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

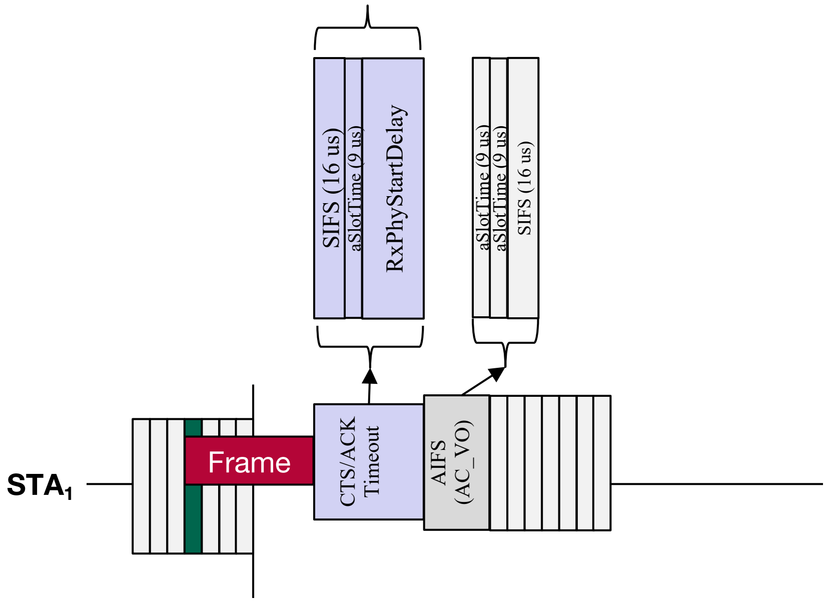
- Lowering the tail-time latency of STAs competing for channel access through EDCA has been addressed in several contributions [11-24/1918][11-24/1144][11-24/0864]
- The High-Priority (HiP) EDCA mechanism [11-24/1918][11-24/1144] allows STAs with LL traffic to send Defer Signal (DS) frame after a certain 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

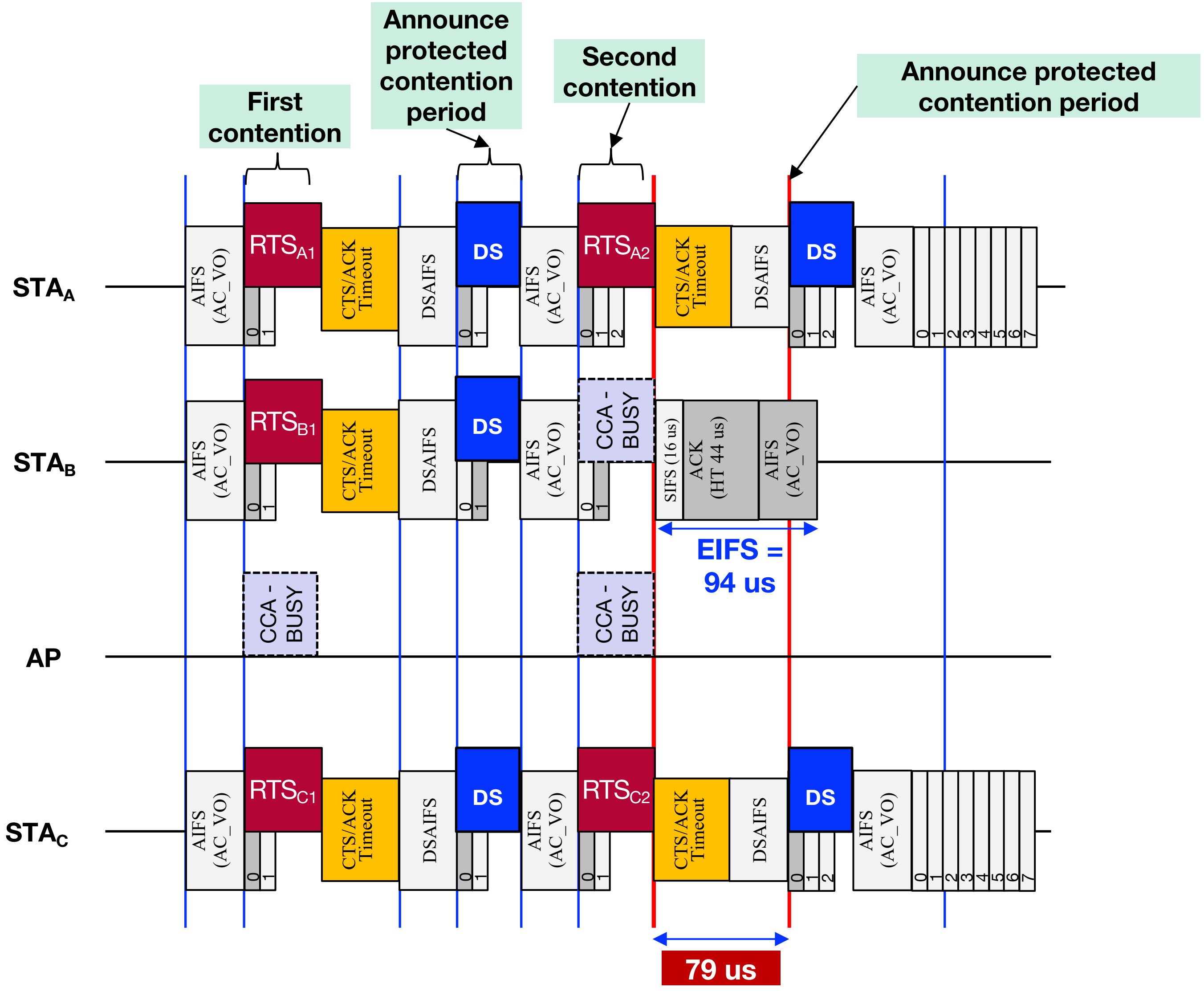
For **non-HT OFDM** frames:
16 (SIFS) + 9 (aSlotTime) + 20 (RxPhyStartDelay) = **45 us**



