SSY145 WIRELESS NETWORKS

Exam Solutions

Date: Tuesday June 2, 2020, 08:30 – 12:30

The solutions are marked in **boldface**. If you have indicated the correct set of choices and the motivation is missing or is wrong, then 0.5 points will be given.

1. (1 point) Mention two basic link performance measures. Explain each briefly.

Probability of bit/block error: a random variable, a ratio of the number of error bits/blocks to the number of total transmitted bits/blocks. Efficiency: Spectral Efficiency - A measure of data rate per unit bandwidth for a given bit error probability and transmitted power. Power Efficiency - A measure of required transmit power to achieve a given data rate for a given bit/block error probability and bandwidth.

2. (1 point) How does OFDM deal with 1) the ISI problem in multi-path frequency-selective channels and 2) the inter-carrier interference within an OFDM symbol?

1) Since symbols that are long relative to the delay spread suffer less from ISI caused by multipath propagation, OFDM splits the signal into a large number of low-rate streams in parallel instead of a single high-rate stream. 2) By using a cyclic prefix to make the channel appear to provide a circular convolution.

3. (1 point) Explain the difference between path loss and shadowing. What is the impact of shadowing on cell design?

Received power variation due to path loss occurs over long distances, whereas variation due to shadowing occurs over distances that are proportional to the length of the obstructing object. Shadowing causes nonuniform coverage and increases the required transmit power, or lowers the coverage area, for a given service quality.

4. (1 point) Give two main functions/requirements of a virtual network in 5G network slicing.

Any two of the following:

- **Ensures that every network slice is isolated from the others.**
- **Dynamically assigns and manages network slices.**
- **Maintains service security.**
- **Ensures network slicing is transparent to customers.**
- **Supports end-to-end resource management.**

5. (1 point) What are the main benefits of network slicing and why?

Flexibility and multi-tenancy, i.e. making it possible to serve many users simultaneously and reconfigure the slices dynamically based on consumers' needs

using a single physical network. The communication systems can also become much more energy and resource efficient, which is more sustainable in both an ecological and economical perspective. Third: It helps network operators in reducing operational and network hardware costs, i.e. expenses (OPEX) and capital expenditure (CAPEX). Fourth: It improves time to market for the delivery of new 5G network services, since new requirements can be met without the need for physical changes in the network.

6. (1 point) Re-farming of 4G LTE bands, in order to improve the coverage of 5G NR is not considered as a good solution. Please briefly explain why.

Re-farming low band carriers from 4G without a corresponding increase in 5G devices penetration might lead to congestion of the remaining 4G LTE carriers, degrading indoor coverage for LTE users who still represent the majority of the subscriber base. This co-existence between 5G and 4G LTE can thus be considered as a flexible re-farming solution.

7. (1 point) Give two technical solutions and explain in your own words why they make mobile networks more energy efficient or energy sustainable.

Any two of the following:

- **Heterogeneous Networks: indoor femto or pico cells reduce penetration loss and path loss.**
- **D2D Communications: avoid transmission through the base station and goes directly from one device to another, and also allow more base station to go into sleep mode.**
- **Femto-cells: complement cellular base stations with small low power cellular base stations that are using existing fixed Internet connections for their backhaul in hot spot areas. In this way energy cost is reduced, and network coverage requirements can be reached.**
- **Renewable energies: reduces the carbon footprint by using weather conditions to power the base stations.**
- **Sleep scheduling: allows to inactivate the base stations when the traffic is low, thus realizing energy saving with less active base stations.**
- **Beamforming in general and massive MIMO in particular can substantially improve energy efficiency by focusing the radio energy towards the users, thus lowering the path loss.**

8. (1 point) Briefly describe one location information which could be used for improving the performance of a communication system.

Any one of the following:

- **Location of Users: By using location information to estimate the channel, the process time can be greatly reduced. This is a time saving method**

which minimizes the number of transmissions while still getting an accurate estimation.

