ISSN 2278-3091
Volume 10, No.1, January - February 2021
International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse291012021.pdf
https://doi.org/10.30534/ijatcse/2021/291012021

Efficient Cluster Head Selection in IEEE 802.11ahfor IoT Applications

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ABSTRACT

IEEE 802.11ah is a wireless LAN standard in the sub-1-GHz license-exempt bands for cost-effective and long-range communication. The most challenging issue in IEEE 802.11ah is to ensure that thousands of stations associate efficiently with a single access point. When several thousand stations try to associate with the access point during network initialization, it causes channel contention and long association delay. IEEE 802.11ah has introduced an authentication control mechanism (ACM) that divides the stations into groups allowing fewest stations to access the medium. In this paper, we propose to automate the cluster head selection using LEACH. Simulation results reveal that our proposed method is efficient in terms of association delay.

Key words:IEEE 802.11ah, LEACH, Internet of things.

1. INTRODUCTION

Over the previous two decades, an enormous expansion has occurred on the Internet, which interconnects billions of clients to each other. This development expanded the number of clients and presented better approaches for communication and new ideas. The original idea is called the Internet of Things (IoT). The word "Things" does not include only computers, mobile phones, and people but also medicinal services devices, vehicles, home appliances, and air quality sensors. This new idea will provide connectivity of devices and will be available anytime, anywhere, for anything.

Concerning the communication aspect of IoT, these networks usually contain sensors in large numbers covering wide areas. For communication, these sensors need long-range technology at low data rates. Towards this, a sub 1 GHz Wi-Fi standard has been released by the IEEE, named as 802.11ah. This technology provides long-range transmission, supports more than 8000 devices, and provides wide coverage. IEEE 802.11ah is also a cost-effective and large-scale wireless network.

One of the most significant challenges the IEEE 802.11ah standard faces is a fast association and efficient group head selection. Association is the process of connecting clients to the Access Point (AP). This kind of network may involve thousands of devices associating at the same time where the association frames may collide with data frames during network initialization when a few clients have completed the association. A few others are in the process of association. This problem is called the Co-existence of Data and Association Frames. Block association reduces this time, which minimizes the collision; however, the existing method of creating groups and group head is not suitable for such autonomic environments.

In this paper, we automate the group head selection in IEEE 802.11ah. In our proposed method we use the LEACH protocol to automate group head selection.

The remainder of this paper is organized as follows: Next section provides overview and main features of IEEE 802.11ah. Section III define the related work. Section IV explains our proposed network model. Section V discusses the obtained experimental results. Finally, we conclude the paper in section VI.

2.OVERVIEW OF IEEE 802.11AH

Typically, traditional 802.11 WLAN supports few devices than 802.11ah wireless LAN. Furthermore, the required transmission range is also much wider than the conventional 802.11 wireless LANs. In sub 1GHz, one-hop transmission coverage is often much higher, allowing to support more devices during a single network.

The IEEE standard 802.11ah is a powerful WLAN technology allowing up to 8,191 devices connections to a single AP [7]. Furthermore, it supports long distances reaching up to 1 km in an outdoor environment. It also utilizes Restricted Access Window (RAW) and Target Wake Time (TWT). Target Wake Time mechanism enables to wake-up devices for specified intervals, thus saving energy. The Restricted Access Window (RAW) divides stations into groups, providing channel access simultaneously to only a single group, which reduces the collision. But when many devices become a network member, a collision between data frames and association frames may become more frequent, requiring more time to get association ID. To improve association process, reducing this collision is a key challenge for future IoT [8].

Some main advantages of a standardized Sub 1GHz WLAN:

1. Support 8,191 devices associated with an AP.
2. Transmission range up to 1 km in outdoor areas.
3. Longer range and less power consumption.
4. Data rates of at 100 Kbps.
5. No license problems, no regulatory issue [9].

2.1 Physical Layer

IEEE 802.11ah physical layer gets the characteristics from 802.11ac. 802.11ac operates at 20 MHz, 40 MHz, 80 MHz, and 160 MHz, whereas 802.11ah operates at 2 MHz, 4 MHz, 8 MHz, 16 MHz, and one additional channel 1 MHz for long coverage. They are operating narrow bandwidth and low frequency, which allows transmission of 1 km and less power consumption as compare to traditional Wi-Fi technology (2.4 and 5 GHz bands).

