5G-NR PHY Layer Processing – Rate Matching (2)

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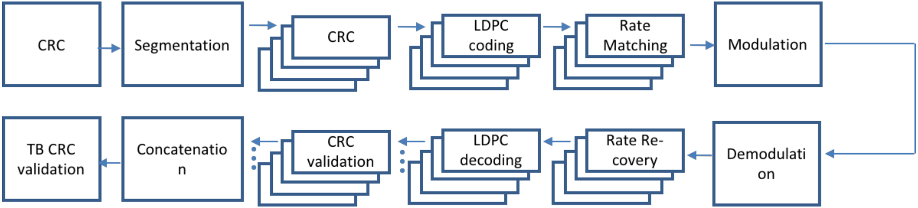
Simulation-Based Design of 5G Wireless Standards (EE698H)

Agenda for today

- Finish discussing rate matching
    - References mentioned later in the slides

5G transceiver chain till rate matching/rate recovery



Second rate matching example (1)

- MCS-0 (4-QAM) for which code rate is 120/1024. Consider $\mathrm{N}_{\mathrm{PRB}} = 10$ over one slot
- Effective transport block size $= 368 + 24 = 392$. Total number of coded blocks $= 1$;

Set Index i_{LS}	Set of Lifting Sizes Z_C
0	{2,4,8,16,32,64,128,256}
1	{3,6,12,24,48,96,192,384}
2	{5,10,20,40,80,160,320}
3	{7,14,28,56,112,224}
4	{9,18,36,72,144,288}
5	{11,22,44,88,176,352}
6	{13,26,52,104,208}
7	{15,30,60,120,240}

- Minimum value of Z_c from Table 5.3.2-1 such that

$$\begin{aligned} K_b \times Z_c &= K \geq K' \\ \Rightarrow 22 \times 18 &= \underbrace{396}_{K} \geq \underbrace{392}_{K'} \end{aligned}$$

Second rate matching example (2)

Set Index i_{LS}	Set of Lifting Sizes Z_C
0	{2,4,8,16,32,64,128,256}
1	{3,6,12,24,48,96,192,384}
2	{5,10,20,40,80,160,320}
3	{7,14,28,56,112,224}
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- Filler bits are added to match to suitable lifting size, and its number is

$$F = K - K' = 396 - 392 = 4$$

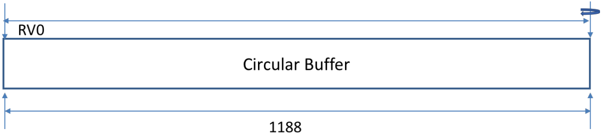
- Total of one code block of size $K = 396$ bits with filler bits $F = 4$
- LDPC encode output for each segmented code block $N_r = 66 \times 18 = 1188$

Second rate matching example (3)

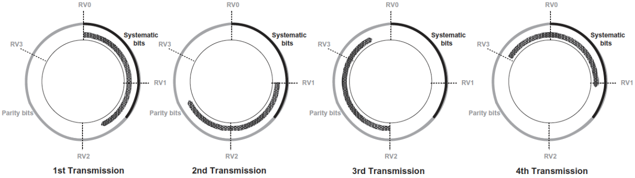
- LDPC encoder rate = 396/1188=1/3
- Total number of bits which can be transmitted for 10 PRBS

$$G = 10(\text{NPRB}) \times 162(\text{RE}) \times 2(\text{4QAM}) = 3240$$

- Length of rate-matched block $E = G/C = 3240/1 = 3240$
- RV indices $k_0 = 0, 306, 594, 1008$

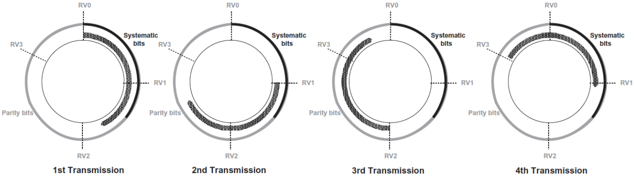


Objective of the rate matching block (1)



