**White Paper**

# LTE: A New Competitive Paradigm for Mobile Broadband

# LTE: A New Competitive Paradigm for Mobile Broadband

White Paper

## Executive Summary

In the race to expand mobile services to include broadband and multimedia, many mobile operators are championing a standard known as Long Term Evolution (LTE). LTE includes substantial changes to both sides of the mobile network – both the radio access network and the core network. But while it will require significant capital investment, LTE is expected to unlock new revenue streams and provide better competitive positioning by allowing mobile network operators to offer broadband services and a better quality of service in a way that greatly improves the efficient use of network resources.

Alternative technical paths to delivering mobile broadband services are available. Some, such as High Speed Packet Access (HSPA), are near-term solutions on a path to later versions of LTE, and others, such as WiMAX, appear to be long-term alternative or complementary architectures. Some mobile network operators have already announced their intentions to pursue these and are actively deploying them.

An examination of the business rationale and key technical components of LTE can provide a solid basis for understanding the bigger picture, which has given rise to the various solutions. This paper is an attempt to explain the high-level architecture standards and issues, and, of course, the “lingo” of the LTE community to those who are familiar with communications technology but who lack in-depth knowledge of the mobile industry.

# LTE: A New Competitive Paradigm for Mobile Broadband

White Paper

## Table of Contents

## Introduction and Market Context

LTE is a coordinated response by the mobile industry establishment to fundamental shifts in both consumer preferences and new technology in the communications market. It is not simply a technical standard, but addresses operator business priorities and concerns.

Market changes that have been underway for several years have reprioritized technical requirements for mobile networks, and have radically altered the competitive landscape for network operators of all kinds. Users are increasingly dependent on ubiquitous broadband access, video media, and local mobility (for example, WiFi and Bluetooth). Both mobile service providers and fixed telephony and cable providers are being forced to rise to the challenge of delivering these new services as they compete with each other and with a new group of emerging providers.

For many years, mobile providers have been able to capitalize on mobility itself as a clear value-added feature for voice and low bitrate data services, such as the Cellular Digital Packet Data (CDPD) capability, which was first introduced in AMPS analog wireless networks and supported a maximum of 19.2 kbps. As user expectations evolved, mobile telephony service providers have also stretched their networks to accommodate usage that is oriented toward consumption of content rather than interaction between users. Examples include internet browsing, file downloads, email access, and other limited on- and off-deck applications.

### *Fixed Line Providers Evolve*

At the same time, the capabilities of competing fixed line providers have also evolved. Voice and low bitrate data services are now a commodity. Value is found in the ability to provide content-consumption-oriented and transactional broadband services, to integrate those services with the mushrooming domain of internet services, and to allow increased independence from any particular geographical place or endpoint. As a result, communications service providers now must offer a full range of service classes and a high degree of service continuity to remain competitive.

Mobile service providers, who are experts in mobility but lag significantly in broadband capability and content delivery, must prepare to go toe-to-toe with cable operators, who are strong in broadband and content but weak in mobility and somewhat new to real-time voice services. Because of these competitive pressures, fixed telephony providers in many parts of the world are aligning themselves with mobile providers to offer a more complete range of access options. These same companies are also experimenting with partnerships and technologies to help them carve out a niche in the content production/delivery value chain.

Today, the availability of various service types differs from one geography to another and depends, in large part, on the accessibility and affordability of various network and technology options. At a macro level, the status of a service type for a given provider encompasses both the ability to provision the service and service continuity.

With the rollout of high-speed fiber networks and the proliferation of WLAN technologies, fixed line service providers are adding some degree of mobility and service continuity to their substantial — and growing — broadband capabilities. And with their long-established relationships in the media content arena, they are well-positioned to capitalize on their network capabilities.

### *Mobile Service Provider Challenges*

Mobile service providers are not burdened with the expensive and time-consuming task of installing, maintaining, and upgrading last-mile physical infrastructure that fixed-line providers face. However, they do face other serious technical and business constraints. In addition to needing more broadband and integrated media services on their networks, they must find a place in the value chain for themselves beyond delivering mobile access, which includes providing content.

In summary, today's specialized networks are likely to cease to exist. The expectation is that all network operators will eventually support a full suite of services that combine:

- Services classes (RT/NRT, low bitrate/broadband)
- Access methods (fixed, wireless, mobile)
- Access devices (smartphones, softphones, mobile internet devices, computers, set-top boxes, embedded devices)
- Media (voice, audio, text, video)

This is the competitive environment that traditional mobile service providers face. LTE is a set of common tools, capabilities, and agreements that provide a cost-effective response.

## What Is LTE?

Before discussing the history, architecture, and service priorities of LTE, it is helpful to define some terms.

LTE is a shorthand way of referring to a particular stage in the evolving set of 3GPP standards that define a basic architecture for mobile networks. 3GPP and 3GPP2 are two of the primary standards bodies through which mobile industry participants define the fundamental design of mobile wireless network architectures. Standards for mobile wireless systems such as GSM, UMTS, and CDMA2000 have been developed by these organizations. The standards for LTE correspond roughly to Release 8 of the 3GPP standards, although some technical specifications from both earlier and later releases also play a critical role. Most major public mobile networks are designed around or have evolved toward compliance with 3GPP or 3GPP2 standards.

A mobile network consists of two fundamental parts:

- **Radio access network** — provides the wireless connection to/from the user endpoint
- **Core network** — establishes end-to-end communications channels and routes traffic to/from the radio links and other users or system elements

Although the term “LTE” is commonly used to refer to the mobile network in general, strictly speaking it is the label for only the radio access portion of this stage of mobile network evolution, also called the Evolved UMTS Terrestrial Radio Access Network (eUTRAN). The core network is referred to as System Architecture Evolution (SAE) or Evolved Packed Core (EPC).

