WiMAX

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WiMAX, meaning ***Worldwide Interoperability for Microwave Access***, is a telecommunications technology that provides wireless transmission of data using a variety of transmission modes, from point-to-multipoint links to portable and fully mobile internet access. The technology provides up to 10 Mbps [1] broadband speed without the need for cables. The technology is based on the IEEE 802.16 standard (also called Broadband Wireless Access). The name "WiMAX" was created by the WiMAX Forum, which was formed in June 2001 to promote conformity and interoperability of the standard. The forum describes WiMAX[2] as "a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL".[3]

Contents

WiMAX base station equipment with a sector antenna and wireless modem on top

A pre-WiMAX CPE of a 26 km (16 mi) connection mounted 13 metres (43 ft) above the ground (2004, Lithuania).

Definitions

The 802.16 standards are sometimes referred to colloquially as "WiMAX", "mobile WiMAX", "802.16d" and "802.16e."[4] Their formal names are as follow:

- **802.16-2004** is also known as 802.16d, which refers to the working party that has developed that standard. It is sometimes referred to as "fixed WiMAX," since it has no support for mobility.
- **802.16e-2005**, often abbreviated to 802.16e, is an amendment to 802.16-2004. It introduced support for mobility, among other things and is therefore also known as "mobile WiMAX".

Uses

The bandwidth and range of WiMAX make it suitable for the following potential applications:

- Connecting Wi-Fi hotspots to the Internet.
- Providing a wireless alternative to cable and DSL for "last mile" broadband access.
- Providing data and telecommunications services.
- Providing a source of Internet connectivity as part of a business continuity plan. That is, if a business has both a fixed and a wireless Internet connection, especially from unrelated providers, they are unlikely to be

affected by the same service outage.
- Providing portable connectivity.

Broadband access

Companies are evaluating WiMAX for last mile connectivity. The resulting competition may bring lower pricing for both home and business customers or bring broadband access to places where it has been economically unavailable.

WiMAX access was used to assist with communications in Aceh, Indonesia, after the tsunami in December 2004. All communication infrastructure in the area, other than amateur radio, was destroyed, making the survivors unable to communicate with people outside the disaster area and vice versa. WiMAX provided broadband access that helped regenerate communication to and from Aceh.

In addition, WiMAX was donated by Intel Corporation to assist the FCC and FEMA in their communications efforts in the areas affected by Hurricane Katrina.[5] In practice, volunteers used mainly self-healing mesh, VoIP, and a satellite uplink combined with Wi-Fi on the local link.[6]

Subscriber units (client units)

WiMAX subscriber units are available in both indoor and outdoor versions from several manufacturers. Self-install indoor units are convenient, but radio losses mean that the subscriber must be significantly closer to the WiMAX base station than with professionally-installed external units. As such, indoor-installed units require a much higher infrastructure investment as well as operational cost (site lease, backhaul, maintenance) due to the high number of base stations required to cover a given area. Indoor units are comparable in size to a cable modem or DSL modem. Outdoor units are roughly the size of a laptop PC, and their installation is comparable to the installation of a residential satellite dish.

With the potential of mobile WiMAX, there is an increasing focus on portable units. This includes handsets (similar to cellular smartphones), PC peripherals (PC Cards or USB dongles), and embedded devices in laptops, which are now available for Wi-Fi services. In addition, there is much emphasis from operators on consumer electronics devices such as Gaming consoles, MP3 players and similar devices. It is notable that WiMAX is more similar to Wi-Fi than to 3G cellular technologies.

Current certified devices can be found at the WiMAX Forum web site. This is not a complete list of devices available as certified modules are embedded into laptops, MIDs (Mobile internet devices), and private labeled devices.

