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Analysis Of Techniques Of Various Ieee 802.11 Standards

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Abstract

WLAN is a form of wireless communication that uses a series of IEEE 802.11 standards. IEEE 802.11 family comprises of several standards which are IEEE 802.11a, b, g, n, and ac,etc. In 1997, IEEE released the first protocol that operated on 2.4GHz ISM band, and used for medium access method CSMA/CA. The coverage area was 20 meters for the indoor and approximate 100 meters for the outdoor usage. The data rate was only 1 to 2 Mbps. Two years later, IEEE released 802.11b that provided higher data rate (11Mbps) with higher coverage area. It covered nearly 38 meters for the indoor and about 140 meters outdoor. The channel bandwidth was 20 MHz and the method of modulation was only DSSS. In 2003, IEEE published next standard which is 802.11g. It has higher throughput compare to its previous standard 802.11b. It included Orthogonal Frequency Division Multiplexing (OFDM) as a modulation scheme.

In 2009, the IEEE published officially next standard which is IEEE 802.11n. The 802.11n standard introduced Multiple Input and Multiple Output MIMO with 40 MHz channel bandwidth [5]. It operates on 2.4 GHz and 5 Ghz band, with capability of 600 Mbps data rate theoretically by using the spatial stream. In late 2013, the IEEE released 802.11ac.This paper provides a comparative study of these standards from the aspects of inception dates, evolution, implementation, operating conditions, and future of the IEEE 802.11.

Keywords: IEEE802.11,WLAN,Wifi, networks

I. Evolution of WLan Standards

In the recent years, there has been a dramatic increase in using mobile communication devices such as smartphones and tablet devices. Mobile users have been trafficking more data than voice while using these mobile devices.

Also, it worth noting that the mobile PCs, tablets, and routers growth is much slower than mobile broadband devices and smart phones. To support the aforementioned growth, new connectivity technologies have emerged in the communication market. These include the WLAN, WiFi, 3G,4G, 4G LTE, WiMax, etc… These technologies follow various standards on how systems are built and how they communicate. The broadband mobile devices utilize the WiFi with IEEE802.11 standards. The smartphones utilize the 3G, 4G, and LTE technologies. The IEEE802.11 standard was released by the IEEE (LAN/MAN) standard committee on June 1997. Since then multiple upgrades have been released to catch up with advancements in the communication technologies mentioned earlier. In this paper, a comparative study of the IEEE802.11a, b, g, n, and ac standards will be presented where each standard features is discussed individually. The paper will have a final section that compares these standards and list benefits and limitation of each standard

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Wireless Generation	1G	2G	3G		4G	5G		
IEEE WLAN Standard	802.11	802.11b	802.11a	802.11g	802.11n	802.11ac Wave1	802.11ac Wave2	802.11ad
Date Ratified	1997	1999	1999	2003	2009	2012	2013	2012
Max. Theoretical Data Rate	2 Mbps	11 Mbps	54 Mbps	54 Mbps	600 Mbps	1.3 Gbps	6.7 Gbps	7 Gbps
Typically Achieved Data Rate	1 Mbps	6.5 Mbps	25 Mbps	25 Mbps	200 Mbps	400 – 700 Mbps	Yet to be tested	Yet to be tested
Frequency band	2.4 GHz	2.4 GHz	5 GHz	2.4 GHz	2.4/ 5 GHz	5 GHz	5 GHz	60 GHz
Max. Spatial Streams	1	1	1	1	4	3	8	-
Backward Compatibility	-	-	-	802.11b	802.11a/g, 802.11b	802.11n	802.11n	-
Coverage Area	-	30 m	30 m	30 m	50 m	70m	80m	Short range
Channel Bandwidth (MHz)	20	20	20	20	20,40	20, 40, 80	20, 40, 80, 160	2160
Modulation Scheme	FHSS, DSSS	HR-DSSS	OFDM	DSSS,OFDM	OFDM, 64-QAM	OFDM (256-QAM)	OFDM(256-QAM)	SC OFDM
Radio Architecture	SISO	SISO	SISO	SISO	MIMO	MIMO	MIMO	-
Typical Usage	Basic Wireless connectivity	Wireless connectivity in homes/offices	Web browsing, email, data transfer	Web browsing, email, data transfer	Video transmission, gaming	Real-time video/ audio, high density WLAN zones	Real-time video/ audio, high density WLAN zones, connectivity to multiple devices	High Definition Video, connectivity to multiple devices
Advanced Antenna Technologies	-	-	-	-	MIMO, up to 4 spatial streams	SU-MIMO	MU-MIMO, Transmit Beamforming	Beam-forming
FHSS: Frequency Hopping Spread Spectrum; DSSS: Direct-Sequence Spread Spectrum; HR-DSSSS: High-Rate Direct-Sequence Spread Spectrum; OFDM: Orthogonal Frequency-Division Multiplexing; QAM: Quadrature Amplitude Modulation; SC-OFDM: Single Carrier Orthogonal Frequency-Division Multiplexing; SISO: Single-Input Single-Output; MIMO: Multiple-Input Multiple-Output; SU-MIMO: Single-User Multiple-Input Multiple-Output; MU-MIMO: Multi-User Multiple-Input Multiple-Output;								