2.2 Medium Access Control Layer

Task Group of 802. 11ah design a MAC layer, which maximizes the number of stations as compared to traditional 802.11 MAC. In the following, MAC layer enhancements are defined in detail [10].

2.2.1 Support of Many Associated Stations

IEEE 802. 11ah supports a large number of STAs. All the STAs are associated with an access point. AP is responsible for the time slot allocation to the STAs above during communication in a BI based on an association identifier (AID). AID is a unique identifier within a network, usually contains 13 bits (STAs supported up to 8191$(2^{13}-1)$) Figure 1[11], which is divided into four levels. Page, Block, Sub-block, and STAs index in sub-block.
In this hierarchical AID structure shown in Figure 2, a page contains 32 blocks, every 32 blocks consist of 8 sub-block, and sub-block have 8 bits; each bit is an association identifier (AID) of a device. This structure increases the number of devices to associate with an access point.

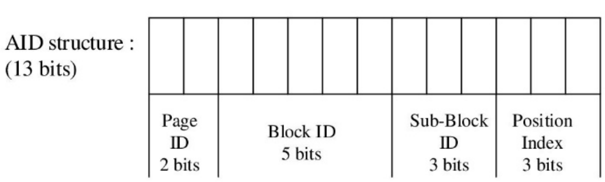

Figure 1 Association Identifier Structure,[11].

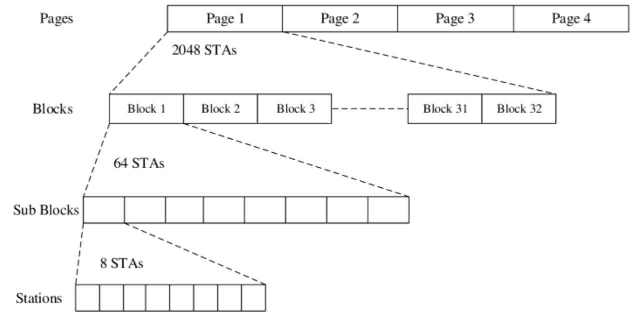

Figure 2 Hierarchical Association IdentifierStructure, [2].

2.2.2 Association and Authentication

The association is a process to becoming a member of a network, and every STAs go through from association process. Figure 3shows how stations become associated with the access point in IEEE 802.11ah. This process consists of two phases, first Authentication, and the second association phase. The process initializes when STAs, send a request of authentication to the access point. When the STAs are authenticated, the access point responds to the authentication response. The station sends an acknowledged. After authentication, an STA sends a request of association to the access point. The request contains encryption types (if required) and other 802.11 capabilities. If the requirements match with the capabilities of the access point, the access point will create an AID for the STA and reply with a response message (Allowing access to the STA). When the STA is associated, once more, STAs send an ACK. Once the STA is associated with access point, it can start communication [6].

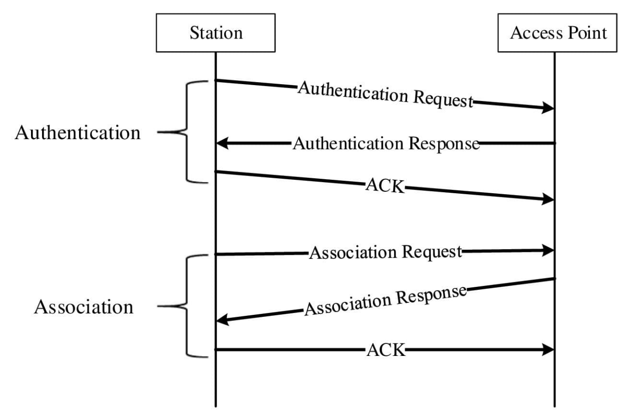

Figure 3 Authentication/Association Procedure in 802.11ah, [5]

3. RELATED WORK

Now a day's technology is growing with immense speed, and one of the fastest-growing technology is wireless communication, which gives access to the network and services without wire. The wireless has many benefits and some drawbacks. One of the significant benefits is mobility; other benefits are like to dynamically join and leave the network. Similarly, to easily create an ad hoc network for a limited time and then depart. In some cases, a wireless network is more straightforward to install than wired networks. The drawback compared to the wired network are such as, data security, lower reliability, and lower data rates[1].

In the IEEE 802.11ah, a single access point services thousands of devices as during the initialization of the network, several thousand STAs may want association with AP. Consequently, it causes channel contention. As conflict becomes challenging, the problem could be solved by restraining the number of STAs connecting at a time.