Mobile handset applications

Sprint Nextel announced in mid-2006 that it would invest about US$ 5 billion in a WiMAX technology buildout over the next few years[7] ($5.29 billion in real terms[8]). Since that time Sprint has faced many setbacks, that have resulted in steep quarterly losses. On May 7, 2008, Sprint Nextel, Google, Intel, Comcast, Bright House, and Time Warner announced a pooling of an average of 120 MHz of spectrum and merged with Clearwire to form a company which will take the name Clear. The new company hopes to benefit from combined services offerings and network resources as a springboard past its competitors. The cable companies will provide media services to other partners while gaining access to the wireless network as a Mobile virtual network operator. Google will contribute Android handset device development and applications and will receive revenue share for advertising and other services they provide. Sprint and Clearwire gain a majority stock ownership in the new venture and ability to access between the new Clear and Sprint 3G networks. Some details remain unclear including how soon and in what form announced multi-mode WiMAX and 3G EV-DO devices will be available. This raises questions that arise for availability of competitive chips that require licensing of Qualcomm's IPR.

HTC currently has a WiMAX device in development. Codenamed, "Supersonic", the HTC A9292 has been deemed considerably sluggish as of January 2010, meaning the device is in early stages of development. The estimated release date is sometime in the second half of 2010.[9]

Some analysts have questioned how the deal will work out: Although fixed-mobile convergence has been a recognized factor in the industry, prior attempts to form partnerships among wireless and cable companies have generally failed to lead to significant benefits to the participants. Other analysts point out that as wireless progresses to higher bandwidth, it inevitably competes more directly with cable and DSL, thrusting competitors into bed together. Also, as wireless broadband networks grow denser and usage habits shift, the need for increased backhaul and media service will accelerate, therefore the opportunity to leverage cable assets is expected to increase.

Backhaul/access network applications

WiMAX is a possible replacement candidate for cellular phone technologies such as GSM and CDMA, or can be used as an overlay to increase capacity. It has also been considered as a wireless backhaul technology for 2G, 3G, and 4G networks in both developed and poor nations.[10][11]

In North America, backhaul for urban cellular operations is typically provided via one or more copper wire line T1 connections, whereas remote cellular operations are sometimes backhauled via satellite. In most other regions, urban and rural backhaul is usually provided by microwave links. (The exception to this is where the network is operated by an incumbent with ready access to the copper network, in which case T1 lines may be used). WiMAX

is a broadband platform and as such has much more substantial backhaul bandwidth requirements than legacy cellular applications. Therefore traditional copper wire line backhaul solutions are not appropriate. Consequently the use of wireless microwave backhaul is on the rise in North America and existing microwave backhaul links in all regions are being upgraded.[12] Capacities of between 34 Mbps and 1 Gbps[*citation needed*] are routinely being deployed with latencies in the order of 1ms. In many cases, operators are aggregating sites using wireless technology and then presenting traffic on to fiber networks where convenient.

Deploying WiMAX in rural areas with limited or no internet backbone will be challenging as additional methods and hardware will be required to procure sufficient bandwidth from the nearest sources — the difficulty being in proportion to the distance between the end-user and the nearest sufficient internet backbone.

Technical information

WiMAX refers to interoperable implementations of the IEEE 802.16 wireless-networks standard, in similarity with Wi-Fi, which refers to interoperable implementations of the IEEE 802.11 Wireless LAN standard.

Illustration of a WiMAX MIMO board

MAC (data link) layer

In Wi-Fi the media access controller (MAC) uses contention access — all subscriber stations that wish to pass data through a wireless access point (AP) are competing for the AP's attention on a random interrupt basis. This can cause subscriber stations distant from the AP to be repeatedly interrupted by closer stations, greatly reducing their throughput.

In contrast, the **802.16** MAC uses a scheduling algorithm for which the subscriber station needs to compete only once (for initial entry into the network). After that it is allocated an access slot by the base station. The time slot can enlarge and contract, but remains assigned to the subscriber station, which means that other subscribers cannot use it. In addition to being stable under overload and over-subscription, the 802.16 scheduling algorithm can also be more bandwidth efficient. The scheduling algorithm also allows the base station to control QoS parameters by balancing the time-slot assignments among the application needs of the subscriber stations.

Physical layer

The original version of the standard on which WiMAX is based (IEEE 802.16) specified a physical layer operating in the 10 to 66 GHz range. 802.16a, updated in 2004 to 802.16-2004, added specifications for the 2 to 11 GHz range. 802.16-2004 was updated by 802.16e-2005 in 2005 and uses scalable orthogonal frequency-division multiple access (SOFDMA) as opposed to the orthogonal frequency-division multiplexing (OFDM) version with 256 sub-carriers (of which 200 are used) in 802.16d. More advanced versions, including 802.16e, also bring multiple antenna support through MIMO. See: WiMAX MIMO. This brings potential benefits in terms of coverage, self installation, power consumption, frequency re-use and bandwidth efficiency. 802.16e also adds a capability for full mobility support. The WiMAX certification allows vendors with 802.16d products to sell their equipment as WiMAX certified, thus ensuring a level of interoperability with other certified products, as long as they fit the same profile.

