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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Authors:

Name	Affiliations	Address	Phone	email
Behnam Dezfouli	Nokia	520 Almanor, Sunnyvale, California		behnam.dezfouli@nokia.com
Davis Robertson				
Klaus Doppler				
Salvatore Talarico				
Kerstin Johnsson				
Mikhail Liubogoshchev				
Prabodh Varshney				

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]

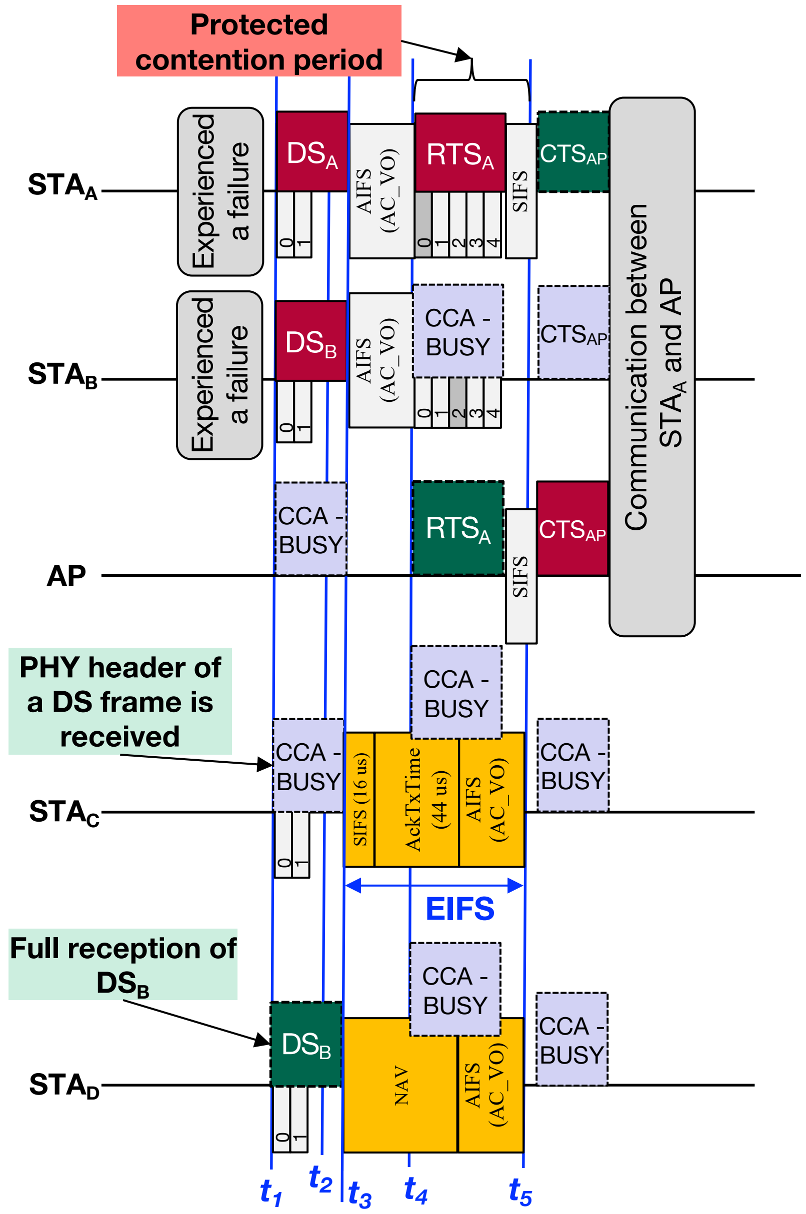
- High-Priority (HiP) EDCA mechanism [11-24/1918][11-24/1144]
  - Allows STAs with LL traffic to send Defer Signal (DS) frame after a certain number of failures
  - These STAs can compete for channel access AIFS[AC] after the end of the DS frame
  - STAs that receive at least the preamble of a DS frame will refrain from contention for EIFS duration; 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 from non-AP STAs at the AP and propose solutions to balance the tail time latency of LL STAs**
- We propose to **consider factors such as the signal quality between non-AP STAs and the AP to determine HiP EDCA parameters**

