Rate Adaptation for Quality of Service (QoS) Improvement in IEEE 802.11ax Wireless Local Area Network (WLAN)

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Abstract

This paper presents rate adaptation for Quality of Service (QoS) improvement in Wireless Local Area Network (WLAN) specifically IEEE802.11ax. The latest WLAN standard provides better results of performance by improving the WLAN data rate to satisfy the growing number of users' demand. By increasing the data rate, high throughput and low delay will be provided as well as a better network performance can be experienced by users. This study implemented a link adaptation technique which adapts the transmission data rate in IEEE 802.11ax WLAN. The main objectives of this paper are to design link adaptation which adapts the transmission data rate based on radio channel condition and to verify the effectiveness of the proposed algorithm. This technique enables the QoS performance to be improved in terms of its throughput and delay that able to adapt the Modulation Coding Scheme (MCS) based on the radio channel condition. This performance metric is analyzed using OMNeT++ simulator. Simulation results show that the data rate adaptation technique offers better performance in terms of throughput and delay.

Keywords: IEEE 802.11ax, WLAN, QoS, delay, throughput, rate adaptation

1. Introduction

These nearly past two decades, the wireless local area network (WLAN) has become one of the important technology and facilities in our daily life. Any devices that include access point (AP) to the internet and use high frequency radio waves, the method for the wireless distribution is called Wireless Local Area Network (WLAN). During late 1990s, most WLAN solutions and software protocols in different variation versions were replaced based on IEEE 802.11 standard (versions "a" through "ac"). IEEE 802.11 defines as a set of physical layer standards that define communication for WLAN WiFi should not be confused with the Wi-Fi Alliance's Wi-Fi trademark [1]. Wi-Fi is not a technical term, but is described as a superset of the standard IEEE 802.11 and is sometimes used interchangeably with the standard [2]. Fig. 1 shows the evolution of Wi-Fi since its first release until 802.11ax. Process of the development of IEEE 802.11ax is a step of innovation of the current standard. It provides more users in pack environments and support a better network performance for wireless LAN networks [3]. The new standard could also power high technology applications such as Ultra High Definition (HD), high quality video, wireless office, and Internet of Things (IoT). IEEE 802.11 ax has been said could offer 4 times better throughput than IEEE 802.11 ac [4].

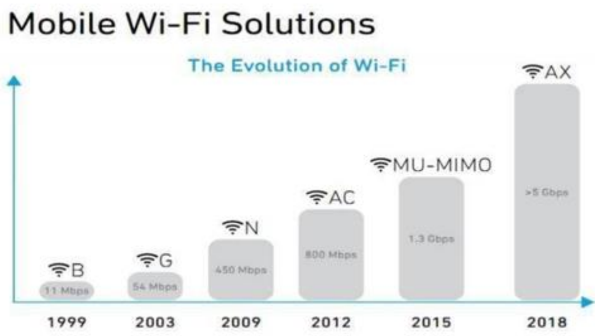

Fig. 1 Wi-Fi evolutions

This modern and technology era has shown the increasing number of smartphone users for more than ten years. The massive number of users give a sign that technology and wireless are growing proportionally with year [5]. Every year more technologies are created for users. Hence, IEEE 802.11ax was developed for maximum ability for one network to work with another, working efficiently with 802.11 devices [6].

Quality of service or also known as QoS, is the characterization or measurement of a service's overall performance, such as a telephony or computer network or cloud technology service, particularly the performance and quality of network users [7]. QoS is the capabilities to prioritize various applications, data flows, clients, or to justify the data flow performance at certain level [8]. QoS has been defined as a quality measures, with many definitions, rather than being referred as reserve capacity. Service quality has also refers to the level of service quality, for instance, the quality of service guaranteed. In this research paper, the QoS is measured on the throughput of the wireless LAN performance.