Most commercial interest is in the 802.16d and 802.16e standards, since the lower frequencies used in these variants suffer less from inherent signal attenuation and therefore give improved range and in-building penetration. Already today, a number of networks throughout the world are in commercial operation using certified WiMAX equipment compliant with the 802.16d standard.

Deployment

As a standard intended to satisfy needs of next-generation data networks (4G), 802.16e is distinguished by its dynamic burst algorithm modulation adaptive to the physical environment the RF signal travels through. Modulation is chosen to be spectroscopically more efficient (more bits per OFDM/SOFDMA symbol). That is, when the bursts have a high signal strength and a carrier to noise plus interference ratio (CINR), they can be more easily decoded using digital signal processing (DSP). In contrast, operating in less favorable environments for RF communication, the system automatically steps down to a more robust mode (burst profile) which means fewer bits per OFDM/SOFDMA symbol; with the advantage that power per bit is higher and therefore simpler accurate signal processing can be performed.

Burst profiles are used inverse (algorithmically dynamic) to low signal attenuation; meaning throughput between clients and the base station is determined largely by distance. Maximum distance is achieved by the use of the most robust burst setting; that is, the profile with the largest MAC frame allocation trade-off requiring more symbols (a larger portion of the MAC frame) to be allocated in transmitting a given amount of data than if the client was closer to the base station.

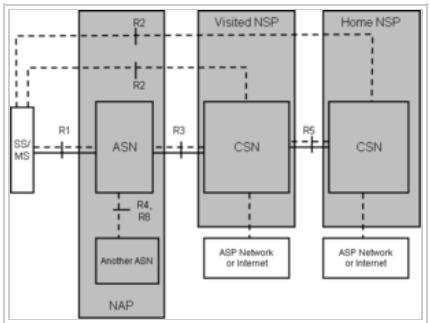
The client's MAC frame and their individual burst profiles are defined as well as the specific time allocation. However, even if this is done automatically then the practical deployment should avoid high interference and multipath environments. The reason for which is obviously that too much interference causes the network function poorly and can also misrepresent the capability of the network.

The system is complex to deploy as it is necessary to track not only the signal strength and CINR (as in systems like GSM) but also how the available frequencies will be dynamically assigned (resulting in dynamic changes to the available bandwidth.) This could lead to cluttered frequencies with slow response times or lost frames.

As a result the system has to be initially designed in consensus with the base station product team to accurately project frequency use, interference, and general product functionality.

Integration with an IP-based network

The WiMAX Forum has proposed an architecture that defines how a WiMAX network can be connected with an IP based core network, which is typically chosen by operators that serve as Internet Service Providers (ISP); Nevertheless the WiMAX BS provide seamless integration capabilities with other types of architectures as with packet switched Mobile Networks.



The WiMAX Forum WiMAX Architecture

The WiMAX forum proposal defines a number of components, plus some of the interconnections (or reference points) between these, labeled R1 to R5 and R8:

- SS/MS: the Subscriber Station/Mobile Station
- ASN: the Access Service Network[13]
- BS: Base station, part of the cSN
- ASN-GW: the ASN Gateway, part of the ASN
- CSN: the Connectivity Service Network
- HA: Home Athourity, part of the CSN
- AAA: Authentication, Authorization and Accounting Server, part of the CSN
- NAP: a Network Access Provider
- NSP: a Network Service Provider

It is important to note that the functional architecture can be designed into various hardware configurations rather than fixed configurations. For example, the architecture is flexible enough to allow remote/mobile stations of varying scale and functionality and Base Stations of varying size - e.g. femto, pico, and mini BS as well as macros.

Comparison with Wi-Fi

Comparisons and confusion between WiMAX and Wi-Fi are frequent because both are related to wireless connectivity and Internet access.

