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P-persistent Based OFDMA Uplink Transmission in the Next Generation Wireless LAN

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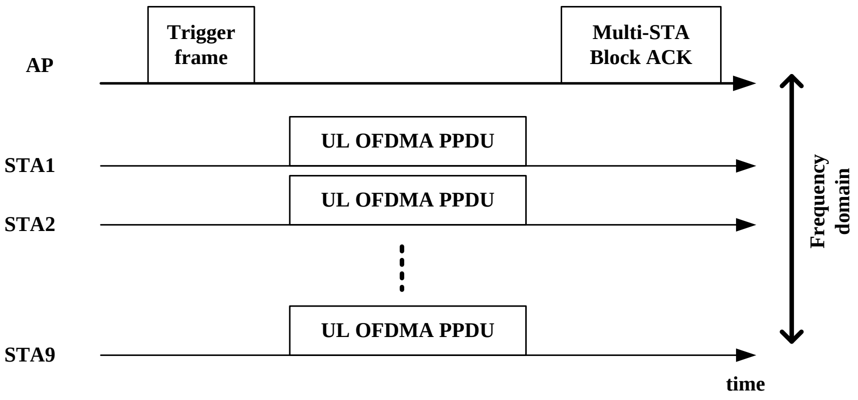
***Abstract:* -** In this paper, a novel p-persistent based Orthogonal Frequency Division Multiple Access (OFDMA) transmission scheme in the next generation Wireless Local Area Network (WLAN) is proposed. In order to enhance the throughput performance, OFDMA is adopted for both uplink and downlink transmission. Since Access Point (AP) cannot pre-schedule all potential uplink users, random access based OFDMA is also adopted. In the random access based OFDMA, AP allocates random amount of uplink resource for uplink random access since AP does not know how many Stations (STAs) would transmit how large packets. Depending on the number of STAs attempting random access, allocated random access resource can be wasted. If the number of STAs attempting random access is small, allocated random access resource would be under-utilized. If the number of STAs attempting random access is large, allocated random access resource would not be used for actual packet transmission because of packet collision. In this paper, in order to alleviate of random access congestion, a novel p-persistent based random access scheme is proposed. In the proposed scheme, depending on the possible number of STAs attempting random access, access probability is set in order to regulate number of attempting users. Also, the proposed scheme considers priority between access classes. Depending on the access class, differentiated access probabilities are assigned to provide differentiated priorities. By using the proposed scheme, next generation WLAN is able to provide a very efficient random access based OFDMA transmission scheme.

