Providing QoS for Multi-Class Traffic in IEEE 802.11 DCF with Constant Contention Window

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Abstract

This paper presents two Medium Access Control algorithms named Limiting Accessible Slots (LAS) and Splitting Accessible Slots (SAS), which enable the IEEE 802.11 distributed coordination function (DCF) with Constant Contention Window protocol to support traffic with different quality of service requirements. LAS algorithm restricts slot access to group 1 users while group 2 users can access all slots. While SAS algorithm restricts slot access to both groups of users. Each group of users can only access the slots allocated to them. There are no slots that are shared by both groups of users. From the results, we found that each group of users has different average delay time for accessing the channel, so these algorithms can be used to provide different Quality of Service (QoS) for multi-class traffic. In conclusion, appropriately setting the accessible slots for group 1 and group 2 users is crucial for achieving the desired QoS levels, highlighting the importance of tailoring these parameters to the specific user distribution.

Keywords: IEEE 802.11 DCF with constant contention window, Multi-class traffic, QoS

I. INTRODUCTION

Nowadays, wireless communication technology has developed greatly and can transmit data much faster than before, resulting in a large number of users in the system. When there are many users who want to send data simultaneously, there is a chance of data collisions. This causes the efficiency of data transmission to decrease. For this reason, there is a need for a protocol that can control access to the channel for data transmission. This protocol is named Medium Access Control (MAC) protocols. Examples of this protocol include TDMA [1], [2], FDMA [3], [4], and CDMA [5], [6]. These three types of protocols clearly divide the channel for each user according to the time, frequency, and code assigned to each user. This causes no data collisions to occur. However, if some users do not have data to send on the channels allocated to them, this results in wasted resources. Therefore, contention based protocols [7], [8] have been developed. Contention based protocols allow each user to compete for the use of the channel, thus being able to support a large number of users. Examples of this type of protocol include Pure ALOHA [9], Slotted-ALOHA [10], [11], and IEEE 802.11 DCF with Constant Contention Window [12]. The IEEE 802.11 DCF with Constant Contention Window protocol is different from Pure ALOHA and Slotted-ALOHA in that the IEEE 802.11 DCF with Constant Contention Window protocol uses a frame structure with a fixed number of slots. In Each frame, the user can choose only one slot to send data, preventing each user from sending data consecutively. This causes fairness in the use of each frame. However, the IEEE 802.11 DCF with Constant Contention Window protocol is not designed to support traffic with varying quality of service requirements. Each type of data requires different quality of service. For example, audio data is more sensitive and delay than general data. This leads to subpar performance for high-priority traffic because IEEE 802.11 DCF's current MAC algorithms are unable to deliver differentiated QoS. The needs of various traffic kinds are not sufficiently satisfied by current techniques. Numerous strategies to improve QoS in wireless networks have been investigated in earlier research. For example, the traffic prioritization performance of EDCA has been well investigated, however it is not always effective in contexts with highly varied traffic kinds. Other strategies, including adjusting the dynamic contention window, have showed promise but still need to be improved for scalability and fairness reasons. For the above reasons, there is a need to develop channel access protocols for wireless communications that can support different service quality requirements.

This paper aims to improve the IEEE 802.11 DCF with Constant Contention Window protocol by presenting channel access algorithms named Limiting Accessible Slots (LAS) and Splitting Accessible Slots (SAS) to be able to support traffic with different quality of service requirements. The following questions are intended to be addressed by this study: For what user groups, what is the effect of the SAS and LAS algorithms on average delay times? Can these algorithms distinguish between QoS for multiple classes in an efficient manner?. Successfully addressing these challenges will not only enhance user experience in wireless networks but also pave the way for more reliable and efficient communication systems, which are crucial for the growth of IoT, smart cities, and other emerging technologies. To evaluate the effectiveness of the proposed algorithms, this study is based on simulation. Under diverse traffic scenarios, key parameter like average delay time will be monitored

The paper is presented in the following order: In section II, we describe the details of the Limited Accessible Slots (LAS) and Separation of Accessible Slots (SAS) algorithms. In section III, results and discussion are presented. Finally, conclusions are presented in section IV.

