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the UMTS Forum

Towards Global Mobile Broadband

Standardising the future of mobile communications with LTE (Long Term Evolution)

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Table of Contents

1. Introduction: What is LTE? 1

2. A Clear Standardisation Path 2

3. LTE Key Features 3

4. Spectral Flexibility Means Wider Deployment Options 5

5. LTE Services 5

6. Who Needs LTE? 7

7. LTE Timescales 8

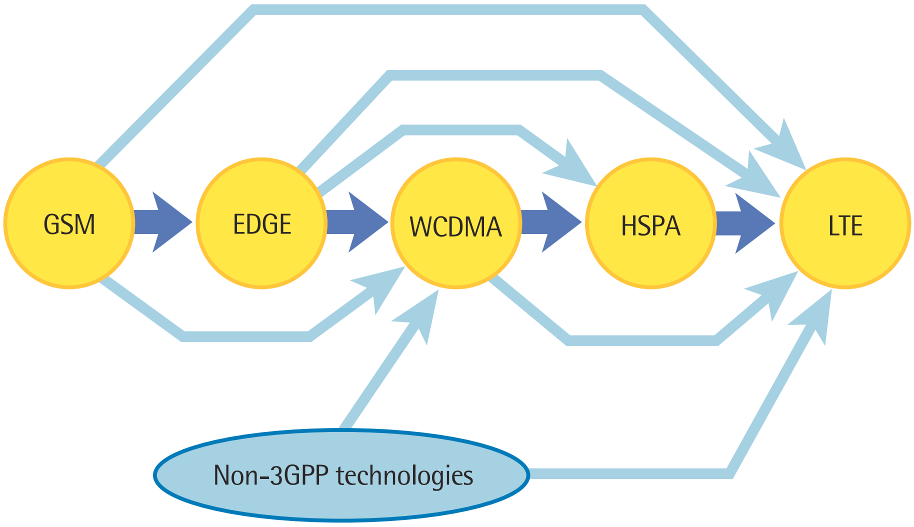
References 9

1. Introduction: What is LTE?

Long Term Evolution (LTE) describes standardisation work by the Third Generation Partnership Project (3GPP) to define a new high-speed radio access method for mobile communications systems.

LTE is the next step on a clearly-charted roadmap to so-called '4G' mobile systems that starts with today's 2G and 3G networks. Building on the technical foundations of the 3GPP family of cellular systems that embraces GSM, GPRS and EDGE as well as WCDMA and now HSPA (High Speed Packet Access), LTE offers a smooth evolutionary path to higher speeds and lower latency. Coupled with more efficient use of operators' finite spectrum assets, LTE enables an even richer, more compelling mobile service environment.

A choice of upgrade paths



LTE provides a smooth evolutionary path for operators deploying all 3GPP and non-3GPP technologies.

In parallel with its advanced new radio interface, realising the full potential of LTE requires an evolution from today's hybrid packet/circuit switched networks to a simplified, all-IP (Internet Protocol) environment. From an operator's point of view, the pay-off is reduced delivery costs for rich, blended applications combining voice, video and data services plus simplified interworking with other fixed and wireless networks.

By creating new value-added service possibilities, LTE promises long-term revenue stability and growth for around two hundred mobile operators that are already firmly committed to the UMTS/HSPA family of 3G systems. Just as importantly, it provides a powerful tool to attract customers who are provided with an increasing number of technology options for broadband connectivity on the move.

Based on the UMTS/HSPA family of standards, LTE will enhance the capabilities of current cellular network technologies to satisfy the needs of a highly demanding customer accustomed to fixed broadband services. As such, it unifies the voice-oriented environment of today's mobile networks with the data-centric service possibilities of the fixed Internet.

Another key goal of the project is the harmonious coexistence of LTE systems alongside legacy circuit switched networks. This will allow operators to introduce LTE's all-IP concept progressively, retaining the value of their existing voice-based service platforms while benefiting from the performance boost that LTE delivers for data services.

