5G Protocol architecture

→ Service Data Adaptation Protocol (SDAP)
- ⊙ Quality of Service (QoS) management

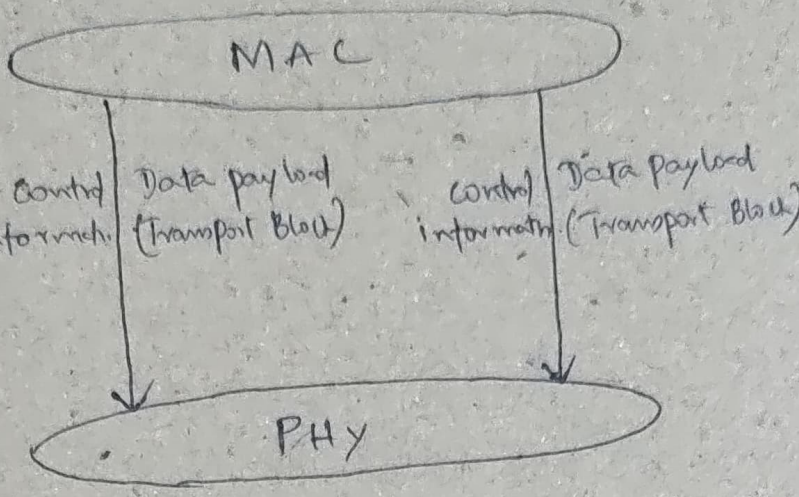
→ Packet Data Convergence Protocol (PDCP)
- ⊙ Encryption to secure data

→ Radio Link Control (RLC)
- ⊙ duplicates detection

→ Medium Access Control (MAC)
- ⊙ hybrid-ARQ retransmission
- ⊙ uplink/downlink scheduling

→ Physical Layer (PHY)
- ⊙ coding / decoding
- ⊙ modulation / demodulation
- ⊙ multi-antenna processing

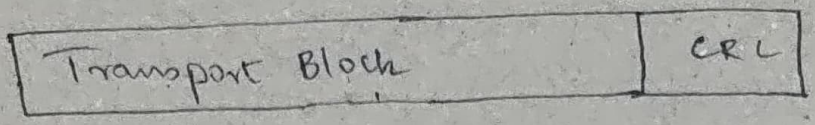
5G MAC - PHY interface at BS and UE



- MAC Layer will pass data and control information to PHY layer for processing.
- Control Information contains MCS index
- PHY has the Data payload (TB) which needs to be
  - → Encoded at a particular rate
  - → Mapped using 4/16/64/256 QAM

  } Specified in MCS table
- Data payload in 5G language – PDSCH
- Control Information in 5G language – PDCCH
- Abbreviation:
  Physical Downlink Shared Channel – PDSCH
  Physical Downlink Control Channel – PDCCH

PHY layer processing of data payload – Overview



→ Minimum TB size = 24 bits (MCS-0, 1 RB)

→ Maximum TB size = 3,19,784 bits (MCS-27, 275 RBs)

Note

1 RB → 12 subcarriers.

12 subcarriers → 1 RB

3300 subcarriers → $\frac{1}{12} \times 3300 = 275$ RBs

→ At the PHY layer, 24/16 bit CRC is attached to the TB

→ 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

→ 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 the 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 occured during the transmission.

→ Example.

* 6-bit TB = 1 1 0 1 0 1
* Generator polynomial = D^2+1
  = 1 0 1
* CRC length = Degree of the polynomial
* Append two zeros to the end of the TB and divide.

Quotient (has no function in CRC calculation)

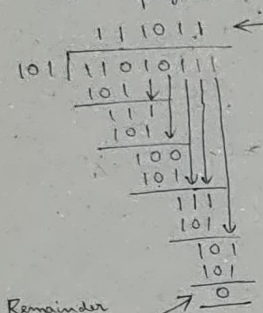
```
        1 1 1 0 1 1
      ┌──────────────
101   │ 1 1 0 1 0 1 0 0
        1 0 1
        ─────
          1 1 1
          1 0 1
          ─────
            1 0 0
            1 0 1
            ─────
              1 1 0
              1 0 1
              ─────
                1 1 0
                1 0 1
                ─────
                  1 1
```

Remainder = CRC Checksum

Message with CRC = 1 1 0 1 0 1 1

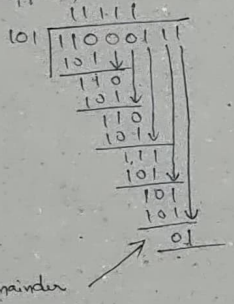
→ Transmit transport block is 11010111

→ Recall, receiver divides the received TB by the same polynomial and by transmitter



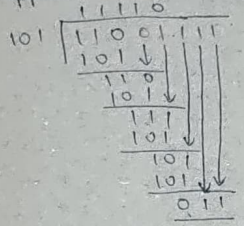
∴ No transmission error

→ Suppose, the transmit transport block has 1 bit error



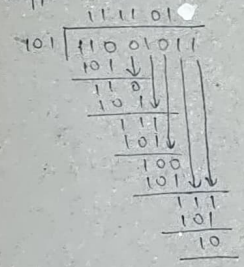
∴ There is transmission error.

→ Suppose, the transmit TB has 2 bits error



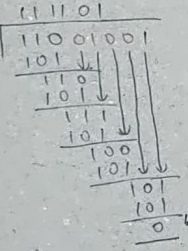
∴ There is transmission error

→ Suppose, the transmit TB has 3 bits error



∴ There is transmission error.

→ Suppose, the transmit TB has 4 bits error



CRC in polynomial form

→ Generator Polynomial → D^2+1
→ 1 0 1

→ Input six bit TB → 1 1 0 1 0 1
→ denoted as $a_0 \dots a_5$

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
→ denoted as $P_0\ P_1$

In polynomial form,

$$P_0 D^1 + P_1$$

→ Eight bit transmit TB → 1 1 0 1 0 1 1 1

In polynomial form,

$$\left(a_0 D^5 + a_1 D^4 + a_2 D^3 + a_3 D^2 + a_4 D^1 + a_5\right) D^2 + P_0 D^1 + P_1$$

→ Standard specifies the above polynomial form
(section 5.1 of 38.212-f20.doc)