High-Priority Timeout for P-EDCA Operation

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Introduction

- EDCA is the primary access method for STAs to reserve a TXOP, especially to send aperiodic, event-driven traffic
- EDCA struggles when multiple STAs with Low-Latency (LL) traffic (AC_VO) compete, or when LL STAs contend with AC_BE STAs

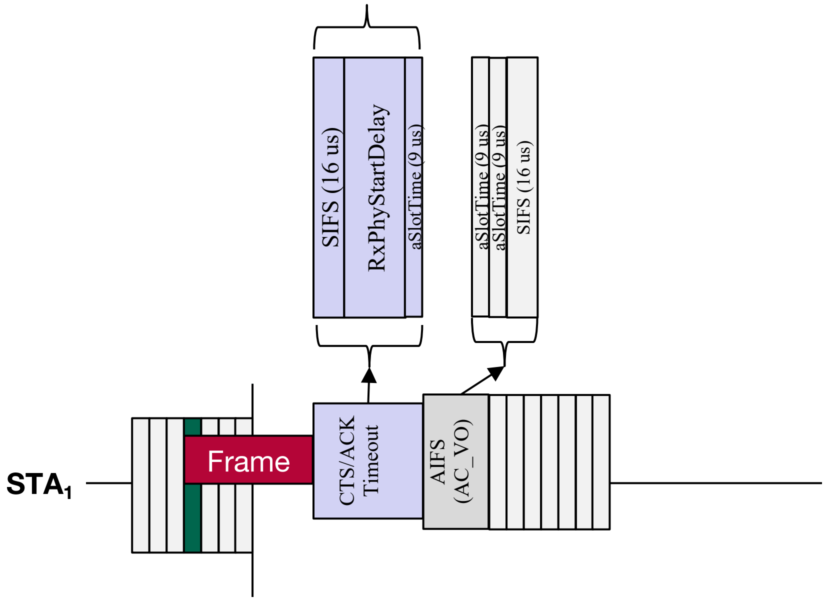
- Lowering the tail-time latency of STAs competing for channel access through EDCA has been addressed in several contributions [11-24/1918][11-24/1144][11-24/0864]
- The High-Priority (HiP) EDCA mechanism [11-24/1918][11-24/1144] allows STAs with LL traffic to send Defer Signal (DS) frame after a certain number of retries, and then use RTS/CTS to reserve a TXOP
  - **Shortcoming**: Using the CTS/ACK Timeout duration after sending response-soliciting frames leads to wasted channel time before successful channel reservation

- **In this contribution, we propose a method to reduce the overhead of the P-EDCA procedure by minimizing the time required to detect transmission failure after sending a response-soliciting frame**
- A STA is allowed to use a **High-Priority Timeout (HPTO)** duration instead of **CTS/ACK Timeout** to retry channel access during P-EDCA

ACK Timeout in 802.11

- When a STA sends a **response-soliciting frame (e.g., RTS)**, it needs to wait for **CTS/ACK Timeout + AIFS[AC]** before competing for channel access again
  - The ACK Timeout duration depends on the PHY layer

