Exhibit 1024

The History of WiFi: 1971 to Today

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The History of WiFi

The history of Wi-Fi is long and interesting. In 1971, ALOHAnet connected the Hawaiian Islands with a UHF wireless packet network. ALOHAnet and the ALOHA protocol were early forerunners to Ethernet, and later the IEEE 802.11 protocols, respectively.

Vic Hayes is often regarded as the "father of Wi-Fi" He started work with in 1974 when he joined NCR Corp., now part of semiconductor components maker Agere Systems.

A 1985 ruling by the U.S. Federal Communications Commission released the ISM band for unlicensed use – these are frequencies in the 2.4GHz band. These frequency bands are the same ones used by equipment such as microwave ovens and are subject to interference.

In 1991, NCR Corporation with AT&T Corporation invented the precursor to 802.11, intended for use in cashier systems. The first wireless products were under the name WaveLAN. They are the ones credited with inventing Wi-Fi.

The Australian radio-astronomer John O'Sullivan with his colleagues Terence Percival, Graham Daniels, Diet Ostry, John Deane developed a key patent used in Wi-Fi as a by-product of a Commonwealth Scientific and Industrial Research Organisation (CSIRO) research project, "a failed experiment to detect exploding mini-black holes the size of an atomic particle".

In 1992 and 1996, CSIRO obtained patents for a method later used in Wi-Fi to "unmeer" the signal.

The first version of the 802.11 protocol was released in 1997, and provided up to 2 Mbits link speeds. This was updated in 1999 with 802.11b to permit 11 Mbit/s link speeds, and this proved to be popular.

The WiFi Brand and Trademark

In 1999, the Wi-Fi Alliance formed as a trade association to hold the Wi-Fi trademark under which most products are sold. The name Wi-Fi, commercially used at least as early as August 1999, was coined by the brand-consulting firm Interbrand. The Wi-Fi Alliance had hired Interbrand to create a name that was "a little catchier than IEEE 802.11b Direct Sequence." Phil Belanger, a founding member of the Wi-Fi Alliance who presided over the selection of the name "Wi-Fi", has stated that Interbrand invented Wi-Fi as a pun upon the word hi-fi. Interbrand also created the Wi-Fi logo.

WiFi Logo

The yin-yang Wi-Fi logo indicates the certification of a product for interoperability.

WiFi Standards and Development History

802.11-1997 (802.11 legacy)

The original version of the standard IEEE 802.11 was released in 1997 and clarified in 1999, but is now obsolete. It specified two net bit rates of 1 or 2 megabits per second (Mbit/s), plus forward error correction and specified three alternative physical layer technologies: diffuse infrared operating at 1 Mbit/s; frequency-hopping spread spectrum operating at 1 Mbit/s or 2 Mbit/s; and direct-sequence spread spectrum operating at 1 Mbit/s or 2 Mbit/s. The latter two radio technologies used microwave transmission over the Industrial Scientific Medical frequency band at 2.4 GHz. Some earlier WLAN technologies used lower frequencies, such as the U.S. 900 MHz ISM band.

802.11b (1999)

The 802.11b standard 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.

Devices using 802.11b experience 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, cordless telephones, and some amateur radio equipment.

802.11a (2012, OFDM waveform)

Originally described as clause 17 of the 1999 specification, the OFDM waveform at 5.8 GHz is now defined in clause 18 of the 2012 specification, and provides protocols that allow transmission and reception of data at rates of 1.5 to 54 Mbit/s. It has seen widespread worldwide implementation, particularly within the corporate workspace. While the original amendment is no longer valid, the term 802.11a is still used by wireless access point (cards and routers) manufacturers to describe interoperability of their systems at 5 GHz, 54 Mbit/s.

