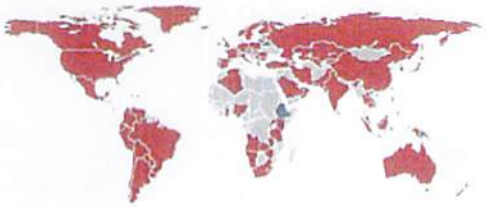
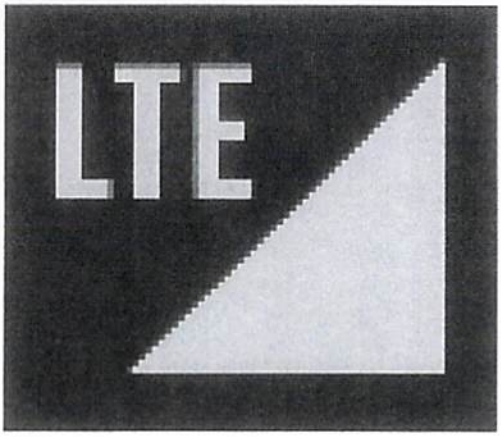
LTE (telecommunication)

"Long-term evolution" redirects here. For the biological concept, see Evolution and E. coli long-term evolution experiment.

Long-Term Evolution (**LTE**) is a standard for high-speed wireless communication 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.[1][2] 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.



Adoption of LTE technology as of December 7, 2014
Countries and regions with commercial LTE service
Countries and regions with commercial LTE network deployment on-going or planned
Countries and regions with LTE trial systems (pre-commitment)



LTE signal indicator in Android

LTE is the upgrade path for carriers with both GSM/UMTS networks and CDMA2000 networks. The different LTE frequencies and bands used in different countries will mean that only multi-band phones will be able to use LTE in all countries where it is supported.

LTE is commonly marketed as **4G LTE**, but it does not satisfy the technical criteria of a 4G wireless service, as specified in the 3GPP Release 8 and 9 document series, for LTE Advanced. The requirements were originally set forth by the ITU-R organization in the IMT Advanced specification. However, due to marketing pressures and the significant advancements that WiMAX, Evolved High Speed Packet Access and LTE bring to the original 3G technologies, ITU later decided that LTE together with the aforementioned technologies can be called 4G technologies.[3] The LTE Advanced standard formally satisfies the ITU-R requirements to be considered IMT-Advanced.[4] To differentiate LTE Advanced and WiMAX-Advanced from current 4G technologies, ITU has defined them as "True 4G".[5][6]

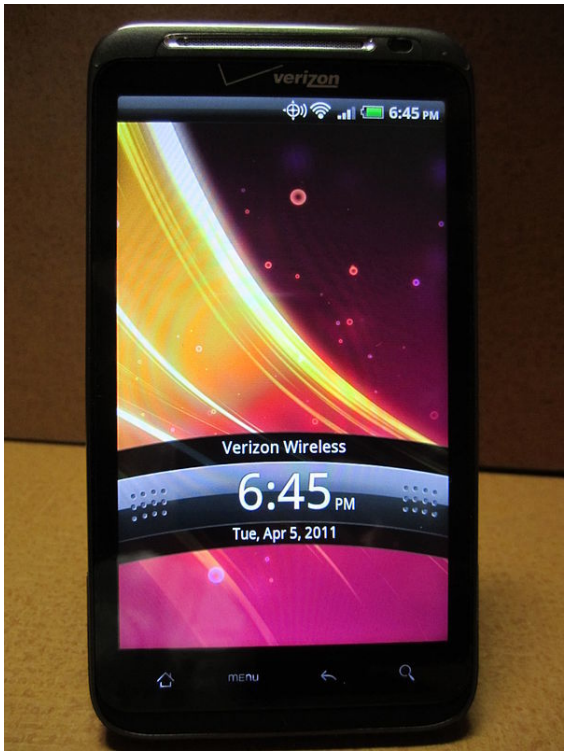
1 Overview

See also: LTE timeline and List of LTE networks

LTE stands for Long Term Evolution[7] and is a registered trademark owned by ETSI (European Telecommunications Standards Institute) for the wireless data communications technology and a development of the GSM/UMTS standards. However, other nations and companies do play an active role in the LTE project. 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 radio spectrum.

