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Performance Analysis of the Differences Restricted Access Window (RAW) on IEEE 802.11ah Standard with Enhanced Distributed Channel Access (EDCA)

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Abstract - IEEE 802.11 standard is a WLAN (Wireless LAN) standard that has been used in all over the world. IEEE 802.11ah is the newer technology that designed to supports Internet of Things (IoT) and Machine-to-machine Communication (M2M). IEEE 802.11ah has a feature called Restricted Access Window (RAW) that capable to reduce power usage and have satisfying Quality of Service (QoS). In this research, Enhanced Distributed Channel Access (EDCA) is also applied. Same as RAW, EDCA also be able to affect QoS by modified the MAC Layer in 802.11 standard. This research used 3 different scenarios for RAW parameters: Modifying the number of RAW Group, Modifying the number of RAW Slot, and Comparing 2 Datamode. The EDCA Parameters that used in this research were: Contention Window and Arbitrary inter-frame Spacing Number. The values that expected to be the output in this research are: Delay, Throughput, Packet Delivery Ratio, Availability, and Reliability. After the research has been simulated, the results are: First, the lowest of average delay was Ngroup = 1, the highest of PDR was Ngroup = Nsta/2, and the highest of Throughput was Ngroup = Nsta/2. Second, the lowest of average delay was RAW Slot = 6, the highest of PDR were RAW Slot = 3 and 4, and the highest of Throughput was RAW Slot = 4. Third, the lowest of average delay was Datamode 3,9 Mbps BW 2 MHz, the highest of PDR was Dat mode 3,9 Mbps BW 2 MHz, and the highest of Throughput was Datamode 3,9 Mbps BW 2 MHz. Reliability, Availability, and Energy Consumption also can be affected by modifying RAW parameters, in 802.11ah Energy Consumption can be reduced by increasing the number of RAW Stations and RAW Groups.

Keywords – 802.11ah, 802.11, EDCA, RAW, WLAN

I. INTRODUCTION

The background of 802.11ah development is to increase the performance of industry automation, home smart appliance, smart metering, farm industries and health solution. These industries mostly used wireless sensor to monitor the physical condition around the industry environment. 802.11ah would increase the efficiency of information distribution in the network with further reduced power consumption by its feature of its advanced power saving function in significant compared to conventional Wi-Fi network uses [1].

Clear Channel Assessment (CCA) is a logic function in PHY layer to do Carrier Sensing and Collision Detection [1]. This function will decide a Wi-Fi device to use available channel and check the distribution channel for its availability. In different case CCA will calculate the energy efficiency level in the wireless device to check the their energy threshold, and availability [1]. The disadvantage for DCF method is treating all kinds of traffic types as same as each other. Then the newest contention-based method introduced on 802.11e standard, i.e. Enhanced Distributed Channel Access (EDCA). In EDCA, traffic data divided into four types, i.e. Voice, Video, Background, and Best Effort. And the channel sensing changes to more flexible duration known as Arbitration Interframe Space (AIFS).

Restricted Access Window (RAW) is a duration of time consists of several time slot. RAW could be used for certain usage [1], and its often used to avoid data collision in data communication [2]. RAW also helps STA to prevent the STA using the channel continuously but limited into fixed duration. So that a STA access is controlled by RAW. As the network controlled by RAW the data transfer process will adjust according to their respective rules of transfer. RAW also can forbid a STA to use particular slot in data transfer [3]. In [4], RAW feature is also able to divide STA into groups, limiting the channel usage by STA itself, this feature help to reduce the chance of data collision while network is busy. While 802.11ah not giving specific method on how dividing and giving duration limit and also for the dividing method itself. IEEE 802.11ah has 1 MHz and 2 MHz channel for its usage in every country to be used and claimed will fulfill the requirement of 802.11 standards. The 1 MHz channel transmission will also increase the coverage and reliability performance for the standard itself [2].