	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 their next DS frames**



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 starts when the STA receives the PHY-TXEND.confirm for the transmitted frame**

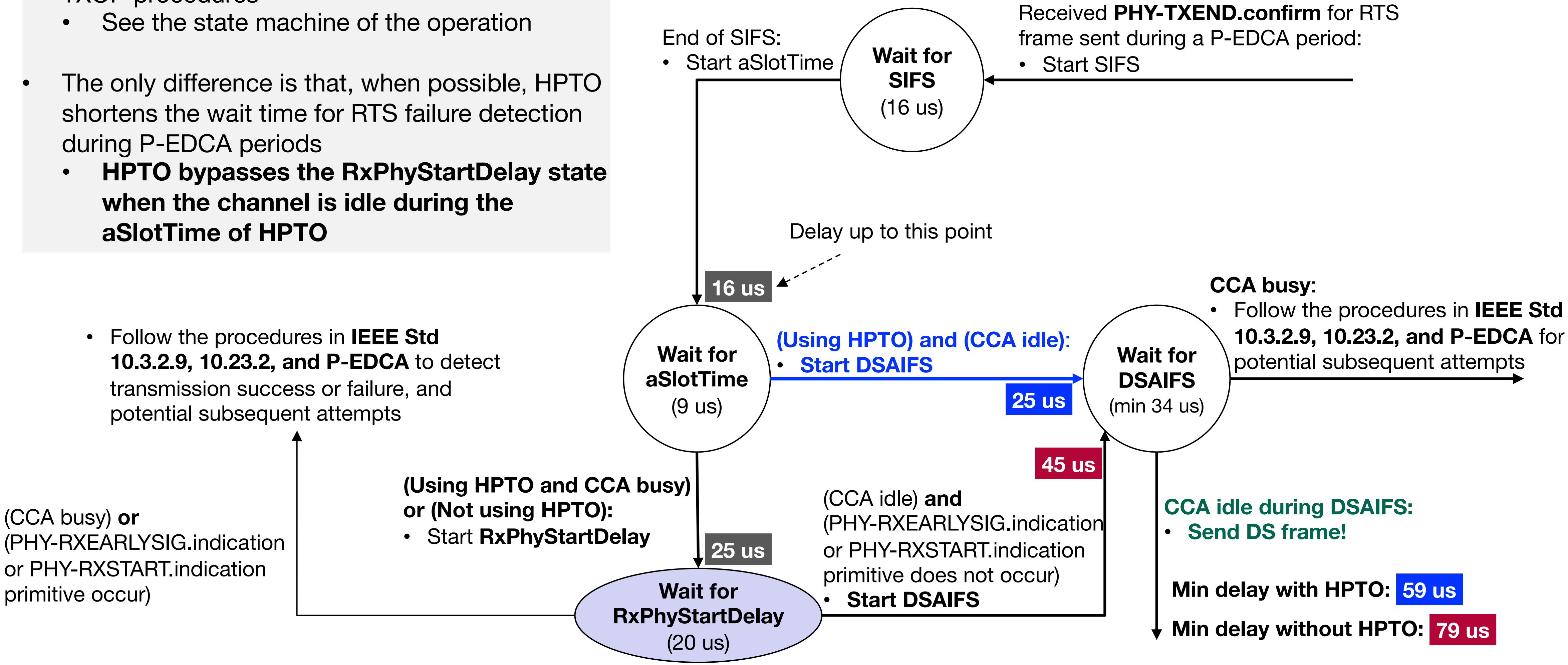
- **HPTO = aSIFTtime + aSlotTime**
  - HPTO provides
    - Enough time for the **receiver** of the response-soliciting frame to receive, process, and start sending a reply to the sender, and
    - Enough time for the **sender** of the response-soliciting frame to perform carrier sensing (CCA) and switch 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 (i.e., CCA idle) during the aSlotTime of HPTO**

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

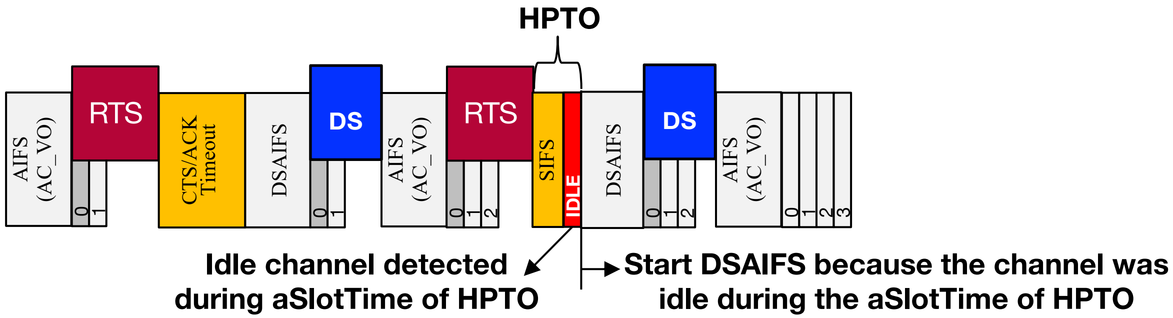
A Shorter Retry Timeout: **High-Priority Timeout (HPTO)**

- HPTO is compatible with the current EDCA and TXOP procedures
  - See the state machine of the operation
- The only difference is that, when possible, HPTO shortens the wait time for RTS failure detection during P-EDCA periods
  - **HPTO bypasses the RxPhyStartDelay state when the channel is idle during the aSlotTime of HPTO**

