

TEC

LTE DEVICES

A Step in the Future

MAYANK MRINAL

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LTE devices or the E-UTRAN (Evolved Universal Terrestrial Access Network) devices are the access part of the Evolved Packet System (EPS).

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Summary

Driving the evolution of wireless broadband technology is customers' increasing expectations for speed, bandwidth, and global access. Customers want more information, such as business and consumer applications, and entertainment available through their mobile devices, but with greater speeds. For wireless carriers to achieve greater speeds and pervasive connectedness, their networks need to start behaving more like landline IP-based networks. Unlike earlier wireless standards, 4G technology is based on TCP/IP, the core protocol of the Internet. TCP/IP enables wireless networks to deliver higher-level services, such as video and multimedia, while supporting the devices and applications of the future.

LTE devices offer a number of significant technological and business advantages. This makes it a superior networking standard. LTE provides untethered services with advanced communication devices that provide a similar immersive experience as found in today's wired networks—whether it's downloading or uploading large files, video, gaming, downloading music, or social networking

LTE is the future of wireless broadband network. This technology will allow users more of what they want, which is untethered mobility. Plus, LTE will support more of the products and services in use today, because of its backward compatibility to 3GPP networks.

For these reasons, it is believed that LTE as the technology will deliver the next generation of mobile services and applications to its customers.

1. Introduction

In contrast to the circuit-switched model of previous cellular systems, Long Term Evolution (LTE) has been designed to support only packet-switched services. It aims to provide seamless Internet Protocol (IP) connectivity between user equipment (UE) and the packet data network (PDN), without any disruption to the end users' applications during mobility.

While the term "LTE" encompasses the evolution of the Universal Mobile Telecommunications System (UMTS) radio access through the Evolved UTRAN (E-UTRAN), it is accompanied by an evolution of the non-radio aspects under the term - "System Architecture Evolution" (SAE), which includes the Evolved Packet Core (EPC) network. Together LTE and SAE comprise the Evolved Packet System (EPS).

The high-level network architecture of LTE is comprised of following three main components:

- The User Equipment (UE).
- The Evolved UMTS Terrestrial Radio Access Network (E-UTRAN).
- The Evolved Packet Core (EPC).

The evolved packet core communicates with packet data networks in the outside world such as the internet, private corporate networks or the IP multimedia subsystem. The interfaces between the different parts of the system are denoted Uu, S1 and S-Gi as shown below:

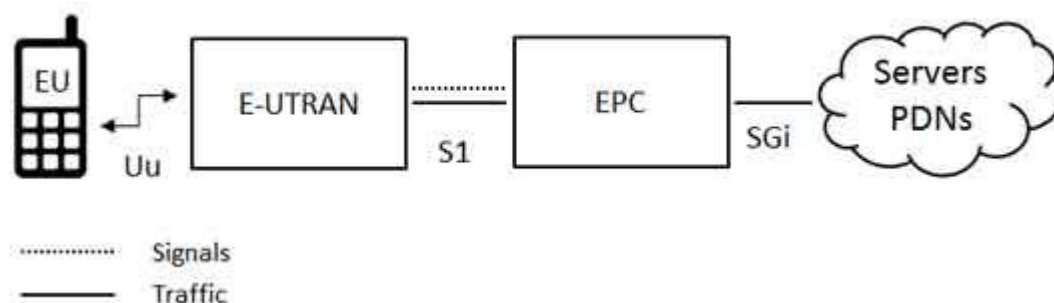


Figure 1: Basic LTE ecology

The key benefits of LTE are as

- + Provides a global ecosystem with inherent mobility

- + Offers easier access and use with greater security and privacy
- + Dramatically improves speed and latency
- + Delivers enhanced real-time video and multimedia for a better overall experience
- + Enables high-performance mobile computing
- + Supports real-time applications due to its low latency
- + Creates a platform upon which to build and deploy the products and services of today and those of tomorrow
- + Reduces cost per bit through improved spectral efficiency

2. Operating bands for LTE Devices

E-UTRA is designed to operate in the operating bands defined in the table below:

E-UTRA Operating Band	Uplink (UL) operating band BS receive UE transmit	Downlink (DL) operating band BS transmit UE receive	Duplex Mode
	$F_{UL_low} - F_{UL_high}$	$F_{DL_low} - F_{DL_high}$	
1	1920 MHz – 1980 MHz	2110 MHz – 2170 MHz	FDD
2	1850 MHz – 1910 MHz	1930 MHz – 1990 MHz	FDD
3	1710 MHz – 1785 MHz	1805 MHz – 1880 MHz	FDD
4	1710 MHz – 1755 MHz	2110 MHz – 2155 MHz	FDD
5	824 MHz – 849 MHz	869 MHz – 894 MHz	FDD
6	830 MHz – 840 MHz	875 MHz – 885 MHz	FDD
7	2500 MHz – 2570 MHz	2620 MHz – 2690 MHz	FDD
8	880 MHz – 915 MHz	925 MHz – 960 MHz	FDD
9	1749.9 MHz – 1784.9 MHz	1844.9 MHz – 1879.9 MHz	FDD
10	1710 MHz – 1770 MHz	2110 MHz – 2170 MHz	FDD
11	1427.9 MHz – 1447.9 MHz	1475.9 MHz – 1495.9 MHz	FDD
12	699 MHz – 716 MHz	729 MHz – 746 MHz	FDD
13	777 MHz – 787 MHz	746 MHz – 756 MHz	FDD
14	788 MHz – 798 MHz	758 MHz – 768 MHz	FDD
15	Reserved	Reserved	FDD

16	Reserved	Reserved	FDD
17	704 MHz-716 MHz	734 MHz-746 MHz	FDD
18	815 MHz- 830 MHz	860 MHz-875 MHz	FDD
19	830 MHz-845 MHz	875 MHz- 890 MHz	FDD
20	832 MHz- 862 MHz	791 MHz-821 MHz	FDD
21	1447.9 MHz- 1462.9 MHz	1495.9 MHz- 1510.9 MHz	FDD
...			
23	2000 MHz-2020 MHz	2180 MHz- 2200 MHz	FDD
24	1626.5 MHz- 1660.5 MHz	1525 MHz-1559 MHz	FDD
25	1850 MHz- 1915 MHz	1930 MHz-1995 MHz	FDD
...			
33	1900 MHz - 1920 MHz	1900 MHz - 1920 MHz	TDD
34	2010 MHz - 2025 MHz	2010 MHz - 2025 MHz	TDD
35	1850 MHz - 1910 MHz	1850 MHz - 1910 MHz	TDD
36	1930 MHz - 1990 MHz	1930 MHz - 1990 MHz	TDD
37	1910 MHz - 1930 MHz	1910 MHz - 1930 MHz	TDD
38	2570 MHz - 2620 MHz	2570 MHz - 2620 MHz	TDD
39	1880 MHz - 1920 MHz	1880 MHz - 1920 MHz	TDD
40	2300 MHz - 2400 MHz	2300 MHz - 2400 MHz	TDD
41	2496 MHz - 2690 MHz	2496 MHz - 2690 MHz	TDD
42	3400 MHz - 3600 MHz	3400 MHz - 3600 MHz	TDD
43	3600 MHz - 3800 MHz	3600 MHz - 3800 MHz	TDD

Table 1: Operating Bands

3. TDD LTE and FDD LTE

3.1 Definition of TDD and FDD

In communication systems, a user needs to exchange data with one or more parties through a shared resource – a common channel. In the case of cellular networks, a limited shared resource (spectrum) needs to be shared with all users so full duplex communication is possible

The two main methods used are:

1. **Time Division Duplexing (TDD)** – The communication is done using one frequency, but the time for transmitting and receiving is different. This method emulates full duplex communication using a half-duplex link.
2. **Frequency Division Duplexing (FDD)** – The communication is done using two frequencies and the transmitting and receiving of data is simultaneous.

The advantages of TDD are typically observed in situations where the uplink and downlink data transmissions are not symmetrical. Also, since the transmitting and receiving is done using one frequency, the channel estimations for beam-forming (and other smart antenna techniques) apply for both the uplink and the downlink. A typical disadvantage of TDD is the need to use guard periods between the downlink and uplink transmissions.

3.2 FDD LTE Devices and TDD LTE Devices

Most LTE networks so far have been built with FDD (Frequency-Division Duplexing) technology, which uses two separate and equal-sized spectrum blocks, one for upstream and one for downstream traffic. The biggest reason FDD is still used is tradition i.e. when cell phones were used mostly for voice, upstream and downstream traffic was equal. The advocates of FDD promote better performance consistency with FDD and it is easier to implement -- particularly when coordinated with other FDD systems.

Advocates of TD-LTE say flexibility is its main advantage. Because TD-LTE uses just one large block, the frequencies within that block can be divided up in any way that makes sense for the way subscribers will use it. That means a TD-LTE service could look more like home broadband, with a relatively thin pipe for sending email messages and URLs and a fatter one for downloading the pages that come with those URLs, as well as video, music, images and other content from the Internet.