In the 3GPP standards, the combination of radio access and core network is referred to as the Evolved Packet System (EPS). Although this paper will briefly discuss some of the radio access features of LTE, it is primarily concerned with the core network (EPC).

### Mobile Network Evolution

The rationale for development of the LTE standards and for migration to 4G mobile technologies in general can be made clear with a basic understanding of its progenitors and their limitations. A variety of mobile network architectures are available in the marketplace, and those networks have constantly evolved.

Mobile networks were originally intended to add mobility to basic voice telephony services. The earliest radio access networks relied on analog protocols on the wireless link, but by the 1990’s those radio interfaces were primarily digital. Early mobile network technologies, based on digital radio protocols, were dubbed “second generation” (2G) mobile networks and end-user devices to contrast them with “first generation” analog networks and devices. Among the most prominent 2G standards were:

- **GSM** — originally deployed in Europe and parts of Asia and eventually introduced in the Americas
- **CDMAone** (IS-95 standard) — deployed primarily in the Americas and parts of Asia
- **PDC** — deployed in Japan

Network operators were able to justify the considerable investment involved in replacing their analog radio equipment primarily because the digital technology made more efficient use of the limited radio spectrum available. This increased the capacity of the mobile network because it allowed more user traffic to be carried across the radio interface and reduced the need for resource-draining cell-splitting. The transition to digital radio also brought important improvements in mobile phone battery life, call quality, network interoperability, service reliability, cost-efficiency, and wireless network operation. However, 2G mobile services were still restricted to basic voice and low-speed data connections at a time when demand for broadband services was burgeoning and was met by fixed technologies such as DSL and cable.

The third-generation (3G) mobile systems were intended both to meet the challenge of providing higher-speed data services over the mobile communications network and to further increase radio network capacity. The actual deployment of 3G networks was initially hampered by a number of factors, including:

- **High costs** due to IPR issues along with the need to acquire new radio spectrum and new network equipment
- **Lack of user interest in new technology** beginning in early 2000 and resulting in a contraction of both user spending on communications technology (and network operator revenues) and network operator spending on infrastructure improvements
- **Splintering of technology standards** adopted in the market among GSM/EDGE, WCDMA/UMTS, CDMA2000, and TD-SCDMA (China), which raised costs and presented additional interoperability challenges

3G technologies are now widely deployed around the world with the notable exceptions of China and India, although both countries are in the advanced planning stages for deploying 3G. Because it became clear that 3G systems would be unable to cost-effectively keep pace with the exploding demand for mobile broadband multimedia communications services, work on post-3G mobile standards was begun a number of years ago. Table 1 provides a summary of the theoretical peak data rates for mobile networks as defined in a succession of 3GPP standards:

| Level | Standard | Uplink (bps) | Downlink (bps) |
|---|---|---|---|
| 2G | GSM | 9.6k | 14.4k |
| 2.5G | Edge | 384k | 513k |
| 3G | UMTS | 384k | 2.0M |
| 3G+ | HSDPA/HSUPA | 5.8M | 14.4M |
| 3G+ | HSPA+ | 11M | 42M |
| "4G" | LTE | 50M | 100M |

*Table 1. Theoretical Peak Data Rates of Selected Standards*

Most of these standards provide much higher peak data rates on the downlink (data flowing from the base station "down" to the user endpoint) than the uplink (data flowing from the user endpoint to the base station), because the predominant type of data traffic has historically been assumed to be asymmetrical. For example, a user sends one command to the network over the uplink to receive a much larger quantity of data, whether it is a webpage, a photo, or a full-length movie, over the downlink.

Asymmetry is expected to continue and even increase with mobile broadband services, but this assumption bears careful watching as users are now originating more content from their endpoints and content generation capabilities of user endpoints are expected to grow as the network evolves. For example, many of today's mobile phones can capture a still photo and upload it over the mobile network. With the introduction of high-bandwidth, low-latency mobile networks, mobile endpoints should be able to stream live video to storage in the network or elsewhere.

Currently, the post-3G standards that have the greatest momentum in the market are WiMAX and LTE. WiMAX was conceived as an evolution of WiFi networks, which would provide broadly accessible wireless internet service. The main intent behind LTE, on the other hand, was to evolve mobile networks. Although both WiMAX and LTE are commonly referred to as 4G standards, neither strictly meets all of the requirements set by the ITU for 4G technology.

The WiMAX standard itself has several variations (revisions): some are designed to provide "nomadic" wireless broadband connectivity, while others are designed for fully mobile wireless broadband connectivity. The difference between the two is in whether or not the wireless connection can be maintained while the wireless device moves from place to place. The majority of deployed WiMAX systems today are nomadic and are intended to quickly and cost-effectively provision communications services, including broadband internet connectivity, in underserved areas. A few mobile WiMAX networks are also in operation (the VMAX system in Taiwan is an example), and more are in early planning or early deployment stages.

WiMAX faces some challenges of its own. First, no common band of radio spectrum is globally allocated for WiMAX networks. Rather, multiple bands in different frequency ranges are supported by the standard, which avoids the slow and costly process of petitioning governments to clear spectrum that has been dedicated to other uses. Although it allows network operators to deploy WiMAX technology more widely, using multiple bands complicates roaming service because it is more difficult (and usually expensive) to create a mobile device that will work on different WiMAX networks.

Another challenge for WiMAX, which is typical of any new technology, is achieving economies of scale that will hold down costs not only for network equipment but also for end user devices. If High Speed Packet Access (HSPA) and LTE gain momentum as technologies for deploying mobile broadband services, fewer network equipment providers are likely to produce the components for WiMAX. Low volume and lack of competition could drive up prices for WiMAX – or for LTE if a majority of network operators stop short of deploying that system in favor of other alternatives.