- **Static environment: By building a channel database with information about the static environment, such as buildings in urban environments, the prediction will be more accurate since the major statistical properties are mapped. This database could help predict for instance the expected shadowing when a user is moving in an urban environment in a more accurate way with less prior knowledge of the channel.**
- **Location information can make beamforming more efficient, in particular at mm-wave frequencies with sparse multi-path channels, since beam scanning time and beam tracking can be greatly reduced, thus improving reliability and latency.**

9. (1 point) Name two approaches and briefly describe how they can improve the energy efficiency of an M2M network mentioned in the report "Energy efficiency challenges in home capillary M2M networks".

Any two of the following:

- **The ADAPT algorithm, which uses tuning of backoff parameters in CSMA/CA to maintain reliability while conserving power. (NOTE: backoff parameters to conserve power is needed as answer.)**
- **Hybrid CSMA/CA, which utilize subgroups and TDMA time slots for these subgroups to reduce overall collisions to save energy from retransmissions. (NOTE: subgroups with TDMA to reduce collision/retransmissions is needed as answer.)**
- **EBI-CSMA/CA or EP-CSMA/CA, where the former utilize backoff intervals to perform energy transfer and the latter utilize dedicated energy packets. (NOTE: If the two methods are mismatched, it would be an incorrect answer.)**
- **Energy harvesting of motion artefacts, where harvesters can utilize the vibration/movement of the environment and convert it to electric energy via materials such as piezoelectric/magnetostrictive materials. (NOTE: mentioning of vibrations or movements in order to convert it to electric energy is enough.)**
- **Energy harvesting of RF energy, where ambient RF signals sent out from other devices using e.g WiFi (routers, mobile phones, computers) are converted to DC via rectifying circuits. (NOTE: mentioning graphene rectennas without mentioning that they might not provide enough energy is incorrect.)**

10. (1 point) What is a key implementation challenge with reconfigurable intelligent surfaces (RIS)?

Performing channel estimations to optimize the SNR in dynamic changing environments. Estimating the channel is considered to be necessary to optimize the

phase shifts caused by the surface, which can be done by implementing some sort of feedback solutions with sensors integrated in the surface.

11. (1 point) Mention at least one advantage and one disadvantage of High Altitude Platforms (HAPs) in comparison with terrestrial systems, and briefly explain them.

Compared with terrestrial systems, HAPs have the advantages of having line of sight to large areas, larger coverage area, and being more flexible where it is possible to change the cell diameter and it is also possible to move it to a different region very quickly. The disadvantage is that it is not always possible to deploy a HAP-unit in an area, since it does not get a sufficient amount of, e.g. solar, energy in certain regions, and HAPs are so far more expensive than terrestrial network nodes.

12. (1 point) How is an individual user equipment (UE) able to know that resources are occupied or available in PC5? In regard to what aspect is PC5 better than DSRC?

By checking received sidelink control information (SCI) messages that contain information regarding reservations and their intervals, each UE can avoid collisions. PC5 is able to raise the rate of successful warning messages delivery in certain scenarios.

13. (1 point) Which of the following statements is/are false about LTE-advanced?

(a) Carrier aggregation capable terminals can receive only the primary component carrier, this increases the terminal's power consumption.

(b) Transmission bandwidth can extended by means of carrier aggregation.

(c) Discrete Fourier transform spread OFDM is used in the uplink.

(d) In cross-carrier scheduling, the scheduling decision is transmitted to the terminal on the same component carrier as for the corresponding data.

(Motivation: Carrier aggregation capable terminals can choose to receive only the primary component carrier, this reduces the terminal power consumption. The scheduling decision is transmitted to the terminal on another component carrier than the corresponding data.)

14. (1 point) Which of the following statements is/are true regarding orthogonal frequency-division multiplexing (OFDM) and multicarrier modulation?

(a) The delay spread must be larger than the guard period to avoid ISI between symbols.

(b) OFDM divides a wideband signal into multiple smaller narrowband subcarriers to avoid frequency-selective fading.