Even though the 802.11ah has not been officially released, there are other research that investigating this standard already, for both the PHY Layer or the MAC Layer. The researches have been done to help for reach the better performance for 802.11ah.

In this paper [5], comparison between the normal AIFS number and the fixed AIFS number, by comparing the number of the RAW Groups =1 and RAW Groups = Nsta/2, and testing the differences number of RAW Slots. Also the result between [5] and this research is, this research got higher PDR percentage and lower Delay number but lower Throughput rate, it is because the Queue Packet number and time in this research given more time than [6], comparing two Error Rate Model, Yans Error Rate and Nist Error Rate and also implementing the RAW. And mainly, the 802.11ah researches are implemented by RAW scenario, because RAW is a new feature built in 802.11ah, that used to minimalize system power consumption. Also, [7], implementing Traffic-Adaptive RAW Optimization Algorithm (TAROA), the using if TAROA is aim to solve the aforementioned problem by estimating the transmission interval of each station on AP side and maximizing the number of successful transmission. Also compared TAROA to EDCA/DCF mechanism.

And there are also researches that implying Hidden Node condition to 802.11ah standard. Hidden Node is a condition where a station cannot hear the other station that located outside the range. Example, there are station A, B, and C, B is in A's range, but C is outside A's range. So when A transmit any data to B, C cannot hear, and C also transmit data to B at the same as A transmit [8]. This problem will cause many data collisions in the network and it will occure performance issue. The Comparison between the 802.11ah standard that implemented with Hidden Node problem and the normal 802.11ah was done by this research [8]. The result is the 802.11ah without Hidden Node has higher Throughput compared to the result for 802.11ah with Hidden Node problem [8]. This research [7] was also implementing the Hidden Node problem in their research.

II. RESEARCH METHOD

A. Research Scenario

This research uses 3 different scenarios, the RAW group, the RAW Slot, and the Datamode. The focus outcome of this research for every scenarios are, Throughput, Packet Delivery Ratio (PDR), Delay, Energy Consumption, Availability, and Reliability. The basic parameters that used in this research will be shown in Table 1.

Table 1. Basic Parameters

Parameter	Informasi
Physical Layer	WLAN / IEEE 802.11
Transport Layer	UDP
Datarate	2,4 Mbps; 2,7 Mbps; 3,9 Mbps
Max Packet Generated	999999
Number of Node	60, 90, 120, and 150
Bandwidth	1 Mhz and 2 Mhz
Beacon Interval	102400 ms
Slot Format	1
Time each Slot (RAWSlotCount)	162
Max range	250 meter
Number of RAW Station (Nsta)	Number of RAW Station = Number of Station

This research also uses EDCA Parameters, and the EDCA parameters are shown by the Table 2.

Table 2. EDCA Parameters

Category	minCW	maxCW	AIFSN
Voice	7	15	2
Video	15	31	2
Best Effort	31	1023	3
Background	31	1023	7

The first scenario is the RAW Group (Ngroup) and the RAW Station (Nsta), the Ngroup uses 2 different numbers which are Ngroup = 1 and Ngroup = Nsta/2 and the RAW station uses 60, 90, 120, and 150 stations. The Datamode for first scenario is Datamode 2.4 Mbps BW 1 MHz or MCS5 BW 1 MHz and RAW Slot = 3.

The second scenario is the RAW Slot and the RAW Station (Nsta). The RAW Slot uses 5 different numbers which are 3, 4, 5, 6, and 7 RAW Slots and the RAW station uses 60, 90, 120, and 150 stations. The Datamode for the second scenario uses the Datamode 2.4 Mbps BW 1 MHz, and the Ngroup =1.

The third scenario is the Datamode and the RAW Station (Nsta). This research uses 2 different kinds of Datamode, first is Datamode 2.7 Mbps BW 1 MHz or MCS 6 BW 1 MHz and second is Datamode 3.9 Mbps

BW 2 MHz or MCS 4 BW 2 MHz. The RAW Station uses 5 different numbers, same as other scenario, which are 60, 90, 120, and 150 stations. Number of Ngroup is Ngroup = 1 and the RAW slot = 3.