Overview of HiP EDCA

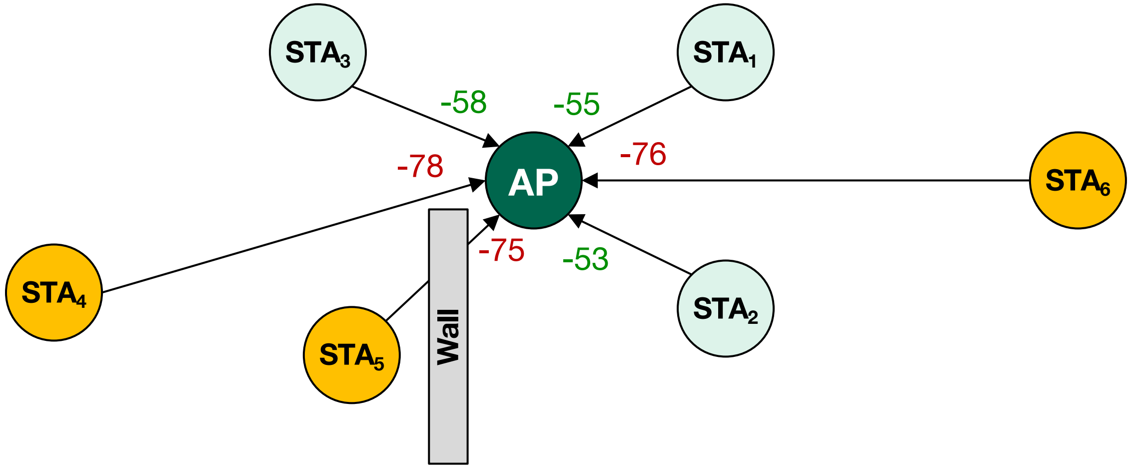
- STA_A, STA_B, STA_C and STA_D have LL (AC_VO) traffic to send to the AP
- STA_A and STA_B have experienced failures; therefore, these STAs **are eligible to send DS frame**
- **STA_A and STA_B send DS frames to announce protected contention periods**
- We assume STA_C receives the preamble of DS_B frame sent by STA_B: **Sets EIFS**
  - 94 microsecond, assuming non-HT PHY parameters
- We assume STA_D receives the entire DS_B frame sent by STA_B: **Sets NAV**

- **In the contention round starting at t_4, only STA_A and STA_B compete**
  - **STA_A wins the channel**



The Unfairness Problem and Tail Time Latency

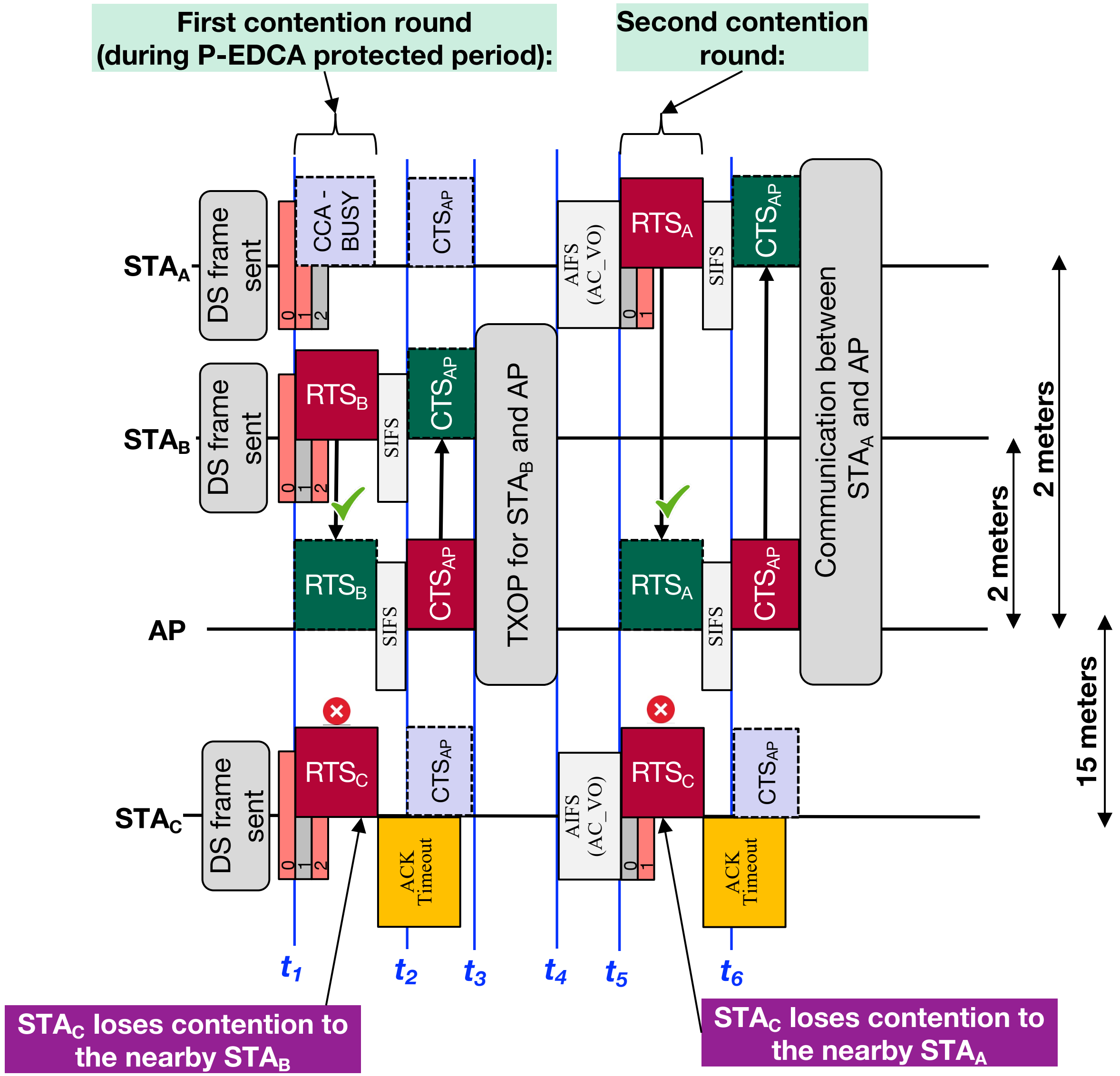
- **When a LL STA_X competes with LL STAs whose received signal quality at the AP is higher, STA_X keeps losing the channel contention to those STAs during P-EDCA periods**
  - This occurs due to the capture effect, which results in receiving a frame from the STA with higher signal quality, even in the presence of interference from other STAs
  - For example, the greater the number of LL STAs whose RSSI is higher than that of 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_A, STA_B and STA_C compete after sending DS
- **STA_A and STA_B are located 2 meters from AP, while STA_C is 15 meters away from the AP**
- **First contention round:** STA_B and STA_C both select timeslot #1 and transmit RTS frames simultaneously at time t_1
  - Since STA_B is closer to the AP, the AP successfully receives RTS_B
- **Second contention round**: STA_A and STA_C select timeslot #0 and transmit RTS frames simultaneously
  - The AP successfully receives the RTS frame sent by STA_A because it is closer than STA_C
- Note: The first and second contention rounds may not be consecutive



