On the Harmonization of Channel Access Policies for High Priority EDCA: **Balancing the Tail Time Latency of STAs during High-Priority EDCA Periods**

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Introduction

- Lowering the tail-time latency of STAs competing for channel access through EDCA has been addressed in several contributions [11-24/1918][11-24/1144][11-24/0864]

- High-Priority (HiP) EDCA mechanism [11-24/1918][11-24/1144]
  - Allows STAs with LL traffic to send Defer Signal (DS) frame after a certain number of retries
  - These STAs can compete for channel access AIFS[AC] after the end of the DS frame
  - STAs that receive at least the preamble of a DS frame will refrain from contention for EIFS
  - STAs that receive the DS frame will refrain from contention for NAV

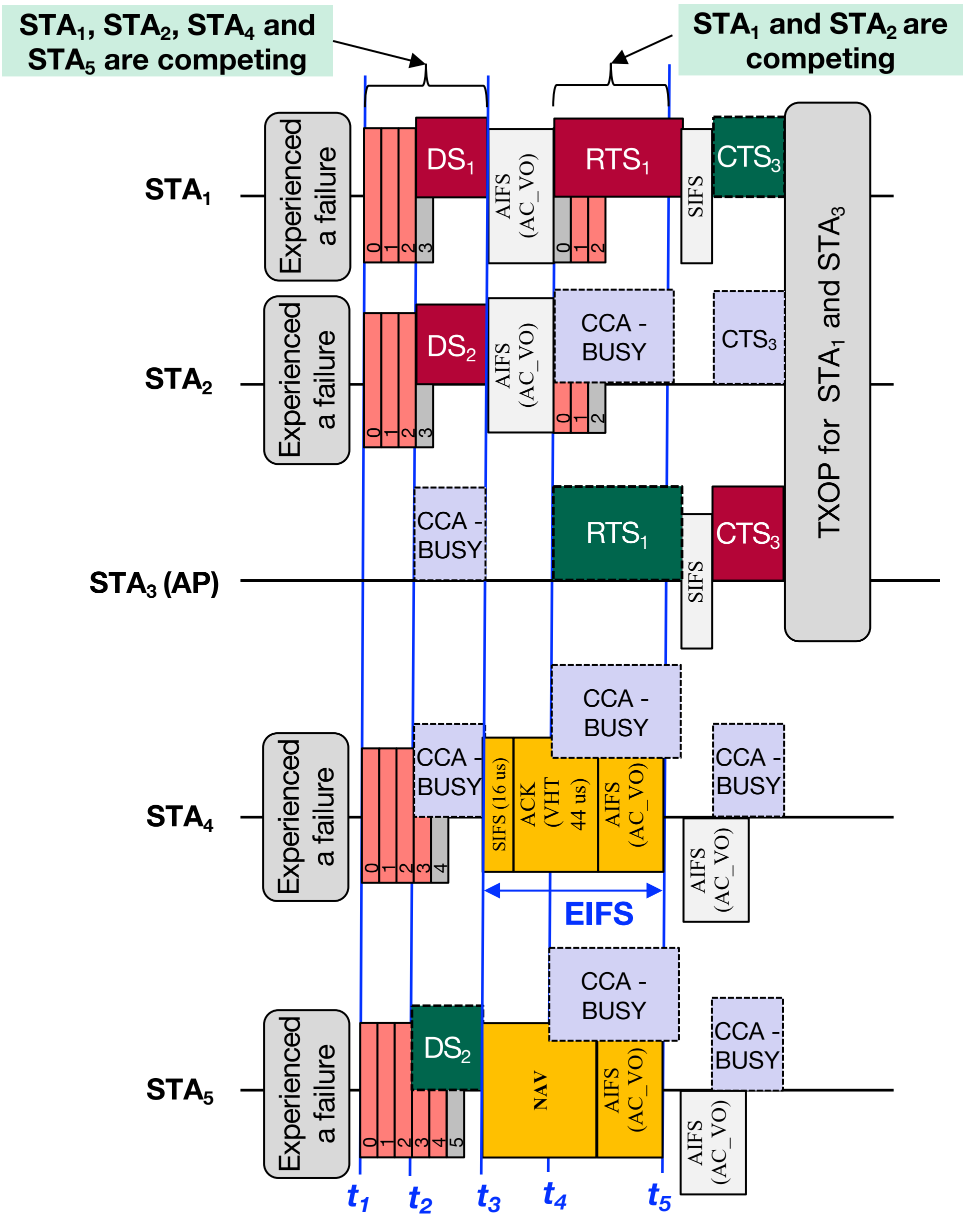
- In this contribution, **we focus on the unfairness problem caused by the difference in the received signal quality (strength) from non-AP STAs at the AP and propose solutions to balance the tail time latency of these STAs**
- **We propose methods where STAs switch to sending a DS frame based on factors such as the signal quality received at the AP**

