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Bat-Inspired Hidden Node Detection Algorithm and Collision Minimization (BIHD-CM) Scheme for IEEE802.11AH

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Abstract: Hidden node problem sometimes referred to as frequent packets collision that mostly leads to loss of packets is no longer new in wireless networks because it affects the previous IEEE802.11 standards. The new IEEE802.11ah standard which is also a sub-standard of IEEE 802.11 is no exemption. As a matter of fact, IEEE802.11ah suffers from hidden node problem more than networks (IEEE 802.11a/b/n/ac) due to their wider coverage which is up to 1km, high number of devices they can support (over 8000 nodes to one AP) and frequent simultaneous sleeping and sending of the nodes (power saving mode). A few researchers have worked on this hidden node problem in IEEE802.11ah but could not get a lasting solution to it. Therefore, this paper proposes an algorithm which detects hidden nodes and also proposes a theoretical solution based on previous works which was also experimentally verified through the BIHD-CM.

Keywords: Restricted Access Window (RAW), Collision, Hidden node, IEEE802.11ah, NS-3, Packet Loss.

1. Introduction

As wireless devices and wireless communication technology is being advanced, there is an increased scarcity of the radio spectrum resources [1] advancements through various innovations and discoveries in wireless technology has brought about the development of various standards under the umbrella of IEEE802.11. These includes; IEEE802.11aa, IEEE802.11ac, IEEE802.11af, IEEE802.11b, IEEE802.11n and lastly IEEE802.11ah. This is commonly referred to as WiFi. Internet of things (IoT) describes the interconnection of living and none living things (such as devices and human being) to the global internet. It is a concept that lays much emphasis on machine-to-machine communication (M2M) [2]. This is because devices in IoT communicates wirelessly [3]. M2M communication or interconnection of devices is important to IoT for it to be able to maximize its potentials because they share some common features such as support for a large number of devices [4], [5], [6]. According to Cisco Internet Business Solution School, IoT a time when the interconnection of things and objects is more than that of people. Based on this, [7] compared the population of six billion three hundred million people in the world to the number of interconnected things which was about five hundred million in 2003. He then concluded that IoT was not yet in existence as at 2003 until later when there was increase in smart devices. An example of these devices are iPhone, which was first introduced in 2007. Figure 1.1 by [8] is a graphical representation that shows increment in the interconnection of devices from the year 2014 to 2020. According to [9] by 2020 one thousand wireless devices will be available for every one person. This continuous increase in interconnection of devices brought about different networking standards.

Considering the continuous increase in IoT, wireless network connection seems to be a better means of interconnection of these devices because they may be scattered all over the earth. Therefore, network standards such as ZigBee, RFID or Bluetooth which can only cover a very short distance of about tens of meters [10] and cannot be adopted. If a lager range is considered, wireless technology (WiFi proffers a better solution to

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the issue of interconnection of things; hence, the adoption of WiFi by IoT. WiFi which is the same as IEEE 802.11 standard for Wireless Local Area Network (WLAN) has been in existence for about 20years with its first version in 1997. It has since then been undergoing various developments and has such been divided into various developmental parts [8].

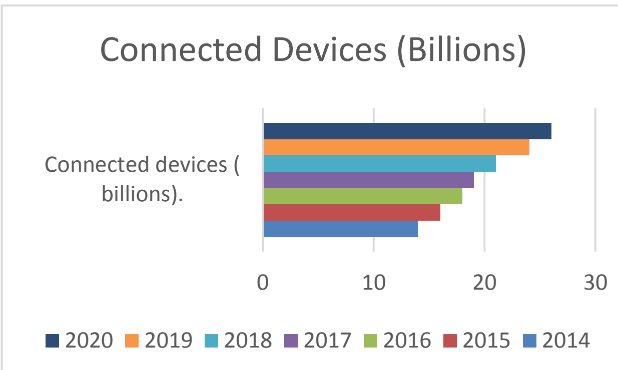

Figure 1 : Estimated increase in number of connected devices towards 2020 [8] (Sinha *et al.*, 2017)