The 802.11a standard uses the same data link layer protocol and frame format as the original standard, but an OFDM based air interface (physical layer). It operates in the 5 GHz band with a maximum net data rate of 54 Mbit/s, plus error correction code, 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 unused 5 GHz band gives 802.11a a significant advantage. However, this high carrier frequency also brings a disadvantage: the effective overall range of 802.11a is less than that of 802.11b/g. In theory, 802.11a signals are absorbed more readily by walls and other solid objects in their path due to their smaller wavelength, and, as a result, cannot penetrate as far as those of 802.11b. In practice, 802.11b typically has a higher range at low speeds (802.11b will reduce speed to 5.5 Mbit/s or even 1 Mbit/s at low signal strength). 802.11a also suffers from interference, but locally there may be fewer signals to interfere with, resulting in less interference and better throughput.

802.11g (2003)

In June 2003, a third modulation standard was ratified: 802.11g. This works in the 2.4 GHz band (like 802.11b), but uses the same OFDM based transmission scheme as 802.11a. It operates at a maximum physical layer bit rate of 54 Mbit/s exclusive of forward error correction codes, or about 22 Mbit/s average throughput.

802.11g hardware is fully backward compatible with 802.11b hardware, and therefore is encumbered with legacy issues that reduce throughput by ~21% when compared to 802.11a.

The then-proposed 802.11g standard was rapidly adopted in the market starting in January 2003, well before ratification, due to the desire for higher data rates as well as to reductions in manufacturing costs. By summer 2003, most dual-band 802.11a/b products became dual-band/bi-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 of an 802.11b participant will reduce the data rate of the overall 802.11g network.

Like 802.11b, 802.11g devices suffer interference from other products operating in the 2.4 GHz band, for example wireless keyboards.

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 8, 2007, 802.11REVma was renamed to the then-current base standard IEEE 802.11-2007.

802.11n (2009)

802.11n is an amendment that improves upon the previous 802.11 standards by adding multiple-input multiple-output antennas (MIMO). 802.11n operates on both the 2.4 GHz and the 5 GHz bands. Support for 5 GHz bands is optional. It operates at a maximum net data rate from 54 Mbit/s to 600 Mbit/s. The IEEE has approved the amendment, and it was published in October 2009.

802.11 (2012)

In May 2007, task group TGmb was authorized to "roll up" many of the amendments to the 2007 version of the 802.11 standard. REVmb or 802.11mb, as it was called, created a single document that merged ten amendments (802.11k, r, y, n, w, p, z, v, u, s) with the 2007 base standard. In addition much cleanup was done, including a reordering of many of the clauses. Upon publication on March 29, 2012, the new standard was referred to as IEEE 802.11-2012.

802.11ac (2013)

IEEE 802.11ac-2013 is an amendment to IEEE 802.11, published in December 2013. It builds on 802.11n, changes in relation to 802.11n include wider channels (80 or 160 MHz versus 40 MHz) in the 5 GHz band, more spatial streams (up to eight versus four), higher-order modulation (up to 256-QAM vs. 64-QAM), and the addition of Multi-user MIMO (MU-MIMO). 802.11ac broadcast data is sent to only one station at a time, but with more channels, three spatial streams, and 256-QAM, yielding a data rate of up to 433.3 Mbit/s per spatial stream, 1300 Mbit/s total, in 80 MHz channels in the 5 GHz band.

Vendors have announced plans to release so-called "Wave 2" devices with support for 160 MHz channels, four spatial streams, and MU-MIMO in 2014 and 2015.

802.11ad (2010)

IEEE 802.11ad is an amendment that defines a new physical layer for 802.11 networks to operate in the 60 GHz millimeter wave spectrum. This frequency band has significantly different propagation characteristics than the 2.4 GHz and 5 GHz bands where Wi-Fi networks operate. Products implementing the 802.11ad standard are being brought to market under the WiGig brand name. The certification program is now being developed by the Wi-Fi Alliance instead of the now defunct WiGig Alliance. The peak transmission rate of 802.11ad is 7 Gbit/s.

