Access Priority Adaptation for Triggered Uplink Channel Access in 802.11ax WLANs

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***Abstract*—Uplink Multi-User (MU) MIMO transmissions allow clients to simultaneously transmit independent data streams to the Access Point (AP), effectively multiplying the capacity of the wireless channel for uplink access. Due to inherent limitations of the distributed wireless networks, extra coordination is required for effective implementation of uplink MU-MIMO. Triggered uplink access (TUA) is the only mechanism that can initiate an uplink MU-MIMO transmission in Wi-Fi: it enables an access point (AP) to start simultaneous uplink multi-user (MU) transmissions. To trigger a MU uplink transmission, the AP must first contend for the channel using the enhanced distributed channel access (EDCA) and win channel access to broadcast the trigger frame in the downlink direction. At the same time, clients that have traffic buffered for uplink transmission also contend for channel access using the same EDCA method. However, the aforementioned mechanism introduces a fundamental conflict in the network. There are potentially two network entities competing for the channel for the same packet, namely, the AP contends for the channel to broadcast the trigger frame, while the clients that have traffic buffered for uplink transmission also contend for single-user (SU) channel access. Yet, while TUA MU transmission is preferable to SU uplink, one cannot disable the latter entirely. In this paper, we introduce Client-side Access Manipulation (CAM) as a mechanism to enable clients to dynamically adapt their channel access priority in order to realize an efficient uplink MU-MIMO WLAN. Through experiments in an end-to-end testbed with the TUA mechanism, an 11ax compliant network, and traffic from bursty closed-loop applications we show that CAM achieves gains in throughput and up to 65% reduction in average latency. Moreover, we show that, on the same scenarios, the aggregate throughput decreases and the average latency increases sharply with the use of the standard's defined access adaptation mechanism.**

***Index Terms*—IEEE 802.11ax, MU EDCA parameter set, Triggered Uplink Access (TUA), Multi-user MIMO.**

I. INTRODUCTION

The IEEE 802.11ax amendment introduces uplink Multi-User (MU) MIMO transmissions to Wi-Fi, i.e., it enables multiple clients to simultaneously transmit independent data streams to the Access Point (AP), effectively multiplying the capacity of the wireless channel for uplink access. To realize uplink MU-MIMO requires the extra steps of coordinating and aligning in time transmissions from distributed devices. Thus, 11ax defines the Triggered Uplink Access (TUA) mechanism as the only way to initiate an uplink MU-MIMO transmission in Wi-Fi, which enables an access point (AP) to start and time synchronize simultaneous uplink MU transmissions. In TUA, the AP broadcasts a trigger frame containing the list of stations that are allowed to participate in the transmission and the resource allocation information [1]. Additionally, to trigger an MU uplink transmission in TUA, the AP must first contend for the channel using the enhanced distributed channel access (EDCA) and win access to broadcast the trigger frame in the downlink direction. At the same time, clients that have traffic buffered for uplink transmission also contend for channel access using the same EDCA method, thus following the mandatory random countdown method for channel access in Wi-Fi.

Unfortunately, the aforementioned procedure introduces a fundamental conflict in the wireless network. There are potentially two network entities competing for the channel to transmit the same packet, i.e., the AP and the client may both be trying to gain access for the same uplink transmission, although the former is MU and the latter is single-user (SU). It is of course preferable for the transmission to be MU-MIMO, if possible, as that realizes the spatial multiplexing gains targeted by 11ax. Although MU transmission is preferable, one cannot disable SU uplink transmissions entirely as this could starve a client if the AP is not planning to trigger it for a MU transmission. Moreover, the AP and clients could only make a joint decision as to which would contend if they were perfectly coordinating state. Yet explicitly coordinating state in a wireless network via a control message can significantly reduce throughput [2].

In this paper, we introduce Client-side Access Manipulation (CAM) as a mechanism that enables clients to dynamically adapt their channel access priority without explicitly coordinating state with the AP in order to realize an efficient uplink multi-user WLAN. In particular our contributions are as follows.