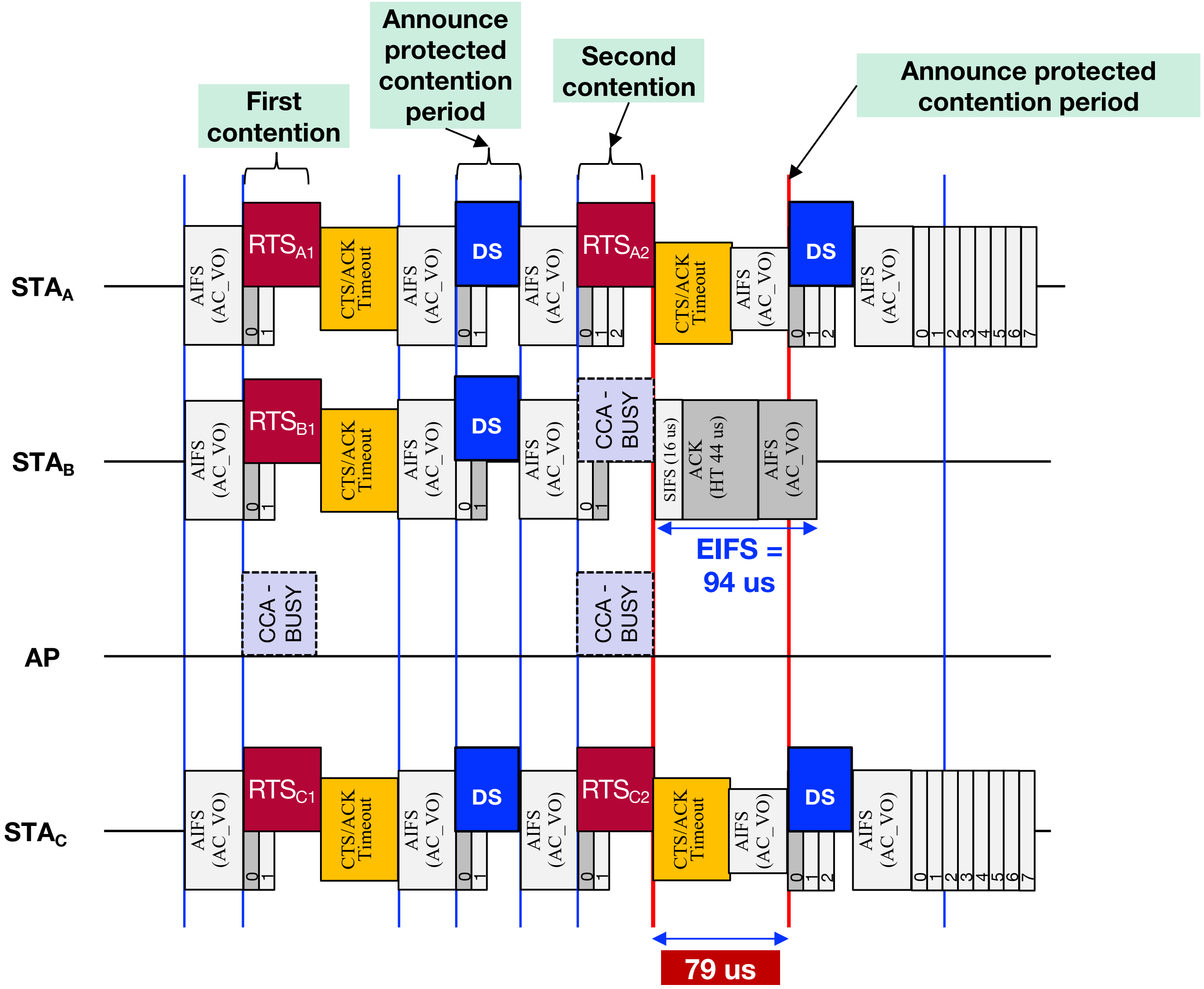
For example, for **non-HT** frames:
16 (SIFS) + 20 (RxPhyStartDelay) + 9 (aSlotTime) = **54 us**



	RxPhyStartDelay (us)
OFDM	20
HT	28 (HT-mixed), 24 (HT-greenfield)
VHT	36 + 4 × $N_{VHT\text{-}LTF}$ + 4
EHT	32 + 4 × $N_{EHT\text{-}SIG}$ for EHT MU PPDU 32 µs for EHT TB PPDUs

❑ Sample Scenario

- **First contention round:** STA_A, STA_B, and STA_C compete; all three STAs use CTS/ACK Timeout after sending their frames
- STA_A, STA_B, and STA_C send DS frames to announce **protected contention period**
- **Second contention round (protected):** STA_A and STA_B send RTS frames, **and they both fail**
- They are allowed to send another DS frames
- **Both STAs wait for CTS/ACK Timeout before sending the next DS frame**



A Shorter Retry Timeout: High-Priority Timeout (HPTO)