The IEEE 802.11ah task group developed a new technology for wireless LAN, Sub 1 GHz for IoT devices. When many devices want to communicate or transfer data, there will be a collision. According to [2], sub 1GHz supports more than 8000 devices so that if all of these devices want to communicate with each other, collision probability will rise. To avoid this problem, restricted access window (RAW) is used to allocate the time slots, but in that case, it cannot consider that traffic load and medium might be inefficiently used. They use sequential transmission, which considers the traffic load and channel access times; in that case, the last devices that need channel access still need a long wait to access that channel.

Inpaper [3] they analyzed the association process which takes up to more than a few minutes with heavy conflict and long association delay during network initialization. At the time of network initialization there are two types of stations: associated stations and those trying to get associated. Therefore, this association takes long time in IEEE 802.11ah and more contention occurs during network starting.

The authors of[4], introducedstation grouping strategy in which STAs are divided into clusters and that cluster of stations get medium access. To avoid a collision, it uses two case-based solutions. The first case in which the total stations are unidentified and station generates a random number for the association. In the second case, the access point knows the overall number of devices in the network, and then it can simply determine un-associated stations.

The authentication control mechanism was introduced which classifies stations into clusters, and only clusters can access the channel at a time. According to [5], the association process can be divided into three stages: firstly, Group Head selection, secondly, Association, and finally Communication. The network is divided into k number of clusters. Each cluster has his group head (GH), which acts as a quick access point and the group head is selected manually. The station will associate with the group head. The group head sends a block affiliation demand to the primary access point. The access point sends a return block of association response, containing the block of association Id for all stations. All stations are connected with the main access point, and communication starts straight with the access point. This association method reduces the total association time but still is costly due to the introduction and manual selection of the group head.

According to [6], when 6000 STAs are trying for authentication at the same time and with a response frame, most of the requests cannot be received by the access point due to collisions. The time required for 100 STAs for authentication process can exceed 5 minutes.

Inthis paper, we mainly focus on automatic group head selection, which is the main research topic of this paper and is discussed in detail in the following section.

4. PROPOSED METHOD

This section presents the complete proposed methodincluding the Network initialization and automatic group head association.Figure 4 shows the flowchart of our proposed method.

Our proposed work is divided into three sub-sections: sub-section I is Automatic Cluster Head selection, sub-section II is Authentication and Association, and last sub-section is Communication.

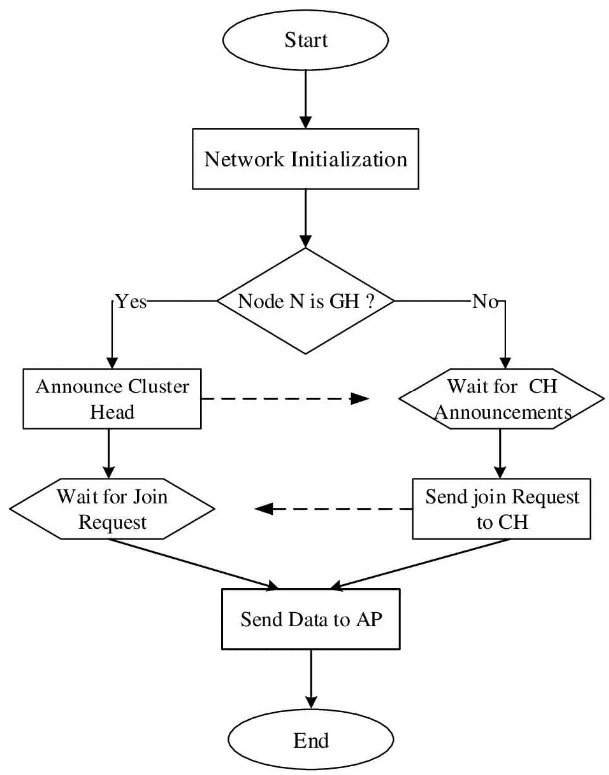

Figure 4 Flowchart of the Algorithm.

4.1 Cluster Head Selection

Clustering in wireless sensor networks (WSN) consist of nodes into clusters/grouping and selecting a group head (GH). The group head is responsible for data collecting from sensor in its cluster and sending the grouped data to the access point. Clustering/ grouping has many advantages, such as saving energy losses, and better use of network and resources.