B. Tools and Material

For this research, *Network Simulator 3 (NS-3)* is used for implementing the 802.11ah network, the version of NS-3 for this research is NS-3.25. The Operating System for this research is Linux Ubuntu 12.04 63-bit and used VMWare Workstation Pro for the *Machine Virtualization* for the Ubuntu.

C. Performance Test Parameter

After the research, the results of the simulation are examined with six test parameters. The test parameters are:

a) Throughput
Throughput is a receive rate for data that received at the receiver in a particular observation time, the measurement for Throughput is *Mbit/s* or *Mbps*. The formula for throughput is:

$$\text{Throughput} = \frac{\text{Received Data (Mbps)}}{\text{Observation Time (s)}} \quad (1)$$

b) Delay
Delay is the average of transmitting time from the transmitter to the receiver. The formula for delay is:

$$\text{Delay} = \frac{\sum(tRx - tTx)}{\sum Received\ Packet} \quad (2)$$

In the equation (2), Received Packet represents the total data that arrive in the receiver, and t is total of time it takes to send the data.

c) Energy Consumption
Energy Consumption is the energy that the system takes for doing its work, from the *Access Point (AP)* to the *end-device*.

d) Reliability
Reliability defined as the probability that shows the system can operating properly without failure or failure free condition within normal operating condition [9][10].

e) Availability
Availability is the probability that the system can perform its required function when it needed to, that it is not failed or under a repairing action [10] [11] [12].

III. RESULT

This research analyzed using 3 given scenario. The first scenario is changing the amount of Ngroup and NSta, the second scenario is changing the amount of RAW slot and NSta and the third scenario is changing the Datamode type and NSTA. From these methods there will be a parameter to be measured, those parameters are: packet delivery ratio (PDR), throughput, delay, availability and reliability.

A. Result for First Scenario

First scenario is the Ngroup scenario with the number of Ngroup are Ngroup = 1 and Ngroup = Nsta/2. This scenario aims to find out how much the throughput can be by changing the number of Ngroup.

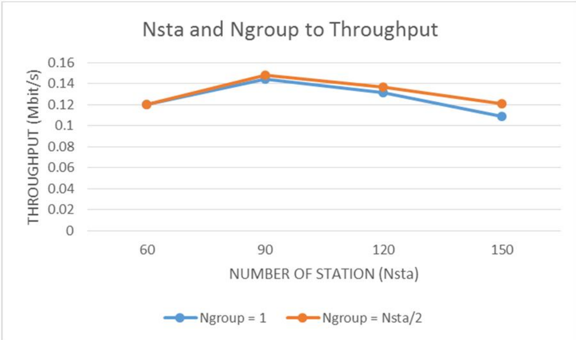

Fig.1. Result for Ngroup and Number of STA to Throughput

In Fig.1, the highest throughput rate for Ngroup = Nsta/2 is 0.148 Mbit/s for 90 stations, while the lowest number is 0.12 Mbit/s for 60 stations. Meanwhile, for the Ngroup = 1, the highest throughput rate is 0.1446 Mbit/s for 90 stations. And the lowest rate is 0.1089 Mbit/s for 150 stations.