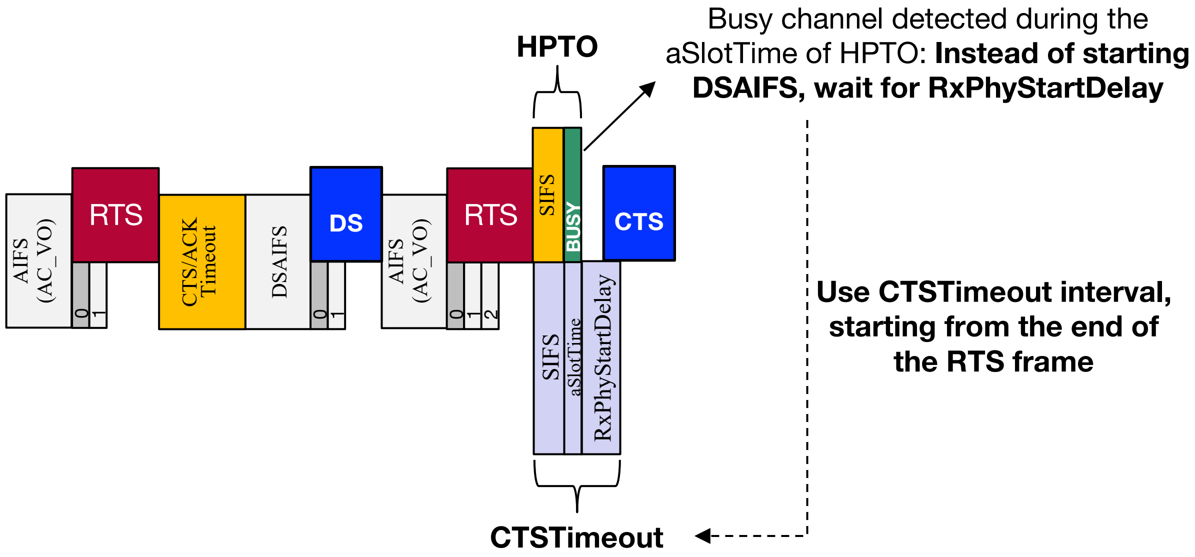


A Shorter Retry Timeout: **High-Priority Timeout (HPTO)**

Example 1:
Channel is sensed as idle during HPTO

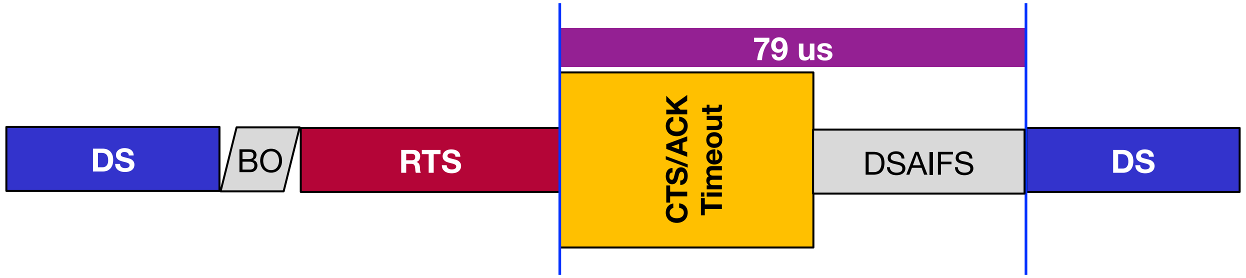


Example 2:
Channel is sensed as busy during HPTO

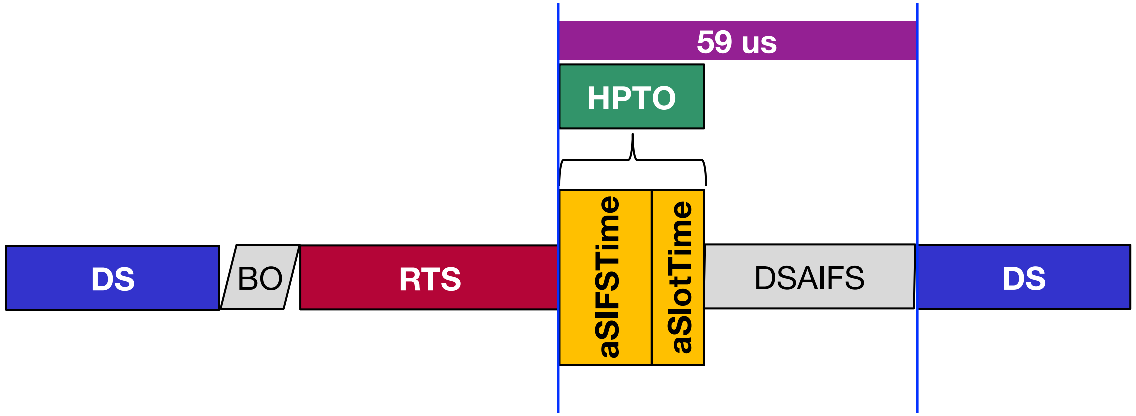


High-Priority Timeout (HPTO)

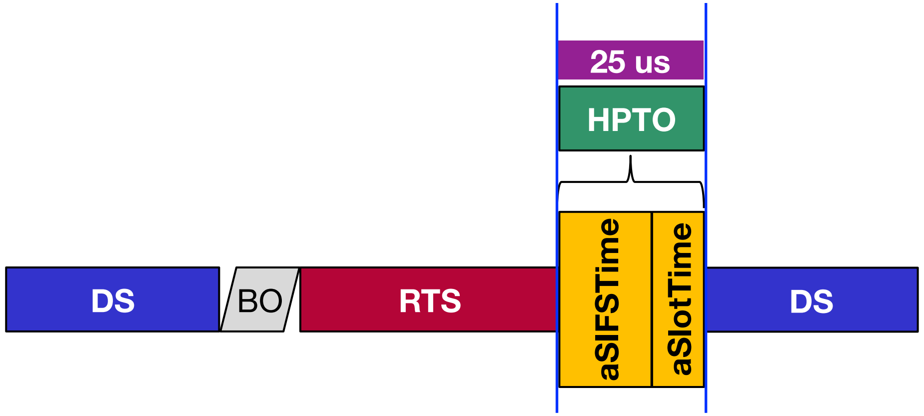
(a) Using CTSTimeout for failure detection, and in case of failure, wait for DSAIFS before sending DS frame



(b) Using HPTO for failure detection, and in case of failure, wait for DSAIFS before sending DS frame

