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# NETWORK ADVANCEMENT in 4G: TD-LTE Technology

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## ABSTRACT

Conceivable applications include amended mobile web access, IP telephony, gaming services, high-definition mobile TV, video conferencing, 3D television and Cloud Computing. A 4G system provides mobile ultra-broadband Internet access, for example to laptops with USB wireless modems, to smartphones, and to other mobile devices.Network system uses the key technology of information gathering, processing and distribution. These systems should be controlled by a server. To enhance the benefits of these networks, we are introducing 4G systems. This paper proposes TD-LTE technology in 4G systemstowardsenhancing the security of 2G and 3G systems.In this paper two 4G candidate systems are commercially deployed: the Mobile WiMAXstandard and the first-release Long Term Evolution (LTE) standard are discussed with TD-LTE Technology.

***Keywords:*** 3G, 4G, TD-LTE, WiMax, UMTS, CDMA, MIMO, OFDMA.

## 1. INTRODUCTION

In March 2008, the International Telecommunications Union-Radio communications sector (ITU-R) specified a set of requirements for 4G standards, named the International Mobile Telecommunications Advanced (IMT-Advanced) specification, setting peak speed requirements for 4G service at 100 megabits per second (Mbit/s) for high mobility communication (such as from trains and cars) and 1 gigabit per second (Gbit/s) for low mobility communication (such as pedestrians and stationary users).

Since the first-release versions of Mobile WiMAX and LTE support much less than 1 Gbit/s peak bit rate, they are not fully IMT-Advanced compliant, but are often branded 4G by service providers. On December 6, 2010, ITU-R recognized that these two technologies, as well as other beyond-3G technologies that do not fulfill the IMT-Advanced requirements, could nevertheless be considered "4G", provided they represent forerunners to IMT-Advanced compliant versions and "a substantial level of improvement in performance and capabilities with respect to the initial third generation systems now deployed".

Mobile WiMAX Release 2 (also known as WirelessMAN-Advanced or IEEE 802.16m') and LTE Advanced (LTE-A) are IMT-Advanced compliant backwards compatible versions of the above two systems, standardized during the spring 2011, and promising speeds in the order of 1 Gbit/s. Services are expected in 2013.

As opposed to earlier generations, a 4G system does not support traditional circuit-switched telephony service, but all-Internet Protocol (IP) based communication such as IP telephony. As seen below, the spread spectrum radio technology used in 3G systems, is abandoned in all 4G candidate systems and replaced by OFDMA multi-carrier transmission and other frequency-domain equalization (FDE) schemes, making it possible to transfer very high bit rates despite extensive multi-path radio propagation (echoes). The peak bit rate is further improved by smart antenna arrays for multiple-input multiple-output (MIMO) communications.

The term "generation" used to name successive evolutions of radio networks in general is arbitrary. There are several interpretations of it, and no official definition has been made despite the large consensus behind ITU-R's labels. From ITU-R's point of view, 4G is equivalent to IMT-Advanced which has specific performance requirements as explained below. But according operators, a generation of network refers to the deployment of a new non-backward-compatible technology. This usually corresponds to a huge investment with its own depreciation period, marketing strategy (if any), and deployment phases. It can even be different among operators. From the end user's point of view, only performance and cost makes sense. It is expected that the next generation of network performs better and cheaper than the previous generation, which is not that simple to state. Indeed, while a new generation of network arrives, the previous one can keep evolving to a point where it outperforms the first version of the new generation. In many countries, GSM, UMTS and LTE networks still coexist. It is thus much less ambiguous to use the name of the technology/standard, possibly followed by its version number, than a subjective arbitrary generation number which is destined to be challenged endlessly.

## 2. LTE TECHNOLOGY

LTE, an initialism of long-term evolution, marketed as 4G LTE, is a standard for wireless communication of high-speed data for mobile phones and data terminals. It is based on the GSM/EDGE and UMTS/HSPA network technologies, increasing the capacity and speed using a different radio interface together with core network improvements. The standard is developed by the 3GPP (3rd Generation Partnership Project) and is specified in its Release 8 document series, with minor enhancements described in Release 9.