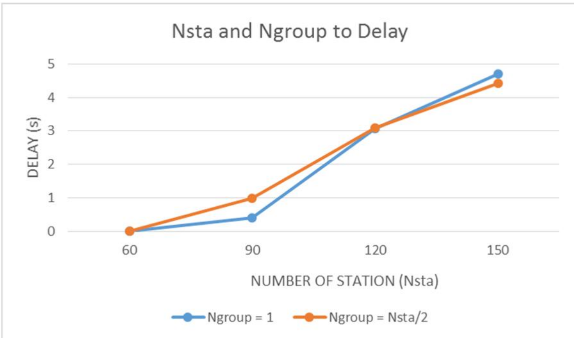

Fig.2. Result for Ngroup and Number of STA to Delay

In Fig.2, the highest delay time is in 150 stations for both Ngroup = 1 and Ngroup = Nsta/2. For Ngroup = 1, the highest delay is 4.7127 s and for Ngroup = Nsta/2 is 4.425 s. For the lowest delay time, for Ngroup = 1 is in 60 stations with 0.0019 s. For Ngroup = Nsta/2, the lowest delay is also in 60 stations with 0.0085 s.

B. Result for Second Scenario

In this scenario, the amount of RAW slot will be adjusted and also the amount of STA will be adjusted. This scenario will use certain amount of RAW slot, there will be 3, 4, 5, 6, and 7 slots RAW to be examined in this scenario. The amount of STA will be also adjusted by 60, 90, 120, and 150.

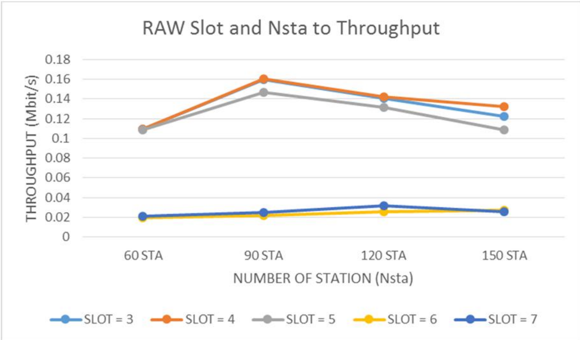

Fig 1. Result for RAW Slot and Number of STA to Throughput

From Fig.3, the highest throughput rate for RAW Slot = 4 is 0.16033 Mbit/s in 90 stations while the lowest rate is 0.1091 Mbit/s in 60 stations. From Fig. 3, RAW slot = 4 has the highest average throughput rate with 0.136 Mbit/s, the second highest is RAW Slot = 3 with 0.133 Mbit/s, the third is RAW Slot = 5 with 0.124 Mbit/s, the fourth is RAW Slot = 7 with 0.02581 Mbit/s.

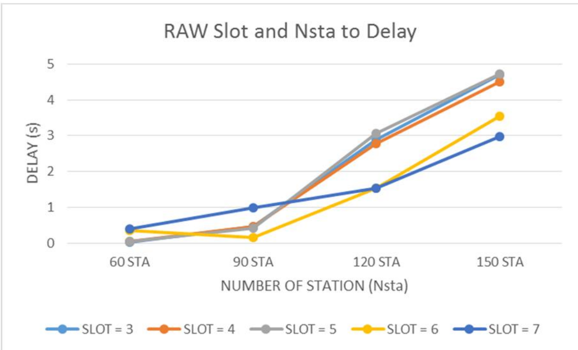

Fig.2. Result for RAW Slot and Number of STA to Delay

From the Fig.4 the highest delay recorded is while the amount of STA is 60 and 90, following by the amount of RAW slot = 7. The recorded delay was 0.3843 s and 0.9847 s. This delay is caused by the maximum duration per slot is increased following by the increasing slot. In this scenario the slot used is SlotFormat =1, where the maximum duration per-slot is 246,14 ms [6].

C. Result for Third Scenario

In the third scenario, the scenario being implemented in the third scenario is the changes of 2 type of datamode with a particular bandwidth and datarate of 2,7 Mbps BW 1 Mhz and 3.9 Mbps BW 2 MHz, and there are an increased pattern of STA from 60, 90, 120, and 150 STA.

