UMTS Forum

2.4 HSPA key technological features

HSDPA introduces a number of new technical capabilities to the radio access network which, when combined, offer a significant improvement for both end-users and operators. These are:

2.4.1 HSDPA

High Speed Downlink Shared Channel (HS-DSCH)

The HS-DSCH is a shared channel with a number of Spreading Factor 16 (SF-16) CDMA codes. Within each 2ms TTI, a constant spreading factor of 16 is used with a maximum of 15 parallel channels in the HS-DSCH. These channels may all be assigned to one user during the TTI, or may be split amongst several HSDPA users.

Transmission Time Interval (TTI) of 2ms

The shorter 2ms TTI (compared with TTI of between 10ms and 80ms in UMTS R99) means that the system is more reactive to changing user or radio conditions and can quickly allocate capacity to users.

Fast scheduling
Fast data traffic scheduling means that variations arising from changing radio conditions can be accommodated and that the BTS is able to allocate as much as possible of the particular cell's capacity to a particular user for a short period of time. This means that a user is able to receive as much data as radio conditions will allow.

Adaptive Modulation and Coding (AMC)
Adaptive Modulation Coding (AMC) with fast link adaptation means that the modulation and coding formats can be changed in accordance with variations in the channel conditions, leading to a higher data rate for users with favourable radio conditions. Whereas UMTS Release 99 used only Quadrature Phase Shift Keying (QPSK) modulation, HSDPA provides the ability to use 16-QAM when the link is sufficiently robust, which can lead to a significant increase in data rate.

Fast Hybrid Automatic Response reQuest (HARQ) techniques
Fast H-ARQ enables erroneous packets to be re-sent within a 10ms window, ensuring that the TCP throughput remains high. In addition, in HSDPA the mechanisms for ARQ are moved to the BTS (from the RNC in R99). By using these approaches, all users, whether near or far from the base station, are able to receive the optimum data rate.

2.4.2 HSUPA

Similarly to HSDPA in the downlink, HSUPA defines a new radio interface for the uplink communication. The overall goal is to improve the coverage and throughput as well as to reduce the delay of the uplink dedicated transport channels. From a 3GPP point of view, the first set of standards was approved in December 2004, and performance aspects were finalised during the summer of 2005. E-DCH is the name adopted in 3GPP for HSUPA which is in 3GPP Release 6. Key technical capabilities introduced with HSUPA are:

A dedicated uplink channel
Unlike HSDPA, HSUPA remains based on a dedicated channel. A series of new channels is introduced for both signalling and traffic to improve overall uplink capabilities.

H-ARQ
Like HSDPA, HSUPA introduces fast retransmissions based on the Hybrid ARQ Protocol for error recovery at the physical layer.

Fast Node B scheduling
Within the limits set by the RNC, the Node B scheduling enables the Node B to control the set of Transport Format Codes from which the UE may choose. This will enable improved coverage and capacity in the uplink.

2.5 VOIP/IMS

The use of Voice over Internet Protocol (VoIP) technology is increasing rapidly in fixed networks. Incumbent operators are facing strong competition to their voice services from ISPs and new operators taking advantage of Internet VoIP technologies deployed over DSL networks.

To date, VoIP has not taken off in mobile networks. There are a number of reasons for this:

- It is still considerably cheaper to offer traditional circuit-switched voice services over cellular networks because the overhead associated with VoIP technology results in high bandwidth consumption.
- For end-users, VoIP with GPRS data tariffs would not be financially attractive compared with traditional voice. This is unlikely to change very soon due to the bandwidth constraints.
- Latency and jitter in today's cellular data networks would result in an inconsistent VoIP experience for the end-user. These performance characteristics differ significantly within the coverage areas of GPRS, EDGE, WCDMA and HSDPA technologies. The general immaturity of proper support for real-time bearers in devices and networks alike exacerbates this situation.
- Mechanisms are required to make IMS VoIP offered by a cellular operator or its partners more efficient than circuit-switched voice, while leaving external service providers without a Service Level Agreement (SLA) with best-effort Internet connectivity for their service.

The technical challenges related to introducing VoIP are being solved through the support of real-time services over HSPA. Other modifications in HSPA will increase the number of VoIP users per cell and take full advantage of the improved spectral efficiency, as has already been done in other standards such as 1xEV DO. Furthermore, the overhead associated with VoIP technology is more than compensated for by the increase in spectral efficiency with HSPA that results in more voice users per carrier than with circuit switched calls.

The introduction of VoIP will, with time, bring the following benefits:

- Increase the number of voice users per cell, compared with existing circuit-switched services, resulting in a lower cost of voice traffic. This will help operators improve profitability and provide low cost delivery for the unlimited voice tariffs that are likely to become the future business standard
- Support for end-to-end IMS services that will benefit end-users, shifting the emphasis away from voice and allowing operators to provide differentiated service offerings
- Converged services across fixed and mobile worlds, made possible through the combination of fixed and mobile access networks with the joint service platform built on IMS.