Overview of the HiP EDCA

[11-24/1918][11-24/1144]

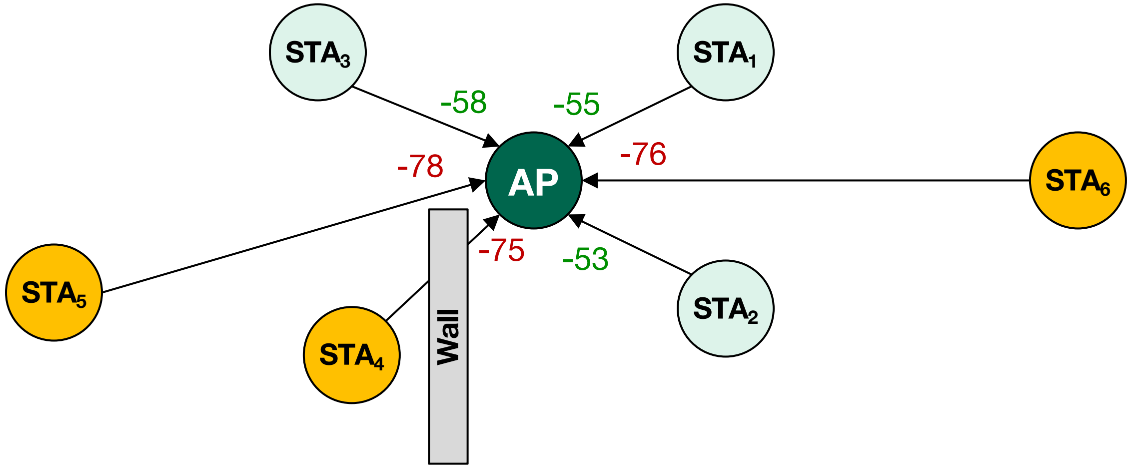
- STA_1, STA_2, STA_4 and STA_5 have LL (AC_VO) traffic to send to the AP (STA_3)
- All these STAs have experienced a certain number of failures (e.g., one or more)
- **All STAs are eligible to send DS frame**
- STA_1 and STA_2 select earlier timeslot (#3) and send DS frames
- We assume STA_4 receives the preamble of DS_2 frame sent by STA_2: **Sets EIFS**
    - 94 microsecond assuming non-HT PHY parameters
- We assume STA_5 receives the entire DS_2 frame sent by STA_2: **Sets NAV**

- **In the contention round starting at t_4, only STA_1 and STA_2 compete**
    - **STA_1 wins the channel**