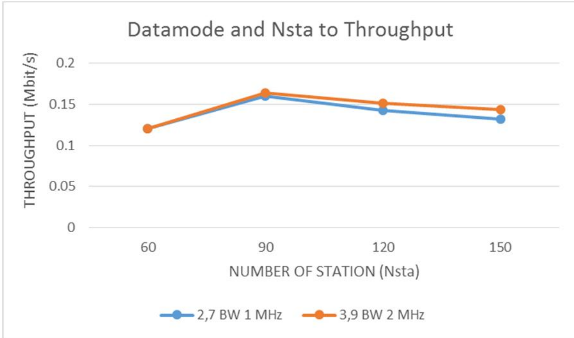

Fig.3. Result for Datamode and Number of STA to Throughput

From Fig.5, the highest throughput rate for Datamode 3.9 Mbps BW 2 MHz is in 90 stations with 0.16324 Mbit/s and the lowest is in 60 stations with 0.12 Mbit/s. Meanwhile, for the Datamode 2.7 Mbps BW 1 MHz, the highest rate is also in 90 stations with 0.1597 Mbit/s and the lowest rate is in 60 stations with 0.1199 Mbit/s.

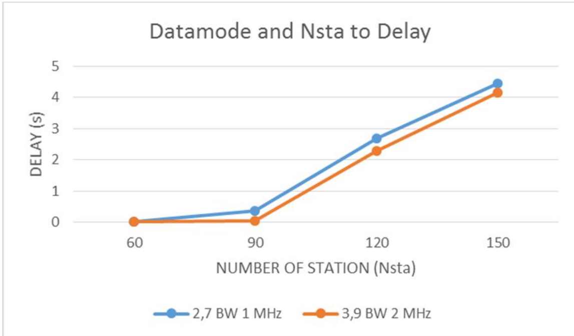

Fig.4. Result for Datamode and Number of STA to Delay

From Fig.6, we can see the lowest delay is achieved while the datamode is 3.9 mbps BW 2 MHz by 0.01363 s STA = 60. While STA = 90, the delay is increased to 0.04716 s, and while STA = 120 and 150 STA there is a significant increased delay with respective score delay of 2.2985 s and 4.1578 s.

D. Result for Energy Consumption

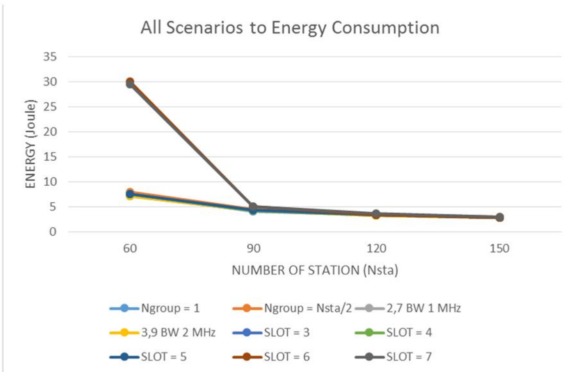

Fig.5. Result for All Scenarios to Energy Consumption

From Fig.7, the biggest average score of energy consumption is achieved by the RAW Slot scenario. RAW Slot = 6 has the highest average energy consumpted with 10.39 Joules, followed by RAW slot = 7 with 10.315 Joules. The Datamode scenario has the lowest score of Energy Consumption. The Datamode 3.9 Mbps BW 2 MHz is the lowest average score among the Datamode scenario with 4.379 Joules. While the Datamode 2.7 Mbps BW 1 MHz got the average score 4.381 Joules. And for the Ngroup scenario, the Ngroup = 1 has the lowest average, with 4.49 Joules. While the Ngroup = Nsta/2 has 4.778 Joules.

