IEEE 802.11

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IEEE 802.11 is a set of standards for wireless local area network (WLAN) computer communication, developed by the IEEE LAN/MAN Standards Committee (IEEE 802) in the 5 GHz and 2.4 GHz public spectrum bands.

Although the terms 802.11 and Wi-Fi are often used interchangeably, the Wi-Fi Alliance uses the term "Wi-Fi" to define a slightly different set of overlapping standards. In some cases, market demand has led the Wi-Fi Alliance to begin certifying products before amendments to the 802.11 standard are complete.

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The five-layer TCP/IP model

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General description

The 802.11 family includes over-the-air modulation techniques that use the same basic protocol. The most popular are those defined by the 802.11b and 802.11g protocols, and are amendments to the original standard. 802.11a was the first wireless networking standard, but 802.11b was the first widely accepted one, followed by 802.11g and 802.11n. Security was originally purposefully weak due to export requirements of some governments, [1] and was later enhanced via the 802.11i amendment after governmental and legislative changes. 802.11n is a new multi-streaming modulation technique that is still under draft development, but products based on its proprietary pre-draft versions are being sold. Other standards in the family (c–f, h, j) are service amendments and extensions or corrections to previous specifications.

A Linksys Residential gateway with an 802.11b radio and a 4-port ethernet switch.

A Compaq 802.11b PCI card

802.11b and 802.11g use the 2.4 GHz ISM band, operating in the United States under Part 15 of the US Federal Communications Commission Rules and Regulations. Because of this choice of frequency band, 802.11b and g equipment may occasionally suffer interference from microwave ovens and cordless telephones. Bluetooth devices, while operating in the same band, in theory do not interfere with 802.11b/g because they use a frequency hopping spread spectrum signaling method (FHSS) while 802.11b/g uses a direct sequence spread spectrum signaling method (DSSS). 802.11a uses the 5 GHz U-NII band, which offers 8 non-overlapping channels rather than the 3 offered in the 2.4GHz ISM frequency band.

The segment of the radio frequency spectrum used varies between countries. In the US, 802.11a and 802.11g devices may be operated without a license, as explained in Part 15 of the FCC Rules and Regulations. Frequencies used by channels one through six (802.11b) fall within the 2.4 GHz amateur radio band. Licensed amateur radio operators may operate 802.11b/g devices under Part 97 of the FCC Rules and Regulations, allowing increased power output but not commercial content or encryption. [2]

Protocols

Summary

Protocol	Release Date	Op. Frequency	Throughput (Typ)	Data Rate (Max)	Modulation Technique	Range (Radius Indoor) Depends, # and type of walls	Range (Radius Outdoor) Loss includes one wall

Legacy	1997	2.4 GHz	0.9 Mbit/s	2 Mbit/s		~20 Meters	~100 Meters
802.11a	1999	5 GHz	23 Mbit/s	54 Mbit/s	OFDM	~35 Meters	~120 Meters
802.11b	1999	2.4 GHz	4.3 Mbit/s	11 Mbit/s	DSSS	~38 Meters	~140 Meters
802.11g	2003	2.4 GHz	19 Mbit/s	54 Mbit/s	OFDM	~38 Meters	~140 Meters
802.11n	June 2009[4] (est.)	2.4 GHz 5 GHz	74 Mbit/s	248 Mbit/s		~70 Meters	~250 Meters
802.11y	June 2008[4] (est.)	3.7 GHz	23 Mbit/s	54 Mbit/s		~50 Meters	~5000 Meters

802.11-1997 (802.11 legacy)

The original version of the standard IEEE 802.11, released in 1997 and clarified in 1999, specified two raw data rates of 1 and 2 megabits per second (Mbit/s) to be transmitted in Industrial Scientific Medical frequency band at 2.4 GHz.

Legacy 802.11 was rapidly supplemented (and popularized) by 802.11b.

802.11a

Release Date	Op. Frequency	Data Rate (Typ)	Data Rate (Max)	Range (Indoor)
October 1999	5 GHz	23 Mbit/s	54 Mbit/s	~35 m

The 802.11a standard uses the same core protocol as the original standard, operates in 5 GHz band with a maximum raw data rate of 54 Mbit/s, which yields realistic net achievable throughput in the mid-20 Mbit/s.

Since the 2.4 GHz band is heavily used to the point of being crowded, using the relatively un-used 5 GHz band gives 802.11a a significant advantage. However, this high carrier frequency also brings a slight disadvantage: The effective overall range of 802.11a is slightly less than that of 802.11b/g; 802.11a signals cannot penetrate as far as those for 802.11b because they are absorbed more readily by walls and other solid objects in their path.

