

4G

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4G refers to the fourth generation of cellular wireless and is a successor to 3G and 2G standards. The rest of this article associates **4G** with *International Mobile Telecommunications-Advanced* (IMT Advanced), though 4G is a broader term and could include standards outside IMT-Advanced. A 4G system may upgrade existing communication networks and is expected to provide a comprehensive and secure IP based solution where facilities such as voice, data and streamed multimedia will be provided to users on an "Anytime, Anywhere" basis and at much higher data rates compared to previous generations.

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Objective and approach

Objectives

4G is being developed to accommodate the QoS and rate requirements set by forthcoming applications like wireless broadband access, Multimedia Messaging Service (MMS), video chat, mobile TV, HDTV content, Digital Video Broadcasting (DVB), minimal services like voice and data, and other services that utilize bandwidth.

The 4G working group has defined the following as objectives of the 4G wireless communication standard:

- A spectrally efficient system (in bits/s/Hz and bits/s/Hz/site),^[1]
- High network capacity: more simultaneous users per cell,^[2]
- 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,^[3]
- A data rate of at least 100 Mbit/s between any two points in the world,^[3]
- Smooth handoff across heterogeneous networks,^[4]
- Seamless connectivity and global roaming across multiple networks,^[5]
- High quality of service for next generation multimedia support (real time audio, high speed data, HDTV video content, mobile TV, etc)^[5]
- Interoperability with existing wireless standards,^[6] and
- An all IP, packet switched network.^[5]

In summary, the 4G system should dynamically share and utilize network resources to meet the minimal requirements of all the 4G enabled users.

Approaches

As described in 4G consortia including WINNER (<http://www.ist-winner.org/>) , *WINNER - Towards Ubiquitous Wireless Access*, and WWRF (<http://www.wireless-world-research.org/>) , a key technology based approach is summarized as follows, where Wireless-World-Initiative-New-Radio (WINNER) is a consortium to enhance mobile communication systems.^{[7][8]}

Consideration points

- Coverage, radio environment, spectrum, services, business models and deployment types, users.

Principal technologies

- Baseband techniques^[9]
 - OFDM: To exploit the frequency selective channel property
 - MIMO: To attain ultra high spectral efficiency
 - Turbo principle: To minimize the required SNR at the reception side
- Adaptive radio interface
- Modulation, spatial processing including multi-antenna and multi-user MIMO
- Relaying, including fixed relay networks (FRNs), and the cooperative relaying concept, known as multi-mode protocol

4G features

According to the members of the 4G working group, the infrastructure and the terminals of 4G will have almost all the standards from 2G to 4G implemented. Although legacy systems are in place to adopt existing users, the infrastructure for 4G will be only packet-based (all-IP). Some proposals suggest having an open Internet platform. Technologies considered to be early 4G include: Flash-OFDM, the 802.16e mobile version of WiMax (also known as WiBro in South Korea), and HC-SDMA (see iBurst). 3GPP Long Term Evolution may reach the market 1–2 years after Mobile WiMax is released.

An even higher speed version of WiMax is the IEEE 802.16m specification. LTE Advanced will be the later evolution of the 3GPP LTE standard.^[10]

Components

Access schemes

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 and 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 a new access scheme called CDMA. Usage of CDMA increased the system capacity and also placed a soft limit on it rather than the hard limit. Data rate is also increased as this access scheme is efficient enough to handle the multipath channel. This enabled the third generation systems to use CDMA as the access scheme IS-2000, UMTS, HSXPA, 1xEV-DO, TD-CDMA and TD-SCDMA. The only issue with CDMA is that it suffers from poor spectrum flexibility and scalability.

Recently, new access schemes like Orthogonal FDMA (OFDMA), Single Carrier FDMA (SC-FDMA), Interleaved FDMA and Multi-carrier code division multiple access (MC-CDMA) are gaining more importance for the next generation systems. WiMax is using OFDMA in the downlink and in the uplink. For the next generation UMTS, OFDMA is being considered for the downlink. By contrast, IFDMA is being considered for the uplink since OFDMA contributes more to the PAPR 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 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 environments since the spatial multiplexing transmission of MIMO systems inherently requires high complexity equalization at the receiver.