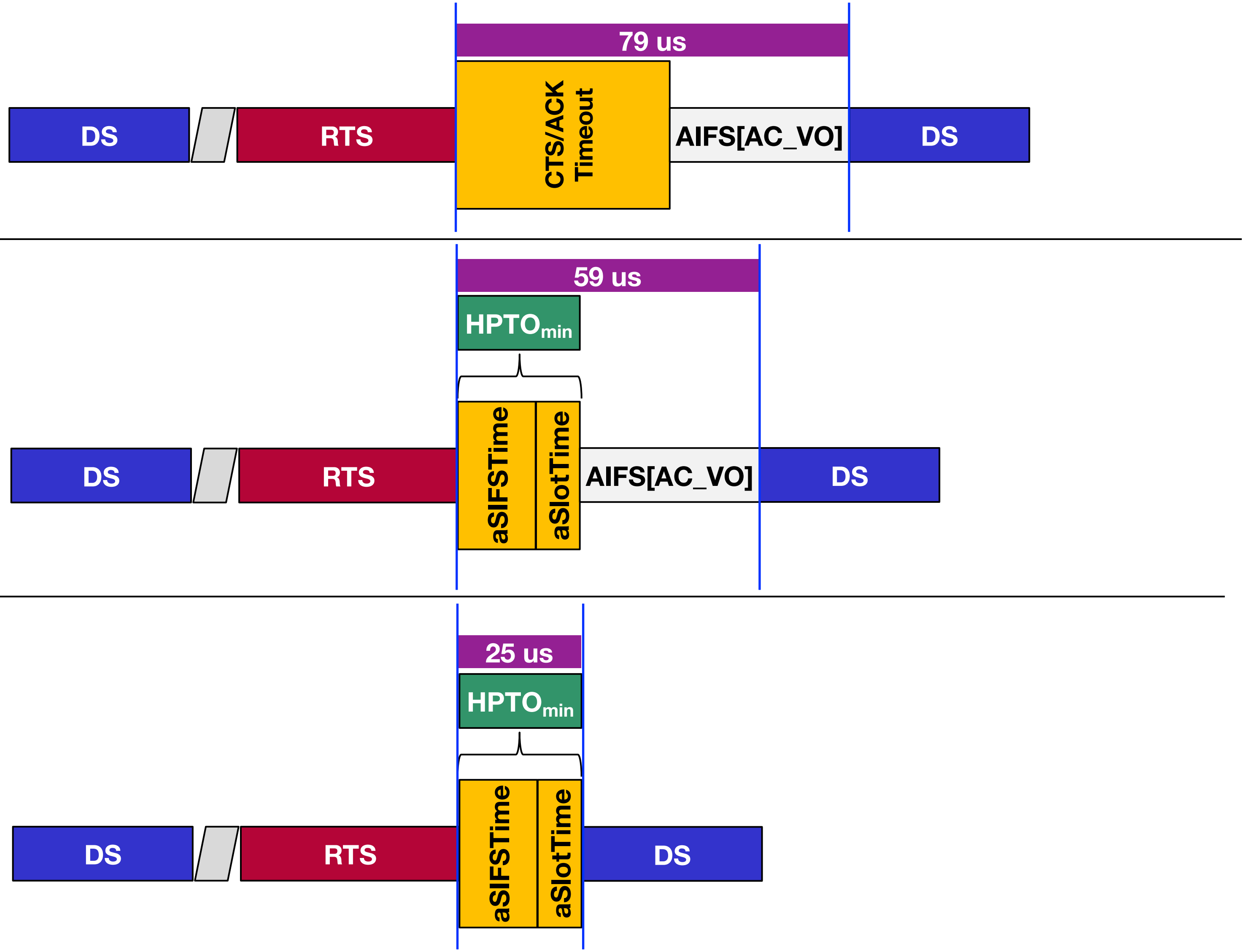
- In this contribution, we allow STAs involved in P-EDCA to **use a High-Priority Timeout (HPTO) duration instead of CTS/ACK Timeout** to reduce the channel time used by P-EDCA

