Support of 1x/2x/4x OFDM Symbol in HE SU PPDU

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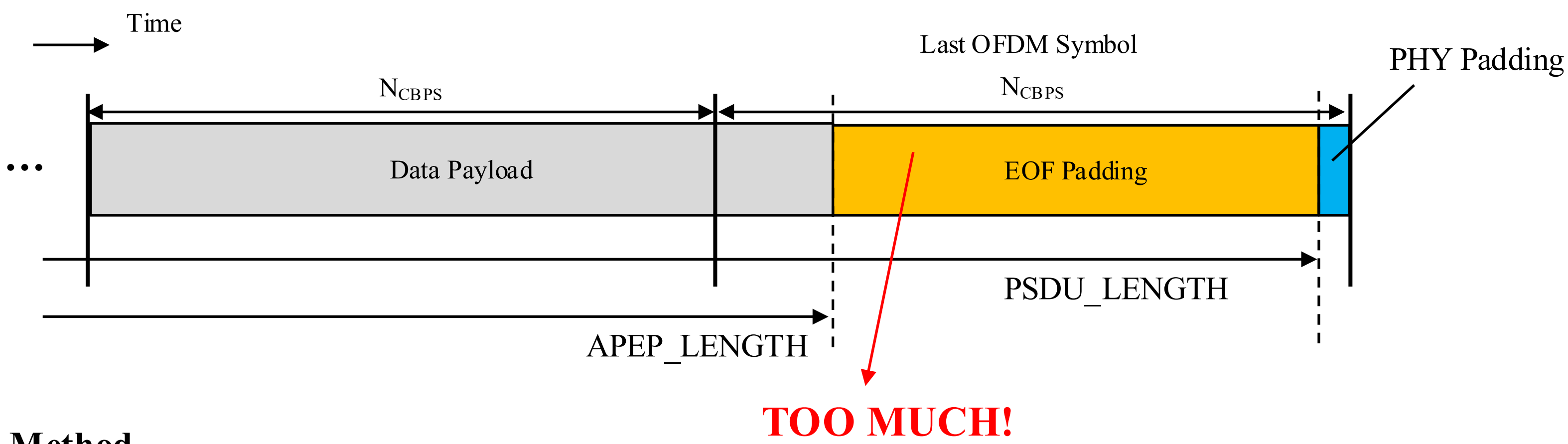
Background

- **In [1], an efficient padding method was proposed. In this submission, we explain the more details of the proposed method.**
  - By adjusting the duration of the last OFDM symbol, e.g., 1x, 2x, and 4x OFDM symbol, the padding inefficiency caused by increasing OFDM symbol duration can be reduced.

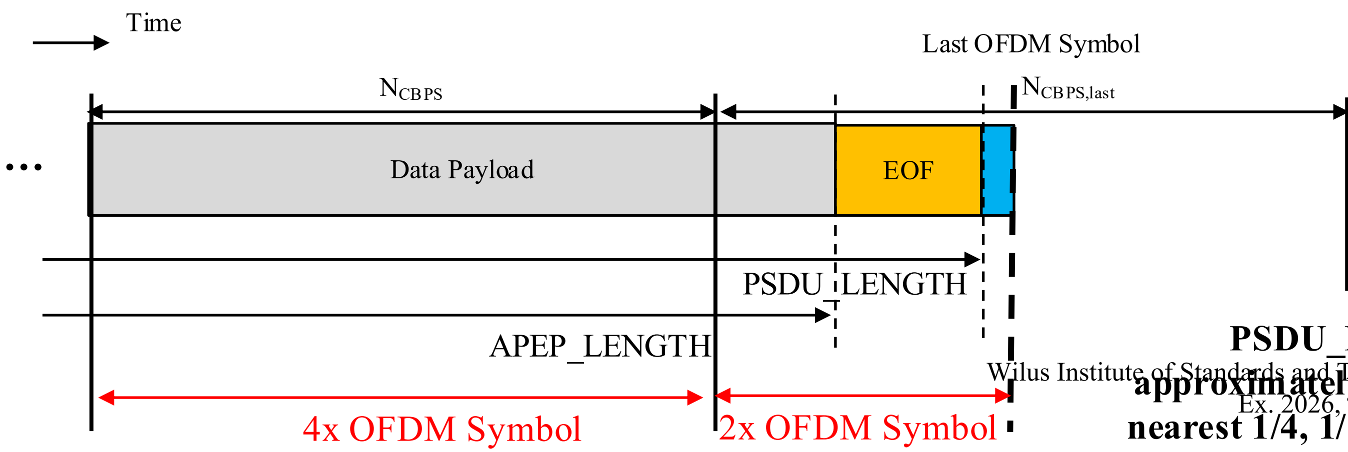
- **Furthermore, we analysis relationship between our proposed method and PHY padding and packet extension method that was proposed in [2].**