802.11b

Release Date	Op. Frequency	Data Rate (Typ)	Data Rate (Max)	Range (Indoor)
October 1999	2.4 GHz	4.5 Mbit/s	11 Mbit/s	~35 m

802.11b has a maximum raw data rate of 11 Mbit/s and uses the same media access method defined in the original standard. 802.11b products appeared on the market in early 2000, since 802.11b is a direct extension of the modulation technique defined in the original standard. The dramatic increase in throughput of 802.11b (compared to the original standard) along with simultaneous substantial price reductions led to the rapid acceptance of 802.11b as the definitive wireless LAN technology.

802.11b devices suffer interference from other products operating in the 2.4 GHz band. Devices operating in the 2.4 GHz range include: microwave ovens, Bluetooth devices, baby monitors and cordless telephones.

802.11g

Release Date	Op. Frequency	Data Rate (Typ)	Data Rate (Max)	Range (Indoor)
June 2003	2.4 GHz	19 Mbit/s	54 Mbit/s	~35 m

In June 2003, a third modulation standard was ratified: 802.11g. This works in the 2.4 GHz band (like 802.11b) but operates at a maximum raw data rate of 54 Mbit/s, or about 19 Mbit/s net throughput. 802.11g hardware is fully backwards compatible with 802.11b hardware.

The then-proposed 802.11g standard was rapidly adopted by consumers starting in January 2003, well before ratification, due to the desire for higher speeds, and reductions in manufacturing costs. By summer 2003, most dual-band 802.11a/b products became dual-band/tri-mode, supporting a and b/g in a single mobile adapter card or access point. Details of making b and g work well together occupied much of the lingering technical process; in an 802.11g network, however, activity by a 802.11b participant will reduce the speed of the overall 802.11g network.

Like 802.11b, 802.11g devices suffer interference from other products operating in the 2.4 GHz band. Devices operating in the 2.4 GHz range include: microwave ovens, Bluetooth devices, baby monitors and cordless telephones.

802.11-2007

In 2003, task group TGma was authorized to "roll up" many of the amendments to the 1999 version of the 802.11 standard. REVma or 802.11ma, as it was called, created a single document that merged 8 amendments (802.11a,b,d,e,g,h,i,j) with the base standard. Upon approval on March 08, 2007, 802.11REVma was renamed to the current standard **IEEE 802.11-2007**.[3] This is the single most modern 802.11 document available that contains cumulative changes from multiple sub-letter task groups.

802.11n

Release Date	Op. Frequency	Data Rate (Typ)	Data Rate (Max)	Range (Indoor)
June 2009 (est.)	5 GHz and/or 2.4 GHz	74 Mbit/s	248 Mbit/s (2 streams)	~70 m

802.11n is a proposed amendment which improves upon the previous 802.11 standards by adding multiple-input multiple-output (MIMO) and many other newer features. Though there are already many products on the market based on Draft 2.0 of this proposal, the TGn workgroup is not expected to finalize the amendment until November 2008. [4]

Channels and international compatibility

See also: Wi-Fi Technical Information

802.11 divides each of the above-described bands into channels, analogously to how radio and TV broadcast bands are carved up but with greater channel width and overlap. For example the 2.4-2.4835 GHz band is divided into 13 channels each of width 22 MHz but spaced only 5 MHz apart, with channel 1 centered on 2412 MHz and 13 on 2472, to which Japan adds a 14th channel 12 MHz above channel 13.

Availability of channels is regulated by country, constrained in part by how each country allocates radio spectrum to various services. At one extreme Japan permits the use of all 14 channels (with the exclusion of 802.11g/n from channel 14), while at the other Spain allows only channels 10 and 11, to which France adds 12 and 13. Most other European countries are almost as liberal as Japan, disallowing only channel 14, while North America and some Central and South American countries further disallow 12 and 13. *For more details on this topic, see List of WLAN channels.*

Besides specifying the center frequency of each channel, 802.11 also specifies (in Clause 17) a spectral mask defining the permitted distribution of power across each channel. The mask requires that the signal be attenuated by at least 30 dB from its peak energy at ± 11 MHz from the center frequency, the sense in which channels are effectively 22 MHz wide. One consequence is that stations can only use every fourth or fifth channel, typically 1, 6 and 11 in the Americas, 1, 5, 9 and 13 in Europe, etc. Another is that channels 1-13 effectively require the band 2401-2483 MHz, the actual allocations being for example 2400-2483.5 in the UK, 2402-2483.5 in the US, etc.