E. Result for Availability and Reliability

For the availability and reliability result, this research uses the first-thirty failed packets data to calculate the downtime from the pcapfile. This method applied to all availability and reliability calculations and graphs in this research.

a) Availability and Reliability for First Scenario

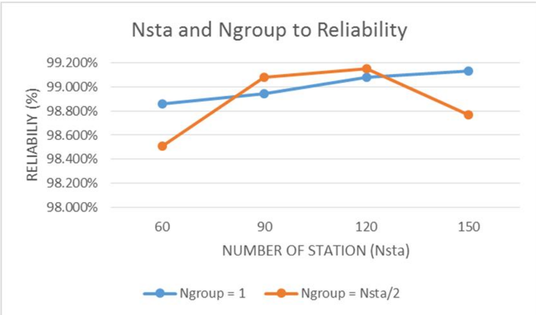

Fig.8. Result for Ngroup and Number of Stations to Reliability

In Fig.8, we can see the highest reliability we could get is in Ngroup = Nsta/2 with the amount of sta = 120 with score of 99.150% and the lowest score of availability is 98.510% where the amount of sta is 60.

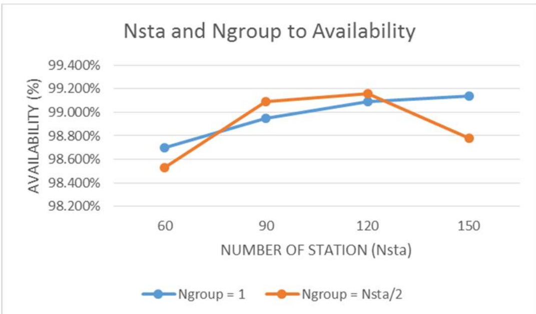

Fig.9. Result for Ngroup and Number of Stations to Availability

From Fig.9, the highest availability for Ngroup = Nsta/2 is 99.160% in 120 stations and the lowest is 98.53% in 60 stations. For the Ngroup = 1, the highest availability is 99.14% in 150 stations and the lowest is 98.7% in 60 stations. In the Fig. 8 and Fig. 9, the degradation occurred on 120 stations to 150 stations. That is because the channel idle time is decreasing caused by the re-transmission request.

b) Availability and Reliability for Second Scenario

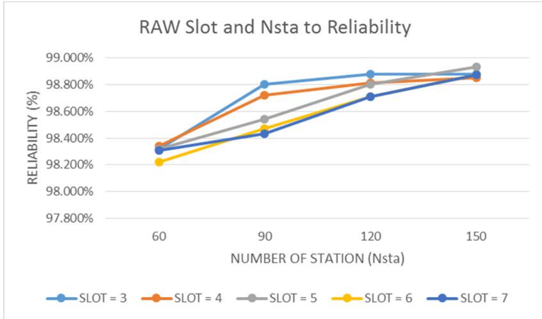

Fig 10. Result for RAW Slot and Number of Stations to Reliability

In the Fig.10, the highest average reliability is 98.72% by RAW Slot = 3, the second is 98.68% by RAW Slot = 4, the third is 98.648% by RAW Slot = 5, the fourth is 98.58% by RAW Slot =7, and the last is 98.568% by RAW Slot =6.

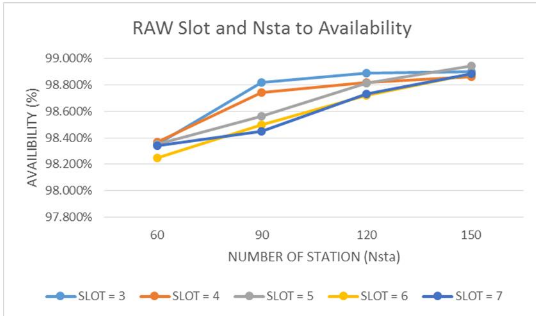

Fig 11. Result for RAW Slot and Number of Stations to Availability

From Fig.11, the highest average availability percentage is RAW Slot = 3 with 98.740%, second is RAW Slot = 4 with 98.698%, third is RAW Slot = 98.655%, fourth is RAW Slot = 7 with 98.6%, and lastly is RAW Slot = 6 with 98.588%.