The Unfairness Problem and Tail Time Latency

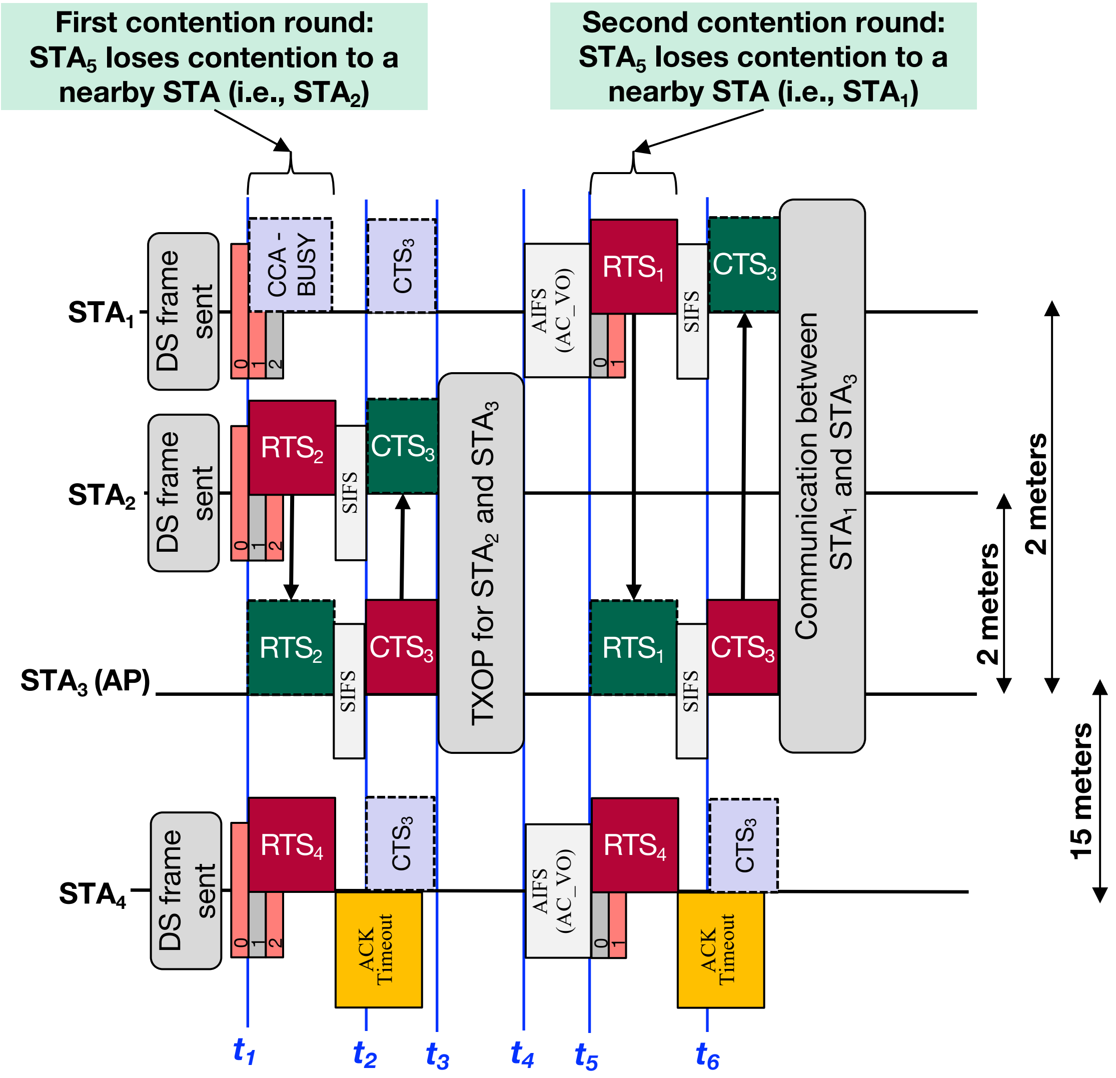
- **When a LL STA_X competes with LL STAs whose received signal quality at the AP is higher, STA_X keeps losing the channel contention to those STAs during P-EDCA periods**
  - This occurs due to the capture effect, which results in receiving a frame from the STA with higher signal quality, even in the presence of interference from other STAs
  - For example, the greater the number of LL STAs that are closer to the AP than STA_X, the higher the probability that STA_X will lose the contention



