5G Physical Layer Processing – CRC Attachment

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

Agenda for today

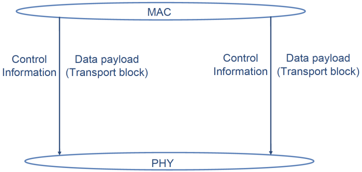
- Discuss 5G protocol architecture
  - Reference – Chap 2.1 of the 5G NR book by SassanA
- Discuss CRC calculation and an algorithm to implement it
  - Reference – Chap 4.1.5 of the 5G NR book by SassanA

5G protocol architecture[1]

- Service data adaptation Protocol (SDAP)
  - Quality of Service (QoS) management
- Packet Data Convergence Protocol (PDCP)
  - Encryption to secure data
- Radio-Link Control (RLC)
  - duplicate detection
- Medium-Access Control (MAC)
  - hybrid-ARQ retransmission, uplink/downlink scheduling
- Physical Layer (PHY)
  - coding/decoding, modulation/demodulation, multi-antenna processing

[1] Chap2.1 of 5G NR SassanA

Our focus – 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)

PHY layer processing of data payload – Overview

- Minimum transport block size (for MCS-0 and 1 RB)- 24
- Maximum transport block size (for MCS-27 and 275 RBs)- 319784
- At the PHY layer, 24/16 bit CRC is attached to the transport block
- CRC performs error detection – does not correct
- An *n*-bit CRC, applied to a data block of arbitrary length, will typically detect
  - any single error burst of length n bits or less
- Essential for HARQ implementation

CRC algorithm[2]

- Transport block is treated by the CRC algorithm as a binary number
- This binary number (after appending necessary zeros) is divided by another binary number
  - Called generator polynomial
  - Division is modulo-2
- Remainder of the division is the CRC checksum, which is appended to the transport block
- Receiver divides the transport block (and appended CRC) by same polynomial used by transmitter
  - If the result of this division is zero, then the transmission was successful
  - If the result is not equal to zero, an error occurred during the transmission

[2] Reference - Wikipedia

Example of CRC generation

- An example six-bit transport block is 1 1 0 1 0 1
- Consider a generator polynomial $= D^2 + 1$ denoted as 1 0 1
- CRC length is equal to the degree of the polynomial
- Append two zeros to the end of the transport block and divide

```
1 1 0 1 0 1 0 0 ÷ 1 0 1 = 1 1 1 0 1
1 0 1
-----
  1 1 1
  1 0 1
  -----
    1 0 0
    1 0 1
    -----
        1 1 0
        1 0 1
        -----
          1 1 0
          1 0 1
          -----
            1 1
```

Quotient (has no function in CRC calculation)

Remainder = CRC checksum

Message with CRC = 1 1 0 1 0 1 1 1

Example of CRC validation

- Transmit transport block is 1 1 0 1 0 1 1 1
- Recall receiver divides the received transport block by same polynomial used by transmitter

```
1 1 0 1 0 1 1 1 ÷ 1 0 1 = 1 1 1 0 1
1 0 1
-----
  1 1 1
  1 0 1
  -----
    1 0 0
    1 0 1
    -----
      1 1 1
      1 0 1
      -----
        1 0 1
        1 0 1
        -----
          0 0
```

Quotient

Checksum is zero, therefore, no transmission error

CRC in polynomial form

- Generator polynomial $= D^2 + 1$ is given as 1 0 1
- Input six-bit transport block 1 1 0 1 0 1 denoted as $a_0 \cdots a_5$
  - In polynomial form $a_0 D^5 + a_1 D^4 + a_2 D^3 + a_3 D^2 + a_4 D^1 + a_5$
- CRC 1 1 is denoted as $p_0 \ p_1$ in polynomial form $p_0 D + p_1$
- Eight-bit transmit transport block is 1 1 0 1 0 1 1 1
  - In polynomial form $(a_0 D^5 + a_1 D^4 + a_2 D^3 + a_3 D^2 + a_4 D^1 + a_5) D^2 + p_0 D + p_1$
- Standard specifies the in above polynomial form – See section 5.1 of 38.212-f20.doc