c) Availability and Reliability for Third Scenario

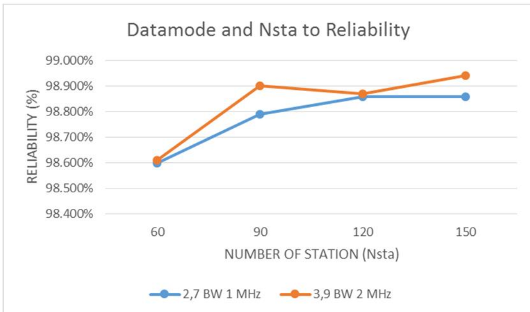

Fig 12. Result for Datamodes and Number of Stations to Reliability

From Fig.12, the highest reliability percentage for Datamode 3.9 Mbps BW 2 MHz is 98.940% at 150 stations. The lowest percentage is 98.610% at 60 stations. For the Datamode 2.7 Mbps BW 1 MHz, the highest is at 120 and 150 station with 98.86% and the lowest is at 60 stations with 98.6%.

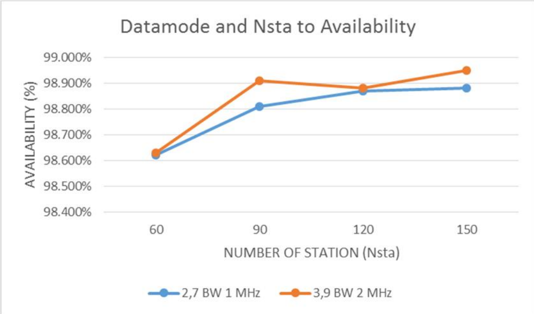

Fig.13. Result for Datamodes and Number of Stations to Availability

From Fig.13, the highest availability percentage for Datamode 2.7 Mbps BW 1 MHz is 98.88% at 150 stations and the lowest is 98.6% at 60 stations. For the Datamode 3.9 Mbps BW 2 MHz, the highest percentage is 98.95% at 150 stations and the lowest percentage is 98.630% at 60 stations.

IV. DISCUSSION

This chapter will discuss about the result that the research has been done. And also analyze about the graphs that computed from the result of this research.

A. QoS Analysis

In the Fig.1 we have analyzed that the Ngroup = Nsta/2 had better Packet Delivery Ratio comparing to Ngroup = 1. Dividing STA in groups improve the performance of the network in case of packet transmitting. This result was also showing by increasing the Ngroup reduce contention, collision and boost the process of re-transmission. From Fig. 2, increasing the amount STA will cause STA delayed their packet transmission. However, the advanced method of re-transmission will reduce the throughput but increasing delay. There is an increased delay shown in the amount of increased STA by 90, 120 and 150, mostly caused by the activity of re-transmission which did by the system [6]. Increasing the amount of STA will also reduce the throughput thus it also reduces the idle time of a channel. The more STA is also causing there are more packet to be send.

From Fig.3, the declining trend of the line graph it's caused by re-transmission activity is higher and higher as the stations increase. It is because more number of stations will increase the packets transmitted in the network. Because the number of packet is increase and the re-transmission activity, it will affects the channel idle time, the more the transmit activity in the network, the less the channel idle time will be.

We can also see from the Fig.4, the more the STA, the delay will also higher. Mostly by the increasing amount of STA will also increase the amount of packet send in the network, that also creating packet collision in the network and also increasing the contention. However, with the rule of RAW slot = 7 and amount STA = 150, the contention rate is lower [13]. The previous set up resulting better performance graph of delay with the best delay achieved by 2.9838 s. From the scenario above we can conclude the more RAW slot we implement is not the main solution to an increased amount of STA, because RAW slot will makes a transmission duration shorter while increasing the packet size transmitted over the network.