- WiMAX is a long range system, covering many kilometers, that uses licensed or unlicensed spectrum to deliver a point-to-point connection to the Internet.
- Different 802.16 standards provide different types of access, from portable (similar to a cordless phone) to fixed (an alternative to wired access, where the end user's wireless termination point is fixed in location.)
- Wi-Fi uses unlicensed spectrum to provide access to a network.
- Wi-Fi is more popular in end user devices.
- WiMAX and Wi-Fi have quite different quality of service (QoS) mechanisms:
  - WiMAX uses a QoS mechanism based on connections between the base station and the user device. Each connection is based on specific scheduling algorithms.
  - Wi-Fi has a QoS mechanism similar to fixed Ethernet, where packets can receive different priorities based on their tags. For example VoIP traffic may be given priority over web browsing.
- Wi-Fi runs on the Media Access Control's CSMA/CA protocol, which is connectionless and contention based, whereas WiMAX runs a connection-oriented MAC.
- Both 802.11 and 802.16 define Peer-to-Peer (P2P) and ad hoc networks, where an end user communicates to users or servers on another Local Area Network (LAN) using its access point or base station.

Spectrum allocation issues

The 802.16 specification applies across a wide swath of the RF spectrum, and WiMAX could function on any frequency below 66 GHz,[14] (higher frequencies would decrease the range of a Base Station to a few hundred meters in an urban environment).

There is no uniform global licensed spectrum for WiMAX, although the WiMAX Forum has published three licensed spectrum profiles: 2.3 GHz, 2.5 GHz and 3.5 GHz, in an effort to decrease cost: economies of scale dictate that the more WiMAX embedded devices (such as mobile phones and WiMAX-embedded laptops) are produced, the lower the unit cost. (The two highest cost components of producing a mobile phone are the silicon and the extra radio needed for each band.) Similar economy of scale benefits apply to the production of Base Stations.

In the unlicensed band, 5.x GHz is the approved profile. Telecommunication companies are unlikely to use this spectrum widely other than for backhaul, since they do not own and control the spectrum.

In the USA, the biggest segment available is around 2.5 GHz,[15] and is already assigned, primarily to Sprint Nextel and Clearwire. Elsewhere in the world, the most-likely bands used will be the Forum approved ones, with 2.3 GHz probably being most important in Asia. Some countries in Asia like India and Indonesia will use a mix of 2.5 GHz, 3.3 GHz and other frequencies. Pakistan's Wateen Telecom uses 3.5 GHz.

Analog TV bands (700 MHz) may become available for WiMAX usage, but await the complete roll out of digital

TV, and there will be other uses suggested for that spectrum. In the USA the FCC auction for this spectrum began in January 2008 and, as a result, the biggest share of the spectrum went to Verizon Wireless and the next biggest to AT&T.[16] Both of these companies have stated their intention of supporting LTE, a technology which competes directly with WiMAX. EU commissioner Viviane Reding has suggested re-allocation of 500–800 MHz spectrum for wireless communication, including WiMAX.[17]

WiMAX profiles define channel size, TDD/FDD and other necessary attributes in order to have inter-operating products. The current fixed profiles are defined for both TDD and FDD profiles. At this point, all of the mobile profiles are TDD only. The fixed profiles have channel sizes of 3.5 MHz, 5 MHz, 7 MHz and 10 MHz. The mobile profiles are 5 MHz, 8.75 MHz and 10 MHz. (Note: the 802.16 standard allows a far wider variety of channels, but only the above subsets are supported as WiMAX profiles.)

Since October 2007, the Radio communication Sector of the International Telecommunication Union (ITU-R) has decided to include WiMAX technology in the IMT-2000 set of standards.[18] This enables spectrum owners (specifically in the 2.5-2.69 GHz band at this stage) to use Mobile WiMAX equipment in any country that recognizes the IMT-2000.

Spectral efficiency

One of the significant advantages of advanced wireless systems such as WiMAX is spectral efficiency. For example, 802.16-2004 (fixed) has a spectral efficiency of 3.7 (bit/s)/Hertz, and other 3.5–4G wireless systems offer spectral efficiencies that are similar to within a few tenths of a percent. The notable advantage of WiMAX comes from combining SOFDMA with smart antenna technologies. This multiplies the effective spectral efficiency through multiple reuse and smart network deployment topologies. The direct use of frequency domain organization simplifies designs using MIMO-AAS compared to CDMA/WCDMA methods, resulting in more effective systems.