***Keywords:* -** *OFDMA, Uplink, Random Access, Access Class, Priority, IEEE 802.11ax*

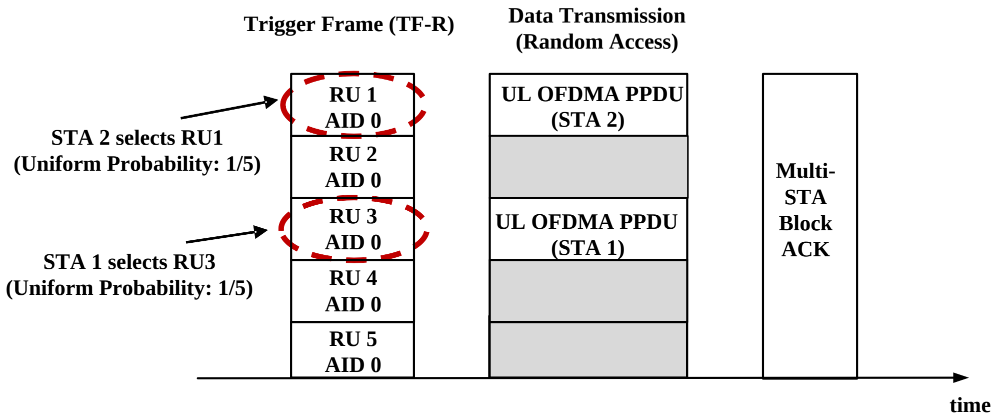
I. INTRODUCTION

Wireless Local Area Network (WLAN) [1] has become one of most popular wireless access technologies with an excellent performance [2], [3]. Nowadays, many communicating devices including smart phones and tablets use WLAN very frequently and data demand from such smart devices has grown exponentially. In order to provide enhanced performance, a new WLAN air interface standard, IEEE 802.11ax commenced its standardization from May 2014 [4]. IEEE 802.11ax aims to enhance its performance at least four times improvement in the average throughput per station in a dense deployment scenario, while maintaining or improving the power efficiency per station. In order to achieve the objective of IEEE 802.11ax, legacy Medium Access Control (MAC) scheme, Distributed Coordination Function (DCF) has to be enhanced since DCF requires contention procedure in order to access wireless channel. In DCF, as the number of contending Stations (STAs) increases MAC access delay exponentially increases. There have been many studies regarding MAC access delay [5], [6].

OFDMA is a well-known multiple access technology used in various wireless access technologies including 3GPP Long Term Evolution [7] and IEEE 802.16m [8]. In order to alleviate such WLAN MAC access delay problem, IEEE 802.11ax adopted OFDMA for both downlink and uplink transmissions. In OFDMA, packets of multiple users can be transmitted at the same time using time-frequency resource. Despite downlink OFDMA is simple, uplink OFDMA requires more sophisticated procedure than downlink OFDMA [9] since AP does not have knowledge on STAs' buffer status. In order to provide a simple uplink OFDMA transmission method, a random access based OFDMA scheme was adopted for IEEE 802.11ax [10]. Adopted random access based OFDMA scheme is somewhat different from OFDMA schemes of other technologies (LTE or IEEE 802.16m) due to WLAN's distributed nature. It is well-known that random access performance is affected by



(a) Uplink OFDMA in IEEE 802.11ax



(b) Random Access Based Uplink OFDMA in IEEE 802.11ax

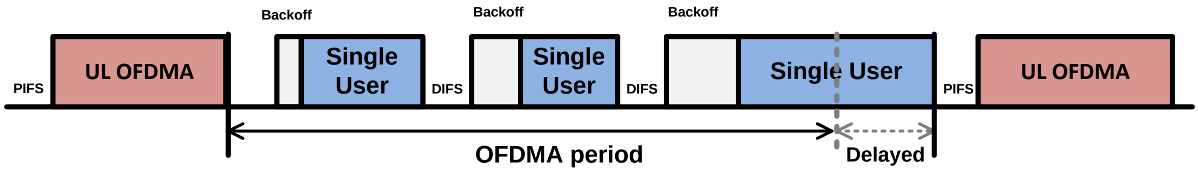
Fig. 1. WLAN Uplink OFDMA & Random Access Based Uplink OFDMA in IEEE 802.11ax

the number of accessing STAs like DCF. Since IEEE 802.11ax assumes dense deployment situation, severe performance degradation of random access based OFDMA is expected.

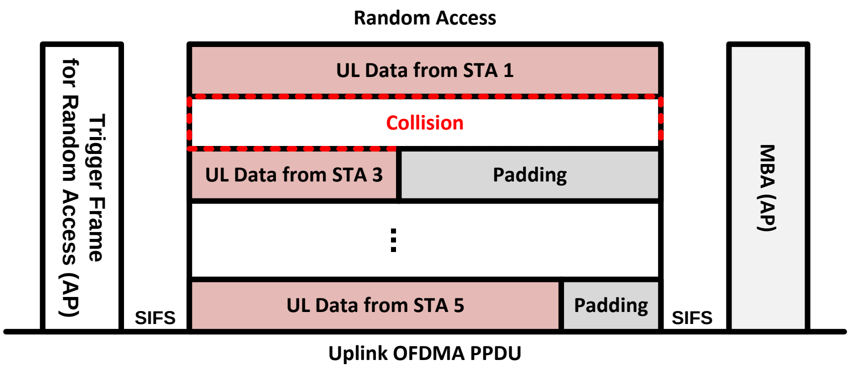
In order to alleviate such performance degradation, in this paper, a novel p-persistent based OFDMA uplink transmission scheme is proposed. In the proposed scheme, depending on the possible number of STAs attempting random access, access probability is set in order to regulate number of attempting users. Also, the proposed scheme considers differentiated priorities between access classes. Depending on the access classes, differentiated access probabilities are assigned to provide differentiated priorities. By using the proposed scheme, next generation WLAN is able to provide a very efficient random access based OFDMA transmission scheme.