Proposed PSDU_LENGTH Calculation

11ac PSDU_LENGTH calculation rules



Proposed Method

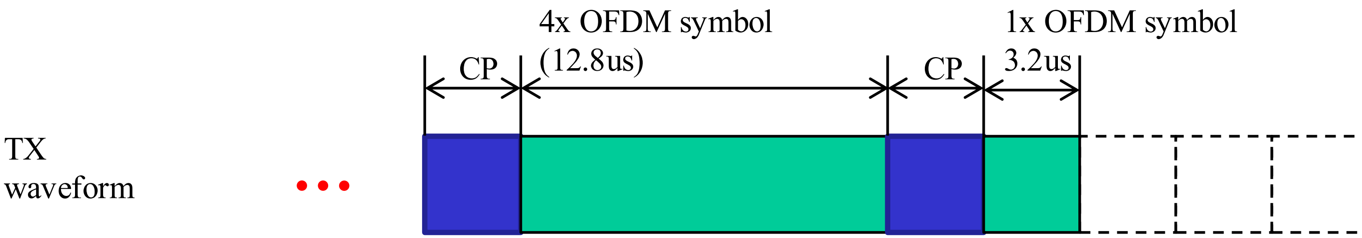


PSDU_LENGTH is approximately calculated to the nearest 1/4, 1/2, or 1 times N_{CBPS}

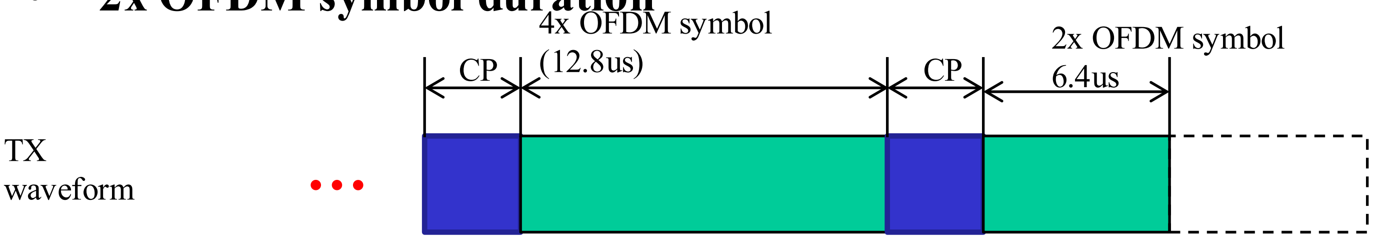
Proposed Frame Structure for HE SU PPDU

1x/2x OFDM symbol only applied to the last OFDM symbol.