2. A Clear Standardisation Path

3GPP proposed migrating towards an all-IP core network as early as Release 4, hinting at what would become a prominent feature of later UMTS/HSPA releases and ultimately LTE.

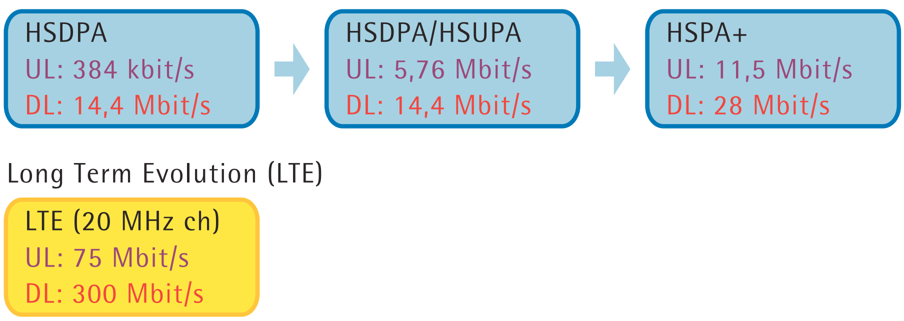
The concept of 'Long Term Evolution' for today's 3G/UMTS standard was discussed in detail in 2004, when a RAN (Radio Access Network) Evolution Workshop in Toronto accepted contributions from more than 40 operators, manufacturers and research institutes (including 3GPP members as well as non-member organisations). Contributors offered a range of views and proposals on the evolution of the UTRAN (Universal Terrestrial Radio Access Network).

Following the Toronto workshop, in December 2004, 3GPP launched a feasibility study in order "to develop a framework for the evolution of the 3GPP radio-access technology towards a high-data-rate, low-latency and packet-optimised radio-access technology". In other words, the study would map out specifications for a radio access network (RAN) capable of supporting the broadband Internet user experience we already enjoy in today's fixed networks – with the addition of full mobility to enable exciting new service possibilities.

Today, specifications for LTE are encapsulated in 3GPP Release 8, the newest set of standards that defines the technical evolution of 3GPP mobile network systems. Release 8 succeeds the previous iteration of 3G standards – Release 7 – that includes specifications for HSPA+, the 'missing link' between HSPA and LTE. Defined in 3GPP Releases 7 and 8, HSPA+ allows the introduction of a simpler, 'flat', IP-oriented network architecture while bypassing many of the legacy equipment requirements of UMTS/HSPA.

Peak data rates with HSPA+ are 28 Mbit/s on the downlink and 11.5 Mbit/s on the uplink using 2x2 MIMO (Multiple-Input Multiple-Output) antenna techniques and 16QAM (Quadrature Amplitude Modulation). However, HSPA+ can further boost data rates up to 42 Mbit/s on the downlink and 23 Mbit/s on the uplink using 2x2MIMO and 64QAM, a combination that is part of Release 8.

As such, HSPA+ slots neatly between the already impressive performance of HSPA (with its theoretical downlink performance of up to 14.4 Mbit/s) and LTE that promises rates of 300 Mbit/s in the downlink and 75 Mbit/s in the uplink for every 20 MHz of paired spectrum.



Uplink and downlink data rates compared for HSPA and LTE.

3. LTE Key Features

From a technical point of view, a fundamental objective of the LTE project is to offer higher data speeds, for both down- and uplink transmission. Apart from this increase in raw data rates, LTE is characterised by reduced packet latency; the restriction that determines the responsiveness of gaming, VoIP, videoconferencing and other real-time services.

From an operator's perspective, the flexible channel bandwidths and harmonised FDD/TDD modes of LTE provide a more efficient use of carriers' existing and future spectrum resources. LTE also provides a more robust platform for operators to offer compelling value-added services in the mobile domain – these service possibilities are considered in Section 5.

The key characteristics of LTE are summarised here, with specific comparison with today's UMTS/HSPA networks:

- **Enhanced air interface allows increased data rates:** LTE is built on an all-new radio access network based on OFDM (Orthogonal Frequency-Division Multiplexing) technology. Specified in 3GPP Release 8, the air interface for LTE combines OFDMA-based modulation and multiple access scheme for the downlink, together with SC-FDMA (Single Carrier FDMA) for the uplink.

