Channel Access Scheduling for IEEE 802.11ah IoT Network Using Slot Length Adjustment

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***Abstract*—This paper proposes the Dynamic Slot Length Adjustment and Time-Stamp-based Scheduling (DSLA-TSS) method to improve the performance of IEEE 802.11ah Internet of Thing (IoT) network. The proposed method divides Restricted Access Window (RAW) into Claiming RAW and Data RAW. Each STA can send the claiming frame indicating it has uplinked data to send to AP in its associated Claiming RAW's claiming slot. AP uses the information about (i) STA's uplinked data, which is in the claiming frames of those STAs that have successfully claimed, and (ii) STA's downlinked data, which AP receives from Internet, to know the load condition of each data slot and then adjusts slots' lengths accordingly. For the issue of channel access's scheduling, the proposed method divides each data slot into two parts: (1) scheduled sub-slot, where AP schedules STAs that have successfully claimed their uplinked data and/or have downlinked data based on the time stamps of received claiming frames and downlinked data, and (2) remaining sub-slot, where STAs having uplinked data but unsuccessfully claimed can use the CSMA/CA control scheme to compete for the channel access privilege. Simulation results show that the proposed method improves overall network performance, including higher throughput, higher channel utilization and lower collision rate.**

Keywords—Internet of Things (IoTs), IEEE 802.11ah, Wi Fi HaLow, Restricted Access Window (RAW), Slot Length Adjustment.

I. INTRODUCTION

IEEE 802.11ah, which is also known as Wi-Fi HaLow [1-2], is designed for Internet of Things (IoT). IEEE 802.11ah adopts the temporal division approach to arbitrate the privilege of channel access for the large amount of IOT devices, which are called Stations (STAs) hereafter, inside an IEEE 802.11ah's Access Point (AP), for which it can support thousands up to 8192 STAs in its signal coverage [3-5]. Referring to Figure 1, a Delivery Traffic Indication Message (DTIM) period consists of some Traffic Indication Map (TIM) intervals. A segment of STAs is assigned to access channel in a TIM interval. A TIM interval consists of several Restricted Access Window (RAW) periods. A group of STAs are allocated to access channel in a RAW period. A RAW period is divided into some slots, on each of which only a subgroup of STAs is allowed to access channel at the same time. STAs inside a slot uses the CSMA/CA control scheme to fight for the privilege of channel access. Referring to Figure 1, each STA needs to wake up to receive the DTIM beacon, which is broadcasted in the initial time of a new DTIM cycle. The DTIM beacon indicates which TIMs' STAs have downlinked data to receive. STAs keep in the sleep mode until it is the time of receiving their respective TIM beacon. Those STAs of the indicated TIMs have to wake up to receive the associated TIM beacons to identify whether they have downlinked data to receive or not; otherwise, STAs of a TIM keep in the sleep mode to save energy.

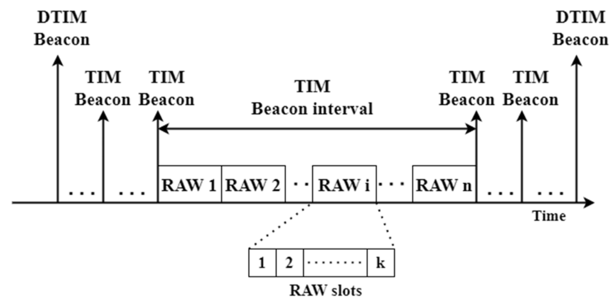

Fig. 1. The temporal division configuration using RAW and TIM mechanisms in a DTIM beacon interval.

When a STA is indicated in its associated TIM beacon that it has some downlinked data to receive from AP, it keeps in the sleep mode until it is in its assigned RAW's slot, in which it can receive downlinked data from AP. If a STA has uplinked data to transmit to AP, it uses the CSMA/CA control scheme to fight for the channel access privilege with other STAs that also have uplinked data to send to AP in its assigned RAW's slot.

Three possible data traffic situations in a RAW's slot are (1) overloaded, (2) underloaded, and (3) load balanced. To resolve the load balance problem, methods of adjusting the slot length have been proposed [6-9]. The method of adjusting the time slot length is to increase/reduce the time of overloaded/underloaded slots such that overloaded slots have the more channel access time, while reducing the unused time of underloaded slots. This work proposes the Dynamic Slot Length Adjustment and Time-Stamp-based Scheduling (DSLA-TSS) method to resolve the load balance problem in IEEE 802.11ah IoT network.