(c) One downside of OFDM is that it is not very spectrum efficient.

(d) The cyclic prefix is used to eliminate the inter symbol interference (ISI).

(Motivation: In OFDM, the guard period must be larger than the delay spread to avoid intra-symbol interference. Cyclic prefix is used to make the channel appear to provide a circular convolution. OFDM divides a wideband signal into smaller subcarriers which have smaller

bandwidth than the coherence bandwidth of the channel, thus avoiding frequency-selective fading. OFDM is spectrum efficient since the subcarriers are orthogonal with minimal spacing.)

15. (1 point) Which of the following is/are correct about scheduling?

(a) The max C/I scheduling scheme always has a higher system throughput compared with Proportional Fair.

(b) When rate adaptation is used in scheduling, the modulation scheme is determined as part of the scheduling.

(c) In order to adapt efficiently to dynamic data traffic conditions, a dedicated channel is the best choice.

(d) Round Robin considers channel quality conditions but has poor performance.

(Motivation: "The larger the unfairness, the higher the system throughput" is only true for full buffers, so the max C/I scheduling doesn't always have a higher system throughput than Proportional Fair. Data rate adaptation to the channel conditions is typically adjusted by dynamically selecting a modulation and coding scheme (MCS) from a set of predefined jointly optimized modulation and coding schemes. Shared channel adapts to instantaneous traffic situation, not dedicated channel. Round Robins does not take channel quality conditions into account.

16. (1 point) When using beamforming, which of the following describe(s) the genetic algorithm (GA)-based search?

(a) First find the queen then adjust the queen by making small changes and replacing a few columns in the beamforming codebook.

(b) First find the queen then adjust the queen by changing columns to their neighbors in the beamforming codebook.

(c) Successively beamform to each user taking interference from previous users into account.

(d) Find the queen roughly with wide beams in the first-level codebook then steer to narrow beams by the second level codebook.

(Motivation: The GA scheme simulates the genetic evolution process, (a) summarizes the key step in each iteration, while (b) describes the Tabu search algorithm, (c) describes the link-by-link search, and (d) descriebs the two-level search algorithm.

17. (1 point) Which of the following create unique challenges for V2X communications compared to other communication systems?

(a) High antenna heights.

(b) High speed of the vehicles.

(c) Dynamic surroundings.

(d) All of the choices.

(Motivation: In V2X communications, usually the height of the antenna is lower than that of user terminal antennas. V2X communications also face the challenges of high vehicle speed and dynamic surroundings.)

18. Which of the following statement(s) is/are true about 5G V2X communication?

(a) The communication between vehicles is done via base stations only.

(b) Radio interfaces should provide low latency and high reliability for V2X communication.

(c) Sidelink communication means that the vehicles are communicating to the network infrastructure via a relay.

(d) URLLC stands for ultra robust low latency communication.

(Motivation: Communications between vehicles are also done via sidelink communication, in which data is exchanged without the network infrastructure. In V2X communication, low latency and high reliability is very important to guarantee safety. URLLC stands for ultra reliable low latency communication.)

19. (1 point) Which of the following statement(s) is/are true about spectrum?

(a) It is the foundation of any wireless system and enables us to use our mobile devices.

(b) The RF spectrum is regulated between 10^{-3} Hz and 10^{22} Hz.

(c) Refarming a certain spectrum prevents deployment of new technologies as it only allows for shift to the same technology.

(d) Utilizing different parts of the spectrum results in different exposure and the typical indoor values can be harmful according to scientific proofs.

(Motivation: Radio waves need spectrum to transmit energy and information, so that we can do everything on our mobile devices. The RF spectrum is allocated between 9 kHz and 300 GHz. Refarming will sometimes be necessary in order to allow new technologies to be deployed and improve spectrum utilization. All safety margins used today are well above normal usage and there has been no scientific proof of health hazards at that level.)

20. (1 point) Which of the following statements is/are true about transport network slicing?