First, we design CAM based on the fundamental properties of distributed 802.11 wireless networks and the scheduling operation of TUA. We introduce a dynamic two-state client side channel access adaptation mechanism, in which clients can switch between two channel access states to manipulate the likelihood of a TUA transmission to be started. In the

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SU state, the goal is for the client to make *single-user* uplink transmissions, rather than waiting for AP triggers. In this state, clients more aggressively contend for the medium, and while this does not guarantee an SU transmission (as the AP does not know which state the client is in and may content for TUA), it weights access in favor of a client SU transmission. Moreover, while SU transmission does not realize spatial multiplexing gains, clients use this state because: 1) it believes the AP will not trigger it; and 2) SU transmissions provide a way to jump start MU by informing the AP of clients' buffer status, yet without an explicit control message, using reports piggybacked on data. In the *MU state*, the client reduces its aggressive accessing the channel in order to increase the chance that the AP will trigger it for (more desirable) *multi-user* uplink transmissions. Yet, because the client cannot ensure that it will be triggered by the AP, it still contends for the channel, albeit less aggressively. In CAM, the client *independently* determines its state to dynamically favor TUA or SU uplink access. This state selection is local to each entity of the network, and the AP does not have direct access to the state of any of its associated stations. We propose the usage of local information at clients to infer the likelihood of being triggered by the AP for MU uplink transmission. Namely, the buffer status reports that are sent by clients to assist the AP in the process of TUA resource allocation is a key indicator of AP selection likelihood. This way, clients can base the access state change on the previous transmissions of buffer status reports and their current backlog. Clients send a report with each uplink channel access, TUA or SU, thus the switch in access state happens with the same frequency. After each uplink transmission, a client selects the SU state if the reported buffer status is below or equal to a predefined threshold value, and selects the MU state if the reported buffer status is above that threshold.

Second, we implement CAM in an end-to-end experimental platform, along with an 802.11ax compliant implementation of the TUA access and buffer status reporting mechanisms. We study the throughput and latency performance of the wireless network and show that *(i)* across a large range of parameter selection the standard's access adaptation mechanism cause a decrease of end-to-end throughput for bursty traffic with a standard compliant reporting strategy when compared to the non-adaptive baseline. With the CAM algorithm, the aggregate throughput presents an increase of up to 15% when compared to the standard's mechanism, and 11% when compared to the non-adaptive baseline. Moreover, the latency profile of the standard adaptation system is shown to quickly increase with the AP priority factor, while CAM reduces the average latency by up to 65% and the standard deviation by a factor of 7.9 times. *(ii)* for bursty traffic, such as end-to-end TCP file transfers, the standard MU EDCA parameter set mechanism's performance is highly dependent on the buffer-status reporting. With the UIB implementation (discussed in section IV-B), in which the TUA selection does not depend on information sent by stations, the performance increases with the introduction of the adaptation mechanism. However, when the reports are necessary for the operation of TUA, our results show that the effect in performance of the stadard MU EDCA adaptation mechanism is the opposite.

II. BACKGROUND ON TUA

In this section we introduce the details of TUA and its related mechanisms in the IEEE 802.11 protocol.

A. *TUA and channel access in Wi-Fi*

The 802.11ax amendment introduced the AP trigger frame, a control frame used for the TUA channel access. The specific variant we discuss in this paper is the trigger frame to allocate resources for an uplink MU MIMO transmission. The trigger frame is a broadcast control frame and contains common and user-specific fields. Among the common fields, it informs stations about the expected response frame length and the bandwidth allocated for the response transmission, among other control parameters. The user specific fields provide individual details on each of the devices participating int he upcoming TUA transmission, including association ID, uplink MCS, number of spatial streams, and target RSSI.

