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

Ana Oktaviana¹, Doan Perdana², and Ridha Muldina Negara³

¹–³Telecommunication Engineering Department, Faculty of Electrical Engineering, Telkom University
Email: ¹anaoktaviana@student.telkomuniversity.ac.id, ²doanperdana@telkomuniversity.ac.id, ³ridhanegara@telkomuniversity.ac.id

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 802.11ah 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 slot number 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

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 802.11ah 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.
Cite this article as: A. Oktaviana, D. Perdana, and R. M. Negara “Performance Analysis on IEEE 802.11ah Standard with Enhanced Distributed Channel Access Mechanism”, CommIT (Communication & Information Technology) Journal 12(1), 35–42, 2018.

...distributed 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).

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 powersaving 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
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 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
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 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 described 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

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

**Fig. 4. Topology of simulation.**

### 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          |
| 2                           | AC_BK                      | Background            |
| 0                           | AC_BE                      | Best Effort           |
| 3                           | AC_BE                      | Best Effort           |
| 4                           | AC_VI                      | Video                 |
| 5                           | AC_VI                      | Video                 |
| 6                           | AC_VO                      | Voice                 |
| Highest                     | 7                           | AC_VO                 | Voice               |

### 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    |

### 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 |
Cite this article as: A. Oktaviana, D. Perdana, and R. M. Negara “Performance Analysis on IEEE 802.11ah Standard with Enhanced Distributed Channel Access Mechanism”, CommIT (Communication & Information Technology) Journal 12(1), 35–42, 2018.

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 when the number of stations is equal to 150 or 0.186129 seconds. Meanwhile, the lowest value is when the number of the station is 30 or 0.00106083 second with the average total delay value about 0.066242 seconds.

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 when the number of stations is equal to 150 or 0.186129 seconds. Meanwhile, the lowest value is when the number of the station is 30 or 0.00106083 second with the average total delay value about 0.066242 seconds.

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 when the number of stations is equal to 150 or 0.186129 seconds. Meanwhile, the lowest value is when the number of the station 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
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 7 3 | 1023 1023 7 3      |
| AIFSN        | 7 3 2 2       | 2 2 1 1            |
| Number of Station | 30, 60, 90, 120 and 150 | 30, 60, 90, 120 and 150 |
| RAW Group    | 1             | 1                  |
| RAW Slot     |               | 1                  |

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

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 Mbps. 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.
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 stations that 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.

REFERENCES

[1] Y. Zhao, “Analysis of energy efficiency in ieee 802.11ah,” Master’s thesis, Masters Programme in Communications Engineering, Aalto University, 2015.
[2] N. Daneshfar, “Performance enhancement mechanism of ieee 802.11ah machine communication system,” Master’s thesis, Department of Electronics and Communications Engineering, Faculty of Computing and Electrical Engineering, Tampere University of Technology, 2015.
[3] M. Park, “IEEE 802.11 ah: Energy efficient mac protocols for long range wireless lan,” in IEEE International Conference on Communications (ICC). IEEE, 2014, pp. 2388–2393.
[4] IEEE standard for information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements—Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications Amendment 6: Wireless Access in Vehicular Environments, IEEE 802.11 Working Group Std., 2010.
[5] S. Prasetya, B. Rahmat, and E. Susanto, “Quality of service improvement with 802.11 e EDCA scheme using enhanced adaptive contention window algorithm,” in IEEE International Conference on Communication, Networks and Satellite (COMNESTAT). IEEE, 2015, pp. 80–85.
[6] R. Achary, V. Vaidhiyanathan, P. Raj, and S. Nagarajan, “Performance enhancement of IEEE 802.1 le wlan by dynamic adaptive contention window,” in 16th International Conference on Advanced Communication Technology (ICACT). IEEE, 2014, pp. 447–452.
[7] R. Qashi, M. Bogdan, and K. Hänssgen, “Case study: The effect of variable priority parameters on the qos of wlan s ieee 802.11 e EDCF,” in IEEE 3rd International Conference on Communication Software and Networks (ICCSN). IEEE, 2011, pp. 104–108.

[8] L. Tian, S. Deronne, S. Latré, and J. Famaey, “Implementation and validation of an ieee 802.11 ah module for ns-3,” in Proceedings of the Workshop on ns-3. ACM, 2016, pp. 49–56.

[9] S. S. B, “A quantitative analysis of 802.11ah wireless standard,” International Journal of Latest Research in Engineering and Technology (IJLRET), vol. 2, no. 2, pp. 26–29, 2016.

[10] T. Anwar and W. G. P. Mui, “Design and implementation of a wireless network system in a smart campus,” CommIT (Communication and Information Technology) Journal, vol. 1, no. 2, pp. 127–139, 2007.

[11] M. I. Denatama, D. Perdana, and R. M. Negara, “Analisis perbandingan kinerja protokol routing DSDV dan OLSR untuk perubahan kecepatan mobilitas pada standar IEEE 802.11 ah,” Jurnal Infotel, vol. 8, no. 2, pp. 100–106, 2016.

[12] M. Qutab-ud din, “Enhancements and challenges in ieee 802.11ah - a sub-gigahertz wi-fi for iot applications,” Master’s thesis, Department of Electronics and Communications Engineering, Faculty of Computing and Electrical Engineering, Tampere University of Technology, 2015.