The former, present and future trend of IEEE 802.11 standards has made WLAN a very attractive research area. It is easily deployed by people because of frequency band of about 2.4GH and 5GHZ. Its effect in different areas of technology form its sub parts such as; robust audio video transport streaming which is IEEE 802.11aa, very high through put at less than 6GHZ which is IEEE 802.ac, TV white spaces which is IEEE 802.af and machine to machine communications which is IEEE 802.11ah specification of the IEEE 802.11 standard. IEEE 802.11 specifications have not been able to define all mechanisms because of the setbacks it is experiencing but it has been able to serve as a foundation on which manufactures can be able to build compatible machines and equipment. There is a re-occurring problem called the hidden node problem in all these standards. The problem caused by a hidden primary user is caused by many factors which includes shadowing or multipath fading that is observed by a secondary user observe while sensing frequency bands occupied by primary users [11] . This usually occurs when node(s) which is not visible to other nodes can be seen by an access point thereby causing collision and loss of packets after sending packets at the same time. IEEE 802.11ah suffers from hidden node problem more than the previous IEEE802.11 networks (IEEE 802.11a/b/n/ac) due to their wide coverage, high number of devices they can support,' and frequent simultaneous sleeping and sending of the nodes (power saving mode) [12] .

IEE802.11ah is said to have the physical layer (PHY) and the Media Access Control (MAC) layer with different protocols. In order to solve this problem, IEEE802.11ah adopted a group-based contention as a selection process where a group is allocated to a node in order to minimize packet collision causing network performance degradation that are likely to occur as a result of the hidden node pairs. Restricted Access Window (RAW) which refers to access interval with several time slots where a station competes for time slot during a medium access tried to solve the hidden node problem but the hidden node problem was not considered during the allocation of the time slot of RAW [16]. This still resulted into station collision as stations that belonged to the same time slot may detect one another.

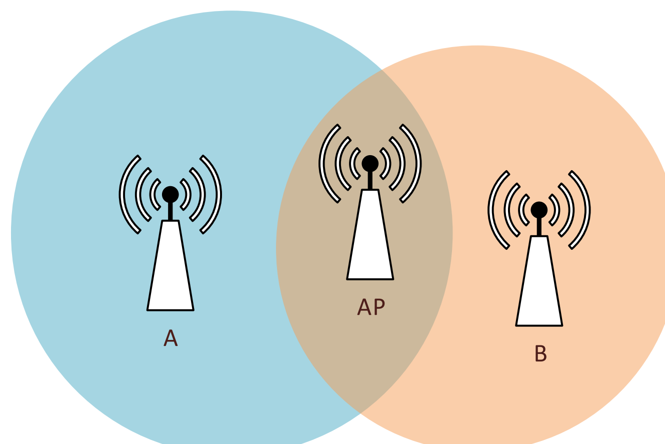

Figure 2: Hidden nodes Node c is hidden from node A and vice versa

2. RELATED RESULT

According to [13] it was said that about 8,000 nodes are handled by one access point (AP) which makes the hidden pairs in IEEE 802.ah to be on a high side when compared to its contemporary amendments of IEEE 80211a/b/g/ac networks resulting in network performance degradation because of network collision. He first indicated how seriously degraded the throughput performance is in a randomly deployed network [14] and later developed a guideline for the process of choosing the number of groups as a means to solve the problem. Similarly, [15] modelled the media access performance by grouping and by using the GS-DCF, which resulted in accurate prediction of throughput performance. The model for GS-DCF was done by using the centralized and decentralized grouping schemes. This study was done analytically and also via simulation. However, two nodes with in a group can be out of each other's detection range and this will result in collision if they transmit data at the same time, therefore the is a need for a better hidden node detection method.