LTE was first proposed by NTT DoCoMo of Japan in 2004, and studies on the new standard officially commenced in 2005.[8] 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.[9][10] 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

Telia-branded Samsung LTE modem



HTC ThunderBolt, the second commercially available LTE smartphone

with a USB modem. The LTE services were launched by major North American carriers as well, with the Samsung SCH-r900 being the world's first LTE Mobile phone starting on September 21, 2010[11][12] and Samsung Galaxy Indulge being the world's first LTE smartphone starting on February 10, 2011[13][14] both offered by MetroPCS and HTC ThunderBolt offered by Verizon starting on March 17 being the second LTE smartphone to be sold commercially.[15][16] 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.[17] 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.[18] Services are expected to commence in 2013.[19]

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) 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.[20] The simpler architecture results in lower operating costs (for example, each E-UTRA cell will support up to four times the data and voice capacity supported by HSPA[21]).

2 History

2.1 3GPP standard development timeline

- In 2004, NTT DoCoMo of Japan proposes LTE as the international standard.[22]
- In September 2006, Siemens Networks (today Nokia Networks) showed in collaboration with Nomor Research the first live emulation of an LTE network to the media and investors. As live applications two users streaming an HDTV video in the downlink and playing an interactive game in the uplink have been demonstrated.[23]

- In February 2007, Ericsson demonstrated for the first time in the world LTE with bit rates up to 144 Mbit/s[24]
- In September 2007, NTT docomo demonstrated LTE data rates of 200 Mbit/s with power level below 100 mW during the test.[25]
- In November 2007, Infineon presented the world's first RF transceiver named SMARTi LTE supporting LTE functionality in a single-chip RF silicon processed in CMOS [26][27]
- In early 2008, LTE test equipment began shipping from several vendors and, at the Mobile World Congress 2008 in Barcelona, Ericsson demonstrated the world's first end-to-end mobile call enabled by LTE on a small handheld device.[28] Motorola demonstrated an LTE RAN standard compliant eNodeB and LTE chipset at the same event.
- At the February 2008 Mobile World Congress:
  - Motorola demonstrated how LTE can accelerate the delivery of personal media experience with HD video demo streaming, HD video blogging, Online gaming and VoIP over LTE running a RAN standard compliant LTE network & LTE chipset.[29]
  - Ericsson EMP (now ST-Ericsson) demonstrated the world's first end-to-end LTE call on handheld[28] Ericsson demonstrated LTE FDD and TDD mode on the same base station platform.
  - Freescale Semiconductor demonstrated streaming HD video with peak data rates of 96 Mbit/s downlink and 86 Mbit/s uplink.[30]
  - NXP Semiconductors (now a part of ST-Ericsson) demonstrated a multi-mode LTE modem as the basis for a software-defined radio system for use in cellphones.[31]
  - picoChip and Mimoon demonstrated a base station reference design. This runs on a common hardware platform (multi-mode / software defined radio) with their WiMAX architecture.[32]
- In April 2008, Motorola demonstrated the first EV-DO to LTE hand-off – handing over a streaming video from LTE to a commercial EV-DO network and back to LTE.[33]
- In April 2008, LG Electronics and Nortel demonstrated LTE data rates of 50 Mbit/s while travelling at 110 km/h.[34]
- In November 2008, Motorola demonstrated industry first over-the-air LTE session in 700 MHz spectrum.[35]
- Researchers at Nokia Siemens Networks and Heinrich Hertz Institut have demonstrated LTE with 100 Mbit/s Uplink transfer speeds.[36]
- At the February 2009 Mobile World Congress:
  - Infineon demonstrated a single-chip 65 nm CMOS RF transceiver providing 2G/3G/LTE functionality[37]
  - Launch of ng Connect program, a multi-industry consortium founded by Alcatel-Lucent to identify and develop wireless broadband applications.[38]
  - Motorola provided LTE drive tour on the streets of Barcelona to demonstrate LTE system performance in a real-life metropolitan RF environment [39]
- In July 2009, Nujira demonstrated efficiencies of more than 60% for an 880 MHz LTE Power Amplifier[40]
- In August 2009, Nortel and LG Electronics demonstrated the first successful handoff between CDMA and LTE networks in a standards-compliant manner [41]
- In August 2009, Alcatel-Lucent receives FCC certification for LTE base stations for the 700 MHz spectrum band.[42]
- In September 2009, Nokia Siemens Networks demonstrated world's first LTE call on standards-compliant commercial software.[43]
- In October 2009, Ericsson and Samsung demonstrated interoperability between the first ever commercial LTE device and the live network in Stockholm, Sweden.[44]
- In October 2009, Alcatel-Lucent's Bell Labs, Deutsche Telekom Laboratories, the Fraunhofer Heinrich-Hertz Institut and antenna supplier Kathrein conducted live field tests of a technology called Coordinated Multipoint Transmission (CoMP) aimed at increasing the data transmission speeds of Long Term Evolution (LTE) and 3G networks.[45]
- In November 2009, Alcatel-Lucent completed first live LTE call using 800 MHz spectrum band set aside as part of the European Digital Dividend (EDD).[46]
- In November 2009, Nokia Siemens Networks and LG completed first end-to-end interoperability testing of LTE.[47]
- On December 14, 2009, the first commercial LTE deployment was in the Scandinavian capitals Stockholm and Oslo by the Swedish-Finnish