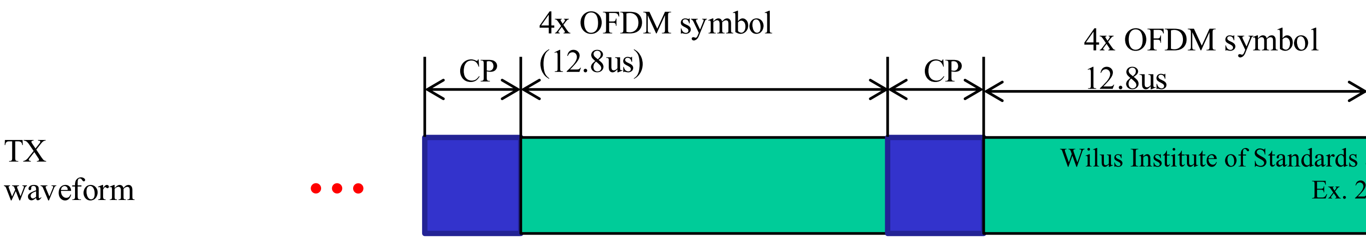
- **1x OFDM symbol duration**



- **2x OFDM symbol duration**



- **4x OFDM symbol duration**



PSDU_LENGTH Calculation Process

1. **Calculate the numbers of OFDM symbols and bits in the last symbol ($N_{SYM,init}$, $N_{Dbit,last}$).**
2. **Determine the number of data subcarrier in the last symbol ($N_{SD,1x}$, $N_{SD,2x}$, $N_{SD,4x}$) and $N_{DPBS,last,init}$, $N_{CBPS,last,init}$.**
3. **For LDPC cases, update N_{SYM}, N_{avbits} depending on the conditions of OFDM symbol extension.**
4. **Calculate the number of padding bits N_{pad}.**

- **Details and examples shown in Appendix**

Relationship with PHY Padding Proposal in [2]

- **PHY Padding proposal in [2] addressed a different aspect of the decoding process. Padding is used to give extra processing time at the receiver for high data rate transmissions. The padding is used for OFDM and OFDMA transmissions.**
- **Our proposal, support of 1x/2x/4x OFDM symbol, targets small payload transmissions in OFDM transmissions. We reduce amount of EOF padding performed and transmit air-time.**
- **However, both proposals change how PSDU_LENGTH is computed and differ in how data tones are mapped to the last OFDM symbol. Therefore, it has potential conflict even though they target very different scenarios and operation modes.**
- **Note that the use of packet extension in [2] can still be applied to 1x/2x/4x OFDM symbol proposal.**

Use Cases for 1x/2x/4x OFDM Symbol and PHY Padding in [2]

Use Case	Small Payload	Large Payload
Low Rate or Small BW	1x/2x/4x OFDM symbol	N/A
High Rate & Large BW	1x/2x/4x OFDM symbol / PHY Padding in [2]	PHY Padding in [2]

- **The two proposal actually have distinct use cases.**
  - The PHY padding in [2] is useful when data rate is high and data bandwidth is large (in both OFDM and OFDMA transmissions).
  - 1x/2x/4x OFDM symbol support is useful when payload sizes is small in OFDM transmissions.
- **Small payload with high data-rate and large bandwidth case (overlap case)**
  - This seems to be a unlikely operating scenario, as allocating larger bandwidth to send small payload would be very wasteful. Furthermore, small payload will result in a single LDPC codeword which may not require any PHY padding.
- **Each solution can be applied to different TX/RXVECTOR configurations**

Conclusion

- The details of a padding method are explained with 1x, 2x, 4x last OFDM symbol duration.
- By exploiting the repeated waveform in 1x, 2x symbol duration cases, we can achieve throughput gain shown in [1].
- Because the computation of PSDU_LENGTH and data tone mapping of the last OFDM symbol have potential conflict with the proposal in [2], careful merger is needed if both proposals are to be supported in 802.11ax.

APPENDIX: ENCODING PROCESS

PSDU_LENGTH Calculation Process

- **Definition of variables**

$$N_{CBPS,1\square} = N_{SD,1\square} \square N_{SS} \square N_{BPSCS}, \quad N_{DBPS,1\square} = \square N_{CBPS,1\square} \square R \square$$

$$N_{CBPS,2\square} = N_{SD,2\square} \square N_{SS} \square N_{BPSCS}, \quad N_{DBPS,2\square} = \square N_{CBPS,2\square} \square R \square$$

$$N_{CBPS,4\square} \left(= N_{CBPS}\right) = N_{SD,4\square} \square N_{SS} \square N_{BPSCS}, \quad N_{DBPS,4\square} \left(= N_{DBPS}\right) = \square N_{CBPS,4\square} \square R \square$$