(a) Space Division Multiplexing (SDM) techniques can help increase the capacity of fronthaul traffic.

(b) Time-Sensitive Networking (TSN) working group intends to devise solution for carrying high and low priority traffic together, with no need for time synchronization.

(c) The latency requirements can be different according to split options.

(d) There is still lack of studies on efficient traffic scheduling.

(Motivation: Space Division Multiplexing (SDM) techniques can provide high capacity, by assigning spatially different SDM resources (e.g., cores and modes) to different services, enabling isolation. The adoption of different splits brings strict latency requirements, calling for time-sensitive and deterministic transport solutions that can adapt to evolving traffic conditions. The Time-Sensitive Networking (TSN) working group intends to devise solutions for carrying high and low priority traffic together. They propose to introduce deterministic delays via time synchronization in Ethernet networks. Slicing can be provided with many architectural solutions but studies on efficient traffic scheduling are still missing.)

21. Which of the following statement(s) is/are true according to the "Wireless backhaul" lecture?

(a) The "optimal" antenna placement in MIMO only depends on frequency.

(b) Precoding in suboptimal antenna separations results in improved availability and capacity.

(c) The total amount of spectrum for W- and D-band is roughly 20 GHz.

(d) Backhaul spectrum is mostly point-to-point licensed.

(Motivation: The "optimal" antenna depends on frequency, hop length, antenna arrangement and site constraints. The total amount of spectrum for W- and D-band is roughly 50 GHz)

22. (1 point) Which of the following statements is/are true about direct broadcast satellites?

(a) They have a geostationary orbit which means they follow the movement of the earth and always stay over the same spot.

(b) They have a lifetime of about 10-15 years.

(c) You need about 30 of these satellites to get global coverage, not including the south and north pole.

(d) These satellites are very large and expensive.

(Motivation: Geostationarity at about 36000 km altitude gives satellites a 24h orbit, which means they stay over the same spot. According to the lecture by Joakim Johansson, only about three of these satellites are needed.)

23. Which of the following is/are true about issues in WEP?

(a) Devices that start sessions with IV of incremental sequence (e.g. 0, 1, 2...) is prone to IV duplication.

(b) The use of CRC enables modification in the checksum to match input even if it is encrypted.

(c) The XOR operation will secure the messages if two plaintexts are encrypted with the same stream.

(d) The short IV space is vulnerable to collision.

(Motivation: With 2 or more devices connected, all IVs will immediately be reused/duplicated. Changing a bit in the input results in a predictable change of the CRC. XOR is not a cipher, messages could still be exposed with some statistical analysis of plaintexts. This is why IV is present in order to create different streams. A busy AP could exhaust the IV space (24 bits = 16 M packets) in less than 1 hour.)

24. (1 point) Which of the following statements is/are true about positioning?

(a) Positioning measurement accuracy is measured using Shannon-information matrix.

(b) The positioning problem always boils down to solving linear equations using matrices.

(c) Monte Carlo gradient algorithms are used to solve dynamic positioning problems.

(d) None of the choices.

(Motivation: Positioning measurement accuracy is measured using the Fisher-information matrix. The positioning problem always boils down to solving nonlinear equations using matrices. Gradient algorithms can only be used in static case. Dynamic case can be solved by numerically approximating the nonlinear least-squares problem using Monte Carlo-based techniques. So none of the choices is correct.)

25. (1 point) Which of the following statements is(are) true?

(a) Angle of arrival based positioning relies on directional measurements.

(b) Time of arrival based positioning relies on time synchronization.

(c) The variance of uncertainty in Okumura-Hata model is chosen depending on the environment in which the mobile device is.

(d) Typical position measurements include momentum and acceleration measurements.

(Motivation: Directional measurements have the capability to resolve various angles of arrival which can be used for positioning. Due to the constant speed of electromagnetic waves, time of arrival differences from a common signal source can be used to estimate distances to that source, provided the nodes have a common rate of time reference with the source node. Typical position measurements include RSS, TOA, TDOA, AOA, etc.)