network operator TeliaSonera and its Norwegian brandname NetCom (Norway). TeliaSonera incorrectly branded the network "4G". The modem devices on offer were manufactured by Samsung (dongle GT-B3710), and the network infrastructure with SingleRAN technology created by Huawei (in Oslo)[48] and Ericsson (in Stockholm). TeliaSonera plans to roll out nationwide LTE across Sweden, Norway and Finland.[49] TeliaSonera used spectral bandwidth of 10 MHz (out of the maximum 20 MHz), and Single-Input and Single-Output transmission. The deployment should have provided a physical layer net bitrates of up to 50 Mbit/s downlink and 25 Mbit/s in the uplink. Introductory tests showed a TCP goodput of 42.8 Mbit/s downlink and 5.3 Mbit/s uplink in Stockholm.[50]

- In December 2009, ST-Ericsson and Ericsson first to achieve LTE and HSPA mobility with a multimode device.[51]
- In January 2010, Alcatel-Lucent and LG complete a live handoff of an end-to-end data call between Long Term Evolution (LTE) and CDMA networks.[52]
- In February 2010, Nokia Siemens Networks and Movistar test the LTE in Mobile World Congress 2010 in Barcelona, Spain, with both indoor and outdoor demonstrations.[53]
- In May 2010, Mobile TeleSystems (MTS) and Huawei showed an indoor LTE network at "Sviaz-Expocomm 2010" in Moscow, Russia.[54] MTS expects to start a trial LTE service in Moscow by the beginning of 2011. Earlier, MTS has received a license to build an LTE network in Uzbekistan, and intends to commence a test LTE network in Ukraine in partnership with Alcatel-Lucent.
- At the Shanghai Expo 2010 in May 2010, Motorola demonstrated a live LTE in conjunction with China Mobile. This included video streams and a drive test system using TD-LTE.[55]
- As of 12/10/2010, DirecTV has teamed up with Verizon Wireless for a test of high-speed Long Term Evolution (LTE) wireless technology in a few homes in Pennsylvania, designed to deliver an integrated Internet and TV bundle. Verizon Wireless said it launched LTE wireless services (for data, no voice) in 38 markets where more than 110 million Americans live on Sunday, Dec. 5.[56]
- On May 6, 2011, Sri Lanka Telecom Mobitel successfully demonstrated 4G LTE for the first time in South Asia, achieving a data rate of 96 Mbit/s in Sri Lanka.[57]