Observing the Unfairness Problem through Simulation

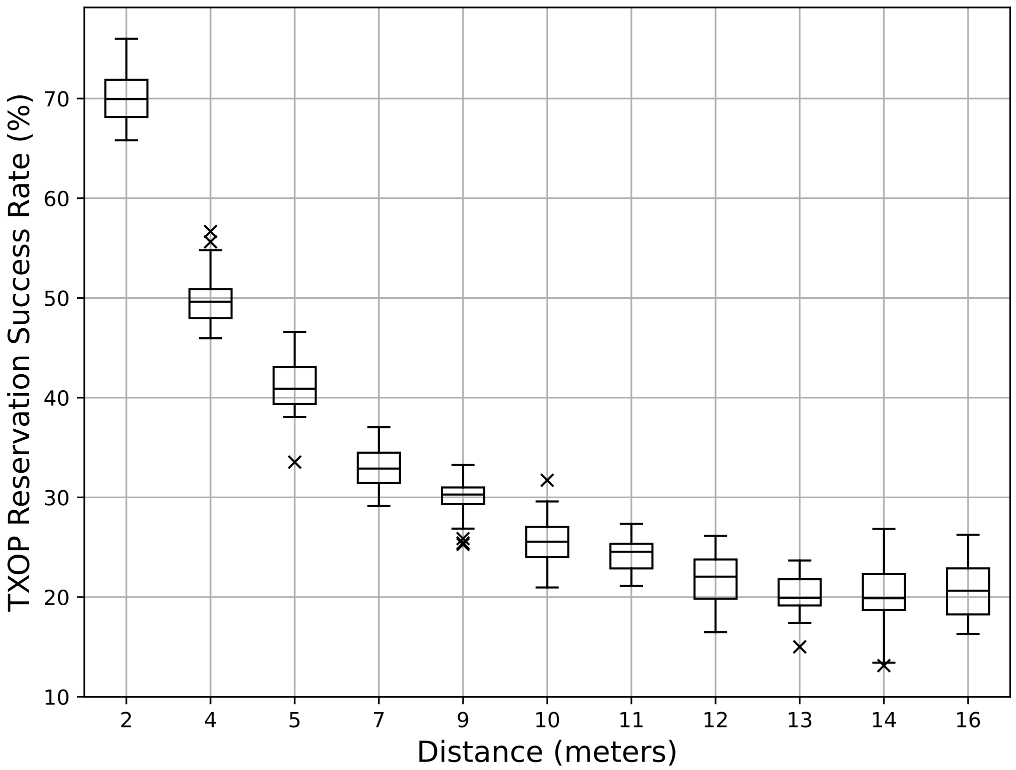
- Simulation parameters: 1 BSS, 40 STAs uniformly distributed, 80% of STAs send AC_BE (constantly), and 20% of STAs send AC_VO traffic (~1 Mbps)

