Performance comparison of wireless protocol IEEE 802.11ax vs 802.11ac

by Adian F. Rochim

Submission date: 17-Jan-2021 07:20PM (UTC+0700) Submission ID: 1488915225 File name: icosta_adian_2019.pdf (1.46M) Word count: 3390 Character count: 17032

Performance comparison of wireless protocol IEEE 802.11ax vs 802.11ac

2 Adian Fatchur Rochim Dept. of Computer Engineering Diponegoro University Semarang, 50275, Indonesia adian@ce.undip.ac.id

Syamsul Fuad Dept. of Electrical Engineering Diponegoro University Semarang, 50275 Indonesia S7amsoel@gmail.com Burhanudin Harijadi Dept. of Electrical Engineering Diponegoro University Semarang, 50275 Indonesia burhanudin.harijadi@gmail.com

Abstract—The sixth generation of wireless protocol IEEE 802.11ax has been launched and offers better performance than the previous fifth-generation wireless protocol IEEE 802.11 ac. This paper reviews the performance of both wireless protocols in the same operating frequency of 5 GHz. We used Network Simulator NS-3 as a simulation tool that offers flexibility, lesser time to set up and ease the experiment to any scenarios we need to perform. Furthermore, this paper focuses on analyzing and comparing the throughput of protocol IEEE 802.11ax Mcs-11 and 802.11ac Mcs-9 with a certain payload size and a various number of clients. The other parameters are set at certain values, such as a spatial stream, channel width, modulation and coding scheme, guard interval time and simulation time. The simulation result shows that the IEEE protocol 802.11ax Mcs-11 has better throughput performance than IEEE 802.11ac Mcs-9 with a large number of clients. In the simulation, a node of access point was accessed of 512 clients, IEEE 802.11ax Mcs-11 have more long delay response time than IEEE 802.11ac Mcs-9 at the beginning for a few milliseconds, but after 0.5 ms IEEE 802.11 ax shown a stable and bigger throughput value than IEEE 802.11ac that its shown decrease.

Keywords—IEEE, protocol, 802.11ax, 802.11ac, performance, throughput

I. INTRODUCTION

Wireless technology provides wireless communication services and supports mobility for many people around the world. Year by year wireless technology based on wireless protocol IEEE 802.11 has been developed and the trend is shown in figure 1.

Wireless-LAN has been significantly developed and can be easily deployed at various zones, for example, airports, hotels, offices, malls, and home residences. One of the major improvements is in the number of users served by an AP (Access Point) system [16] W-LAN described at IEEE 802.11 protocol implements a CSMA / CA (carrier sense multiple access with collision avoidance) techniques, requiring endpoints to listen for an all-clear signal before transmitting. In the occasions of interference, congestion or collision, the endpoint goes into a backoff procedure, wait for the channel all clear then transmits. 2'osepin Petra Purbanugraha Dept. of Electrical Engineering Diponegoro University Semarang, 50275 Indonesia petrayosepin@gmail.com

Kuntoro Adi Nugroho Dept. of Computer Engineering Diponegoro University Semarang, 50275 Indonesia kuntoro@live.undip.ac.id

First of all, in CSMA the wireless remote station (RSTA) senses the channel and tries to avoid a collision by transmitting just when the channel condition is idle [3].



Fig. 1. Wireless technology trend [5]

When the RSTA senses another RSTA using the channel, then the RSTA waits for a random amount of times so the RSTA stops its transmitting before it returns to check whether the channel is free or not. When the RS 221 can transmit, it transmits all packet data. RSTA sends an RTS / CTS (Request to send / clear to send) command to get access to shared media. The AP (Access 21 int) issues CTS commands to an RSTA at a time, a13 then the STA sends the entire frame to the AP. The RSTA waits for an acknowledgment (ACK), it commands from the AP that indicates the packet was received. If the RSTA does not get an ACK in time, it assumes that the packet collides with some transmitted packages, which directs the RSTA to an exponential binary back-off period. The RSTA will try to access the media and resend the packet after the countdown has expired [10]. Although the Clear Channel Assessment and Collision Avoidance protocols function work well to divide channels evenly among all RSTAs, the collision domain, and its efficiency decrease when the number of stations grows larger.