As of 2009, LTE appears to be the primary migration path for most major incumbent mobile network operators. Several operators have announced intentions to move aggressively to HSPA+ as an interim step to achieving better and more efficient broadband services in the near-term while delaying the capital investment in new radio and core network infrastructure required for LTE. A few operators have announced that they intend to use both LTE and WiMAX, and some possible co-existence scenarios between LTE and WiMAX systems will be discussed below.

LTE standards and equipment have lagged behind WiMAX in some areas, but in 2008, key aspects of LTE technology were successfully prototyped. Field trials are anticipated in 2009, and the earliest commercial deployment is expected in 2010. Verizon has already announced plans to deploy LTE in 2010, and Japan is also likely to deploy since NTT DoCoMo is approaching the capacity limit of its existing 3G network.

## Overview of LTE Architecture

LTE network architecture is optimized not only for the technical rollout of mass market mobile broadband and multimedia services, but also for the associated business drivers discussed in a later section of this paper. Before turning to these business drivers, a brief look at the technical aspects of LTE will be helpful. Figure 1 gives a general overview of LTE architecture.

On the radio side of an LTE system, several important changes to earlier standards have been introduced. The radio access technology used, Orthogonal Frequency Division Multiple Access (OFDMA), is completely new and is designed to increase throughput over the radio link and improve spectral efficiency. This should provide higher potential data rates between the mobile device and the base station, and greater capacity per MHz of spectrum. New, highly flexible scheduling and spectrum allocation mechanisms allow the system to better adjust radio resources to accommodate changes in the traffic flow on both the uplink and the downlink.

Advanced forms of antenna technology are also written into the LTE standards. For example, a technique known as Multiple Input Multiple Output (MIMO) uses an array of antennas, instead of just one, to increase peak data rates. Beam-forming technology helps provide more consistent Quality of Service (QoS) throughout the LTE network by improving the coverage of the radio signal so that data rates do not drop precipitously at the outer edges of a base station coverage area.

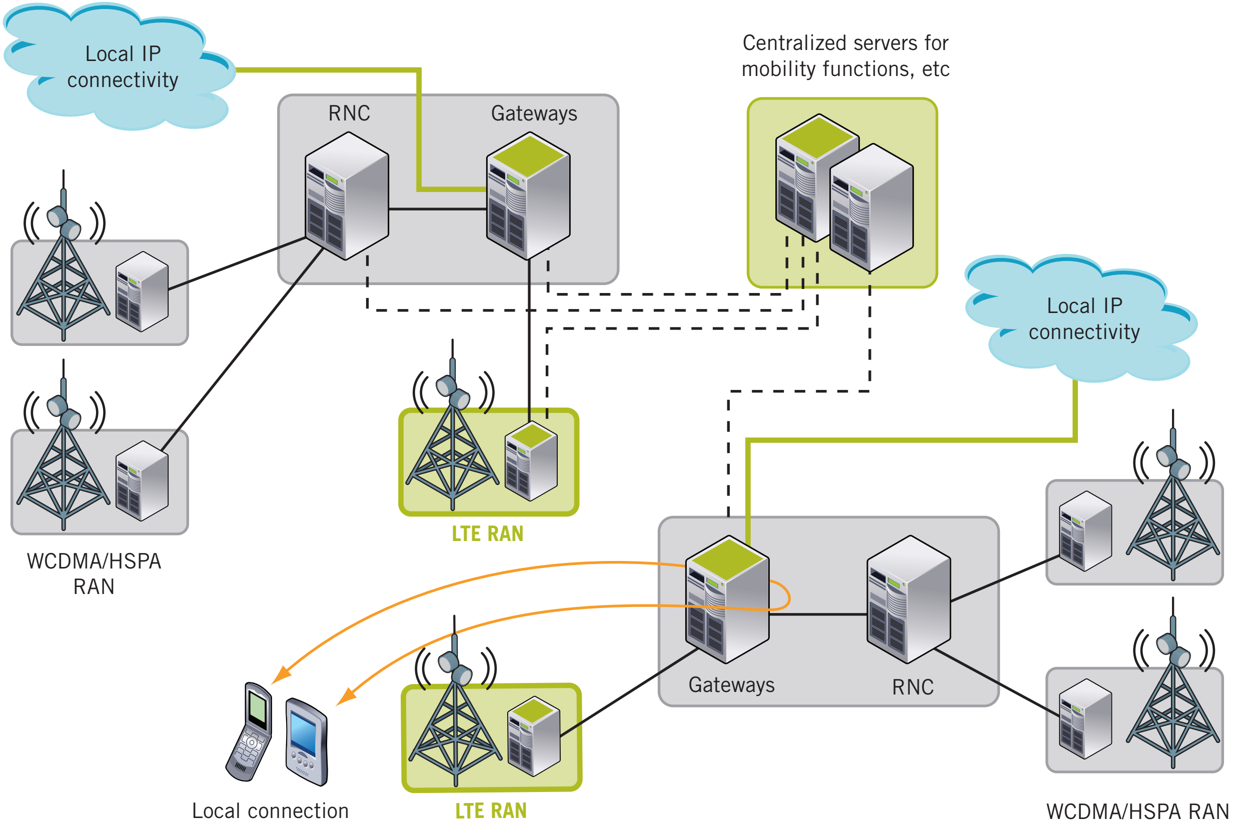

*Figure 1. Overview of LTE Architecture*

In the core network (EPC), the LTE standards provide the following key elements:

- **A common anchor point and gateway node for all access technologies** — A common anchor point not only enables service continuity across various types of access networks so that, for example, LTE user devices can connect to 2G wireless and fixed line endpoints, but it also provides a point at which policy enforcement can be implemented.
- **Optimized architecture for the user plane** — In the LTE architecture, user traffic passes through only two node types (base stations and gateways). Optimized user plane architecture is often referred to as a "flat architecture," and is designed to help minimize end-to-end latency and enable high quality real-time multimedia services.
- **IP-based protocols at all interfaces** — An all-IP infrastructure eliminates the bandwidth and throughput constraints of circuit-switched connections except perhaps in cases where the user session requires a connection to endpoints in a legacy circuit-switched network. It also reduces the overhead of some transcoding and transrating functions needed in current systems to convert between circuit-switched protocols for the radio link and IP protocols on the other end.
- **RAN-CN functional split similar to that of WCDMA/HSPA** — Keeping a similar functional distribution as the network evolves from WCDMA/HSPA to LTE can ease the introduction of new elements into the network and reduce operational complexities in hybrid networks. In a mobile network, many tasks are involved in the "mobility management" function, which tracks the location of moving endpoints and maintains communications connections as radio signal quality, elements in the connection path, and even local network capabilities vary. Network evolution can be simplified if the distribution of the discrete tasks involved in this process for LTE networks is similar to the distribution in predecessor networks.

- **Control/user plane split between the mobility management entity (MME) and the gateway** — A split in the control/user plane between distinct elements in the core network improves cost-effectiveness by allowing the network operator to scale capacity where needed. For example, user traffic is anticipated to grow at a considerably faster pace than the related control traffic.
- **Integration of non-3GPP access technologies using client- as well as network-based mobile IP** — The integration of non-3GPP access technologies potentially extends the reach of LTE services to user endpoints outside of the LTE coverage area.

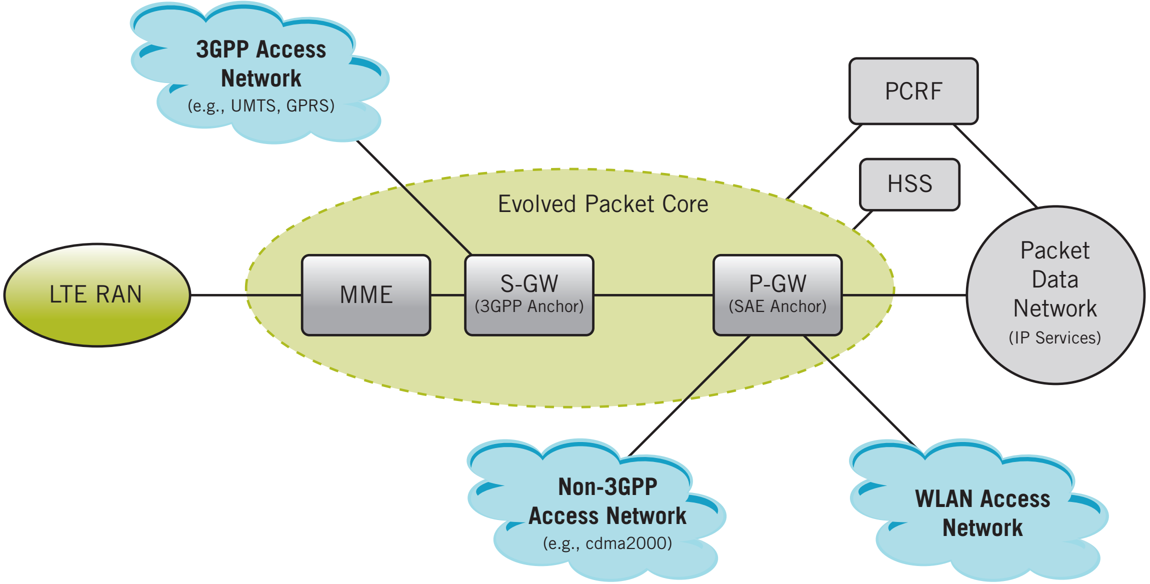

*Figure 2. LTE Architecture*

The fundamental architectural entities of the EPC are shown in the central oval in Figure 2. Their basic functions are:

- **Serving Gateway (S-GW)** — Referred to as the 3GPP Anchor, the S-GW is the mobility anchor for the user plane when the mobile endpoint is connected via an LTE radio link or another 3GPP Radio Access Technology (RAT). It provides a stable IP point of presence, allowing user traffic to flow uninterrupted as the user endpoint moves from one eNB to another within a 3GPP environment. The S-GW handles mobility functions related to handovers between eNBs within a network or between eNBs in different 3GPP networks. The latter scenario would occur whenever a user moves from an LTE network to a UMTS (3G) or GSM (2G) network, or from one LTE network to another. The functions of the S-GW also include packet routing and forwarding, as well as certain low-level QoS procedures.
- **PDN Gateway (P-GW)** — The P-GW provides the interface for LTE user traffic to/from external packet data networks. Referred to as the SAE anchor, the P-GW also serves as the mobility anchor point for user traffic transmitted over non-3GPP RATs, such as CDMA and WiMAX networks. It provides a stable IP point of presence for user sessions regardless of access technology or movement between access networks. In addition to performing handoff functions, the P-GW provides Deep Packet Inspection (DPI), policy enforcement, and higher-level QoS procedures.
- **Mobility Management Element (MME)** — MME terminates control signaling from the RAN, handles overall mobility management within an LTE network, and maintains the status of user endpoints. The MME handles signaling between 3GPP networks for mobility-related procedures and supports interfaces to the Serving GPRS Support Node (SGSN) in legacy 3GPP networks. In a network deployment, it would likely be combined with the S-GW.

Protocols on interfaces within the EPC are strictly IP-based.

## Services in LTE Standards

The 3GPP standards define various types of services supported by the underlying network technology. End user applications (commonly called "services" or "value-added services" by providers) may be built on top of one or multiple service capabilities. For example, a Chat application may require a combination of Multimedia Messaging and Packet-Switched Streaming services.