HSPA provides high bandwidth on both uplink and downlink and so is particularly suitable for symmetric voice services. HSPA in conjunction with IMS will provide operators with the option of migrating voice from circuit-switched to packet-switched operation, enabling innovative services that combine voice and data.

2.6 Positive moves: HSPA+

Operators have already invested massively in the deployment of 3G/UMTS networks and will continue to invest over the coming years, increasing coverage of existing networks and deploying new 3G/UMTS networks in developing countries.

They naturally wish to maximise their return on these investments. An evolutionary approach to standardisation supports this requirement. Phased enhancements to the 3G/UMTS standards are made possible by the continuing improvements in underlying technologies.

While standardisation work is not yet complete, enhancements currently being defined by 3GPP under the banner HSPA+ consider two significant improvements to HSPA. These are an enhanced air interface plus a simpler, more cost efficient architecture.

2.6.1 More traffic, same equipment: HSPA+ defined

The main improvements are to the air interface. HSPA+ will have increased spectral efficiency and average rates per cell. This will help support increasing traffic, especially traffic from data services, without having to deploy new sites and with limited hardware upgrades of existing equipment.

- MIMO is being introduced to increase spectral efficiency in hot spots by an estimated 10 to 20%; MIMO requires additional antennas, possibly hidden in rearranged antenna systems, and transmitters in existing base stations

- 64 QAM modulation is being proposed to increase data rates under good propagation conditions, contributing to an overall 20% increase in throughput.

Architectural improvements for HSPA+ are also being discussed in 3GPP where several items are being analysed. The objectives are a simpler and more cost efficient architecture for mobile broadband access services, together with better delay performance.

- A simpler architecture would result from the elimination of macro diversity and the associated RNC node. All RAN functions would be put in the Node B, directly connected through the current Iu interface to the core network. Although macro diversity is a key feature of CDMA-based technologies, its elimination is made possible through two considerations:
  - The introduction of HSPA in the downlink has been done with very limited use of macro diversity
  - HSPA in the uplink is based on macro diversity for optimal performance but in dense areas downlink capacity is the limiting factor; a decrease in the theoretical capacity of the uplink is acceptable as this limit is never reached.

Such an evolution would result in a simpler system with a consequent decrease in cost. It also allows the possibility to deploy Node Bs from any supplier in dense areas – a flexibility resulting from standard interfaces, not available today as the Iub interface is not really open.

- Better delay performance will result from integration of the 3G/UMTS network with the forthcoming 3G LTE/SAE network

2.6.2 HSPA+ timeframe

For enhancements to the air interface, such as MIMO and 64 QAM modulation, agreement on implementation principles has already been reached in 3GPP. These items could be fully standardised in 2007 for possible deployment as soon as 2008. This would deliver improved HSPA performance with reasonable upgrade costs at a time when HSPA traffic is increasing and could otherwise require additional sites. Details of the architecture improvement items are currently being discussed within 3GPP.

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Section 3

Looking to the Future: 3G/UMTS Long Term Evolution

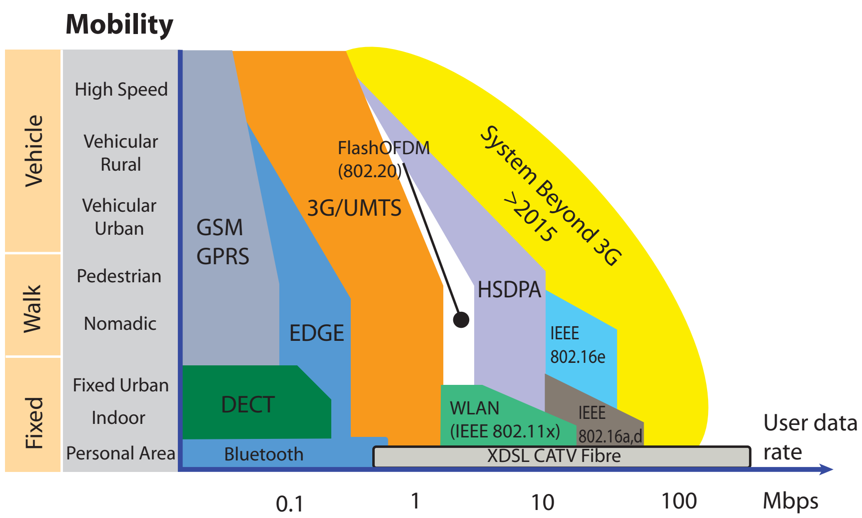
3.1 Planning ahead: technology choices in a complex world

3.1.1 Dimensioning for the future

The past decade has seen explosive growth in mobile communications within every single continent across the globe. Spearheaded by GSM systems, the mobile communications sector in many countries is now experiencing subscriber penetration levels approaching or even exceeding 100%. Voice traffic continues its apparently inexorable migration from fixed to mobile networks. Multimedia services are starting to take hold as 3G/UMTS networks are rolled out – attracting subscribers at a faster rate than the first GSM networks – and appealing terminal devices become widely available.