Limitations

A commonly-held misconception is that WiMAX will deliver 70 Mbit/s over 50 kilometers (30 miles). In reality, WiMAX can either operate at higher bitrates or over longer distances but not both: operating at the maximum range of 50 km increases bit error rate and thus results in a much lower bitrate. Conversely, reducing the range (to under 1 km) allows a device to operate at higher bitrates. There are no known examples of WiMAX services being delivered at bit rates over around 40 Mbit/s.

Typically, fixed WiMAX networks have a higher-gain directional antenna installed near the client (customer) which results in greatly increased range and throughput. Mobile WiMAX networks are usually made of indoor "customer-premises equipment" (CPE) such as desktop modems, laptops with integrated Mobile WiMAX or other Mobile WiMAX devices. Mobile WiMAX devices typically have omnidirectional antennae which are of lower-gain compared to directional antennas but are more portable. In current deployments, the throughput may reach 2 Mbit/s symmetric at 10 km with fixed WiMAX and a high gain antenna. It is also important to consider that a throughput of 2 Mbit/s can mean 2 Mbit/s symmetric simultaneously, 1 Mbit/s symmetric or some asymmetric mix (e.g. 0.5 Mbit/s downlink and 1.5 Mbit/s uplink or 1.5 Mbit/s downlink and 0.5 Mbit/s uplink), each of which required slightly different network equipment and configurations. Higher-gain directional antennas can be used with a WiMAX network with range and throughput benefits but the obvious loss of practical mobility.

Like most wireless systems, available bandwidth is shared between users in a given radio sector, so performance could deteriorate in the case of many active users in a single sector. In practice, most users will have a range of 2-3 Mbit/s services and additional radio cards will be added to the base station to increase the number of users that may be served as required.

Because of these limitations, the general consensus is that WiMAX requires various granular and distributed network architectures to be incorporated within the IEEE 802.16 task groups. This includes wireless mesh, grids, network remote station repeaters which can extend networks and connect to backhaul.

Silicon implementations

A critical requirement for the success of a new technology is the availability of low-cost chipsets and silicon implementations.

Mobile WiMAX has a strong silicon ecosystem with a number of specialized companies producing baseband ICs and integrated RFICs for implementing full-featured Mobile WiMAX Subscriber Stations based on the IEEE 802.16e standard. It is notable that most of the major semiconductor companies have not developed WiMAX chipsets of their own and have instead chosen to invest in and/or utilise the well developed products from smaller specialists or start-up suppliers. These companies include but not limited to Beceem, Sequans and PicoChip. The chipsets from these companies are used in the majority of Mobile WiMAX devices.

Intel Corporation is a leader in promoting WiMAX, but has limited its WiMAX chipset development and instead chosen to invest in these specialized companies producing silicon compatible with the various WiMAX deployments throughout the globe.

Standards

The current WiMAX incarnation, Mobile WiMAX, is based upon IEEE Std 802.16e-2005,[19] approved in December 2005. It is a supplement to the IEEE Std 802.16-2004,[20] and so the actual standard is 802.16-2004 as amended by 802.16e-2005 — the specifications need to be read together to understand them.

IEEE Std 802.16-2004 addresses only fixed systems. It replaced IEEE Standards 802.16-2001, 802.16c-2002, and 802.16a-2003.

IEEE 802.16e-2005 improves upon IEEE 802.16-2004 by:

- Adding support for mobility (soft and hard handover between base stations). This is seen as one of the most important aspects of 802.16e-2005, and is the very basis of 'Mobile WiMAX'.
- Scaling of the Fast Fourier transform (FFT) to the channel bandwidth in order to keep the carrier spacing constant across different channel bandwidths (typically 1.25 MHz, 5 MHz, 10 MHz or 20 MHz). Constant carrier spacing results in a higher spectrum efficiency in wide channels, and a cost reduction in narrow channels. Also known as Scalable OFDMA (SOFDMA). Other bands not multiples of 1.25 MHz are defined in the standard, but because the allowed FFT subcarrier numbers are only 128, 512, 1024 and 2048, other frequency bands will not have exactly the same carrier spacing, which might not be optimal for implementations.
- Advanced antenna diversity schemes, and hybrid automatic repeat-request (HARQ)
- Adaptive Antenna Systems (AAS) and MIMO technology
- Denser sub-channelization, thereby improving indoor penetration
- Introducing Turbo Coding and Low-Density Parity Check (LDPC)
- Introducing downlink sub-channelization, allowing administrators to trade coverage for capacity or vice versa
- Fast Fourier transform algorithm
- Adding an extra QoS class for VoIP applications.

802.16d vendors point out that fixed WiMAX offers the benefit of available commercial products and implementations optimized for fixed access. It is a popular standard among alternative service providers and operators in developing areas due to its low cost of deployment and advanced performance in a fixed environment. Fixed WiMAX is also seen as a potential standard for backhaul of wireless base stations such as cellular, or Wi-Fi.

SOFDMA (used in 802.16e-2005) and OFDM256 (802.16d) are not compatible thus equipment will have to be replaced if an operator is to move to the later standard. Intel provides a dual-mode 802.16-2004 802.16-2005 chipset[21] for subscriber units which can be used in the production of dual-mode CPE's for network operators which have an existing OFDM256 investment.

Conformance testing

TTCN-3 test specification language is used for the purposes of specifying conformance tests for WiMAX implementations. The WiMAX test suite is being developed by a Specialist Task Force at ETSI (STF 252).[22]

Associations

WiMAX Forum

The WiMAX Forum is a non profit organization formed to promote the adoption of WiMAX compatible products and services.[23]

A major role for the organization is to certify the interoperability of WiMAX products.[24] Those that pass conformance and interoperability testing achieve the "WiMAX Forum Certified" designation, and can display this mark on their products and marketing materials. Some vendors claim that their equipment is "WiMAX-ready", "WiMAX-compliant", or "pre-WiMAX", if they are not officially WiMAX Forum Certified.

Another role of the WiMAX Forum is to promote the spread of knowledge about WiMAX. In order to do so, it has a certified training program that is currently offered in English and French. It also offers a series of member events and endorses some industry events.

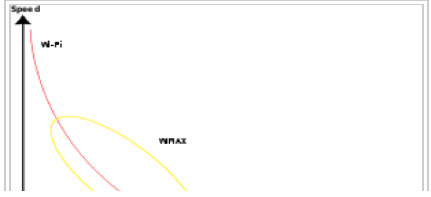
WiMAX Spectrum Owners Alliance

WiSOA was the first global organization composed exclusively of owners of WiMAX spectrum with plans to deploy WiMAX technology in those bands. WiSOA focussed on the regulation, commercialisation, and deployment of WiMAX spectrum in the 2.3–2.5 GHz and the 3.4–3.5 GHz ranges. WiSOA merged with the Wireless Broadband Alliance in April 2008. [25]

WiSOA logo

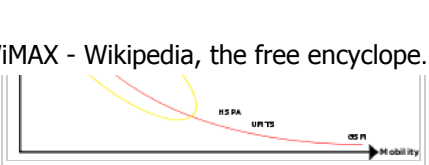
Competing technologies

Within the marketplace, WiMAX's main competition comes from existing, widely deployed wireless systems such as UMTS, CDMA2000 and of course long range mobile Wi-Fi and mesh networking.



3G cellular phone systems usually benefit from already having entrenched infrastructure, having been upgraded from earlier systems. Users can usually fall back to older systems

when they move out of range of upgraded equipment, often relatively seamlessly.



Speed vs. Mobility of wireless systems: Wi-Fi, HSPA, UMTS, GSM

The major cellular standards are being evolved to so-called 4G, high-bandwidth, low-latency, all-IP networks with voice services built on top. The worldwide move to 4G for GSM/UMTS and AMPS/TIA (including CDMA2000) is the 3GPP Long Term Evolution effort. A planned CDMA2000 replacement called Ultra Mobile Broadband has been discontinued. For 4G systems, existing air interfaces are being discarded in favor of OFDMA for the downlink and a variety of OFDM based techniques for the uplink, similar to WiMAX.

