

ETSN11, Final Exam 2024-11-01, 08:00-13:00

Note: The exam is performed via the Inspira platform, using Inspira Safe Exam Browser. You are welcome to use a calculator, and the formula sheet.

The exam includes 90 points. Grade 3: You need in total 45 points to pass the exam. **Grade 4:** At least 60 points. **Grade 5:** At least 75 points (the limits for Grade 4 and 5 may be adjusted downwards depending on the results).

Part A: Technologies and architectures (30 points)

In the **multiple-choice questions**, you get points for each correct answer, but minus 1 point for each incorrect answer. You cannot get a lower score than 0 in the multiple-choice questions. In the **text questions**, you need to correctly describe the specific terms and concepts to get full points.

1. Which of the following statements are true for **Bluetooth Low Energy (BLE)**? (3p)
 - a. BLE is a network technology aimed at non-critical applications.
 - b. BLE is a network technology aimed at time-critical applications.
 - c. Animal and environmental monitoring are some targeted applications for BLE.
 - d. Smart homes and industrial sensors and actuators are some targeted applications BLE.
 - e. Self-driving vehicles, robots and drones are some targeted applications for BLE.
 - f. BLE is based on a decentralized network architecture.
 - g. BLE is based on a centralized network architecture.
 - h. BLE uses delay-tolerant networking.
 - i. BLE allows for multi-hop data dissemination.
 - j. The data dissemination in BLE can only be performed in single-hop.
2. Which of the following statements are true for **Centralized network architectures**? (3p)
 - a. ZigBee is based on a centralized network architecture.
 - b. 5G is based on a centralized network architecture.
 - c. Starlink is based on a centralized network architecture.
 - d. LoRa is based on a centralized network architecture.
 - e. WiFi Direct is based on a centralized network architecture.
 - f. In a centralized network architecture, nodes can communicate with a base station / access point using single-hop communication.
 - g. In a centralized network architecture, nodes can communicate with a base station / access point using multi-hop communication.
 - h. "Centralized" means that nodes only communicate with one base station / access point.
 - i. "Centralized" means that nodes are geographically close to each other.
 - j. "Centralized" means that the base station / access point controls the medium access for nodes.
 - k. "Centralized" means that nodes communicate via a base station / access point, not directly with each other.

3. Which of the following statements are true for **sensor networks**? (3p)

- a. There is always only one sink in the network.
- b. There are always multiple sinks in the network.
- c. Each sensor has a MAC/physical address.
- d. Each sensor has an IP-address.
- e. The aim of a sensor network is to transport data to a sink.
- f. The aim of a sensor network is to communicate with a back-end system.
- g. The aim of a sensor network is to allow nodes to communicate with each other.
- h. A centralized network architecture can be used.
- i. A decentralized network architecture can be used.
- j. A sensor network has a limited geographic range due to the resource-constrained communication technology.
- k. In a sensor network, nodes are stationary.

4. Which of the following statements are true for **Delay- and Disruption Tolerant Networks (DTNs)**? (3p)

- a. The DTN technology allows multi-hop data dissemination.
- b. The DTN technology only allows single-hop data dissemination.
- c. The DTN-specific protocols are implemented on the PHY/Link layer in the TCP/IP model.
- d. The DTN-specific protocols are implemented on the Network layer in the TCP/IP model.
- e. The DTN-specific protocols are implemented on the Transport layer in the TCP/IP model.
- f. The DTN-specific protocols are implemented on the Application layer in the TCP/IP model.
- g. In a DTN, there must be some stationary nodes.
- h. In a DTN, there must be some mobile nodes.
- i. DTNs can be used for time-critical applications.
- j. DTNs can be used for non-critical applications.
- k. Licklider is a DTN-specific protocol.
- l. JANUS is a DTN-specific protocol.
- m. Gossiping is a DTN-specific protocol.