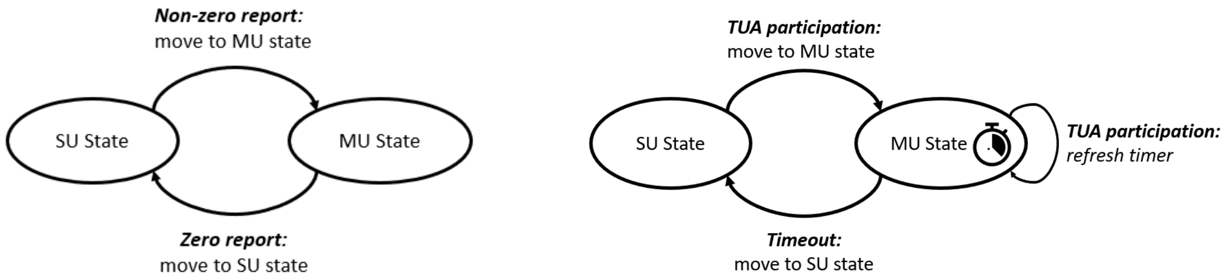
Since TUA is the only mechanism to initiate an uplink MU transmission in Wi-Fi, this significant uplink access mode depends on the AP selection of stations for efficient MU transmissions. For the distributed nature of the protocol, the AP does not have direct knowledge of which stations are backlogged or not at a certain time. Therefore, the potential gains that come from simultaneous multi-user transmissions via uplink MU MIMO and OFDMA depend on the coordination between stations to report the uplink buffer status.

B. *Buffer status and reporting*

Buffer status is defined as the number of data packets and backlog size that each client station has buffered in its queue for transmission. A station has direct access to its own buffer status at any time, but extra resources are required to acquire the information from other stations, generally via the exchange of control messages. This buffer status information is key for the AP to select and trigger clients for efficient TUA transmissions, since only stations with enough backlog should be selected. Because of that, the 802.11 standard contains mechanisms for clients to report their buffer status back to the AP. One reporting mechanism defined by the standard is to piggy-back a station's buffer status in uplink frame transmissions. This is called Unsolicited Buffer Status Report, which can be used by any client and involves the implicit report of buffer status in control fields of any uplink data (or null data) frame transmission (but not 802.11 ACK frames). This is a low overhead mechanism that only adds the negligible overhead of the Buffer Status Report field in each uplink frame transmission.

III. CHANNEL ACCESS PRIORITY ADAPTATION MECHANISM

This section presents in detail CAM, our proposed access priority adaptation mechanism for uplink MU-MIMO in WLANs. It also presents the channel access priority adaptation



(a) CAM

(b) MU EDCA Parameter Set

Fig. 1: The CAM and the Standard access adaptation algorithms represented in the two-state framework

mechanism from 802.11ax and discuss the role of channel access priority for the performance of MU uplink transmissions.

A. Two-state Framework for Channel Access Adaptation

The enhanced distributed channel access (EDCA) coordination function in 802.11 networks is a distributed function for channel access control. EDCA uses a random back-off time to avoid collision and coordinate the sequence in which simultaneously backlogged stations access the channel. With TUA, it would be beneficial to coordinate the sequence in which simultaneously backlogged stations access the uplink channel based on the AP's ability to trigger a MU-MIMO transmission. That is, if a station is likely to participate in a MU-MIMO TUA transmission, it should defer from contending aggressively for SU channel access, and allow the AP to win contention more often. However, explicitly coordinating states via control message exchange can disproportionately decrease throughput in a random access wireless network [2].

We propose that in contrast to such explicit coordination, the *clients* manipulate the AP's trigger likelihood by changing their own access behavior. We define a two-state framework, in which clients can switch between two targeted channel access behavior states, the *SU state* and the *MU state*. The *SU state* specifies a more aggressive contention for SU uplink channel access, whereas the *MU state* reduces the uplink contention access to allow the AP to win contention more often. In either access state, TUA and SU uplink transmissions may still happen, but the likelihood of each type of access is weighted in one possibility or the other. By default, clients start in the *SU state* and can switch between states to target more efficient operation as defined below.