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**

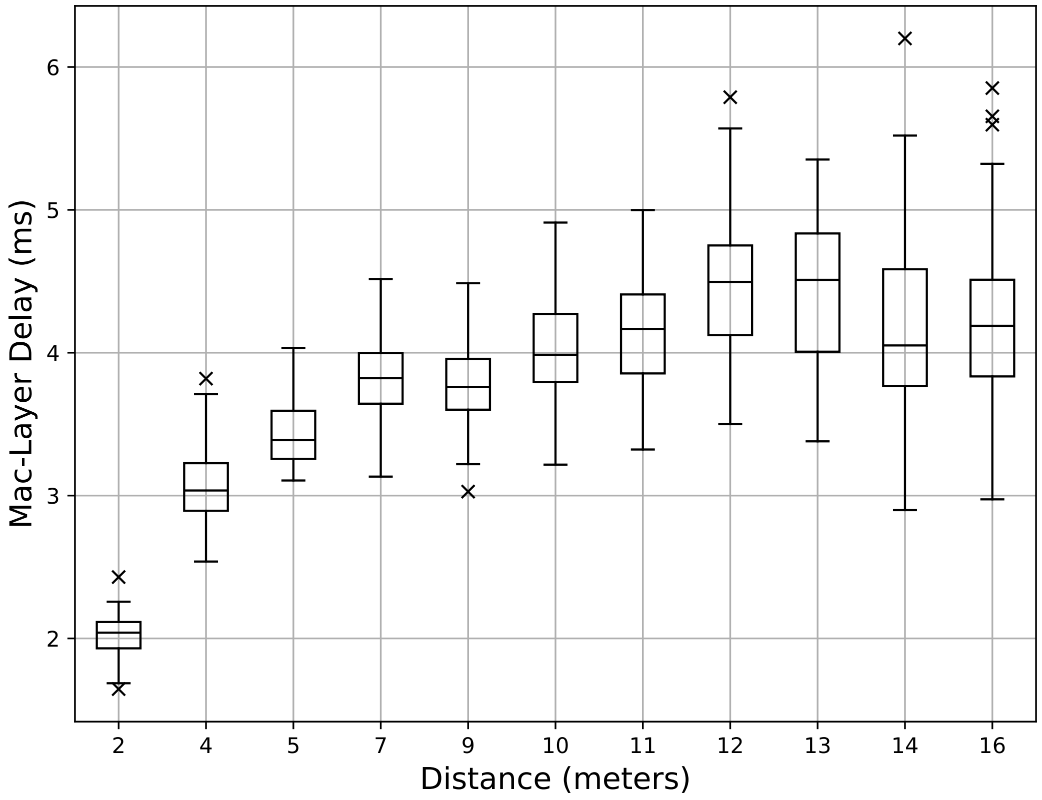
- Note: Experiment repeated multiple times to place the 20% of AC_VO STAs at various distances



❑ 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

- While this is a well-known problem, the use of P-EDCA provides an easy approach to address this problem (e.g., compared to transmission power control)

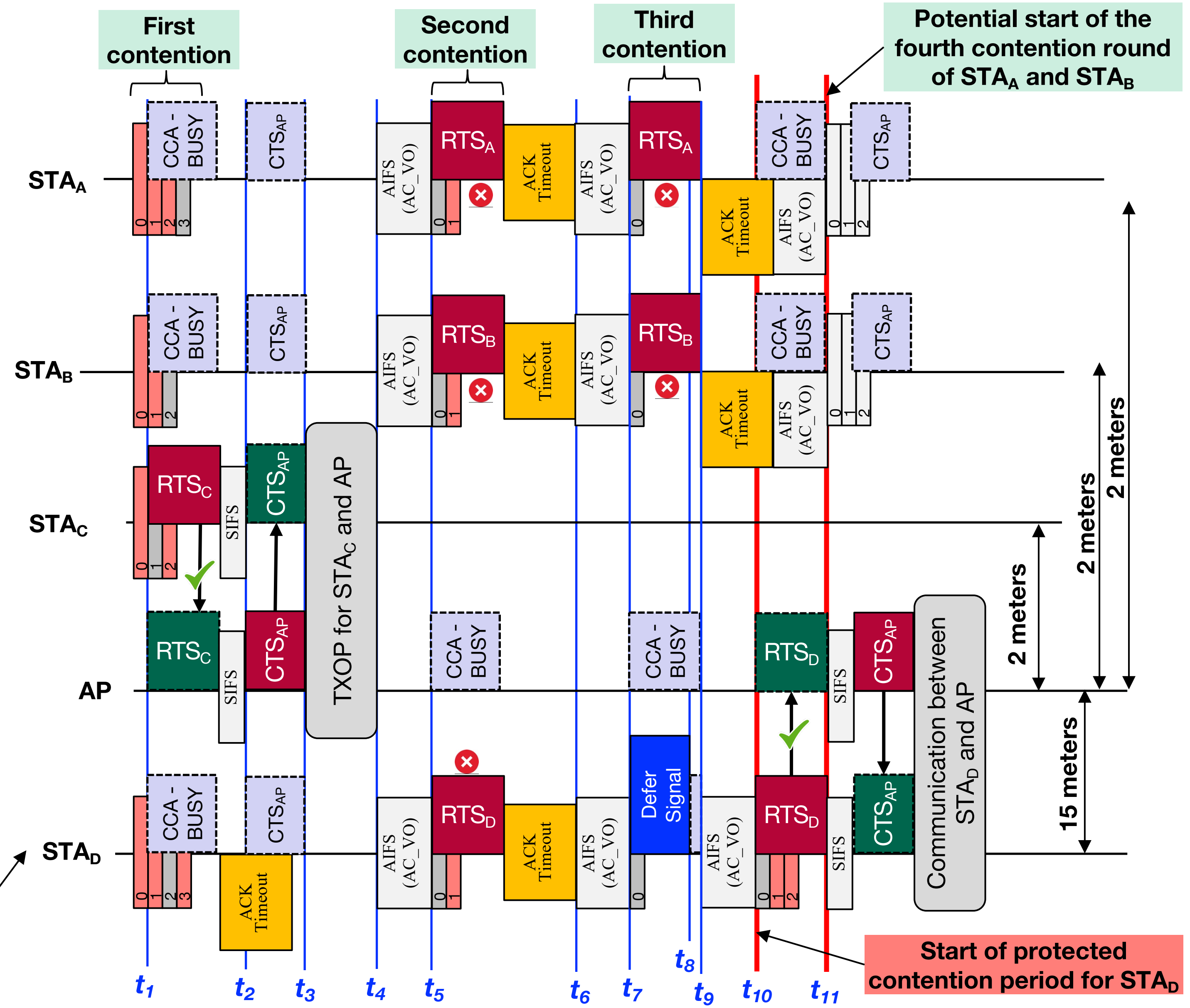
- In this contribution, we aim to provide LL STAs with signal-quality-aware channel access parameters and to balance the tail latency across all LL STAs