II. PROPOSED ALGORITHMS

This paper presents 2 algorithms that can support traffic with different priority requirements, which are Limiting Accessible Slots (LAS) and Splitting Accessible Slots (SAS) algorithms. The details of all proposed algorithms are as follows.

A. Limiting Accessible Slots (LAS)

This algorithm restricts slot access to group 1 users, while group 2 users can access all slots. An example channel access of this algorithm is shown in Fig.1. In this example, user A is only group 1 user and the slot that user A can access is the first slot only. While the remaining 5 users, which are users B, C, D, E, F, can access all slots. From the figure, it can be seen that User A successfully accessed the channel from the first slot in the first frame. In this example, User A has a delay of 1 slot. While users B and C access the same slot in the first frame this causes a collision. Users B and C are unsuccessful in accessing the first frame. They then continue to access the channel in frame 2. It can be seen that user B successfully accesses slot 3 in frame 2. Therefore, user B has a delay of 8 (number of slots in the first frame) + 3 = 11 slots.

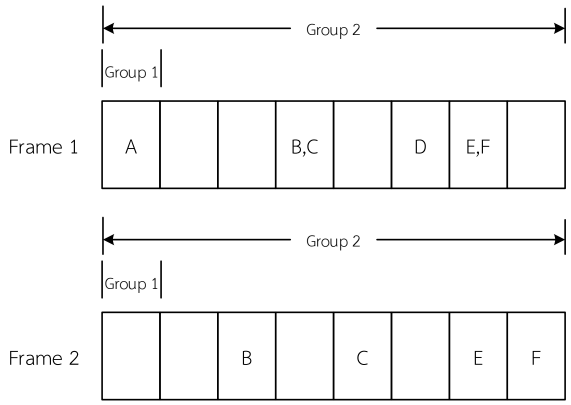

Figure 1: Collision resolution mechanism of LAS algorithm when both accessible slots and number of group 1 users are equal to 1.

In Fig. 2, users A and B are group 1 users, which can access the first 3 slots, while the remaining 4 users, which are C, D, E, F, are group 2 users and can access all slots. From the figure, we can see that each group of user has different channel access characteristics. As a result, each group of user has different average delay time in accessing the channel.

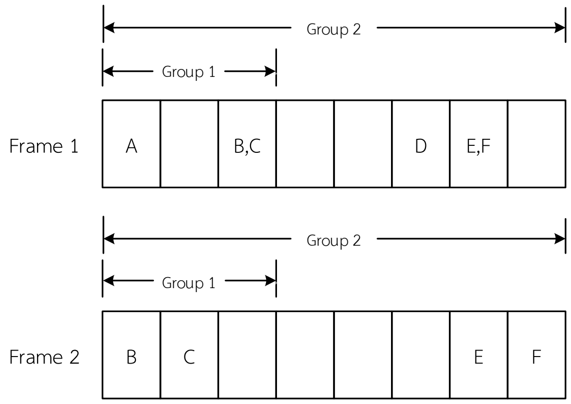

Figure 2: Collision resolution mechanism of LAS algorithm when accessible slots and number of group 1 users are equal to 3 and 2, respectively.

B. Splitting Accessible Slots (SAS)

The SAS algorithm allocates specific slots to each group of users, ensuring that no slots are shared between groups. An example of channel access using this algorithm is shown in Fig. 3. In this example, user A is only group 1 user and the slot that user A can access is the first slot only. Meanwhile, the remaining 5 users, namely users B, C, D, E, F can access the remaining slots later, which are slots 2 – 8. In Fig. 4, users A and B are group 1 users, which can access the first 3 slots, while the remaining 4 users, which are C, D, E, F, are group 2 users and can access the remaining slots later, which are slots 4 – 8. From the different characteristics of channel access, each group of user has different average delay time in accessing the channel.

LAS algorithm restricts slot access to group 1 users only, while group 2 users are able to access all slots.

By assigning unique slots to every group, the SAS method, in contrast, prevents shared access."

We can therefore apply these 2 proposed algorithms to systems that need to support traffic that requires different Quality of Service.

