Performance Analysis on IEEE 802.11ah Standard with Enhanced Distributed Channel Access Mechanism

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***Abstract*—IEEE 802.11ah is a new task group on the IEEE 802.11 standard designed to work on the 900 MHz. It is with a range of communication coverage up to 1 kilometer, lower energy consumption, and up to 8191 stations. There are two types of STAs in 802.11ah: sensor type to support sensor service and non-sensor type for offload service. In this research, it only focuses on non-sensor STA. For non-sensor STA, maximizing throughput is more important than power consumption. This research aims to see the performance of IEEE 802.1 1ah with Enhanced Distributed Channel Access (EDCA). To achieve that purpose, a mechanism is needed to provide guarantees various services required by the STA. EDCA is an access mechanism used to set the Quality of Service (QoS) for the IEEE 802.11 standard through modifications in MAC layer. In this research, it focuses on one of the EDCA parameters, Arbitration Inter-Frame Space (AIFS). In addition, this research also focuses on the 802.11ah feature is Restricted Access Window (RAW) by changing the number of the RAW groups. From the results of the research, it is found that the improvement scheme with Arbitration Inter-Frame Space Number (AIFSN) value AC_BK = 2, AC_BE = 1, AC_VI = 1, AC_VO = 1 has better performance compared to the default scheme with AIFSN value AC_BK = 7, AC_BE = 3, AC_VI = 2, AC_VO = 2) with an average throughput of 1.504598 Mbps, average overall delay of 0.066242 second and average PDR of 62%. In addition, changes in the number of RAW groups and RAW slots affect network performance. This feature can improve the value of throughput, average delay, and Packet Delivery Ratio. The goals of this research is to know the effect of AIFSN value changes on AIFSN parameters, variation of RAW group and RAW slot number to throughput, average delay and packet delivery ratio.**

***Index Terms*—AIFS, EDCA, IEEE 802.11ah, QoS, RAW**

I. INTRODUCTION

INSTITUTE of Electrical and Electronics Engineers (IEEE) 802.11ah is new task group in IEEE 802.11. It operates in the sub-gigahertz band (863–868.8 MHz in Europe; 950.8–957.6 MHz in Japan; 314–316 MHz, 433–432 MHz, 433–434.79 MHz in China; 917–923.5 MHz in Korea and 902–928 MHz in North America). It also can provide additional Wi-Fi network coverage compared to another conventional Wi-Fi network that operates on 2.4 and 5 GHz band frequency [1].

In IEEE 802.11ah, the energy consumption used is lower than other WLAN standards. This is because each STA connected to the AP will be in awake condition if STA receives or sends packets. Otherwise, it will be in the “doze” state, so it causes the energy consumption in IEEE 802.11ah to be lower [2]. Although the energy consumption on IEEE 802.11ah is lower than the existing WLAN standard, the coverage area is wider. It can reach up to 1 kilometer. Moreover, IEEE 802.11ah introduces an efficient paging and scheduling method to provide scalability for thousand stations. IEEE 802.11ah can serve up to 8191 stations [3]. IEEE 802.11ah also introduces a new mechanism, Restricted Access Window (RAW), which groups the station (STA) into groups. Each group has limited access channel during a certain period, and this mechanism is used to minimize collision [1].

There are two types of STAs in IEEE 802.11ah, sensor type to support sensor service and non-sensor type for offload service. The sensor STA is expected to have limited available power, low traffic volume and data frame with small payload size. On the other hand, for non-sensor STA, power consumption is not critical and maximizing throughput is more important [4]. This research only focuses on non-sensor STA. A mechanism is needed to provide guarantees services required by the non-sensor STA [4].

