

Efficient padding for last OFDM Symbol

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Background

- **According to SFD [1], data symbols in an HE PPDU shall use a DFT period of 12.8 μ s and subcarrier spacing of 78.125 kHz.**
 - 256 subcarriers are defined in 20MHz bandwidth.
- **In [2], the padding overhead in the last symbol was analyzed in SU transmission .**
 - 12.8us OFDM symbol duration can cause excessive padding and result in throughput loss.
 - Especially for OFDM transmission with wide BW, high MCS, and many STSs.

Ratio btw padding bits and data bits [2]

Padding bits with typical packets

	40 +44bytes ¹	576+44bytes ²	1500+44bytes ³
MCS0 (80MHz, NSTS = 1)	45.8%	8.67%	3.14%
MCS1 (80MHz, NSTS = 1)	45.8%	18.6%	3.14%
MCS2 (80MHz, NSTS = 1)	119%	18.6%	7.11%
MCS3 (80MHz, NSTS = 1)	192%	18.6%	11.1%
MCS4 (80MHz, NSTS = 1)	338%	18.6%	19.0%
MCS5 (80MHz, NSTS = 1)	483%	58.1%	26.9%
MCS6 (80MHz, NSTS = 1)	556%	77.8%	7.11%
MCS7 (80MHz, NSTS = 1)	629%	97.6%	19.0%
MCS8 (80MHz, NSTS = 1)	775%	18.6%	42.8%

¹ IPv4 TCP/IP ACK (without option) : 40 bytes + 4 bytes (A-MPDU header) + 32 bytes (MAC header + FCS) + 3 bytes (LLC header) + 5 bytes (SNAP extension LLC header)

² Minimum IPv4 datagram size : 567 bytes + 44 (MAC & LLC overhead)

³ Ethernet MTU : 1500 bytes + 44 bytes (MAC & LLC overhead)

Reducing symbol duration

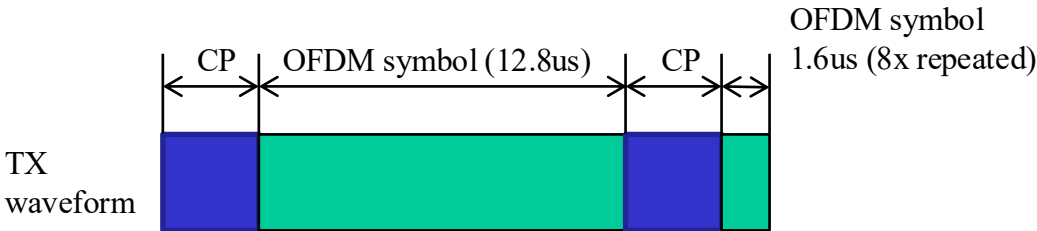
- **Adjust the duration of the last OFDM symbol**
 - Similar concept in 2x HE-LTF design.
 - 2x HE-LTF uses only even tones. (only half of the IDFT output is transmitted)
 - If the even tones($2k$, $k=\pm 1, \pm 2, \pm 3, \dots$) are used, the output of IDFT has two repeated waveform. With the first half, we can decode the OFDM symbol. (The red indices can or cannot be included depending on the number of DC tones)
 - If the every 4th tones($4k$, $k=\pm 1, \pm 2, \pm 3, \dots$) are used, the output of IDFT has 4 repeated waveform. With the first quarter, we can decode the OFDM symbol.
 - and so on

Easing Implementation Complexity

- **Different number of available tones for data typically requires new BCC interleaver design.**
- **Avoid new BCC interleaver design and only use tone sizes that existing OFDM RU sizes offer.**
 - For example, 24/48/102/234 data tones from 26/56/106/242-tone RUs in SFD.
- **Re-use BCC interleaver designs for OFDM RUs**

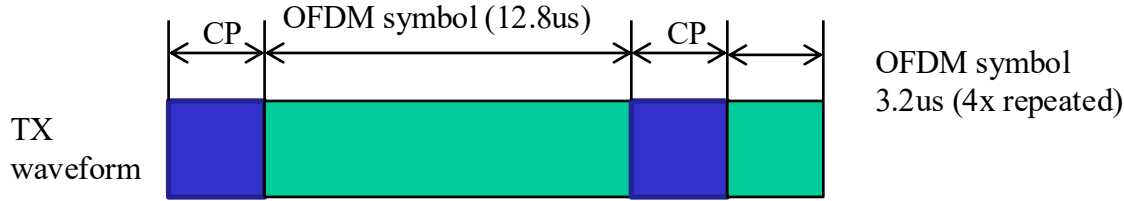
TX Frame structure (last two symbols)