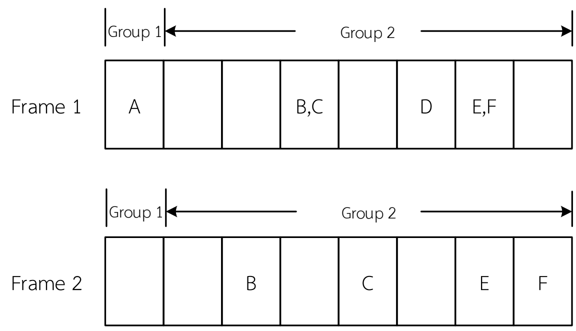

Figure 3: Collision resolution mechanism of SAS algorithm when both accessible slots and number of group 1 users are equal to 1.

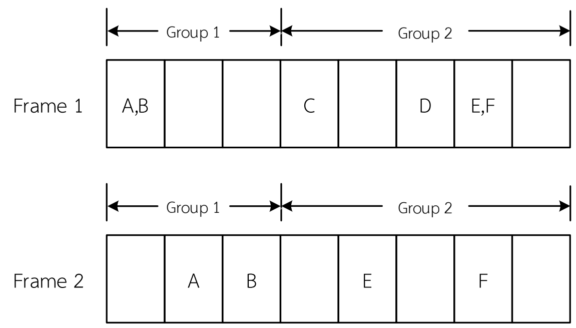

Figure 4: Collision resolution mechanism of SAS algorithm when accessible slots and number of group 1 users are equal to 3 and 2, respectively.

III. RESULTS AND DISCUSSION

In this section, we investigate the performance of the 2 proposed algorithms using MATLAB. This study is predicated on the use of a set number of users and unchanging traffic patterns. The details of the investigation are as follows.

A. Performance of Limiting Accessible Slots (LAS)

We set the total number of slots and the total number of users to be equal to 8. Users are divided into 2 groups. Group 1 users access the first few slots. While group 2 users can access all slots.

As seen in Fig. 5, when the accessible slots of group 1 users are equal to 1 and the number of users in group 1 and group 2 are equal to 1 and 7, respectively. The average delay time of group 1 users is below than the average delay time of group 2 users. The reason why the performance of group 1 users is better than group 2 users is because group 1 user has only one user and this user has access only to the first slot. Meanwhile, there are 7 users in group 2, and these 7 users have access to slots 1 to 8, giving group 1 user a chance to succeed before group 2 users. It can be noticed that the average delay time of group 1 users increases with accessible slot of group 1 users because the more accessible slot of group 1 users is, the greater the chance that group 1 users will be successful in later slots. When accessible slot of group 1 users is equal to 8, the average delay time of group 1 users and group 2 users are the same. Because in this situation group 1 users and group 2 users can access all slots. Therefore, there are no differences between the two groups of users.

When increasing the number of users of group 1 users to 2, 4, 6, and 7 respectively while maintaining the total number of users equal to 8 users, as shown in Figs. 6-9. It is found that the average delay time of group 1 users is low while the accessible slot of group 1 users is high. This is because when the accessible slots of group 1 users increase, it can help reduce the chance of collisions among group 1 users. Moreover, the average delay time of group 1 users and group 2 users are the same when the accessible slot of group 1 users is equal to 8. As described earlier, in this scenario there is no difference between two groups of users.

It will be noted that some values of average delay time of group 1 and group 2 users are not displayed, such as when setting accessible slot of group 1 users to be equal to 1 and setting the number of group 1 users to be equal to 2. This is because in this situation 2 users select the first slot. This definitely causes collisions and will continue to collide every frame, making the average delay time of group 1 users equal to infinity. This value is therefore not plotted on the graph.