  All OFDM schemes split available spectrum into thousands of extremely narrowband carriers, each carrying a part of the signal. In LTE, the innate spectral efficiency of OFDM is further enhanced with higher order modulation schemes such as 64QAM, and sophisticated FEC (Forward Error Correction) schemes such as tail biting, convolutional coding and turbo coding, alongside complementary radio techniques like MIMO and Beam Forming with up to four antennas per station.

  The result of these radio interface features is significantly improved radio performance, yielding up to five times the average throughput of HSPA. Downlink peak data rates are extended up to a theoretical maximum of 300 Mbit/s per 20 MHz of spectrum. Similarly, LTE theoretical uplink rates can reach 75 Mbit/s per 20 MHz of spectrum, with theoretical support for at least 200 active users per cell in 5 MHz.

  As explained in the following paragraphs, the performance of HSPA is itself evolving through the use of technologies like 64QAM and MIMO. These features are part of 3GPP Release 7, while a combination of 64QAM and MIMO for HSDPA (FDD) is specified in Release 8. LTE, however, delivers even greater improvements in overall performance and efficiency through the use of OFDM technology for the air interface, rather than the WCDMA-based UTRAN common to WCDMA and HSPA systems, and through more complex MIMO and beam forming antenna configurations.

  The capabilities of LTE will also evolve, with improvements specified in forthcoming Releases allowing LTE (advanced) to fulfil the requirements of IMT-Advanced, the ITU term for so-called '4G' systems that will be the eventual successors to evolved 3G and 3G+ technologies.

- **High spectral efficiency:** LTE's greater spectral efficiency allows operators to support increased numbers of customers within their existing and future spectrum allocations, with a reduced cost of delivery per bit.

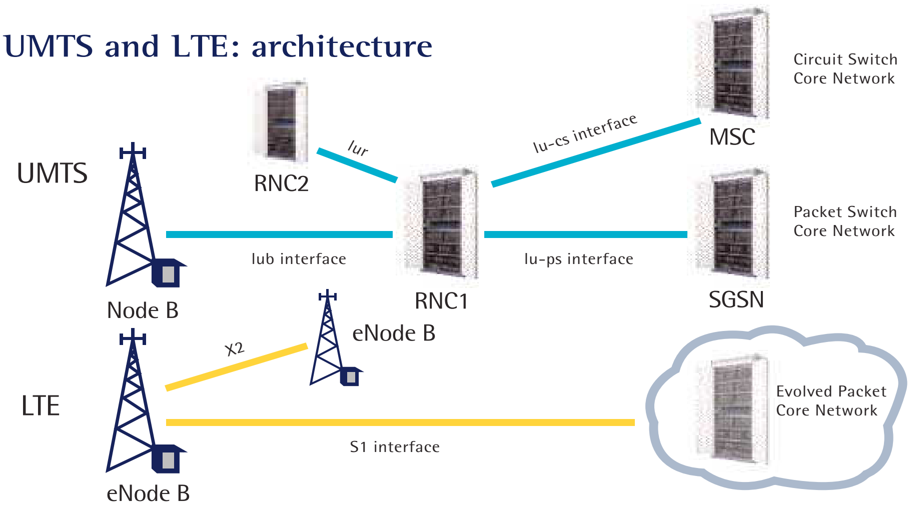
- **Flexible radio planning:** LTE can deliver optimum performance in a cell size of up to 5 km. It is still capable of delivering effective performance in cell sizes of up to 30 km radius, with more limited performance available in cell sizes up to 100 km radius. See Section 4 for more information on spectrum for LTE and deployment flexibility.

- **Reduced latency:** By reducing round-trip times to 10ms or even less (compared with 40–50ms for HSPA), LTE delivers a more responsive user experience. This permits interactive, real-time services such as high-quality audio/videoconferencing and multi-player gaming.