In wireless communications, the term link adaptation or adaptive coding and modulation (ACM) is used to indicate the adjustment of modulation, coding and other signal and protocol parameters to the radio link conditions. In this situation, WLAN uses a rate adaptation and power adaptation algorithm that adapts the modulation and coding scheme(MCS) to the performance and quality of radio channel, hence the bit rate and data transmission robustness [9] [10]

In this research, a rate adaptation technique is used to determine the throughput performance. Rate adaptation can be defined as a change in data rate based on traffic conditions. This condition has three categories which are low traffic conditions, medium traffic conditions, and high traffic conditions. This technique was chosen because of its ability to improve network performance. Besides, its ability in adapting modulating and coding schemes have an advantage in maintaining the QoS especially in high traffic conditions in IEEE 802.11ax.

Link adaptation has been well studied by many researchers to improve network performance, especially in throughput. Yalda et al introduce a novel machine learning-based approach for dynamically selecting whether to enable or disable the RTS/CTS of IEEE 802.11 DCF [11]. The proposed technique compares the cost of using RTS/CTS or retransmitting data based on the air time, or the ratio between the size of data/control information being broadcast and transmission rate, and network contention. Our algorithm then dynamically switches RTS/CTS on and off as necessary.

Purandare et al [12] presented a Loss Differentiated Channel Aware Rate Adaptation (LD-CARA) for IEEE 802.11n Wireless Links which implements an open-loop per packet for 802.11 ac standard. This research uses block acknowledgment (ACK) in order to differentiate losses as well as optimizing throughput performance for that standard. The algorithm is carried out to observe the behavior of signal to noise ratio at the receiver and based on the measurement will directly related to the bit error rate in the link. Network simulator NS3 is used to run the simulation and compare the adaptations. LD-CARA is a stable algorithm that helps to improve network throughput in 3 situations; static, mobile and interfered channels.

Hence, this research is done based on the objectives of to study the IEEE 802.11ax WLAN standard using rate adaptation technique and analyze the network performance of QoS via OMNeT++ simulator [13] Section 1 briefed a summary of analysis and the case study related with this research. Section II provides an overview of OMNeT++ and performance metric of IEEE

802.11ax standard. Section III will be focusing on the technique of rate adaptation and sector 1V discussed performance analysis based on rate adaptation technique. Lastly section V concludes the paper with suggestion of future works.

2. Background

A. OMNeT++

The OMNeT++ simulator is a simulator used to design a simulation network model in this study. OMNeT++ was used in this project to obtain the performance analysis of IEEE 802.11ax network model. The main elements are modules that have various types of modules, which are basic modules and complex modules. The actual simulation model in OMNeT++ is a complex module called "Network" as stated in [10]. Simulation specified in the configuration file runs with parameter values of IEEE 802.11ax and develops simulation networks using a framework called INET.

B. Performance Metrics

Performance metrics are used to evaluate the behavior, activities, and performance of a service. In this project, performance metrics focuses on Quality of Services (QoS) which are throughput and delay.

Throughput is an important measure in the wireless network which refers to the successful level of information or packet transmission across a communication channel. The throughput is usually being stated in Kilobits per second (kbps), Megabits per second (Mbps) or Gigabits per second(Gbps). On the other hand, throughput refers to the total number of data packets transmitted to the receiver.

Delay is defined as the time required for a packet to reach the receiver site successfully. For good network performance, low delay is required in order to achieve good throughput and better QoS performance.

3. Methodology

A. Network Model

OMNeT++ is used to perform the simulation process. The example of network model scenario of proposed algorithm in OMNeT++ simulator is shown in Fig 2. The initial model network consists of user terminals and one access point (AP) placed randomly.

Fig. 2. Network model

Table 1 displays simulation parameters that need to be set in the omnetpp.ini configuration file in order to evaluate the performance of the rate adaptation technique for IEEE 802.11ax. The tables show the parameters that need to be taken into account before running the simulation.