IEEE 802.11e-2005 or 802.11e is a standard for IEEE 802.11 that sets service quality (QoS) for WLAN through modifications in Media Access Control (MAC) layer. IEEE 802.11e has two MAC protocols, Dis-

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tributed Coordination Function (DCF) and Point Coordination Function (PCF). DCF is based on Carrier Sense Multiple Access with Collision Avoidance (CSMA / CA), whereas PCF is a polling mechanism controlled by Access Point (AP). In its development, there is a new protocol which is called as Hybrid Coordination Function (HCF). In HCF, there are two access mechanisms. HCF Controlled Channel Access (HCCA) is centralized, and Enhanced Distributed Channel Access (EDCA) is distributed [5]. However, these two MAC protocols are basically designed for data transmission and do not guarantee QoS [6].

The research focuses on IEEE 802.11ah with EDCA mechanism. This mechanism is much easier regarding implementation and analysis, and most previously researchers focus on this mechanism [5]. In the EDCA mechanism, there are three parameters to improve QoS, windows contents, Arbitration Inter-Frame Space (AIFS), and Transmission Opportunity (TXOP). This research focuses on AIFS parameters, where previous research [7] only focused on the effect of EDCA parameters on QoS WLAN IEEE 802.11e EDCF. It changes the AIFSN value in AIFS parameters so that it can improve the QoS. The researchers take AIFSN value in Ref. [7] that can improve the QoS.

In addition, this research focuses on how the effect of changes in the RAW group is to throughput, delay, and Packet Delivery Ratio (PDR). In previous research [8] for parameters tested only throughput and delay, but in this research for the parameters tested are throughput, delay, and PDR.

II. Research Method

A. IEEE 802.11

IEEE 802.11 is a standard implementation of wireless that works on 2.4; 3.6; 5 and 60 GHz frequencies. All devices and provisions that are wireless today follow the IEEE 802.11 standard. With this standard, it is intended that every different wireless device can stay in touch with different vendors. In IEEE 802.11, there are several task groups that have specifications of the frequency band, bandwidth, modulation scheme, channel architecture, maximum data rate, coverage, and maximum different transmit power [9]. Table I shows group on IEEE 802.11.

There are two major WLAN topologies. There is ad-hoc and infrastructure. Ad-hoc WLAN is peer to peer network that is set to serve the temporary need. There is no central coordination exist in this topology. Meanwhile, the infrastructure WLAN is topology whose station will access the wireless channel under the coordination of Base Station (BS) or AP [10].

Fig. 1. The use of IEEE 802.11ah for Internet of Things (IoT).

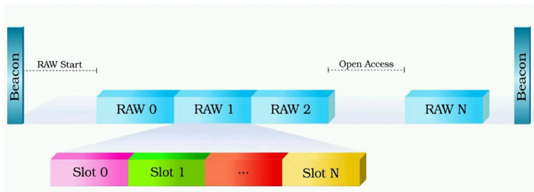

Fig. 2. The RAW structure.

B. IEEE 802.11AH

IEEE 802.11ah is a development of IEEE 802.11. It can be used to meet the need of Wireless Sensor Network (WSN) and Machine to Machine (M2M). IEEE 802.11ah is also capable of delivering smart solutions for smart metering, plan automation, e-Health, and intelligent transport systems. In addition, IEEE 802.11ah can manage the station (STA) in large quantities because it has a signaling hierarchy and the existence of power saving management.

The main cases of the use of IEEE 802.11ah are in the industry, home automation, smart metering, plantation and agriculture, and health as illustrated in Fig. 1. In this application, mostly use wireless sensors by monitoring and working together to pass the collected data to the network. IEEE 802.11ah introduces efficient paging and scheduling methods to provide scalability for thousands of stations. This only supports infrastructure mode and sends data at high speed on different conditions. Meanwhile, a better power-saving mechanism is proposed to address high energy consumption on conventional Wi-Fi technology [1, 11].

C. Restricted Access Window (RAW)

To support a number of devices associated with AP, TGah has developed a new mechanism to reduce congestion in channel access. In this mechanism during a certain time, the window is called as the Restricted Access Window (RAW). A group of stations is allocated with a certain time slot used to access the channel in RAW during a beacon interval as in Fig. 2. The

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TABLE I
THE IEEE 802.11 STANDARD.