Since downlinked data is received by AP from Internet, AP has the information of downlinked data. To have AP to know

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the load of each slot, this work adopts the triggered RAW mode of IEEE 802.11ah [1] to allow STAs having uplinked data to send claiming frames in the claiming phase to obtain the privilege of transmitting their uplinked data[1]. Thus, AP can identify which STAs need to transmit uplinked data and how much uplinked data they have. AP then calculates the required channel access time for each slot based on (i) the uplinked data's amount and (ii) the downlinked data's amount. In this way, AP can understand each time slot's load and adjust the time lengths of overloaded and underloaded RAWs' slots accordingly.

How to schedule STAs' channel access sequence in a slot is the other problem to be resolved. This work proposes to use time stamps for scheduling the sequence of STAs' channel access during the data phase. When an STA transmits its claiming frame in the claiming phase, AP records the arrival time of the claiming frame as the Scheduling Channel Access's Time Stamps (SCA-TSs). If the STA has only downlinked data, AP records the arrival time of the earliest arrived data packet of the downlinked data as its SCA-TS. If a STA (i) successfully claims its uplinked data to send and (ii) has some downlinked data to receive, AP uses the smaller SCA-TSs of these two SCA-TSs as the corresponding STA's SCA-TS. In the data phase, AP schedules STAs having (i) some uplinked data to send and successfully claimed and (ii) only some downlinked data to receive to access channel according to their SCA-TSs in the ascending order, while those unsuccessfully claimed STAs use the CSMA/CA control scheme to compete for the privilege of channel access within the slot's remaining time after the channel access of those scheduled STAs is finished.

The remaining part of this paper is organized as follows. Section 2 presents related work. The proposed method functional scenario is introduced in Section 3. The proposed method is presented in Section 4. The of performance evaluation results are presented in Section 5. Conclusion remarks are given in Section 6.

II. RELATED WORK

This Section presents related work of the proposed method.

In [6], the authors proposed a slot length adjustment method to address the delays inherent in the legacy IEEE 802.11ah. The proposed method focuses on two main enhancements. The first slot in each RAW period is set as a reserved slot, for which STAs that were unable to access channel in the past DTIM period(s) are assigned to reserved slots to ensure that they have the higher priority in subsequent channel access's attempts. The reserved slot's length is dynamically adjusted. If the number of collisions becomes smaller than that of the previous DTIM, the reserved slot of the next DTIM is decreased for 1ms; otherwise, the reserved slot of the next DTIM is increased by 1ms. Simulation results show that the proposed method reduces the maximum delay compared to the legacy IEEE 802.11ah. Since the fixed reserved slot length is adjusted without considering the traffic demand of different STAs, the increment/decrement of slot's time may cause the reserved slot too long or too short.

In [7], the authors proposed a mathematical model to calculate the appropriate lengths of slots based on the number of STAs in each slot. The holding period refers to the time interval on which a STA can retain channel access without having to compete for it. The holding period is set at the end of the slot. By comparing the utilization of the holding period with the calculated slot length and the original slot length, it can determine whether the calculated slot length is more efficient in terms of resource utilization compared to the original slot length or not to adjust the slot length accordingly. Simulation results show that the proposed method performs better than the legacy 802.11ah in terms of throughput and resource usage. However, the collision probability in the slot becomes complicated to predict when the number of STAs increases.

In [8], the authors proposed the Load-Aware Channel Allocation (LACA) method to resolve the RAW mechanism's limitation. By considering the spatial distribution of STAs and Rayleigh fading channels with capture effects, the proposed LACA method tries to ensure that the allocated RAW slots result in neither packet delays, i.e., are too short, nor wasted channel time, i.e., are too long. The capture effect means that when multiple STAs initiate transmission at the same time and cause collision, AP still can successfully receive packets whose signal strength exceeds the capture threshold. A two-level renewal process model is designed in LACA. The first level refers to the intervals between successive transmission attempts to identify whether the packets are successfully delivered or not; the second level focuses on the intervals between successful transmissions only. Using the mathematical modeling of these two levels, the required RAW slot duration can be calculated based on the number of STAs in the slot. The simulation results show that packet delivery rate and overall channel usage efficiency are improved. However, network traffic changes and collision probabilities become complicated to predict when the number of STAs increases.