The Clear Channel Assessment Protocol scenario is shown in figure 2.

A. IEEE 802.11ac

2020 International Conference on Smart Technology and Applications (ICoSTA)

The limited performance of the 802.11n protocol is the basis for the development of the 802.11ac protocol [1]. To get a higher performance in 802.11ac done in the following ways:

Greater bandwidth, namely 80 MHz and 160 MHz, as a development of 40 MHz bandwidth in the 802.11n protocol

Signal modulation is greater, using QAM-256 modulation, as the development of QAM-64 modulation used by the 802.11n protocol.

Implement multiple input multiple outputs with 8 spatial streams, which are larger than 802.11n, which only has 4 spatial streams.



Fig. 2. Wireless 802.11 Clear Channel Assessment Protocol [3]

The 802.11ac Access Points (AP) that work in a frequency band 80 MHz and or 160 MHz still support 802.11n user protocols that are connected and can be served its communication well [9]. The way it works is that the beacon signal will be sent at a bandwidth of 20 MHz of 802.11n, which will be the main channel in the 80 MHz bandwidth. In this condition, the Access Point and the client connected to it will receive and process the data received on this main channel. So that clients on the 802.11n Access Point will be compatible and still be able to communicate data transmission on the 802.11ac access point (AP).



Fig. 3. Wireless 802.11ax channel allocation [2]

Various types of Access Points and its connected users have different carrier sensing periods and can transmit data at any time using various sub-channels. In theory, 802.11ac with 160 MHz bandwidth will be able to produce a throughput of 1.3 Gb/s [5].

B. IEEE 802.11ax

IEEE 802.11ax is a development protocol to improve the performance of the 802.11ac protocol, which has limited uplink contention-based access [2]. 802.11ax provides greater network capacity, higher efficiency, better performance, and reduced latency. This new protocol is primarily aimed at implementing new methods to serve more users with reliable and consistent data flows that aim to increase throughput.

The features of IEEE 802.11ax over IEEE 802.11ac are shown in figure 4.

IEEE 802.11ax made significant changes to the standard physical layer [3]. However, 802.11ax still maintains compatibility with devices with the 802.11a / b / g / n / ac protocol, so that the 802.11ax RSTA can receive and send data to STA with the previous protocol. This legacy client will also be able to demodulate and decode 802.11ax packet headers, even if not the entire 802.11ax packet, and then back when the 802.11ax RSTA transmits. The difference in PHY characteristics between IEEE 802.11ax and IEEE 802.11ax is shown in table 1.





TABLE I. PHY characteristic of IEEE 802.11 ax and 802.11ac [3]

Wireless P 9) tocols	Wifi 802.11 ac	Wifi 892.11 ax	
Bands (GHz)	5	2.4 and 5	
Channel Width	20, 40, 80, and 160	20, 40, 80, and 160	
(MHz)			
12 FFT sizes	64, 128, 256, and 512	256, 512, 1024, and 2048	
Subcarrier Spacing	312.5	78.125	
(kHz)			
OFDM symbol	3.2 + 0.8 / 0.4	12.8 + 0.8 / 1.6 / 3.2	
23 interval			
Highest Modulation	10 256-QAM	1024-QAM	
	433 Mbps (80 MHz, 1	600.4 Mbps (80 MHz, 1	
Data rates	SS) 6,933 Mbps (160	SS), and 9,607.8 Mbps	
	MHz, 8SS)	(160 MHz, 2SS)	

The 802.11ax standard has two modes of operation [3] i.e. single-user and multi-user. In single-user mode, wireless sequential RSTA mode sends and receives data at once after they secure access to media. While in multiuser mode, can carry out simultaneous operations of several non-AP STAs.