Group Head selection has already been discussed in several literature. However, the low-energy adaptive clustering hierarchy (LEACH) is one of the most popular hierarchical routing algorithms for sensor networks. We use LEACH for automatic Group Head selection. This GH works as a temporary access point.

Group Head Selection is based on the desired percentage of GHs for the network and the number of times the node has been a GH so far. When a STA is initialized, it generates a random number between the intervals 0 and 1. If the random number is less than the threshold, then the node becomes a GH for the current round. Threshold number T (n) is shown in the following equation:

$$T(n) = \begin{cases} \dfrac{P}{1 - P \times (r \bmod {}^{1}/_{P})}, & \text{if } n \in G \\ 0, & \text{Otherwise} \end{cases}$$

Where P is the GH desired percentage, r denotes the current round, and G denotes a node that was not GH in the last 1/P rounds.

Figure 5shows the IEEE 802.11ah network model. Each group has one group head and every group head is responsible for its group.

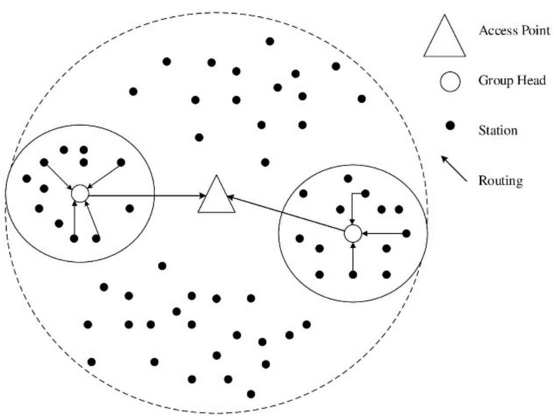

Figure 5 Network Model.

4.2 Authentication and Association

The second stage is Authentication and Association. The selected group head performs the authentication and association simultaneously with the access point on behalf of all the stations without interfering with other groups. Figure 6show the authentication and block association procedure. After GH association, STAs authenticated by the GH for AID, then GHs send the request of block association to the access point. Access point reply with response of block association (BA) to the GHs for the STAs.

Figure 6shows the association process between the Group Head and Access Point. The complete procedure is described in detail steps as follows:

1. Once the group head selection is completed, then the association procedure is started.
2. The group head performs a BA with the access point.
3. The BA request is then sent to the access point.
4. The BA request holds the association request of all the STAs in the group.
5. If required, then the group head may send one or numerous BA requests to APs.
6. The access point examines the BA request, and if found valid, it responds with the BA response.
7. The BA response frame broadcast by the access point can be received by all the STAs.
8. Once the STAs confirm its association identifier in the association response frame, it can start communication.

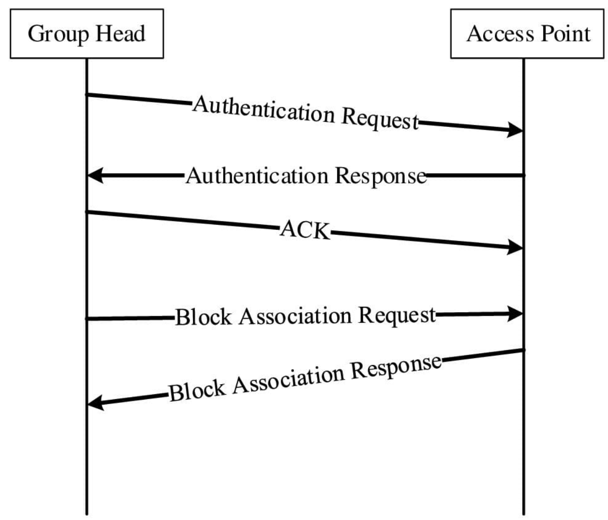

Figure 6 Authentication and Block Association, [5].

4.3 Communication

Communication is the process of transferring messages from one point to another point. When the station is associated with an access point or get association identifier (AID), STAs directly communicate with access point in a single hop. Group head (GH) works as a temporary access point until the station becomes associated with AP. The communication procedure execute in the similar method as defined in IEEE 802.11ah.

5. Results and Discussion

This section is included to analyze the results of our proposed work. These analyses are taken from Network Simulation. The Simulation was conducted in NS-2 [12]. The obtained results are from analytical and simulation framework. Our Network model is shown in Figure 5.The available code of IEEE 802.11ah was modified for automate the group head selection.