Since the spectral mask only defines power output restrictions up to ± 22 MHz from the center frequency to be attenuated by 50 dB, it is often assumed that the energy of the channel extends no further than these limits. It is more correct to say that, given the separation between channels 1, 6, and 11, the signal on any channel should be sufficiently attenuated to minimally interfere with a transmitter on any other channel. Due to the near-far problem a transmitter can impact a receiver on a "non-overlapping" channel, but only if it is close to the victim receiver (within a meter) or operating above allowed power levels.

Although the statement that channels 1, 6, and 11 are "non-overlapping" is limited to a spacing or product density, the 1–6–11 guideline has merit. If transmitters are closer together than channels 1, 6, and 11 (for example, 1, 4, 7, and 10), overlap between the channels may cause unacceptable degradation of signal quality and throughput. [5]

Standard and amendments

Within the IEEE 802.11 Working Group,[4] the following IEEE Standards Association Standard and Amendments exist:

- IEEE 802.11 - THE WLAN STANDARD was original 1 Mbit/s and 2 Mbit/s, 2.4 GHz RF and IR standard (1997), all the others listed below are Amendments to this standard, except for Recommended Practices 802.11F and 802.11T.
- IEEE 802.11a - 54 Mbit/s, 5 GHz standard (1999, shipping products in 2001)
- IEEE 802.11b - Enhancements to 802.11 to support 5.5 and 11 Mbit/s (1999)
- IEEE 802.11c - Bridge operation procedures; included in the IEEE 802.1D standard (2001)
- IEEE 802.11d - International (country-to-country) roaming extensions (2001)
- IEEE 802.11e - Enhancements: QoS, including packet bursting (2005)
- *IEEE 802.11F - Inter-Access Point Protocol (2003) Withdrawn February 2006*
- IEEE 802.11g - 54 Mbit/s, 2.4 GHz standard (backwards compatible with b) (2003)
- IEEE 802.11h - Spectrum Managed 802.11a (5 GHz) for European compatibility (2004)
- IEEE 802.11i - Enhanced security (2004)
- IEEE 802.11j - Extensions for Japan (2004)
- IEEE 802.11-2007 - A new release of the standard that includes amendments a, b, d, e, g, h, i & j. (July 2007)
- IEEE 802.11k - Radio resource measurement enhancements (proposed - 2007?)
- IEEE 802.11l - (reserved and will not be used)
- IEEE 802.11m - Maintenance of the standard. Recent edits became 802.11-2007. (ongoing)
- IEEE 802.11n - Higher throughput improvements using MIMO (multiple input, multiple output antennas) (September 2008)
- IEEE 802.11o - (reserved and will not be used)
- IEEE 802.11p - WAVE - Wireless Access for the Vehicular Environment (such as ambulances and passenger cars) (working - 2009?)
- IEEE 802.11q - (reserved and will not be used, can be confused with 802.1Q VLAN trunking)
- IEEE 802.11r - Fast roaming Working "Task Group r" - 2007?
- IEEE 802.11s - ESS Extended Service Set Mesh Networking (working - 2008?)
- IEEE 802.11T - Wireless Performance Prediction (WPP) - test methods and metrics Recommendation (working - 2008?)
- IEEE 802.11u - Interworking with non-802 networks (for example, cellular) (proposal evaluation - ?)
- IEEE 802.11v - Wireless network management (early proposal stages - ?)
- IEEE 802.11w - Protected Management Frames (early proposal stages - 2008?)
- IEEE 802.11x - (reserved and will not be used, can be confused with 802.1x Network Access Control)
- IEEE 802.11y - 3650-3700 MHz Operation in the U.S. (March 2008?)
- IEEE 802.11z - Extensions to Direct Link Setup (DLS) (Aug. 2007 - Dec. 2011)

There is no standard or task group named "802.11x". Rather, this term is used informally to denote any current or future 802.11 amendment, in cases where further precision is not necessary. (The IEEE 802.1x standard for port-based network access control is often mistakenly called "802.11x" when used in the context of wireless networks.)

802.11F and 802.11T are recommended practices rather than standards, and are capitalized as such.

Standard or amendment?

Both the terms "standard" and "amendment" are used when referring to the different variants of **IEEE 802.11**. Which is correct?

As far as the IEEE Standards Association is concerned, there is only one current standard, it is denoted by- **IEEE 802.11** followed by the date that it was published. IEEE 802.11-2007 is the only version currently in publication. The standard is updated by means of amendments. Amendments are created by task groups (TG). Both the task group and their finished document are denoted by 802.11 followed by a non-capitalized letter. For example IEEE 802.11a and IEEE 802.11b. Updating 802.11 is the responsibility of task group m. In order to create a new version, TGm combines the previous version of the standard and all published amendments. TGm also provides clarification and interpretation to industry on published documents. New versions of the **IEEE 802.11** were published in 1999 and 2007.