- **HPTO_{min} = aSIFTtime + aSlotTime**
  - HPTO_{min} provides
    - Enough time for the **receiver** of the response-soliciting frame to receive, process, and start sending a reply to the sender, and
    - Enough time for the **sender** of the response-soliciting frame to perform carrier sensing (CCA) and switch to TX mode if the channel is sensed as idle

- **When a STA sends a response-soliciting frame (e.g., RTS), it can detect transmission failure if the channel is sensed as idle during the aSlotTime (after SIFS)**

- Note: A longer HPTO, such as aSIFTtime + 2 x aSlotTime may be used if sensing the channel for a longer duration is necessary

High-Priority Timeout (HPTO)

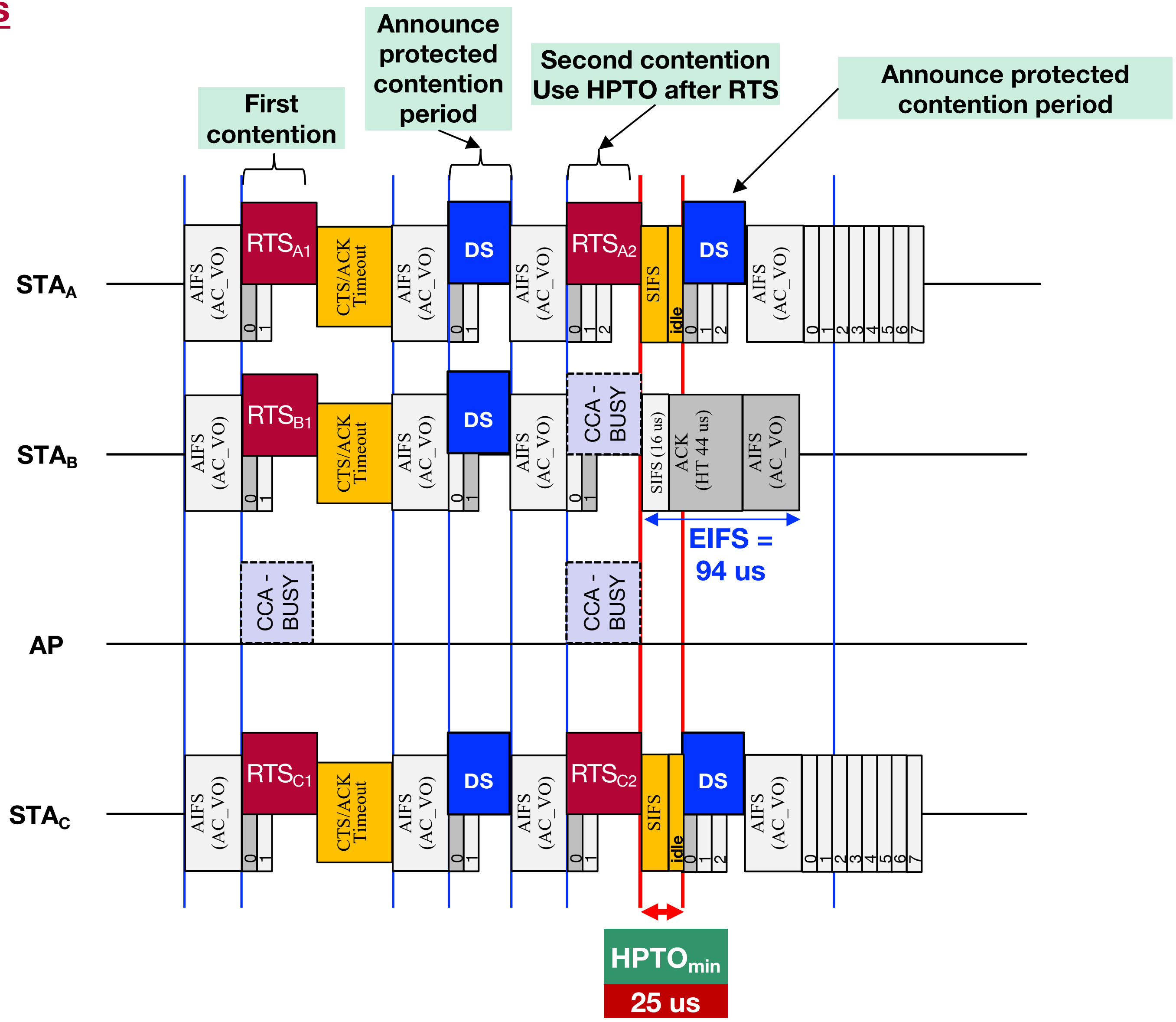


- HPTO$_{min}$ is the minimum amount of time a STA needs to wait before determining a transmission failure

- After sending an RTS, a STA may use the HPTO$_{min}$ duration to determine transmission failure
- If the channel is sensed as idle during the aTimeSlot duration, the transmission is considered as failed

❑ Using HPTO before DS retransmissions

- **HPTO = HPTO_{min} + aSlotTime**
- **First contention round:** STA_A, STA_B, and STA_C compete; all three STAs use CTS/ACK Timeout after sending their frames
- STA_A, STA_B, and STA_C send DS frames to announce **protected contention period**
- **Second contention round (protected):** STA_A and STA_B send RTS frames, **and they both fail**
- They are allowed to send another DS frames
- **Instead of using CTS/ACK Timeout after their RTS frames, both STAs wait for HPTO before sending the next DS frame**