In general, the LTE standards do not define entirely new types of services. Rather, the fundamental changes in LTE standards (in comparison to previous versions of the 3GPP standards) provide:

- Improvements in the ability of the network architecture to support particular types of services, such as broadcast
- A definition of the IP bearer and the addition of more robust QoS capabilities to that bearer
- An expanded policy management role
- Revised definitions of many services to accommodate access independence so that a given end user application is available over virtually any underlying network technology

The primary types of services available in an LTE environment are described below.

### *Multimedia Telephony Services for IMS (MTSI)*

MTSI provides real-time bidirectional conversational transfer of speech, video, or data between two or more users. Communication is point-to-point between endpoints and involves one or more types of media, and additional types of media may be added as the communication progresses. MTSI is intended to cover the usage models of traditional telephony services and supplementary services that are based on speech or speech combined with additional media components, although MTSI services are not required to involve speech.

The 3GPP specifications for MTSI are designed to support conversational speech (including DTMF), video, and text transported over RTP, and aim to deliver a user experience equivalent to or better than circuit-switched conversational services while using the same amount of network resources.

3GPP TS 22.173 provides a general definition of MTSI.

### *Multimedia Messaging Services (MMS)*

MMS provides non-real-time transmission between mobile users that involves one or more media elements combined in an ordered and synchronized manner. It will allow users to send and receive messages exploiting the entire array of media types available today (for example, text, images, audio, voice, video) while also enabling support for new content types as they become popular.

MMS supplies a set of service capabilities on which new services can be built. The capabilities are designed to ensure interoperability across networks and terminals and allow unified applications that integrate the composition, storage, access, and delivery of different kinds of media in combination with additional mobile requirements.

3GPP TS 22.140 provides general information about MMS.

### *Packet-Switched Streaming Services (PSS)*

PSS deals with mechanisms that allow media content to be rendered at an endpoint at the same time as it is being transmitted over the network. PSS can support on-demand applications, such as music video and news-on-demand, and live information delivery applications, such as live (but not broadcast) radio and television programs, which can be built on top of streaming services.

Streaming services are required whenever instant access to multimedia information needs to be integrated into an interactive media application. This contrasts with other multimedia services, such as MMS, where multimedia content is delivered to the user asynchronously as a "message."

3GPP TS 22.233 provides general information about PSS.

### *Multimedia Broadband and Multicast Services (MBMS)*

MBMS is a unidirectional point-to-multipoint service in which data is transmitted from a single source in the network to multiple endpoints. A traditional broadcast service transmits data to all users in the broadcast area who have enabled the broadcast service. A multicast service transmits data that can be received only by user endpoints which have subscribed to the particular multicast service.

One benefit of MBMS for LTE networks is that it increases the efficiency of network resource usage because it enables multiple users to receive the same data but sends that data only once from the core network to a given Radio Network Controller and transmits the data on a common radio channel instead of using a separate channel for each endpoint.

A variety of MBMS user services can be built on top of the MBMS bearer service. Two delivery methods for the MBMS user services are possible: download, for applications such as news or software updates, and streaming, for applications such as live music or event transmission.

3GPP TS 22.146 and related specifications provide additional information about MBMS.

A future release of the 3GPP standards, sometimes referred to as "LTE Advanced," is expected to include standards for a MBMS Single Frequency Network (MBSFN). In this service, the data transmission is time-synchronized across multiple contiguous cells in the service area so that the endpoint processes it as one transmission from a single large cell. When a threshold number of users are receiving the same transition in a cell, resource efficiency is improved. Interruptions or gaps are also eliminated in the content received by an endpoint if it is moving between cells during the transmission.

MBSFN is expected to enable Mobile TV using the LTE infrastructure, and may become a competitor to DVB-H-based TV broadcast.

### *Location Services (LCS)*

Location services provide information about the current location of a user's terminal or the likely location of a specific mobile entity, along with additional attributes describing the location information provided, such as accuracy, coverage, privacy, and transaction rate.

LCS can be used for a wide variety of functions and applications within the network, external to the network, or in the mobile endpoint itself. Examples of these functions and applications are:

- Value-added (end-user) services
- Charging functions
- Lawful intercept
- Emergency calls
- Positioning (telemetry) services

3GPP TS 22.071 and related specifications provide additional information about LCS.

### *Presence Services*

Presence services allow access to information about a user's context and availability as well as information about user devices, services, and service components managed by the network.

The definition of presence service capabilities in the LTE standards is intended to support the interoperability of these services in both wireless and fixed telecommunications networks and with external networks, although existing internet presence services are often closed, proprietary systems.

3GPP TS 22.141 and related specifications provide additional information about Presence Services.

## Support for Circuit-Switched Services

Methods of providing support for circuit-switched domain services, such as (non-IP) voice, SMS, and USSD-based services, have been an ongoing subject of debate. Release 8 of the 3GPP standards specifies only a "fallback" method. This method satisfies any need to access circuit-switched domain services by providing a mechanism to shift the connection from the EPS to an overlapping 2G or 3G network.

Investigation of other possibilities for provisioning circuit-switched domain services may result in additional methods being written into future releases of the standards. At least one alliance of equipment providers and wireless network operators (the VoLGA Forum) has already launched an independent effort to codify an alternative method that would allow such services to be supported with the EPS. For more information on the VoLGA Forum, visit their website at www.volga-forum.com.

The current “CS Fallback” method for provisioning circuit-switched service is available in 3GPP TS 23.272 and related specifications.

## LTE Key Business Drivers

The key business drivers for mobile service providers to move to LTE are relatively clear. In order to compete effectively in a communications market that crosses service classes, access methods, and media types, the service providers must be able to:

- Offer cost-effective broadband services to a mass market
- Monetize the value of content and services (that is, capture value beyond acting as a “pipe”)
- Expand the scope of service continuity beyond the wireless access network domain

These three business drivers will be discussed in this section: broadband services, monetization of services, and service continuity.

