Group-based Contention in IEEE 802.11ah Networks

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***Abstract*—IEEE 802.11ah which mainly aims for vast range sensor networks offers a transmission range of up to 1 km and about 8,000 nodes are handled by a single access point (AP). As a result, an 802.11ah network has more hidden pairs than conventional 802.11a/b/g/n/ac networks. Therefore, packets frequently collide resulting in network performance degradation. To solve the problem, the 802.11ah uses a group based contention. In this paper, we propose a guideline for choosing the number of groups. Through simulations, we also show how severely degraded the throughput performance is in a randomly deployed network.**

I. Introduction

The 802.11ah Task Group (TGah) has started to establish a new IEEE 802.11 WLAN called *IEEE 802.11ah* which is operating sub 1 GHz industrial, scientific and medical (ISM) bands. It aims for vast range sensor networks such as smart grid, and for cellular offloading. Owing to the superior propagation feature of lower frequency spectrum, the 802.11ah provides longer transmission range compared to the previous 802.11a/b/g/n/ac WLANs. In addition to that, to cover the vast range networks, the maximum number of associated nodes to an access points (AP) in the 802.11ah also increases up to about 8,000 nodes.

These distinctive features of the 802.11ah causes a more severe hidden node problem [1] resulting in network performance degradation. To alleviate the hidden node problem, the 802.11ah uses a group based contention. Each node is allocated to a group, and the node contends within the same group.

The group based contention, however, cannot solve the problem completely. Also, the 802.11ah does not suggest any guideline for choosing the number of groups. In this paper, we suggest a guideline for a proper number of groups in the network, and show the performance degradation due to the hidden pairs through simulations.

The rest of the paper is organized as follows. In Section II, we briefly describe the IEEE 802.11ah. Then, we give a guideline for choosing the number of groups in Section III. In Section IV, we show that the network performance through simulations, and conclude our paper in Section V.

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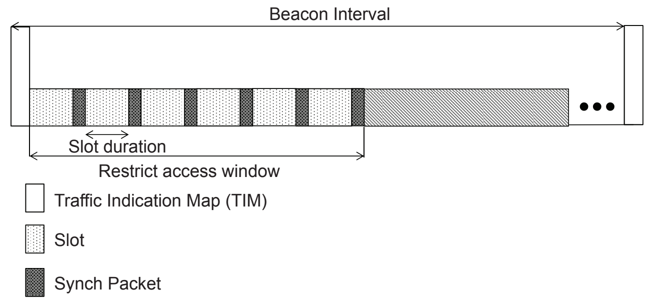

Fig. 1. An example of a beacon interval in the 802.11ah. In a restrict access window, there are six slots. That is, the number of groups is six in the network.

II. IEEE 802.11ah: Overview

IEEE 802.11ah standardization project has been working since November 2010. The first draft of IEEE 802.11ah was published October 2013 [2] and it is expected that the standardization will be completed by March 2016. The 802.11ah has many unique features compared to the previous 802.11a/b/g/n/ac WLANs. Because of page limit, we introduce two things related with our topic.

1) Maximum number of nodes: One important enhancement in the 802.11ah is the number of associated nodes in an AP. To cover a large area, one 802.11ah AP needs to support more nodes. To this end, 802.11ah nodes have a 13-bit of identifier, called Association Identifier (AID). So, the maximum supported number of station is up to 8,191, i.e., $2^{13} - 1$, which is about four times larger than that of the conventional WLAN, i.e., 2,007 nodes [3].

2) Group based contention: Because of the large number of nodes, too many nodes simultaneously attempt to send frames resulting in increase of collisions between hidden nodes. To solve this problem, the 802.11ah defines a grouping method. The AP divides all the nodes into several groups and allocates a non-overlapping period to each group. Therefore, each node contends within the same group at the assigned period. The period is called as a slot.