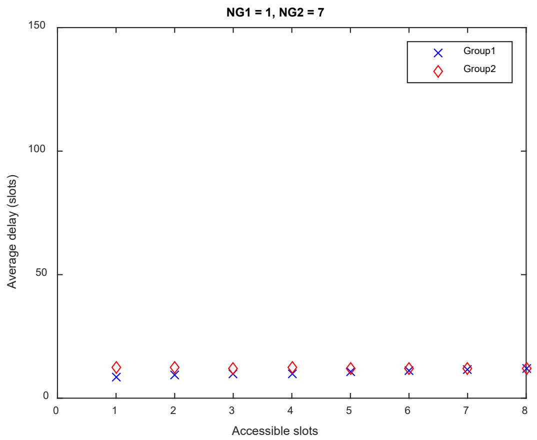

Figure 5: Average delay time vs the number of accessible slot of group 1 users for the LAS algorithm when NG1=1, NG2=7.

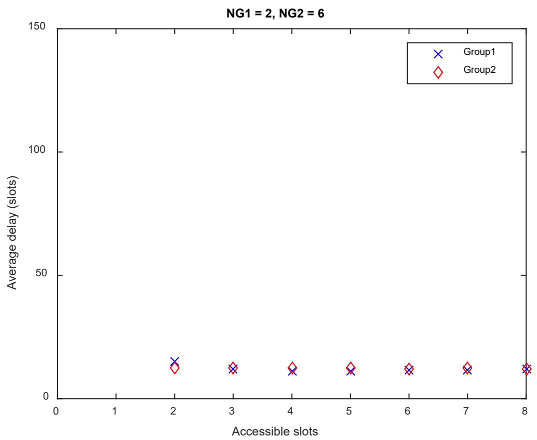

Figure 6: Average delay time vs the number of accessible slot of group 1 users for the LAS algorithm when NG1=2, NG2=6.

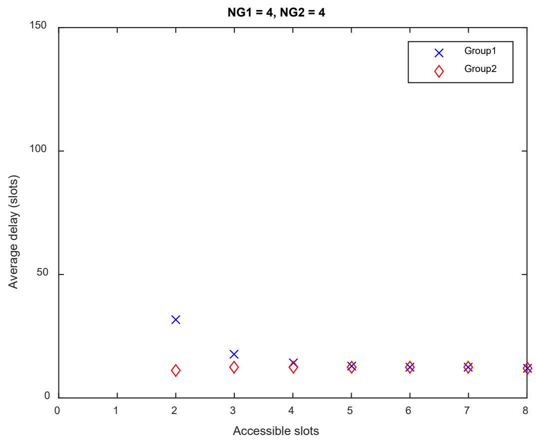

Figure 7: Average delay time vs the number of accessible slot of group 1 users for the LAS algorithm when NG1=4, NG2=4.

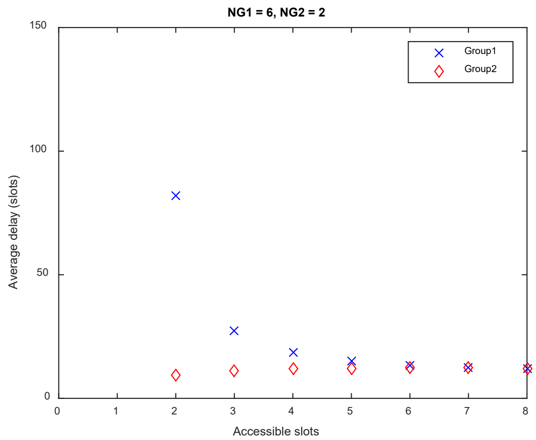

Figure 8: Average delay time vs the number of accessible slot of group 1 users for the LAS algorithm when NG1=6, NG2=2.

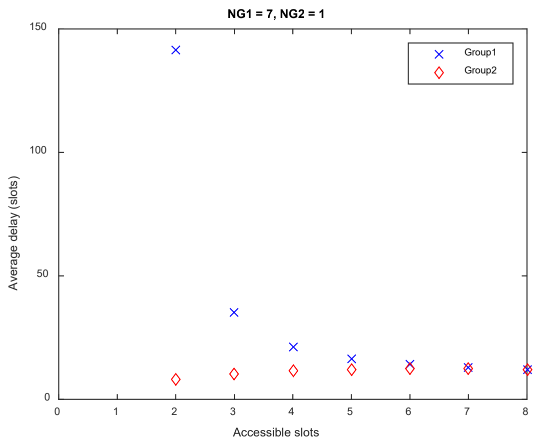

Figure 9: Average delay time vs the number of accessible slot of group 1 users for the LAS algorithm when NG1=7, NG2=1.