### Broadband Services

Today’s mobile service providers, unlike other communications service providers, are limited in their ability to provide mass market broadband services. The primary limitations stem from:

- The persistence of legacy circuit-switched infrastructure, particularly for bearer transport — replacing this architecture with IP/SIGTRAN signaling is already in progress
- The architecture of existing 2G and 3G RATs — upgrading radio link architecture is not cheaply or easily accomplished and is constrained by the need to support existing mobile service

LTE standards include a new scheme for the air interface technology that allocates radio link capacity for broadband services with maximum efficiency. Despite early doubts about the achievability of this scheme, LTE lab trials and field trials have successfully validated the radio link technology, link budget, and handoff requirements that are key to the success of the LTE system. Many early LTE demos also concentrated on demonstrating broadcast and interactive applications that would make heavy use of PSS services and, to some extent, the MBMS services. The adequate provisioning of network resources to support intensive use of these services is an important focus of discussion in the LTE arena.

The devices used to access multimedia services over the LTE network will vary, and devices supported in early deployments are unlikely to be traditional mobile phones. LTE chipsets are expected to be available first for laptop-like devices rather than for mobile phones. For mobile network operators, LTE is, at least in part, a bid to expand beyond the “phone” as an endpoint and beyond telephony-oriented applications. LTE network operators will have powerful incentives to target user applications involving integrated media and broadband connections because they are likely to be the highest revenue-generating applications and will allow operators to provide service continuity across access networks.

Today, mobile operators seem to be under-emphasizing real-time streaming video applications. Consequently, many mobile developers see no pressing need to develop applications to deliver streaming video because of the lack of proven business models for them. As LTE trials and early deployments focus on real-time streaming video applications for laptops, set-top boxes and/or gaming consoles, mobile multimedia developers and technology vendors may need to reexamine their readiness to support those services, including technical underpinnings such as codecs, scalability issues, and latency requirements.

Another aspect of LTE technology that is designed to better support wireless broadband services is what is known as its “flat IP architecture.” This core network design is a significant departure from previous mobile networks, which have a hierarchical architecture and specialized functions segregated in separate network elements. The flat IP architecture is designed to deliver higher speeds and lower latency at potentially lower costs than can be achieved with current or future iterations of W-CDMA and HSPA network technology.

While several benefits could be mentioned for a network architecture that reduces the number of nodes in the path of user traffic, latency is perhaps the most important. The business case for LTE rests fundamentally on its promised ability to provide mass market, RT broadband services, and its ability to provide RT broadband services over a wireless, IP-based network hinges on removing as much delay as technically possible from the bearer path. Indeed, one of the earliest testing concerns was verification of the latency limits over the LTE air interface, which was specified in the standards to be as low as 10 ms per round trip.

Finally, the separation of user and control plane elements in LTE architecture has the potential to reduce the cost of provisioning wireless broadband services. An increase in the usage of high-bandwidth applications clearly has a disproportionate effect on growth in signaling traffic versus growth in user traffic. The economics of a network designed specifically to provide high-bandwidth services on a mass scale requires the ability to scale user traffic independent of signaling traffic.

### Monetization of Services

Because they recognize that they are at risk of becoming non-value-added communications transmission utilities, mobile service providers are attempting to implement a new business model. The “walled garden” approach to capturing the value of content, which has been favored by providers in the United States, was an attempt to monetize the pieces of the business by strictly controlling both content accessibility from the mobile device and content loading onto the mobile device. Such an approach is quickly becoming outmoded.

The LTE charging/billing environment will be considerably more nuanced than what exists today and will likely be predicated on “value-based services pricing,” which has implications for both core network functions and the application servers that interact with the core network. Mobile service providers will have the ability to “fine tune” revenue with a tiered service model. Such a model requires the ability to identify not only subscriber profile parameters, but also service characteristics such as RT vs. NRT throughput demands, bandwidth, and service reliability (ranging from “best-effort” service to dedicated channels), and to authorize services and bill for them accordingly.

To facilitate a differentiated pricing model, a service class structure is built into the LTE standards. A service class is essentially a specific set of QoS parameters grouped together to handle a particular type of traffic, and the LTE standards also address mechanisms to monitor QoS and/or Quality of Experience (QoE) so that contracted levels of service can be guaranteed. This involves not just the core network but the end-to-end implementation of an application as well. At the MRF, for example, features such as RTCP-XP (RFC 3611) are expected to be a key requirement for LTE deployments.

Building a flexible, tailored service authorization and charging model will require the deployment of relatively new network functions, such as Deep Packet Inspection (DPI) and the Policy and Charging Rules Function (PCRF), and application servers in an LTE environment will need to communicate with one or both of these new functions using the Diameter protocol, as specified in the LTE standards.

DPI capabilities would be located in or at the P-GW — either as an application blade within the P-GW to maximize efficiency or as a standalone server to avoid having the compute-intensive nature of the application negatively impact the processing of user traffic. There are various options for the deployment of the policy server function, and no configuration seems predominant yet.

With greater flexibility to competitively price services, mobile service providers in the LTE environment will be better able to adapt quickly to changes or exploit opportunities in the broader communications market. They can also charge a premium for their unique competence — mobility — where and when it adds the most value.

### Service Continuity

From its inception, one of the fundamental objectives of the LTE architecture has been to expand service continuity by integrating interfaces not only with earlier 3GPP standards but also with existing and new non-3GPP networks, such as CDMA and WiMAX. Various aspects of the LTE architecture are designed to support this objective.

The split between the RAN and the core network, for example, is in many ways consistent with the existing W-CDMA model and opens up the possibility of a common core network to serve both 3G and 4G 3GPP RANs, which could help lower operational costs for the network operator, since support for “legacy” networks will be required for some time.