The two versions of LTE are very similar. In fact, they differ only in the physical layer and, as a result, the version implemented is transparent to the higher layers. This means that UEs will be able to support both TDD-LTE and FDD-LTE with one chipset with only minor modifications required. LTE TDD is not a separate technology from LTE, but rather just a different mode of operation catering to a single block of spectrum. LTE TDD is part of the same LTE ecosystem as LTE FDD. All the chipsets and devices on the market will be capable of LTE TDD on the baseband side.

3.3 TDD LTE Growth in the market

LTE-TDD is now gaining market traction in all regions as it is commonly considered in the evolution path of any wireless cellular TDD technology (TD-SCDMA, UTRA-TDD and WiMAX™). LTE-TDD is an integral part of the 3GPP standards, sharing significant common properties with LTE-FDD and offering comparable performance characteristics with similar high-spectral efficiency.

Globally, 80 LTE networks were launched in 38 countries between December 2009 and June 2012⁵. LTE-TDD is now entering maturity stage: 33 trial and 23 commercial LTE-TDD networks launched in Brazil, India, Japan, Poland, the Russian Federation and Saudi Arabia by April 2012; and several new rollouts will take place in 2012 also involving the USA and all the BRIC countries (Brazil, Russia, India and China). All major network equipment manufacturers stressed the importance of LTE-TDD and have already launched their LTE-TDD solutions.

LTE-TDD will reach economies of scale comparable with LTE-FDD in the longer term⁶. With its large spectrum availability (up to 100MHz in the lowest available TDD band in Europe⁷), the 2300MHz band will play a major role within the European 'TDD bands' in the short term⁸. Growing support from global industry for the 2300MHz band is increasingly evident; in March DIGITAL EUROPE clearly stated its position in favor of rapid availability of 2300MHz harmonized spectrum across Europe⁹.

From an early stage, the European 2300MHz market will be able to leverage economies of scale from global TDD consolidation, enabled by the ITU-R global allocation, and by the growing availability of spectrum, as well as the arrival of suitable end-user devices.

3.4 LTE mobile device availability summary

LTE 3500 MHz band summary

- UK Broadband launched a TD-LTE network in March 2013 expected go live in May 2013 with mobile devices available in September 2013
- Standards supporting the band were published in March 2011.

LTE 2600 MHz band summary

- Currently supports the largest selection and mix of commercial devices with 94 FDD and 45 TDD in total including USB modems, tablets and handsets
- More than 57 out of 139 devices support multi-frequency

- More than half of 139 devices support multi-mode with a mixture of HSPA, HSPA+ and DC-HSPA+

LTE 2300 MHz band summary

- There is growing support for this band and 2600 MHz in various devices
- There are 43 devices in total including USB modems, tablets and handsets
- Majority of vendors are supporting deployments in Asian and Far Eastern markets

LTE 2100 MHz band

- Currently supports a collection of 8 different devices
- 6 out of the 8 devices support multi-frequency
- All devices support multi-mode with a mixture of HSPA, HSPA+ and DC-HSPA+

LTE 1800 MHz band summary

- Supports a well-established mix of devices with a total of 75 different devices including dongles, tablets and handsets
- All devices support multi frequency
- More than half out of the 75 devices support multi-mode with a mixture of HSPA, HSPA+ and DC-HSPA+

LTE 900 MHz band summary

- Currently supports more than 6 devices with a small mix of modules, routers and USB modems
- All devices support multi frequency
- All devices support multi-mode with a mixture of HSPA, HSPA+ and DC-HSPA+

LTE 800 MHz band summary

- Currently supports a growing mix of devices with a total 72 different devices including dongles, tablets and handsets
- More than 57 out of the 72 devices support multi frequency
- More than half out of the 72 devices support multi-mode with a mixture of HSPA, HSPA+ and DC-HSPA+

4. LTE Devices Growth in India: Band 40 and 41

4.1 Present Scenario

The 2.3 GHz BWA auction began with 11 companies bidding for 2 blocks in each of the 22 circles. The government had earlier allocated one 20 MHz unpaired spectrum block each to MTNL and BSNL.

Tikona Digital Networks won spectrum in 5 circles and is committed to deploy LTE TDD. Commercial launch is expected in early 2013.

Qualcomm and Bharti Airtel won 4 circles each. Qualcomm gained spectrum in the key circles of Delhi, Mumbai, Haryana and Kerala, announced Global Holding Corporation and Tulip Telecom as initial shareholders for its LTE venture for network deployment, and started trials. In May 2012 it was announced that Bharti Airtel will buy 49% of the Qualcomm license, comprising the 26% owned by Global Holding Corporation and Tulip Telecom, plus a further 23% of the company (according to reports, as a first step to taking full ownership in 2014). Bharti Airtel has BWA licenses in four other circles - Kolkata, Karnataka, Punjab and Maharashtra. Bharti Airtel is a member of the Global TD-LTE Initiative.