In [9], the authors proposed a dynamic network slicing mechanism that adjusts the slot to meet different Quality of Service (QoS) requirements. One or more RAWs can form a slice, for which the number of RAWs that a slice can have is proportional to the number of STAs contained in that slice. Moreover, to minimize channel contention, only one STA is assigned per RAW slot. Consequently, when the number of slots in a given RAW is insufficient, a new RAW must be created. When QoS constraints are violated due to delays exceeding the acceptable range, the proposed method increases STA's channel access time by adding a specified increment (τ) to the current

1 In the triggered RAW mode of IEEE 802.11ah, the RAW period is divided into two phases: (i) the claiming phase and (ii) the data phase. During the claiming phase, each STA having uplinked data sends a claiming frame to AP. AP then informs those STAs that can access channel when the claiming phase ends. These notified STAs are allowed to transmit their uplinked data during their designated RAW slots in the data phase.

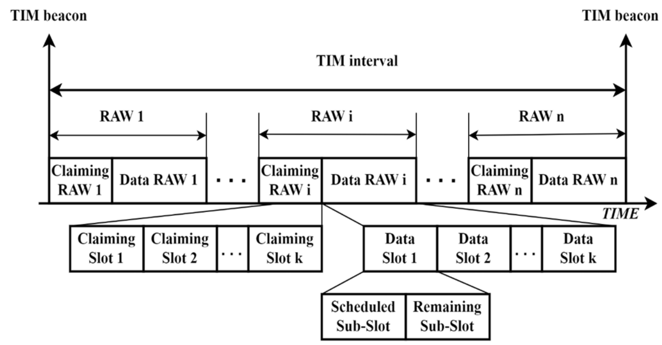


Fig. 2. The abstract time flow configuration of a TIM in the proposed method.

slot duration. Simulation results show that the method can maintain QoS requirements by reallocating resources when it is needed. However, since the fixed slot length is increased each time without considering the traffic demand of different STAs, the increment/decrement of the slot time may cause the slot too long or too short, which cannot meet the traffic demand of the STAs in the slot.

III. THE PROPOSED FUNCTIONAL SCENARIO

In this Section, the functional scenario of the proposed method is presented.

Referring to Figure 2, each RAW consists of the Claiming RAW and the Data RAW. Each Claiming/Data RAW is divided into k claiming/data slot. STAs with uplinked data assigned to data slot i can send their claiming frames indicating their intentions of transmitting uplinked data in the corresponding i^{th} claiming slot. Each data slot is divided into two sub-slots: (i) the scheduled sub-slot and (ii) the remaining sub-slot. The scheduled sub-slot is used by STAs that have successfully claimed their uplinked data and/or have downlinked data. If there is still some remaining time after scheduled STAs utilizing channel, STAs with uplinked data but claimed unsuccessfully can use the CSMA/CA scheme to compete for the privilege of channel access in the remaining sub-slot.

Four phases in the proposed method are (1) Claiming phase, (2) Slot Adjustment phase, (3) Scheduled Data Transmission phase, and (4) Remaining Time Data Transmission phase.

In the Claiming phase, those STAs that have uplinked data to send compete for the privilege of transmitting their claiming frames using the CSMA/CA control scheme in their designated Claiming slot. The STA that successfully transmits its claiming frame can be scheduled to access channel in the corresponding Data RAW's data slot by AP. Since (1) the claiming control frame is small and (2) IoT devices typically generate small data volumes at lower frequencies, the contention window (CW) is set to the minimum value of 32 to minimize the time spent on backoff's count down during the Claiming phase.

When the Claiming phase is over, AP can get the information of (1) which STAs have some downlinked data to receive and the number of downlinked data frames that each one of these STAs has; (2) which STAs have some uplinked data to send and have successfully claimed, and the number of uplinked data frames that each one of these STAs has. As a result, AP can derive the channel access time required for the scheduled sub-slot of each data slot and adjust the length of each slot accordingly in the Slot Adjustment phase.

After the slot time's adjustment is complete, AP selects the first STA that is allowed to access channel in the scheduled sub-slot of each data slot according to the SCA-TSs of the STAs that are to be scheduled. At the end of the Slot Adjustment phase, AP broadcasts the aforementioned information using an ACK frame to all STAs in the RAW group. In this way, the STA that can access channel at first in each slot can be informed.