To control the access behavior, clients modify their EDCA function parameters. The EDCA function is controlled by an AP defined base EDCA parameter set, which includes the contention window limits (CW_{min}, CW_{max}) for back-off counter selection and collision avoidance. The two-state framework for channel access adaptation modifies the EDCA parameter set values as a way to change the aggressiveness with which a client contends for channel access. For example, increasing the CW_{min} parameters at clients increases the AP priority to access the channel.

Furthermore, we define the downlink priority factor as the ratio between the MU EDCA CW_{min} parameter and the default CW_{min} used in the network. This parameter defines the reduction of uplink SU access, and the larger this value, the less likely stations are to win contention. Under this mechanism, access shifts from the distributed contention-based access scheme of EDCA to a centralized polling scheme in which the AP is responsible for allocating resources for uplink channel access.

B. Client-side Access Manipulation

The Client-side Access Manipulation (CAM) mechanism estimates the likelihood of a client being triggered for TUA using the buffer status reports. This information is local and is updated with each new uplink transmission, so that clients perform adaptation in a per transmission basis. The last report sent by a client is equivalent to the most recent AP information about that client's buffer. Therefore, in CAM, if the last report is non-zero, the client assumes that it is likely to be triggered for uplink MU-MIMO and switches to the *MU state*. Otherwise, the client assumes that it is unlikely to be triggered and switches to the *SU state*. Figure 1a depicts the CAM algorithm.

In each uplink channel access, a client takes the following steps: *(i)* Add the current buffer-status report to the uplink data frame being transmitted; *(ii)* Use the value of buffer-status being transmitted as a proxy to the likelihood of being selected by the AP for an uplink MU-MIMO transmission; *(iii)* Switch to the corresponding contention state. Each client defines its likelihood of being selected for TUA based on the buffer-status reported. If the most recent buffer-status report sent to the AP is non-zero, it moves to the MU state. Otherwise, the client moves to the SU state. This adaptation is made with the goal of favoring the more efficient uplink MU-MIMO, over SU uplink transmissions, when it is likely to invoked by the AP.

C. Standard MU EDCA parameter set adaptation

The 802.11ax amendment defines the MU EDCA parameter set as a set of access parameter values that a station uses in place of the default after being granted participation in a TUA uplink transmission. Its goal is to improve performance by reducing the less efficient uplink transmission mode of SU channel access. For this, the values for the MU EDCA set are typically higher than the default EDCA ones, to reduce the access probability of non-AP stations. The return from MU EDCA parameter set to the default one happens after a specified amount of time (also part of the MU EDCA Parameter Set) in which a station does not take part in an uplink TUA access. Figure 1b represents this adaptation mechanism in the two-state framework. In summary, the standard defined mechanism is a two state adaptation system where stations change their channel access probability based on participation in a TUA transmission and a timeout.

The MU EDCA parameter set mode defined by the standard has the implicit assumption that stations selected for TUA transmissions will be selected again in the near future. However, prior work indicates that selection for TUA can be dependent on multiple factors, such as traffic regime, buffer status reports, and even frame aggregation [3]. Because of that, it is expected that the timeout mechanism may create a situation of temporary starvation of uplink traffic for certain stations, where the uplink SU access probability is reduced by the MU EDCA parameter set mode and that station is not selected for uplink TUA transmissions.

IV. EXPERIMENTS AND RESULTS

This section presents the experimental platform and scenarios used for the experiments in the project, together with the results from our experiments.

A. Platform

We use the PERFORM WLAN emulator [4] as our testbed in this project. This end-to-end experimental platform supports full-stack network traffic from commercial devices, including Internet traffic or any arbitrary application. It also allows for flexible implementation of MAC policies and mechanism, including MU-MIMO, TUA, buffer status reports, and EDCA parameter adaptation.

