Wikipedia 4G Article

**Introduction**

In [telecommunications](http://en.wikipedia.org/wiki/Telecommunication), **4G** is the fourth generation of [cellular](http://en.wikipedia.org/wiki/Cellular) [wireless](http://en.wikipedia.org/wiki/Wireless) standards. It is a successor to the [3G](http://en.wikipedia.org/wiki/3G) and [2G](http://en.wikipedia.org/wiki/2G) families of standards. In 2009, the [ITU-R](http://en.wikipedia.org/wiki/ITU-R) organization specified the [IMT-Advanced](http://en.wikipedia.org/wiki/IMT-Advanced) (International Mobile Telecommunications Advanced) requirements for 4G standards, setting peak speed requirements for 4G service at 100 [Mbit/s](http://en.wikipedia.org/wiki/Megabits_per_second) for high mobility communication (such as from trains and cars) and 1 [Gbit/s](http://en.wikipedia.org/wiki/Gigabits_per_second) for low mobility communication (such as pedestrians and stationary users).[[1]](http://en.wikipedia.org/wiki/4g#cite_note-0)

A 4G system is expected to provide a comprehensive and secure all-[IP](http://en.wikipedia.org/wiki/Internet_protocol) based [mobile broadband](http://en.wikipedia.org/wiki/Mobile_broadband) solution to laptop computer [wireless modems](http://en.wikipedia.org/wiki/Wireless_modem), [smartphones](http://en.wikipedia.org/wiki/Smartphones), and other mobile devices. [Facilities](http://en.wikipedia.org/wiki/Facility_(telecommunications)) such as [ultra-broadband](http://en.wikipedia.org/wiki/Ultra_Mobile_Broadband) Internet access, [IP telephony](http://en.wikipedia.org/wiki/IP_telephony), gaming services, and streamed multimedia may be provided to users.

4G technologies such as [mobile WiMAX](http://en.wikipedia.org/wiki/Mobile_WiMAX) and first-release [Long term evolution](http://en.wikipedia.org/wiki/Long_term_evolution) (LTE) have been on the market since 2006[[2]](http://en.wikipedia.org/wiki/4g#cite_note-kt-1) and 2009[[3]](http://en.wikipedia.org/wiki/4g#cite_note-Unstrung-2)[[4]](http://en.wikipedia.org/wiki/4g#cite_note-Wallstreet-3)[[5]](http://en.wikipedia.org/wiki/4g#cite_note-dailymobile-4) respectively. The [ITU](http://en.wikipedia.org/wiki/ITU) announced in December 2010 that WiMax, LTE, and HSPA+ are 4G technologies.[[6]](http://en.wikipedia.org/wiki/4g#cite_note-5)

[IMT](http://en.wikipedia.org/wiki/International_Mobile_Telecommunications-2000)-Advanced compliant versions of the above two standards are under development and called “[LTE Advanced](http://en.wikipedia.org/wiki/LTE_Advanced)” and “[WirelessMAN-Advanced](http://en.wikipedia.org/wiki/WirelessMAN-Advanced" \o "WirelessMAN-Advanced)” respectively. ITU has decided that “LTE Advanced” and “WirelessMAN-Advanced” should be accorded the official designation of IMT-Advanced. On December 6, 2010, ITU announced that current versions of LTE, WiMax and other evolved 3G technologies that do not fulfill "IMT-Advanced" requirements could be considered "4G", provided they represent forerunners to IMT-Advanced and "a substantial level of improvement in performance and capabilities with respect to the initial third generation systems now deployed."[[7]](http://en.wikipedia.org/wiki/4g#cite_note-ITUSeminar-6)

As seen below, in all suggestions for 4G, the [CDMA](http://en.wikipedia.org/wiki/CDMA) [spread spectrum](http://en.wikipedia.org/wiki/Spread_spectrum) radio technology used in 3G systems and [IS-95](http://en.wikipedia.org/wiki/IS-95) is abandoned and replaced by [OFDMA](http://en.wikipedia.org/wiki/OFDMA) and other [frequency-domain equalization](http://en.wikipedia.org/wiki/Single-carrier_FDMA) schemes. This is combined with [MIMO](http://en.wikipedia.org/wiki/MIMO) (Multiple In Multiple Out), e.g., multiple antennas, [dynamic channel allocation](http://en.wikipedia.org/wiki/Dynamic_channel_allocation) and [channel-dependent scheduling](http://en.wikipedia.org/wiki/Channel-dependent_scheduling).

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**Background**

The nomenclature of the generations generally refers to a change in the fundamental nature of the service, non-backwards compatible transmission technology, higher [spectral bandwidth](http://en.wikipedia.org/w/index.php?title=Spectral_bandwidth&action=edit&redlink=1) and new frequency bands. New generations have appeared about every ten years since the first move from 1981 analog (1G) to digital (2G) transmission in 1992. This was followed, in 2001, by 3G multi-media support, [spread spectrum](http://en.wikipedia.org/wiki/Spread_spectrum) transmission and at least 200 kbit/s, in 2011 expected to be followed by 4G, which refers to all-[IP](http://en.wikipedia.org/wiki/Internet_Protocol) [packet-switched](http://en.wikipedia.org/wiki/Packet_switching) networks, mobile ultra-broadband (gigabit speed) access and [multi-carrier](http://en.wikipedia.org/wiki/Multi-carrier) transmission.[[*citation needed*](http://en.wikipedia.org/wiki/Wikipedia:Citation_needed)]

The fastest 3G based standard in the [WCDMA](http://en.wikipedia.org/wiki/WCDMA) family is the [HSPA+](http://en.wikipedia.org/wiki/HSPA%2B) standard, which was commercially available in 2009 and offers 28 Mbit/s downstreams without [MIMO](http://en.wikipedia.org/wiki/MIMO), i.e. only with one antenna (it would offer 56 Mbit/s with 2x2 MIMO), and 22 Mbit/s upstreams. The fastest 3G based standard in the [CDMA2000](http://en.wikipedia.org/wiki/CDMA2000) family is the [EV-DO Rev. B](http://en.wikipedia.org/wiki/EV-DO_Rev._B), which was available in 2010 and offers 15.67 Mbit/s downstreams.[[*citation needed*](http://en.wikipedia.org/wiki/Wikipedia:Citation_needed)]

**Requirements**

In mid 1990s, the [ITU-R](http://en.wikipedia.org/wiki/ITU-R) organization specified the [IMT-2000](http://en.wikipedia.org/wiki/IMT-2000) specifications for what standards that should be considered [3G](http://en.wikipedia.org/wiki/3G) systems. However, the cell phone market only brands some of the IMT-2000 standards as 3G (e.g. WCDMA and CDMA2000), but not all ([3GPP EDGE](http://en.wikipedia.org/wiki/3GPP_EDGE), [DECT](http://en.wikipedia.org/wiki/DECT) and mobile-[WiMAX](http://en.wikipedia.org/wiki/WiMAX) all fulfil the IMT-2000 requirements and are formally accepted as 3G standards, but are typically not branded as 3G). In 2008, ITU-R specified the [IMT-Advanced](http://en.wikipedia.org/wiki/IMT-Advanced) (International Mobile Telecommunications Advanced) requirements for 4G systems.