- **STA_4, STA_5, and STA_6 are at a disadvantage when competing with STA_1, STA_2, and STA_3**
- The numerical values represent the RSSI received by the AP from each STA

❑ The Unfairness Problem

- STA_1, STA_2 and STA_4 compete after sending DS
- **STA_1 and STA_2 are located 2 meters from STA_3 (AP), while STA_4 is 15 meters away from the AP**
- **First contention round:** STA_2 and STA_4 both select timeslot #1 and transmit RTS frames simultaneously at time t_1
  - Since STA_2 is closer to the AP, the AP successfully receives the RTS frame sent by STA_2 (i.e., RTS_2)
- **Second contention round *B***: STA_1 and STA_4 select timeslot #0 and transmit RTS frames simultaneously
  - The AP successfully receives the RTS frame sent by STA_1 because it is closer than STA_4
- Note: The first and second contention rounds may not be consecutive



Observing the Unfairness Problem through Simulation

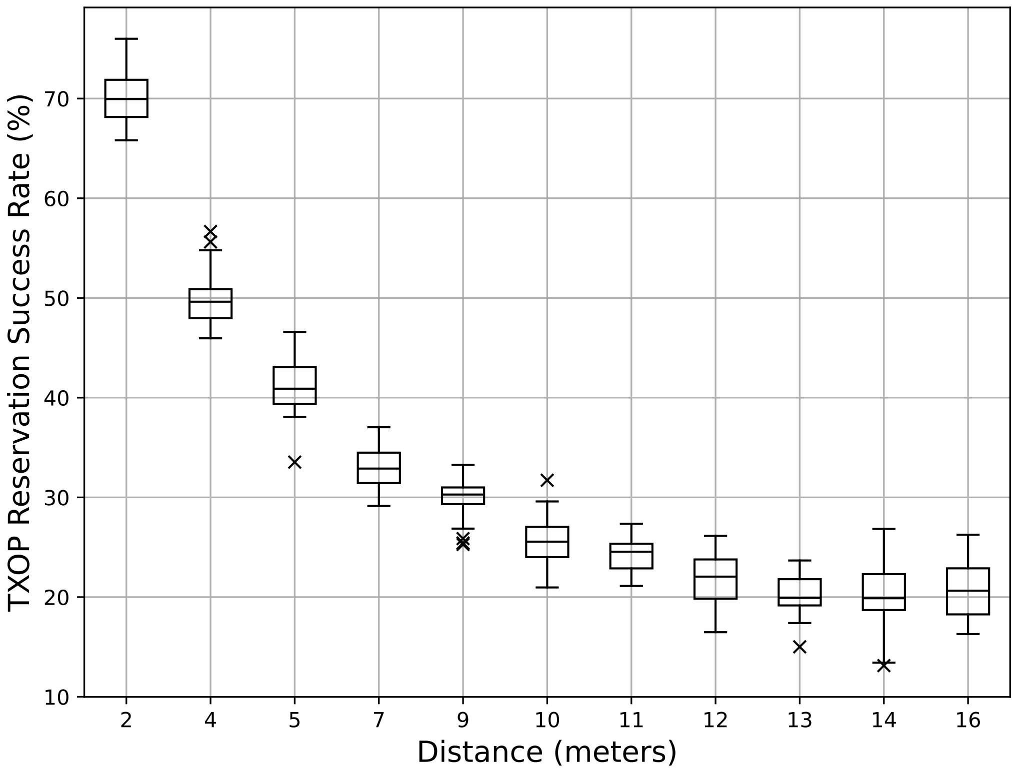
- Simulation parameters: 1 BSS, 40 STAs uniformly distributed, 80% of STAs send AC_BE (constantly), and 20% of STAs send AC_VO traffic (~1 Mbps)