B. Uplink reports and TUA selection strategies

In order to evaluate the variations of the MU EDCA channel access mechanism we compare each variation under two different TUA implementations. The first one, used as an ideal scenario for the access mechanism, provides the perfect instantaneous knowledge of uplink buffer status to the AP without any overhead, and is called Unimplementable Instantaneous Buffer-Status (UIB). This TUA selection strategy represents a scenario in which the AP has instantaneous access to the buffer status of all associated stations and can use this information for TUA selection, which is not practical since the AP does not have direct access to the information of which stations are backlog or not for TUA transmissions. In contrast, the second TUA selection strategy is based on uplink reports sent by client station alongside each uplink channel access. This strategy, called Standard Buffer-Status Reporting (SBR), includes the buffer status information is each uplink data transmission, incurring in small overhead, and provides the necessary information for the AP to make decisions on which stations to trigger for uplink TUA.

C. Traffic

The traffic for our experiments is generated in a controlled way by a TCP file transfer application running full network stacks in each client station. It uses the OS's native implementation of TCP (cubic), with all the default reliability mechanisms and congestion control algorithms and parameters. The traffic itself is a series of uploads and downloads of fixed size files, with independent start time in each station and load equally distributed among all clients. Each client downloads or uploads files, randomly selecting the direction of the transmissions for each file. The time interval between the end of a transmission and the beginning of the next one is drawn from a uniform distribution with fixed mean, equal for all stations.

D. Performance of the MU EDCA parameter set mechanism under closed-loop traffic dynamics

Research Question. The MU EDCA parameter set adaptation mechanism aims at increasing the link layer data rate by favoring uplink multi-user (MU) TUA over single-user (SU) access. This mechanism enables the dynamic control of access priority at non-AP stations based on TUA activity, but still maintains their ability to contend for SU channel access, supporting the necessary distributed nature of the protocol implementation. However, because the TUA mechanism depends on the buffer status information, reducing the access probability for SU also reduces the frequency of uplink reports and compromises the efficiency of the uplink MU access, in special for non-saturated, bursty traffic [3]. In this first experiment we evaluate the net effect of the access adaptation mechanism on end-to-end system performance in the form of aggregate throughput.

Experimental setup. To measure and compare the performance of the adaptation mechanism we run the following experiment. A single AP equipped with 8 antennas serves 32 single-antenna user stations employing an 802.11ax compliant protocol. The channel access adaptation mechanism uses the two-state model described in section III, with a timeout of 2 seconds and downlink priority factor varying from 3 to 100. Application traffic is generated independently in each of the user stations and a server, physically co-located with the AP. Each transmitted file has a random and equal probability of being a download or an upload, making it a 50/50 mix of downloads and uploads in each station. The file size is fixed to 300 kB and the application operates in saturation at the transport layer, without any time interval between the conclusion of a file transmission and the beginning of the following file at the application level. Note that due to the congestion control algorithm and other protocols of the communication stack it does not mean fully backlogged at the network layer.

Results. Figure 2 presents the throughput achieved by three variations of the system. The values plotted on the y-axis represent the end-to-end aggregate throughput measured at the application layer, as a result of the operation of the entire