The world's first publicly available LTE service was launched by TeliaSonera in Oslo and Stockholm on December 14 2009. LTE is the natural upgrade path for both carriers with GSM/UMTS networks and for CDMA holdouts such as Verizon Wireless, who launched the first large-scale LTE network in North America in 2010, and au by KDDI in Japan have announced they will migrate to LTE. LTE is, therefore, anticipated to become the first truly global mobile phone standard, although the use of different frequency bands in different countries will mean that only multi-band phones will be able to use LTE in all countries where it is supported.

Although marketed as a 4G wireless service, LTE as specified in the 3GPP Release 8 and 9 document series does not satisfy the technical requirements the 3GPP consortium has adopted for its new standard generation, and which were originally set forth by the ITU-R organization in its IMT-Advanced specification. However, due to marketing pressures and the significant advancements that WIMAX, HSPA+ and LTE bring to the original 3G technologies, ITU later decided that LTE together with the aforementioned technologies can be called 4G technologies. The LTE Advanced standard formally satisfies the ITU-R requirements to be considered IMT-Advanced. And to differentiate LTE-Advanced and WiMAX-Advanced from current 4G technologies, ITU has defined them as "True 4G".

### 2.1 OVERVIEW OF LTE

LTE is a standard for wireless data communications technology and an evolution of the GSM/UMTS standards. The goal of LTE was to increase the capacity and speed of wireless data networks using new DSP (digital signal processing) techniques and modulations that were developed around the turn of the millennium. A further goal was the redesign and simplification of the network architecture to an IP-based system with significantly reduced transfer latency compared to the 3G architecture. The LTE wireless interface is incompatible with 2G and 3G networks, so that it must be operated on a separate wireless spectrum.

LTE was first proposed by NTT DoCoMo of Japan in 2004, and studies on the new standard officially commenced in 2005. In May 2007, the LTE/SAE Trial Initiative (LSTI) alliance was founded as a global collaboration between vendors and operators with the goal of verifying and promoting the new standard in order to ensure the global introduction of the technology as quickly as possible. The LTE standard was finalized in December 2008, and the first publicly available LTE service was launched by TeliaSonera in Oslo and Stockholm on December 14, 2009 as a data connection with a USB modem. In 2011, LTE services were launched by major North American carriers as well, with the Samsung Galaxy Indulge offered by MetroPCS starting on February 10, 2011 being the first commercially available LTE smartphone and HTC ThunderBolt offered by Verizon starting on March 17 being the second LTE smartphone to be sold commercially. In Canada, Rogers Wireless was the first to launch LTE network on July 7, 2011 offering the Sierra Wireless AirCard® 313U USB mobile broadband modem, known as the "LTE Rocket™ stick" then followed closely by mobile devices from both HTC and Samsung. Initially, CDMA operators planned to upgrade to rival standards called UMB and WiMAX, but all the major CDMA operators (such as Verizon, Sprint and MetroPCS in the United States, Bell and Telus in Canada, au by KDDI in Japan, SK Telecom in South Korea and China Telecom/China Unicom in China) have announced that they intend to migrate to LTE after all. The evolution of LTE is LTE Advanced, which was standardized in March 2011. Services are expected to commence in 2013.