In just a decade, mobile communications has had a massive impact on economies and societies. That impact is continuing as the previously voice-centric mobile networks embrace data and video services and as convergence irreversibly changes the structure of the telecommunications industry. The amalgamation of mobile communications and the Internet is set to strengthen as broadband access networks are deployed and legacy PSTNs are replaced by all-IP environments.

Evolution to higher bitrates drives convergence between fixed/mobile systems and the Internet



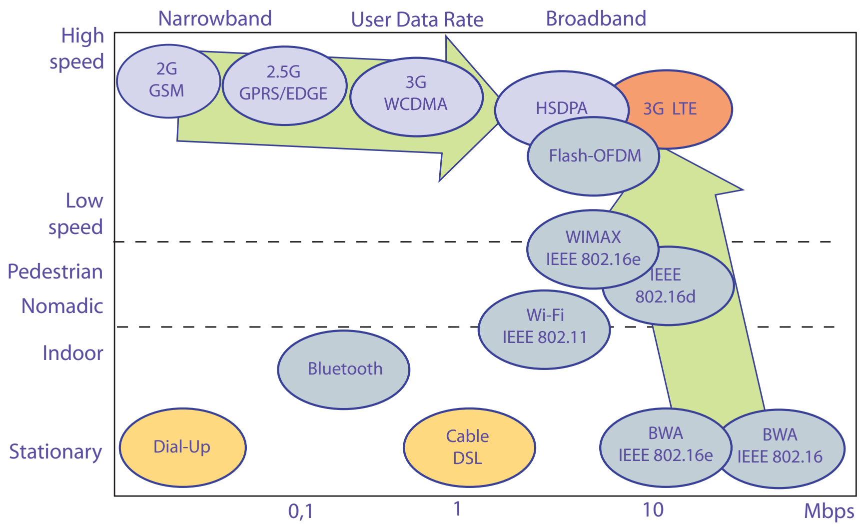
Source: Siemens

These new dimensions make planning for the future an urgent but daunting task. The underlying problem is unpredictability – the future can no longer be approached as an extrapolation of the past. No-one can be certain what mix of products and services the next generation of users will be demanding from the information and communications industries a decade from now.

Voice services will undoubtedly be part of that demand. When digital cellular systems were originally designed, voice was the primary target service. System design focused on technology issues. Which technological approach could best satisfy the required criteria for coverage, capacity and quality in a mobile environment? Technology choices are still a major factor in the planning of future systems – but no longer such a dominant factor as in the past.

The addition of mobile multimedia and internet services with 3G systems such as UMTS introduced a new dimension. Different services impose different requirements on radio access technologies and networks. The anticipated mix of services became an important factor in system specifications. Market demand for different categories of service became one of the important design criteria.

Trends in Mobile Wireless Access – Several technologies move in the same direction: Mobile Broadband



Source: Siemens & UMTS Forum

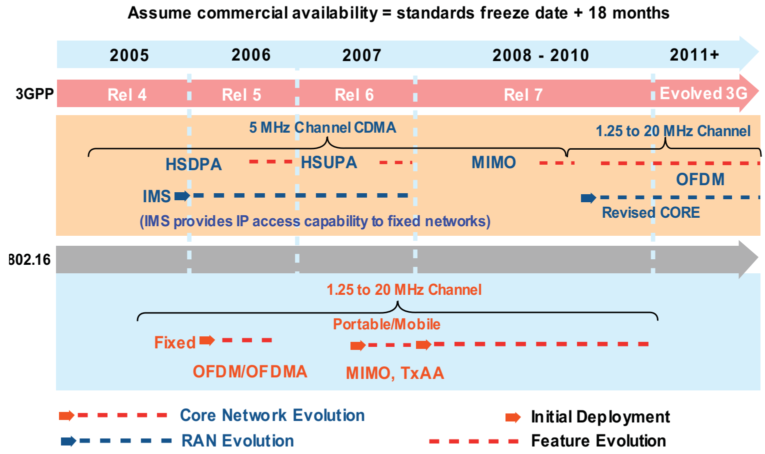
Market demand for new services remains a key consideration in the planning for the evolution of 3G/UMTS. But yet another dimension has emerged as a vital factor affecting the design of evolved systems. Compatibility with existing systems has become an important requirement, allowing both users and operators to retain the benefits of the existing rich portfolio of services in the most cost effective fashion.