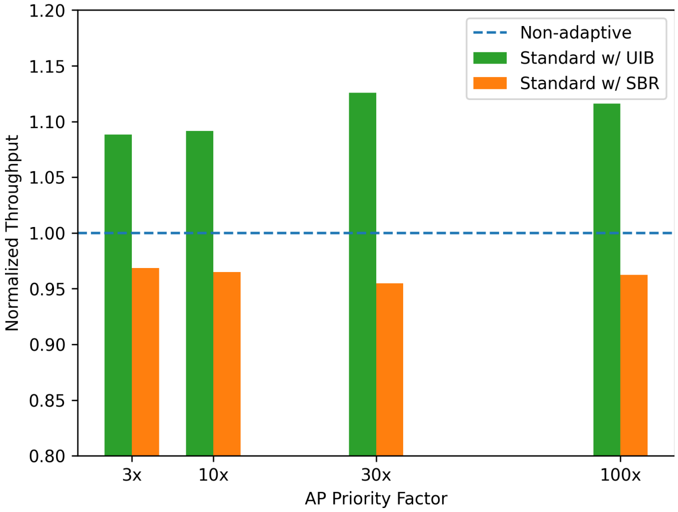


Fig. 2: Normalized throughput versus CW_{min} increase factor for SBR and UIB

communication stack, including the Wi-Fi channel access mechanism.

First, the fixed CW_{min} non-adaptive baseline (blue line) that does not use the access adaptation mechanism is used as a baseline value for the evaluation. The dashed line at normalized throughput of 1 represents the performance of the system when stations continue to contend for uplink access with default access parameters. A characteristic of this implementation is that non-AP stations win contention and transmit in uplink SU access mode at times when it would be more efficient for the AP to trigger uplink TUA. As a result, a portion of the channel time is used by this less efficient access type, which was the reason for creating the MU EDCA parameter set access adaptation mechanism.

Second, the introduction of the two-state adaptation mechanism with the UIB uplink (green) leads to an increase in normalized throughput across all values of MU CW_{min} increase factor. The gains varying between 9% and 13% when compared to the fixed CW_{min} baseline, with a peak at the intermediate value of 30x, after which it falls slightly when the MU CW_{min} increase factor is larger. This result represents an increase in aggregate throughput by shifting SU uplink access to MU TUA transmissions, where multiple users are served simultaneously by the AP. Even though this shift is combined with the increased latency for uplink SU transmissions, the net effect leads to the resultant gains in aggregate throughput. The relationship between these two effects explain the drop in performance for large values of MU CW_{min} increase factor.

Finally, the orange bars shows the performance of the two-state adaptation mechanism with SBR uplink (orange), where the only source of backlog information used by the AP to select users for TUA are the implicit reports sent with each uplink channel access. Because the operation of TUA with SBR depends on the single-user uplink access we see a sharp decrease in performance with the introduction of this enhancement mechanism, contrary to the intended effect. The resultant normalized throughput is between 95% and 97% of the non-adaptive baseline, a small decrease of when compared to the results without adaptation.

Findings. For bursty traffic, such as end-to-end TCP file transfers, the standard MU EDCA parameter set access adaptation mechanism for TUA can decrease throughput compared to the baseline system without any adaptation. The interplay between traffic dynamics, buffer reporting mechanism, and access priority adaptation is responsible for this effect, and it can only be observed with all three elements interacting. However, because TCP is one of the main protocols of the Internet protocol suite, one can expect that such scenarios will occur in practice.