- **An all-IP environment:** One of the most significant features of LTE is its transition to a 'flat', all-IP based core network with a simplified architecture and open interfaces. Indeed, much of 3GPP's standardisation work targets the conversion of existing core network architecture to an all-IP system. Within 3GPP, this initiative has been referred to as Systems Architecture Evolution (SAE) – now called Evolved Packet Core (EPC). SAE/EPC enables more flexible service provisioning plus simplified interworking with fixed and non-3GPP mobile networks.

EPC is based on TCP/IP protocols – like the vast majority of today's fixed data networks – thus providing PC-like services including voice, video, rich media and messaging. This migration to an all-packet architecture also enables improved interworking with other fixed and wireless communication networks.

UMTS and LTE: architecture



LTE gives operators the benefits of evolution to a simplified, all-IP network architecture.

- **Co-existence with legacy standards and systems:** LTE users should be able to make voice calls from their terminal and have access to basic data services even when they are in areas without LTE coverage. LTE therefore allows smooth, seamless service handover in areas of HSPA, WCDMA or GSM/GPRS/EDGE coverage. Furthermore, LTE/SAE supports not only intra-system and inter-system handovers, but inter-domain handovers between packet switched and circuit switched sessions.

- Extra cost reduction capabilities: The introduction of features such as a multi-vendor RAN (MVR) or self optimising networks (SON) should help to reduce opex and provide the potential to realise lower costs per bit.

4. Spectral Flexibility Means Wider Deployment Options

A key characteristic of LTE technology is its suitability for deployment in scalable bandwidths ranging from 1.25 MHz to 20 MHz. What is more, it can operate in all 3GPP frequency bands in paired and unpaired spectrum allocations.

In practical terms, the actual performance achievable with LTE depends on the bandwidth allocated for services, and not the choice of spectrum band itself. This gives operators considerable flexibility in their commercial and technical strategies. Deployed at higher frequencies, LTE is attractive for strategies focused on network capacity, whereas at lower frequencies it can provide ubiquitous cost-effective coverage.

As such, LTE networks could be rolled out in any of the bands already harmonised for use by 3GPP systems. These include IMT-2000 core frequency bands (1.9-2 GHz) and extension bands (2.5 GHz), as well as at 850-900 MHz, 1800 MHz, AWS spectrum (1.7 GHz-2.1 GHz) and portions of the UHF band recently identified at the World Radiocommunication Conference (WRC-07) for mobile services in some parts of the world. For more information on the allocation and identification of frequencies in the UHF band for IMT mobile services, see the UMTS Forum press release "Significant step forward for the wireless industry at WRC-07" (22 November 2007).

Outside current allocations, a number of candidate bands below 5 GHz have also been identified by the ITU as being potentially suitable for IMT services such as LTE. While the exploitation of frequencies higher than 5 GHz for the provision of extremely high data rates through LTE network deployments is feasible, challenges are posed regarding the provision of wide area/national coverage at realistic cost.

LTE's flexibility to operate at a scalable bandwidth also allows operators to deploy LTE in their existing spectrum allocations. This could be achieved via re-farming, considered by many parties in the mobile telecommunications value chain as a cost-efficient option to address increasing traffic demands.

Aside from the obvious appeal of LTE to WCDMA/HSPA operators, one major wireless carrier has expressed interest in LTE as an evolutionary option for its own CDMA operations.

If this interest is confirmed – possibly followed by other CDMA operators – it will result in a significant expansion of the 3GPP-compliant 'footprint' globally.

5. LTE Services

Through a combination of very high downlink (and uplink) transmission speeds, more flexible, efficient use of spectrum and reduced packet latency, LTE promises to enhance the delivery of mobile broadband services while adding exciting new value-added service possibilities.

But what does this mean in terms of operator revenues and subscriber growth in a market where broadband connectivity is rapidly becoming commoditised?

An overarching objective for LTE is the stabilisation and reversal of steadily declining ARPU (Average Revenue Per User) that is characteristic of many mobile markets.