This article uses 4G to refer to IMT-Advanced (*International Mobile Telecommunications Advanced*), as defined by [ITU-R](http://en.wikipedia.org/wiki/ITU-R). An IMT-Advanced [cellular system](http://en.wikipedia.org/wiki/Mobile_phone) must fulfill the following requirements:[[8]](http://en.wikipedia.org/wiki/4g#cite_note-Vilches.2C_J._2010-7)

* Based on an all-IP packet switched network.
* Peak data rates of up to approximately 100 Mbit/s for high mobility such as mobile access and up to approximately 1 Gbit/s for low mobility such as nomadic/local wireless access, according to the ITU requirements.
* Dynamically share and use the network resources to support more simultaneous users per cell.
* Scalable channel bandwidth 5–20 MHz, optionally up to 40 MHz.[[9]](http://en.wikipedia.org/wiki/4g" \l "cite_note-IMT-Advanced-requirements-8)[[9]](http://en.wikipedia.org/wiki/4g#cite_note-IMT-Advanced-requirements-8)[[10]](http://en.wikipedia.org/wiki/4g#cite_note-9)
* Peak [link spectral efficiency](http://en.wikipedia.org/wiki/Link_spectral_efficiency) of 15 bit/s/Hz in the downlink, and 6.75 bit/s/Hz in the uplink (meaning that 1 Gbit/s in the downlink should be possible over less than 67 MHz bandwidth).
* [System spectral efficiency](http://en.wikipedia.org/wiki/System_spectral_efficiency) of up to 3 bit/s/Hz/cell in the downlink and 2.25 bit/s/Hz/cell for indoor usage.[[9]](http://en.wikipedia.org/wiki/4g#cite_note-IMT-Advanced-requirements-8)
* Smooth handovers across heterogeneous networks.
* Ability to offer high quality of service for next generation multimedia support.

In September 2009, the technology proposals were submitted to the International Telecommunication Union (ITU) as 4G candidates.[[11]](http://en.wikipedia.org/wiki/4g#cite_note-10) Basically all proposals are based on two technologies:

* [LTE Advanced](http://en.wikipedia.org/wiki/LTE_Advanced) standardized by the [3GPP](http://en.wikipedia.org/wiki/3GPP)
* [802.16m](http://en.wikipedia.org/wiki/802.16m) standardized by the [IEEE](http://en.wikipedia.org/wiki/IEEE) (i.e. WiMAX)

Present implementations of WiMAX and LTE are largely considered a stopgap solution that will offer a considerable boost while WiMAX 2 (based on the 802.16m spec) and LTE Advanced are finalized. Both technologies aim to reach the objectives traced by the ITU, but are still far from being implemented.[[8]](http://en.wikipedia.org/wiki/4g#cite_note-Vilches.2C_J._2010-7)

The first set of 3GPP requirements on LTE Advanced was approved in June 2008.[[12]](http://en.wikipedia.org/wiki/4g#cite_note-11) LTE Advanced will be standardized in 2010 as part of the Release 10 of the 3GPP specification. LTE Advanced will be fully built on the existing LTE specification Release 10 and not be defined as a new specification series. A summary of the technologies that have been studied as the basis for LTE Advanced is included in a technical report.[[13]](http://en.wikipedia.org/wiki/4g#cite_note-12)

Current LTE and WiMAX implementations are considered pre-4G, as they don't fully comply with the planned requirements of 1 Gbit/s for stationary reception and 100 Mbit/s for mobile.

Confusion has been caused by some mobile carriers who have launched products advertised as 4G but which are actually current technologies, commonly referred to as '3.9G', which do not follow the ITU-R defined principles for 4G standards. A common argument for branding 3.9G systems as new-generation is that they use different frequency bands to 3G technologies; that they are based on a new radio-interface paradigm; and that the standards are not backwards compatible with 3G, whilst some of the standards are expected to be forwards compatible with "real" 4G technologies.

While the ITU has adopted recommendations for technologies that would be used for future global communications, they do not actually perform the standardization or development work themselves, instead relying on the work of other standards bodies such as IEEE, The WiMAX Forum and 3GPP. Recently, ITU-R Working Party 5D approved two industry-developed technologies (LTE Advanced and WirelessMAN-Advanced)[[14]](http://en.wikipedia.org/wiki/4g#cite_note-ITU_paves_way_for_next-generation_4G_mobile_technologies-13) for inclusion in the ITU’s International Mobile Telecommunications Advanced (IMT-Advanced program), which is focused on global communication systems that would be available several years from now.

**4G and near-4G systems**

The wireless telecommunications industry as a whole has early assumed the term 4G as a shorthand way to describe those advanced cellular technologies that, among other things, are based on or employ wide channel OFDMA and SC-FDE technologies, [MIMO](http://en.wikipedia.org/wiki/MIMO) transmission and an all-IP based architecture.[[*citation needed*](http://en.wikipedia.org/wiki/Wikipedia:Citation_needed)] Mobile-WiMAX, first release LTE, IEEE 802.20 as well as Flash-OFDM meets these early assumptions, and have been considered as 4G candidate systems, but do not yet meet the more recent ITU-R IMT-Advanced requirements.

**4G candidate systems**

**LTE Advanced**

*See also:* [*3GPP Long Term Evolution (LTE)*](http://en.wikipedia.org/wiki/4G#3GPP_Long_Term_Evolution_.28LTE.29) *below*

[LTE Advanced](http://en.wikipedia.org/wiki/LTE_Advanced) (Long-term-evolution Advanced) is a candidate for IMT-Advanced standard, formally submitted by the [3GPP](http://en.wikipedia.org/wiki/3GPP) organization to ITU-T in the fall 2009, and expected to be released in 2012. The target of 3GPP LTE Advanced is to reach and surpass the ITU requirements.[[15]](http://en.wikipedia.org/wiki/4g#cite_note-14) LTE Advanced is essentially an enhancement to LTE. It is not a new technology but rather an improvement on the existing LTE network. This upgrade path makes it more cost effective for vendors to offer LTE and then upgrade to LTE Advanced which is similar to the upgrade from WCDMA to HSPA. LTE and LTE Advanced will also make use of additional spectrum and multiplexing to allow it to achieve higher data speeds. Coordinated Multi-point Transmission will also allow more system capacity to help handle the enhanced data speeds. Release 10 of LTE is expected to achieve the LTE Advanced speeds. Release 8 currently supports up to 300 Mbit/s download speeds which is still short of the IMT-Advanced standards.[[16]](http://en.wikipedia.org/wiki/4g#cite_note-15)