II. IEEE 802.11AX UPLINK OFDMA

Fig. 1 shows the basic uplink OFDMA scheme adopted in IEEE 802.11ax. As shown in Fig. 1 (a), uplink OFDMA starts with the transmission of Trigger Frame. In the Trigger Frame, STAs to transmit uplink packets and allocated uplink resources are indicated. As an immediate response to the Trigger Frame, indicated STAs transmit uplink packets using the allocated resources. Depending on the used sub-channel configurations, number of users and amount of resource per user is defined. Fig 1 (a) is the case of 9 sub-channel per 20MHz channel. After the transmission of the allocated uplink OFDMA Physical Packet Data Unit (PPDU), AP transmits acknowledgement for STAs, which is called Multi-STA Block ACK. Basic OFDMA scheme shown in



(a) Proposed Periodic Uplink OFDMA Transmission



(b) Uplink Random Access Based OFDMA Problem

Fig. 2. Proposed Uplink OFDMA Allocation & Problem Description on Uplink Random Access Based OFDMA

Fig. 1 (a) has difficulty in resource allocation. In order for AP to allocate uplink resource efficiently, AP has to know all STAs buffer status which is very difficult and sophisticated procedure.

In order to simplify the uplink OFDMA procedure, random access based uplink OFDMA shown in Fig. 1 (b) was adopted. In the random access based uplink OFDMA, uplink OFDMA resources are allocated for STAs to randomly access. Trigger frame containing random access resource allocation is called Trigger Frame Random Access (TF-R). Random access resource can be indicated with Access Identifier (AID) 0. STAs with uplink packet to transmit randomly choose using uniform probability among allocated random access resources. Since Fig. 1 (b) allocated 5 resource units, STAs selects a sub-channel with the probability of 1/5. Using the selected sub-channels, STAs transmit their uplink packets. When a sub-channel is selected by more than two STAs, packet collision will happen cause resource waste.

III. PROPOSED P-PERSISTENT BASED UPLINK OFDMA

The proposed periodic uplink OFDMA transmission allocation and problem description of the basic uplink OFDMA are illustrated in Fig. 2. Since uplink OFDMA allows STAs to avoid contention for channel access, it would be beneficial for STAs to be polled by uplink OFDMA as frequent as possible. However, if there are not enough number STAs for uplink transmission, allocated resources are wasted. Therefore, adaptive periodic uplink OFDMA allocation is proposed. Uplink OFDMA is allocated periodically and period is adaptively adjusted based on the access history. Point Coordination Function (PDF) Inter-Frame Spacing (PIFS) is used for uplink OFDMA period allocation in order to provide priority compared to DCF. Normal single user transmission with DCF Inter-Frame Spacing (DCF) and backoff follows the uplink OFDMA period. Similar to the beacon transmission, when the OFDMA period cannot be initiated due to ongoing single user transmission, the OFDMA period is delayed until the ongoing single user transmission finishes.

As we can see from Fig. 2 (b), there are two problems with random access based uplink OFDMA. Since AP does not have knowledge on STAs' buffer status, the random access uplink resources cannot be efficiently scheduled. When the duration of uplink transmission is too short, STAs' uplink packets should be fragmented into many pieces cause large overhead. When the duration of uplink transmission is too long, STAs'