2.2 Carrier adoption timeline

Main article: List of LTE networks

Most carriers supporting GSM or HSUPA networks can be expected to upgrade their networks to LTE at some stage. A complete list of commercial contracts can be found at:[58]

- August 2009: Telefónica selected six countries to field-test LTE in the succeeding months: Spain, the United Kingdom, Germany and the Czech Republic in Europe, and Brazil and Argentina in Latin America.[59]
- On November 24, 2009: Telecom Italia announced the first outdoor pre-commercial experimentation in the world, deployed in Torino and totally integrated into the 2G/3G network currently in service.[60]
- On December 14, 2009, the world's first publicly available LTE service was opened by TeliaSonera in the two Scandinavian capitals Stockholm and Oslo.
- On May 28, 2010, Russian operator Scartel announced the launch of an LTE network in Kazan by the end of the 2010.[61]
- On October 6, 2010, Canadian provider Rogers Communications Inc announced that Ottawa, Canada's national capital, will be the site of LTE trials. Rogers said it will expand on this testing and move to a comprehensive technical trial of LTE on both low- and high-band frequencies across the Ottawa area.[62]
- On May 6, 2011, Sri Lanka Telecom Mobitel successfully demonstrated 4G LTE for the first time in South Asia, achieving a data rate of 96 Mbit/s in Sri Lanka.[63]
- On May 7, 2011, Sri Lankan Mobile Operator Dialog Axiata PLC switched on the first pilot 4G LTE Network in South Asia with vendor partner Huawei and demonstrated a download data speed up to 127 Mbit/s.[64]
- On February 9, 2012, Telus Mobility launched their LTE service initial in metropolitan areas include Vancouver, Calgary, Edmonton, Toronto and the Greater Toronto Area, Kitchener, Waterloo, Hamilton, Guelph, Belleville, Ottawa, Montreal, Québec City, Halifax and Yellowknife.[65]
- Telus Mobility has announced that it will adopt LTE as its 4G wireless standard.[66]
- Cox Communications has its first tower for wireless LTE network build-out.[67] Wireless services should launch late 2009.

Below is a list of countries by 4G LTE penetration as measured by OpenSignal.com in 2015. [68][69]

3 LTE-TDD

Long-Term Evolution Time-Division Duplex (**LTE-TDD**), also referred to as TDD LTE, is a 4G telecommunications technology and standard co-developed by an international coalition of companies, including China Mobile, Datang Telecom, Huawei, ZTE, Nokia Solutions and Networks, Qualcomm, Samsung, and ST-Ericsson. It is one of the two mobile data transmission technologies of the Long-Term Evolution (LTE) technology standard, the other being Frequency-Division Long-Term Evolution (LTE-FDD). While some companies refer to LTE TDD as "TD-LTE", there is no reference to that acronym anywhere in the 3GPP specifications.[70][71][72]

There are two major differences between LTE-TDD and LTE-FDD: how data is uploaded and downloaded, and what frequency spectra the networks are deployed in. While LTE-FDD uses paired frequencies to upload and download data,[73] LTE-TDD uses a single frequency, alternating between uploading and downloading data through time.[74][75] The ratio between uploads and downloads on a LTE-TDD network can be changed dynamically, depending on whether more data needs to be sent or received.[76] LTE-TDD and LTE-FDD also operate on different frequency bands,[77] with LTE-TDD working better at higher frequencies, and LTE-FDD working better at lower frequencies.[78] Frequencies used for LTE-TDD range from 1850 MHz to 3800 MHz, with several different bands being used.[79] The LTE-TDD spectrum is generally cheaper to access, and has less traffic.[77] Further, the bands for LTE-TDD overlap with those used for WiMAX, which can easily be upgraded to support LTE-TDD.[77]

