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A Comparison between IEEE 802.11a, b, g, n and ac Standards

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Abstract: *Recent advances in the communications and connectivity has encouraged the development and definition of various IEEE 802.11 series of standards, such as IEEE802.11a, b, g, n, and ac. Each of the standards is equipped with capabilities and features that suits the type of applications the standard is intended for. This paper provides a comparative study of these standards from the aspects of inception dates, evolution, implementation, operating conditions, and future of the IEEE 802.11a, b, g, n, and ac standards. This study also provide a summary of benefits and limitations of these standards.*
Keywords: *IEEE802.11, networking, communications, WiFi, WLAN, LAN*

I. Introduction

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. According to [1], the number of mobile devices subscription outlook between 2014 - 2020 will be as shown in Table 1.

Table 1: Mobile subscription outlook as stated by [1]

Subscriptions	**2014**	**2020**
Total mobile	7.1 billion	9.2 billion
Mobile broadband	2.9 billion	7.7 billion
Smartphones	2.6 billion	6.1 billion
Mobile PCs, tablets and routers	250 million	400 million

From Table 1, the vast number of mobile devices as well as the rapid growth of subscribers are evident. 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. The Table 2. shows the technical specification list of IEEE802.11[2] versions a, b, g, n, and ac versions that will be the focus of this work.

Table 2. Comparison Between IEEE 802.11a,b,g,n and ac[2]

802.11 network PHY standards								
802.11 protocol	**Release date**	**Frequency**	**Band-width**	**Stream Data Rate**	**Allowable MIMO streams**	**Modulation Antenna Tech.**	**Approx. range**	
							In	**Out**
		(GHz)	**(MHz)**	**Min-Max (Mbit/s)**			**(m)**	**(m)**
802.11	Jun 1997	2.4	22	1-2	1	DSSS, FHSS	20	100
a	Sep 1999	5	20	6-54	1	OFDM	35	120
		3.7				(SISO)	—	5K

b	Sep 1999	2.4	22	1-11	1	DSSS (SISO)	35	140
g	Jun 2003	2.4	20	6-54	1	OFDM, DSSS (SISO)	38	140
n	Oct 2009	2.4/5	20	7.2 -72.2 (6.5- 65)	4	OFDM (MIMO)	70	250
			40	15 - 150 (13.5 - 135)			70	250
ac	**Dec 2013**	**5**	**20**	**7.2 - 96.3 (6.5 - 86.7)**	**8**	**OFDM (MU-MIMO)**	**35**	
			40	**15 - 200 (13.5 - 180)**			**35**	
			80	**32.5 - 433.3 (29.2 - 390)**			**35**	
			160	**65 - 866.7 (58.5 - 780)**			**35**	

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.

A. 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.

B. IEEE 802.11b

IEEE 802.11b standard was released on September 1999 as well. This standard provides 11 Mbps transmission (with a fallback to 5.5, 2 and 1 Mbps) in the 2.4 GHz operating frequency and bandwidth of 22MHz. The 802.11b uses only DSSS (Direct Sequence Spread Spectrum) modulation technique. This standard also employs the SISO antenna technology as in the IEEE802.11a standard. The IEEE802.11b standard was ratified on 1999 from the original IEEE802.11 standard which allowed wireless functionality comparable to Ethernet. The IEEE802.11b standard is prone to higher interference due to the fact that the 2.4GHz frequency range is becoming crowded with carriers, hence increased interference risk. The indoor and outdoor ranges for this standard is 35m to 140m.

C. 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.

D. 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.

E. IEEE 802.11ac

IEEE 802.11ac is the fifth generation in Wi-Fi networking standards released December 2013[5-6]. This standard operating frequency is 5GHz, and bandwidth of 20, 40, 80, 160MHz sectors. The stream rates ranges for these bandwidth sectors are 7.2 - 96.3Mbps for 20MHz, and 15 – 200Mbps for 40MHz, 32.5 - 433.3Mbps for 80MHz, and 65 - 866.7Mbps for 160MHz. This standard exhibits better performance, and better coverage compared to IEEE 802.11a,b,g and n standards. The 802.11ac standard uses a wider channel and an improved modulation scheme that also supports more clients. The IEEE 802.11ac standard utilizes a modulation technique known as multi-user MIMO. This technique allows a set of users or wireless terminals, each with one or more antennas, o communicate with each other. The indoor range is 35m, and there is no recorded max for outdoor range.

III. Ieee802.11a, B, G, N, Ac Standard Comparison

Table. 3 provide a qualitative comparison between the standards of IEEE802.11a, b, g, n, and ac on the aspects of beamforming, coverage, capacity, interference, and quality. In this section more details on these qualities will be presented.

F. Beamforming:

The Beamforming is a signal processing technique that measures the ability of transmitting or receiving data in a directional signal beam[7]. Both the IEEE802.11n, and ac possess this feature, while other standards lack the beamforming capability.

G. Coverage and Capacity

As discussed earlier, the IEEE802.11ac exhibits wide area coverage when compared to other standard. The IEEE802.11ac equipped with MUMIMO and multi spatial streams which allows higher stream rates. Table. 4 shows IEEE802.11ac Maximum Achievable PHY Data Rates for bandwidth/spatial streams supported ranges.

H. Interference and Quality:

The IEEE802.11ac uses the operating frequency of 5GHz, which is less prone to interference when compared to IEEE802.11 b, g as they operates on 2.4GHz frequency. For IEEE802.11a, n when operating with 2.4GHz these standard are more prone to interference, while when operating with 5GHz they exhibit less interference similar to IEEE802.11ac standard[8].

Table 3. Comparison Between IEEE 802.11a,b,g,n and ac additional features

Feature	802.11a	802.11b	802.11g	802.11n	802.11ac
Beamforming	No	No	No	Yes	**Yes**
Coverage	Low	Low	Low	Low	**High**
Capacity	Low	Low	Low	Low	**High**
Interference	More on 2.4GHz Less on 5GHz	More	More	More on 2.4GHz Less on 5GHz	**Less**
Quality	Low	Low	Low	Low	**High**

Table 4: IEEE802.11ac Maximum Achievable PHY Data Rates (Mbps) bandwidth/spatial streams[6].

BW(MHz) #SP. Str.	20MHz	40MHz	80MHz	160MHz
1	86.7	200	433.3	866.7
2	173.3	400	866.7	1733
3	288.9	600	1300	2340
4	346.7	800	1733	3466
5	433.3	1000	2166	4333
6	577.8	1200	2340	5200
7	606.7	1400	3033	6066.7
8	693.3	1600	3466	6933

IV. Conclusions

This paper describe how IEEE802.11ac enhance the quality and performance when compared with IEEE 802.11a,b,g and n standards. IEEE 802.11ac standard is new technology released December 2013 to achieve throughput and data stream rate in the range of Giga bits per second. The IEEE802.11ac exhibits

performance improvement such as less interference as the standard operates at 5GHz frequency. It supports a range of a wide bandwidths ranges from 20, 40, 80, and 160MHz. It can support up to 8 spatial streams and employs OFDM modulation and MU-MIMO antenna technology.

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