To determine how many times the average delay time is different between group 1 users and group 2 users. Ratio value is defined by setting this value to be equal to the ratio of the average delay time of group 2 users divided by the average delay time of group 1 users. If the Ratio value is greater than 1, it means that group 2 users spend more time on average than group 1 users, that is, group 1 users have better service quality than group 2 users. On the other hand, if the Ratio value is less than 1, it means that group 2 users spend less time on average than group 1 users, that is, group 2 users have better service quality than group 1 users. To understand clearly, let's give an example as follows. If the Ratio value is equal to 1.4, it means that in accessing the channel, group 2 users take more time on average than group 1 users, with an average delay time equal to 1.4 times that of group 1 users.

When considering Fig.10, it can be found that when group 1 users is equal to 1, the Ratio value will be greater than 1 at low accessible slot of group 1 users. That is, in this situation, group 1 users have a chance of being successful in accessing the channel. higher than group 2 users. When the number of accessible slots of group 1 users is equal to 8, the Ratio value is equal to 1, that is, both groups of users have the same chance of success in accessing the channel. When the number of group 1 users is equal to 2, the Ratio value is lower than 1 at the accessible slot of group 1 users equal to 2. This is because there are only 2 slots for group 1 users and in these 2 slots group 2 users can compete with group 1 users. While 6 group 2 users can access any of the 8 slots, the last 6 slots are competition among group 2 users, making group 1 users' chances of success in using the channel lower than group 2 users. However, when the number of group 1 users is greater than 2, the Ratio tends to increase to more than 1 because group 1 users have more slots that can be accessed. This causes collisions between group 1 users to decrease and results in better channel access performance for group 1 users.

When the number of group 1 users is greater than 2, the Ratio value is lower than 1 at low accessible slot of group 1 users. This is because there are a large number of group 1 users, while the number of slots that group 1 users can access is limited. While the number of group 2 users is decreasing and group 2 users can access all slots. As a result, group 2 users have a higher chance of success in accessing the channel than group 1 users, resulting in the Ratio being lower than 1.

In addition, when increasing the number of accessible slots of group 1, the Ratio value increases. Because increasing the number of accessible slots of group 1 can reduce the chance of collisions among group 1 users and cause the average delay time of group 1 users to be lower. When the number of accessible slots of group 1 users is equal to 8, the Ratio value is equal to 1. It is found that the Ratio values in Fig. 10 are mostly lower than 1, so we plot the Inverse ratio, which is equal to the average delay time of group 1 users divided by the average delay time of group 2 users. As shown in Fig. 11, it is found that most of the Inverse Ratio values are greater than 1. That is, in many situations group 2 users have better performance than group 1 users.

From Fig. 10, it can be found that the accessible slot of group 1 users and the number of group 1 users affect the system performance. In some cases, it is found that group 1 users have better service quality than group 2 users. While in other cases, group 2 users have better service quality than group 1 users. We can apply this algorithm to traffic that requires different quality of service requires adjusting the accessible slot of group 1 users value to suit the number of group 1 users, number of group 2 users, and the desired Ratio value. According to the findings, as compared to the DCF protocol's baseline, the LAS algorithm dramatically lowers the average delay time for high-priority traffic.

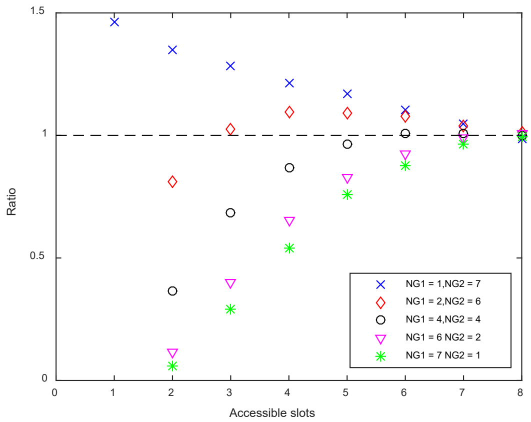

Figure 10: The Ratio vs the number of accessible slot of group 1 users for the LAS algorithm for various number of group 1 users and group 2 users.