TABLE I. SIMULATION PARAMETER

Parameters	Value
WLAN Standard	IEEE 802.11ax
Carrier Frequency	5GHz
Bandwidth	20MHz
Propagation model	Free space path loss
Spatial Steam	8
Transmission Range	100-200 meters
Simulation Time	120 seconds
Network Load (node)	10,20,30,40,50

B. Block Diagram

Fig. 3 shows a block diagram of rate adaptation in the IEEE 802.11 ax. First of all, the initial data rate value for transmission is set at the maximum rate by each transmitter. Then, after packets are sent to the receiver, and delay will be used as a parameter adaptation which represents the traffic condition. The delay of each transmission will be measured, so the transmission data rate is adjusted to its successive rate transmission. If the delay is more than the threshold value for the delay in IEE 802.11 ax which is 1µs, the transmission data rate will be reduced to one step to another step so it can achieve its target to get minimum delay with high throughput.

Apart from that, if the delay is much smaller than the threshold value, the transmission data rate will be increased since the data rate is inversely proportional to the delay. This process is done in order to gain the advantage of achieving the maximum throughput for users.

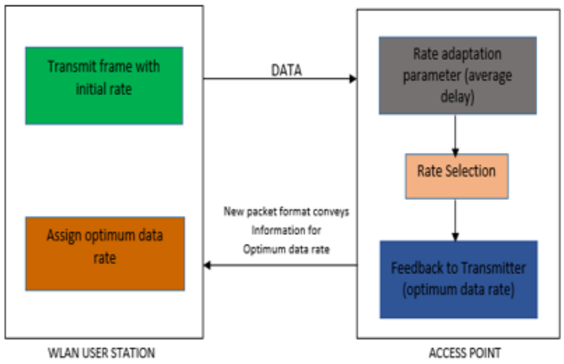

Fig. 3. Block Diagram for Rate Adaptation Technique

Determination of the change of data rate based on traffic conditions in a communication network is known as rate adaptation [13]. Table for transmission data rate and Modulation & Coding Scheme (MCS) for IEEE 802.11ax standard is shown in Table II. Higher MCS values lead to higher SNR values that contribute to higher data rates that provide higher performance.

TABLE II. TRANSMISSION DATA RATE FOR IEEE 802.11ax STANDARD

Modulation	Coding Rate	Data Rate (Mbps)	Minimum SNR (dB)
BPSK	1/4	3.6	2
BPSK	1/2	7.3	5
QPSK	1/4	7.3	9
QPSK	1/2	14.6	11
QPSK	3/4	21.9	15
16-QAM	1/4	14.6	18
16-QAM	1/2	29.3	20
16-QAM	3/8	21.9	25
16-QAM	3/4	43.9	29
64-QAM	2/3	58.5	31
64-QAM	3/4	65.8	33
64-QAM	5/6	73.1	35
256-QAM	3/4	87.8	37
256-QAM	5/6	97.5	39
1024-QAM	3/4	109.7	40
1024-QAM	5/6	121.9	41

C. Flowchart

Fig. 4. shows the flowchart of the proposed algorithm. The first flow starts with transmitting a packet, i from transmitter to receiver. Each time one packet is transmitted, the transmitter will wait for the acknowledgment (ACK) packet from the receiver. If there is no indicator of ACK packet received at the receiver, the transmitter will retransmit the information again until the ACK packet is received via the carrier-sense multiple access with collision avoidance (CSMA/CA). While if the packet is successfully received at the receiver, the delay for a packet to arrive at the receiver will be measured. This procedure will be repeated until all of the packets are sent. After all, packets are sent, the average delay of the packets will be recorded.