The standard divides this mode further into Down-link and Up-link Multi-user [11]. Multi-user downlink is based on data carried out by the AP for several related wireless STAs simultaneously.

Multilink MU-MIMO provides features to both 802.11ac and 802.11ax access points so that they can receive and send simultaneously to multiple users (MU) from an access point. This feature provides flexibility for access points to serve user clients in the work area of the access 18 nt. The methods used in both protocols are multi-user MIMO and Orthogonal Frequency Division Multiple Access (OFDMA) [13].

The technology used on 4G cellular is implemented on IEEE 802.11ax to accommodate more users on the same channel, this technology is called OFDMA. The other method applied is to set specific sub-operators for one user. 802. 11ax divides channels into the smallest sub-channels, with a total of 26 sub-carriers. The rules for channel allocation are by setting all available resources at the downlink, then all channels

allocated for only a user at the same time. Figure 5 shows services to several users simultaneously.



Fig. 5. A single user in a channel of OFDM compares to multiplexing multiuser in the same channel of OFDMA [3].

This research aims to find out how are **IEEE 802.11ax and IEEE 802.11ac** work with the various clients. We will know how fast their response time and how high the throughput in 2 to 512 client number.

This paper is divided into five sections. The first section describes the background and purpose of the protocols. The second section describes the research methodology used throughout this paper. The next section describes the result and discussion comparison of the 802.11ac and ax. Finally, this paper is closed by the conclusion.

II. LITERATURE REVIEW

Several researchers have previously performed simulation performance of several IEEE protocol 802.11. They simulated IEEE 802.11e, 802.11n, and 802.11ac

NS-3 simulation was utilized to evaluate the mechanism of IEEE 802.11e and IEEE 802.11n protocols for sending audio-video traffic over W-LAN. In the study, 802.11e was compared with 802.11n to provide different channel access for different types of traffic. The 802.11n yielded better results in handling real-time applications with stringent QoS requirements such as Audio and Video at 15 Mb/s compared to 802.11e at only 6 Mb/s [4].

Simulation with NS-3 was also carried out to compare the performance (15)2.11n and 802.11ac protocols. The goal of the study is to compare the throughput between IEEE 802.11n and IEEE 802.11ac using various Spatial Streams (SS), data rates, and a number of clients. The study demonstrated that the throughput of IEEE 802.11n is the same as 802.11ac at

40 MHz bandwidth and client and spatial streams of 1-4. Moreover, the throughput of 802.11ac is higher than 802.11n at 40 MHz bandwidth and 2 clients (1-4SS) [5].

III. METHODOLOGY

We used NS-3.29 to conduct this simulation. The simulation has some advantages i.e. shorter time to explore models, lower cost and flexibility in any scenarios simulated compared to actual hardware testing.

The TCP New-Reno protocol is a transport layer protocol which is widely used in a variety of network. Therefore, we also use TCP new-reno in conducting this simulation because is more stable when compared to ordinary TCP [8]. This protocol contains three components: slow start (SS), congestion avoidance (CA) and fast recovery (FR) [6]. The protocol needs to maintain two parameters: the congestion window (cwnd) and a slow start threshold (ssthresh). The protocol could avoid the congestion of the network to some extent. TCP new-reno could be used on wired or wireless networks with very low segment loss [7].

Steps of the exploration and research activities:

1. Designing the architecture of the system

2. Running NS-3 script of 802.11ax and 802.11ac of AP clients

- 3. Collecting data throughput and analyze it
- 4. Representing the result of simulation

The performance evaluation of the 802.11ax and 802.11ac are counted from the receiving traffic through the wireless connection of AP node and Client node. A metric to compare performance between 802.11ax and 802.11ac is throughput, it describes the traffic size through a link in a selected range of time.