II. Details Of IEEE802.11 Various Standards

The IEEE802.11 has released multiple set of standards for various operating frequency, and ranges specification. The first release was IEEE802.11 original standard release that was defined 1997 and clarified 1999. Some of these old standards are now obsolete, and some are still active. One would be interested in investigating in details the available standards to determine a suitable standard for the intended application of the WLAN network.

1. IEEE802.11a

The IEEE802.11a standard was released on September 1999. Networks using 802.11a operate at radio frequency of 5GHz or 3.7GHz and a bandwidth of 20MHz. The specification uses a modulation scheme known as orthogonal frequency-division multiplexing (OFDM) that is especially well suited to use in office settings. In 802.11a, data speeds as high as 54 Mbps are possible. This standard employ the single input, single output (SISO) antenna technologies, and the indoor/outdoor ranges from 35m to 125m for 5GHz operating frequency. The outdoor range goes to 5Km for operating frequency of 3.7G. The IEEE802.11a is less prone to interference compared to with 802.11b due to the high operating frequency of 5GHz.

2.IEEE802.11b:

IEEE used the Complementary Code Keying (CCK) standard with the DSSS technology to achieve 5.5Mbps and 11Mbps rates. CCK uses a set of 64 eightbit unique complex code words called polyphase codes. Using CCK, up to 6 bits can be represented by any codeword (instead of the 1 bit represented by a Barker symbol). As a set, these code words have unique mathematical properties that allow them to be correctly distinguished from one another by a receiver, even in the presence of significant noise (such as interference due to

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multiple radio reflections indoors). The CCK modulation used by 802.11b transmits data in symbols of eight chips,

where each chip is a complex QPSK bit-pair at a chip rate of 11 Mchip/s. The 5.5 Mbps rate uses CCK to encode 4

bits per carrier, while the 11 Mbps rate encodes 8 bits per carrier

3.IEEE 802.11g

The standard 802.11g was ratified in 2003 as an IEEE standard for Wi-Fi wireless networking and it supports maximum network bandwidth of 54 Mbps compared to 11 Mbps for 802.11b. This standard operates at 2.4GHz frequency and bandwidth of 20MHz. This standard uses the OFDM or DSSS modulation schemes. This standard employ the SISO antenna technologies, and its indoor/outdoor range are from 38m to 140m respectively

4.IEEE 802.11n

The 802.11n standard was ratified in 2009 and it utilizes multiple wireless antennas in tandem to transmit and receive data[3-4]. The IEEE802.11n standard employs OFDM modulation technique. The antenna technology used with the IEEE802.11n standard is known as Multiple Input, Multiple Output (MIMO). This technology refers to the ability of 802.11n and similar technologies to coordinate multiple simultaneous radio signals. The MIMO increases both the range and throughput of a wireless network. An additional technique employed by 802.11n involves increasing the channel bandwidth from 20MHz to 40MHz. The 802.11n standard support maximum theoretical network bandwidth up to 300 Mbps. The IEEE802.11n indoor/outdoor ranges are 75m, and 250m respectively