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| Data speeds of LTE Advanced | |
|  | **LTE Advanced** |
| Peak Download | 1 Gbit/s |
| Peak Upload | 500 Mbit/s |

**IEEE 802.16m or WirelessMAN-Advanced**

The [IEEE 802.16m](http://en.wikipedia.org/wiki/IEEE_802.16m) or [WirelessMAN-Advanced](http://en.wikipedia.org/wiki/WirelessMAN-Advanced) evolution of 802.16e is under development, with the objective to fulfill the IMT-Advanced criteria of 1 Gbit/s for stationary reception and 100 Mbit/s for mobile reception.[[17]](http://en.wikipedia.org/wiki/4g#cite_note-16)

**4G predecessors and discontinued candidate systems**

**3GPP Long Term Evolution (LTE)**

*See also:* [*LTE Advanced*](http://en.wikipedia.org/wiki/4G#LTE_Advanced) *above*

[http://bits.wikimedia.org/skins-1.18/common/images/magnify-clip.png](http://en.wikipedia.org/wiki/File:Samsung_4G_LTE_modem-4.jpg)

[Telia](http://en.wikipedia.org/wiki/TeliaSonera)-branded Samsung LTE modem

The pre-4G technology [3GPP Long Term Evolution](http://en.wikipedia.org/wiki/3GPP_Long_Term_Evolution) (LTE) is often branded "4G", but the first LTE release does not fully comply with the IMT-Advanced requirements. LTE has a theoretical [net bit rate](http://en.wikipedia.org/wiki/Net_bit_rate) capacity of up to 100 Mbit/s in the downlink and 50 Mbit/s in the uplink if a 20 MHz channel is used — and more if [multiple-input multiple-output](http://en.wikipedia.org/wiki/Multiple-input_multiple-output) (MIMO), i.e. antenna arrays, are used.

The physical radio interface was at an early stage named *High Speed* [*OFDM*](http://en.wikipedia.org/wiki/OFDM) *Packet Access* (HSOPA), now named [Evolved UMTS Terrestrial Radio Access](http://en.wikipedia.org/wiki/Evolved_UMTS_Terrestrial_Radio_Access) (E-UTRA). The first [LTE](http://en.wikipedia.org/wiki/3GPP_Long_Term_Evolution) USB dongles do not support any other radio interface.

The world's first publicly available LTE service was opened in the two Scandinavian capitals [Stockholm](http://en.wikipedia.org/wiki/Stockholm) ([Ericsson](http://en.wikipedia.org/wiki/Ericsson) and [Nokia Siemens Networks](http://en.wikipedia.org/wiki/Nokia_Siemens_Networks) systems) and [Oslo](http://en.wikipedia.org/wiki/Oslo) (a [Huawei](http://en.wikipedia.org/wiki/Huawei) system) on 14 December 2009, and branded 4G. The user terminals were manufactured by Samsung.[[3]](http://en.wikipedia.org/wiki/4g#cite_note-Unstrung-2) Currently, the two publicly available LTE services in the United States are provided by [MetroPCS](http://en.wikipedia.org/wiki/MetroPCS),[[18]](http://en.wikipedia.org/wiki/4g#cite_note-MetroPCS-17) and [Verizon Wireless](http://en.wikipedia.org/wiki/Verizon_Wireless).[[19]](http://en.wikipedia.org/wiki/4g#cite_note-VerizonLTE-18) [AT&T](http://en.wikipedia.org/wiki/AT%26T) also has an LTE service in planned for deployment between mid-2011 and end of 2013, [Sprint Nextel](http://en.wikipedia.org/wiki/Sprint_Nextel) has stated it's considering switching from [WiMax](http://en.wikipedia.org/wiki/WiMax) to LTE in the near future.[[19]](http://en.wikipedia.org/wiki/4g#cite_note-VerizonLTE-18)

In South Korea, SK Telecom and LG U+ have enabled access to LTE service since 1 July 2011 for data devices, slated to go nationwide by 2012.[[20]](http://en.wikipedia.org/wiki/4g#cite_note-19)

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| Data speeds of LTE | |
|  | **LTE** |
| Peak Download | 100 Mbit/s |
| Peak Upload | 50 Mbit/s |

**Mobile WiMAX (IEEE 802.16e)**

The [Mobile WiMAX](http://en.wikipedia.org/wiki/Mobile_WiMAX) (IEEE 802.16e-2005) mobile wireless broadband access (MWBA) standard (also known as [WiBro](http://en.wikipedia.org/wiki/WiBro) in South Korea) is sometimes branded 4G, and offers peak data rates of 128 Mbit/s downlink and 56 Mbit/s uplink over 20 MHz wide channels[[*citation needed*](http://en.wikipedia.org/wiki/Wikipedia:Citation_needed)].

The world's first commercial mobile WiMAX service was opened by [KT](http://en.wikipedia.org/wiki/KT_(telecommunication_company)) in Seoul, South Korea on 30 June 2006.[[2]](http://en.wikipedia.org/wiki/4g#cite_note-kt-1)

[Sprint Nextel](http://en.wikipedia.org/wiki/Sprint_Nextel) has begun using Mobile WiMAX, as of September 29, 2008 branded as a "4G" network even though the current version does not fulfil the IMT Advanced requirements on 4G systems.[[21]](http://en.wikipedia.org/wiki/4g#cite_note-20)

In Russia, Belarus and Nicaragua WiMax broadband internet access is offered by a Russian company [Scartel](http://en.wikipedia.org/wiki/Scartel), and is also branded 4G, [Yota](http://en.wikipedia.org/wiki/Yota).

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| Data speeds of WiMAX | |
|  | **WiMAX** |
| Peak Download | 128 Mbit/s |
| Peak Upload | 56 Mbit/s |

**UMB (formerly EV-DO Rev. C)**

*Main article:* [*Ultra Mobile Broadband*](http://en.wikipedia.org/wiki/Ultra_Mobile_Broadband)

UMB ([Ultra Mobile Broadband](http://en.wikipedia.org/wiki/Ultra_Mobile_Broadband)) was the brand name for a discontinued 4G project within the [3GPP2](http://en.wikipedia.org/wiki/3GPP2) standardization group to improve the [CDMA2000](http://en.wikipedia.org/wiki/CDMA2000) mobile phone standard for next generation applications and requirements. In November 2008, [Qualcomm](http://en.wikipedia.org/wiki/Qualcomm), UMB's lead sponsor, announced it was ending development of the technology, favouring LTE instead.[[22]](http://en.wikipedia.org/wiki/4g#cite_note-21) The objective was to achieve data speeds over 275 Mbit/s downstream and over 75 Mbit/s upstream.

**Flash-OFDM**

At an early stage the [Flash-OFDM](http://en.wikipedia.org/wiki/Flash-OFDM) system was expected to be further developed into a 4G standard.

