Answers to exam in the course Modern Wireless Systems – LTE and Beyond (ETTN15), October 22, 2012, 14-19.

1.

a) False, since to obtain channel estimates where CRS are not sent interpolation is used. This will give good channel estimates provided that the channel variation is not too large between positions where CRS are sent.

b) False, the transmitted sub-carrier signals are not orthogonal over the entire OFDM-interval since this interval includes the cyclic prefix.

c) True, since at least 8 CRS symbols are sent in a resource block pair.

d) False, since the statement is not true for the uplink.

e) False, since Rel-8/9 terminals do not support uplink multi-antenna transmission.

2.

a) Examples of what is needed to be able to transmit the PUSCH: The terminal needs a valid scheduling grant. It also needs to know the number of resource blocks to use and if clusters should be used or not, also if 11 or 12 OFDM intervals should be used. Transmit timing is also required.

Examples of what is needed to be able to create the PUSCH: Transmission parameters (M-QAM, code rate, block-size). Antenna configuration and parameters (transmission mode).

b) The details in a) are found in the control region in the downlink signal.

c) Examples: Channel estimation needs to done. The length of the control region needs to be found. Then extracting the control signals intended to the receiver. Allocated resource block pairs, antenna configuration and parameters (transmission mode), Transmission parameters (M-QAM, code rate, block-size) needs to be known by the terminal.

d) SRS signals give the base station a possibility to obtain uplink channel knowledge.

3.

a) A reasonable strategy is to assign more resources to better channels, while also give resources to worse channels. So, a possible allocation of resource block pairs is: 2 for T1, 8 for T2 and 4 to T3.

b) T1: QPSK + transmit diversity with two antennas, T2: 64-QAM + 4x4 spatial multiplexing, T3: 16-QAM + 2x2 spatial multiplexing.

c) In the problem: "within a subframe" should be replaced with "within the subframe". Also "coded bits" should be replaced with "information carrying coded bits".

No CRS symbols are sent in the 10th OFDM interval so all coded bits carry information.

To T1: 2x12 QPSK symbols within an OFDM interval yields 0.672 Mbps (coded bits) per antenna, i.e. 1.344 Mbps.

To T2: 8x12 64-QAM symbols within an OFDM interval yields 8.06 Mbps (coded bits) per antenna, i.e. 32.3 Mbps.

To T3: 4x12 16-QAM symbols within an OFDM interval yields 2.69 Mbps (coded bits) per antenna, i.e. 5.38 Mbps.

d) Other uplink users in other cells which are close to the cell border of the current cell may introduce interference if they use the same resource elements as T1.

4.

a) In total 4x24=96 information carrying QAM-symbols should be allocated to the OFDM signals transmitted from each antenna. The figure shows that 24 symbols are mapped to each antenna, and since 24 is a relatively small number we here assume that all 96 symbols are transmitted within the i:th OFDM interval.

The first four output symbols from the precoder (index 0 in the figure) are mapped to the corresponding antenna (OFDM signal) and these four values should use the same sub-carrier.

The next vector of four output symbols from the precoder (index 1) are mapped to the corresponding antenna (OFDM signal) and these four values should use the same next available sub-carrier.

Finally, the last vector of four output symbols from the precoder (index M-1=23 in the figure) are mapped to the corresponding antenna (OFDM signal) and these four values should use the same next available sub-carrier.

So, the same M subcarriers are used in the OFDM signal from antenna 1, as in the OFDM signal from any of the other three antennas. Hence, in total 4 QAM-symbols are sent in each specific sub-carrier.

4b)

The DFT output at subcarrier k, at receive antenna j, can be expressed as:

$$r_j^{(k)} = \sum_{i=1}^{4} h_{j,i}^{(k)} s_i^{(k)} + n_j^{(k)} = (h_{j,1}, h_{j,2}, h_{j,3}, h_{j,4})\, \underline{s}^{(k)} + n_j^{(k)}, \quad j = 1,2,3,4$$

In standard form: $\underline{r}^{(k)} = \mathcal{H}^{(k)} \underline{s}^{(k)} + \underline{n}^{(k)}$

4c) No, since there are more CRS symbols and they do not interfere with each other. Furthermore, cover codes assumes quite small channel variation over the span of orthogonality.

5.

a) $C_2 = (BW)_2 \Rightarrow (S_0/N_0)_2 = (BW)_2$

$$C_1 = C_2 = (BW)_2 = (BW)_1 \log_2\left(1 + \frac{(S_0/N_0)_1}{(BW)_1}\right) =$$
$$= (BW)_1 \log_2\left(1 + \frac{2(BW)_2}{(BW)_1}\right)$$

So, $2^{(BW)_2/(BW)_1} = 1 + 2\frac{(BW)_2}{(BW)_1}$

From a sketch of the LHS and of the RHS we conclude that $\frac{(BW)_2}{(BW)_1} \approx 2.7$

i.e. $(BW)_1 \approx 0.37\,(BW)_2$

$(BW)_2 = (S_0/N_0)_2$

b) The persons suggested assumption would imply that the capacity to terminal T2 cannot be the same as the capacity to terminal T1. Hence, the person is wrong.