Despite the differences in how the two types of LTE handle data transmission, LTE-TDD and LTE-FDD share 90 percent of their core technology, making it possible for the same chipsets and networks to use both versions of LTE.[77][80] A number of companies produce dual-mode chips or mobile devices, including Samsung and Qualcomm,[81][82] while operators China Mobile Hong Kong Company Limited and Hi3G Access have developed dual-mode networks in China and Sweden, respectively.[83]

3.1 History

The creation of LTE-TDD involved a coalition of international companies that worked to develop and test the technology.[84] China Mobile was an early proponent of LTE-TDD,[77][85] along with other companies like Datang Telecom[84] and Huawei, which worked to deploy LTE-TDD networks, and later developed technology allowing LTE-TDD equipment to operate in white spaces—frequency spectra between broadcast TV stations.[71][86] Intel also participated in the development, setting up a LTE-TDD interoperability lab with Huawei in China,[87] as well as ST-Ericsson,[77] Nokia,[77] and Nokia Siemens (now Nokia Solutions and Networks),[71] which developed LTE-TDD base stations that increased capacity by 80 percent and coverage by 40 percent.[88] Qualcomm also participated, developing the world's first multi-mode chip, combining both LTE-TDD and LTE-FDD, along with HSPA and EV-DO.[82] Accelleran, a Belgian company, has also worked to build small cells for LTE-TDD networks.[89]

Trials of LTE-TDD technology began as early as 2010, with Reliance Industries and Ericsson India conducting field tests of LTE-TDD in India, achieving 80 megabit-per second download speeds and 20 megabit-per-second upload speeds.[90] By 2011, China Mobile began trials of the technology in six cities.[71]

Although initially seen as a technology utilized by only a few countries, including China and India,[91] by 2011 international interest in LTE-TDD had expanded, especially in Asia, in part due to LTE-TDD 's lower cost of deployment compared to LTE-FDD.[71] By the middle of that year, 26 networks around the world were conducting trials of the technology.[72] The Global LTE-TDD Initiative (GTI) was also started in 2011, with founding partners China Mobile, Bharti Airtel, SoftBank Mobile, Vodafone, Clearwire, Aero2 and E-Plus.[92] In September 2011, Huawei announced it would partner with Polish mobile provider Aero2 to develop a combined LTE TDD and FDD network in Poland,[93] and by April 2012, ZTE Corporation had worked to deploy trial or commercial LTE-TDD networks for 33 operators in 19 countries.[83] In late 2012, Qualcomm worked extensively to deploy a commercial LTE-TDD network in India, and partnered with Bharti Airtel and Huawei to develop the first multi-mode LTE-TDD smartphone for India.[82]

In Japan, SoftBank Mobile launched LTE-TDD services in February 2012 under the name **Advanced eXtended Global Platform** (AXGP), and marketed as SoftBank 4G (ja). The AXGP band was previously used for Willcom's PHS service, and after PHS was discontinued in 2010 the PHS band was re-purposed for AXGP service.[94][95]

In the U.S., Clearwire planned to implement LTE-TDD, with chip-maker Qualcomm agreeing to support Clearwire's frequencies on its multi-mode LTE chipsets.[96] With Sprint's acquisition of Clearwire in 2013,[73][97] the carrier began using these frequencies for LTE service on networks built by Samsung, Alcatel-Lucent, and Nokia.[98][99]

As of March 2013, 156 commercial 4G LTE networks existed, including 142 LTE-FDD networks and 14 LTE-TDD networks.[84] As of November 2013, the South Korean government planned to allow a fourth wireless car-

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