Researchers in [16] proposed a spatial group RAW media access control (MAC) scheme, which optimized the process of station allocation as a way to reduce the influence of hidden nodes and collision problems. This was implemented by MATLAB simulator and compared to legacy DCF and conventional RAW and a notable improvement was recorded in terms of throughput performance. This actually reduce the hidden node problem by reducing collision probability but the hidden node problem could not totally be solved as there are still existing hidden nodes. Because of this, an open issue needs to be addressed. Researchers in [18] investigated how the Traffic Indication Map (TIM) segmentation and RAW affects scalability, energy efficiency, throughput and latency in the presence of bi-directional TCP/IP traffic. It was discovered that up to 6960 stations transmitting every 60seconds can be connected with no lost packets which enabled the modification of TIM and RAW parameters for applications that demands a very good throughput at one end and also networks that require a very low-throughput with bilateral traffic at the other side.

2.1. Back-off Algorithm

This is a method of solving the problem of network congestion by spacing out repeated retransmissions of the same block of data. There are two major types of back-off algorithms the binary exponential back-off and the truncated binary back-off. The retransmission is delayed by an amount of time derived from the slot time (which is at least the time it takes a packet to travel the length of the maximum distance between two nodes) and the number of attempts to retransmit. These two algorithms were included in the CSMA/CA and CSMA/CD as part of their channel access method.

3. METHODOLOGY

3.1. IHD-CM Frame Work

The BIHD-CM frame work in Figure 3 is a summary of the features in the BIHD-CM MAC layer. All other blocks except the bat algorithm block and the back off block describes the features of the IEEE802.11ah MAC layer worked on.

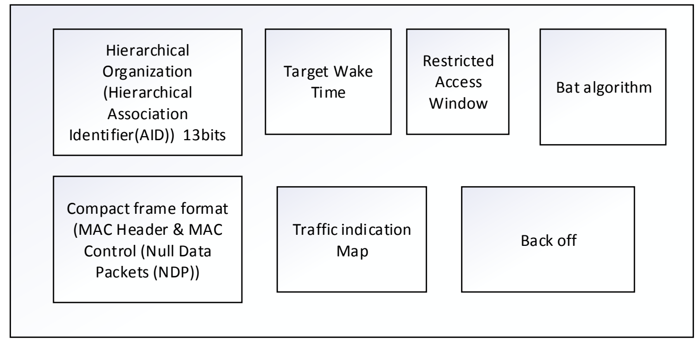

Figure 3: The BIHD-CM frame work

3.2. Bat Algorithm block

This scenario of AP-STA relationship can be compared to the bat-prey relationship that led to the development of bat algorithm. Hence, the methodology for the hidden node detection algorithm was inspired by bat algorithm, this was indicated by the bat block in Figure 3. Two out of the three idealized rules that governs bat algorithm were adopted to govern this algorithm, these include:

a. Bats flying randomly to search for prey with velocity v_i at position x_i, with fixed frequency f_{min} which can automatically be adjusted. Similarly, for the purpose of this research, the AP represents the bat which fly randomly to search for its preys which was represented by the STAs. The packets are sent at different time, the frequency here too is updated using the frequency update equation in bat algorithm.
b. Bats senses distance generally using echolocation and can differentiate between food/prey and background. Similarly, in the algorithm, STAs sends packets to the AP at different time; collision occurs when two or more STAs sends packets at the same time. The algorithm helps to detect collision by differentiating between when we have just one STA sending packets at a time (a case of no collision) and when we have more than one STAs sending packets at a time (a case of collision).

3.3. Back off block

The back off in the BIHD-CM frame work in Figure 3 is activated after detection of hidden node pairs. In order to check the effect of back off time on the matrixes used for this research, the back off value was varied for different number of STAs. By doing

3.4. Packet transmission in BIHD-CM

In IEEE802.11ah RAW, packets generated are either delivered or lost without any consideration of a retransmission process for lost packets as illustrated in Figure 3.3 On the other hand, in BIHD-CM frame work, there is a provision of retransmission after activating a back off time in order to ensure that more packets get to their destination. As shown in Figure 3.3 and 3.4, STA1 and STA2 represents two STAs that belong to the same RAW/ group but are hidden from each other there by sending packets at the same time because their communication range differs.