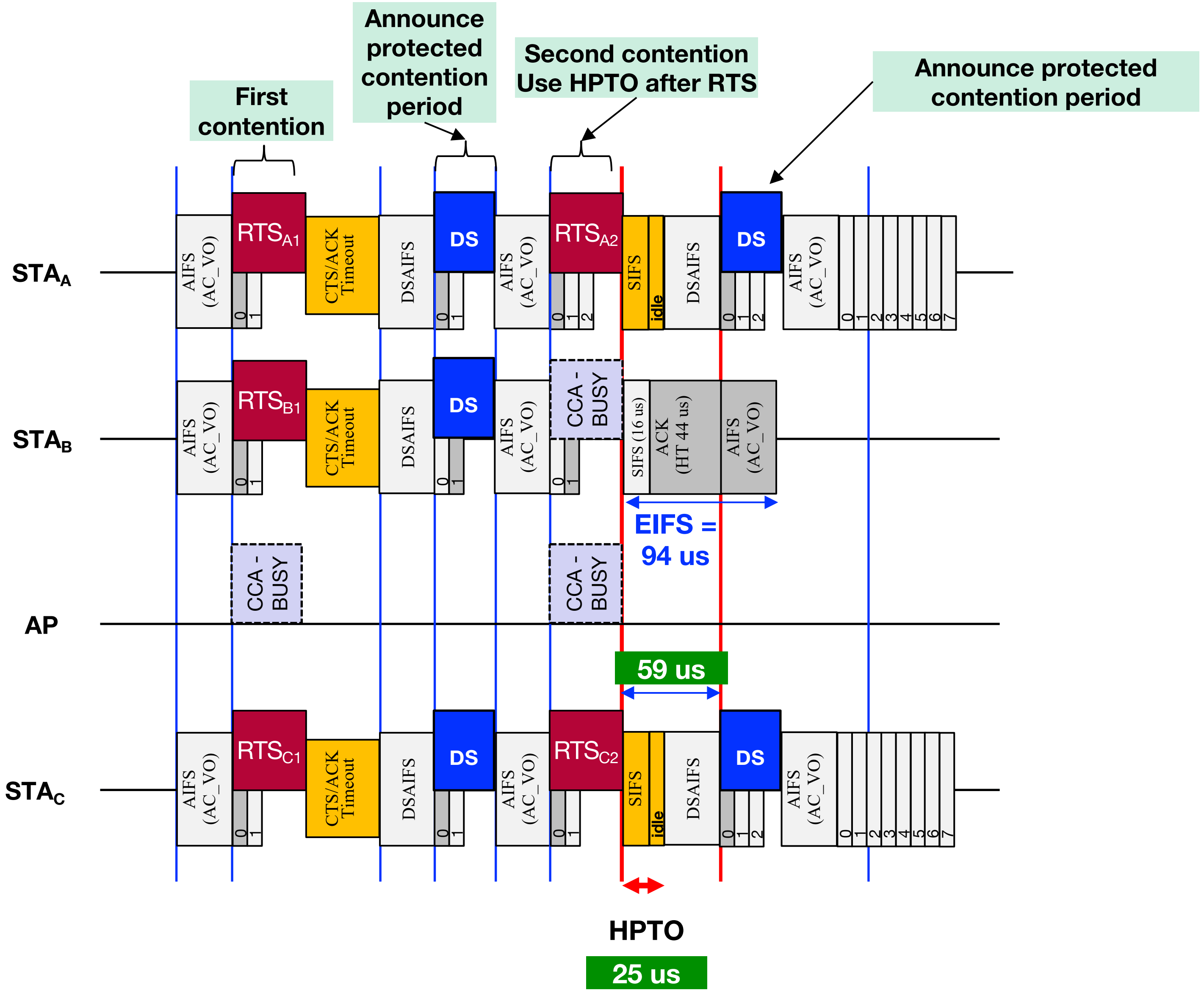


(c) Using HPTO for failure detection, and in case of failure, send DS frame immediately



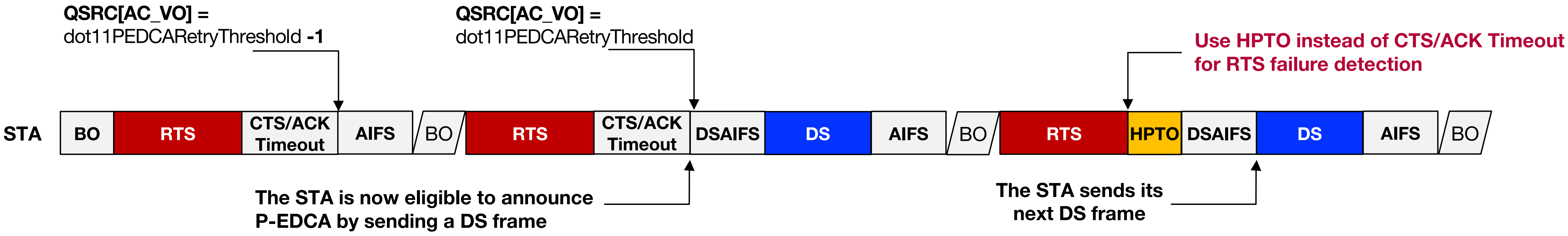
❑ Using HPTO for DS retransmissions

- In the figure, it is assumed that the earliest time a P-EDCA eligible STA can resend a DS frame is **DSAIFS 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 for DS retransmissions

- Assume a STA starts P-EDCA by sending DS frame when QSRC[AC_VO] = **dot11PEDCARetryThreshold**
- During the P-EDCA's protected contention periods, after sending an RTS frame, the STA uses HPTO to detect RTS transmission failure
- If the channel is sensed as idle during the aSlotTime of HPTO, the STA starts the DSAIFS duration immediately



Performance Evaluation

VO STA:

AIFSN = 2

CWmin = 4, CWmax = 8 (AC_VO)

RTS/CTS: on

P-EDCA, HPTO variants:

- P-EDCA: off, HPTO: off
- P-EDCA: on (enforce RTS/CTS: on, enforce preamble detection: on/off), HPTO: on/off
- Variants with max_hip_attempts and retx_threshold
  - max_ds_attempts = {3}
  - retx_threshold = {1}