In a study conducted in 2007 for the UMTS Forum, Analysys Research compared the services supported by today's mobile network technologies with the richer service possibilities that LTE enables through higher downlink speeds and reduced latency for packet-based services.

For consumers, this enriched user experience will be typified by the large-scale streaming, downloading and sharing of video, music and rich multimedia content. All these services will need significantly greater throughput to provide adequate quality of service, particularly as users' future expectations will be increased by the growing popularity of other high-bandwidth platforms like High Definition TV transmission.

For business customers it will mean high-speed transfer of large files, high-quality videoconferencing and secure nomadic access to corporate networks.

Similarly, LTE brings the characteristics of today's 'Web 2.0' into the mobile space for the first time. Alongside secure e-commerce, this will span real-time peer-to-peer applications like multiplayer gaming and file sharing.

In addition, Analysys considers a quite distinct set of services that do not have clear analogies in today's fixed network environment. These include 'machine to machine' (M2M) applications and the large-scale exchange of information within community-based projects.

The following table illustrates some of the services and applications that LTE will enable and enrich in the mobile space.

Service category	Current environment	LTE environment
Rich voice	Real-time audio	VoIP, high quality video conferencing
P2F messaging	SMS, MMS, low priority e-mails	Photo messages, IM, mobile e-mail, video messaging
Browsing	Access to online information services, for which users pay standard network rates. Currently limited to WAP browsing over GPRS and 3G networks	Super-fast browsing, uploading content to social networking sites
Paid information	Contentforwhich users pay over and above standard network charges. Mainly text-based information.	E-newspapers, high quality audio streaming
Personalisation	Predominantly ringtones, also includes screensavers and ringbacks	Realtones (original artist recordings), personalised mobile web sites
Games	Downloadable and online games	A consistent online gaming experience across both fixed and mobile networks
TV/ video on demand	Streamed and downloadable video content	Broadcast television services, true on-demand television, high quality video streaming
Music	Full track downloads and analogue radio services	High quality music downloading and storage
Content messaging and cross media	Peer-to-peer messaging using third party content as well as interaction with other media	Wide scale distribution of video clips, karaoke services, video-based mobile advertising
M-commerce	Commission on transactions (including gambling) and payment facilities undertaken over mobile networks	Mobile handsets as payment devices, with payment details carried over high speed networks to enable rapid completion of transactions
Mobile data networking	Access to corporate intranets and databases, as well as the use of applications such as CRM	P2P file transfer, business applications, application sharing, M2M communication, mobile intranet/ extranet

Classification of mobile services that will be enabled or enriched in an LTE environment.
[Source: Analysys Research/UMTS Forum 2007]

6. Who Needs LTE?

Less than a decade on from the launch of the first 3G/UMTS networks, why is the cellular industry considering additional investments in its radio access and core network infrastructures?

The answer lies in a changing market landscape, where user expectations are constantly increasing. In the fixed world, broadband connectivity is now ubiquitous with multi-megabit speeds available at reasonable cost to customers and business users via DSL and cable connections.

Broadband is part of today's mobile customer experience. This shift in user perception is demonstrated by the rapid increase in the uptake of WCDMA and HSPA networks worldwide. As of February 2008, there are already around 20 million subscribers to HSDPA networks, and hundreds of terminal devices supporting theoretical downlink speeds of up to 7.2 Mbit/s commercially available. In the same timeframe, more than twenty-five operators worldwide had also commercialised HSUPA (High Speed Uplink Packet Access) networks, with at least a hundred more rollouts publicly announced.

The natural counterpart to HSDPA, HSUPA boosts mobile uplink speeds as high as 5.8 Mbit/s. This provides a valuable complement for operators wishing to introduce mobile broadband services demanding greater capacity and speed on both uplink and downlink. An example of this is Voice over IP (VoIP), where voice calls are delivered over the Internet or other IP networks in a totally packet-based session.