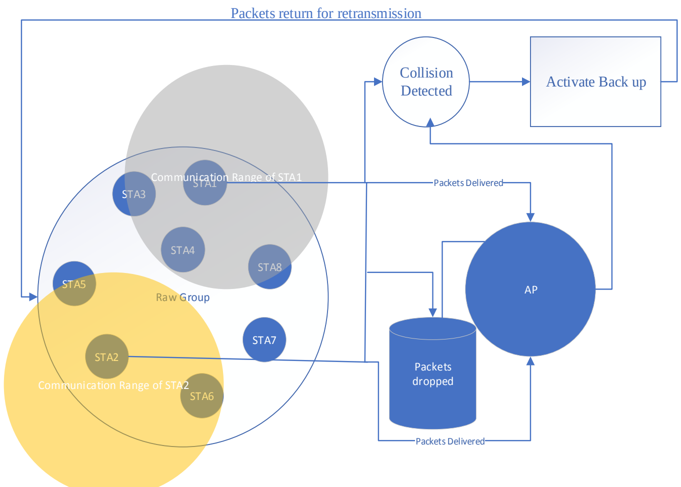

Figure 4: Packet transmission in BIHD-CM

4. PROPOSED METHOD

The proposed method is as described in the flow chat in Figure 5

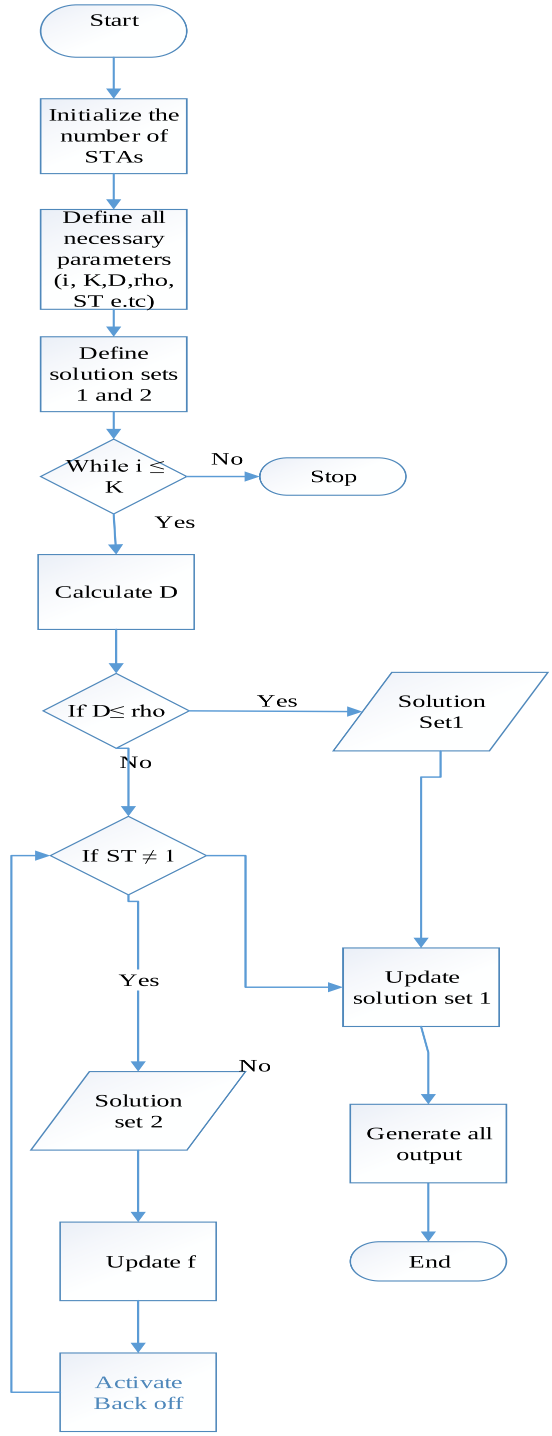

Figure 5: flow chat

5. RESULTS

The results are as described in Figure 6 to Figure 9. The performance of the collision minimization algorithm was based on the results obtained before and after implementing the BIHD-CM scheme.