- Case 1**



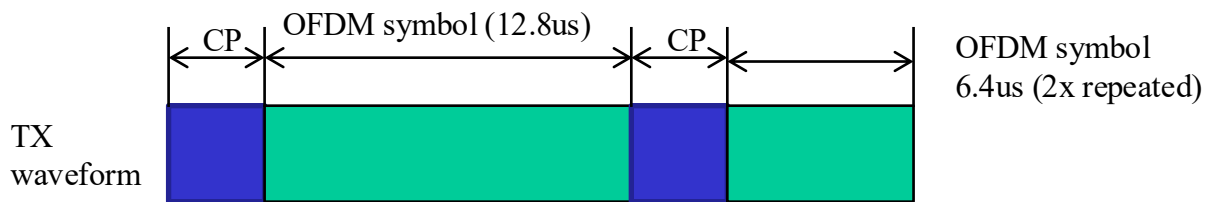
TX waveform

OFDM symbol 1.6us (8x repeated)
- Case 2**



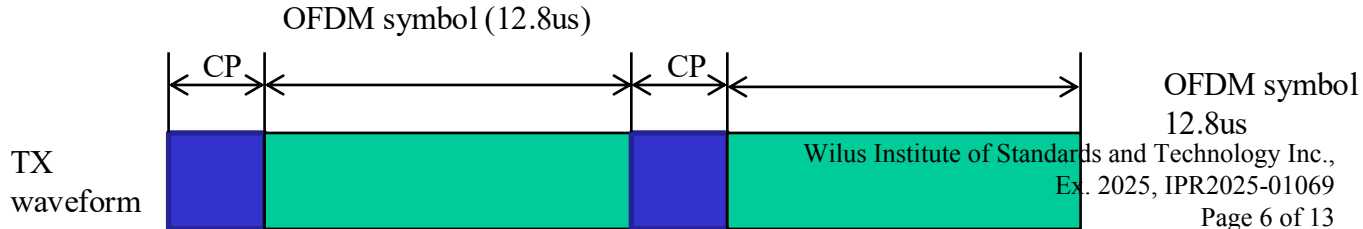
TX waveform

OFDM symbol 3.2us (4x repeated)
- Case 3**



TX waveform

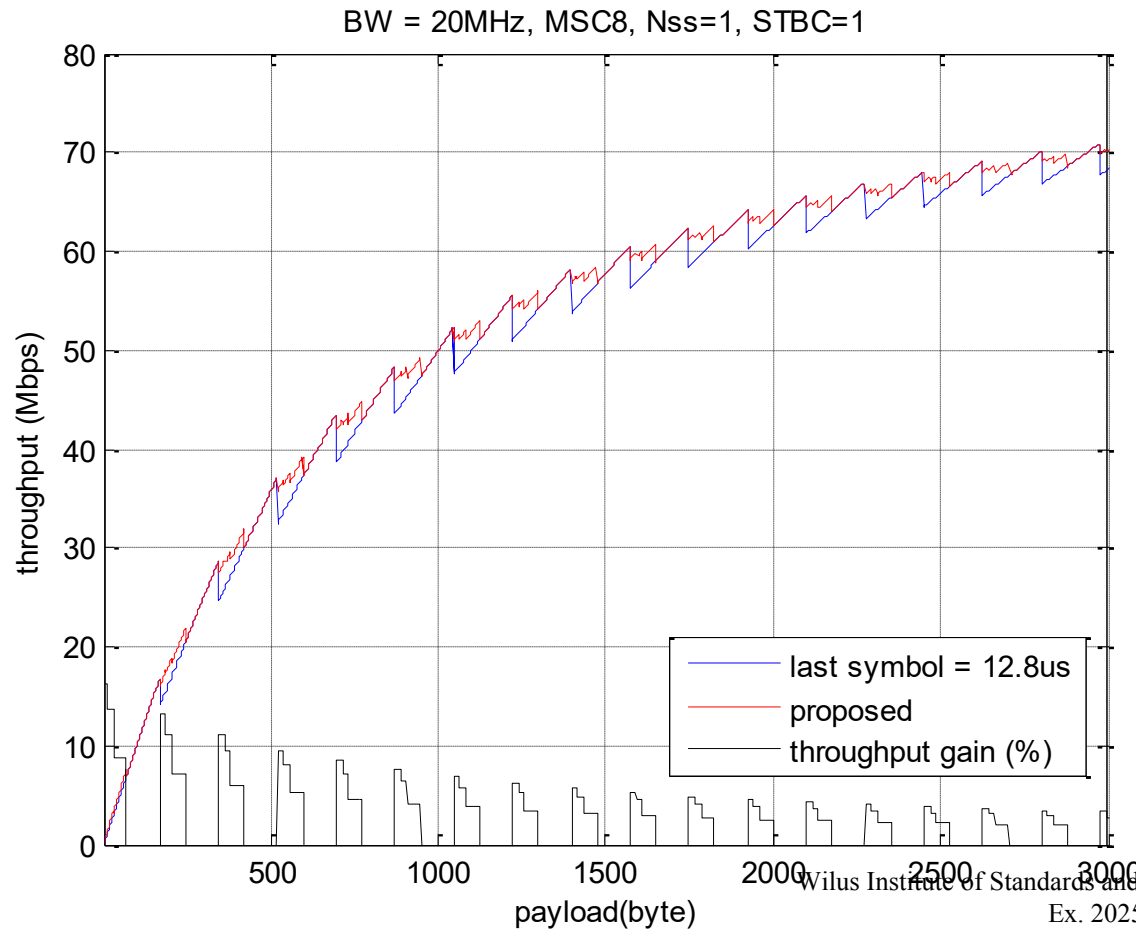
OFDM symbol 6.4us (2x repeated)
- Case 4**



