TD4: LTE Peak Data Rate and NR Latency

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Question 1

The maximum possible signal bandwidth in LTE is 20MHz corresponding to 100 resource blocks.

Question 2

In the normal configuration, LTE has 7 OFDM symbols per slot.

Each radio frame has 20 slots $\implies$ 140 OFDM symbols per radio frame.

Now we do dimensional analysis to get the corresponding number of REs,

$$1 \text{ radio frame} \cdot \frac{20 \text{ slots}}{1 \text{ radio frame}} \cdot \frac{100 \text{ RBs}}{1 \text{ slot}} \cdot \frac{84 \text{ REs}}{1 \text{ RB}} = 168000 \text{ REs} \tag{1}$$

Question 3

To maximize the data rate, the control region occupies one OFDM symbol per sub-frame. So the number or REs is

$$1 \text{ OFDM symbol} \cdot 12 \text{ sub-carriers} \cdot 100 \text{ RBs} = 1200 \text{ REs} \tag{2}$$

Question 4

The PSS is transmitted in 2 slots per radio frame and mapped to 62 active subcarriers $\implies$ 62 REs per slot. So per frame we have 124 REs.

Similarly, the SSS is transmitted in 2 slots per radio frame and mapped to 62 active subcarriers $\implies$ 62 REs per slot. So per frame we have 124 REs.

The PBCH is transmitted in 4 slots per radio frame and mapped to 72 active subcarriers $\implies$ 72 REs per slot. So per frame we have 288 REs.

In total we have 124 REs + 124 REs + 288 REs = 536 REs.

Question 5

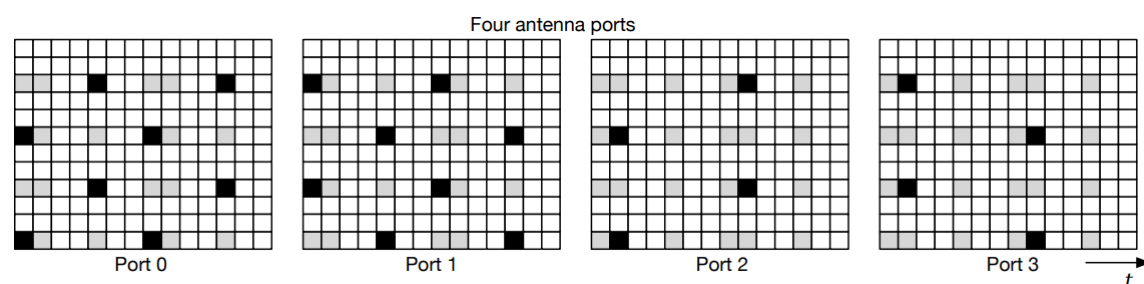Figure 1: REs used for Reference signals for 4 antenna transmission

4 antennas $\implies$ 12REs per RB which is $\frac{12}{84} = 14\%$ of all REs.

Question 6

The densest modulation in LTE is 64-QAM. Each symbol in 64-QAM carries 6 bits.

Maximum number of MIMO parallel flows is 4 (using 4x4 MIMO, 4 input flows/output flows).

Duration of a radio frame is 10ms.

The number of REs transmitting useful data is 168000 REs − 1200 REs − 536 REs = 166264 REs.

Raw peak data rate is

$$\frac{0.86 \cdot 166264 \text{REs} \cdot 6 \text{bits} \cdot 4 \text{parallel flows}}{10 \text{ms}} = 343.2 \text{Mbps} \tag{3}$$

Question 7

We have $\frac{3}{4} \cdot 343.2\text{Mbps} = 257.4\text{Mbps}$

Question 8

The measured data rates are probably a bit smaller because we assume ideal channel conditions with no interference, no errors, no congestion and an idealized overhead. And we assume there is no sharing of the resources with other users.

Question 9

OFDM symbol duration

Without cyclic prefix we have $T_{\text{symbol}} = \frac{1}{\Delta f} = 33.3\mu s$

With cyclic prefix we have

$$T'_{\text{symbol}} = \frac{1}{\Delta f} + t_{\text{prefix}} = 33.3\mu s + 2.3\mu s = 35.6\mu s \tag{4}$$

Duration of the periodic scheme

We have 3 different periodic schemes: DDDSU, DDDDDDDSUU and DSDU.

The DDDSU scheme has 5 OFDM symbols per period $\implies T_{\text{DDDSU}} = 5 \cdot 35.6\mu s = 178\mu s$.

The DDDDDDDSUU scheme has 10 OFDM symbols per period $\implies T_{\text{DDDSU}} = 10 \cdot 35.6\mu s = 356\mu s$.

And the DSDU scheme has 4 OFDM symbols per period $\implies T_{\text{DDDSU}} = 4 \cdot 35.6\mu s = 142.4\mu s$.

Minimum and maximum DL latency

For minimum latency we consider that reception starts exactly at the beginning of **S**. For maximal latency, we consider that reception misses the first **DL** symbol of **S** and must wait until transmission reaches **S** again to receive the right data.
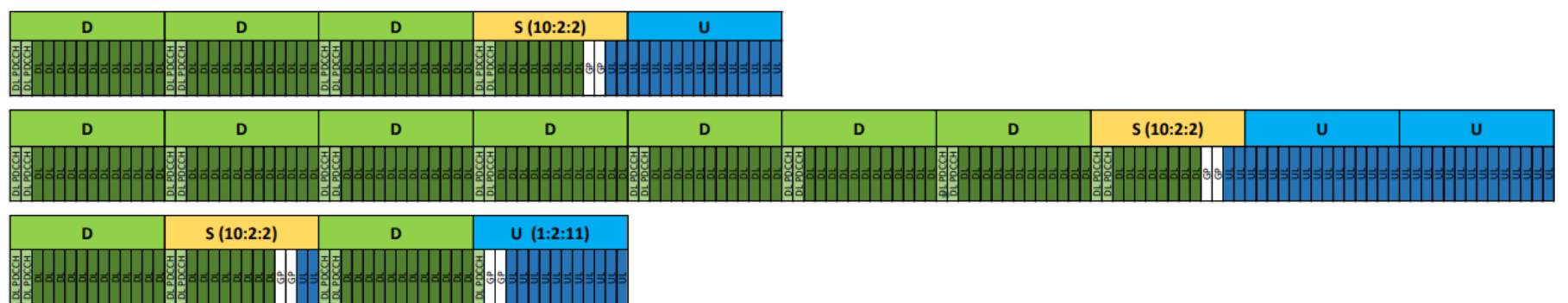

Figure 2: Possible frame structures

Frame Structure	Min DL Latency	Max DL Latency
DDDSU	12 symbols = 427.2 μs	81 symbols = 2883.6 μs
DDDDDDDSUU	12 symbols = 427.2 μs	151 symbols = 5375.6 μs
DSDU	12 symbols = 427.2 μs	51 symbols = 1815.6 μs