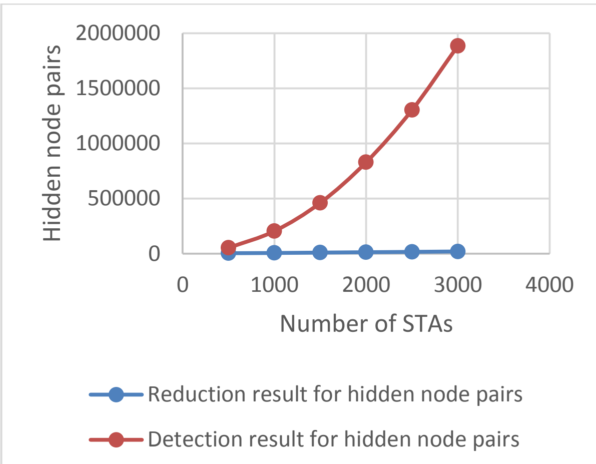

Figure 6: Performance Evaluation for Hidden node pairs

The results obtained after implementing back-off in the algorithm for the purpose of collision minimization was compared to the results obtained in ordinary RAW for hidden node pairs as illustrated in Figure 6. It was found that results obtained using the collision minimization algorithm is much better because the figures obtained were lower when compared to the results obtained in the detection result with ordinary RAW.

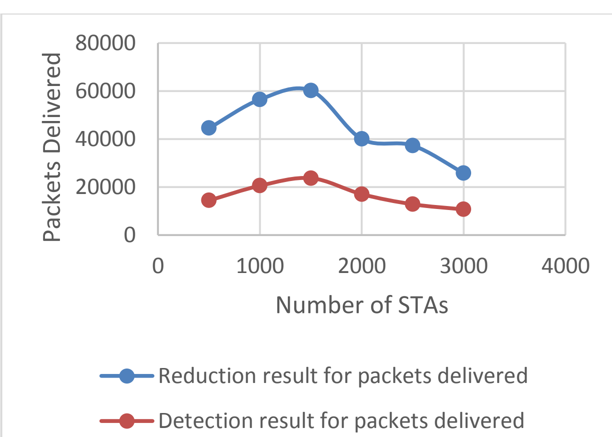

Figure 7: Performance Evaluation for packets delivered

Considering the results for packets delivered from Figure 7, it was found that results obtained using the collision minimization algorithm is much better when compared to the results obtained when using ordinary RAW because a greater number of packets with an average of 29172 were delivered instead of getting lost as a result of collision after implementing the collision minimization algorithm. This majorly shows the effectiveness of our algorithm.

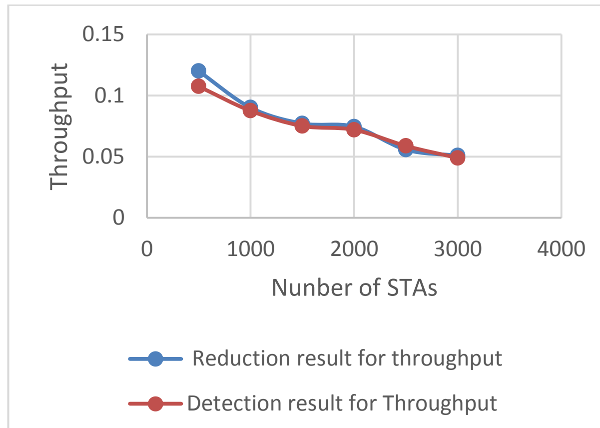

Figure 8: Performance Evaluation for throughput

The results obtained for throughput after implementing the collision reduction scheme in Figure 8 do not show much difference although it is still a little bit better than the results obtained in ordinary RAW. This was shown by the improvement difference of 0.0124665 Mbps obtained for 500 STAs. This is because throughput is the rate at which packets sent are being delivered. Therefore, the total number of packets delivered may not have much impact on the number of packets delivered within a specific period of time or the number of packets delivered per second.