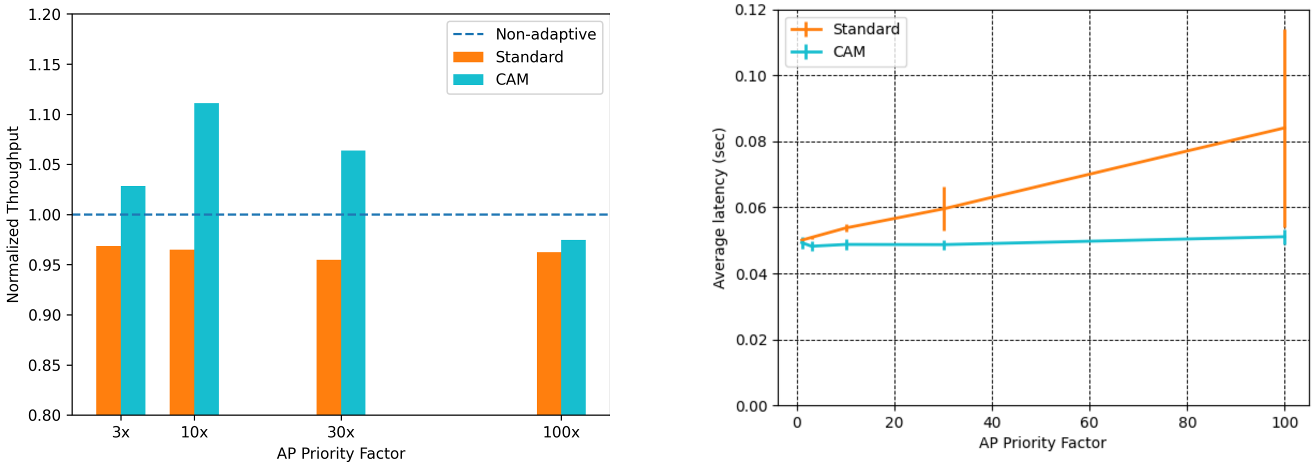
E. Client-driven quick adaptation

Research Question. The standard mechanism to reduce SU uplink access fails to achieve gains because the switch between EDCA parameters is done by a timeout mechanism, without regards to the direct AP ability to trigger TUA or not. In section III-B we describe the CAM client-driven enhancement that allows a station to go back to the default EDCA parameters once it infers that the AP is unlikely to use TUA to trigger them for a MU transmission, based on current buffer status and previous reports to the AP. In this experiment we evaluate the performance of the Wi-Fi system with the SBR uplink implementation and the two versions of the mechanism to dynamically adapt the channel access priority: the standard-defined AP-driven version, and our proposed CAM adaptation mechanism.

Experimental setup. Similarly to the first experiment, we emulate a multi-antenna AP serving 32 active clients simultaneously. The main difference is that we omit the non-implementable UIB uplink and only compare the results for the SBR implementation. We measure the achieved throughput and average latency per file for the two variations of the channel access adaptation mechanism, standard and CAM. The results are normalized by the non-adaptive baseline which also uses the SBR uplink implementation.

Results. Figure 3 show the aggregate throughput and file transfer latency achieved with each of the two mechanisms.

In figure 3a we can observe the gap between standard's AP-driven adaptation mechanism and the proposed Client-driven modification. The Client-driven achieves higher throughput across all range of MU CW_{min} analyzed, with gains up to 11% at the MU CW_{min} increase factor of 10x. That can explained because the client-driven version maintains the gains of favoring multi-user uplink over SU channel access for stations that were recently selected for TUA transmissions and avoids the situation where a station cannot be selected for TUA and has to wait for the timeout to go back to the default EDCA parameter set. Moreover, while the AP-driven version incurs throughput reductions compared to the baseline as discussed in the previous experiment, the Client-driven modification instead realizes throughput gains unless the downlink priotity factor is set too large, viz., to 100x. For



(a) Normalized throughput

(b) Per-file latency variation

Fig. 3: Performance versus CW_{min} increase factor for AP and client driven strategies with SBR.

small and moderate increase factors CAM shows gains when compared to the baseline, with the best performance at the 10x factor. In this case, the relative gains are close to the best scenario of the UIB uplink shown in the previous experiment. gains observed with the unimplementable UIB uplink in the previous experiment, which achieved . Finally, performance still depends on reports and AP likelihood of triggering an uplink TUA transmission in the system, and thus gains are limited when compared to the unrealistic implementation from previous experiment and related work with fully saturated traffic. Even though the absolute gains are modest for the scenarios evaluated, where the access parameters were tuned to the best values for the number of active stations and traffic regimes, the switch in behavior is consistent and can display larger gaps in scenarios where the default parameters are not optimized for the dynamic scenarios.

While the throughput results show important but modest changes with the CAM adaptation, the per-file latency changes are more significant.