5. Which of the following statements are true for **wireless underwater networks**? (3p)

- a. Acoustic communication on low frequency bands can be used for long-range communication.
- b. Acoustic communication on high frequency bands can be used for long-range communication.
- c. Radio and optical communication links are not suitable for wireless underwater communication.
- d. Argos can be used for underwater sensor communication.
- e. JANUS can be used for underwater communication.
- f. LoRa can be used for underwater communication.
- g. Localization of nodes can be performed with GPS.
- h. Localization of nodes is not possible underwater.
- i. Multi-hop communication can be used in underwater networks.
- j. Only single-hop communication can be used in underwater networks.

6. Describe the general network architecture and main protocols for **WiFi 6/7 mesh**. (5p)
7. What is a **Cloud-based RAN (C-RAN)**? Also, describe the general system architecture for a C-RAN. (5p)
8. Describe what a **Space Relay** is and when it is used. (5p)

Part B: Performance analysis problems (30 points)

Your solutions must be clear and well explained, and please note that there is a math editor. You need to motivate your chosen formulas and calculations to get full points.

9. You are analyzing a client-server application, and you use **a queueing model with one server** for the server part of the application. In your model, new requests arrive according to a Poisson process with mean 8 requests per second. Also, the average service time for each request is 0.1 seconds. Finally, you assume that all requests and service times are independent of each other. (15p)
- (a) Your first assumptions are that **the queue is unlimited and that the service times are exponentially distributed**. What is the average utilization of the server, the throughput, and the average response time, T , for requests that are served based on these assumptions? (5p)
- (b) Your next assumptions are that **the queue is unlimited and that the service times are deterministic**. What is the average utilization of the server, the throughput, and the average response time, T , for requests that are served based on these assumptions? (5p)
- (c) Your final assumptions are that there is **no queue and that the service times are exponentially distributed**. What is the average utilization of the server, the throughput, and the average response time, T , for requests that are served based on these assumptions? (5p)
10. You analyze a Multiple-User Multiple-Input, Multiple-Output (MU-MIMO) based WiFi-system where the access point has 3 antennas. Using space-division multiplexing and advanced coding, each antenna can be used by one or more users. There are currently 4 users (A-D) connected to the access point. (15p)

The MAC protocol is based on a basic contention-free and time-slotted system. Each time slot is 100 milliseconds. During a time slot, a user can send up to 1000 kbits (If the user wants to send less than 1000 kbits, this transmission still uses the full time slot). Before each time slot a user notifies the access point if it has data to send. We can assume that this is done on a separate channel with no extra time delays. The access point distributes the antennas to all the users that have data to send, and then the users send their data during the time slot without any data collisions.

Since there are 3 antennas and 4 users, there will be time slots where all users have data to send. In these time slots, two of the users need to share one antenna. These users are randomly selected, and they will get half the capacity of the communication channel during that specific time slot using a contention-free procedure. So, there are never any risks of data collisions or blocking of requests.

Also, during time slots where there are less than three users that want to send data, one or more users are randomly selected to get more than one antenna, so that no antennas are unused during the time slot. However, in this case, no users share an antenna. This means that if there is only one user that wants to send data in the time slot, this user gets all three antennas (with three times the capacity). If there are two users, one of these users gets two antennas, and the other user gets one antenna.

Consider the following scenario: One user (User A) has 10 Mbits data to send. Therefore, User A needs to use several time slots after each other until all data is sent. The other users (Users B-D) are independent of A and each other, and they only want to use single time slots. User B wants to send data in a time slot with probability 0.5. User C wants to send data in a time slot with probability 0.6. User D wants to send data in a time slot with probability 0.8.

In average, how long time will it take for User A to send its data?

Part C: System design scenarios (30 points)