The LTE specification provides downlink peak rates of 300 Mbit/s, uplink peak rates of 75 Mbit/s and QoS provisions permitting a transfer latency of less than 5 ms in the radio access network. LTE has the ability to manage fast-moving mobiles and supports multi-cast and broadcast streams. LTE supports scalable carrier bandwidths, from 1.4 MHz to 20 MHz and supports both frequency division duplexing (FDD) and time-division duplexing (TDD). The IP-based network architecture, called the Evolved Packet Core (EPC) and designed to replace the GPRS Core Network, supports seamless handovers for both voice and data to cell towers with older network technology such as GSM, UMTS and CDMA2000. The simpler architecture results in lower operating costs (for example, each E-UTRAN cell will support up to four times the data and voice capacity supported by HSPA)

## 3. FEATURES OF 4G TECHNOLOGY

The following key features can be observed in all suggested 4G technologies:

- Physical layer transmission techniques are as follows:
  - MIMO: To attain ultra-high spectral efficiency by means of spatial processing including multi-antenna and multi-user MIMO.
  - Frequency-domain-equalization, for example multi-carrier modulation (OFDM) in the downlink or single-

carrier frequency-domain-equalization (SC-FDE) in the uplink: To exploit the frequency selective channel property without complex equalization.

- Frequency-domain statistical multiplexing, for example (OFDMA) or (single-carrier FDMA) (SC-FDMA, a.k.a. linearly precoded OFDMA, LP-OFDMA) in the uplink: Variable bit rate by assigning different sub-channels to different users based on the channel conditions.

- Turbo principle error-correcting codes: To minimize the required SNR at the reception side.

- Channel-dependent scheduling: To use the time-varying channel.

- Link adaptation: Adaptive modulation and error-correcting codes.

- Mobile-IP utilized for mobility.

IP-based femtocells (home nodes connected to fixed Internet broadband infrastructure)

## 4. CHARACTERISTICS OF LTE TECHNOLOGY

Much of the LTE standard addresses the upgrading of 3G UMTS to what will eventually be 4G mobile communications technology. A large amount of the work is aimed at simplifying the architecture of the system, as it transits from the existing UMTS circuit + packet switching combined network, to an all-IP flat architecture system. E-UTRA is the air interface of LTE. Its main features are:

- Peak download rates up to 299.6 Mbit/s and upload rates up to 75.4 Mbit/s depending on the user equipment category (with 4x4 antennas using 20 MHz of spectrum). Five different terminal classes have been defined from a voice centric class up to a high end terminal that supports the peak data rates. All terminals will be able to process 20 MHz bandwidth.

- Low data transfer latencies (sub-5 ms latency for small IP packets in optimal conditions), lower latencies for handover and connection setup time than with previous radio access technologies.

- Improved support for mobility, exemplified by support for terminals moving at up to 350 km/h (220 mph) or 500 km/h (310 mph) depending on the frequency band.

- OFDMA for the downlink, SC-FDMA for the uplink to conserve power.

- Support for both FDD and TDD communication systems as well as half-duplex FDD with the same radio access technology.

- Support for all frequency bands currently used by IMT systems by ITU-R.

- Increased spectrum flexibility: 1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz and 20 MHz wide cells are standardized. (W-CDMA requires 5 MHz slices, leading to some problems with roll-outs of the technology in countries where 5 MHz is a commonly allocated amount of spectrum, and is frequently already in use with legacy standards such as 2G GSM and cdmaOne.)

- Support for cell sizes from tens of metres radius (femto and picocells) up to 100 km (62 miles) radius macrocells. In the lower frequency bands to be used in rural areas, 5 km (3.1 miles) is the optimal cell size, 30 km (19 miles) having reasonable performance, and up to 100 km cell sizes supported with acceptable performance. In city and urban areas, higher frequency bands (such as 2.6 GHz in EU) are used to support high speed mobile broadband. In this case, cell sizes may be 1 km (0.62 miles) or even less.

- Supports at least 200 active data clients in every 5 MHz cell.

- Simplified architecture: The network side of E-UTRAN is composed only of eNodeBs.

- Support for inter-operation and co-existence with legacy standards (e.g. GSM/EDGE, UMTS and CDMA2000). Users can start a call or transfer of data in an area using an LTE standard, and, should coverage be unavailable, continue the operation without any action on their part using GSM/GPRS or W-CDMA-based UMTS or even 3GPP2 networks such as cdmaOne or CDMA2000)

- Packet switched radio interface.