- **Calculate $N_{SYM,init}$.**

$$N_{SYM,init} = \begin{cases} m_{STBC} \left\lceil \dfrac{8 \cdot \text{APEP\_LENGTH} + N_{tail} N_{ES} + N_{service}}{m_{STBC} N_{DBPS}} \right\rceil & \text{for BCC} \\ m_{STBC} \left\lceil \dfrac{8 \cdot \text{APEP\_LENGTH} + N_{service}}{m_{STBC} N_{DBPS}} \right\rceil & \text{for LDPC} \end{cases}$$

PSDU_LENGTH Calculation Process (cont.)

- **Calculate the number of data bits in the last OFDM symbol.**

$$N_{Dbit,last} = \begin{cases} \mathrm{mod}\left(8 \cdot \mathrm{APEP\_LENGTH} + N_{tail} N_{ES} + N_{service},\quad m_{STBC} N_{DBPS}\right) & \text{for BCC} \\ \mathrm{mod}\left(8 \cdot \mathrm{APEP\_LENGTH} + N_{service},\quad m_{STBC} N_{DBPS}\right) & \text{for LDPC} \end{cases}$$

- **Define $N_{SD,1x}$, $N_{SD,2x}$, and $N_{SD,4x}$ (= N_{SD}) depending on channel BW**

	$N_{SD,1x}$	$N_{SD,2x}$	$N_{SD,4x}$
20MHz	48	102	234
40MHz	102	234	458
80MHz	240	480	980
160MHz	480	980	980*2

  – N_{SD} is defined in 11ax . Use of above parameters result in re-use of agreed BCC interleaver parameters.

PSDU_LENGTH Calculation Process (cont.)

- **If $0 < N_{Dbit,last} \leq m_{STBC} \times N_{DBPS,1x}$, (1x OFDM symbol duration)**
  - $N_{DBPS,last,init} = N_{DBPS,1x}$ ($N_{CBPS,last,init} = N_{CBPS,1x}$)
  - BCC case: interleaver size = $N_{SD,1x}$
  - Data subcarrier with 4k (k=1,2…) indices excluding DC and pilot tones are used.

- **If $m_{STBC} \times N_{DBPS,1x} < N_{Dbit,last} \leq m_{STBC} \times N_{DBPS,2x}$, (2x OFDM symbol duration)**
  - $N_{DBPS,last,init} = N_{DBPS,2x}$ ($N_{CBPS,last,init} = N_{CBPS,2x}$)
  - BCC case: interleaver size = $N_{SD,2x}$
  - Data subcarrier with 2k (k=1,2…) indices excluding DC and pilot tones are used.

- **If $m_{STBC} \times N_{DBPS,2x} < N_{Dbit,last} \leq m_{STBC} \times N_{DBPS,4x}$, (4x OFDM symbol duration)**
  - $N_{DBPS,last,init} = N_{DBPS,4x} (=N_{DBPS})$ ($N_{CBPS,last,init} = N_{CBPS,4x} (=N_{CBPS})$)
  - BCC case: interleaver size = $N_{SD,4x} (=N_{SD})$
  - Data subcarrier with k (k=1,2…) indices excluding DC and pilot tones are used.

PSDU_LENGTH Calculation Process (cont.)

- **PSDU_LENGTH**
  - BCC

$$\text{PSDU\_LENGTH} = \left\lfloor \frac{(N_{SYM,init} - m_{STBC}) \cdot N_{DBPS} + m_{STBC} \cdot N_{DBPS,last,init} - N_{Tail} \cdot N_{ES} - N_{service}}{8} \right\rfloor$$

  - LDPC

$$\text{PSDU\_LENGTH} = \left\lfloor \frac{(N_{SYM,init} - m_{STBC}) \cdot N_{DBPS} + m_{STBC} \cdot N_{DBPS,last,init} - N_{service}}{8} \right\rfloor$$

Special Cases for LDPC encoding

- **Calculate $N_{DBPS,last,init}$ and $N_{CBPS,last,init}$**

$$N_{CBPS,last,init}, N_{DBPS,last,init}$$

- **Calculate N_{pld} and N_{avbits}.**

$$N_{pld} = \left(N_{SYM,init} - m_{STBC}\right) \cdot N_{DBPS} + m_{STBC} \cdot N_{DBPS,last,init}$$

$$N_{avbits,init} = \left(N_{SYM,init} - m_{STBC}\right) \cdot N_{CBPS} + m_{STBC} \cdot N_{CBPS,last,init}$$

Special Cases for LDPC encoding (cont.)