Figure 3b shows the file transfer latency as the AP priority factor changes. The two curves indicate the average time to transfer each fixed-size file across the network and the vertical bars indicate the standard deviation. First, the AP-driven mechanism yields an end-to-end latency that increases with the CW_{min} factor. In other words, the more priority that is given to the TUA channel access, the larger the file transfer latency. When the CW_{min} increase factor goes from 1x to 100x, the average latency increases from 50 ms to 84 ms. Additionally, and more striking, the standard deviation also increases with the MU CW_{min}. Within the same range change, the standard deviation increases from 16 ms to 135 ms, an increase of 744%. Both changes can be explained by the way the AP-driven mechanism works. With the timeout based return to default CW_{min} parameter, while some file transmissions go well, with latency close to the non-adaptive baseline when the mechanism is off, other file transmissions face the situation where the latancy for uplink SU access is increased due to large values of CW_{min} and TUA is unlikely to be triggered by the AP due to lack of buffer reports. This way, the latency on the later files is highly increased, thus increasing both the average and standard deviation.

Second, the Client-driven mechanism shows that it is capable of avoiding the uplink slow-down problem when the reports are unavailable for TUA triggereing by the AP. With the change in the downlink priority factor, the average per-file latency with this version of the mechanism remains relatively constant, with similar result for the standard deviation. This result shows that the end-to-end latency remains close to the non-adaptive baseline for most of the files transmitted in the network, without the significant number of outliers that the standard version of the mechanism presents.

Findings. The client-driven modification to the access control mechanism in TUA improves the performance of the end-to-end network when standard compliant buffer status reports are used, changing from a performance loss to a gain scenario. Moreover, this CAM modification dramatically reduces the standard deviation of the file transfer time, reducing the average time to transmit a file by up to 65% when compared to the standard MU EDCA parameter set adaptation, and reducing the standard deviation by a factor of 7.9 times.

V. RELATED WORK

Contention Window Control in IEEE 802.11 WLANs. Prior work extensively investigated the impact of contention window control mechanisms in Wi-Fi networks [5–7]. From deterministic window, to optimization schemes, to dynamically adaptive backoff algorithms, much was proposed to improve channel access in Wi-Fi. This work focus on the analysis of the 802.11ax standard defined mechanism to adapt access priority for purposes of multi-user access and is the first to experimentally evaluate the MU EDCA access mode combined with a standard implementation of TUA with MU-MIMO and buffer status reports.

Channel access in 11ax. A large body of prior work focus on OFDMA performance and the optional non-orthogonal multiple access (NOMA) mechanism [8–11] and includes analytical modeling and simulation studies However, most analyses are limited to SISO transmissions and ignore the MU EDCA channel access mechanism. In contrast, this work focuses on TUA operation in 11ax combined with MU-MIMO transmissions and the performance of the MU EDCA channel access mode under realistic scenarios.

MU EDCA channel access mode. Prior work analyzed the performance of the MU EDCA channel access mode for OFDMA operation in 11ax [12, 13]. The authors show that the standard adaptation mechanism can improve throughput with fully backlogged traffic and reduce latency in a variety of traffic scenarios. Prior work also proposed the use of MU EDCA channel access combined with multi-AP coordinated OFDMA from the next generation 11be to create a transmission scheme that shifts the channel access from random access to AP controlled access [14]. In contrast, this work studies a different application scenario of the mechanism, and is the first to analyze the MU EDCA channel access mechanism for MU-MIMO uplink access in 11ax combined with realistic buffer status reporting strategies and traffic from real applications.

VI. CONCLUSIONS

In this paper we experimentally evaluated the MU EDCA parameter set for channel access priority adaptation in the IEEE 802.11 standard. We find that in a scenario with bursty traffic and a reports-based operation of TUA, the throughput and latency performance of the WLAN with the addition of the mechanism decreases compared to the fixed CW_{min} baseline. Moreover, we propose CAM, a client-side access manipulation, and show that in the same scenarios our mechanism provides gains in throughput and significant reduction of end-to-end latency.

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