TXOP reservation success rate versus distance

- A TXOP reservation is successfully reserved when the RTS sent by the STA is received and acknowledged by the AP
- If no response (CTS) is received, the STA needs to compete for channel access again

- **Observation: The TXOP reservation success rate decreases as the signal quality received at the AP deteriorates**

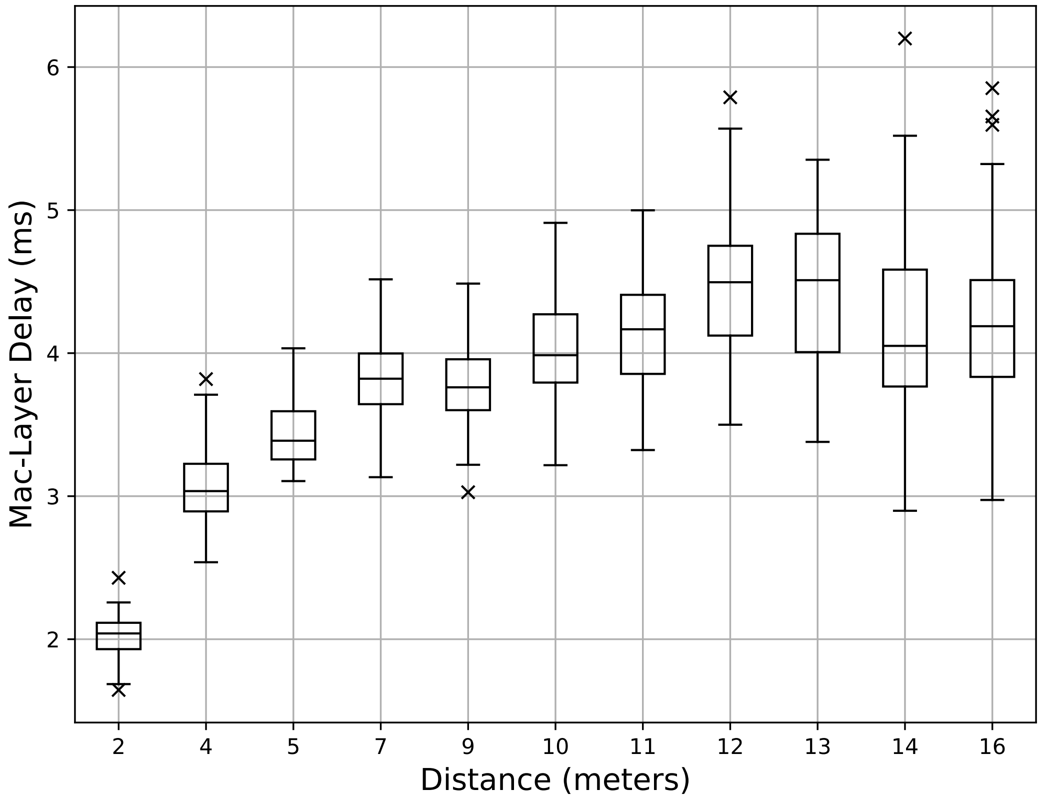
- Note: Experiment repeated multiple times to place the 20% of AC_VO STAs at various distances



❑ Observing the Unfairness Problem through Simulation

Latency

- Measured as the time between the arrival of a frame in the MAC layer of a non-AP STA (AC_VO) until successful delivery to the AP
- **Observation: Latency increases as the signal quality received at the AP deteriorates**