**iBurst and MBWA (IEEE 802.20) systems**

The [iBurst](http://en.wikipedia.org/wiki/IBurst) system ( or HC-SDMA, High Capacity Spatial Division Multiple Access) was at an early stage considered as a 4G predecessor. It was later further developed into the [Mobile Broadband Wireless Access](http://en.wikipedia.org/wiki/Mobile_Broadband_Wireless_Access) (MBWA) system, also known as IEEE 802.20.

**Objective and approach**

**Objectives assumed in the literature**

4G is being developed to accommodate the [quality of service](http://en.wikipedia.org/wiki/Quality_of_service) (QoS) and rate requirements set by further development of existing 3G applications like [mobile broadband](http://en.wikipedia.org/wiki/Mobile_broadband) access, [Multimedia Messaging Service](http://en.wikipedia.org/wiki/Multimedia_Messaging_Service) (MMS), [video chat](http://en.wikipedia.org/wiki/Videoconferencing), [mobile TV](http://en.wikipedia.org/wiki/Mobile_TV), but also new services like [HDTV](http://en.wikipedia.org/wiki/High-definition_television). 4G may allow roaming with wireless local area networks, and may interact with [digital video broadcasting](http://en.wikipedia.org/wiki/Digital_video_broadcasting) systems.

In the literature, the assumed or expected 4G requirements have changed during the years before IMT-Advanced was specified by the ITU-R. These are examples of objectives stated in various sources:

* A nominal data rate of 100 Mbit/s while the client physically moves at high speeds relative to the station, and 1 Gbit/s while client and station are in relatively fixed positions as defined by the [ITU-R](http://en.wikipedia.org/wiki/ITU-R)[[24]](http://en.wikipedia.org/wiki/4g#cite_note-4Groadmap-23)
* A data rate of at least 100 Mbit/s between any two points in the world[[24]](http://en.wikipedia.org/wiki/4g#cite_note-4Groadmap-23)
* Smooth [handoff](http://en.wikipedia.org/wiki/Handoff) across heterogeneous networks[[25]](http://en.wikipedia.org/wiki/4g#cite_note-mobilitymanagement-24)
* Seamless connectivity and global [roaming](http://en.wikipedia.org/wiki/Roaming) across multiple networks[[26]](http://en.wikipedia.org/wiki/4g#cite_note-beyond3garticle-25)
* High quality of service for next generation multimedia support (real time audio, high speed data, HDTV video content, mobile TV, etc.)[[26]](http://en.wikipedia.org/wiki/4g#cite_note-beyond3garticle-25)
* Interoperability with existing wireless standards[[27]](http://en.wikipedia.org/wiki/4g#cite_note-pathto4g-26)
* An all IP, [packet switched](http://en.wikipedia.org/wiki/Packet_switched) network[[26]](http://en.wikipedia.org/wiki/4g#cite_note-beyond3garticle-25)
* IP-based [femtocells](http://en.wikipedia.org/wiki/Femtocell) (home nodes connected to fixed Internet broadband infrastructure)

**Approaches**

**Principal technologies**

* Physical layer transmission techniques are as follows:[[28]](http://en.wikipedia.org/wiki/4g#cite_note-WWRF_WG5-27)
  + [MIMO](http://en.wikipedia.org/wiki/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*](http://en.wikipedia.org/wiki/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](http://en.wikipedia.org/wiki/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](http://en.wikipedia.org/wiki/Turbo_code) [error-correcting codes](http://en.wikipedia.org/wiki/Error-correcting_code): To minimize the required [SNR](http://en.wikipedia.org/wiki/Signal-to-noise_ratio) at the reception side
* [Channel-dependent scheduling](http://en.wikipedia.org/wiki/Channel-dependent_scheduling): To utilize the time-varying channel.
* [Link adaptation](http://en.wikipedia.org/wiki/Link_adaptation): [Adaptive modulation](http://en.wikipedia.org/wiki/Adaptive_modulation) and error-correcting codes
* Relaying, including fixed relay networks (FRNs), and [the cooperative relaying concept](http://en.wikipedia.org/wiki/Cooperative_wireless_communications), known as multi-mode protocol

**4G features assumed in early literature**

The 4G system was originally envisioned by the Defense Advanced Research Projects Agency (DARPA).[[*citation needed*](http://en.wikipedia.org/wiki/Wikipedia:Citation_needed)] The DARPA selected the distributed architecture, end-to-end Internet protocol (IP), and believed at an early stage in peer-to-peer networking in which every mobile device would be both a transceiver and a router for other devices in the network eliminating the spoke-and-hub weakness of 2G and 3G cellular systems.[[29]](http://en.wikipedia.org/wiki/4g#cite_note-28) Since the 2.5G GPRS system, cellular systems have provided dual infrastructures: packet switched nodes for data services, and circuit switched nodes for voice calls. In 4G systems, the circuit-switched infrastructure is abandoned, and only a packet-switched network is provided, while 2.5G and 3G systems require both packet-switched and circuit-switched [network nodes](http://en.wikipedia.org/wiki/Network_node), i.e. two infrastructures in parallel. This means that in 4G, traditional voice calls are replaced by IP telephony.

Cellular systems such as 4G allow seamless mobility; thus a file transfer is not interrupted in case a terminal moves from one cell (one base station coverage area) to another, but [handover](http://en.wikipedia.org/wiki/Handover) is carried out. The terminal also keeps the same IP address while moving, meaning that a mobile server is reachable as long as it is within the coverage area of any server. In 4G systems this mobility is provided by the [mobile IP](http://en.wikipedia.org/wiki/Mobile_IP) protocol, part of IP version 6, while in earlier cellular generations it was only provided by physical layer and datalink layer protocols. In addition to seamless mobility, 4G provides flexible interoperability of the various kinds of existing wireless networks, such as satellite, cellular wirelss, WLAN, PAN and systems for accessing fixed wireless networks.[[30]](http://en.wikipedia.org/wiki/4g#cite_note-29)

While maintaining seamless mobility, 4G will offer very high data rates with expectations of 100 Mbit/s wireless service. The increased bandwidth and higher data transmission rates will allow 4G users the ability to utilize high definition video and the video conferencing features of mobile devices attached to a 4G network. The 4G wireless system is expected to provide a comprehensive IP solution where multimedia applications and services can be delivered to the user on an 'Anytime, Anywhere' basis with a satisfactory high data rate, premium quality and high security.[[31]](http://en.wikipedia.org/wiki/4g#cite_note-30)

4G is described as MAGIC: mobile multimedia, any-time anywhere, global mobility support, integrated wireless solution, and customized personal service.[[*citation needed*](http://en.wikipedia.org/wiki/Wikipedia:Citation_needed)] Some key features (primarily from users' points of view) of 4G mobile networks are:[[*citation needed*](http://en.wikipedia.org/wiki/Wikipedia:Citation_needed)]