802.11af (2014)

IEEE 802.11af, also referred to as "White-Fi" and "Super Wi-Fi" is an amendment, approved in February 2014, that allows WLAN operation in TV white space spectrum in the VHF and UHF bands between 54 and 790 MHz.

It uses cognitive radio technology to transmit on unused TV channels, with the standard taking measures to limit interference for primary users, such as analog TV, digital TV, and wireless microphones.

Access points and stations determine their position using a satellite positioning system such as GPS, and use the Internet to query a geolocation database (GDB) provided by a regional regulatory agency to discover what frequency channels are available for use at a given time and position. The physical layer uses OFDM and is based on 802.11ac.

The propagation path loss as well as the attenuation by materials such as brick and concrete is lower in the UHF and VHF bands than in the 2.4 and 5 GHz bands, which increases the possible range. The frequency channels are 6 to 8 MHz wide, depending on the regulatory domain. Up to four channels may be bonded in either one or two contiguous blocks.

MIMO operation is possible with up to four streams used for either space-time block code (STBC) or multi-user (MU) operation. The achievable data rate per spatial stream is 26.7 Mbit/s for 6 and 7 MHz channels, and 35.6 Mbit/s for 8 MHz channels. With four spatial streams and four bonded channels, the maximum data rate is 426.7 Mbit/s for 6 and 7 MHz channels and 568.3 Mbit/s for 8 MHz channels.

Future WiFi enhancements and upgrades:

802.11ah

IEEE 802.11ah defines a WLAN system operating at sub-1 GHz license-exempt bands, with final approval slated for September 2016.

Due to the favorable propagation characteristics of the low frequency spectra, 802.11ah can provide improved transmission range compared with the conventional 802.11 WLANs operating in the 2.4 GHz and 5 GHz bands. 802.11ah can be used for various purposes including large scale sensor networks, extended range hotspot, and outdoor Wi-Fi for cellular traffic offloading, whereas the available bandwidth is relatively narrow. The protocol intends consumption to be competitive with low power Bluetooth, at a much wider range.

802.11ai

IEEE 802.11ai is an amendment to the 802.11 standard that will add new mechanisms for a faster initial link setup time.

802.11aj

IEEE 802.11aj is a rebanding of 802.11ad for use in the 45 GHz unlicensed spectrum available in some regions of the world (specifically China).

802.11aq

IEEE 802.11aq is an amendment to the 802.11 standard that will enable pre-association discovery of services. This extends some of the mechanisms in 802.11u that enabled device discovery to further discover the services running on a device, or provided by a network.

802.11ax

IEEE 802.11ax is the successor to 802.11ac, and will increase the efficiency of WLAN networks. Currently in development, this project has the goal of providing 4x the throughput of 802.11ac.

802.11ay

IEEE 802.11ay is a standard that is being developed. It is an amendment that defines a new physical layer for 802.11 networks to operate in the 60 GHz millimeter wave spectrum. It will be an extension of the existing 11ad, aimed to extend the throughput, range and use-cases. The main use-cases include: indoor operation, sub-door back-haul and short range communications. The peak transmission rate of 802.11ay is 20 Gbit/s. The main extensions include: channel bonding (2, 3 and 4), MIMO and higher modulation schemes.

802.11-2016

IEEE 802.11-2016 is a revision based on IEEE 802.11-2012, incorporating 5 amendments (11aa, 11ae, 11ad, 11ac, 11af). In addition, existing MAC and PHY functions have been enhanced and obsolete features were removed or marked for removal. Some clauses and annexes have been renumbered.

Outdoor Grade WiFi and Hotspots

Some vendors have extended WiFi technology to include Outdoor WiFi and proprietary extensions such as Mesh and other features. These devices allow greater use access to WiFi in public spaces.

CableFree Amber Crystal 802.11ac MIMO radio WiFi

CableFree Amber Crystal 802.11ac MIMO WiFi radio

A CableFree outdoor-grade WiFi Hotspot device, with 2 or more radio cards capable of multi-band multi-standard operation, supporting Hotspot Controller and Mesh features

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