- HiP EDCA does not balance the tail time of all LL STAs
- **We propose that the configuration of P-EDCA parameters should take into account the RSSI of LL STAs**
  - e.g., **switching criteria from EDCA to P-EDCA** (#failures), **number of consecutive DS frames**, etc.

- Justification: A STA sending a non-response-soliciting frame (DS 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_D, which is located 15 meters from the AP, is competing with STA_A, STA_B and STA_C, which are located 2 meters from the AP
- **First contention:** STA_C captures the channel
- **Second contention:** No STA succeeds
- **Third contention:** STA_D switches to sending DS frame (CTS-to-self), while STA_A and STA_B use RTS
- **The fourth contention round of STA_D is earlier than that of STA_A and STA_B**
    - STA_D wins the channel and reserves a TXOP successfully



Switching Criteria

- The operational parameters of P-EDCA can be determined in various ways

- **Sample method**
  - The AP announces P-EDCA parameters based on RSSI values

Eligible RSSI	#failures	Consecutive DS frames	Eligible RSSI	#failures	Consecutive DS frames
-50 to -69	2	1	-70 to -79	1	2

The AP allows STAs with RSSI between -50 to -69 dBm to:
- Switch to sending DS frames after experiencing 2 failures
- The number of allowed consecutive DS frames is 1

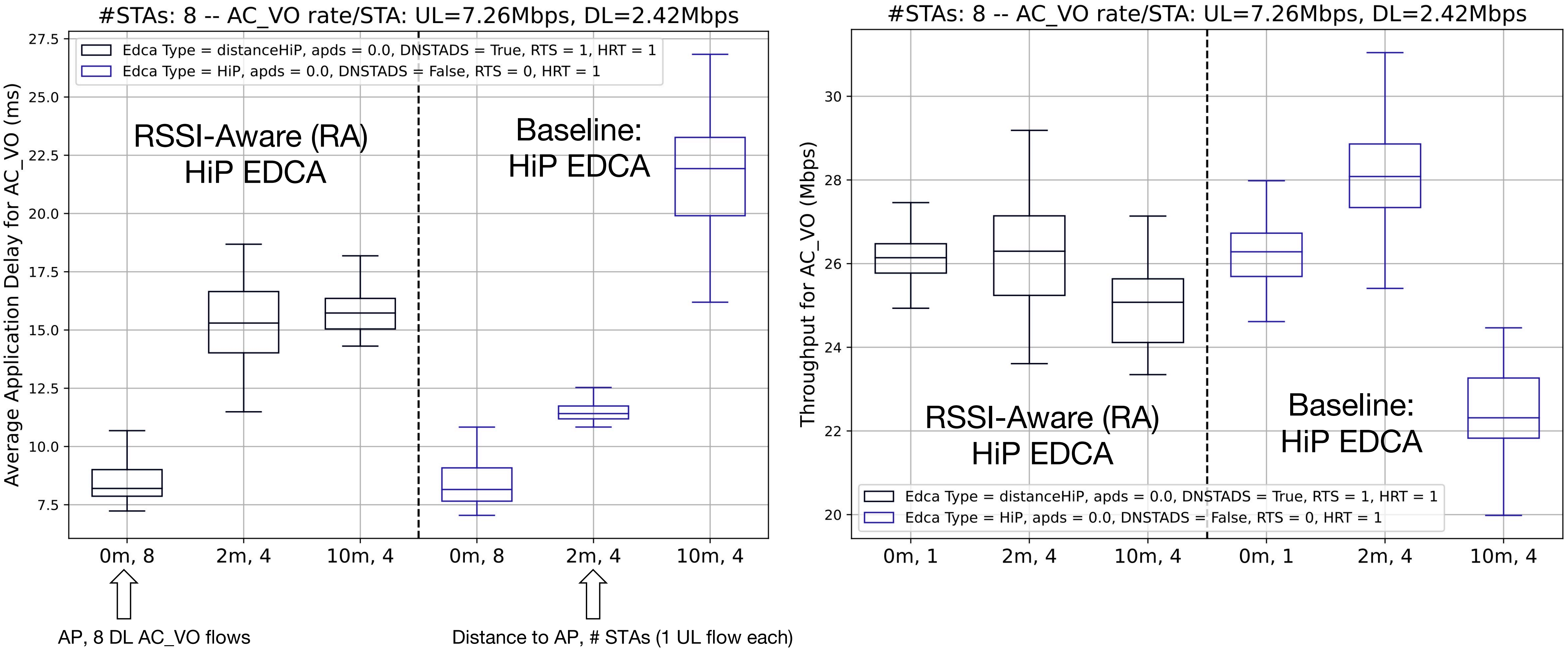
The AP allows STAs with RSSI between -70 to -79 dBm to:
- Switch to sending DS frames after experiencing 1 failure
- The number of allowed consecutive DS frames is 2