From Fig.6, we can see the lowest delay is achieved while the Datamode is 3.9 Mbps BW 2 MHz by 0.01363 s STA = 60. While STA = 90, the delay is increased to 0.04716 s, and while STA = 120 and 150 STA there is a significant increased delay with respective score delay of 2.2985 s and 4.1578 s. we can conclude from the graph with the Datamode of 3.9 Mbps and BW 2 MHz the scenario achieved a lower delay score for each amount of STA compared to the Datamode of 2.7 Mbps BW 1 MHz. this case is happening because of the higher datarate and the higher the bandwidth will reduce the delay following a narrowed packet transmission lane. From Fig. 5, he throughput rate in Datamode 3.9 Mbps BW 2 MHz is having higher score by 0.144 Mbit/s compared to Datamode 2.7 Mbps BW 1 MHz which is scored by 0.138 Mbit/s. It caused by faster re-transmission in the Datamode 3.9 Mbps BW 2 MHz so that the demand of re-transmission can be fulfilled much more rather than Datamode 2.7 Mbps BW 1 MHz.

B. Energy Consumption Analysis

For the Energy Consumption, from Fig. 7 with the increasing amount of sta, the energy to transmit is much smaller as stated in [14] [15], the more sta we deploy there is much less energy consumed in the system. The main point of energy consumption is caused by RAW usage a non-transmitting sta will be stated as idle sta. without RAW, increasing the number of sta will cause the packet queueing longer so that the idle time is decreased because of the contention.

C. Availability and Reliability Analysis

From Fig.8, we can see from the line graph of Ngroup = nsta/2, starting from 60 STA to 12 sta, there is an increase to reliability score, while the highest increase is happening while the sta increase from 60 to 90 sta. this case is caused by self-healing factor of the system. From Fig. 9, the score of availability is affected by the score of downtime and also uptime. The Ngroup = nsta/2 scenario there is a downtrend of performance with sta = 150 sta which is mainly caused by the increasing trend of downtime, the root of this problem is caused by the inability of system self-healing so that the packet delivered slowly. There is also a chance of collision because of the increasing amount of sta, resulting more packet to be delivered in the network.

For the RAW Slot scenario, in Fig.10, the score of reliability is showing an uptrend following the increase of sta number. We can conclude that the amount of packet circulating in the network will not affect the performance of the network in their self-healing factor. From Fig.11, from the pattern of the lien graph, scenario is affecting the availability. This mostly caused, while we increase the RAW slot, the idle status of the channel will be shorter caused by lot of RAW attempting to access the channel in the same time.

Lastly, for the Datamode scenario's availability, in Fig.12 and Fig.13 we can see the relation between data rate changes and bandwidth changes from 2 type of Datamodes compared to current availability and reliability respectively. According to the result it is expectable, with higher bandwidth, it is easier to improve the QoS score, which is also affecting the availability score and also reliability. A high data rate and bigger bandwidth will reduce contention in the system.

V. CONCLUSION

Based on the test results, we can conclude that, increasing the Ngroup will affect the performance of 802.11ah network. This is due to the ability of the standard to divides Ngroup will reduce the traffic load. Increasing the RAW slot on the network in a less station will increase the chance of data collision. It is proven by the score of throughput and percentage of packet delivery ratio to the amount of raw slot of 3,4, and 5 having higher score than raw slot of 6 and 7. From the Datamode scenario, we can conclude with a higher speed and bigger bandwidth, the network itself will be more productive and performing better. It is because, providing better datarate and bandwidth can reduce the chance to drop the packets.

Availability is a comparison between a time where the network is working with its total amount of time working to the downtime where the network is unavailable. While reliability is a terminology where the network is able to work correctly and flawless subtracted by the factor of the network downtime. However, the score of availability and reliability is affected by the QoS score of the network, resulting a variable of uptime and downtime of the network. Increasing the amount of station in 802.11ah will cause less energy consumption. It is due to one of 802.11ah RAW features. With RAW, the station which is not transmitting at the time will be considered as perfectly idle station. In the idle state, the station is not consuming a noticeable amount of energy.

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