First contention

Announce protected contention period

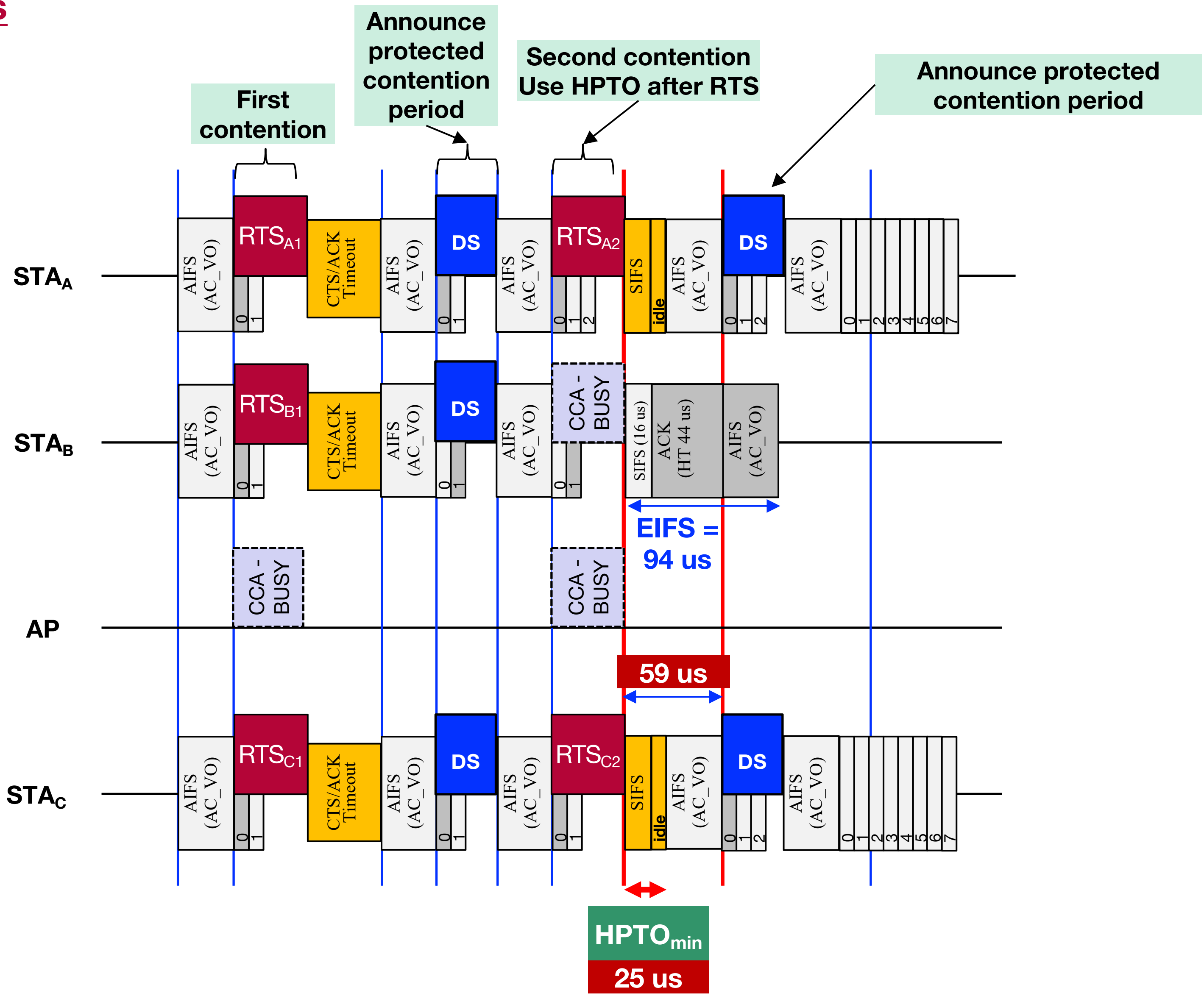
Second contention Use HPTO after RTS

Announce protected contention period

❑ Using HPTO before DS retransmissions

- In the figure, it is assumed that the earliest time a P-EDCA eligible STA can resend a DS frame is **AIFS after the failure detection**

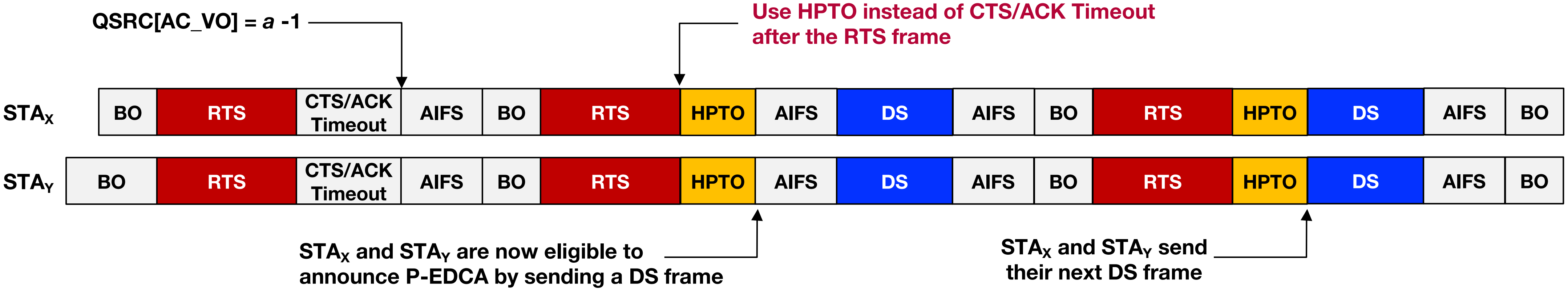
- This results in a 59 us interval between the end of a RTS and the start of a DS
  - Compare with 79 us when using CTS/ACK Timeout (slide 4)



❑ Using HPTO before sending the first DS frame

- HPTO may also be used before sending the first DS frame

- Assume a STA may start P-EDCA contention by sending DS frame when QSRC[AC_VO] = *a*
- When QSRC[AC_VO] = *a* - 1, and after sending an RTS frame, the STA uses HPTO to determine if the transmission of the RTS frame has failed
  - If the channel is sensed idle during the aSlotTime of HPTO, the STA sends a DS frame immediately