❑ Switching Criteria

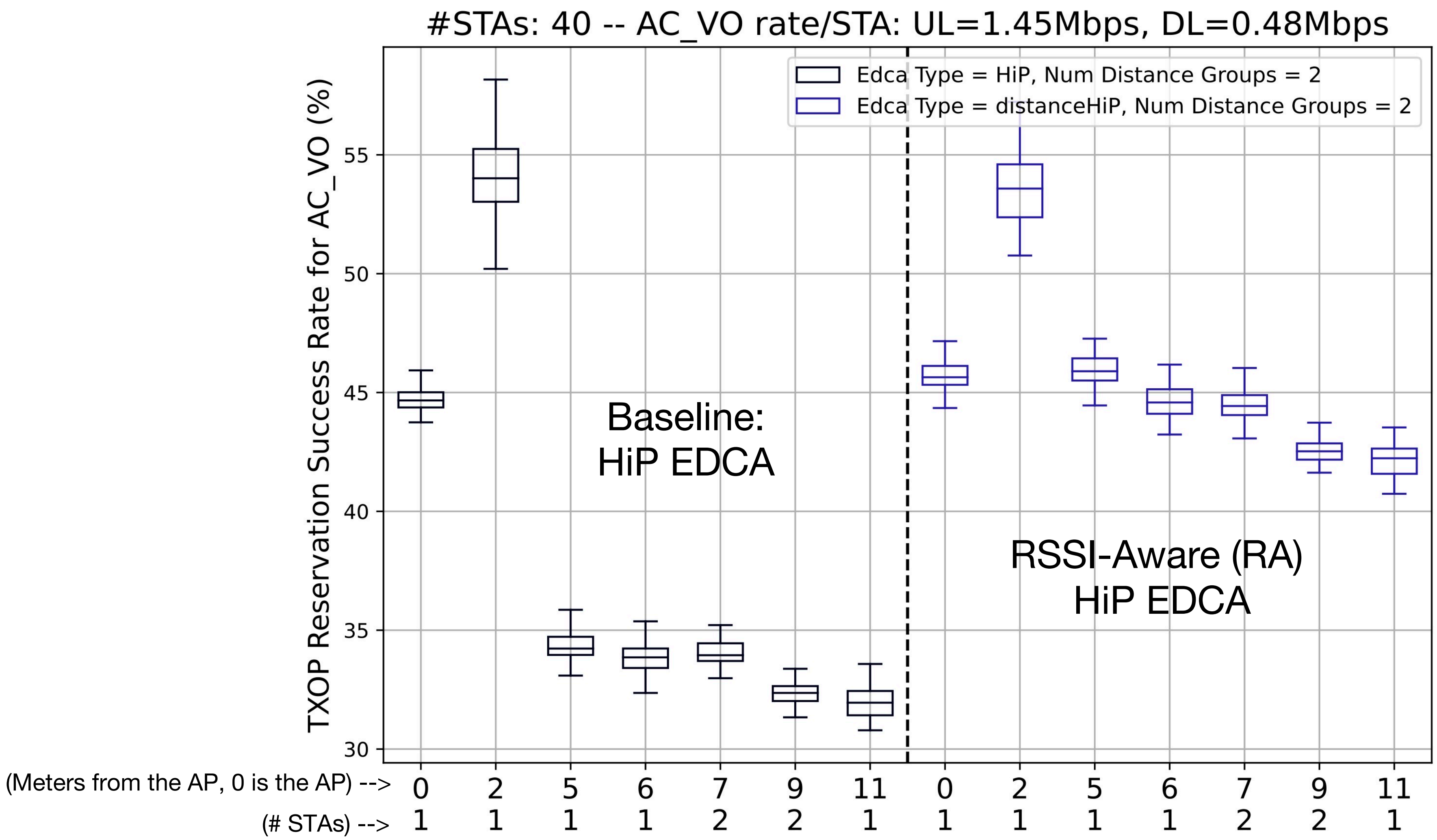
- **Sample method**
  - The AP announces the RSSI distribution of LL STAs
  - Based on this information, non-AP STAs decide about the operational parameters of P-EDCA