Standard	Freq Band	BW	Mod Scheme	Channel Arc
802.11	2.4 GHz	20 MHz	BPSK to 256-QAM	DSSS, FHSS
b	2.4 GHz	21 MHz	BPSK to 256-QAM	CCK, DSSS
a	5.0 GHz	22 MHz	BPSK to 256-QAM	OFDM
g	2.4 GHz	23 MHz	BPSK to 256-QAM	DSSS, OFDM
n	2.4, 5.0 GHz	24, 40 MHz	BPSK to 256-QAM	OFDM
ac	5.0 GHz	20, 40, 80, 160 MHz	BPSK to 256-QAM	OFDM
ad	60 GHz	2.16 GHz	BPSK to 256-QAM	SC, OFDM
af	54–790 MHz	6, 7, 8 MHz	BPSK to 256-QAM	SC, OFDM
ah	900 MHz	1, 2, 4, 8, 16 MHz	BPSK to 256-QAM	SC, OFDM

station is not allowed to access the channel when it is outside RAW of the station slot. In addition, in the beacon interval, there are several RAWs that are allowed to access the channel [12].

In IEEE 802.11ah, each station uses two back-off states for EDCA to manage transmissions within and outside the respective defined RAW. The first back-off state is used outside of RAW and the second is used in the RAW slot. For the first back-off state, the station delays the back-off at the beginning of each RAW and returns it to continue the back-off at the end of RAW. For the second back-off situation, the station initiates a back-off with the beginning of a back-off state in the RAW slot and removes the back-off state at the end of the RAW slot [8].

D. IEEE 802.11e

IEEE 802.11e-2005 or 802.11e is a standard for IEEE 802.11 that governs the QoS for WLAN through modifications to the MAC layer. QoS is designed to help end users become more productive by ensuring that users get reliable performance from network-based applications. QoS refers to the ability of the network to provide better service on certain network traffic through different technologies. IEEE 802.11e defines a new coordination function called as Hybrid Coordination Function (HCF).

E. Enhanced Distributed Channel Access (EDCA)

EDCA is designed to maximize QoS by adding functionality to DCF. Then on the MAC layer, it defines four First in First out (FIFO) queues called as Access Category (AC). The access mechanism is similar to DCF. However, it is different for the duration of DIFS as it is replaced by AIFS. Before entering the MAC layer, each packet of data received from the above layer is assigned to a specific user priority value between 0 and 7. This priority maps the four AC such as background task traffic (AC_BK), best effort traffic (AC_BE), video traffic (AC_VI), and voice traffic (AC_VO) [5]. There are three main parameters for QoS

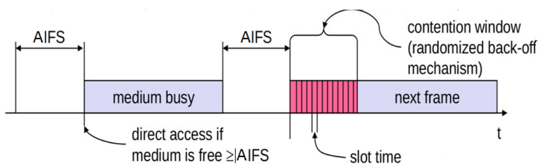

Fig. 3. The EDCA parameters.

adjustment to EDCA describes in Fig. 3: (1) Arbitration Inter-Frame Space (AIFS): space-time after station sends packets, (2) Transmission Opportunity (TXOP): the period required by the station to deliver the packet, and (3) Contention Window (CW): back-off timer after AIFS and before the station sends packets or frames. If the medium is idle, CW can be set to zero to be sent immediately. The number of CWs is driven between CWmin and CWmax.

EDCA provides a mechanism for distinguishing data flow types so that this technique assumes that each type of data stream has different priorities and each data stream will be classified under User Priorities (UP) and Access Category (AC). In total there are eight types of User Priorities (UP) which are mapped into four types of Access Category (AC) as in Table II. In 802.11ah system, an AP can indicate the type of STAs supports. It can select to support sensor type STA, non-sensor type of STA, or both. In IEEE 802.11ah, each STA sensors and non-sensors access channel channels using different EDCA parameters as illustrated in Tables III and IV. For STA sensor access category best effort is selected as the default setting, while in STA non-sensor category access category voice access category as default.