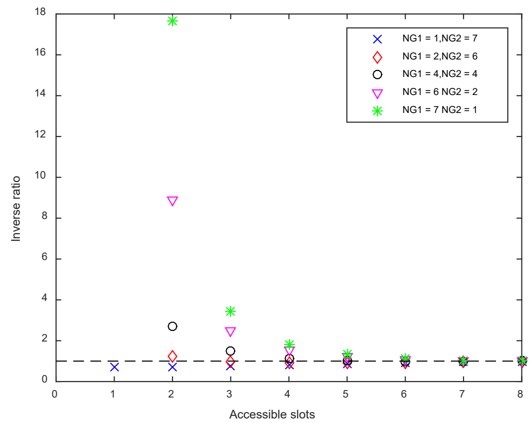

Figure 11: The Inverse ratio vs the number of accessible slot of group 1 users for the LAS algorithm for various number of group 1 users and group 2 users.

B. Performance of Splitting Accessible Slots (SAS)

Here, we set the number of slots and the total number of users to be equal to 8. Users are divided into 2 groups, with group 1 users accessing the early slots while group 2 users accessing the remaining later slots.

As can be seen in Fig. 12, when the accessible slot of group 1 users is equal to 1 and the number of group 1 users and group 2 users are equal to 1 and 7, respectively, the average delay time of group 1 users is below than the average delay time of group 2 users. The reason why the performance of group 1 users is better than group 2 users is because there is only one user in group 1 users and this user only accesses the first slot, making him definitely successful in accessing the slot. While group 2 users access the remaining slots in the latter, causing group 1 users succeed before group 2 users.

It is found that the average delay time of group 2 users increased with accessible slot of group 1 users and become very high when accessible slot of group 1 users is large. For example, where the accessible slots of group 1 users are equal to 6. Because in this situation, group 2 users have only 2 slots left to access, which are slots 7 and 8, but there are up to 7 group 2 users, causing a high chance of collisions.

When increasing the number of users of group 1 users to 2, 4, 6, and 7 respectively while maintaining the total number of users equal to 8 users, as shown in Figs. 13-16. It can be noticed that the average delay time of group 1 users is high at low accessible slot of group 1 users. This is because when the number of group 1 users is high while the accessible slot of group 1 users is low, there will be a higher chance of collisions between group 1 users. When increasing the accessible slot of group 1 users, it is found that the average delay time of group 1 users decreased because increasing the number of slots accessible to group 1 users can reduce the chance of collisions between group 1 users.

While the average delay time of group 2 users increases with accessible slot of group 1 users because when increasing the accessible slot of group 1 users, group 2 users are left with only fewer slots to access. Therefore, there is a higher chance of collision between group 2 users, causing the average delay time of group 2 users to increase accordingly.

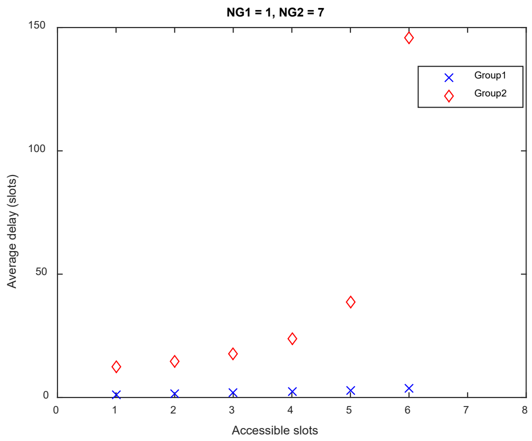

Figure 12: Average delay time vs the number of accessible slot of group 1 users for the SAS algorithm when NG1=1, NG2=7.