QSRC[AC_VO] = *a* -1

Use HPTO instead of CTS/ACK Timeout after the RTS frame

STA$_X$	BO	RTS	CTS/ACK Timeout	AIFS	BO	RTS	HPTO	AIFS	DS	AIFS	BO	RTS	HPTO	DS	AIFS	BO
STA$_Y$	BO	RTS	CTS/ACK Timeout	AIFS	BO	RTS	HPTO	AIFS	DS	AIFS	BO	RTS	HPTO	DS	AIFS	BO

STA$_X$ and STA$_Y$ are now eligible to announce P-EDCA by sending a DS frame

STA$_X$ and STA$_Y$ send their next DS frame

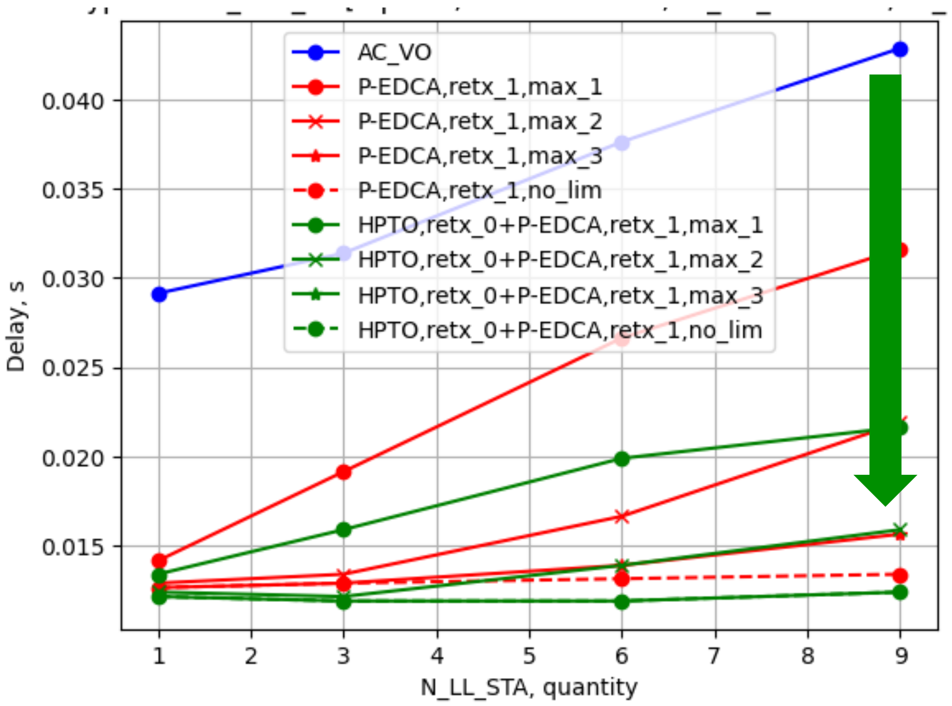
Performance benefits of HPTO

Scenario:

- **1 BSS**
- **20 BE STAs**
  - full-buffer UL+DL traffic
  - TxOP limit = 5ms
  - RTS/CTS always
- **5 legacy VO STAs**
  - UL
  - packet size 160 B
  - Uniform [10, 20] ms inter-arrival time
  - RTS/CTS always
- ***N* LL STAs**
  - UL
  - packet size 160 B
  - Uniform [10, 22] ms inter-arrival time
  - RTS/CTS always
  - Channel access methods:
    - Legacy AC_VO
    - P-EDCA with QSRC threshold = 1
    - P-EDCA+HPTO with QSRC threshold = 1
  - DS max consecutive attempts PSRC = {1, 2, 3, inf}.