* High usability: anytime, anywhere, and with any technology
* Support for multimedia services at low transmission cost
* Personalization
* Integrated services

**Components**

**Access schemes**

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As the wireless standards evolved, the access techniques used also exhibited increase in efficiency, capacity and scalability. The first generation wireless standards used plain [TDMA](http://en.wikipedia.org/wiki/Time_division_multiple_access) and [FDMA](http://en.wikipedia.org/wiki/FDMA). In the wireless channels, TDMA proved to be less efficient in handling the high data rate channels as it requires large guard periods to alleviate the multipath impact. Similarly, FDMA consumed more bandwidth for guard to avoid inter carrier interference. So in second generation systems, one set of standard used the combination of FDMA and TDMA and the other set introduced an access scheme called [CDMA](http://en.wikipedia.org/wiki/CDMA). Usage of CDMA increased the system capacity, but as a theoretical drawback placed a soft limit on it rather than the hard limit (i.e. a CDMA network setup does not inherently reject new clients when it approaches its limits, resulting in a denial of service to all clients when the network overloads; though this outcome is avoided in practical implementations by [admission control](http://en.wikipedia.org/w/index.php?title=Admission_control&action=edit&redlink=1) of circuit switched or fixed bitrate communication services). Data rate is also increased as this access scheme (providing the network is not reaching its capacity) is efficient enough to handle the multipath channel. This enabled the third generation systems, such as [IS-2000](http://en.wikipedia.org/wiki/IS-2000), [UMTS](http://en.wikipedia.org/wiki/UMTS), [HSXPA](http://en.wikipedia.org/wiki/High_Speed_Packet_Access), [1xEV-DO](http://en.wikipedia.org/wiki/1xEV-DO), [TD-CDMA](http://en.wikipedia.org/wiki/TD-CDMA) and [TD-SCDMA](http://en.wikipedia.org/wiki/TD-SCDMA), to use CDMA as the access scheme. However, the issue with CDMA is that it suffers from poor spectral flexibility and computationally intensive time-domain equalization (high number of multiplications per second) for wideband channels.

Recently, new access schemes like [Orthogonal FDMA](http://en.wikipedia.org/wiki/OFDMA) (OFDMA), [Single Carrier FDMA](http://en.wikipedia.org/wiki/SC-FDMA) (SC-FDMA), [Interleaved FDMA](http://en.wikipedia.org/w/index.php?title=Interleaved_FDMA&action=edit&redlink=1) and [Multi-carrier CDMA](http://en.wikipedia.org/wiki/Multi-carrier_code_division_multiple_access) (MC-CDMA) are gaining more importance for the next generation systems. These are based on efficient [FFT](http://en.wikipedia.org/wiki/FFT) algorithms and frequency domain equalization, resulting in a lower number of multiplications per second. They also make it possible to control the bandwidth and form the spectrum in a flexible way. However, they require advanced dynamic channel allocation and traffic adaptive scheduling.

[WiMax](http://en.wikipedia.org/wiki/WiMax) is using OFDMA in the downlink and in the uplink. For the [next generation UMTS](http://en.wikipedia.org/wiki/3GPP_Long_Term_Evolution), OFDMA is used for the downlink. By contrast, IFDMA is being considered for the uplink since OFDMA contributes more to the [PAPR](http://en.wikipedia.org/wiki/Crest_factor) related issues and results in nonlinear operation of amplifiers. IFDMA provides less power fluctuation and thus avoids amplifier issues. Similarly, MC-CDMA is in the proposal for the [IEEE 802.20](http://en.wikipedia.org/wiki/802.20) standard. These access schemes offer the same efficiencies as older technologies like CDMA. Apart from this, scalability and higher data rates can be achieved.

The other important advantage of the above mentioned access techniques is that they require less complexity for equalization at the receiver. This is an added advantage especially in the [MIMO](http://en.wikipedia.org/wiki/MIMO) environments since the [spatial multiplexing](http://en.wikipedia.org/wiki/Spatial_multiplexing) transmission of MIMO systems inherently requires high complexity equalization at the receiver.

In addition to improvements in these multiplexing systems, improved [modulation](http://en.wikipedia.org/wiki/Modulation) techniques are being used. Whereas earlier standards largely used [Phase-shift keying](http://en.wikipedia.org/wiki/Phase-shift_keying), more efficient systems such as 64[QAM](http://en.wikipedia.org/wiki/QAM) are being proposed for use with the [3GPP Long Term Evolution](http://en.wikipedia.org/wiki/3GPP_Long_Term_Evolution) standards.

**IPv6 support**

Unlike 3G, which is based on two parallel infrastructures consisting of [circuit switched](http://en.wikipedia.org/wiki/Circuit_switched) and [packet switched](http://en.wikipedia.org/wiki/Packet_switched) network nodes respectively, 4G will be based on packet switching *only*. This will require [low-latency](http://en.wikipedia.org/wiki/Lag) data transmission.

By the time that 4G was deployed, the process of [IPv4 address exhaustion](http://en.wikipedia.org/wiki/IPv4_address_exhaustion) was expected to be in its final stages. Therefore, in the context of 4G, [IPv6](http://en.wikipedia.org/wiki/IPv6) support is essential in order to support a large number of wireless-enabled devices. By increasing the number of [IP addresses](http://en.wikipedia.org/wiki/IP_address), IPv6 removes the need for [network address translation](http://en.wikipedia.org/wiki/Network_address_translation) (NAT), a method of sharing a limited number of addresses among a larger group of devices, although NAT will still be required to communicate with devices that are on existing [IPv4](http://en.wikipedia.org/wiki/IPv4) networks.

As of June 2009[[update]](http://en.wikipedia.org/w/index.php?title=4G&action=edit), [Verizon](http://en.wikipedia.org/wiki/Verizon) has posted [specifications](https://www22.verizon.com/opendev/Forum/LTE_Document_Archives.aspx) that require any 4G devices on its network to support IPv6.[[32]](http://en.wikipedia.org/wiki/4g#cite_note-31)

**Advanced antenna systems**

The performance of radio communications depends on an antenna system, termed [smart](http://en.wikipedia.org/wiki/Smart_antenna) or [intelligent antenna](http://en.wikipedia.org/wiki/Intelligent_antenna). Recently, [multiple antenna technologies](http://en.wikipedia.org/wiki/Multiple_antenna_research) are emerging to achieve the goal of 4G systems such as high rate, high reliability, and long range communications. In the early 1990s, to cater for the growing data rate needs of data communication, many transmission schemes were proposed. One technology, [spatial multiplexing](http://en.wikipedia.org/wiki/Spatial_multiplexing), gained importance for its bandwidth conservation and power efficiency. Spatial multiplexing involves deploying multiple antennas at the transmitter and at the receiver. Independent streams can then be transmitted simultaneously from all the antennas. This technology, called [MIMO](http://en.wikipedia.org/wiki/MIMO) (as a branch of [intelligent antenna](http://en.wikipedia.org/wiki/Intelligent_antenna)), multiplies the base data rate by (the smaller of) the number of transmit antennas or the number of receive antennas. Apart from this, the reliability in transmitting high speed data in the fading channel can be improved by using more antennas at the transmitter or at the receiver. This is called *transmit* or *receive diversity*. Both transmit/receive diversity and transmit spatial multiplexing are categorized into the space-time coding techniques, which does not necessarily require the channel knowledge at the transmitter. The other category is closed-loop multiple antenna technologies, which require channel knowledge at the transmitter.