TXOP limit: 2.08 ms (multiple pkts in the same TXOP can be transmitted with RIFS spacing)

BE STAs:

AIFSN = 3

CWmin = 16, CWmax = 1024

RTS/CTS: on

P-EDCA, HPTO: off (using AC_BE EDCA)

TXOP limit: 5 ms (multiple pkts in the same TXOP can be transmitted with RIFS spacing)

AP:

AIFSN = 1

CWmin = 16, CWmax = 64

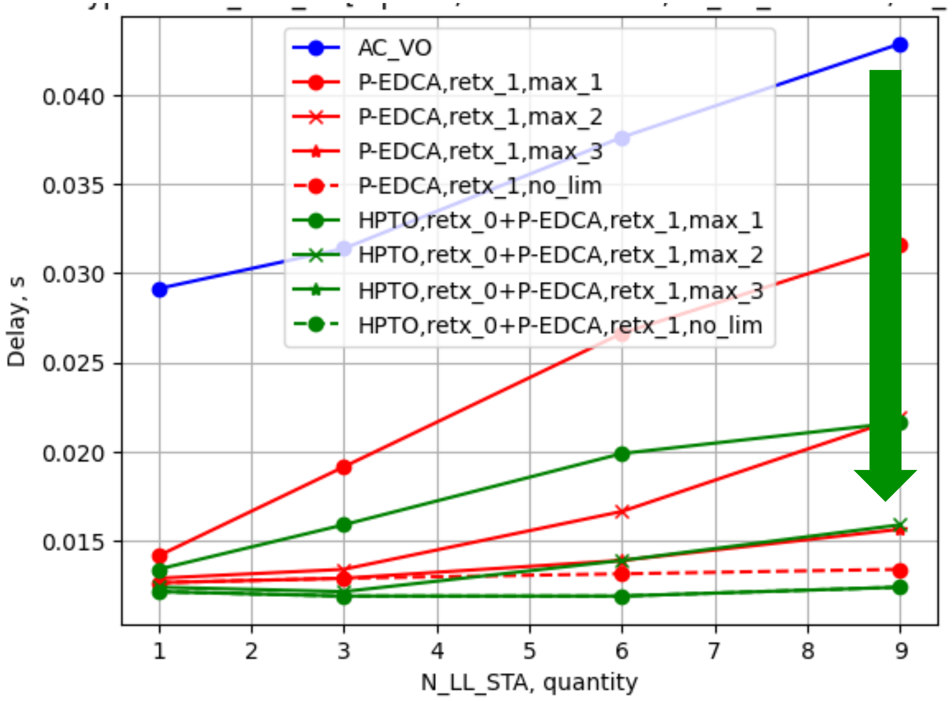
RTS/CTS: on

P-EDCA, HPTO: off

TXOP limit: 5 ms (multiple pkts in the same TXOP can be transmitted with RIFS spacing)

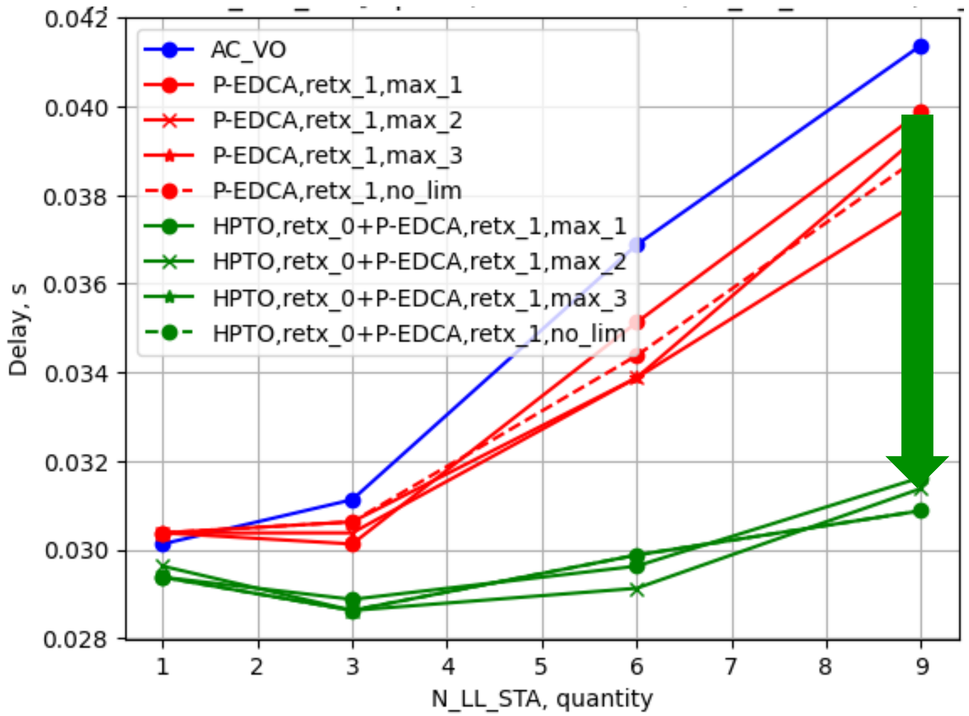
Performance benefits of HPTO. Results

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 bypass CTS/ACK Timeout and instead use a High-Priority Timeout (HPTO) duration
  - **After sending an RTS frame, a STA waits for *HPTO* = *aSIFSTime* + *aSlotTime* to determine transmission failure**

- The combination of P-EDCA with HPTO:
  - **Allows a higher number of LL STAs use P-EDCA during a shorter time frame**
  - **Reduces the impact of using P-EDCA on legacy STAs**

Straw Poll

SP1. Do you agree that when QSRC[AC_VO] >= dot11PEDCARetryThreshold, 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" 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