Throughput =
$$\frac{\sum number of packet}{\sum simulation time} * \frac{8}{10^6} (Mb/s)$$
(1)

A. Parameter Settings

802. 11ac was simulated using QAM- 256 modulations, while 802. 11ax uses QAM-1024 modulation. Spatial streams cannot be used because NS-3 does not yet have this function in the NS-3.29 version (ref.). The other parameters setting i.e. payload size, channel width, guard time intervals, and a number of clients, are the same for both.

In this simulation, we analyze and compare the IEEE 802.11ax throughput and the IEEE 802.11ac protocol by providing specific content and varying the number of clients. Table 2. shows the parameter setting.

TABLE II. SIMULATION PARAMETER SETTING

Parameters	802.11ac	802.11ax	
Modulation and	QAM-256	QAM-1024	
Codung			
Guard Interval	800 ns	800 ns	
Channel Width	160 MHz	160 MHz	
Frequency	5 GHz	5 GHz	
Spatial Stream	1	1	
Payload Size	1448 byte	1448 byte	
Client number	2 to 512 clients	2 to 512 clients	
Simulation time	2 s	2 s	

Figure 6 shows the topology of the network in the simulation. Star topology is used in this simulation test because clients 20 mmonly use it. All clients are connected directly to the Access Point. Therefore, the Access Point's load is equal to the number of connected clients. By using this star topology, the Access Point is forced to work optimally when they are serving client nodes. Therefore the performance of each Access Point (802.11ax and IEEE 802.11ac) could be monitored easily.

B. Scenarios

Scenario 1 shown the activities of the IEEE 802.11ax simulation. Each of the parameters setting is simulated which parameters i.e. Spatial Streams, Modulation and Coding Scheme set at a certain value. We simulate a number of clients from 2 up to 512 client numbers to find the optimal value of the data rates.

2020 International Conference on Smart Technology and Applications (ICoSTA)

Simulation of the first and two of the scenarios were run with a number of clients from 2 to 512 clients. The process of the simulation was done to find the maximum value of the throughput of each protocol. Parameter settings of the protocols are summarized in table 2.

Scenario 2 shown the activities of the IEEE 802.11ac simulation. Each of the parameters setting is simulated to parameter setting table i.e Spatial Streams, Modulation and Coding Scheme set at a certain value. We simulate with a number of clients from 2 to 512 client numbers to find the optimal value of the data rates.



Fig. 6. Network topology

IV. RESULT AND DISCUSSION

The simulation scenario 1 and scenario 2 considered several parameters set at a 19 rtain value. We run the simulation using various client number i.e.: 2, 4, 8, 16, 32, 64, 128, 256, 512 clients. The simulation time runs 2 seconds every data rate.

The simulation results of small client number i.e. 2 and 4 clients, show fast respond time with good throughput value, while the bit rate value of IEEE 802.11ax bigger than IEEE 802.11ac. Both protocols showed a stable throughput from start simulation at 0.1 seconds until the end of simulation at 2 seconds. It is shown in figure 7.

The simulation results of medium client number i.e. **7** 16 and 32 clients shown the time response of both similarly **IEEE 802.11ax** and **IEEE 802.11ac** have few late of response time and shown have good throughput value start from a time 0.3 second, while bit rate value of IEEE 802.11ax keeps bigger than IEEE 802.11ac. It shows MIMO implementation of 802.ax more effective than 802.11ac although both protocols showed a stable throughput from simulation time at 0.3 seconds until the end of simulation at 2 seconds, shown in figure 8.



Fig. 7. Throughput 802.11ax Mcs-11 vs 802.11ac Mcs-9 with a small client number (2 and 4).



Fig. 8. Throughput 802.11ax Mcs-11 vs 802.11ac Mcs-9 with a medium client number (2 and 4).