5. IEEE 802.11ac: The 802.11ac standard operates only in the 5 GHz band. Theoretically, 802.11ac proposes data rates over 1 Gbps. The new specifications are based on the 802.11n standard, by expanding the channel bandwidth to 80 MHz and adding optional 160 MHz channels. In addition, 802.11ac utilizes MIMO with up to 8 spatial

streams and a higher order modulation scheme called 256-Quadrature Amplitude Modulation (256-QAM). The

standard also provides support for other advanced features such as beamforming and Low Density Parity

Check (LDPC). In the beamforming process, an access point utilizes more than one antenna to transmit a signal.

The multiple signals are sent to client devices to receive feedback about the best transmission path to the client.

Beamforming is used to create a directional Radio Frequency (RF) beam while LDPC is utilized by

802.11ac to improve the Signal-to-Noise Ratio (SNR).

6. IEEE 802.11ad: The 802.11ad standard operates in the unlicensed 60 GHz band. The standard proposes a

theoretical data rate of 7 Gbps with low power consumption. 802.11ad is expected to employ wide

channels of 2.16 GHz. This standard is intended to support high-performance wireless implementations such

as high- definition video.

7.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.[50] 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.[29] With four spatial streams and four bonded channels, the maximum data rate is 426.7 Mbit/s for 6 and 7 MHz channels and 568.9 Mbit/s for 8 MHz channels.

8.IEEE 802.11-2016 :which was known as IEEE 802.11 , is a revision based on IEEE 802.11-2012, incorporating 5 amendments (11ae, 11aa, 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.

9.IEEE 802.11ah: published in 2017, defines a WLAN system operating at sub-1 GHz license-exempt bands. 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.

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

11.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).[57]Alternatively known as China Milli-Meter Wave (CMMW).

802.11aq

12.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

13. IEEE 802.11ax: (aka "Wi-Fi 6") 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 at the user layer,[58] having just 37% higher nominal data rates at the PHY layer.[59] In the previous amendment of 802.11 (namely 802.11ac), Multi-User MIMO has been introduced, which is a spatial multiplexing technique. MU-MIMO allows the Access Point to form beams towards each Client, while transmitting information simultaneously. By doing so, the interference between Clients is reduced, and the overall throughput is increased, since multiple Clients can receive data at the same time. With 802.11ax, a similar multiplexing is introduced in the frequency domain, namely OFDMA. With this technique, multiple Clients are assigned with different Resource Units in the available spectrum. By doing so, an 80 MHz channel can be split into multiple Resource Units, so that multiple Clients receive different type of data over the same spectrum, simultaneously. In order to have enough amount of subcarriers to support the requirements of OFDMA, the number of subcarriers are increased by a factor of 4 (compared to 802.11ac standard). In other words, for 20, 40, 80 and 160 MHz channels, there are 64, 128, 256 and 512 subcarriers in 802.11ac standard; while there are 256, 512, 1024 and 2048 subcarriers in 802.11ax standard. Since the available bandwidths have not changed and the number of subcarriers are increased with a factor of 4, the subcarrier spacing is reduced by a factor of 4 as well. This introduces 4 times longer OFDM symbols. E.g., for 802.11ac and 802.11ax, the duration of an OFDM symbol is 3.2 micro seconds and 12.8 micro seconds (both without guard intervals), respectively

14.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, out-door back-haul and short range communications. The peak transmission rate of 802.11ay is 20 Gbit/s.[60] The main extensions include: channel bonding (2, 3 and 4), MIMO and higher modulation schemes.

15. IEEE 802.11be: Extremely High Throughput (EHT) is the potential next amendment of the 802.11 IEEE standard. It will build upon 802.11ax, focusing on WLAN indoor and outdoor operation with stationary and pedestrian speeds in the 2.4, 5 and 6 GHz frequency bands. Being the potential successor of Wi-Fi 6, the Wi-Fi Alliance will most likely certify it as Wi-Fi 7

CONCLUSION

In this paper, we have presented recent technological advancement and developments that have enhanced

wireless speeds and led to the deployment of various WLAN standards.

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