We performed simulations with a maximum number of 1000 stations. As shown inFigure 7, the increase in number of stations results in a small increase in association time, where the maximum delay is in acceptable limit.

Another experiment is aimed at analysis of effect of number of group heads on association time. Block association (BA) under different network sizes (100 nodes to 1000 nodes step 100) and three group head sizes (10, 30, 40) are plotted in Figure 8. Here, one can notice that a group head size of 10 leads to minimum association time as compared to other sizes. Which is negligible.

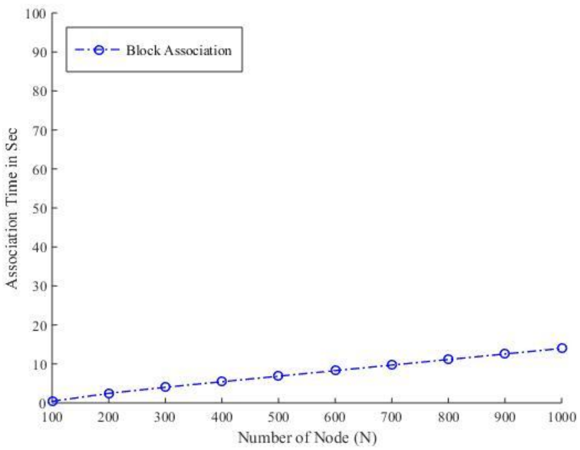

Figure 7 Total time of Block Association, for various network sizes.

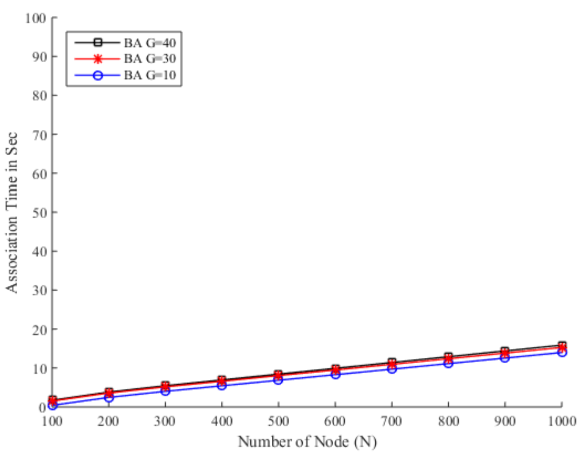

Figure 8 Total time of Association, for various network sizes.

Similarly, we observed the effect of a range of group head sizes over the association time for the same network. As depicted in Figure 9, initially the association time reduces as the group head size augments, however, after a certain number the association time starts increasing slowly with increasing number of group head sizes. Such an optimal number is 10 in our case.

The significant-end of this test is that essentially keeping the quantity of Group Heads of ten is sufficient, which keeps the complete association time under half a minute. These results also show that when the group head size increases, the association time is also increased, due to channel collision and thus requiring more time for the association.

To conclude the results discussion, we have noticed that the automatic cluster head selection through LEACH protocol keeps the association time in acceptable limit.

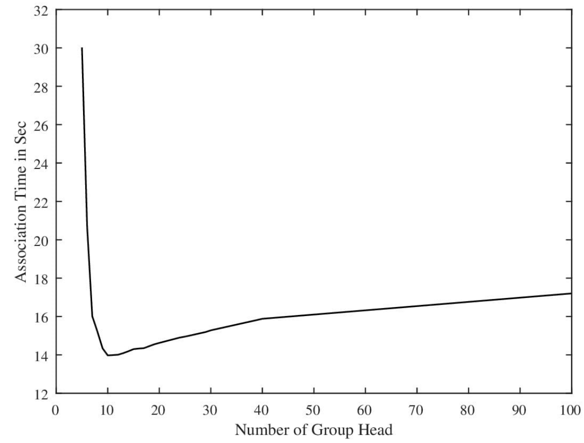

Figure 9 Total Association time for various group heads**.**

6. Conclusion

IEEE 802.11ah is promising technology that is cost-effective and provides long-range communication. Since IEEE 802.11ah supports a large number of terminals, efficient association of these devices is a challenging task. Block association is an efficient method that reduces the association time significantly. We proposed to automate the group head selection using LEACH protocol. We performed simulations through NS-2 simulator to validate our proposed method. Simulation results confirm that using LEACH for cluster head selection keeps the association time within low. As a future work we intend to that, still it is needed to find more efficient, scalable and stable scheme for data and association frame.

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