- **With above parameters, determine {L_{LDPC}, N_{CW}, N_{shrt}, N_{rep}, N_{punc}} as in 11n/11ac.**
  - **In the puncturing step, if one of conditions for LDPC OFDM symbol extension is met,**

$$N_{CBPS,last} = \begin{cases} N_{CBPS,2\times}, \\ N_{CBPS,4\times}, \\ N_{CBPS,1\times}, \end{cases} \quad N_{DBPS,last} = \begin{cases} N_{DBPS,2\times}, \\ N_{DBPS,4\times}, \\ N_{DBPS,1\times}, \end{cases} \quad N_{SYM} = \begin{cases} N_{SYM,init}, & \text{if} \quad N_{DBPS,last,init} = N_{DBPS,1\times} \\ N_{SYM,init}, & \text{if} \quad N_{DBPS,last,init} = N_{DBPS,2\times} \\ N_{SYM,init} + m_{STBC,} & \text{if} \quad N_{DBPS,last,init} = N_{DBPS,4\times} \end{cases}$$

$$N_{avbits} = \left(N_{SYM} - m_{STBC}\right) \cdot N_{CBPS} + m_{STBC} \cdot N_{CBPS,last}$$

  - **Re-compute Npunc, Nrep based on updated parameters.**

PHY Padding Bits

- **Calculation of the number of PHY padding bits (0~7 bits)**
  - BCC

$$N_{PAD} = (N_{SYM} - m_{STBC}) \cdot N_{DBPS} + m_{STBC} \cdot N_{DBPS,last} - 8 \cdot \mathrm{PSDU\_LENGTH} - N_{Tail} \cdot N_{ES} - N_{service}$$

  - LDPC

$$N_{PAD} = (N_{SYM} - m_{STBC}) \cdot N_{DBPS} + m_{STBC} \cdot N_{DBPS,last} - 8 \cdot \mathrm{PSDU\_LENGTH} - N_{service}$$

Example) LDPC Case

- **APEP_LENGTH = 1000, MCS7 (64-QAM, 5/6-code), Nss = 1, No STBC. 40MHz Channel**
- **$N_{DBPS,4x}$ = 2290, $N_{DBPS,2x}$ = 1170, $N_{DBPS,1x}$ = 510**
- **$N_{CBPS,4x}$ = 2748, $N_{CBPS,2x}$ = 1404, $N_{CBPS,1x}$ = 612**

- **$N_{SYM,init}$ = ceil((8*1000+16)/2290) = 4**
- **$N_{Dbit,last}$ = (8*1000+16)-2290*3 = 1146**
  - The last symbol is 2x OFDM symbol.
  - $N_{DBPS,last,init} = N_{DBPS,2x}$=1170, $N_{CBPS,last,init} = N_{CBPS,2x}$ =1404.

Example) LDPC Case (cont.)

- **N_{pld} = 3*2290 + 1*1170 = 8040**
- **N_{avbits} = 3*2748 + 1*1404 = 9648**

- **From Table 20-16,**
  - N_{CW} = ceil(8040/(1944*5/6)) = 5
  - L_{LDPC} = 1944
- **N_{shrt} = 5*1944*5/6-8040 = 60**
- **N_{punc} = 5*1944-9648-60 = 12, No symbol extension.**
  - $N_{SYM} = N_{SYM,init}$
  - $N_{DBPS,last,init} = N_{DBPS,2x}$=1170, $N_{CBPS,last,init} = N_{CBPS,2x}$ =1404.