- Support for MBSFN (Multicast-Broadcast Single Frequency Network). This feature can deliver services such as Mobile TV using the LTE infrastructure, and is a competitor for DVB-H-based TV broadcast.

## 5. IMPLEMENTATION OF VOICE CALLS IN LTE TECHNOLOGY

The LTE standard only supports packet switching with its all-IP network. Voice calls in GSM, UMTS and CDMA2000 are circuit switched, so with the adoption of LTE, carriers will have to re-engineer their voice call network. Three different approaches sprang up:

- VoLTE (Voice over LTE): This approach is based on the IP Multimedia Subsystem (IMS) network, with specific profiles for control and media planes of voice service on LTE defined by GSMA in PRD IR.92. This approach results in the voice service (control and media planes) being delivered as data flows within the LTE data bearer. This means that there is no dependency on (or ultimately, requirement for) the legacy Circuit Switch voice network to be maintained.

- CSFB (Circuit Switched Fallback): In this approach, LTE just provides data services, and when a voice call is to be initiated or received, it will fall back to the CS domain. When using this solution, operators just need to upgrade the MSC instead of deploying the IMS, and therefore, can provide services quickly. However, the disadvantage is longer call setup delay.

- SVLTE (Simultaneous Voice and LTE): In this approach, the handset works simultaneously in the LTE and CS modes, with the LTE mode providing data services and the CS mode providing the voice service. This is a solution solely based on the handset, which does not have special requirements on the network and does not require the deployment of IMS either. The disadvantage of this solution is that the phone can become expensive with high power consumption.

One additional approach which is not initiated by operators is the usage of Over-the-top content services, using applications like Skype and Google Talk to provide LTE voice service. However, now and in the foreseeable future, the voice call service is, and will still be, the main revenue source for the mobile operators. So handing the LTE voice service over completely to the OTT actors is thus something which is expected to not receive too much support in the telecom industry.

Most major backers of LTE preferred and promoted VoLTE from the beginning. The lack of software support in initial LTE devices as well as core network devices however led to a number of carriers promoting VoLGA (Voice over LTE Generic Access) as an interim solution. The idea was to use the same principles as GAN (Generic Access Network, also known as UMA or Unlicensed Mobile Access), which defines the protocols through which a mobile handset can perform voice calls over a customer's private Internet connection, usually over wireless LAN.

VoLGA however never gained much support, because VoLTE (IMS) promises much more flexible services, albeit at the cost of having to upgrade the entire voice call infrastructure. VoLTE will also require Single Radio Voice Call Continuity (SRVCC) in order to be able to smoothly perform a handover to a 3G network in case of poor LTE signal quality.

While the industry has seemingly standardized on VoLTE for the future, the demand for voice calls today has led LTE carriers to introduce CSFB as a stopgap measure. When placing or receiving a voice call, LTE handsets will fall back to old 2G or 3G networks for the duration of the call.

## 5.1 PROPOSED WORK TO ENHANCE VOICE QUALITY

To ensure compatibility, 3GPP demands at least AMR-NB codec (narrow band), but the recommended speech codec for VoLTE is Adaptive Multi-Rate Wideband, also known as HD Voice. This codec is mandated in 3GPP networks that support 16 kHz sampling.

Fraunhofer IIS has demonstrated Full-HD Voice, an implementation of the AAC-ELD (Advanced Audio Coding – Enhanced Low Delay) codec for LTE handsets. Where previous cell phone voice codecs only supported frequencies up to 3.5 kHz and upcoming wideband audio services branded as HD Voice up to 7 kHz, Full-HD Voice supports the entire bandwidth range from 20 Hz to 20 kHz. For end-to-end Full-HD Voice calls to succeed however, both the caller and recipient's handsets as well as networks have to support the feature.