In this work, for IEEE 802.11ax specification, the delay threshold for this standard is set as 1µs [14]. The value of the average delay that has been recorded is checked whether it has exceeded or not higher than the threshold value. In the case of the recorded average delay obtained is less than the threshold value for example 0.5µs, the transmission data rate will be increased in order to get a better result of throughput. Meanwhile, if the average delay is higher than the threshold value for example 1.5µs, adaptation of the transmission data rate to much lower level will be performed to control the delay. This discussion can be mathematically expressed by the equation (1) below,

$$t = \frac{L}{R} \quad (1)$$

where t represents delay and R represents the transmission data rate and L represents the packet size. The equation as shown in equation (1) indicates that low delay can be obtained if the transmission data rate is increased. Hence, the new transmission packet will use the new adaptation of the data rate that has been implemented. This process will be repeated until the final packet has been successfully delivered to the receiver as set in simulation.

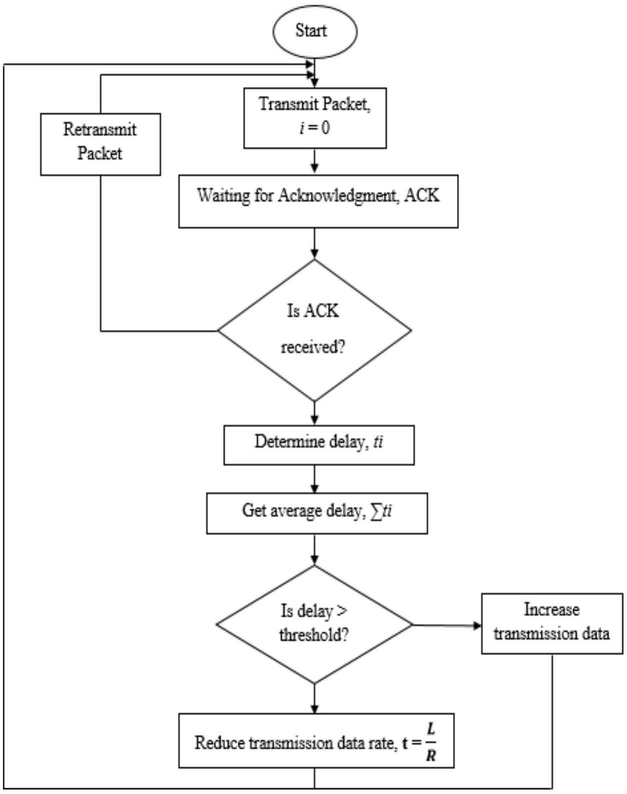

Fig. 4. Flowchart of rate adaptation

4. Results and Discussion

Results of simulation on performance analysis of rate adaptation algorithm in IEEE 802.11ax WLAN are presented in Fig. 5 to Fig. 7. Transmission rate for three conditions are well illustrated in Fig.5. The blue line indicates low traffic condition, the orange line indicates medium traffic condition and the grey line indicates high traffic condition. The node represents the number of users in the network. At low traffic condition (blue), the transmission rate value is higher than the other two condition and is decreasing when number of user increasing. This can be explained by equation in (1) which applies that delay value is lower than threshold value (1µs) when in low traffic condition. Hence, selection of high level transmission data rate based on MCS will give opportunity of throughput performance increment.

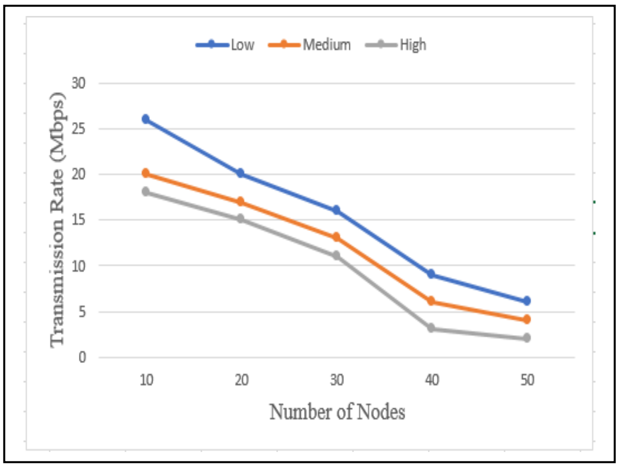

Fig. 5. Transmission rate for three network conditions

Fig. 6. shows the throughput for three conditions of network traffic. As the number of user increase, the throughput value or network performance for high traffic condition does not give satisfy value of throughput. This is because, during high traffic condition, the chances of packet loss during the transmission process is higher due to the congested network there. Hence, it will lead to higher collisions level.