- Encoded output is directly written in a circular buffer
- Calculates number of bits to be read for each of the rate 1/3 encoded block
- Bits are read from buffer, starting from offset position and increasing bit index
- If bit index reaches its maximum, it is reset to the first bit in the buffer
- Redundancy version (RV) specifies a starting point in the circular buffer

Objective of the rate matching block (2)



- Different RVs are specified by defining different starting points
- Usually RV-0 is selected for initial transmission – sends large number of systematic bits
- Scheduler can choose different RVs to support Chase and IR HARQ
- Systematic bits are also punctured;enhances performance at high-code rates

RV position calculation in circular buffer

rv_{id}	k_0	
	LDPC Base Graph 1	LDPC Base Graph 2
0	0	0
1	$\left\lfloor \frac{17N_{cb}}{66Z_c} \right\rfloor Z_c$	$\left\lfloor \frac{13N_{cb}}{50Z_c} \right\rfloor Z_c$
2	$\left\lfloor \frac{33N_{cb}}{66Z_c} \right\rfloor Z_c$	$\left\lfloor \frac{25N_{cb}}{50Z_c} \right\rfloor Z_c$
3	$\left\lfloor \frac{56N_{cb}}{66Z_c} \right\rfloor Z_c$	$\left\lfloor \frac{43N_{cb}}{50Z_c} \right\rfloor Z_c$

- Consider $N_{cb} = N$ in our case
- RV index $k_0 = 0$,
- RV index $k_1 = \lfloor \frac{17N}{66Z_c} \rfloor = 5984$
- RV index $k_2 = 11616$
- RV index $k_3 = 19712$

Rate matching in the standard (1)[1]

- Recall bits output from LDPC encoder are denoted as $d_0, d_1, d_2, d_3, \ldots, d_{(N-1)}$
- Bits Input to rate matcher are denoted as $d_0, d_1, d_2, d_3, \ldots, d_{(N-1)}$
- Bits output of rate matcher are denoted as $e_0, e_1, f_2, e_3, \ldots, e_{(E-1)}$

[1] (Sec 5.4.2 of 38.212)

Rate matching in the standard (2)

Denote by rv_{id} the redundancy version number for this transmission (rv_{id} = 0, 1, 2 or 3), the rate matching output bit sequence e_k, $k = 0,1,2,\ldots,E-1$, is generated as follows, where k_0 is given by Table 5.4.2.1-2 according to the value of rv_{id} and LDPC base graph:

$k = 0$;

$j = 0$;

while $k < E$

if $d_{(k_0+j) \bmod N_{cb}} \neq < NULL >$

$e_k = d_{(k_0+j) \bmod N_{cb}}$;

$k = k + 1$;

end if

$j = j + 1$;

end while

Rate matching in the standard (3)

Denoting by E_r the rate matching output sequence length for the r-th coded block, where the value of E_r is determined as follows:

Set $j = 0$

for $r = 0$ to $C - 1$

if the r-th coded block is not scheduled for transmission as indicated by CBGTI according to Subclause 5.1.7.2 for DL-SCH and 6.1.5.2 for UL-SCH in [6, TS 38.214]

$E_r = 0$;

else

if $j \leq C' - \mathrm{mod}(G/(N_L \cdot Q_m), C') - 1$

$$E_r = N_L \cdot Q_m \cdot \left\lfloor \frac{G}{N_L \cdot Q_m \cdot C'} \right\rfloor;$$

else

$$E_r = N_L \cdot Q_m \cdot \left\lceil \frac{G}{N_L \cdot Q_m \cdot C'} \right\rceil;$$

end if

$j = j + 1$;

end if

end for

Rate matching in the standard (4)

where

- N_L is the number of transmission layers that the transport block is mapped onto;
- Q_m is the modulation order;
- G is the total number of coded bits available for transmission of the transport block;
- $C' = C$ if CBGTI is not present in the DCI scheduling the transport block and C' is the number of scheduled code blocks of the transport block if CBGTI is present in the DCI scheduling the transport block.