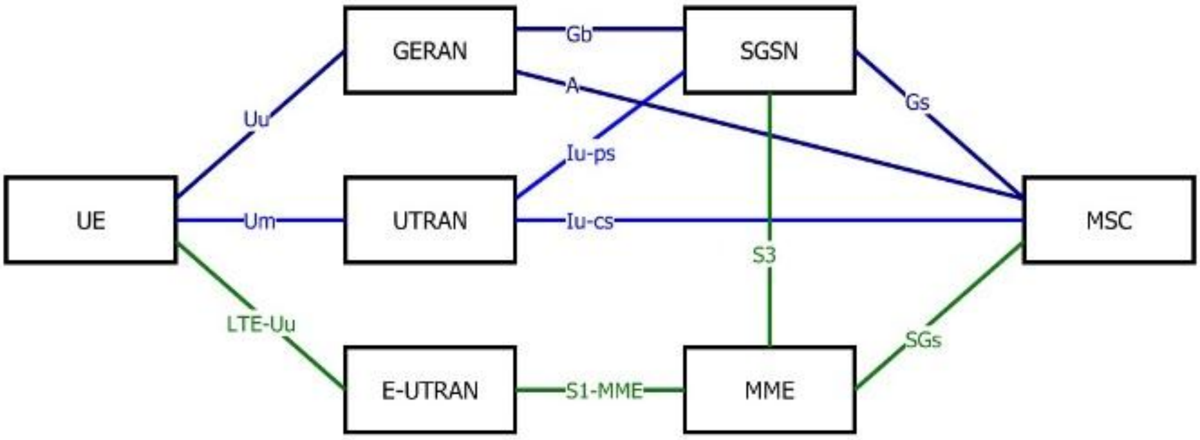


***Fig 1:*** LTE CSFB to GSM/UMTS network interconnects

## 5.2 FREQUENCY BANDS

The LTE standard can be used with many different frequency bands. In North America, 700/800 and 1700/1900 MHz are used; 2500 MHz in South America; 800, 900, 1800, 2600 MHz in Europe; 1800 and 2600 MHz in Asia; and 1800 MHz in Australia. As a result, phones from one country may not work in other countries. Users will need a multi-band capable phone for roaming internationally.In LTE, the differences between TDD and FDD are solely a physical layer manifestation and therefore invisible to higher layers. As a result, there are no operational differences between the two modes in the system architecture. Table 1 provides the available frequency bands spectrum.

At the physical layer, the fundamental design goal is to achieve as much commonality between the two modes as possible. The key design differences between the two stem from the need to support various TDD UL/DL allocations and provide coexistence with other TDD systems. In this regard, several additional features are exclusive only to TD-LTE.

| Band | Identifier | Frequencies (MHz) |
|---|---|---|
| 33,34 | TDD 2000 | 1900 -1920<br>2010- 2025 |
| 35,36 | TDD 1900 | 1850 – 1910 |

| | | |
|---|---|---|
| | | 1930 – 1990 |
| 37 | PCS Center Gap (1915) | 1910 – 1930 |
| 38 | IMT Extension Center Gap | 2570 – 2620 |
| 39 | China TDD | 1880 – 1920 |
| 40 | China TDD | 2300 – 2400 |
| NewlyProposed | US TD-LTE | 2496 – 2690 |

Table 1: TD-LTE Technology Frequency bands spectrum

# 6. CONCLUSION

7. LTE networks are now in commercial operation alongside HSPA networks. The evolutionof LTE, also referred to as LTE-Advanced or LTE Release 10, provides bandwidth extensionand spectrum aggregation, extended multi-antenna transmission, relaying functionality andenhanced support for HetNet deployments. 4G should be provided very smooth globalroaming ubiquitously with lower cost. Conclusively, 4G is a set to deliver 100Mbps to aroaming mobile device globally and up to 1Gbps to a stationary mobile.Consequently, LTE is a4G technology positioned to meet the ever-growing requirements of not only today's mobilebroadband networks, but also those of the future. 4G will bring almost perfect real worldwireless or called WWWW: World Wide Wireless Web.

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