Each node wakes up when its assigned slot boundary. At the slot boundary, a synch frame is sent by the AP. Through the synch packet, all the nodes in the same group can synchronize each other and ready to access the channel.

With a simple modulo operation, the AP can divide all the nodes into groups. A group number of nodes is formally defined as $x \bmod N_g = i$, where x and N_g denote AID of node and the number of groups. The group numbers to nodes is delivered through the Traffic Indication Map (TIM) element which is delivered through beacon frames [4]. Fig. 1 shows a

TABLE I
SIMULATION PARAMETERS

Simulation parameter	Value
Data rate	0.65 Mbps
Bandwidth	2 MHz
Minimum contention window	32
Maximum contention window	1024

beacon interval in the 802.11ah. The AP broadcasts TIM at every start of a beacon interval.

III. GUIDELINE FOR THE NUMBER OF GROUPS

To use the group based contention, the size of group is the most important design parameter. In the 802.11ah standard, however, does not give any guideline for that. Both too large and too small numbers of groups degrade the network performance. It is because too small number of groups induces large number of retransmissions and because too large number of groups causes unnecessary overheads. In this paper, we propose a simple guideline for the number of groups.

Let N_{target} denote the number of active nodes per group. Then, we have the following inequality

$$\lceil \frac{N \cdot \lambda \cdot T_B}{N_g} \rceil \leq N_{target},$$

where λ and T_B are the traffic arrival rate and beacon interval, respectively. Therefore, we can get

$$N_g \geq \lfloor \frac{N \cdot \lambda \cdot T_B}{N_{target} - 1} \rfloor.$$

For instance, when $N = 8000$, $\lambda = 1/\text{min.}$, $T_B = 1\text{sec.}$, and $N_{target} = 10$, $N_g \geq 14$.

IV. SIMULATIONS

In this section, we compare the performance of the 802.11ah standard with and without hidden pairs.

A. Simulation Settings

We consider a 802.11ah network with N sensor nodes and a single AP for a wide area sensor network. All nodes have no mobility and each node has one 28-byte packet to transmit. In the case of with hidden pairs, all nodes are distributed uniformly within the coverage of the AP. With no hidden pair, all nodes can sense any transmission from other nodes. The system parameters in the 802.11ah standard [2] are listed in Table I. Since the performance of the case of with hidden pairs heavily depends on node positions, simulations are performed 100 times with random distributions and all the results are averaged.

B. Simulation Results

The main performance metrics are the number of retransmissions and end time presented in Table II. We define the end time as the time when all the nodes finish their data transmissions. A shorter end time indirectly represents a higher network throughput. We simulated three cases that are 5, 10, and 20 nodes in the network. When the nodes are randomly deployed, about 41% of node pairs are hidden pairs. Because of the hidden pairs, the main performance metrics are degraded. The number of retransmissions significantly increases about 4 to 8 times with hidden pairs compared to that with no hidden pair. In 10 and 20 nodes case, the end time of the case with hidden pairs takes about 2.3 and 2.6 times longer than that of the cases with no hidden pair, respectively.

TABLE II
SIMULATION RESULTS

Number of hidden pairs		with hidden Pairs	without hidden pairs
5	# of hdd nodes	4.01	0
	# of retransmissions	4.91	0.6
	end time (msec)	15.58	8.271
10	# of hdd nodes	18.8	0
	# of retransmissions	18.2	2.75
	end time (msec)	39.11	16.58
20	# of hdd nodes	79.43	0
	# of retransmissions	55.94	12.46
	end time (msec)	94.09	35.56

V. CONCLUSION

IEEE 802.11ah mainly targets a wide area of sensor network since it has longer transmission range and larger number of nodes in one access point. However, the two characteristics are exacerbated the hidden node problem. One solution for the problem is the group based contention proposed by the 802.11ah. In this paper, we proposed a simple guideline to choose a proper number of groups and we showed that how hidden pairs severely influence the 802.11ah network performances through simulations.

For the future work, another solution for the hidden node problem is considered.

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