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 $124 \text{ REs} + 124 \text{ REs} + 288 \text{ REs} = 536 \text{ REs}$.

Question 5

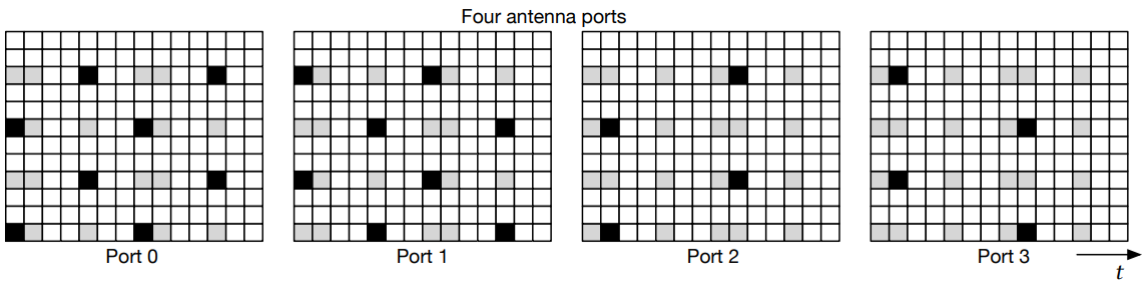

Figure 1: REs used for Reference signals for 4 antenna transmission

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 $168000 \text{ REs} - 1200 \text{ REs} - 536 \text{ REs} = 166264 \text{ REs}$.

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.

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.

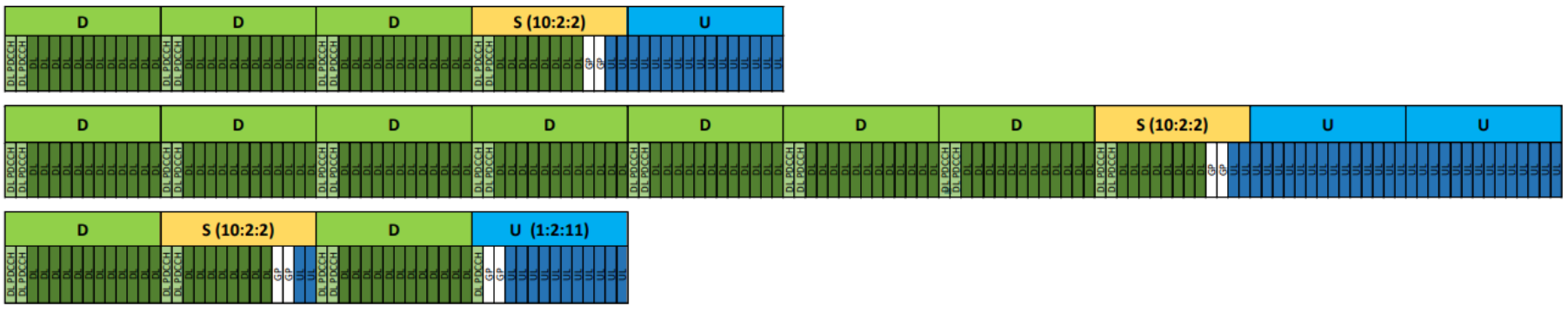

Figure 2: Possible frame structures

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	165 symbols = 5874 μs
DSDU	12 symbols = 427.2 μs	65 symbols = 2314 μs