Furthermore, other technologies have matured since UMTS was first commercialised in 2001. Mobile WiMAX – recently accepted by the ITU as the sixth radio access method for IMT-2000, under the terminology 'IMT-2000 OFDMA TDD WMAN' – is being deployed by a limited number of operators, chiefly in Asia-Pacific and the Americas.

Some European carriers have expressed interest in deploying the technology as a complement to their current 3G/UMTS operations. The acceptance of mobile WiMAX as a part of the IMT-2000 definition of 3G opens up the possibility of operators deploying the technology in their existing licensed 3G/UMTS spectrum allocations.

Operators are thus presented with a choice of technologies to provide their customers with wireless broadband services. This will allow them either to compete with fixed operators or to provide broadband services in areas where the fixed infrastructure does not exist and would be too expensive to deploy.

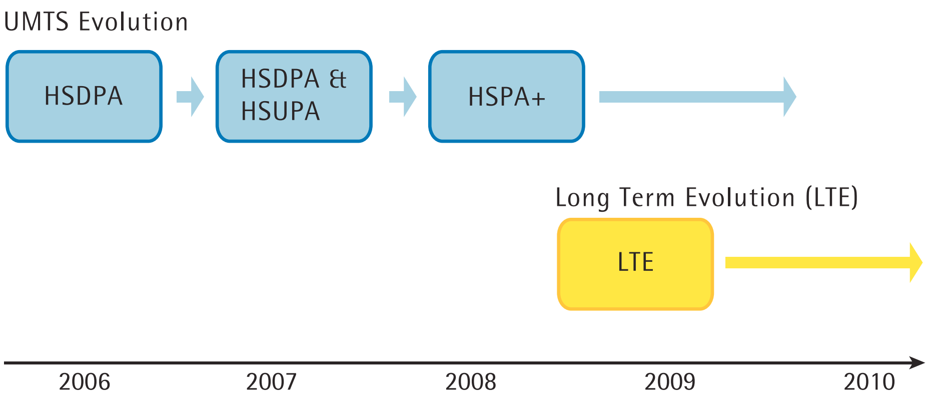
Against this backdrop, LTE offers compelling attractions for incumbent UMTS/HSPA operators – notably the ability to re-use significant portions of their existing infrastructures, together with re-use of their existing spectrum assets.

While LTE looks firmly to the future, it does not negate the value of operators' existing investments. Presenting a smooth evolution from current technologies like HSPA that are already generating strong revenues for operators – and will continue to do so for many years to come – LTE also simplifies interworking with non-3GPP networks via SAE. As a result, LTE will allow operators to generate fresh sources of value from their existing network investments while enjoying the significant economies of scale that flow from participation in the world's biggest and most successful family of evolving cellular systems that are specified by 3GPP.

7. LTE Timescales

A number of companies have already demonstrated various elements at public events. With 3GPP Release 8 now being consolidated (3GPP has recently approved the LTE specifications – they are now under change control and will be completed by the end of 2008), many industry players and observers anticipate the commercial launch of the first LTE networks and terminal devices in around 2010. To make this objective possible, LTE technology will have matured through field trials performed in 2008 and pre-commercial networks with friendly users in 2009.

There is widespread industry consensus that operator-retained revenues from LTE will gradually replace those generated by WCDMA and HSPA. By way of example, a study by ABI Research suggests that LTE will dominate the world's mobile infrastructure markets after 2011.



Evolution timeframe for planned 3GPP systems.

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Footnote:

This paper includes information previously published by the Third Generation Partnership Project (www.3gpp.org). The UMTS Forum is indebted to 3GPP for its assistance and support for the production of this paper.

LTE and 3GPP

The standardisation of LTE is managed by the Third Generation Partnership Project (www.3gpp.org), the grouping of telecommunications standards bodies that produces global technical standards for the Third Generation (3G) mobile system based on evolved GSM core networks and the radio access technologies that they support.

The UMTS Forum is a Market Representation Partner in 3GPP. As such, the UMTS Forum provides market-focused inputs to support technical work that is conducted by the project’s Organisational Partners. Current Organisational Partners are ARIB, CCSA, ETSI, ATIS, TTA and TTC.

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