There are four types of STAs that need to be scheduled in the Scheduled Data Transmission phase: (1) STA x has only uplinked data that have been successfully claimed; (2) STA x has only downlinked data; (3) STA x has (i) downlinked and (ii) has successfully claimed its uplinked data; (4) STA x has (i) downlinked and (ii) has unsuccessfully claimed its uplinked data. In the Scheduled Data Transmission phase, STAs with uplinked data, i.e., STAs of types (1) and (3), will be scheduled first, while STAs with only downlinked data, i.e., STAs of types (2) and (4), need to wait until the channel access of STAs with uplinked data ends, for which STAs are selected by AP to access channel in the ascending order of their SCA-TSs. For STAs of type (4), downlinked data's channel access is scheduled, while uplinked data's channel access still needs to use the CSMA/CA control scheme in the remaining sub-slot.

When the scheduled STAs finish their channel access and there is some remaining time, the remaining time can be allocated as the "Remaining sub-slot" of the corresponding slot. STAs of types (2) and (4) compete for the privilege of channel access to transmit uplinked data using the CSMA/CA control scheme in the remaining time of the assigned data slot.

Figure 3 depicts an example of how the proposed channel access procedure operates. In Figure 3, (1) STA 1 has one downlinked data frame and one uplinked data frame, which has been claimed successfully; (2) STA 2 has two uplinked data frames, which has been claimed successfully; (3) STA 3 has (i) one downlinked data frame and (ii) one uplinked data frame, which has been claimed unsuccessfully.

Referring to Figure 3, since STA 1 has the smallest SCA-TS among the STAs having successfully claimed, STA 1 is selected as the first STA to access channel. After receiving STA 1's uplinked data frame, AP sends the ACK frame. Since STA 1 also has downlinked data to receive, the ACK frame includes the AID of 1, which indicates the next STA to access channel is STA 1. After receiving the PS-POLL frame of STA 1, AP sends the downlinked data frame to STA 1, which also indicates that STA 2 is the next STA to access channel.

Since all STAs can overhear the data frame sent from AP, STA 2 is aware that it is the next STA to access channel. After overhearing STA 1's ACK frame, STA 2 sends the uplinked data frame to AP, for which the "more bit" is set to 1 to indicate that there are still uplinked data frames to be sent after this

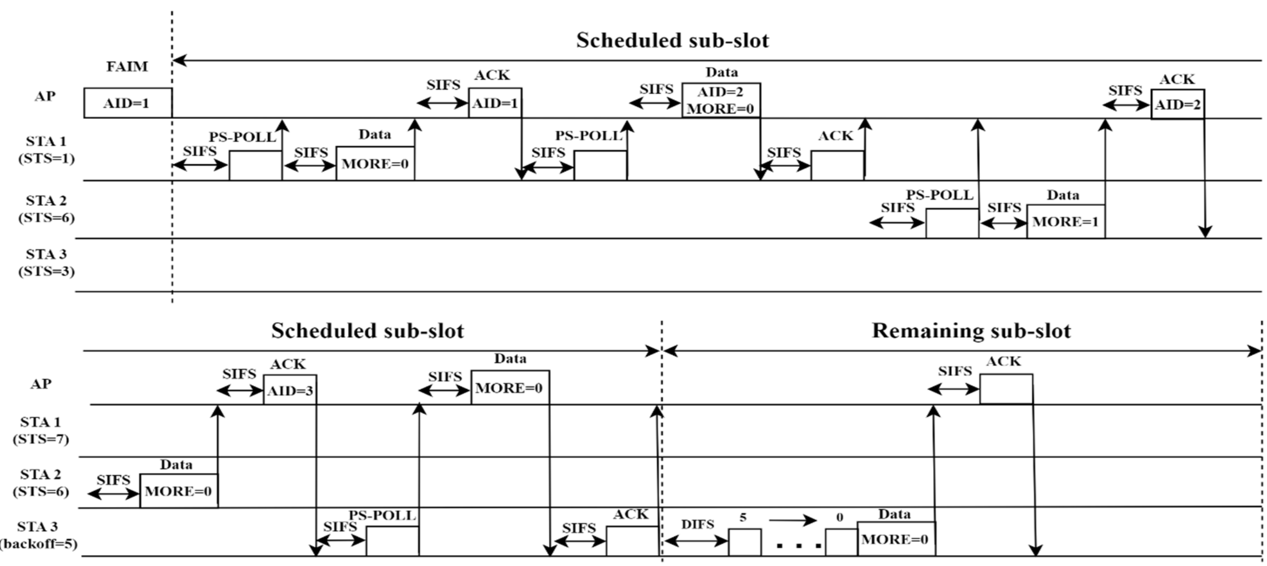


Fig. 3. An example of STAs' channel access.