In addition to improvements in these multiplexing systems, improved modulation techniques are being used. Whereas earlier standards largely used Phase-shift keying, more efficient systems such as 64QAM are being proposed for use with the 3GPP Long Term Evolution standards.

IPv6 support

Unlike 3G, which is based on two parallel infrastructures consisting of circuit switched and packet switched network nodes respectively, 4G will be based on packet switching *only*. This will require low-latency data transmission.

By the time that 4G is deployed, the process of IPv4 address exhaustion is expected to be in its final stages. Therefore, in the context of 4G, IPv6 support is essential in order to support a large number of wireless-enabled devices. By increasing the number of IP addresses, IPv6 removes the need for 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 networks.

As of June 2009, 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.^[11]

Advanced Antenna Systems

The performance of radio communications obviously depends on the advances of an antenna system, refer to smart or intelligent antenna. Recently, multiple antenna technologies are emerging to achieve the goal of 4G systems such as high rate, high reliability, and long range communications. In the early 90s, to cater the growing data rate needs of data communication, many transmission schemes were proposed. One technology, spatial multiplexing, gained importance for its bandwidth conservation and power efficiency. Spatial multiplexing involves deploying multiple antennae at the transmitter and at the receiver. Independent streams can then be transmitted simultaneously from all the antennae. This increases the data rate into multiple folds with the number equal to minimum of the number of transmit and receive antennae. This is called MIMO (as a branch of intelligent antenna). Apart from this, the reliability in transmitting high speed data in the fading channel can be improved by using more antennae 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 transmit. The other category is closed-loop multiple antenna technologies which use the channel knowledge at the transmitter..

Software-Defined Radio (SDR)

SDR 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.

Developments

The Japanese company NTT DoCoMo has been testing a 4G communication system prototype with 4x4 MIMO called VSF-OFCDM at 100 Mbit/s while moving, and 1 Gbit/s while stationary. In February 2007, 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 100MHz frequency bandwidth while moving at 10 km/h,^[12] and is planning on releasing the first commercial network in 2010.

Digiweb, an Irish fixed and wireless broadband company, has announced that they have received a mobile communications license from the Irish Telecoms regulator, ComReg. This service will be issued the mobile code *088* in Ireland and will be used for the provision of 4G Mobile communications.^{[13][14]} Digiweb launched a mobile broadband network using FLASH-OFDM technology at 872 MHz.

Pervasive networks 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, IEEE 802.21). These access technologies can be Wi-Fi, UMTS, EDGE, or any other future access technology. Included in this concept is also smart-radio (also known as cognitive radio technology) to efficiently manage spectrum use and transmission power as well as the use of mesh routing protocols to create a pervasive network.

Verizon Wireless announced on September 20, 2007 that it plans a joint effort with the Vodafone Group to transition its networks to the 4G standard LTE. On December 9, 2008, Verizon Wireless announced that they intend to build and begin to roll out a LTE network by the end of 2009.

Telus and Bell Canada, the major Canadian cdmaOne and 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 to go live by early 2010.^[15]

Sprint announced it will be offering a 3G/4G connection plan for \$79.99, but it is only currently available in Baltimore^[16]

Applications

At the present rates of 15-30 Mbit/s, 4G is capable of providing users with streaming high-definition television. At rates of 100 Mbit/s, the content of a DVD-5 (for example a movie) can be downloaded within about 5 minutes for offline access.

4G wireless standards

3GPP is currently standardizing LTE Advanced as future 4G standard. A first set of 3GPP requirements on LTE Advanced has been approved in June 2008.^[17] The working groups are currently evaluating various proposals for standardization. LTE Advanced will be standardized as part of the Release 10 of the 3GPP specification.

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Additional resources

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