The simulation results of big client number i.e. 64, 128, 256 and 512 clients show 802.11ac has a faster response than IEEE 802.11ax start since simulation time 0.2 second until 0.4 seconds, start from simulation time 0.5 second until 0.4 seconds, start from simulation time 0.5 second until EEE 802.11ac has a have bigger bit rate value than IEEE 802.11ac. IEEE 802.11ax keeps bigger throughput than IEEE 802.11ac until the end of simulation time at 2 seconds, shown in faure 9. Figure 9 shows the throughput stability comparison of IEEE 802.11ax and IEEE 802.11ac with a number of clients from 64 to 512.

IEEE 802.11ax looks to have more stable of throughput value than the through 7 of 802.11ac. Figure 11 shows a difference throughput between IEEE 802.11ax vs IEEE 802.11ac. From 2 to 8 connected clients, they have almost the same throughput.



Fig. 9. Throughput 802.11 ax Mcs-11 vs. 802.11 ac Mcs-9 with a big client number (2 and 4).

Higher throughput difference starts at 16 clients until 512 clients. The IEEE 802.11ax has bigger throughput of 8.9 percent on average than IEEE 802.11ac.

17 2020 International Conference on Smart Technology and Applications (ICoSTA)



Fig. 10. Average throughput IEEE 802.11ax Mcs-11 compare to IEEE 02.11ac Mcs-9 with various big client number (64, 128, 256 and 512)



Fig. 11. Difference percentage of throughput IEEE 802.11ax Mcs-11 compare to IEEE 802.11ac Mcs-9 with various client number

V. CONCLUSION

Both IEEE 802.11ax Mcs-11 and IEEE 802.11ac Mcs-9 with small client number i.e. 2 and 4 clients have the same good throughput value. Simulation with the 16 to 512 clients IEEE 802.11ax has bigger throughput value than IEEE 802.11ac. At medium client number, both IEEE.802ax Mcs-11 and IEEE 802.11ac Mcs-9 shown similar delay response time, but IEEE 802.11ac A big client number, IEEE 802.11ac Mcs-11 look, has more delay response time than IEEE 802.11ac Mcs-9 at the beginning for a few milliseconds, but after 0.5 ms IEEE 802.11ac that its shown decrease.



This research was financially supported by the Faculty of Engineering, Diponegoro University, Semarang, Indonesia, through Strategic Research Grant 2019 number: 3161/3/UNT7.3.3/PG/2019.

REFERENCES

- [1] 802.11ac The Fifth Generation of Wifi, Cisco white paper, 2018
- [2] 802.11ax The Sixth Generation of Wifi, Cisco white paper, 2018
- [3] Introduction to 802.11ax High-Efficiency Wireless, National instruments, 2019
- [4] Teuku Yuliar Arif and Rin Fitri Sari, Performance comparison of video traffic over WLAN IEEE 802.11e and IEEE 802.11n, in Ubi-comm the fourth international conference on ubiquitous mobile computing, systems, services and technologies, 2010
- [5] Adian Fatchur Rochim and Riri Fitri Sari, Performance comparison of IEEE 802.11n and IEEE 802.11ac, in International conference on computer, control, informatics and its application, 2016
- [6] Y. Qin, W. Yang, Y. Ye, and Y. Shi, "Analysis for TCP in data center networks: Outcast and Incast," J. Netw. Comput. Appl., vol. 68, pp. 140–150, 2016
- [7] S. Utsumi and S. M. S. Zabir, "A new high-performance TCP friendly congestion control over wireless networks," J. Netw. Comput. Appl., vol. 41, no. 1, pp. 369–378, 2014.
- [8] X. Wang and D. Y. Eun, "Local and global stability of TCPnewReno/RED with many flows," Comput. Commun., vol. 30, no. 5, pp. 1091–1105, 2007.
- [9] Oran Sharona, Yaron Alpert, MAC level Throughput comparison: 802.11ac vs. 802.11n, Elsevier, 2014
- [10] Oran Sharona, Yaron Alpert, The combination of QoS, aggregation and RTS/CTS in Very High Throughput IEEE 802.11ac networks, Elsevier, 2015
- [11] Hyunwoo Choi, Taesik Gong, Jaehun Kim, Jaemin Shin, Sung-Ju Lee, Use MU-MIMO at your own risk — Why we don't get Gb/s Wi-Fi,
- [12] Elsevier, 2018
- [13] Boris Bellaltaa, Luciano Bononi, Raffaele Brunoc, Andreas Kassler, The next generation IEEE 802.11 Wireless Local Area Networks, Current status, future directions and open challenges, Elsevier, 2015
- [14] Boris Bellaltaa, Katarzyna Kosek-Szott, AP-initiated multi-user transmissions in IEEE 802.11ax WLANs, Elsevier, 2018.