3.1.2 A holistic process

Planning for the long term evolution of 3G/UMTS is no longer a one-dimensional exercise of selecting the technology with the best performance. Technology remains important of course; mobile radio standards have always evolved to take best advantage of technological developments. But planning has now become a three-dimensional task in which technology choices have to be balanced against user demand for different services whilst preserving the advantages of today's mature mobile environment. Planning has become a holistic process.

Although 3G/UMTS will remain highly competitive for several more years as a result of enhancements such as HSPA, 3GPP is already planning an evolution of the radio interface as well as the radio network architecture. Broadband services and applications are the primary driver behind this evolution. Apart from the evident aims of increased performance and cost effectiveness, designs for future systems are tasked to ensure compatibility with existing commercial and regulatory environments. This is a deliberately evolutionary rather than revolutionary approach that recognises the need to build on existing investments and the impact of increasingly diverse spectrum allocations. The goal is to ensure competitiveness over the next decade and beyond. The project has been entitled Long Term Evolution (LTE) although that could be a bit of a misnomer. LTE standards are planned to be completed by the end of 2008 with equipment availability scheduled for 2009 – more mid-term than long-term, reflecting the rapidly evolving nature of the mobile industry.

Standards Evolution



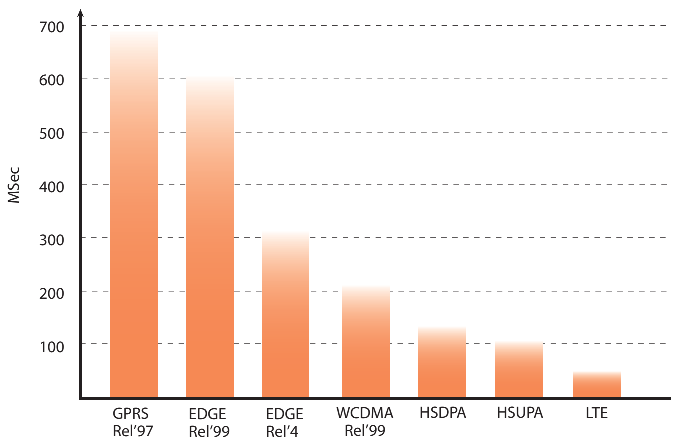
Source: Motorola & UMTS Forum

3.2 Technology options: balancing performance and flexibility

3.2.1 Addressing the limits of physics

Elements being considered as part of this 3G/UMTS Long Term Evolution include a packet-optimised radio access technology with reduced latency, higher user data rates, improved system capacity and coverage, and reduced cost for the operator. Support for both wider and narrower transmission bandwidths than UMTS is planned, giving LTE significant flexibility for deployment in a wide range of environments.

Latency Comparison



Source: Rysavy Research/3G Americas

Peak data rates rather than user data rates are often quoted as a measure of the performance of 3G mobile networks. But peak data rates represent theoretical limits, in practice signalling overhead will reduce the available data rate which then has to be shared between users. The individual data rates experienced by those users will vary with time according to network loading and radio link conditions. Peak data rates are simply not a good indicator of user experience or network quality. Life is far more complex.

In fact no single figure such as peak or user data rate can quantify network performance in a meaningful way as such parameters are not independent. For example, increasing the data rate will reduce the range of a cell. The effect is not insignificant – a tenfold increase in data rate halves the range. The downlink range of a cell is largely determined by the peak data rate and the base station transmit power. That is just one example of the inevitable trade-off between capacity and coverage.

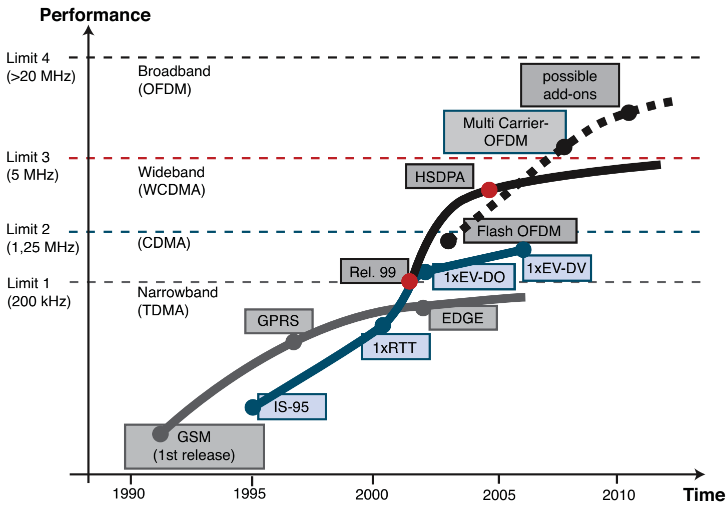
Base stations can transmit far more power than mobile terminal devices, particularly if those devices are battery-powered handsets, and so the ultimate limiting factor in the range of a cell is the uplink transmit power.