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

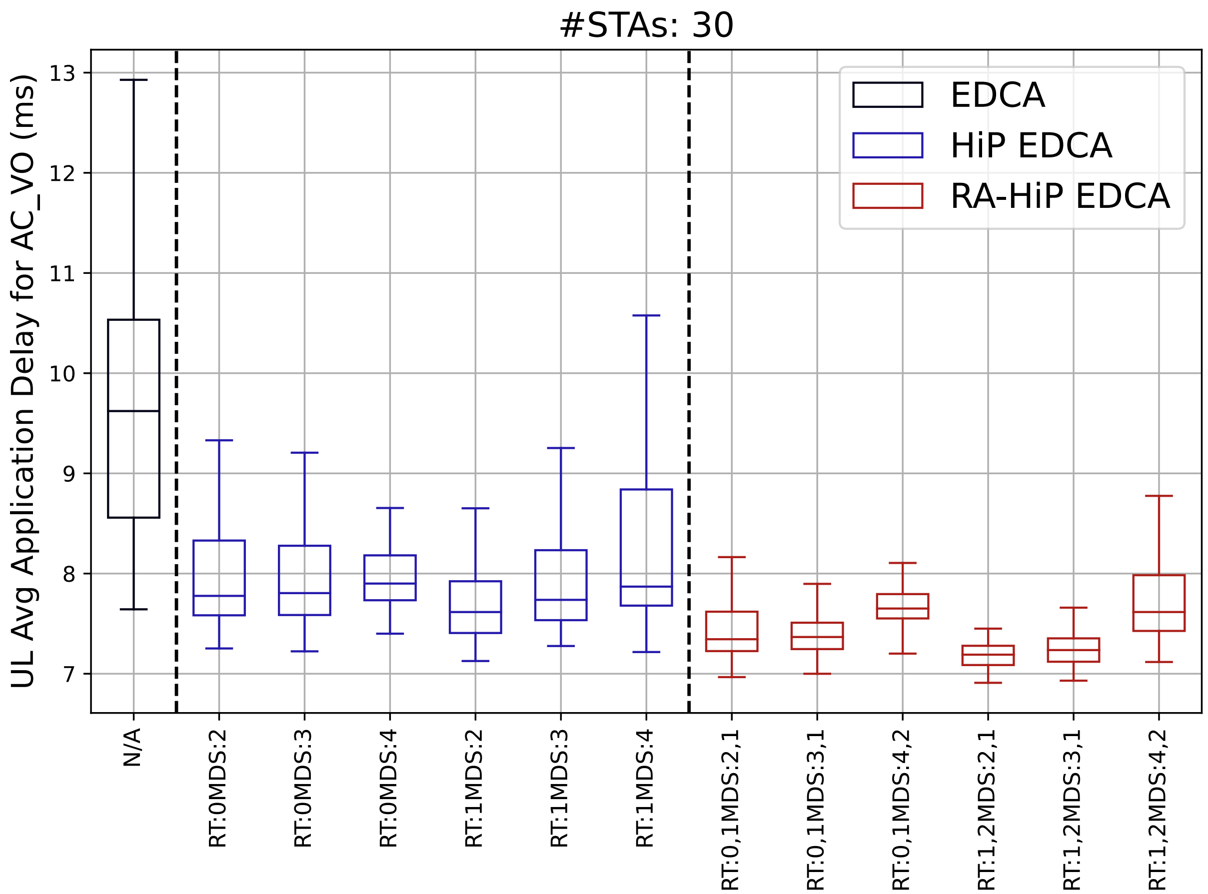
- Concentric Circles: 8 STAs, 100% VO

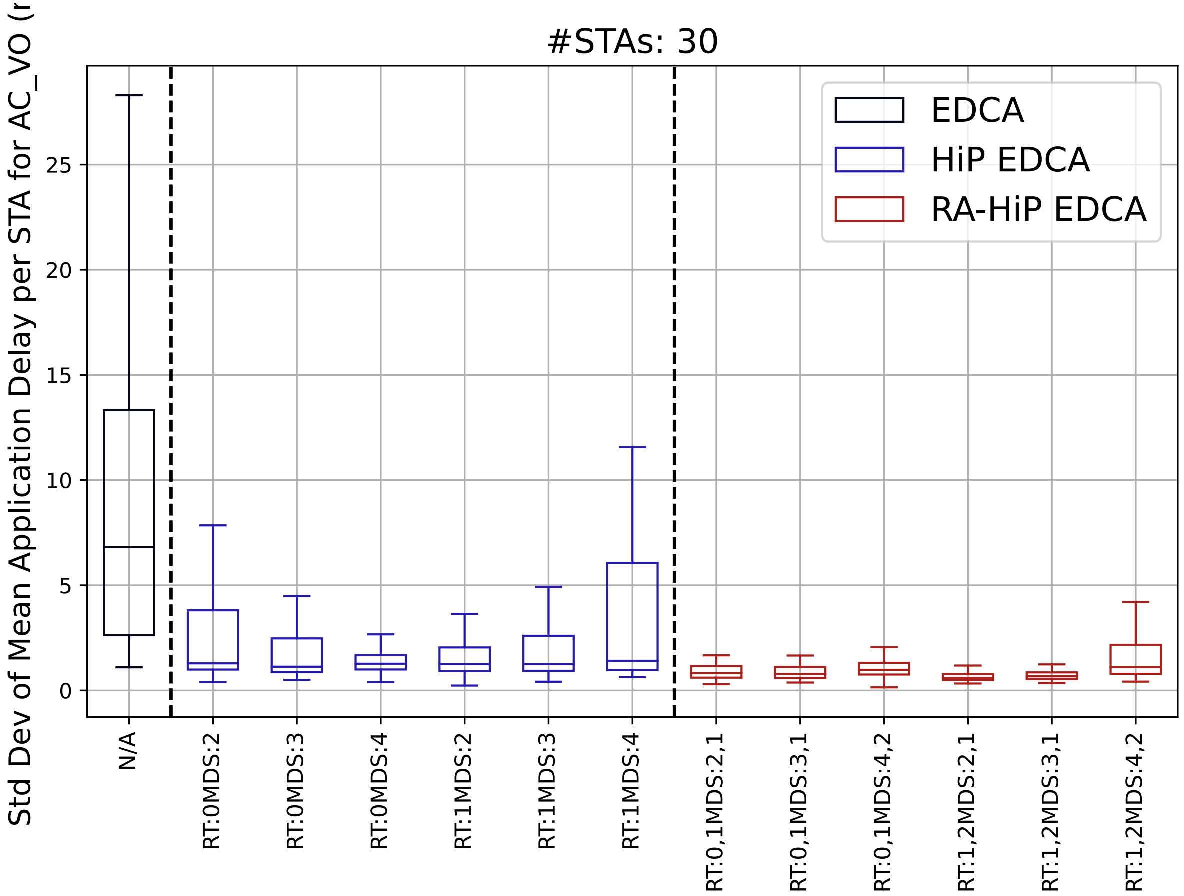


- Grid Deployment: 40 STAs, 20mx20m room, 80% BE, 20% VO



❑ Concentric Circles: 30 STAs, 80% BE, 20% VO





RT (Retry Threshold): #retries required before sending a DS frame. For example, 0 indicates DS may be sent after 1 failed transmission, 1 indicates DS sent after 2 failures, etc.

MDS (Maximum consecutive DS) frames: The maximum number of DS frames a STA may send consecutively. After reaching this limit, STA must transmit a non-DS frame with normal EDCA parameters at least once.

RT: *x*, *y*, *z*: indicates STAs with a low, medium, and high RSSI need to experience *x*, *y* and *z* retries, respectively, before sending a DS.

Summary

- **When LL STAs have dissimilar received signal quality at the AP, those with higher signal quality have a greater chance of benefiting from P-EDCA**
  - **This results in an imbalance in the tail latency among LL STAs and lower effectiveness of P-EDCA**

- **To balance the tail time of LL STAs, in this contribution, we proposed to use different P-EDCA parameters, based on the RSSI of STAs**
- For example, STAs that are further from the AP or located behind obstacles may switch to P-EDCA after two failures, whereas STAs closer to the AP may switch to P-EDCA after three failures

- **This method is much easier to implement and has significantly fewer side effects than transmission power control**

Straw Poll

- Do you agree that P-EDCA should strive to provide LL STAs with a similar chance of channel access success during the protected contention periods (e.g., regardless of their received RSSI by the AP)?

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**
- **P-EDCA provides a means to address the unfairness problem**

- 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 and reduced spectral efficiency
    - TPC must comply with DFS requirements; reducing power may impair radar detection reliability, while increasing power could result in regulatory violations