Performance comparison of wireless protocol IEEE 802.11ax vs 802.11ac

ORIGIN	ALITY REPORT				
SIMIL	5% ARITY INDEX	8% INTERNET SOURCES	14 % PUBLICATIONS	5% STUDENT PA	\PERS
PRIMA	RY SOURCES				
1	Qin, Yang Shi. "Ana Outcast a Computer Publication	g, Weihong Yang lysis for TCP in o ind Incast", Jour r Applications, 20	g, Yibin Ye, an data center ne nal of Network 016.	d Yao tworks: and	2%
2	R Rizal Is Julietta. "I using regi extraction on Inform Electrical Publication	nanto, Ajub Ajul Pattern recogniti ion-based invaria ", 2016 3rd Inter ation Technolog Engineering (IC	ian Zahra, Pat ion on herbs le ants feature rnational Confe ly, Computer, a ITACEE), 2010	ricia eaves erence and 6	2%
3	Submitted Student Paper	d to Universitas I	Negeri Semara	ang	1%
4	WWW.SCIT	o.org			1%
5	Karlisa Pr "Developr System u	riandana, Rama ment of Automat sing Soil Moistu	dina Al-Fatihał tic Plant Irrigat re Sensors for	n Wahyu. ion	1%

Precision Agriculture of Chili", 2020 International Conference on Smart Technology and Applications (ICoSTA), 2020

1%

1%

Publication

6

Adian F. Rochim, Mukhlish A. Aziz, Adnan Fauzi. "Design Log Management System of Computer Network Devices Infrastructures Based on ELK Stack", 2019 International Conference on Electrical Engineering and Computer Science (ICECOS), 2019 Publication

 Oran Sharon, Yaron Alpert. "Scheduling Strategies and Throughput Optimization for the Downlink for IEEE 802.11ax and IEEE 802.11ac Based Networks", Wireless Sensor Network, 2017 Publication

8	Enang Rusnandi, Edi Winarko, Azhari SN. "A	1 ~
0	Survey on Multimodal Information Retrieval	∎ %
	Approach", 2020 International Conference on	
	Smart Technology and Applications (ICoSTA),	
	2020	
	Publication	



Sādhanā, 2019

Publication

11	"ICoSTA 2020 Program", 2020 International Conference on Smart Technology and Applications (ICoSTA), 2020 Publication	<1%
12	eprints.soton.ac.uk Internet Source	<1%
13	Submitted to CSU, San Jose State University Student Paper	<1%
14	Toshihisa NABETANI, Narendar MADHAVAN, Hiroki MORI, Tsuguhide AOKI. "A Novel Low- Overhead Channel Sounding Protocol for Downlink Multi-User MIMO in IEEE 802.11ax WLAN", IEICE Transactions on Communications, 2018 Publication	<1%
15	www.dtic.upf.edu Internet Source	<1%
16	www.edrawsoft.com Internet Source	<1%
17	librarysearch.aut.ac.nz	<1%
18	dr.ntu.edu.sg	<1%



Exclude quotes	On	Exclude matches	Off
Exclude bibliography	On		