On April 10, 2012 Bharti Airtel commercially launched India's first LTE service (TDD) in Kolkata. Commercial LTE service started in Bangalore on May 7, 2012 and in Pune on October 18, 2012.

Aircel won BWA spectrum in eight circles and plans to commercially launch LTE TDD service in 2013, initially in Chennai and Tamilnadu.

Infotel Broadband was the only pan-India winner, and later bought by Reliance Industries Ltd (RIL).

Reliance Industries Ltd (RIL) is deploying an LTE TDD network for commercial launch in early 2013.

BSNL had acquired BWA spectrum licenses in the 2.6 GHz band in 22 circles for \$1.6 billion. BSNL and MTNL are studying introducing LTE TDD possibly in addition to current WiMAX deployments.

Regulator TRAI is consulting on 700 MHz spectrum and IMT-Advanced (incl. LTE-Advanced) systems.

4.2 Challenges in deployment in 2300 MHz band

There are several reasons for the delay in LTE services in this frequency band.

- LTE ecosystem is still developing. The number of towers required to launch LTE services (due to frequency band of 2300 MHz) will be more thereby, increasing cost to the operator.
- Widespread availability of LTE-enabled devices working on 2300 MHz band will be a challenge and depends on the price point at which they will be launched.
- Hence the economies of scale on both handset and network side is an important factor for faster deployment of LTE services in India

5. A Growing Market for LTE-Connected Products and Applications

5.1 LTE Momentum

The Global Mobile Suppliers Association (GSA) reports that, as of Jan 2013, 196 operators in 85 countries are investing in 3GPP LTE systems. LTE is the fastest developing mobile system technology in the history of the industry. Even among network operators that have migrated to or are expanding HSPA+ deployments, many now view LTE as the eventual unifying technology for their mobile broadband networks. Indeed, in some regions, LTE is expected to have an even broader reach than current cellular and fixed-line networks—opening entirely new markets.

There are good reasons for this rapid growth. The first factor is the explosive growth in worldwide mobile data traffic as more smart-phones, tablets, computing devices, and connected machine-to-machine (M2M) applications are added to mobile networks. Growing adoption of cloud computing and new applications for connected products is also increasing mobile broadband adoption. These trends are driving demand for mobile broadband devices that deliver higher speeds, more capacity, lower latency, and a more seamless and consistent user experience. LTE addresses all of these concerns. LTE provides:

- **Enhanced user experience:** LTE-enabled devices can deliver substantially increased capacity and data rates, with theoretical peak download speeds of 100 Mbps and upload speeds of 50 Mbps. (Future generations of LTE, such as LTE-Advanced, will support even faster speeds.) LTE also provides as much as 10 times lower latency than 3G technologies, providing an immediate improvement in the user experience.
- **Expanded flexibility:** LTE's inherent flexibility benefits connected device manufacturers, network operators, and users alike. LTE services can be deployed in existing 2G and 3G bands, in new spectrum such as 2.6 GHz, and in lower spectrum in many regions. As a result, operators can reuse 2G spectrum

and shift heavy data users off of the existing 3G network—providing a better experience for both LTE users and existing 3G users, who no longer have to share resources with the heaviest mobile broadband users.

LTE is also scalable to operate in multiple allocations (1.4 MHz through 20 MHz), uplink and downlink, paired and unpaired, etc. This flexibility means that those developing LTE devices and applications can enjoy higher-speed networks and more capacity, as well as greater available wireless spectrum.

- **Significantly lower costs:** LTE is an all-IP network technology with simplified IP-based core and transport networks, making it less expensive for operators to deploy and maintain. The technology's self-configuration and self-optimization capabilities also reduce rollout costs and timelines. These attributes allow for significantly lower cost per Gigabyte of data delivered—and ultimately lower the total cost of ownership for connected devices and applications.