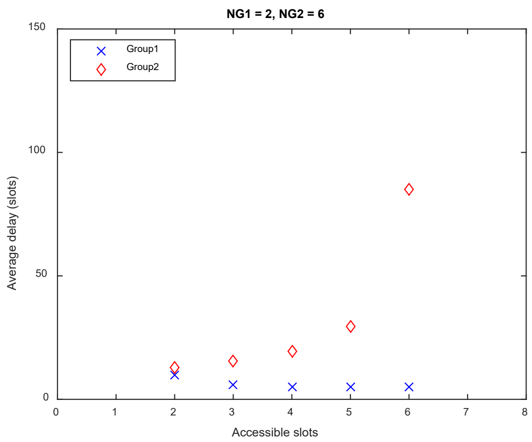

Figure 13: Average delay time vs the number of accessible slot of group 1 users for the SAS algorithm when NG1=2, NG2=6.

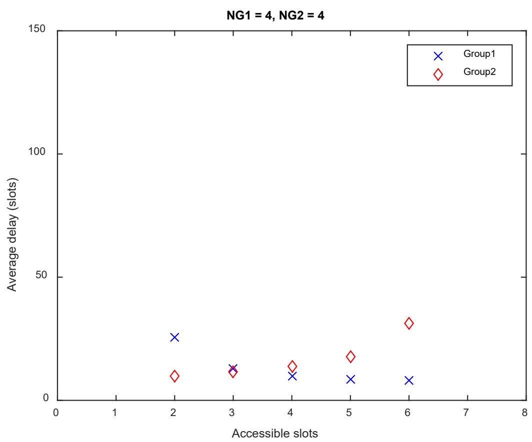

Figure 14: Average delay time vs the number of accessible slot of group 1 users for the SAS algorithm when NG1=4, NG2=4.

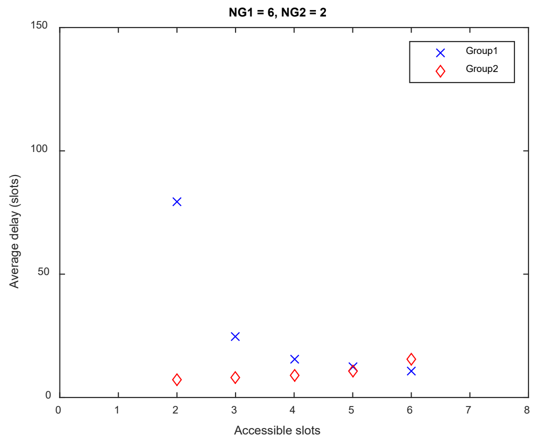

Figure 15: Average delay time vs the number of accessible slot of group 1 users for the SAS algorithm when NG1=6, NG2=2.

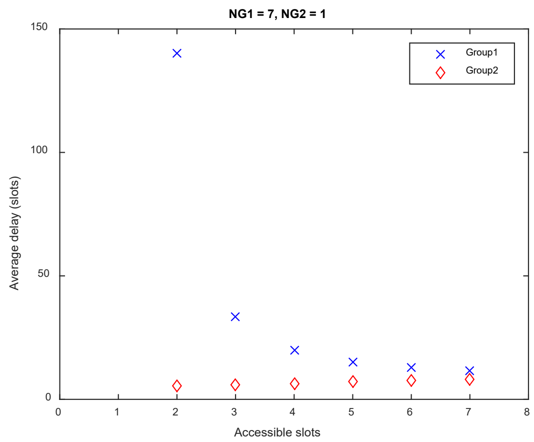

Figure 16: Average delay time vs the number of accessible slot of group 1 users for the SAS algorithm when NG1=7, NG2=1.

We see an increase in delay for low-priority traffic using the SAS algorithm in certain scenarios. This is related to high traffic condition. When considering the Ratio value, which is the ratio of the average delay time of users in group 2 to the average delay time of users in group 1, as shown in Fig. 17. It is found that when group 1 users is equal to 1, the Ratio value is greater than 1 because there is only one group 1 user and this user has definitely successfully accessed the slot. Meanwhile, the second group of 7 users must compete compete for access to the remaining slots. As a results, the average delay time of group 2 users is higher than the average delay time of group 1 users.

When the number of group 1 users is 2, 4, 6, and 7, the Ratio value is higher than 1 when the accessible slot of group 1 users value is higher than or equal to the number of group 1 users. Because in this case the number of slots is sufficient compared to the number of group 1 users, there is little chance of collision. Increasing accessible slot of group 1 users will cause group 2 users to have fewer accessible slots later. This causes a high chance of collision. As a result, the average delay time of group 2 users is higher than the average delay time of group 1 users.