transmission. Thus, the ACK frame that AP sends after receiving STA 2's uplinked data frame indicates the next STA to access channel is STA 2. After receiving STA 2's second uplinked data, in which the "more bit" is set to 0 to indicate that this is the last uplinked data frame, AP sends the ACK frame that indicates the next STA to access channel is STA 3. Thereafter, after receiving STA 3's PS-POLL frame, AP sends STA 3's downlinked data frame to STA 3.

The Scheduled Data Transmission phase is ended after STA 3 completing its channel access. The slot's remaining time can then be used for STAs that have unsuccessfully claimed their uplinked data to compete for the privilege of channel access based on the CSMA/CA control scheme. Referring to Figure 3, STA 3 selects a backoff counter of 5 in the remaining sub-slot. When the backoff counter reaches 0, STA 3 sends its uplinked data frame to AP. AP responds the ACK frame to indicate the successful reception after receiving STA 3's uplinked data frame. Since there is no more STA needing to access channel, the slot remains idle until its time duration elapses.

IV. The Proposed Slot Adjustment Method

In this Section, details of the proposed slot adjustment method are presented.

Let T_{slot} be the default time length of the slot. After AP calculating the access time $T_{scheduled}$ required for each data slot's scheduled sub-slot, it can know which data slots have surplus/deficit time. Slots can be categorized as the following three types: (1) T_{slot} is sufficient to allow all scheduled STAs to complete channel accesses; (2) T_{slot} is insufficient to allow all scheduled STAs to complete channel accesses; (3) No STA needs to access channel.

Since the slot time is sufficient for scheduled STAs to access channel completely, the remaining time of the first and the third types' slots can be used by the second type of slots. Thus, the first and third types' slots are the surplus slots (S-slots), and the second type's slots are the deficit slots (D-slots).

Let $T_{remaining}$ be equal to subtract $T_{scheduled}$ from T_{slot}. Before adjusting the slots' lengths, sort D-slots in the ascending order based on their $T_{remaining}$. Let $\mathbb{D}\text{-}\mathbb{SLOT} = \{D_1, D_2, D_3, .., D_k\}$ denote the k slots whose $T_{remaining}$ be negative, and slot D_i represents the slot that has the i^{th} smallest $T_{remaining}$ among these k slots. Note that since $T_{remaining}$ of slot D_i, $i = 1, 2, \ldots, k$, is a negative value, the relationship of the absolute value of $T_{remaining}$ of slot D_i, $i = 1, 2, .., k$, is $\left|T_{remaining}^{D_i}\right| \geq \left|T_{remaining}^{D_{i+1}}\right|$. Then, sort S-slots in the ascending order based on their $T_{remaining}$. Let $\mathbb{S}\text{-}\mathbb{SLOT} = \{S_1, S_2, \ldots, S_m\}$ denote the m slots whose $T_{remaining}$ is positive, and the relationship of the value of $T_{remaining}$ of slot S_i, $i = 1, 2, \ldots, m$, is $T_{remaining}^{S_i} \leq T_{remaining}^{S_{i+1}}$.

When both $|\mathbb{D}\text{-}\mathbb{SLOT}|$ and $|\mathbb{S}\text{-}\mathbb{SLOT}|$ are bigger than 0, it can do the Slot Adjustment phase; otherwise, all of slots' time lengths are still equal to the default slot time length. Let both $|\mathbb{D}\text{-}\mathbb{SLOT}|$ and $|\mathbb{S}\text{-}\mathbb{SLOT}|$ be bigger than 0 and I_d/I_s indicate the ${I_d}^{th}/{I_s}^{th}$ element in the set $\mathbb{D}\text{-}\mathbb{SLOT}/\mathbb{S}\text{-}\mathbb{SLOT}$, for which both initial values of I_d and I_s are 1. Given a slot D_{I_d}, its slot time's adjustment can be as follows:

(1) If the sum of the currently remaining $T_{remaining}$ in all S-slots is bigger than or equal to $\left|T_{remaining}^{D_{I_d}}\right|$, then find the smallest x such that the sum of $T_{remaining}^{S_{I_s}}$, $T_{remaining}^{S_{I_s+1}}$, ..., and $T_{remaining}^{S_x}$ is greater than or equal to $\left|T_{remaining}^{D_{I_d}}\right|$. Then, $T_{slot}^{D_{I_d}}$ is adjusted to $T_{slot}^{D_{I_d}} + \left|T_{remaining}^{D_{I_d}}\right|$, $T_{slot}^{S_i}$, where $i = I_s, I_s +$

$1, \ldots, x-1$, is adjusted to $T_{slot}^{S_i} - T_{remaining}^{S_i}$, and $T_{slot}^{S_x}$ is adjusted to $T_{slot}^{S_x} - \left(\left|T_{remaining}^{D_{I_d}}\right| - \sum_{i=I_s}^{x-1} T_{remaining}^{S_i}\right)$; set (i) I_s to x and (ii) I_d being increased by 1.
(2) If the sum of the currently remaining $T_{remaining}$ in all S-slots is smaller than $\left|T_{remaining}^{D_{I_d}}\right|$, then give all of the currently remaining $T_{remaining}$ in all S-slots to slot D_{I_d}. Then, $T_{slot}^{D_{I_d}}$ is adjusted to $T_{slot}^{D_{I_d}} + \sum_{i=I_s}^{m} T_{remaining}^{S_i}$, where S_m represents the last slot's ID in $\mathbb{S}$-$\mathbb{SLOT}$, and $T_{slot}^{S_i}$, where $i = I_s, I_s+1, \ldots, m$, is adjusted to $T_{slot}^{S_i} - T_{remaining}^{S_i}$.

V. PERFORMANCE EVALUATION

In this Section, the performance evaluation is presented.

The simulation environment, which includes an AP and varying numbers of STAs, simulates the IEEE 802.11ah network using NS3. Parameters of DTIM interval, number of STAs, data frame arrival rate, etc., can be configured.

Performance comparison is based on the following methods:
(1) "Legacy" denote the legacy IEEE 802.11ah, which adopts the generic RAW mode with the fixed slot lengths.
(2) "QoS-ECA" is the method proposed in [6]. The method (i) uses the generic RAW mode and (ii) dynamically increases or decreases the slot length of the next DTIM based on changes in the collision count of the current and previous DTIMs. Each adjustment is set as 10ms in the simulation environment.
(3) "DSLA-TSS" denotes the proposed method.

Note that the proposed method maintains a constant RAW length when adjusting slot lengths, whereas the QoS-ECA method causes changes in RAW slots' lengths, which in turn may modify the follow-up DTIM periods' lengths.

The adopted performance metrics are as follows:
(1) Throughput (bps): The average throughput is calculated by taking the total amount of data transmitted and received by all STAs in both scheduled and remaining sub-slots during the experiment and dividing it by the duration of the experiment.
(2) Channel utilization (%): It is derived through dividing the channel time used to (i) transmit scheduled uplinked and downlinked data in the scheduled sub-slot and (ii) transmit spontaneously uplinked data processed in the remaining sub-slot, which excludes the collision and backoff count down time, by the total observation time.
(3) Collision rate (%): It denotes the average collision rate of all STAs. Each STA's collision rate is derived through dividing the total number of collisions, including collisions occurred in both Claiming and Remaining Time Data Transmission phases, during channel access by the total number of channel access's attempts for that STA during the experiment.

Table 1 depicts environmental parameters that are set in [10] and their values used in the experiment. Each experiment has 4 DTIM periods; each experiment is executed for 10 times. The experiment results are the average of these 10 times.

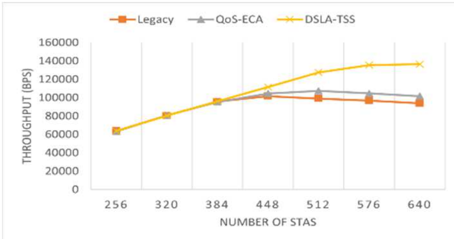
TABLE 1. Parameters and their values that are adopted in the simulation environment.