The advanced modulation and coding schemes that deliver the highest data rates and capacity require a high quality transmission path – conditions not always found over a radio link. Propagation conditions that vary over time and space result in transmission errors, requiring information to be resent and a fallback to less critical but less efficient modulation and coding schemes. In contrast to the controlled conditions of wireline networks, wide area wireless systems have to operate in an inherently tough and unstable environment.

3.2.2 Finite resources: bandwidth and practical limits on mobility

Higher data rates can be most reliably achieved by increasing bandwidth, either by combining channels – effectively increasing the bandwidth at the expense of capacity, techniques used very successfully by enhancements such as EDGE and HSPA – or by utilising higher bandwidth channels. Different generations of air interface technologies have all gone this route – from narrowband TDMA systems such as GSM with 200 kHz channels, through CDMA systems such as 1xEV DO with 1.25 MHz channels to wideband CDMA systems such as UMTS with 5 MHz channels.

Performance of evolved radio technologies



Source: Siemens

The option of increasing bandwidth to deliver higher data rates is also incorporated within 3G LTE which can support transmission bandwidths wider than 5 MHz. 3G/UMTS LTE will deliver broadband over 10, 15 and 20 MHz channels. It will also support bandwidths less than 5 MHz – down to 1.25 MHz in fact – to allow for flexibility in whichever frequency bands the system may be deployed.

It is impractical to support mobility in spectrum above 3 GHz, and GSM and UMTS systems typically operate in frequency bands around 900 MHz and 2 GHz. Higher frequencies experience greater diffraction loss on non line-of-sight paths and so they have shorter range than these bands. The lower frequencies with greater range are preferable for the provision of wide area coverage in rural and suburban areas – doubling the frequency almost halves the non line-of-sight range and so could require four times the number of cells to achieve the same coverage.

Achieving 20 MHz channel widths is difficult in the lower frequency bands currently used by UMTS. So the highest data rates, not needed for all services, may require deployment at higher frequencies, perhaps in hotspot or pico cell configurations. The greater amount of spectrum available in the high frequency ranges will allow 3G LTE to keep pace with advances in data rate anticipated over fixed access lines.

But in-building penetration gets worse with increasing frequency – not an ideal situation, as the services requiring the highest data rates are liable to be deployed in indoor nomadic rather than outdoor mobile scenarios. This conflict is another example of interdependence and the need for trade-offs.

Network latency (the time taken for data to traverse the network) can be more important than user data rates or throughput, where real-time services such as voice are concerned. 3G LTE has the challenging target of reducing latency in the radio access network to less than 10 ms to enable VoIP services.

3.2.3 Technology choices in the real world

Although it is clear that no technology is inherently 'better' than any other technology, it is true that particular technologies are sometimes optimal for specific situations. Orthogonal Frequency Division Multiplexing (OFDM) for instance was one of the candidates for the IMT-2000 air interface originally considered in 1997. In OFDM the signal is split into a number (typically 100-1000) of separate tones and the data to be transmitted is split between them. It was deemed to be too difficult to implement with the processing power available at that time. Today, as chip performance has improved by orders of magnitude as a result of Moore's Law, OFDM has become viable for radio access networks and is indeed the technology that will be deployed in 3G/UMTS LTE for the downlink. OFDM is an entirely digital multiplexing approach, using Fast Fourier Transform technology to split the signal into many narrowband carriers and spread data across the modulation of all the carriers.

On the uplink, however, 3G LTE has chosen Single Carrier Frequency Division Multiple Access (SC FDMA) rather than the Orthogonal Frequency Division Multiple Access (OFDMA) technique selected by other systems such as WiMAX. OFDMA techniques, in which different users are assigned to subsets of tones, can result in high peak to average power ratios which reduce power efficiency. Although not critical for devices connected to a/c electricity supplies, power efficiency is an important factor in preserving battery life in mobile devices.

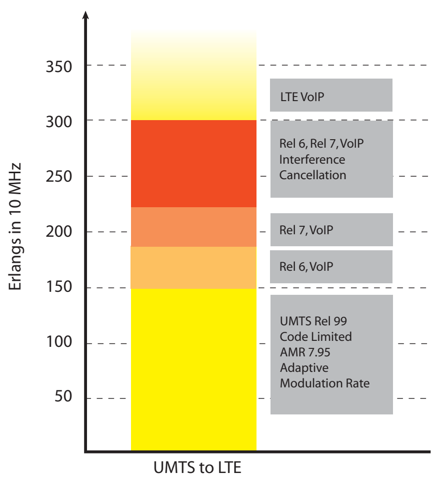
Further improvements in data rates and capacity will come through the use of multiple antennas at both base station and terminal in LTE systems. Multiple Input Multiple Output (MIMO) antenna technologies enhance data throughput and system capacity by improving the signal to interference ratio. MIMO can deploy antenna beam switching, steerable phased array antennas and interference cancellation techniques. MIMO techniques exploit spatial multiplexing to increase data rates by a factor related to the number of transmit or receive antennas – they do not violate the Shannon limit which still applies individually to each antenna. Such techniques enhance performance by minimising interference through intelligent antennas or through interference co-ordination between sectors and cells and are available to all technologies. The problem is they introduce complexity into the physical layer: another trade-off.