LTE DEVICE MARKET FORECAST

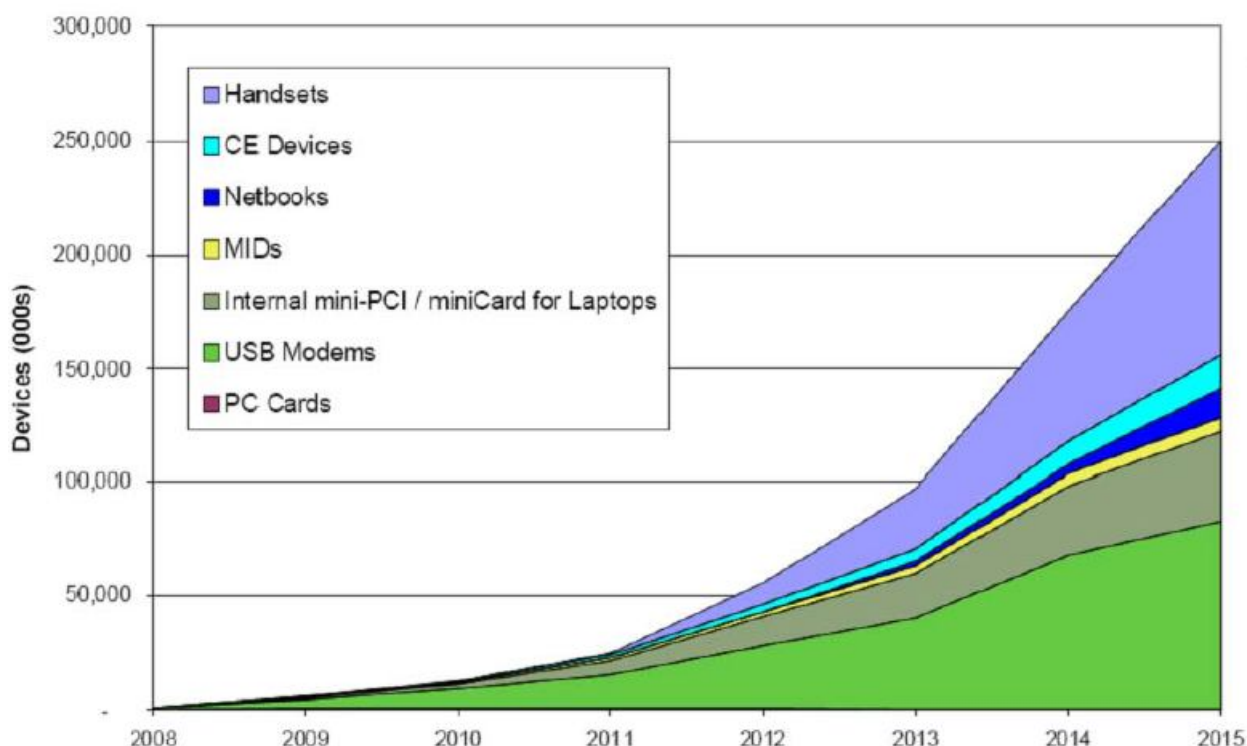


Figure2: LTE Devices market forecast

Conclusion

LTE coverage will be extensive in many regions, and ultimately will follow the path of every other major cellular network launch in history. As carriers around the world make commitments for new networks and significant investments in LTE systems, the pace of LTE deployment has accelerated. For OEMs, system integrators, and application developers, there should be no more debate about the viability of these technologies. To deliver successful connected product and applications over the next several years, companies need to be considering LTE connections right now, and preparing to bring them to market.

Some questions remain about how different carriers and markets will implement LTE networks, and the path that those network evolutions will take. However, by carefully considering the unique requirements of LTE technologies, and working with suppliers and vendors with the expertise to meet them, OEMs can position themselves for success.

Glossary

3GPP	3rd Generation Partnership Project
BW	Bandwidth
CAPEX	Capital Expenditure
CDMA	Code Division Multiple Access
DL	Downlink
ERC	European Radio Committee
ETSI	European Telecommunications Standards Institute
EU	European Union
E-UTRA	Evolved Universal Terrestrial Radio Access
FDD	Frequency Division Duplex
Gbps	Gigabit per second
HSPA	High Speed Packet Access (HSDPA with HSUPA)
GSM	Global System for Mobile Communications
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
ITU	International Telecommunication Union
ITU-R	International Telecommunication Union – Radio
Kbps	Kilobits per second
LTE-A	LTE Advanced
Mbps	Megabit per second

MIMO	Multiple Input / Multiple Output
QoS	Quality of Service
LTE	Long Term Evolution
LTE-A	LTE Advanced
RAN	Radio Access Network
RF	Radio Frequency
RX	Receiver
UE	user equipment
UMTS	Universal Mobile Telecommunications System
UE	User Equipment
UHF	Ultra High Frequency
UL	Uplink
UMTS	Universal Mobile Telecommunications System
UTRAN	UMTS Terrestrial Radio Access Network
VHF	Very High Frequency
VoIP	Voice over IP
WiMAX	Worldwide interoperability for Microwave Access
WP5D	Working Party 5D
WRC	World Radio Conference

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