However, at low traffic condition, as the user is increasing, the throughput is also increasing at such high rates. This happens because as the number of users keep expanding, the transmission data rate boots up their data rate in order to let the user experience a better throughput and network performance.

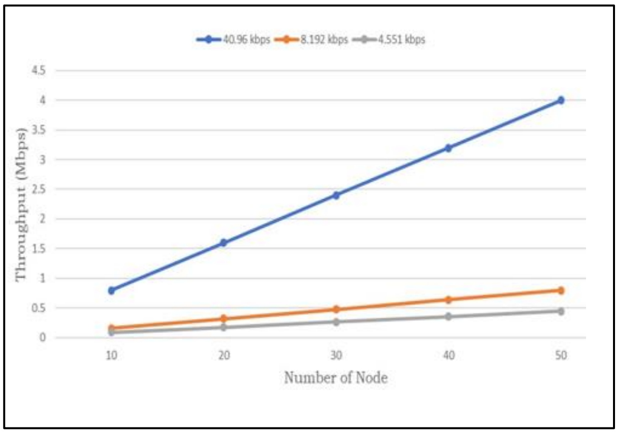

Fig. 6. Throughput for different traffic network conditions

The results of delay for the time taken for the packets to arrive at the receiver is being pictured in Fig. 7. It can be seen that during low traffic condition, when user is increasing, the average delay for the packet transmission is also keeps increasing. This is due to the traffic load has become congested at this condition, making the duration of packets transmission become slower because more packets try to access the network. Delay is proportional to node or number of user. When user in the network increases, the delay will also follow the result. This is also can be supports by higher contention level in the network which leads to lower percentage of successful packet transmission.

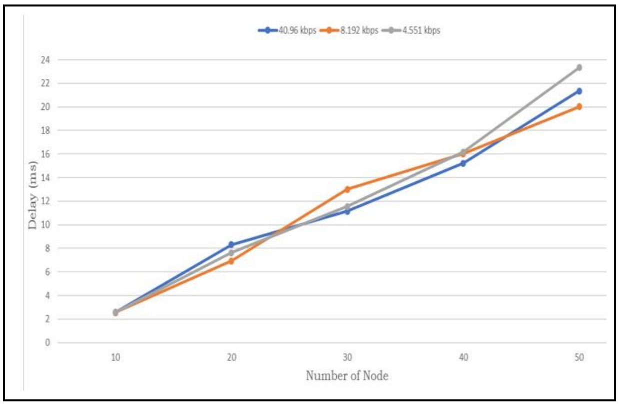

Fig. 7. Average delay for different traffic network conditions

5. Conclusion

In a conclusion, the performance analysis of rate adaptation technique in wireless network for IEEE 802.11ax are being studied. The QoS performance which is throughput and delay for tis standard has been analyzed and obtained based on different network condition and they are high traffic condition, medium traffic condition and low traffic condition. Based on the results, it has proven that by applying rate adaptation technique, it gives a better network QoS performance of IEEE 802.11ax standard. This will be an advantage for the low traffic and medium traffic user because they get to experience better data rates and network performance despite of its traffic condition.

6. Recommendation

For the recommendation, a new rate adaptation algorithm will be designed for the new Wi-Fi standard IEEE 802.11ax WLAN. This new algorithm will be designed in order to give more advantage on QoS performance as well as energy- efficient performance for this standard. This is because the reduction of power consumption on a device can prolong the lifetime of a battery.

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