In some areas of the world, the wide availability of UMTS and a general desire for standardization has meant spectrum has not been allocated for WiMAX: in July 2005, the EU-wide frequency allocation for WiMAX was blocked.

Harmonization

Early WirelessMAN standards, the European standard HiperMAN and Korean standard WiBro have been harmonized as part of WiMAX and are no longer seen as competition but as complementary. All networks now being deployed in South Korea, the home of the WiBro standard, are now WiMAX.

Comparison

Main article: Comparison of wireless data standards

The following table should be treated with caution because it only shows peak rates which are potentially very misleading. In addition, the comparisons listed are not normalized by physical channel size (i.e., spectrum used to achieve the listed peak rates); this obfuscates spectral efficiency and net through-put capabilities of the different wireless technologies listed below.

Comparison of Mobile Internet Access methods

Standard	Family	Primary Use	Radio Tech	Downlink (Mbit/s)	Uplink (Mbit/s)	Notes
LTE	UMTS/4GSM	General 4G	OFDMA/MIMO/SC-FDMA	360	80	LTE-Advanced update expected to offer peak rates of at least 1 Gbit/s fixed speedsa and 100 Mbit/s to mobile users.
WiMAX	802.16e	Mobile Internet	MIMO-SOFDMA	144	35	WiMAX update IEEE 802.16m expected offer up to 1 Gbit/s fixed speeds.
Flash-OFDM	Flash-OFDM	Mobile Internet mobility up to 200mph (350km/h)	Flash-OFDM	5.3 10.6 15.9	1.8 3.6 5.4	Mobile range 18miles (30km) extended range 34 miles (55km)
HIPERMAN	HIPERMAN	Mobile Internet	OFDM	56.9	56.9	
Wi-Fi	802.11 (11n)	Mobile Internet	OFDM/MIMO	288.9 (Supports 600Mbps @ 40MHz channel width)		Antenna, RF front end enhancements and minor protocol timer tweaks have helped deploy long range P2P networks compromising on radial coverage, throughput and/or spectra efficiency (310km (http://www.alvarion.com/presscenter/pressreleases/3263/) & 382km (http://www.eslared.org.ve/articulos/Long%20Distance%20WiFi%20Trial.pdf)).
iBurst	802.20	Mobile Internet	HC-SDMA/TDD/MIMO	95	36	Cell Radius: 3–12 km Speed: 250kmph Spectral Efficiency: 13 bits/s/Hz/cell Spectrum Reuse Factor: "1"
EDGE Evolution	GSM	Mobile Internet	TDMA/FDD	1.9	0.9	3GPP Release 7
UMTS W-CDMA HSDPA+HSUPA HSPA+	UMTS/3GSM	General 3G	CDMA/FDD CDMA/FDD/MIMO	0.384 14.4 42	0.384 5.76 11.5	HSDPA widely deployed. Typical downlink rates today 2 Mbit/s, ~200 kbit/s uplink; HSPA+ downlink up to 42 Mbit/s.
UMTS-TDD	UMTS/3GSM	Mobile Internet	CDMA/TDD	16	16	Reported speeds according to IPWireless (http://www.ipwireless.com/technology/) using 16QAM modulation similar to HSDPA+HSUPA
1xRTT	CDMA2000	Mobile phone	CDMA	0.144	0.144	Succeeded by EV-DO
EV-DO 1x Rev. 0 EV-DO 1x Rev.A EV-DO Rev.B	CDMA2000	Mobile Internet	CDMA/FDD	2.45 3.1 4.9xN	0.15 1.8 1.8xN	Rev B note: N is the number of 1.25 MHz chunks of spectrum used. Not yet deployed.

Notes: All speeds are theoretical maximums and will vary by a number of factors, including the use of external antennae, distance from the tower and the ground speed (e.g. communications on a train may be poorer than when standing still). Usually the bandwidth is shared between several terminals. The performance of each technology is determined by a number of constraints, including the spectral efficiency of the technology, the cell sizes used, and the amount of spectrum available. For more information, see *Comparison of wireless data standards*. See also Comparison of mobile phone standards, Spectral efficiency comparison table and OFDM system comparison table.