TX waveform

OFDM symbol 12.8us

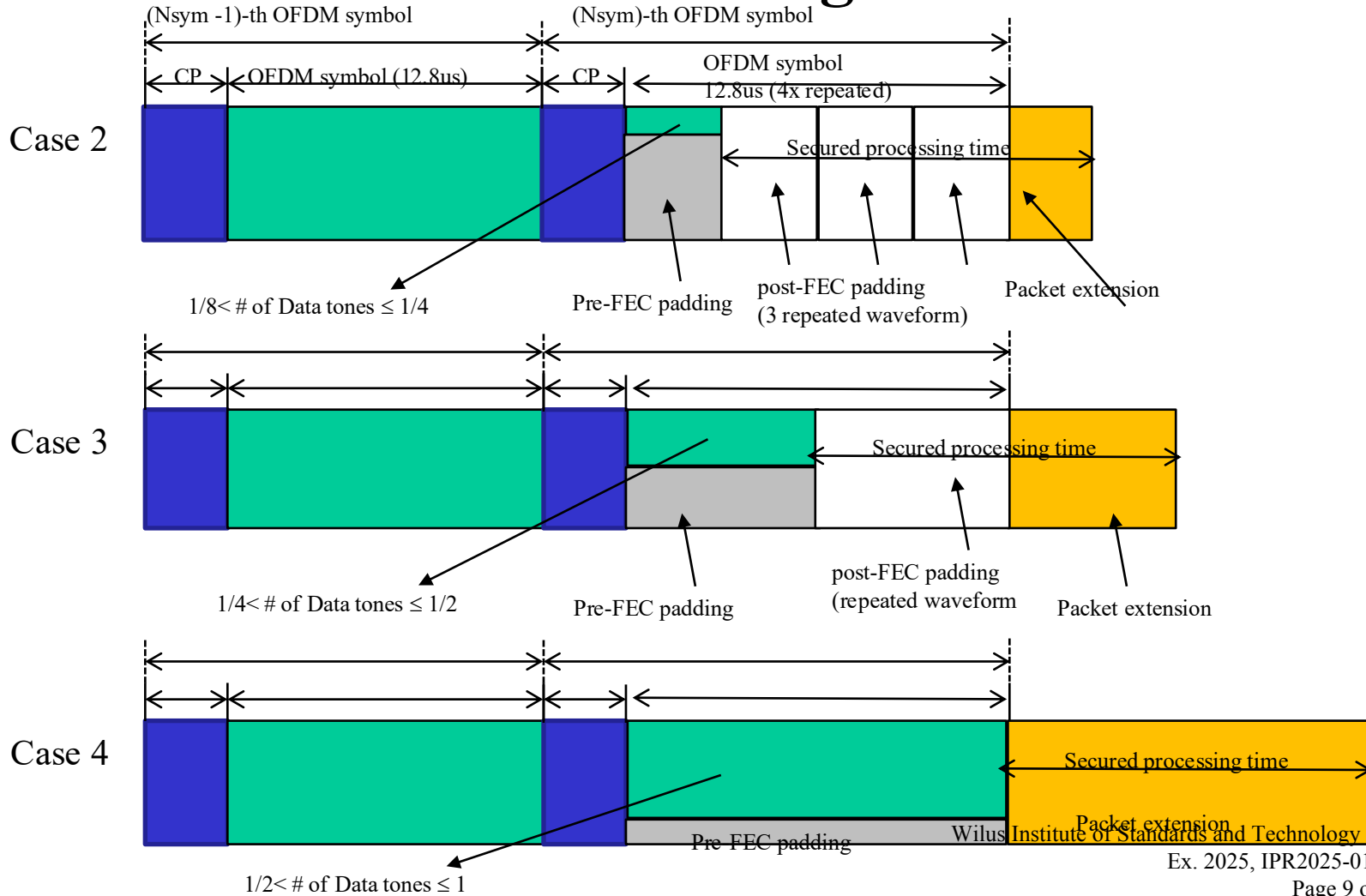
Throughput gain



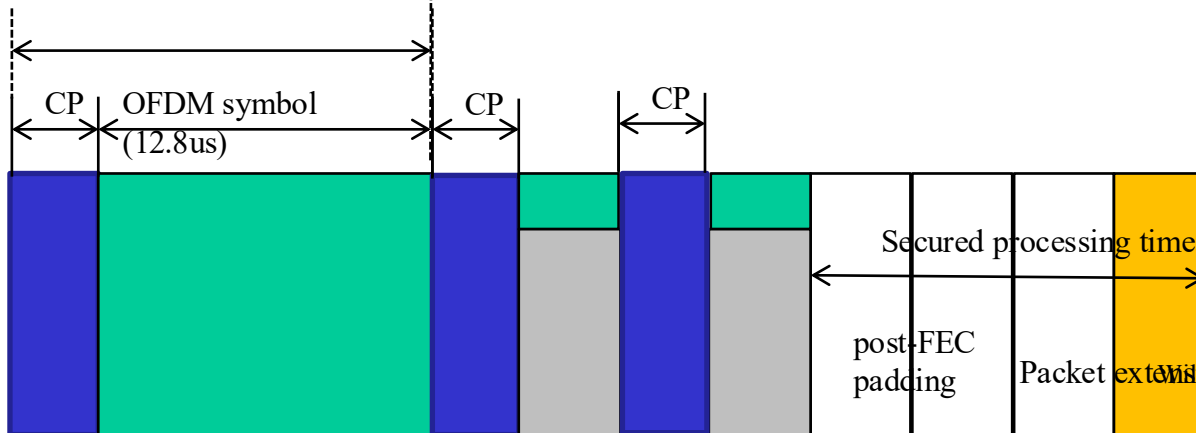
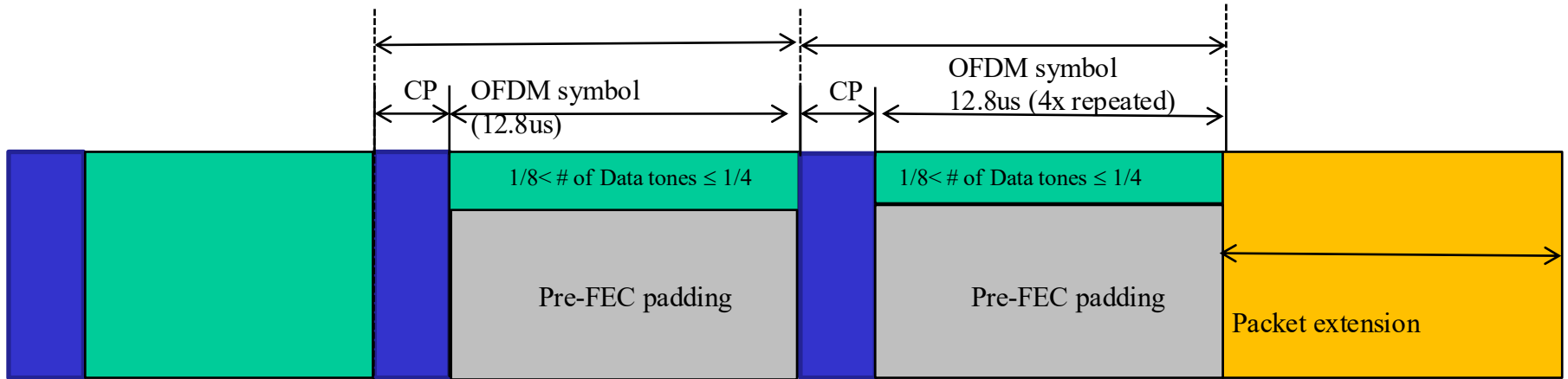
Decoding latency and packet extension

- **Factors of decoding latency**
 - FFT operation
 - Buffer delay
 - FEC decoding
 - Etc
- **Among the above factors, “buffer delay” may be one of dominant factors.**
- **Depending on the number of data tones, the packet extension after the last OFDM symbol can be needed.**
 - In the last symbol, the repeated waveforms are transmitted prior to the packet extension.

CASE 2 – 4 with signal extension



STBC in CASE 2



Conclusions

- **Depending on payload size, the last OFDM symbol duration is changed.**
- **By adjusting the duration of the last OFDM symbol, we can reduce the padding inefficiency caused by increasing OFDM symbol duration.**
- **To secure processing time at receivers, signal extension can be applied more effectively.**

Straw poll

- **Do you support the concept**

HE shall include mechanisms to enhance the MAC/PHY padding efficiency by adjusting OFDM symbol duration in the last OFDM symbol for SU transmissions.

Reference

- **[1] 11-15-0132-05-00ax-Specification Framework for Tgax**
- **[2] 11-15-0572-01-00ax-PHY inefficiency of 256FFT per 20MHz**