Switching between Response-Soliciting and Non-Response-Soliciting Frames

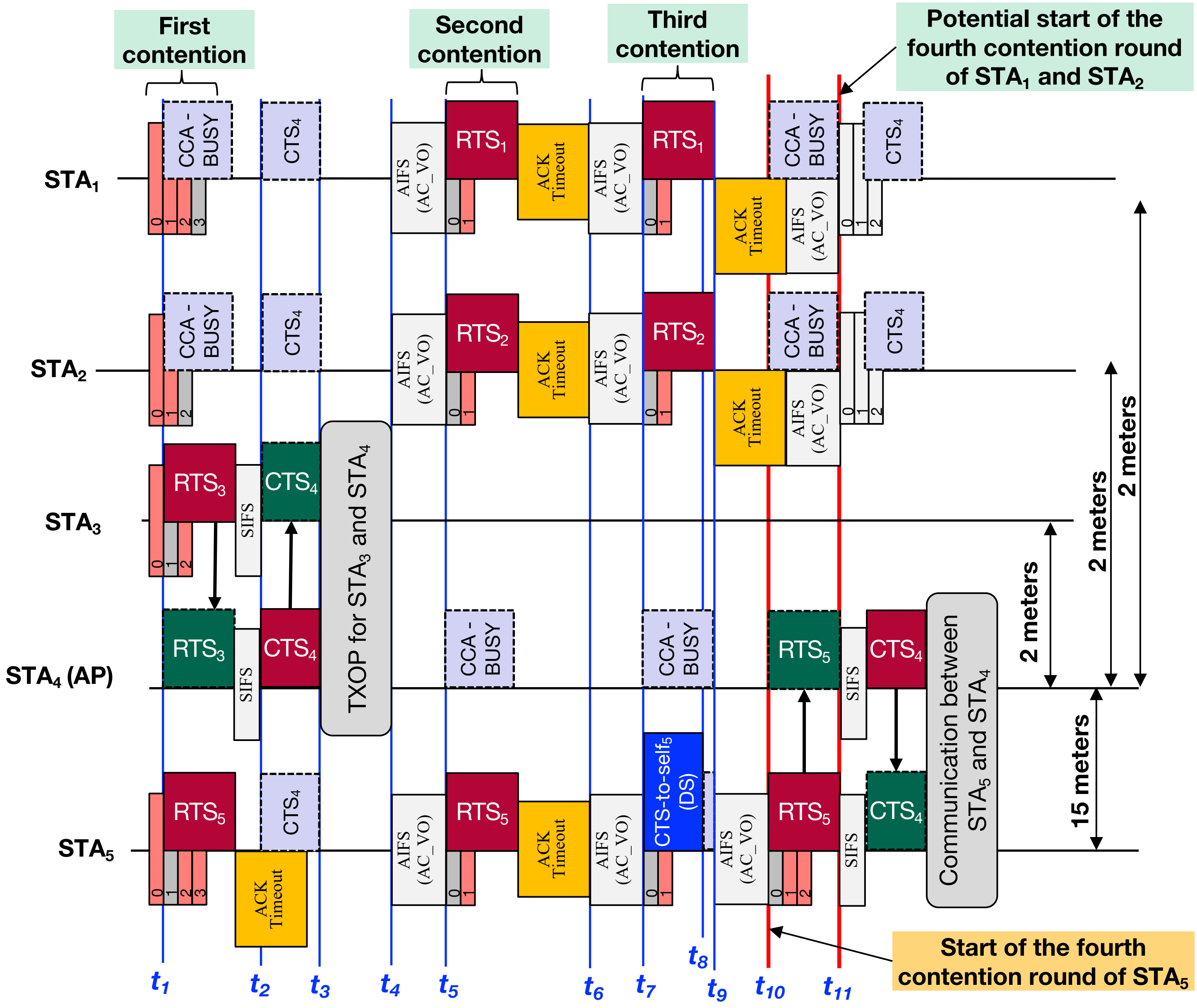
- In this contribution, we strive to provide the STAs with a signal-quality-aware channel access probability and balance the tail time latency of all STAs

- We propose that, during EDCA periods, **STAs switch from sending response-soliciting frames (e.g., RTS, data frames) to non-response-soliciting frames (e.g., DS/CTS-to-self) based on different metrics**
    - e.g., **Received RSSI from/by AP**