LTE is expected to be ratified at the end of 2008, with commercial implementations becoming viable within the next two years.

Future development

The IEEE 802.16m [1] (http://www.networkworld.com/news/2010/012810-wimax-2.html?hpg1=bn) standard is the core technology for the proposed Mobile WiMAX Release 2, which enables more efficient, faster, and more converged data communications. The IEEE 802.16m standard has been submitted to the ITU for IMT-Advanced standardization[26]. IEEE 802.16m is one of the major candidates for IMT-Advanced technologies by ITU. Among many enhancements, IEEE 802.16m systems can provide four times faster data speed than the current Mobile WiMAX Release 1 based on IEEE 802.16e technology.

Mobile WiMAX Release 2 will provide strong backward compatibility with Release 1 solutions. It will allow current Mobile WiMAX operators to migrate their Release 1 solutions to Release 2 by upgrading channel cards or software of their systems. Also, the subscribers who use currently available Mobile WiMAX devices can communicate with new Mobile WiMAX Release 2 systems without difficulty.

It is anticipated that in a practical deployment, using 4X2 MIMO in the urban microcell scenario with only a single 20-MHz TDD channel available system wide, the 802.16m system can support both 120 Mbit/s downlink and 60 Mbit/s uplink per site simultaneously. It is expected that the WiMAX Release 2 will be available commercially in the 2011-2012 timeframe[27].

The goal for the long-term evolution of WiMAX is to achieve 100 Mbit/s mobile and 1 Gbit/s fixed-nomadic bandwidth as set by ITU for 4G NGMN (Next Generation Mobile Network).

Interference

A field test conducted by SUIRG (Satellite Users Interference Reduction Group) with support from the U.S. Navy, the Global VSAT Forum, and several member organizations yielded results showing interference at 12 km when using the same channels for both the WiMAX systems and satellites in C-band.[28] The WiMAX Forum has yet to respond.

Deployments

Main article: List of deployed WiMAX networks

As of October 2009, the WiMAX Forum claims there are over 500 WiMAX (fixed and mobile) networks deployed in over 145 countries[29].

Dangers

WiMAX testing in Sweden led to a massive negative physical response by the population. As reported in GQ magazine by Christopher Ketchum:

"In the summer of 2006, a super-Wi-Fi system known as WiMAX was tested in rural Sweden. Bombarded with signals, the residents of the village of Götene—who had no knowledge that the transmitter had come online—were overcome by headaches, difficulty breathing, and blurred vision, according to a Swedish news report. Two residents reported to the hospital with heart arrhythmias, similar to those that, more than thirty years ago, Allen Frey induced in frog hearts. This happened only hours after the system was turned on, and as soon as it was powered down, the symptoms disappeared" (Ketchum, Christopher."Warning Your Cellphone Might Be Hazardous to Your Health." GQ, Feb. 2010. Retrieved on Feb 10, 2010)[30].

See also

- Customer-premises equipment
- Evolved HSPA
- High-Speed Packet Access (HSPA)
- List of deployed WiMAX networks
- Mobile broadband
- Mobile VoIP
- Municipal broadband
- Packet Burst Broadband (PBB)
- Switched mesh

- WiBro
- Wireless bridge
- Wireless broadband
- Wireless local loop

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External links

- WiMAX Forum (http://www.wimaxforum.org/home)
- How WiMAX Works (http://www.howstuffworks.com/wimax1.htm) at HowStuffWorks
- Patent alliance formed for WiMAX 4G technology (http://www.eetimes.eu/208403034)
- WiMAX.com (http://www.wimax.com)

Internet access								
Network type	**Wired**					**Wireless**		
	Optical	**Coaxial cable**	**Twisted pair**	**Phone line**	**Power line**	**Unlicensed terrestrial bands**	**Licensed terrestrial bands**	**Satellite**
LAN	Ethernet	G.hn	Ethernet	HomePNA · G.hn	G.hn	Wi-Fi · Bluetooth · DECT · Wireless USB		
WAN	PON · Ethernet	DOCSIS	Ethernet	Dial-up · ISDN · DSL	BPL	Muni Wi-Fi	GPRS · iBurst · WiBro/**WiMAX** · UMTS-TDD, HSPA · EVDO · LTE	Satellite