**Software-defined radio (SDR)**

[SDR](http://en.wikipedia.org/wiki/Software-defined_radio) is one form of open wireless architecture (OWA). Since 4G is a collection of wireless standards, the final form of a 4G device will constitute various standards. This can be efficiently realized using SDR technology, which is categorized to the area of the radio convergence.

**History of 4G and pre-4G technologies**

* In 2002, the strategic vision for 4G—which [ITU](http://en.wikipedia.org/wiki/ITU) designated as IMT-Advanced—was laid out.
* In 2005, [OFDMA](http://en.wikipedia.org/wiki/OFDMA) transmission technology is chosen as candidate for the [HSOPA](http://en.wikipedia.org/wiki/HSOPA) downlink, later renamed 3GPP Long Term Evolution (LTE) air interface [E-UTRA](http://en.wikipedia.org/wiki/E-UTRA).
* In November 2005, [KT](http://en.wikipedia.org/wiki/KT_(telecommunication_company)) demonstrated mobile WiMAX service in Busan, South Korea.[[33]](http://en.wikipedia.org/wiki/4g#cite_note-kt_demo-32)
* In June 2006, [KT](http://en.wikipedia.org/wiki/KT_(telecommunication_company)) started the world's first commercial mobile WiMAX service in Seoul, South Korea.[[2]](http://en.wikipedia.org/wiki/4g#cite_note-kt-1)
* In mid-2006, [Sprint Nextel](http://en.wikipedia.org/wiki/Sprint_Nextel) announced that it would invest about US$5 billion in a [WiMAX](http://en.wikipedia.org/wiki/WiMAX) technology buildout over the next few years[[34]](http://en.wikipedia.org/wiki/4g#cite_note-sprint-33) ($5.45 billion in [real](http://en.wikipedia.org/wiki/Real_versus_nominal_value_(economics)) terms[[35]](http://en.wikipedia.org/wiki/4g#cite_note-inflation-US-34)). Since that time Sprint has faced many setbacks, that have resulted in steep quarterly losses. On May 7, 2008, [Sprint](http://en.wikipedia.org/wiki/Sprint_Nextel), [Imagine](http://en.wikipedia.org/wiki/Imagine_Communications), [Google](http://en.wikipedia.org/wiki/Google), [Intel](http://en.wikipedia.org/wiki/Intel), [Comcast](http://en.wikipedia.org/wiki/Comcast), [Bright House](http://en.wikipedia.org/wiki/Bright_House_Networks), and [Time Warner](http://en.wikipedia.org/wiki/Time_Warner) announced a pooling of an average of 120 MHz of spectrum; Sprint merged its [Xohm](http://en.wikipedia.org/wiki/Xohm) WiMAX division with [Clearwire](http://en.wikipedia.org/wiki/Clearwire) to form a company which will take the name "Clear".
* In February 2007, the [Japanese company](http://en.wikipedia.org/wiki/Japanese_company) [NTT DoCoMo](http://en.wikipedia.org/wiki/NTT_DoCoMo) tested a 4G communication system prototype with 4x4 [MIMO](http://en.wikipedia.org/wiki/MIMO) called [VSF-OFCDM](http://en.wikipedia.org/wiki/VSF-OFCDM) at 100 [Mbit](http://en.wikipedia.org/wiki/Mbit)/s while moving, and 1 [Gbit](http://en.wikipedia.org/wiki/Gbit)/s while stationary. NTT DoCoMo completed a trial in which they reached a maximum packet transmission rate of approximately 5 Gbit/s in the downlink with 12x12 MIMO using a 100 MHz frequency bandwidth while moving at 10 km/h,[[36]](http://en.wikipedia.org/wiki/4g#cite_note-35) and is planning on releasing the first commercial network in 2010.
* In September 2007, NTT Docomo demonstrated e-UTRA data rates of 200 Mbit/s with power consumption below 100 mW during the test.[[37]](http://en.wikipedia.org/wiki/4g#cite_note-36)
* In January 2008, a U.S. [Federal Communications Commission](http://en.wikipedia.org/wiki/Federal_Communications_Commission) (FCC) [spectrum auction](http://en.wikipedia.org/wiki/Spectrum_auction) for the 700 MHz former analog TV frequencies began. As a result, the biggest share of the spectrum went to Verizon Wireless and the next biggest to AT&T.[[38]](http://en.wikipedia.org/wiki/4g#cite_note-37) Both of these companies have stated their intention of supporting [LTE](http://en.wikipedia.org/wiki/3GPP_Long_Term_Evolution).
* In January 2008, EU commissioner [Viviane Reding](http://en.wikipedia.org/wiki/Viviane_Reding) suggested re-allocation of 500–800 MHz spectrum for wireless communication, including WiMAX.[[39]](http://en.wikipedia.org/wiki/4g#cite_note-38)
* On 15 February 2008 - Skyworks Solutions released a front-end module for e-UTRAN.[[40]](http://en.wikipedia.org/wiki/4g#cite_note-39)[[41]](http://en.wikipedia.org/wiki/4g#cite_note-40)[[42]](http://en.wikipedia.org/wiki/4g#cite_note-41)
* In 2008, [ITU-R](http://en.wikipedia.org/wiki/ITU-R) established the detailed performance requirements of IMT-Advanced, by issuing a Circular Letter calling for candidate Radio Access Technologies (RATs) for IMT-Advanced.[[43]](http://en.wikipedia.org/wiki/4g#cite_note-42)
* In April 2008, just after receiving the circular letter, the 3GPP organized a workshop on IMT-Advanced where it was decided that LTE Advanced, an evolution of current LTE standard, will meet or even exceed IMT-Advanced requirements following the ITU-R agenda.