F. Simulation Model

The simulation is using Network Simulator 3.23 with IEEE 802.11ah module. It is modified by the addition of RAW feature. The model of a network simulation with an AP with a number of stations distributed using Uniform Disc Position Allocator as

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TABLE II
USER PRIORITY IN EDCA.

Priority	User Priority (UP)	802.11 Access Category (AC)	802.11 AC Designation	802.11D Designation
Lowest	1	AC_BK	Background	BK
	2	AC_BK	Background	-
	0	AC_BE	Best Effort	BE
	3	AC_BE	Best Effort	EE
	4	AC_VI	Video	CL
	5	AC_VI	Video	VI
	6	AC_VO	Voice	VO
Highest	7	AC_VO	Voice	NC

TABLE III
EDCA PARAMETERS FOR SENSOR STA.

Access Category	AIFSN	CWmin	CWmax
Background	7	15	1023
Best Effort	3	15	1023
Video	2	7	15
Voice	2	3	7

TABLE IV
EDCA PARAMETERS FOR NON-SENSOR STA.

Access Category	AIFSN	CWmin	CWmax
Background	7	15	1023
Best Effort	2	3	15
Video	5	7	15
Voice	4	7	15

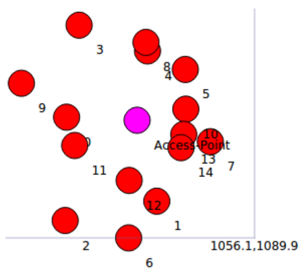

Fig. 4. Topology of simulation.

describe in Figure 4. The mobility of user uses RandomDirection2dMobilityModel with a range of speed about 1.2–1.8 m/s. It simulates the users. For energy consumption, it uses TX, RX, Idle, and Sleep modes in accordance with Ref. [8].

In the simulation of 802.11ah in NS3, there are two types of slot format, 0 and 1. For slot format 0, the maximum number of RAW slots is 64. For slot format 1, the maximum limit for RAW number slots is 8. For slot format 0, the maximum RAW slot count that is used to calculate the duration of each slot is 256. For slot format 1, the maximum RAW slot count limit is 2048. The parameters set out in general for the 802.11ah network scenario can be seen in Table V.

The simulation is done through two scenarios. Each

TABLE V
SIMULATION PARAMETERS.

Parameter	Information
Physical Layer	WLAN / IEEE 802.11
Transport Layer	UDP
Datarate	7.8 Mbps
Bandwidth	2 MHz
Mobility Model	Random Direction 2D Mobility Model
STA Speed	1.2–1.8 m/s
Max range	100 m
TX Current	0.280 A
RX Current	0.204 A
Idle Current	0.178 A
Sleep Current	0.140 A

TABLE VI
PARAMETERS OF VARIATION RAW GROUP NUMBER.

Parameters	Information
Number of RAW Group	1 and N/2
Number of Stations (N)	30, 60, 90 and 120
Distance	100 m
Number of RAW Slot	1

scenario presents a certain change. The first scenario presents a change in the value of AIFSN to the number of stations. The second scenario presents the RAW group changes to the number of stations.