In addition, it can be observed that the Ratio value is lower than 1 when the accessible slot of group 1 users is less than the number of group 1 users. Because in this case the number of slots is too small compared to the number of group 1 users, there is a high chance of collision. When accessible slots of group 1 users are small, this means that group 2 users have more accessible slots. This reduces the chance of a collision between group 2 users. As a result, the average delay time of group 2 users is lower than the average delay time of group 1 users and causes the Ratio to be lower than 1.

It is found that some Ratio values in Fig. 17 are lower than 1, so we plot the Inverse ratio, which is equal to the ratio of the average delay time of group 1 users divided by the average delay time of group 2 users. 2 As shown in Fig. 18, some Inverse ratio values are greater than 1. That is, in some situations, group 2 users have better performance than group 1 users, such as when the number of group 1 users is greater than the accessible slot of group 1 users. We can apply this algorithm to traffic that requires different quality of service by adjusting the accessible slot of group 1 users to suit the number of group 1 users, number of group 2 users and the desired Ratio value.

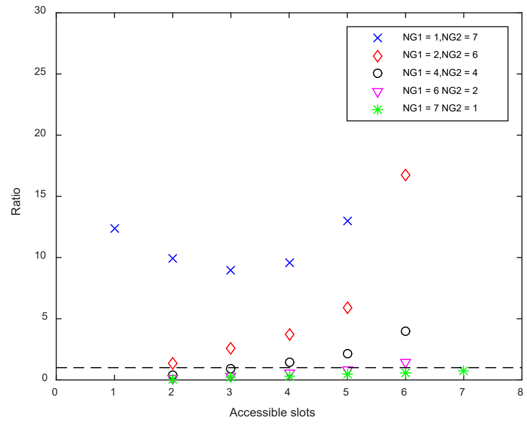

Figure 17: The Ratio vs the number of accessible slot of group 1 users for the SAS algorithm for various number of group 1 users and group 2 users.

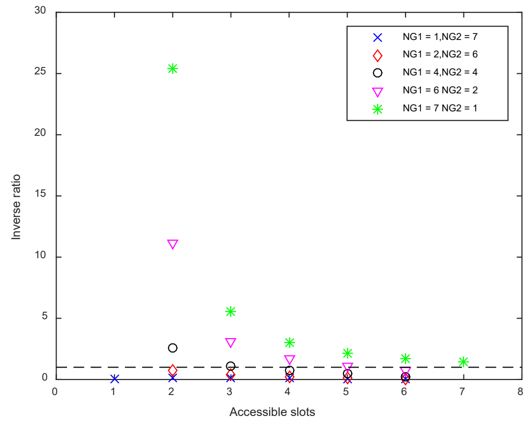

Figure 18: The Inverse ratio vs the number of accessible slot of group 1 users for the SAS algorithm for various number of group 1 users and group 2 users.

IV. CONCLUSION

In this paper, we present 2 new algorithms, LAS and SAS algorithms. The proposed algorithms are derived from IEEE 802.11 DCF with Constant Contention Window. LAS algorithm restricts slot access to group 1 users while group 2 users can access all slots. While SAS algorithm restricts slot access to both groups of users. Each group of users can only access the slots allocated to them. There are no slots that are shared by both groups of users. Our results indicate that each user group experiences distinct average delay times for channel access, demonstrating that these algorithms can effectively differentiate QoS for multi-class traffic.

It can be concluded that the accessible slot of group 1 users and group 2 users are the important parameters that must be set appropriately according to the number of group 1 users and the number of group 2 users to achieve the desired level of QoS. To prioritize traffic and enhance user experience generally, network operators can apply the LAS and SAS algorithms in a variety of settings, including public Wi-Fi networks. These algorithms can also be included into Internet of Things frameworks to guarantee that vital applications receive data in a timely manner. The use of static traffic patterns in the simulations is one of the study's limitations. To properly represent real-world settings, dynamic traffic scenarios and mobility should be included in future studies.

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