OFDM PHY Receiver Specification

IEEE Std 802.11, Section 17.3.10

OFDM PHY Receiver Specification

CCA requirements

- The PHY shall indicate a medium busy condition by issuing a **PHY-CCA.indication** primitive when the carrier sense/clear channel assessment (CS/CCA) mechanism detects a channel busy condition
- For the operating classes requiring CCA-Energy Detect (CCA-ED), the PHY shall also indicate a medium busy condition when CCA-ED detects a channel busy condition
- **The start of an OFDM transmission** at a receive level greater than or equal to the minimum modulation and coding rate sensitivity
    - –82 dBm for 20 MHz channel spacing, –85 dBm for 10 MHz channel spacing, and –88 dBm for 5 MHz channel spacing) shall cause CS/CCA to detect a channel busy condition with a probability > 90% within 4 us for 20 MHz channel spacing, 8 us for 10 MHz channel spacing, and 16 us for 5 MHz channel spacing

- Additionally, **the CS/CCA mechanism shall detect a medium busy condition within 4 us of any signal with a received energy that is 20 dB above the minimum modulation and coding rate sensitivity** (minimum modulation and coding rate sensitivity + 20 dB resulting in –62 dBm for 20 MHz channel spacing, –65 dBm for 10 MHz channel spacing, and –68 dBm for 5 MHz channel spacing)

❑ OFDM PHY Receiver Specification

Receive PHY

- Upon receiving a PHY preamble, the PHY measures the received signal strength level
  - **This indicates activity to the MAC via PHY-CCA.indication primitive**
  - **A PHY-CCA.indication(BUSY) primitive shall be issued for reception of a signal prior to correct reception of the PPDU**
  - The RSSI parameter reported to the MAC in the RXVECTOR

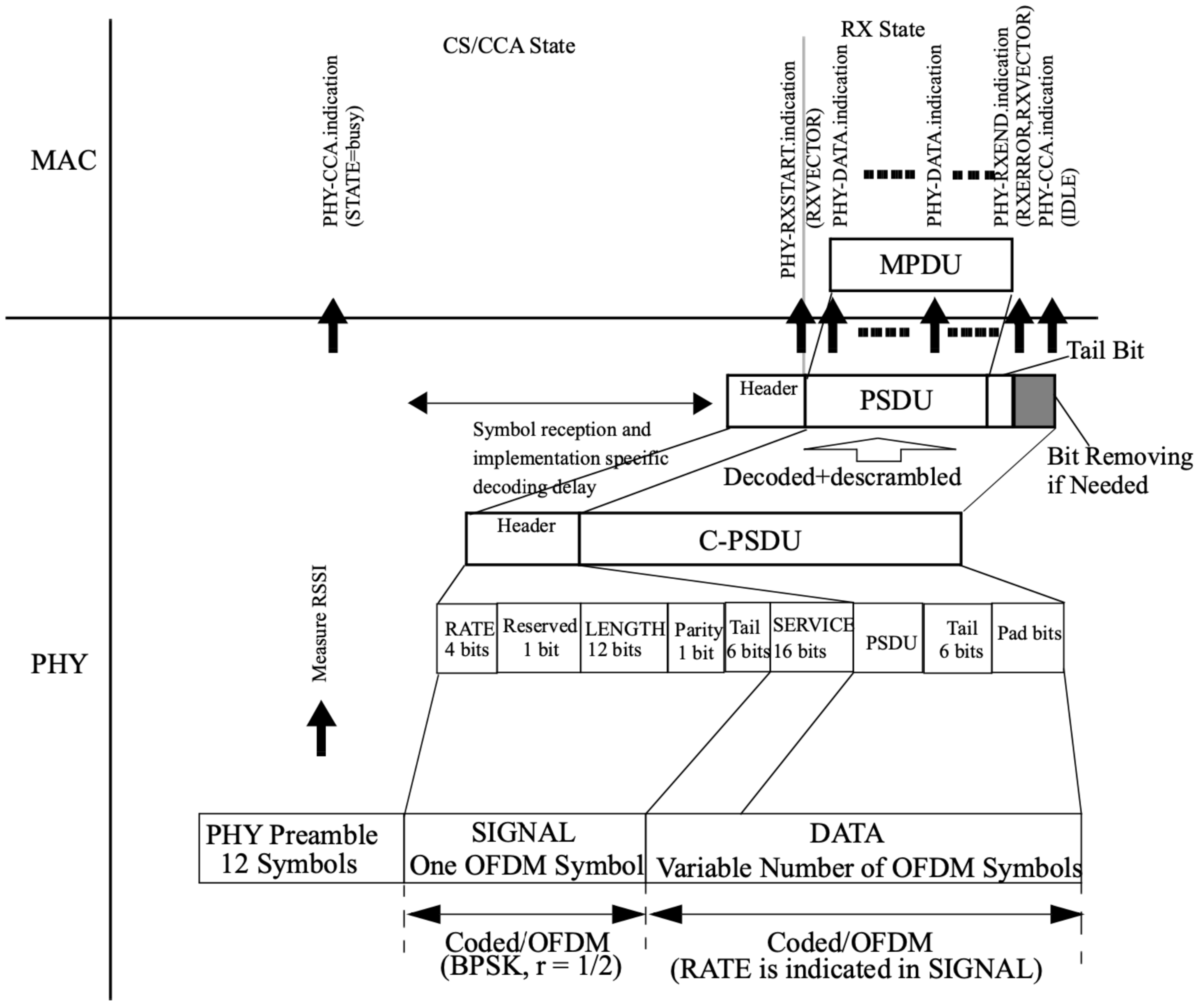


Figure 17-19—Receive PHY

❑ OFDM PHY Receiver Specification

- After a PHY-CCA.indication primitive is issued, the PHY entity shall begin receiving the training symbols and searching for the SIGNAL
  - In order to set the length of the data stream, the demodulation type, and the decoding rate
- **If the PHY header reception is successful (and the SIGNAL field is completely recognizable and supported)**
  - A **PHY-RXSTART.indication(RXVECTOR)** primitive shall be issued