1) Variation of AIFSN Value Scenario. This scenario aims to simulate IEEE 802.11 standard with EDCA mechanism and AIFS parameter value change that is AIFSN to change station number. The number of stations starts from 30 with the addition of 30 to 150 stations and the maximum distance between the AP and the station is 100 meters as describe in Table VII. The Modulation and Coding Scheme (MCS) used in this scenario is MCS 8 with 7.8 Mbps data rate and 2 MHz bandwidth. The Arbitration Inter-Frame Space Number (AIFSN) value in the improvement scheme is found in Ref. [7] that QoS improves compared to the default scheme. The result is in Table VI.
2) Variation of RAW Number Group Scenario. This scenario is conducted to determine the effect of

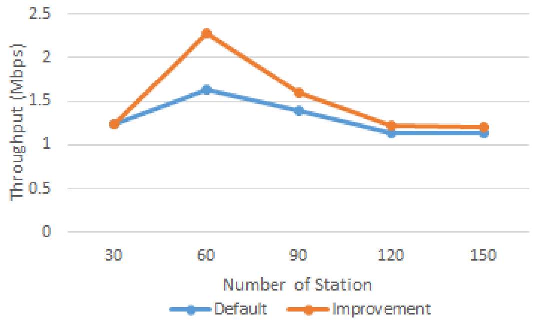

Fig. 5. Effect changes of AIFSN value to throughput.

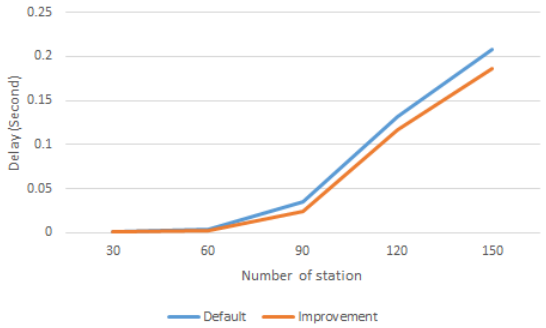

Fig. 6. Effect changes of AIFSN value to delay.

RAW group changes on the value of throughput, average delay, and PDR. The change in the number of RAW groups is 1 and Number Station (N) is /2. The number of stations is started from 30 with the addition of stations as many as 30 to 120 with the maximum distance between AP and station is 100 meters as describe in Table VII. In this scenario, it also uses EDCA parameters from improvement scheme in the first scenario.

III. Results and Discussion

A. Variation of AIFSN Value Result

In Fig. 5, it can be seen that the performance of the default scheme is under the performance of improvement scheme. It is reviewed based on the throughput result with the addition of the number of stations. In the default scheme, the highest throughput value is when the number of stations is equal to 60 or 1.62099 Mbps. Meanwhile, the lowest value is when the number of stations is 150 such as 1.12742 Mbps with the average value of the overall throughput around 1.302732 Mbps.

In Fig. 5, it can also be seen that in the improved scheme, the throughput value is improved compared to the default scheme, which the improvement is 13.68202%. In the improved scheme, the highest throughput value is when the number of stations is equal to 60 or 2.27601 Mbps. Then, the lowest value is when the number of the station is 150 or 1.21037 Mbps with the average throughput overall about 1.504598 Mbps.

The throughput with improvement scheme has better results compared to the default schema. This is because, in the improvement scheme, the AIFSN value is smaller than the default scheme. It causes the AIFS value to become smaller and the medium access priority to be higher. Higher priority can lead to higher chances of accessing the channel, which is the reason why the value of throughput can increase. On the other hand, if the AIFS value is greater, it can reduce the overall system throughput. It is because the station's chance to access the channel becomes small. In addition, the large AIFS values can also cause the network to be under a large load.

From Fig. 5, it can be seen that throughput decreases when station number is 90 to 150. This throughput reduction is most likely due to the occurrence of collisions within the channel. This collision occurs because, in this scenario, the number of RAW groups and the number of RAW slots used is 1. This means there is no channel access restriction for each station, so all stations will try to compete with each other to access the channel. This causes the throughput value to decrease.

In Fig. 6, it can be seen that the default scheme performance is under the performance of improvement scheme. It is based on the average delay result with the addition of the number of stations. In the default scheme, the highest average delay value is when the number of stations is equal to 150 like 0.208564 seconds. The lowest value is when the number of the station is 30, that is 0.001128 seconds with the average total delay value about 0.076152 second.

