5G PHY Layer Processing – Transport Block Segmentation

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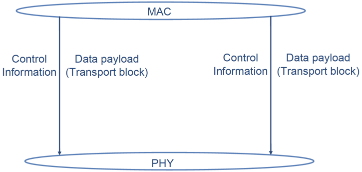
Simulation-Based Design of 5G Wireless Standards (EE698H)

Agenda for today

- Discuss transport block segmentation
  - Section 5.2.2 of 36.218
- Very very briefly LDPC encoding
  - Reference – Chap 4.1.7.3 of 5G NR by SassanA for LDPC

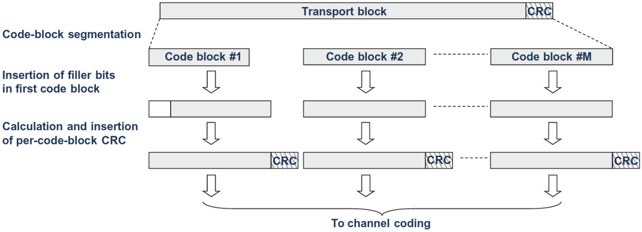
Recap – 5G MAC-PHY interface at BS and UE



- MAC layer will pass data and control to PHY layer to process
- Control information – MCS index,
- PHY has a transport block (data payload) which needs to be
  - First encoded at a particular rate and
  - Later mapped using 4/16/64/256-QAM
- Data payload in 5G language- Physical Downlink Shared Channel (PDSCH)
- Control information in 5G language - Physical Downlink Control Channel (PDCCH)

Transport block segmentation

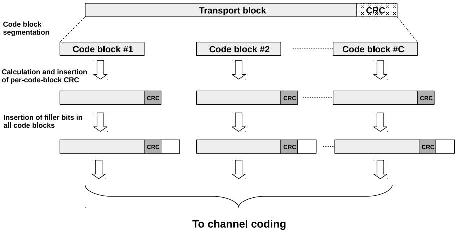
- Maximum input code block size which 5G LDPC encoder can process $(= K_{cb})$ – 8448/3840
- Transport block size can be greater than LDPC code block size
  - Maximum Transport block size (for MCS-26 and 275 RBs)- 319874
- TB should be segmented if TB length + 24-bit TB-CRC $= B > K_{cb}$



CRC for segmented code blocks

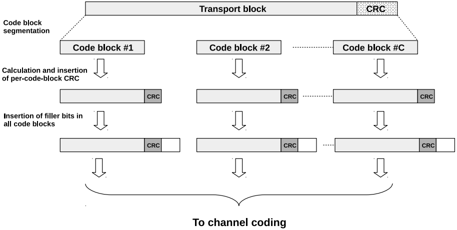
- Why not limit the maximum input code block size of LDPC encoder to largest TB size
  - Decoding complexity increases with increase in code block length
  - To reduce the encoding/decoding time by running multiple LDPC encoders/decoders in parallel
- CRC is computed for each segmented code block along with transport block
  - Allows error detection at the segmented code-block level and request for their retransmission
- Why do we need CRC for transport block when each segmented code-block has a CRC
  - Duplication of efforts?
  - Different polynomials for transport block CRC and segmented code-block CRC
  - Allows detection of any residual errors

Transport block segmentation (1)



- Maximum input code block size which 5G LDPC encoder can process ($= K_{cb}$) – 8448/3840
- Transport block (TB) size can be greater than LDPC code block size
  - Maximum TB block size (for MCS-27 and 275 RBs)- 319784,
- TB should be segmented if TB length + 24-bit TB-CRC $= B > K_{cb}$

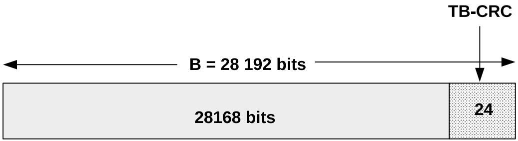
Transport block segmentation (2)



- C = total number of segmented code-blocks
- If $C = 1$, 24-bit TB-CRC is only used
- If $C > 1$, an additional CB-CRC of length $(L = 24)$ is attached to each codeblock

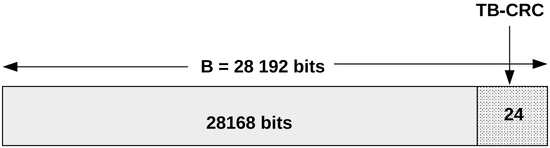
Wrong way of segmenting a transport block (1)

- Consider this system configuration which we use throughout today's class
  - Assume a user is allocated 70 resource blocks over a slot of 14 symbols
  - MCS-16 (16-QAM), which has a code rate of $658/1024 = 0.642$
- MAC will send a transport block of size 28168 bits
  - Will calculate later



- $B = 28192$ bits that include 28168 data bits and 24 bits transport block CRC (TB-CRC)

Wrong way of segmenting a transport block (2)



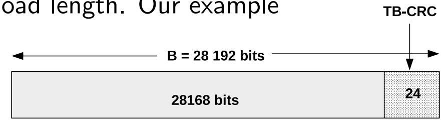
- Segment it into 3 code blocks of size 8448 bits and one of size $28192 - 8448 \times 3 = 2848$ bits
  - Coding gain is less
- Segmentation block ensures that a transport block is divided into equal size code-blocks
- BLER performance is limited by the smallest transport block size
  - Coding gain is less

Segmentation details – as in the standard

- Total number of code-blocks C is determined as below:

$$\begin{array}{llll} \text{if } (B > K_{cb}) & L = 24, & C = \lceil B/(K_{cb} - L) \rceil, B' = B + C \times L \\ \text{if } (B \leq K_{cb}) & L = 0, & C = 1, B' = B \end{array}$$

- B' is effective payload length. Our example



$$\begin{aligned} C &= \lceil B/(K_{cb} - L) \rceil = \lceil 28192/(8448 - 24) \rceil = 4 \\ B' &= B + C \times L = 28192 + 4 \times 24 = 28288 \end{aligned}$$

- Each code block size : $K' = \lceil B'/(C) \rceil = \frac{28288}{4} = 7072$. Not done like this.