* In April 2008, LG and Nortel demonstrated e-UTRA data rates of 50 Mbit/s while travelling at 110 km/h.[[44]](http://en.wikipedia.org/wiki/4g#cite_note-43)
* On 12 November 2008, [HTC](http://en.wikipedia.org/wiki/High_Tech_Computer) announced the first WiMAX-enabled mobile phone, the [Max 4G](http://en.wikipedia.org/wiki/Max_4G)[[45]](http://en.wikipedia.org/wiki/4g#cite_note-44)
* In December 2008, [San Miguel Corporation](http://en.wikipedia.org/wiki/San_Miguel_Corporation), Asia's largest food and beverage conglomerate, has signed a memorandum of understanding with Qatar Telecom QSC ([Qtel](http://en.wikipedia.org/wiki/Qtel)) to build wireless broadband and mobile communications projects in the Philippines. The joint-venture formed wi-tribe Philippines, which offers 4G in the country.[[46]](http://en.wikipedia.org/wiki/4g#cite_note-45) Around the same time [Globe Telecom](http://en.wikipedia.org/wiki/Globe_Telecom) rolled out the first WiMAX service in the Philippines.
* On 3 March 2009, Lithuania's LRTC announcing the first operational "4G" [mobile WiMAX](http://en.wikipedia.org/wiki/Mobile_WiMAX) network in Baltic states.[[47]](http://en.wikipedia.org/wiki/4g#cite_note-46)
* In December 2009, Sprint began advertising "4G" service in selected cities in the United States, despite average download speeds of only 3–6 Mbit/s with peak speeds of 10 Mbit/s (not available in all markets).[[48]](http://en.wikipedia.org/wiki/4g#cite_note-sprint4g-47)
* On 14 December 2009, the first commercial LTE deployment was in the Scandinavian capitals [Stockholm](http://en.wikipedia.org/wiki/Stockholm) and [Oslo](http://en.wikipedia.org/wiki/Oslo) by the Swedish-Finnish network operator [TeliaSonera](http://en.wikipedia.org/wiki/TeliaSonera) and its Norwegian brandname [NetCom (Norway)](http://en.wikipedia.org/wiki/NetCom_(Norway)). TeliaSonera branded the network "4G". The modem devices on offer were manufactured by [Samsung](http://en.wikipedia.org/wiki/Samsung) (dongle GT-B3710), and the network infrastructure created by [Huawei](http://en.wikipedia.org/wiki/Huawei) (in Oslo) and [Ericsson](http://en.wikipedia.org/wiki/Ericsson) (in Stockholm). TeliaSonera plans to roll out nationwide LTE across Sweden, Norway and Finland.[[4]](http://en.wikipedia.org/wiki/4g#cite_note-Wallstreet-3)[[49]](http://en.wikipedia.org/wiki/4g#cite_note-48) TeliaSonera used spectral bandwidth of 10 MHz, and single-in-single-out, which should provide physical layer [net bitrates](http://en.wikipedia.org/wiki/Net_bitrate) of up to 50 Mbit/s downlink and 25 Mbit/s in the uplink. Introductory tests showed a [TCP](http://en.wikipedia.org/wiki/Transmission_Control_Protocol) [throughput](http://en.wikipedia.org/wiki/Throughput) of 42.8 Mbit/s downlink and 5.3 Mbit/s uplink in Stockholm.[[5]](http://en.wikipedia.org/wiki/4g#cite_note-dailymobile-4)
* On 25 February 2010, Estonia's [EMT](http://en.wikipedia.org/wiki/EMT_(mobile_operator)) opened LTE "4G" network working in test regime.[[50]](http://en.wikipedia.org/wiki/4g#cite_note-49)
* On 4 June 2010, [Sprint Nextel](http://en.wikipedia.org/wiki/Sprint_Nextel) released the first WiMAX smartphone in the US, the [HTC Evo 4G](http://en.wikipedia.org/wiki/HTC_Evo_4G).[[51]](http://en.wikipedia.org/wiki/4g#cite_note-50)
* In July 2010, [Uzbekistan](http://en.wikipedia.org/wiki/Uzbekistan)'s [MTS](http://en.wikipedia.org/wiki/Mobile_TeleSystems) deployed LTE in [Tashkent](http://en.wikipedia.org/wiki/Tashkent).[[52]](http://en.wikipedia.org/wiki/4g#cite_note-51)
* On 25 August 2010, [Latvia](http://en.wikipedia.org/wiki/Latvia)'s [LMT](http://en.wikipedia.org/wiki/Latvian_Mobile_Telephone) opened LTE "4G" network working in test regime 50% of territory.
* On 6 December 2010, at the ITU World Radiocommunication Seminar 2010, the [ITU](http://en.wikipedia.org/wiki/ITU) stated that [LTE](http://en.wikipedia.org/wiki/3GPP_Long_Term_Evolution), [WiMax](http://en.wikipedia.org/wiki/WiMax) and similar "evolved 3G technologies" could be considered "4G".[[7]](http://en.wikipedia.org/wiki/4g#cite_note-ITUSeminar-6)
* On 12 December 2010, VivaCell-MTS launches in [Armenia](http://en.wikipedia.org/wiki/Armenia) 4G/LTE commercial test network with a live demo conducted in [Yerevan](http://en.wikipedia.org/wiki/Yerevan).[[53]](http://en.wikipedia.org/wiki/4g#cite_note-52)
* On 28 April 2011, [Lithuania](http://en.wikipedia.org/wiki/Lithuania)'s [Omnitel](http://en.wikipedia.org/wiki/Omnitel) opened LTE "4G" network working in 5 biggest cities.[[54]](http://en.wikipedia.org/wiki/4g#cite_note-53)
* In September 2011, All three Saudi telecom giants [STC](http://en.wikipedia.org/wiki/Saudi_Telecom_Company), [Mobily](http://en.wikipedia.org/wiki/Mobily) and [Zain](http://en.wikipedia.org/wiki/Zain) announced that they will offer 4G LTE for high speed USB sticks for mobile computers, with further development for telephones by 2013. [[55]](http://en.wikipedia.org/wiki/4g#cite_note-SaudiMac-54)