3.3 Services and applications: balancing resources and demand

Improvements in data rates are vital for some service categories but not for others. Different services impose very different requirements on the system. Downloading large files for example requires high downlink data rates and bit errors cannot be tolerated. But the end-to-end delay or latency in the network is not a serious constraint.

Voice services on the other hand are tolerant of bit error rates but have stringent requirements on latency and jitter. They are real-time services requiring priority treatment. They are symmetric services requiring equivalent uplink and downlink performance.

Voice Spectral Efficiency Comparison



Source: Rysavy Research/3G Americas

These apparently conflicting requirements have to be balanced across both the radio access network and the core network. An all-IP core network is envisaged to complement the radio platform of 3G LTE. IP Multimedia Subsystem (IMS) technology will allow the integration and interaction of real-time and non-real time services. A flat network architecture, with fewer nodes than previous systems, will help to reduce latency and complexity.

IMS was originally developed by 3GPP and has subsequently been widely adopted outside the mobile community. IMS facilitates convergence between fixed and mobile systems and is a crucial element enabling the integration of legacy networks with 3G LTE. Such integration is crucial to permit operators to manage the transition from legacy circuit-switched (CS) voice to packet-switched (PS) voice.

Although 3G LTE assumes an all IP network architecture and is designed to support voice in the packet domain, it recognises that interworking with circuit-switched voice could be required for some time. With 3G/UMTS evolutionary technology, both CS and PS traffic occupy the same radio channel. Dynamic adjustment of power between CS and PS traffic allows users to be migrated from circuit voice to packet voice according to an operator's commercial imperatives.

IMS is a component in the System Architecture Evolution (SAE) being developed within 3GPP. SAE will be a packet-optimised system supporting multiple radio access technologies, recognising that operators will need to provide seamless service across GSM, GPRS, EDGE, UMTS, HSPA and LTE networks.

SAE will deliver high data rates and low latency to support all services – including voice – in the PS domain. It is intended for deployment with LTE but could also be used in conjunction with HSPA+ to provide a stepping stone to LTE.

The need for cost effective support of multicast as well as unicast services imposes another tough challenge for SAE. The Multimedia Broadcast Multicast Service (MBMS) which was part of 3GPP Release 6 enables multiple users to receive data over the same radio resource.

An advantage of the OFDM/SC FDMA based system selected for 3G LTE is the possibility of operating MBMS in a single frequency network manner where significant performance gains can be achieved without additional receiver complexity.

The combination of voice and multimedia data services in 3G/UMTS results in a mixture of traffic over the network. The different categories of traffic – such as data downloads and video telephony – have very different quality of service constraints. Some data applications require significantly greater network resources than conventional voice traffic. Voice traffic demands low end-to-end delays across the entire network.

3G LTE has to support all service categories and so design targets are determined by the most stringent requirements of specific services. These targets include low latency and high throughput as well as support for security and quality of service. Seamless mobility is equally important – remember that the success of GSM originated from the combination of high mobility and roaming. All this has to be balanced against the need for cost effectiveness resulting from simplicity and economies of scale.

Network performance depends critically on the mix of traffic and so the design of 3G/UMTS systems and the allocation of the spectrum bands they occupy have relied heavily on estimates of market demand for each of the different service categories.

Market studies have subsequently been extended to cover the period up to 2020. They are being used by the ITU to estimate the traffic that future mobile networks will carry and the additional spectrum that will be required to support that traffic. Data from these studies are of great value for the design of broadband 3G/UMTS LTE systems.

Although the market studies analyse a range of specific services and applications, standards such as 3G/UMTS LTE do not prescribe individual services. Rather they provide a tool kit for service provision, recognising that many compelling services cannot be predicted in advance.

The enormously successful short message service, for example, emerged out of demand from teenage users. Ubiquitous capability for SMS within handsets encouraged widespread adoption of SMS and, once interoperability between networks was implemented, the service exploded in popularity. Even now SMS traffic generates the bulk of data revenues within the industry. Users continue to surprise with their imaginative use of the personalisation capabilities provided by mobile networks. No-one predicted the popularity of ringtones. No-one anticipated the eruption of user-generated content and the impact of peer-to-peer video traffic on the Internet.

Mobile networks have become part of the infrastructure of society. They are being used in innovative ways that would have been unimaginable when the systems were first designed. Standardisation of future systems is now adopting a pragmatic approach in which the secret is to be predictive but not prescriptive.