The working title of 802.11-2007 was 802.11-REVma. This denotes a third type of document, a "revision". The complexity of combining 802.11-1999 with 8 amendments made it necessary to revise already agreed upon text. As a result, additional guidelines associated with a revision had to be followed.

Nomenclature

Various terms in 802.11 are used to specify aspects of wireless local-area networking operation, and may be unfamiliar to some readers.

For example, Time Unit (usually abbreviated TU) is used to indicate a unit of time equal to 1024 microseconds. Numerous time constants are defined in terms of TU (rather than the nearly-equal millisecond).

Also the term "Portal" is used to describe an entity that is similar to an IEEE 802.1D bridge. A Portal provides access to the WLAN by non-802.11 LAN STAs.

Community networks

With the proliferation of cable modems and DSL, there is an ever-increasing market of people who wish to establish small networks in their homes to share their high speed Internet connection.

Many hotspot or free networks frequently allow anyone within range, including passersby outside, to connect to the Internet. There are also efforts by volunteer groups to establish wireless community networks to provide free wireless connectivity to the public.

Security

In 2001, a group from the University of California, Berkeley presented a paper describing weaknesses in the 802.11 Wired Equivalent Privacy (WEP) security mechanism defined in the original standard; they were followed by Fluhrer, Mantin, and Shamir's paper entitled "Weaknesses in the Key Scheduling Algorithm of RC4". Not long after, Adam Stubblefield and AT&T publicly announced the first verification of the attack. In the attack they were able to intercept transmissions and gain unauthorized

access to wireless networks.

The IEEE set up a dedicated task group to create a replacement security solution, 802.11i (previously this work was handled as part of a broader 802.11e effort to enhance the MAC layer). The Wi-Fi Alliance announced an interim specification called Wi-Fi Protected Access (WPA) based on a subset of the then current IEEE 802.11i draft. These started to appear in products in mid-2003. IEEE 802.11i (also known as WPA2) itself was ratified in June 2004, and uses government strength encryption in the Advanced Encryption Standard AES, instead of RC4, which was used in WEP. The modern recommended encryption for the home/consumer space is WPA2 (AES PreShared Key) and for the Enterprise space is WPA2 along with a radius server the strongest is EAP-TLS.

In January 2005, IEEE set up yet another task group TGw to protect management and broadcast frames, which previously were sent unsecured. See IEEE 802.11w

Non-standard 802.11 extensions and equipment

Many companies implement wireless networking equipment with non-IEEE standard 802.11 extensions either by implementing proprietary or draft features. These changes may lead to incompatibilities between these extensions.

> *For more details on this topic, see 802.11 non-standard equipment.*

See also

- Bluetooth, another wireless protocol primarily designed for shorter range applications.
- Ultra-wideband
- Wibree
- Spectral efficiency comparison table
- IEEE 802.15
- IEEE 802.16 (aka WiMAX)
- IEEE 802.20
- IEEE 802.22
- List of device bandwidths
- Wi-Fi Alliance

External links

- IEEE 802.11 working group (http://www.ieee802.org/11/)
- Download the 802.11 standards from IEEE (http://standards.ieee.org/getieee802/802.11.html)
- Official IEEE 802.11 Work Plan predictions (http://grouper.ieee.org/groups/802/11/Reports/802.11_Timelines.htm)
- "Using the Fluhrer, Mantin, and Shamir Attack to Break WEP" (2001) (http://ftp.die.net/mirror/papers/802.11/wep_attack.pdf) , paper by Stubblefield (PDF)
- 802.11n: Next-Generation Wireless LAN Technology (http://www.broadcom.com/docs/WLAN/802_11n-WP100-R.pdf) , paper by Broadcom

References

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2. ^ ARRLWeb: Part 97 - Amateur Radio Service (http://www.arrl.org/FandES/field/regulations/news/part97/) . American Radio Relay League.
3. ^ IEEE 802.11 Working Group (2007-06-12). *IEEE 802.11-2007: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications*. ISBN 0-7381-5656-9.
4. ^ ***a b c d*** Official IEEE 802.11 working group project timelines (http://grouper.ieee.org/groups/802/11/Reports/802.11_Timelines.htm) (2007-11-15). Retrieved on 2007-11-18.
5. ^ Channel Deployment Issues for 2.4 GHz 802.11 WLANs (http://www.cisco.com/en/US/products/hw/wireless/ps430/prod_technical_reference09186a00802846a2.html) . Cisco Systems, Inc. Retrieved on 2007-02-07.

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