- **Justification: A STA sending a non-response-soliciting frame can compete for channel access before the STAs sending response-soliciting frames**
    - A STA sending a non-response-soliciting frame may compete for channel access after **AIFS[AC]** after the end of the frame
    - In contrast, a STA sending a response-soliciting frame must wait for **ACK Timeout + AIFS[AC]** before competing for channel access

❑ Proposed Solution

- STA_5, which is located 15 meters from the AP, is competing with STA_1, STA_2 and STA_3, which are located 2 meters from the AP
- **First contention:** STA_1 loses the first contention round to STA_3
- **Second contention:** No STA succeeds
- **Third contention:** STA_1 switches to sending DS frame (CTS-to-self), while STA_1 and STA_2 use RTS
- **The fourth contention round of STA_5 is earlier than that of STA_1 and STA_2**
  - STA_5 wins the channel and reserves a TXOP successfully



Switching Criteria

- The criteria for switching between sending response-soliciting and non-response-soliciting frames can be determined in various ways

- **Sample method**
  - The AP announces the range of RSSI values that are eligible for sending non-response-soliciting frames
  - In addition, the AP may announce probabilities or priorities for each RSSI range

Eligible RSSI	#retries	Switching probability	Eligible RSSI	#retries	Switching probability
-50 to -69	2	0.4	-70 to -79	2	0.6

The AP allows STAs with RSSI between -60 to -69 dBm to switch to sending non-response-soliciting frames for 40% of contention rounds after experiencing 2 failures

The AP allows STAs with RSSI between -70 to -70 dBm to switch to sending non-response-soliciting frames for 60% of contention rounds after experiencing 1 failures

Switching Criteria

- **Sample method**
  - The AP announces the RSSI distribution of LL STAs
  - Based on this information, non-AP STAs decide about the criteria, such as the number of failed transmissions (i.e., channel access retries), before switching to non-response-soliciting frames

RSSI	#STAs	RSSI	#STAs	RSSI	#STAs
-50 to -59	4	-60 to -69	3	-70 to -79	2

Summary

- **When STAs whose received signal quality at the AP is different, the STAs with higher signal quality have a higher chance of capturing the channel and succeeding during EDCA periods**
    - This results in longer tail time latency of STAs whose signal quality at the AP is lower

- **To balance the tail time of STAs, in this contribution, we proposed to use different criteria for switching between response-soliciting and non-response-soliciting frames**
- For example, STAs that are further from the AP or located behind obstacles may switch to sending a Defer Signal (DS) frame after two failures, whereas STAs closer to the AP may switch to sending a Defer Signal (DS) frame after three failures

Straw Poll

- Do you agree that the signal quality (e.g., RSSI) between the AP and non-AP STAs should be considered when determining the switching criteria between response-soliciting (e.g., RTS) and non-response-soliciting (e.g., Defer Signal/CTS-to-Self) frames during high-priority EDCA periods?

YES/NO/ABSTAIN

Appendix

Clarification of the Unfairness Problem

- The unfairness problem is not limited to P-EDCA periods alone
  - In general, this issue can occur during any EDCA period, regardless of the Access Category (AC) of the STAs
- **However, since the primary goal of P-EDCA is to reduce tail latency for all low-latency (LL) STAs, it is essential to balance tail latency across all STAs, irrespective of their signal quality received at the AP**

- Using Transmission Power Control (TPC) is a potential solution
  - However, the use of TPC complicates the solution landscape due to various constraints and considerations, including OBSS Packet Detection (PD), Spatial Reuse (SR), and Dynamic Frequency Selection (DFS)
  - For example:
    - Increasing power for distant STAs can lead to inter-BSS interference, reducing spectral efficiency.
    - TPC must comply with DFS requirements—reducing power may impair radar detection reliability, while increasing power could result in regulatory violations.