3.4 Compatibility: an eye on past and future investments

The evolutionary path represented by GSM/GPRS/EDGE/UMTS/HSPA/LTE is designed to deliver ever higher data throughputs and spectral efficiency, enhanced security and QoS, and reduced latency. At the same time it is expected to reduce costs while retaining the high quality of services that users have come to expect. It must do all this within an environment of scarce radio resources.

A key focus of all future systems therefore has to be maximising the value of existing assets. Future systems will need to be compatible with existing systems and legacy services, allowing users and operators the flexibility to migrate at the most opportune and cost effective moment from their perspective. That flexibility is important; users and operators face very different situations and conditions in different environments. They demand and deserve the ability to decide when and how they wish to upgrade to preserve their competitive position.

Achieving this imposes new demands on future systems such as 3G/UMTS LTE. They need to build firmly on the solid base of the past rather than deliver replacement systems. They need to interoperate with a wide variety of existing and alternative systems to deliver maximum flexibility and choice. They need to reduce complexity in order to preserve the ability to achieve economies of scale. They need to optimise their use of scarce resources, in particular the limited availability of suitable spectrum.

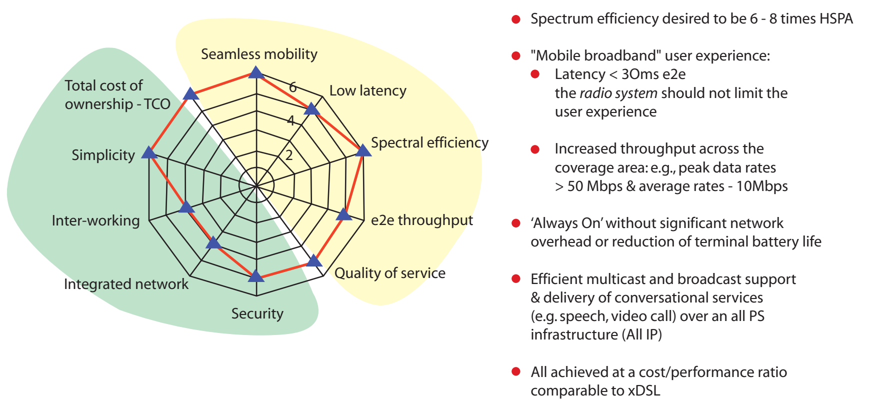
Future systems have challenging performance enhancement targets to achieve. But, given the minimal differences in performance across the different candidate technologies, it is clear that an evolutionary path is the most reliable and cost effective route to follow.

Compatibility with existing ecosystems is emerging as a key requirement. Optimising the use of existing assets and reducing complexity to achieve economies of scale is becoming a crucial design criterion. Peak data rates and theoretical spectral efficiency targets are no longer the primary virility symbols. The keys to success build upon existing infrastructures, experience, assets and customer relationships. The keys to success are availability, pricing, coverage, roaming and devices. Such a strategy takes proper account of user requirements as well as the needs of all stakeholders.

3.5 LTE and NGMN

A similar approach to future systems has recently been articulated by a group of the world's most important mobile operators. The Next Generation Mobile Networks (NGMN) group argue that reuse of existing assets, the overall customer proposition and a smooth evolutionary roadmap are among the most important imperatives that should determine the design of future systems. The NGMN initiative is targeted at a single integrated network for the seamless introduction of mobile broadband services – a network that will co-exist with legacy networks whilst providing them with a smooth migration path.

NGMN – Priorities



Source: NGMN

A focus on one integrated network rather than on interoperability between functional elements will help reduce the number of redundant options often found in current standards. Combined with the proposal to include standards for operations and maintenance, this represents a more holistic approach to the standardisation process.

The UMTS Forum believes the 3G/UMTS LTE work and activities – initiated entirely independently of the NGMN group – are fully compatible with these imperatives. Specific examples below illustrate how the LTE targets are aligned with the key objectives of the NGMN initiative.

Reuse of existing assets

The need to build upon existing ecosystems is reflected in the first imperative of the NGMN initiative: maximising the reuse of operators' existing assets. Such assets include investments in spectrum as well as physical resources such as sites and antennas. Efficient reuse of spectrum demands that future technologies must deliver the maximum possible spectral efficiency. Efficient reuse of sites and antennas implies that a minimal number of additional sites should be necessary and future antennas should be compatible in size and shape with existing antennas.