In Figure 9, we observed that the packets dropped after implementing the collision reduction algorithm tends to be higher than the packets dropped obtained with the detection algorithm. This is because of the mode of operation of the back-off algorithm. The back-off algorithm first allows the collision to take place which will definitely result in some numbers of packets been dropped before assigning additional back-off slot window size according to the packets which of course is smaller than the biggest back-off slot window and then retransmits the packets until resolution succeeds or after exhausting the maximum number of retransmissions. In the process of retransmission, there would be some packets that might still collide there by leading to additional packets drops. Since the process will be continued until the packets are through or finally dropped depending on the number of retransmissions, therefore the increase in the number of packets dropped after running the minimization algorithm is justifiable.

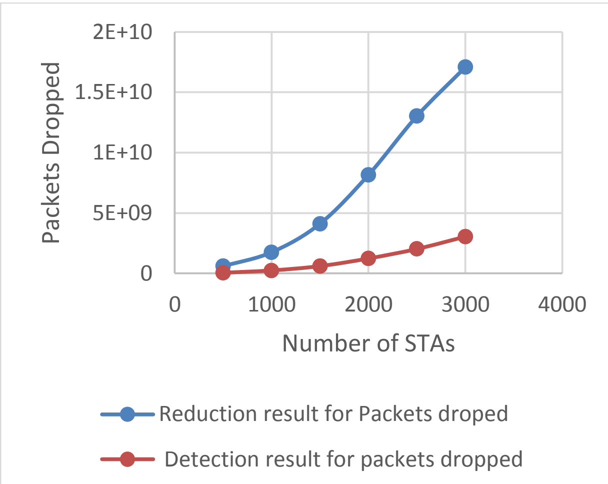

Figure 9: Performance Evaluation for packets dropped

5.1. Evaluation

The results obtained after implementing back-off in the algorithm for throughput, packets delivered and hidden node pairs were found to be much better because the figures obtained were higher when compared to the results obtained in the detection result with ordinary RAW. However, in figure 4.15, we observed that the packets dropped after implementing the back-off algorithm tends to be higher than the packets dropped obtained with the ordinary detection algorithm. This we believe is because of the mode of operation of the back-off algorithm. The back-off algorithm first allows the collision to take place which will definitely result in some numbers of packets been dropped before assigning additional back-off slot window size according to the packets which of course is smaller than the biggest back-off slot window and then retransmits the packets until resolution succeeds based on the number of retransmissions. In the process of retransmission, there would be some packets that might still collide there by leading to additional packets drops. Since the process will be continued until the packets are through or finally dropped depending on the number of retransmissions, therefore the increase in the number of packets dropped running the minimization algorithm is justifiable. The aim of this research was achieved because the overall number of hidden nodes after implementing BIHD-CM scheme was reduced.

6. CONCLUSION

Hidden node problem is a serious problem that leads to frequent packets collision which affects wireless networks and most especially, IEEE802.11ah. To mitigate this problem, we require an adequate and efficient hidden node detection and dynamic regrouping algorithm. The proposed algorithm leverages on Ps-poll structure configuration and group-based contention in RAW that was proposed for IEEE802.11ah. The implementation which will be done using NS-3 will greatly reduce the hidden node problem.

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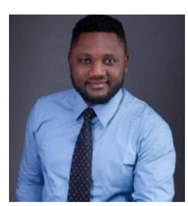

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