In Fig. 6, it can also be seen that the average delay performance of improvement scheme is better than the default scheme. The improvement obtained is 18.06041%. In the improvement scheme, the highest average delay value is at the number of stations about 150 or 0.186129 seconds. Meanwhile, the lowest value is when the number of the station of is 30 or 0.00106083 second with the average total delay value about 0.066242 seconds.

Figure 6 also shows that the increasing number of users will increase the value of average delay. This is because more stations are trying to access the channel to transmit data packets. Therefore, each station has to wait for other stations to access the channel. The length of each waiting station causes the delay to increase as the number of stations increases. The average delay in the repair scheme has a better result compared

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TABLE VII
PARAMETERS OF VARIATION OF AIFSN VALUE.

Parameter	Default Scheme				Improvement Scheme			
AC	BK	BE	VI	VO	BK	BE	VI	VO
CWmin	15	15	7	3	15	15	7	3
CWmax	1023	1023	15	7	1023	1023	15	7
AIFSN	7	3	2	2	2	1	1	1
Number of Station	30, 60, 90, 120 and 150							
RAW Group	1							
RAW Slot	1							

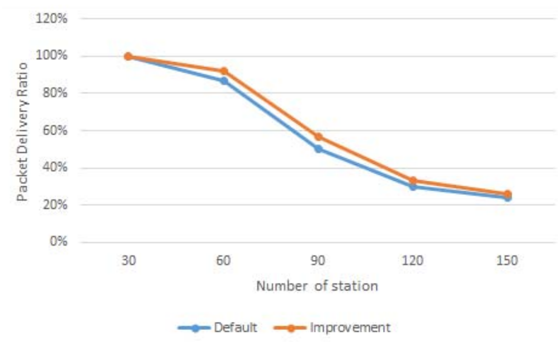

Fig. 7. Effect changes of AIFSN value to PDR.

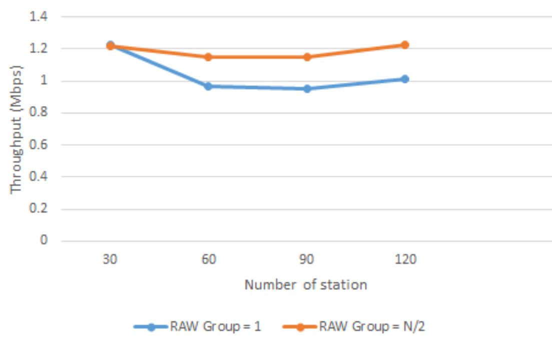

Fig. 8. Effect changes of RAW Group number to throughput.

to scheme 1 (default scheme). This is as previously described in the throughput results that the higher priority can cause the station's chance to access the channel to be higher. The station does not have to wait too long to access the medium. Therefore, the repair scheme has better average delay results compared to the default scheme.

In Fig. 7, it can be seen that the performance of the default scheme is under the performance of the improvement scheme. It is based on the PDR results with the addition of the number of stations. In the default scheme, the highest PDR value is the number of stations about to 30 i.e., 100%. Then, the lowest value is when the station number is 150 i.e., 24% with the overall average PDR value of 58%. Figure 7 shows that the performance of improvement scheme is better than default scheme. The improvements obtained by the improvement scheme are 8%. In the scheme of improvement, the highest PDR value occurs when the number of stations is equal to 30 i.e., 100%. Meanwhile, the lowest value is at the station number about 150 i.e., 12% with the overall 62% of PDR average.

In Fig. 7, it can be implied that the more number of stations on a network results in the PDR to decline. This is because more stations are trying to access the channel. It causes the possibility of collisions to be larger. Thus, this can cause the packet to be a lot of loss. The number of packet loss causes the value of PDR to decline.