**Deployment plans**

In May 2005, [Digiweb](http://en.wikipedia.org/wiki/Digiweb), an Irish fixed and wireless broadband company, announced that they had received a mobile communications license from the Irish Telecoms regulator, [ComReg](http://en.wikipedia.org/wiki/ComReg). This service will be issued the mobile code *088* in Ireland and will be used for the provision of 4G Mobile communications.[[56]](http://en.wikipedia.org/wiki/4g#cite_note-55)[[57]](http://en.wikipedia.org/wiki/4g#cite_note-56) Digiweb launched a mobile broadband network using FLASH-OFDM technology at 872 MHz.

On September 20, 2007, [Verizon Wireless](http://en.wikipedia.org/wiki/Verizon_Wireless) announced plans for a joint effort with the [Vodafone Group](http://en.wikipedia.org/wiki/Vodafone_Group) to transition its networks to the 4G standard LTE. On December 9, 2008, Verizon Wireless announced their intentions to build and begin to roll out an LTE network by the end of 2009. Since then, Verizon Wireless has said that they will start their rollout by the end of 2010.

On July 7, 2008, [South Korea](http://en.wikipedia.org/wiki/South_Korea) announced plans to spend 60 billion [won](http://en.wikipedia.org/wiki/South_Korean_won), or US$58,000,000, on developing 4G and even 5G technologies, with the goal of having the highest mobile phone market share by 2012, and the hope of an international standard.[[58]](http://en.wikipedia.org/wiki/4g#cite_note-57)

[Telus](http://en.wikipedia.org/wiki/Telus) and [Bell Canada](http://en.wikipedia.org/wiki/Bell_Canada), the major Canadian [cdmaOne](http://en.wikipedia.org/wiki/CdmaOne) and [EV-DO](http://en.wikipedia.org/wiki/EV-DO) carriers, have announced that they will be cooperating towards building a fourth generation (4G) LTE wireless broadband network in Canada. As a transitional measure, they are implementing 3G [UMTS](http://en.wikipedia.org/wiki/UMTS) that went live in November 2009.[[59]](http://en.wikipedia.org/wiki/4g#cite_note-TELUS.com-58)

Sprint offers a 3G/4G connection plan, currently available in select cities in the United States.[[48]](http://en.wikipedia.org/wiki/4g#cite_note-sprint4g-47) It delivers rates up to 10 Mbit/s.

In the [United Kingdom](http://en.wikipedia.org/wiki/United_Kingdom), [Telefónica O2](http://en.wikipedia.org/wiki/Telef%C3%B3nica_Europe) is to use [Slough](http://en.wikipedia.org/wiki/Slough) as a guinea pig in testing the 4G network and has called upon [Huawei](http://en.wikipedia.org/wiki/Huawei) to install LTE technology in six masts across the town to allow people to talk to each other via HD video conferencing and play PlayStation games while on the move.[[60]](http://en.wikipedia.org/wiki/4g#cite_note-59)

Verizon Wireless has announced that it plans to augment its CDMA2000-based EV-DO 3G network in the United States with LTE. [AT&T](http://en.wikipedia.org/wiki/AT%26T_Mobility), along with Verizon Wireless, has chosen to migrate toward LTE from 2G/GSM and 3G/HSPA by 2011.[[61]](http://en.wikipedia.org/wiki/4g#cite_note-60)

[Sprint Nextel](http://en.wikipedia.org/wiki/Sprint_Nextel) has deployed WiMAX technology which it has labeled 4G as of October 2008. It is currently deploying to additional markets and is the first US carrier to offer a WiMAX phone.[[62]](http://en.wikipedia.org/wiki/4g#cite_note-61)

The U.S. FCC is exploring the possibility of deployment and operation of a nationwide 4G public safety network which would allow [first responders](http://en.wikipedia.org/wiki/First_responders) to seamlessly communicate between agencies and across geographies, regardless of devices. In June 2010 the FCC released a comprehensive white paper which indicates that the 10 MHz of dedicated spectrum currently allocated from the [1700 MHz](http://en.wikipedia.org/w/index.php?title=1700_MHz&action=edit&redlink=1) spectrum for public safety will provide adequate capacity and performance necessary for normal communications as well as serious emergency situations.[[63]](http://en.wikipedia.org/wiki/4g#cite_note-62)

[TeliaSonera](http://en.wikipedia.org/wiki/TeliaSonera) started deploying LTE (branded "4G") in Stockholm and Oslo November 2009 (as seen above), and in several Swedish, Norwegian, and Finnish cities during 2010. In June 2010, Swedish television companies used 4G to broadcast live television from the Swedish Crown Princess' Royal Wedding.[[64]](http://en.wikipedia.org/wiki/4g#cite_note-63)

Safaricom, a telecommunication company in East& Central Africa, began its setup of a 4G network in October 2010 after the now retired& Kenya Tourist Board Chairman, Michael Joseph, regarded their 3G network as a white elephant i.e. it failed to perform to expectations. Huawei was given the contract the network is set to go fully commercial by the end of Q1 of 2011

[Telstra](http://en.wikipedia.org/wiki/Telstra) announced on 15 February 2011, that it intends to upgrade its current Next G network to 4G with Long Term Evolution (LTE) technology in the central business districts of all Australian capital cities and selected regional centers by the end of 2011.[[65]](http://en.wikipedia.org/wiki/4g#cite_note-64)

Sri Lanka Telecom Mobitel and Dialog Axiata announced that first time in South Asia Sri Lanka have successfully tested and demonstrated 4G technology on 6th of May 2011(Sri Lanka Telecom Mobitel) and 7th of May 2011(Dialog Axiata) and began the setup of their 4G Networks in Sri Lanka.[[66]](http://en.wikipedia.org/wiki/4g#cite_note-65)[[67]](http://en.wikipedia.org/wiki/4g#cite_note-66)

On May 2011, [Brazil](http://en.wikipedia.org/wiki/Brazil)'s Communication Ministry announced that the 12 host cities for the [2014 FIFA World Cup](http://en.wikipedia.org/wiki/2014_FIFA_World_Cup) to be held there will be the first to have their networks upgraded to 4G.[[68]](http://en.wikipedia.org/wiki/4g#cite_note-67)

In mid September 2011, [ <http://www.mobily.com.sa/> ] Mobily of [Saudi Arabia](http://en.wikipedia.org/wiki/Saudi_Arabia), announced their 4G LTE networks to be ready after months of testing and evaluations.

On September 2011, [UAE](http://en.wikipedia.org/wiki/UAE)'s [Etisalat](http://en.wikipedia.org/wiki/Etisalat) announced commercial launch of 4G LTE services covering over 70% of country's urban areas.

**Beyond 4G research**

A major issue in 4G systems is to make the high bit rates available in a larger portion of the cell, especially to users in an exposed position in between several base stations. In current research, this issue is addressed by [macro-diversity](http://en.wikipedia.org/wiki/Macro-diversity) techniques, also known as [group cooperative relay](http://en.wikipedia.org/wiki/Cooperative_diversity), and also by [Beam-Division Multiple Access (BDMA)](http://en.wikipedia.org/w/index.php?title=Beam-division_multiple_access&action=edit&redlink=1).[[69]](http://en.wikipedia.org/wiki/4g#cite_note-68)

[Pervasive networks](http://en.wikipedia.org/wiki/Pervasive_network) are an amorphous and at present entirely hypothetical concept where the user can be simultaneously connected to several wireless access technologies and can seamlessly move between them (See [vertical handoff](http://en.wikipedia.org/wiki/Vertical_handoff), [IEEE 802.21](http://en.wikipedia.org/wiki/IEEE_802.21)). These access technologies can be [Wi-Fi](http://en.wikipedia.org/wiki/Wi-Fi), [UMTS](http://en.wikipedia.org/wiki/Universal_Mobile_Telecommunications_System), [EDGE](http://en.wikipedia.org/wiki/Enhanced_Data_Rates_for_GSM_Evolution), or any other future access technology. Included in this concept is also smart-radio (also known as [cognitive radio](http://en.wikipedia.org/wiki/Cognitive_radio)) technology to efficiently manage spectrum use and transmission power as well as the use of [mesh routing](http://en.wikipedia.org/wiki/Mesh_networking) protocols to create a pervasive network.