Symbol	Description
CWmin	32
CWmax	1024
MAC header Type	Legacy header
MAC header	14 bytes
Payload Size	128 bytes
Backoff count down time slice	52us
DIFS	264us
SIFS	160us
Wi-Fi Mode	MCS10, 1MHz
DTIM Interval	3.84s

In the experiment, each DTIM contains two TIMs, each TIM contains two RAWs, and each RAW contains four slots. Each STA generates 0~3 uplinked data packets and 0~1 downlinked data packets in each DTIM period. The average uplinked (downlinked) data packet arrival rate for the overall network is 1 pkt/s (0.5 pkt/s). Both uplinked and downlinked data packet arrival rates follow the Poisson distribution.

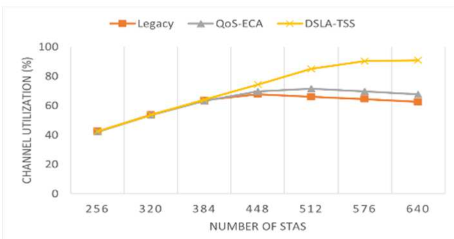
Referring to Figure 4-(a) and Figure 4-(c), when the number of STAs does not exceed 448, throughput and channel utilization of all three methods increase when the number of STAs increases because the traffic demand in the network increases when the number of STAs increases. However, when the number of STAs is equal to or greater than 448 (512), the increased number of collisions results in significant time being spent on collision handling, which reduces the available time for data transmission and causes the throughput and channel utilization of the Legacy method (the QoS-ECA method) to start decreasing. In contrast, the proposed method maintains its upward trend in throughput and channel utilization. The reason is twofold. Firstly, even if collisions occur in the claiming slots, the collisions' overhead is smaller compared to using the generic RAW. The reason is that STAs use short claiming frames to compete for the channel access privilege in the Claiming phase when the triggered RAW mode is adopted, while STAs use long data frames to compete for the channel access privilege in the data slot when the generic RAW mode is adopted. Secondly, using the proposed time-stamp-based scheduling scheme, only STAs with uplinked data need to compete for the channel access privilege, while downlinked data can be directly scheduled by AP. Thus, the proposed method has a lower number of collisions than the QoS-ECA method and the Legacy method in the situation of having the same number of STAs. When the number of STAs is equal to or greater than 576, the upward trend of throughput and channel utilization of the proposed method gradually slows down due to the limitation of the RAW length.

Referring to Figure 4-(b), when the number of STAs in the network increases, the collision rate of all three methods increases. The proposed method has the lower collision rate than that of the Legacy method and the QoS-ECA method. The



(a)

(b)



(c)

Fig. 4. The performance evaluation results for different numbers of STAs: (a) throughput, (b) collision rate, and (c) and channel utilization.

reason is as follows. Using the proposed time-stamp-based scheduling scheme, only STAs having uplinked data need to compete for the channel access privilege using the small size's claiming frames in the Claiming phase, while downlinked data can be directly scheduled by AP. Therefore, the proposed method has a lower number of collisions than the other two methods in the situation of having the same number of STAs. Using the proposed method, STAs having uplinked data that successfully claimed but failed to complete their channel access in the current DTIM need to reclaim in the next DTIM. When network congestion reaches a certain level, i.e., when the number of STAs is equal to or greater than 576, the limitation of RAW length increases the number of STAs that are unable to complete channel access within the current DTIM. Therefore, the collision rate of the proposed method increases faster when the number of STAs is equal to or greater than 576.

VI. Conclusion

This paper has proposed the Dynamic Slot Length Adjustment and Time-Stamp-based Scheduling (DSLA-TSS) method for dynamically adjusting slots' lengths to improve network performance for the triggered RAW mode of IEEE 802.11ah IoT network. The proposed method can move those slots' surplus time to the slots that have deficit time. For the channel access sequence in each scheduled sub-slot, the proposed time-stamp-based scheduling scheme has AP to be able to schedule STAs' channel access based on the time stamps of received claiming frames and/or downlinked data in the scheduled sub-slot; STAs that have unsuccessfully claimed their uplinked data can use the CSMA/CA control scheme to compete for the channel access's privilege in the remaining sub-slot. Simulation results have shown that the proposed DSLA-TSS method can improve the overall network's performance, including higher throughput and channel utilization, as well as lower collision rate. Possible future work is to consider the power saving issue to reduce the power consumption.

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