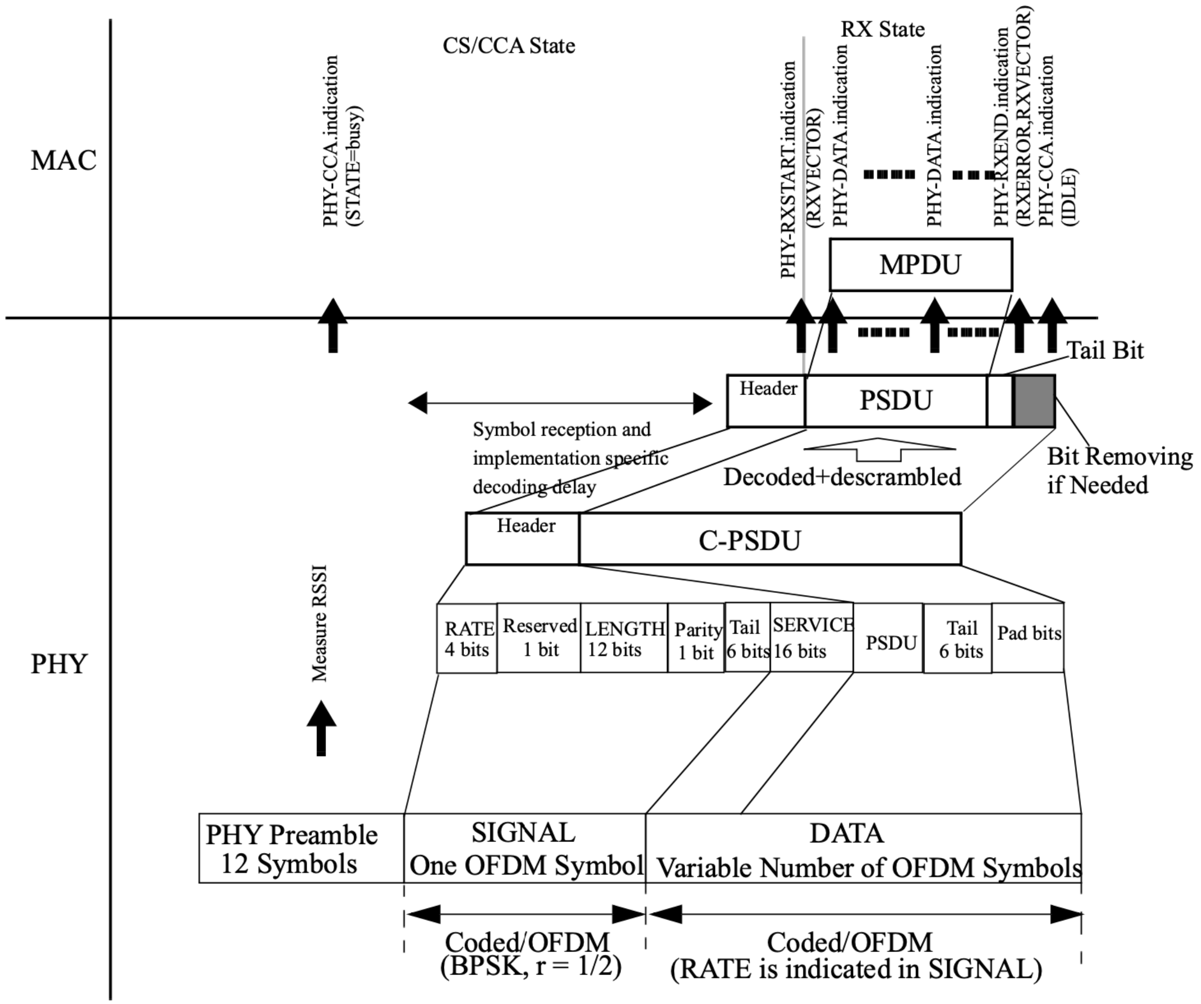


Figure 17-19—Receive PHY

❑ OFDM PHY Receiver Specification

- The received PSDU bits are assembled into octets, decoded, and presented to the MAC using a series of **PHY-DATA.indication(DATA)** primitive exchanges
- The rate change indicated in the SIGNAL field shall be initiated from the SERVICE field data of the PHY header, as described in 17.3.2
- The PHY shall proceed with PSDU reception
- After the reception of the final bit of the last PSDU octet indicated by the LENGTH field of the SIGNAL field, the receiver shall be returned to the RX IDLE state, as shown in Figure 17-19
- A **PHY-RXEND.indication(NoError)** primitive shall be issued

