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

We know that PCFICH is always carried by 16REs at the first symbol of each subframe (source).

For PHICH, an ACK or NACK is encoded in 3 bits. Each bit of PHICH is spread by 4 bits using normal prefix $\implies$ each PHICH becomes 12 bits. PHICH is modulated in BPSK $\implies$ each symbol carries one bit. Each RE carries 1 symbol $\implies$ we need 12REs to carry one PHICH (source).

The PDCCH occupies the remaining REs in the control region which occupies one symbol per subframe $\implies$ 16800 REs in total. So PDCCH occupies $16800 - 12 - 16 = 16772$REs.

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 one subframe every 4 frames and also mapped to 72 active subcarriers $\implies$ $\frac{72}{4} = 18$ REs per frame.

Question 5

4 antennas $\implies$ 12REs per RB (source) 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.

Raw peak data rate is

$$\frac{0.86 \cdot 168000\text{REs} \cdot 6\text{bits} \cdot 4\text{parallel flows}}{10\text{ms}} = 346.8\text{Mbps} \tag{2}$$

Question 7

We have $\frac{3}{4} \cdot 346.8\text{Mbps} = 260\text{Mbps}$

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

$$T'_{\text{symbol}} = \frac{1}{\Delta f} + t_{\text{prefix}} = 33.3\mu s + 2.3\mu s = 35.6\mu s \tag{3}$$

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 maximal latency we consider the full duration of each scheme and for the minimal latency we consider the duration up to the first possible uplink symbol (can be U or S).

Frame Structure	**Min DL Latency**	**Max DL Latency**
DDDSU	4 symbols = 142.4 μs	5 symbols = 178 μs
DDDDDDDSUU	8 symbols = 284.8 μs	10 symbols = 356 μs
DSDU	2 symbols = 71.2 μs	4 symbols = 142.4 μs