The design of the P-GW as the stable IP point of presence for user sessions across heterogeneous RATs makes seamless service continuity a possibility across both mobile service provider and non-mobile provider networks as well. Because an LTE service environment is not predicated on mobility or on the mobile phone as the user endpoint, a user session will likely have the additional ability to move from one user endpoint to another, for example, from a laptop to a mobile phone. This will be a marked change for today's mobile networks, since mobile service providers are only concerned with enabling a user session to move from base station to base station and, occasionally, from one service provider network to another transparently.

Although it is unclear exactly how such "mobility" would be handled from end-to-end unless all the devices were on the LTE network, it appears inevitable that the application itself would need to be aware of such changes and have the ability to adjust service parameters accordingly.

## LTE and WiMax

No firm consensus has appeared to date on the relationship between WiMAX, particularly fixed WiMAX, and LTE in the marketplace for wireless broadband multimedia services. However, a number of interesting scenarios have been suggested:

- **Rural coverage** — Because it can cover a large area with relatively simple technology, fixed WiMAX is proving popular for bringing broadband communications to underserved rural areas.
- **Backhaul** — The backhaul requirements for LTE systems are several times greater than for current 3G base stations. High-capacity (fixed) WiMAX links could replace E1/T1, microwave, and satellite links between the LTE base station and controller.
- **Last mile connectivity** — In many cases, last-mile connectivity can include devices with limited or no mobility requirements as a possible alternative to using WiFi to connect those devices to existing fixed-line connections, such as cable. Another possibility is using fixed WiMAX to aggregate the traffic from a number of WiFi hot spots and provide a backend connection.

## LTE in the Marketplace

News about LTE trial and deployment expectations surfaces weekly, if not daily. TeliaSonera, Verizon, and NTT DoCoMo are expected to begin field trials shortly with commercial launch in 2010. And although some network operators intend to build out HSPA+ before moving to LTE or LTE Advanced, industry analysts report that GSM and W-CDMA operators want LTE brought to market "sooner rather than later." [3G Squeeze, p. 18]

Still, skepticism remains about the likelihood of significant large-scale LTE commercial service availability before 2012. Such doubts stem in part from the perception that the introduction of new wireless technologies is historically preceded by a period of rollout "hype." 3G network technology, for example, was a technology whose imminent arrival was announced for four or five years before substantial commercial deployments actually got underway.

Certainly a degree of caution is warranted: "It will be 2012 before HSPA operators require the capacity and performance of LTE, except in a few select markets. Early leaders in the LTE space are expected to be Verizon Wireless in the US and NTT DoCoMo in Japan, as both operators face unique pressures on their current 3G networks. At a global level, this implies that capital spending on LTE networks will start to ramp up from 2011 onwards." [LR-FIPA, p. 30]

On the other hand, there are a number of key differences between the transition to LTE and the transition from 2G to 3G networks.

- **Competitive pressure** — Because the transition to 3G was, in many ways, technology-driven rather than demand-driven, and not a competitive requirement, the potential consequences of delaying 3G service rollout were less important. In addition, neither GSM nor early CDMA networks were capable of supporting mass market data services, much less broadband, and broadband service in the fixed line world was nascent. Today, cdma2000 network operators, in particular, are facing stiff competition from UMTS networks for mobile broadband services, and traditional mobile wireless access networks are looking to compete with fixed and "new" wireless access networks in order to capture revenue from broadband service consumers. For specific information about competitive pressures, see LR-FIPA, p. 31.
- **Intellectual property delays** — Because of delays imposed on earlier versions of wireless network standards due to intellectual property issues, the creators of the LTE standards have had to observe the principle that any intellectual property incorporated into the standards must be available to all participants on clear and reasonable terms.
- **Handset availability** — Network operators now seem to be working only with integrators who can offer a "full package," including commercial user endpoint technology. In addition, the focus on broadband services enabled by LTE creates the likelihood that the initial endpoints on the network will be computers, set-top boxes, and/or gaming consoles rather than mobile phones, and recent announcements have confirmed this. The more stringent power, heat dissipation, footprint, and weight limitations of mobile phones tend to delay the creation of chipsets for those devices. The increasing need to run and store applications on the device adds complexity to the development of chipsets for a 4G mobile phone environment.

Although we tend to think of LTE as a new generation of mobile access, mobile phones may not be the first or most prevalent LTE end user devices. LTE technology aims to enable IP broadband services in general and empower mobile service providers to compete effectively with fixed line providers. The type and range of applications to be supported in an LTE environment is much larger and more diverse than those currently associated with mobile services.

Rather than focus on debates about commercial deployment dates or likely revenue ramps, developers and technology vendors should consider positioning themselves to participate in the near-term LTE RFPs and lab and field trials. The race starts considerably earlier than initial commercial deployment, and when LTE capital spending begins to ramp, those likely to gain the most will be those who already have done business successfully with network operators and TEMs. Developers and equipment vendors who work through an SI or middleware vendors are likely to find their cycle of RFP-to-commercial-deployment on the order of two years.