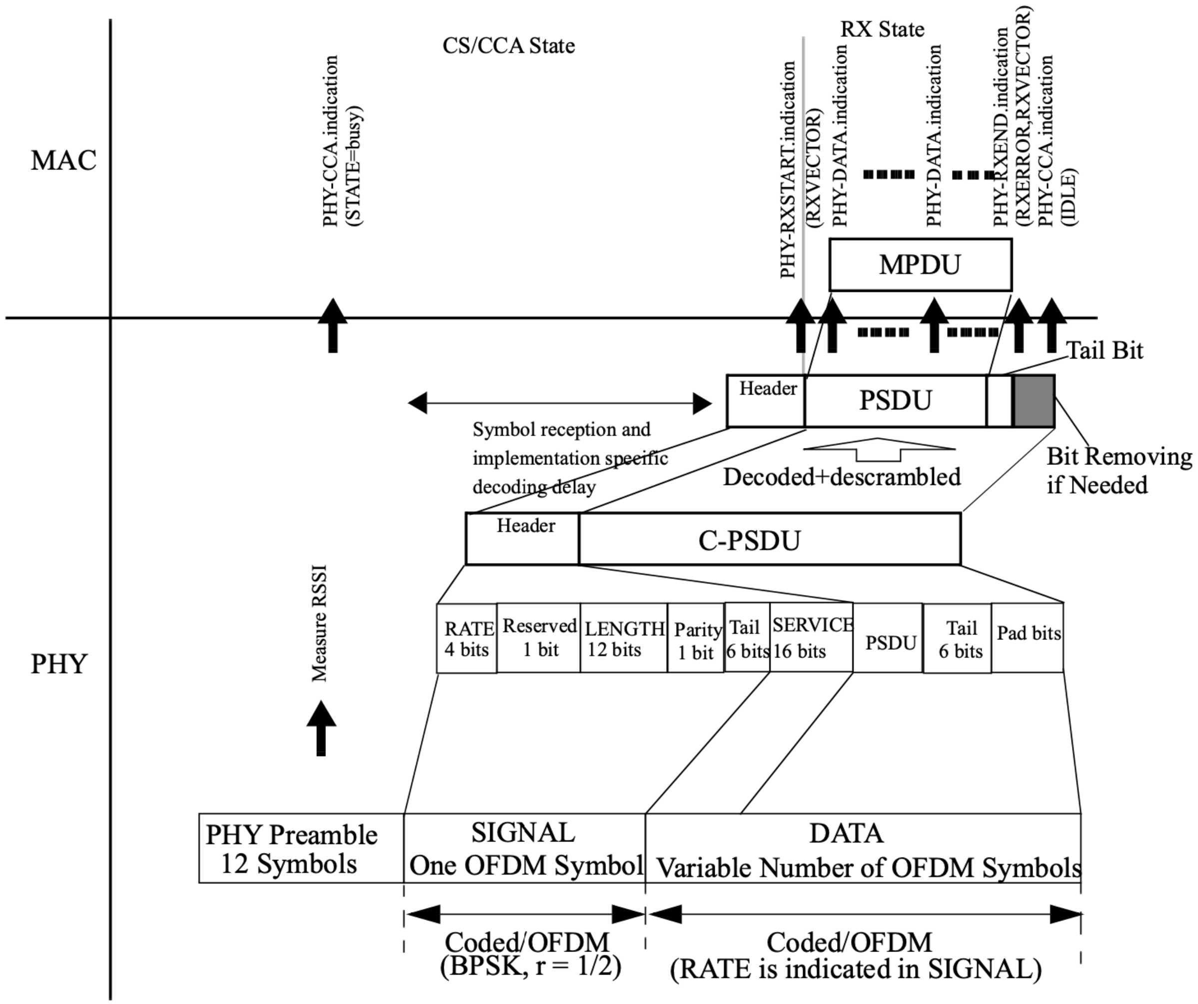


Figure 17-19—Receive PHY

- OFDM PHY Receiver Specification

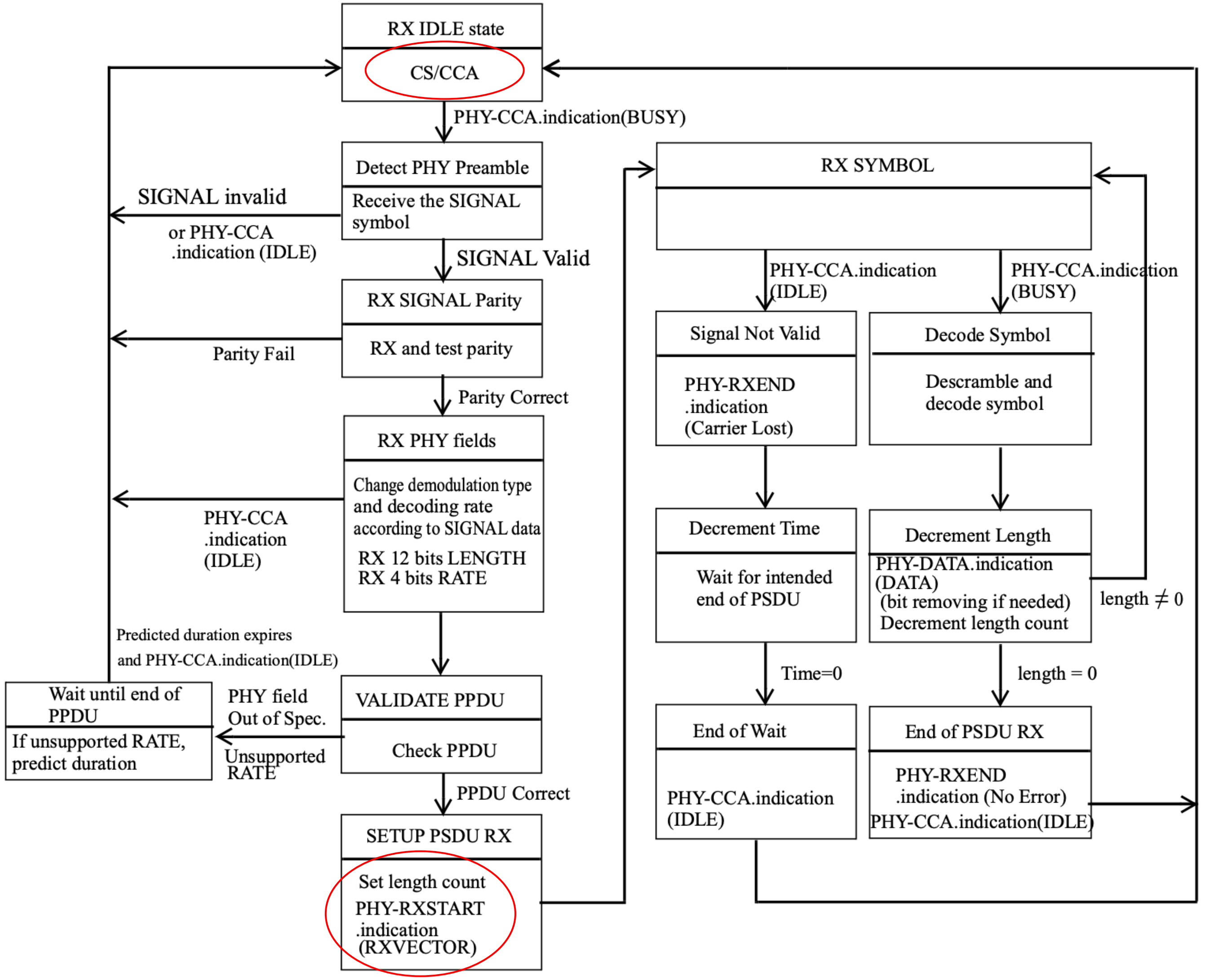


Figure 17-20—PHY receive state machine