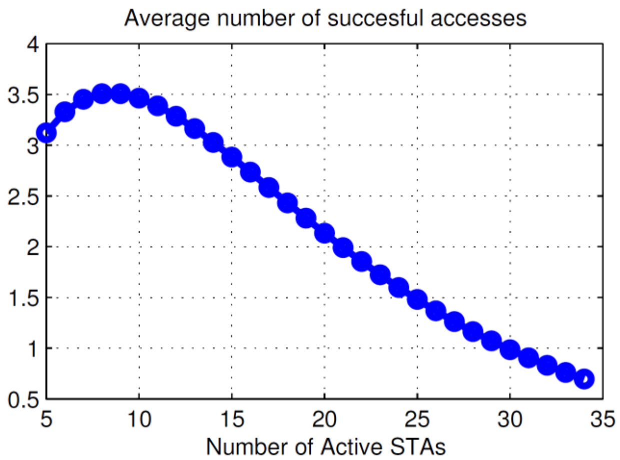


Fig. 3. Acceptance Rate of Slotted Random Access

Control	P0
AC_VO	P1
AC_VI	P2
AC_BE	P3
AC_BK	P4

P0 > P1 > P2 > P3 > P4

Channel Selection: Uniform Distribution
Transmission with P persistent: P
AP Announces congestion probability: P_c
Access Probability = P_c * P

Fig. 4. Proposed Access Probabilities for Access Classes and Congestion Levels

uplink packets should be padded which is a waste of resource. Second problem is random access sub-channel allocation. If too many random access sub-channels are allocated, the allocated sub-channels would be wasted. If too few random access sub-channels are allocated, packet collision from multiple STAs would cause the waste of the allocated sub-channel.

It is well known that the maximum efficiency of the slotted aloha random access is 37%. Random access based OFDMA is also slotted aloha type random access, successful acceptance ratio can be calculated. The calculated result is shown in Fig. 3. In this study, 9 sub-channel allocation is used. Since there are 9 sub-channels, the maximum efficiency can be obtained when there are 9 active STAs. We can see that the acceptance ratio drops as the number of active STAs increases. Low acceptance ratio causes both resource waste and MAC access delay increase. Therefore, when there are many STAs attempting random access, the number of transmitting STAs should be controlled.

Fig. 4 shows the proposed p-persistent random access based uplink OFDMA transmission scheme. There are 6 probability values are defined. The congestion probability, P_c is to control the congestion level. The probabilities, P0, P1, P2, P3, and P4 are to provide differentiated access probabilities to different access classes. AP includes P_c values in TF-R and P0, P1, P2, P3, and P4 (access class probability) are pre-defined and both AP and STAs know these values. Upon reception of TF-R, STAs can obtain P_c and they calculate transmission probability using the congestion probability (P_c) and the access class probability (P0, P1, P2, P3, and P4). Control and management packets' access class probability is P0, AC_VO (Voice) is P1, AC_VI (Video) is P2, AC_BE (Best Effort) is P3, and AC_BK (Background) is P4. In case of the STA with voice traffic, the transmission probability is P_c * P1. After the selection of the random access sub-channel, the STA picks a random number between 0 and 1. When the selected random number is below the transmission probability, the STA transmits uplink packet, otherwise the uplink transmission fails without actual transmission.

P_c can be calculated based on the access history. Similar to TCP congestion control, moving average based probability value can be used.

IV. CONCLUSION

In this paper, a novel p-persistent based OFDMA transmission scheme in the next generation WLAN is proposed. In the next generation WLAN, IEEE 802.11ax, OFDMA for throughput enhancement and random access based OFDMA for simple operation are adopted. In the random access based OFDMA, AP allocates random amount of uplink resource for uplink random access. Depending on the number of STAs attempting random access, allocated random access resource can be wasted. In this paper, in order to efficiently utilize the random access resources, a novel p-persistent based random access scheme is proposed. In the proposed scheme, depending on the possible number of STAs attempting random access, access probability is set in order to regulate number of attempting users. Also, the proposed scheme considers different priorities among different access classes. Depending on the access class, differentiated access probabilities are assigned to provide differentiated priorities. By using the proposed scheme, next generation WLAN is able to provide a very efficient random access based OFDMA transmission scheme.

V. ACKNOWLEDGEMENTS

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