## Acronyms

| | |
|---|---|
| **3GPP** | Third Generation Partnership Project |
| **AMPS** | Advanced Mobile Phone System |
| **CDMA** | Code Division Multiple Access |
| **CDN** | Content Delivery Network |
| **CDPD** | Cellular Digital Packet Data |
| **CN** | Core Network |
| **DPI** | Deep Packet Inspection |
| **DTMF** | Dual-Tone Multi-Frequency |
| **EDGE** | Enhanced Data Rates for GSM Evolution |
| **eNB** | Evolved Node B |
| **EPC** | Evolved Packet Core |
| **ePDG** | Evolved Packet Data Gateway |
| **EPS** | Evolved Packet System |
| **E-UTRAN** | Evolved UMTS Terrestrial Radio Access Network |
| **GPRS** | General Packet Radio Service |
| **GSM** | Global System for Mobile communications |
| **HSDPA** | High-Speed Downlink Packet Access |
| **HSPA** | High-Speed Packet Access |
| **HSS** | Home Subscriber Server |
| **HSUPA** | High-Speed Uplink Packet Access |
| **LCS** | LoCation Services |
| **LSTI** | Long Term Evolution/System Architecture Evolution Trial Initiative |
| **LTE** | Long Term Evolution |
| **MBMS** | Multimedia Broadcast/Multicast Service |
| **MBSFN** | MBMS Single Frequency Network |

| | |
|---|---|
| **MME** | Mobility Management Entity |
| **MMS** | Multimedia Message Service |
| **MTSI** | Multimedia Telephony Services for IMS |
| **NRT** | Non Real Time |
| **OFDMA** | Orthogonal Frequency Division Multiple Access |
| **P2P** | Peer-to-Peer |
| **PCRF** | Policy and Charging Rules Function |
| **PDC** | Personal Digital Cellular |
| **PDN** | Packet Data Network |
| **P-GW** | PDN GateWay |
| **PSS** | Packet-switched Streaming Service |
| **QOE** | Quality of Experience |
| **QOS** | Quality of Service |
| **RAN** | Radio Access Network |
| **RAT** | Radio Access Technology |
| **RT** | Real Time |
| **SAE** | System Architecture Evolution |
| **SGSN** | Serving GPRS Support Node |
| **S-GW** | Serving GateWay |
| **SMS** | Short Message Service |
| **UMTS** | Universal Mobile Telecommunications System |
| **UTRAN** | UMTS Terrestrial Radio Access Network |
| **VoIP** | Voice over IP |
| **WCDMA** | Wideband CDMA |
| **WLAN** | Wireless Local Area Network |

## References

[3G Squeeze] Patrick Donegan, 3G Squeeze: GSM, LTE & the Future of Wideband CDMA, Heavy Reading, Vol. 6, No. 8, May 2008.

[LR-FIPA] Gabriel Brown, Flat IP Architectures in Mobile Networks: From 3G to LTE, Heavy Reading, Vol. 6, No. 5, April 2008.

## For More Information

Along with the two research reports cited as references, the following presents a general overview:

Long Term Evolution (LTE): A Technical Overview, Motorola Corporation, 2007

Also useful for information on LTE are various timely articles in Wikipedia, including:

- 3GPP Long Term Evolution
- LTE Advanced
- 4G
- System Architecture Evolution
- E-UTRA

Wikipedia articles also offer links to additional white papers.

Industry associations are also important sources of information:

- 3GPP (Third Generation Partnership Project) — Association that provides access to all 3GPP network and technology standards and posts industry and partner news
- GSMA (GSM Association) — Industry consortium that offers information about technology, news, and active initiatives
- LSTI (LTE/System Architecture Evolution (SAE) Trial Initiative) — Industry consortium of network operators and equipment vendors that aims to accelerate LTE commercialization and facilitate technology trials and interoperability testing
- NGMN (Next Generation Mobile Networks Alliance) — A mobile network operator association formed to support evolution to packet-based mobile broadband networks
- 3G Americas — Association of mobile operators and manufacturers in the Americas whose products and services relate to 3GPP standards

Telecom equipment manufacturers may also provide product-specific LTE information. Consult the LSTI membership page at http://www.lstiforum.org/about/lsti_membership.html for a list of TEMs whose website you may want to check.

Dialogic®
Making Innovation Thrive™

www.dialogic.com

**Dialogic Corporation**
9800 Cavendish Blvd., 5th floor
Montreal, Quebec
CANADA H4M 2V9

INFORMATION IN THIS DOCUMENT IS PROVIDED IN CONNECTION WITH PRODUCTS OF DIALOGIC CORPORATION OR ITS SUBSIDIARIES ("DIALOGIC"). NO LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE, TO ANY INTELLECTUAL PROPERTY RIGHTS IS GRANTED BY THIS DOCUMENT. EXCEPT AS PROVIDED IN A SIGNED AGREEMENT BETWEEN YOU AND DIALOGIC, DIALOGIC ASSUMES NO LIABILITY WHATSOEVER, AND DIALOGIC DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY, RELATING TO SALE AND/OR USE OF DIALOGIC® PRODUCTS INCLUDING LIABILITY OR WARRANTIES RELATING TO FITNESS FOR A PARTICULAR PURPOSE, MERCHANTABILITY, OR INFRINGEMENT OF ANY INTELLECTUAL PROPERTY RIGHT OF A THIRD PARTY.

Dialogic is a registered trademark of Dialogic Corporation or its subsidiaries. Dialogic's trademarks may be used publicly only with permission from Dialogic. Such permission may only be granted by Dialogic's legal department at 9800 Cavendish Blvd., 5th Floor, Montreal, Quebec, Canada H4M 2V9. Any authorized use of Dialogic's trademarks will be subject to full respect of the trademark guidelines published by Dialogic from time to time and any use of Dialogic's trademarks requires proper acknowledgement.

The names of actual companies and product mentioned herein are the trademarks of their respective owners. Dialogic encourages all users of its products to procure all necessary intellectual property licenses required to implement their concepts or applications, which licenses may vary from country to country.

Dialogic products are not intended for use in medical, life saving, life sustaining, critical control or safety systems, or in nuclear facility applications.

Dialogic may make changes to specifications, product descriptions, and plans at any time, without notice.

This document discusses one or more open source products, systems and/or releases. Dialogic is not responsible for your decision to use open source in connection with Dialogic products (including without limitation those referred to herein), nor is Dialogic responsible for any present or future effects such usage might have, including without limitation effects on your products, your business, or your intellectual property rights.

Copyright © 2009 Dialogic Corporation All rights reserved.