The UMTS Forum believes this set of objectives will be achieved through a variety of mechanisms. These include:

- 3G/UMTS LTE is designed to co-exist with 3G/UMTS networks and is deployable in bandwidths from 1.25 to 20 MHz, making it possible to introduce it gradually into any and all existing GSM or 3G spectrum bands.
- 3G LTE will achieve higher peak data rates and average throughput – at least double that of HSPA+. This will be achieved through a combination of OFDM technology, higher order modulation, and advanced error correction techniques, powerful MIMO algorithms, and sophisticated resource (sub-carrier) management algorithms for interference mitigation at cell edges. Macro diversity will no longer be needed.
- Reuse of sites will be facilitated through base stations capable of handling more than one standard. Such multi-standard base stations could contain hardware modules capable of managing several RF carriers. The waveform carried over each carrier, specific to the standard being deployed, would be determined by software. This approach of generic hardware with software determined functionality will allow modules to handle RF carriers running at different frequencies, extending the range of spectrum bands served by a single module.
- Antennas will follow a parallel evolution, with standards-independent antennas operating in a large spectrum window capable of serving several networks.

Competitiveness in terms of an overall customer proposition
The underlying principle of the second NGMN imperative is the support of end-to-end low latency and 'always on' operation. Added value must then be delivered through the support of end-to-end QoS, mobility and roaming. Cost efficiency is a common theme running through all these requirements.

The UMTS Forum believes specific design elements already being implemented within 3G LTE will accommodate these objectives. These include:

- Implementation of a flat architecture with fewer nodes. Deploying a simple network consisting of one or two nodes will result in simpler protocols, fewer interactions between nodes and a smoother processing of the control and user planes.
- A simpler architecture combined with high spectral efficiency and flexible spectrum usage makes operations and maintenance less complex, so increasing cost effectiveness.
- A much reduced Transmission Time Interval (down to 0.5ms) resulting in the faster transfer of small packets and significantly reduced end-to-end latency.

NGMN must be developed in a timely fashion without impacting the current HSPA roadmap
The UMTS Forum fully supports this position. The introduction of 3G/UMTS LTE will be beneficial for the entire industry if it can be introduced in a smooth fashion in UMTS networks as a stepping stone to LTE. HSPA+ should only be deployed where necessary and fully justified as part of a migration path to allow 3GPP and the industry to prepare for 3G/UMTS LTE.

3.6 LTE towards IMT-Advanced

Detailed market studies exploring future user demand for mobile services have recently been conducted by a number of organisations, including the UMTS Forum. These studies forecast the traffic types and volumes that future networks could face in the year 2020 and have been used by the ITU to estimate the additional spectrum that will be required to manage this traffic.

As well as additional spectrum, the ITU has concluded that, around the year 2010, there may be a requirement for a new radio interface with the ability to deliver data rates up to 100 Mbps for mobile services and applications. These requirements are part of the ITU's vision for the future development of IMT-2000 systems entitled IMT Advanced.

Discussions on the detailed characteristics of IMT Advanced are now starting within the ITU. Clearly 3G/UMTS LTE or its evolution will be a candidate, given its anticipated performance and generic design principles. Paving the way towards IMT Advanced would certainly be a particularly effective contribution that 3G/UMTS LTE could bring to the market place.

3.7 LTE in context: more capabilities for more users at lower cost

All new technologies are expected to increase performance. 3G/UMTS LTE will do so – by substantial factors – in an intelligent fashion, optimising performance in line with user demand and spectrum availability.

3G/UMTS LTE will simultaneously lower costs by reducing complexity and by leveraging existing investments in GSM and UMTS to take full advantage of the resulting economies of scale.

3G LTE is designed to support an instantaneous downlink peak data rate of 100 Mbps within a 20 MHz downlink spectrum allocation (5 bit/s/Hz) and an instantaneous uplink peak data rate of 50 Mbps (2.5 bit/s/Hz) within a 20 MHz uplink spectrum allocation. The peak data rates scale linearly with bandwidth.

A particularly important – and challenging – feature is an increase in bit rates at the edges of cells whilst maintaining current site locations. Increased cell edge performance helps deliver a more uniform user experience across the cell area. Average user throughputs on the downlink will be 3-4 times higher and cell-edge user throughputs will be 2-3 times higher than Release 6 HSPA. On the uplink the average and cell-edge user throughputs will be 2-3 times higher than Release 6 HSPA.

The combination of a flat architecture and a short Transmission Time Interval (0.5ms compared with 2ms for HSPA+) will deliver very low latency in 3G LTE. The round-trip time between the user equipment and the base station will be some 10ms (compared with 50ms for HSPA+).

3G/UMTS LTE delivers significantly improved spectral efficiency (2-4 times higher than Release 6), increasing user throughput and system capacity. It allows scalable bandwidth operation up to 20 MHz but has the flexibility to be deployed in narrow spectral allocations as low as 1.25 MHz.

In essence, 3G/UMTS LTE is a new technology that delivers enhanced performance enabling new services and increased support of existing services. It not only delivers these benefits to many more users than existing technologies but it also delivers them at a lower cost. The deliberate focus on smooth evolutionary paths will enable 3G LTE to be implemented through simple upgrades of existing 3G networks.

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