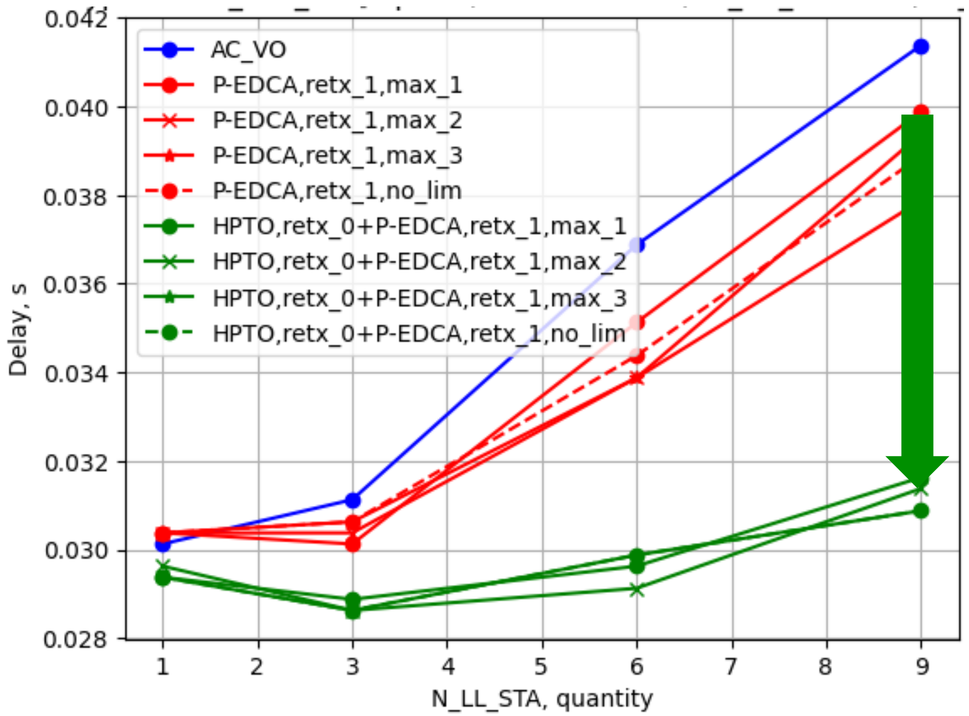
Performance benefits of HPTO. Results

LL STAs, 99th percentile



-65% tail delay for LL STAs if P-EDCA + HPTO is used

AC_VO STAs, 99th percentile



-30% tail delay AC_VO STAs if LL STAs use HPTO: thanks to a reduced overhead in case of collisions and reduced contention for AC_VO

Summary

- Normally, when a STA sends a response-soliciting frame (e.g., RTS, data), it waits for an CTS/ACK Timeout duration to determine if the transmission has failed

- **In this contribution, we proposed that STAs involved in P-EDCA may bypass CTS/ACK Timeout and instead use a High-Priority Timeout (HPTO) duration**
  - After sending a response-soliciting frame, a STA waits for $HPTO_{min}$ = *aSIFSTime* + *aSlotTime* to determine transmission failure
- The combination of P-EDCA with HPTO allows improving latencies for both LL STAs, which use P-EDCA and HPTO, and the legacy AC_VO STAs, which benefit from a low-overhead collision resolution by the LL STAs.

Straw Poll

SP1. Do you agree that when "QSRC[AC_VO] >= dot11PEDCARetryThreshold - 1” a P-EDCA capable STA may use the High-Priority Timeout (HPTO), defined as SIFS + aSlotTime, to detect the failure of an RTS frame, as long as PSRC[AC_VO] < dot11PEDCAConsecutiveAttempt?

YES/NO/ABSTAIN

SP2. Do you agree that when "QSRC[AC_VO] >= dot11PEDCARetryThreshold - 1” a P-EDCA capable STA may use the High-Priority Timeout (HPTO), defined as SIFS + aSlotTime, to detect the failure of an RTS frame transmission, increment QSRC[AC_VO], and subsequently transmit the DS frame at:

- Option A: The end of HPTO,
- Option B: The end of HPTO + DSAIFS[AC_VO],

as long as PSRC[AC_VO] < dot11PEDCAConsecutiveAttempt

Note: DSAIFS[AC_VO] = aSIFSTime + (AIFSN + DSr) × aSlotTime [from the latest PDT]

YES/NO/ABSTAIN