SSY145 Wireless Networks
Quiz A4 Answer Key
Date: April 20, 2020

The solutions are marked in **boldface**.

1. Which of the following statements is/are correct about millimeter wave communication?

   (a) Antenna arrays are possible using millimeter waves because of small size of each antenna element.

   Motivation: Since the size of the antenna elements decreases with the frequency, the number of antenna elements that can be packed into a given area can also increase with the square of the frequency.

   (b) Penetration losses are higher for millimeter waves compared with waves with lower wavelength.

   Motivation: The penetration losses through buildings and other clutter increases with higher frequencies.

   (c) Fading channel matrices in millimeter wave communication are sparse.

   Motivation: The channel at higher frequencies is expected to be sparse since the signal arrives at the receiver through a small number of scattering clusters. This implies that the large channel matrices at mm-wave frequencies can be in fact expressed with a reduced set of parameters such as the angles of departures, angles of arrivals and path gains of each of the few paths.

   (d) Low resolution ADCs can be used to improve energy efficiency in millimeter wave communication.

   Motivation: Converters with a high sampling rate and with high resolution are costly and power hungry. The use of such devices comes actually at odds with the goal of higher energy efficiency in future wireless communications, the so-called Green communication. To deal with this bottleneck, the resolution of the converters could be decreased and hence, the transceiver and the air interface should be designed such that the coarse quantization of the converters is taken into account, for instance with low resolution ADCs at the receiver.

2. Which of the following statements is/are correct about millimeter wave communication?

   (a) Digital beamforming in millimeter wave communication is complex to implement if we require maximum performance.

   Motivation: Although fully digital beamforming delivers the maximum performance, this comes at the expense of implementation complexity, power consumption and cost since one RF chain is required per transmit/receive antenna.

(b) Hybrid beamforming, which is proposed for millimeter wave communication, involves operations in analog domain as well as digital domain.

Motivation: In hybrid beamdorming, part of the beamforming operations are performed in the analog domain and the other part in the digital baseband as shown in Fig. 1.

(c) "Dirty RF" concept proposes to compensate for non-ideal hardware in digital base-band processing.

Motivation: Dirty RF is the concept of compensating for non-ideal analog radio hardware in digital base-band processing.

(d) Noise in reference clocks can lead to phase noise.

Motivation: Phase-noise is an impairment that occurs due to noise in the components of frequency synthesizers: reference clocks (crystals), phase-frequency detectors, charge pumps, loop filters and voltage controlled oscillators.

3. Which of the following is/are true about licensed spectrum?

(a) Exclusive right to a certain frequency range

(b) Control of the interference situation

(c) Typically associated with no license cost
Motivation: unlicensed spectrum

(d) Relatively low output power and short range of coverage
Motivation: unlicensed spectrum

4. Which of the following is/are true about error control in LTE?

(a) Hybrid-ARQ is slower than RLC retransmissions.
Motivation: RLC retransmission takes several 10 ms to 100 ms round trip time, while Hybrid-ARQ retransmsision is scheduled 8 ms later if the data is incorrectly received.

(b) Hybrid-ARQ indicates success/failure outband after reception of each 1 ms subframe of data.

Motivation: Unlike the RLC retransmission, which uses selective repeat protocol and status reports are sent inband.

(c) Because of the incremental redundancy supported by Hybrid-ARQ, the initial transmission could have two times the code rate as the first retransmission.

Motivation: If there is still an error after the initial transmission, the first retransmission retransmits a new set of coded bits which represents the same information, together with the coded bits of the initial transmission. So the code rate of the first retransmission is half of the initial transmission.

(d) RLC retransmissions handle most of the errors.
Motivation: Hybrid-ARQ in the MAC layer handles most of the errors.