B. Variation of RAW Group Number

Figure 8 shows that RAW Group = 1 is under the performance of the RAW Group scheme = N/2. It is based on the throughput result with the addition of the number of stations. In the RAW Group scheme = 1, the highest throughput value is when the number of stations equals 30 i.e., 1.227433043 Mbps and the lowest value is the station number 90, which is 0.95232 Mbps with the average throughput overall about 1.04 Mbps.

In Fig. 8, it can also be seen that with RAW Group = N/2, the throughput value improves compared to the RAW Group = 1 scheme. The increase is 15.05417%. In RAW Group = N/2, the highest throughput value is when the number of stations is equal to 120 or 1.22572896 Mbp. Meanwhile, the lowest value is at the station number 60 that is 1.14688 Mbps with the average throughput overall about 1.1864 Mbps.

The RAW Group = N/2 scheme is better than the RAW Group = 1 scheme. It indicates that grouping stations can improve throughput values. The value of throughput can be good because each station has limits to access the channel, which limits the purpose of minimizing the occurrence of contention and the probability of occurrence of collisions. Then, the contention and collision can cause the network performance to drop.

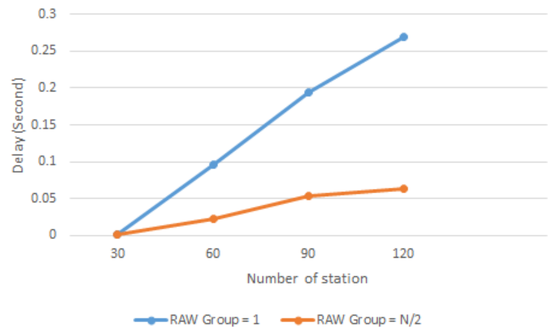

Fig. 9. Effect changes of RAW Group number to delay.

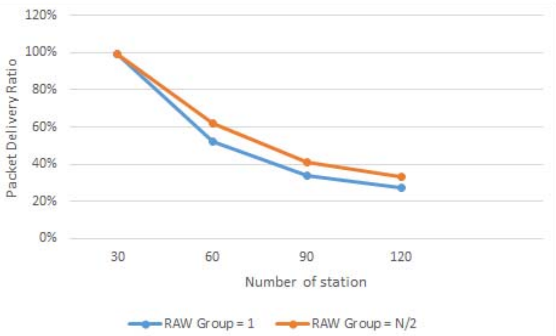

Fig. 10. Effect changes of RAW Group number to PDR.

Figure 9 shows that the increasing number of users will increase the value of average delay. This is because more stations are trying to access the channel to transmit data packets. Therefore, each station must wait for other stations to finish accessing the channel. The length of each waiting station causes the delay to increase along with the increasing number of stations.

The RAW Group Scheme = N/2 is better than the RAW Group of 1 scheme. It implies that grouping stations can improve the average delay value. The average delay value can be good for RAW Group N/2 because there are 30 stationsthat are divided into 15 groups, so a group contains 2 stations. The 2 stations in one group will compete to access the channel, where waiting time for channels in idle condition is less compared to 30 stations in one group. For 30 stations in one group, each station must wait longer due to the number of stations that access the channel.

From Fig. 10, it can be concluded that the number of stations on a network cause the PDR to decline. This is because more stations are trying to access the channel. It causes the possibility of collisions to be larger, so this can cause the packet to decline. The number of packet loss is the causes of PDR value to decline.

IV. Conclusion

AIFSN value change affects network performance. From the results of the research, it is found that the AIFSN value in the improvement scheme (AC_BK = 2, AC_BE = 1, AC_VI = 1, AC_VO = 1) has more performance compared to the default scheme (AC_BK = 7, AC_BE = 3, AC_VI = 2, AC_VO = 2). The changes in the number of RAW affect the performance of the network. The RAW mechanism can increase the value of throughput, average delay, PDR, and energy consumption. However, this depends on the used evaluation metrics, the number of stations, and the traffic load on the network. From this research, energy efficiency mechanism in 802.11ah works well despite the change of AIFSN value and number of the RAW group.

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