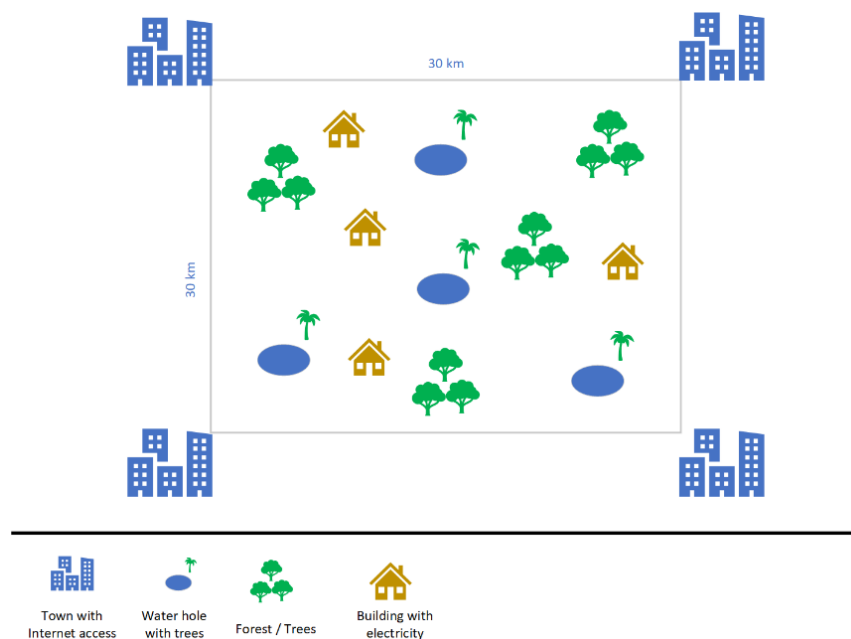
For each of the scenarios (15p each), describe how you would design the network system. You need to give a suitable solution to the specific scenario. This solution must address the requirements and challenges in the specific scenario and include specific protocols and technologies to get full points.

- 11.** The national parks in Africa experience lots of problems with illegal hunting. You have been given the task to help a national park in South Africa with a surveillance monitoring system. A simple map of the park is illustrated in the figure below. The area not marked in the map is a savanna, made up of large expanses of grasses interrupted by scattered shrubs and small trees. There are several different types of animals in the park, including lion, leopard, rhinoceros, elephant, and African buffalo (The "Big 5" for hunting), in the park, and they all visit the water holes at regular times. At other times, they are spread out over the park.

Your task is to design the network architecture for a surveillance system for the park. The surveillance system should detect potential hunters. If a hunter is detected, the position of the hunter should be estimated, and a warning signal should be sent to the headquarters (placed in the top right town in the figure).

You have access to all types of sensors, including heat and motion sensors, and various small microprocessor computers (Raspberry Pis). Also, you have access to trail cameras (small cameras that take low-quality images when actuated). All equipment can use all types of communication technology standards. There is no cellular coverage within the national park (only in the towns). Starlink is available in South Africa.

You have a decent budget for your solution, but it is preferable if the system can have low maintenance and be deployed with minimum interference with the wildlife. Also, the park appreciates low operational costs.



- 12.** Your task is to help Scania with their new project that investigates mobile robots for “last meters” deliveries in cities. The image below to the left shows Scania’s new mobile robot prototype Carrie. Carrie can deliver packages and boxes from a truck (parked on the street) to the door of a building on this street (the image shows an elevator, but your project targets outdoor deliveries). With Carrie, trucks do not have to drive in all the narrow streets of a city. Instead, trucks can be parked at the beginning of a street, and then Carrie delivers the packages the last meters. With Carrie, city logistics and deliveries become more sustainable, both from a transport perspective and a human perspective, since the trucks can be parked further away from the destination building and drivers do not have to deliver heavy packages the last distance.

Currently, Carrie is remote-controlled by the driver with a direct radio communication link (Line-of-sight). However, Scania wants to investigate how Carrie can be self-driving using a driving control AI system in the cloud. Carrie will have various on-board cameras and sensors that can be used by the AI system for giving driving decisions.

Your task is to design a network system for Carrie’s new self-driving mechanism. The targeted scenario is illustrated in the image below to the right. The truck parks at the beginning of a street in the city (we can assume that it is a Swedish city). The targeted streets are up to 100 meters long. Carrie should be able to safely deliver packages to all front doors on this street by driving on the sidewalks (we assume that the sidewalks are broad enough for Carrie). Carrie will have a fail-safe mechanism for short losses of connectivity, so that accidents do not occur if there is a short period of bad connectivity. For longer streets with multiple deliveries, the truck can have multiple Carrie robots to decrease delivery times. If so, the robots will deliver packages at the same time.

