

ETSN11, Final exam 2023-10-25, 14:00-19:00

Note: The real exam will be done via the Inspera platform, using Inspera Safe Exam Browser. This means that you need to bring a laptop to the exam, and that you have installed Safe Exam Browser before the exam. On the exam, you are welcome to use a calculator, and the formula sheet (which will be handed out).

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 a point deduction for each incorrect answer. You cannot get a lower score than 0 in the multiple choice questions.

1. Which of the following statements are true for a **Decentralized network architecture? (3p)**

- a. This architecture can be used for time-critical applications.
- b. This architecture can be used for non-critical applications.
- c. "Decentralized" means that there is no gateway in the network.
- d. "Decentralized" means that the nodes organizes themselves.
- e. "Decentralized" means that the nodes are distributed over a larger area.
- f. LoRa uses a decentralized network architecture.
- g. ZigBee uses a decentralized network architecture.

2. Which of the following statements are true for WiFi 6 mesh? (3p)

- a. It is a network technology aimed at time-critical applications.
- b. It is a network technology aimed at non-critical applications.
- c. It uses a centralized network architecture.
- d. It uses a decentralized network architecture.
- e. It is good for resource-constrained devices.
- f. It uses delay-tolerant networking.
- g. Animal and environmental monitoring are typical applications for this technology.
- h. Industrial automation and robotics are typical applications for this technology.

3. Which of the following statements are true for **NB-IoT**?? (3p)
- a. It is a good technology for time-critical applications.
 - b. It is a good technology for resource-constrained networking.
 - c. It is a good technology for underwater networks.
 - d. A device must connect with a base-station before it can send data.
 - e. A device can send data at any time (i.e ad-hoc).
 - f. It is a single-hop network technology.
 - g. It is a multi-hop network technology.
4. Which of the following statements are true? (3p)
- a. Underwater communications can use radio, optical and acoustic signals.
 - b. Interplanetary communication can use radio, optical, and acoustic signals.
 - c. The Licklider transmission protocol does not use ACKs.
 - d. The Licklider transmission protocol uses ACKs for some of the data.
 - e. The Licklider transmission protocol uses ACKs for all data.
 - f. A DTN is based on specific network protocols that handle store-and-forward data dissemination.
 - g. A DTN is based on specific link protocols that handle store-and-forward data dissemination.
 - h. A DTN is based on specific application protocols that handle store-and-forward data dissemination.
5. Which of the following statements are true?? (3p)
- a. Starlink is a good technology for time-critical applications.
 - b. Argos is a good technology for time-critical applications.
 - c. Starlink is a good technology for non-critical applications.
 - d. Argos is a good technology for non-critical applications.
 - e. Argos provides full duplex communication.
 - f. Starlink provides full duplex communication.
 - g. Argos provides one-way communication.
 - h. Starlink provides one-way communication.
 - i. Argos provides half-duplex communication.
 - j. Starlink provides half-duplex communication.
6. Describe the general architecture of a **sensor network** and give an example of an application that uses a sensor network.? (3p)
7. What is **fog computing**? (2p)
8. Describe the purpose and general architecture of a **Private 5G Network**. (3p)
9. Describe a **routing algorithm** that can be suitable for a **vehicular ad-hoc network** that should warn drivers about hazardous roads ahead. (3p)
10. Explain what the procedure **frequency hopping** is, and explain why it is used in communication systems. (4p)

Part B: Performance analysis problems (30 points)

11. You are doing performance modeling of a web server system. You measure the arrival rate of new requests and find that the arrivals can be modelled as a Poisson process with an average rate of 10 requests per second. Also, you measure the service times of request, and find that the service times are independent and that they can be modelled with an exponential distribution with an average of 0.06 seconds. Also, you see that the web server system can be modelled as a conservative single server system with unlimited queue. **(10p)**

a. What is the **average utilization** of the server? (2p)

b. What is the **average throughput** of the server system? (2p)

c. What is the **average total number of requests** in the server system? (2p)

d. Assume instead that the service times can be modelled as a **deterministic distribution**. What is the **average total number of requests** in the system in this case? (4p)

12. You are modelling a very simple MAC protocol. A device can send a data packet at any time. If a request is received correctly by the receiver, the receiver sends an ACK packet after exactly 1 second. If the device does not receive the ACK packet correctly, it retransmits the data packet after another 1 second. The cycle repeats until the device has received an ACK. The probability that any data or ACK packet are received correctly is 0.8. **(8p)**

What is the average time from when the device starts to send its data packet until it has received an ACK?

In your calculations, you can ignore all processing, transmission, and propagation delays. Also, the devices are perfectly synchronized.

13. You are designing a communication link from the Earth to the Moon. The sender is one of several ground stations on the Earth, and the receiver is a ground station on the Moon. You can assume that there always is line-of-sight between the two ground stations (you use the optimal ground station on the Earth for your data transmission). You achieve an average **transmission capacity of 1 Mbits/second** on your communication link. What will the average total **one-way delay** be for a data message of **10 kbits**? **(4p)**

14. You are investigating the performance of the queueing system shown in the figure. New requests are arriving as a Poisson process with mean $\lambda=6$ requests per second. The service times are independent and exponentially distributed with mean service rate of $\mu=5$ requests per second. The queue is limited with only 2 places. You perform measurements on the queueing system and find that at any random time instant, the probabilities that there are k requests in the system ($k = 0$ to 3) are: $P(k=0) = 0.19$; $P(k=1) = 0.23$; $P(k=2) = 0.26$; $P(k=3) = 0.32$. Also, a request is simply blocked if it arrives when the queue is full. The queueing policy is first-come-first-serve (i.e an ordinary queueing system) **(8p)**

- a. What is the average number of requests in the system? **(2p)**
- b. What is the average throughput of the system? **(2p)**
- c. Assume that a request R arrives and takes the last place in the queue (i.e, there are 2 requests in the system when it arrives). What is the average total response time for request R ? **(4p)**

Part C: System design scenarios (30 points)

For each of the scenarios given below, describe how you would design the network system. For full points, your solution must address the information given in the scenario, and give good motivations and justifications for all parts of your solution, as described in the lectures.

- 15.** The Skåne University Hospital (SUS) in Lund wants you to design a **(10p)** network system for them. The network system should track different types of mobile medical equipment, since medical equipment has a tendency to get lost in the large hospital. There are about 1000 medical equipment devices, placed on small carts with wheels, which should be tracked. You can focus on the 12 story central building, also called Blocket. SUS wants to monitor the location of the devices, and the most important requirement is to know on which story a specific device is placed. The image below shows a typical cart for medical equipment.



16. Scania is a large Swedish company and a world-leading truck manufacturer. (10p)

Currently, Scania investigates solutions for so called vehicle platooning, that is, solutions where several self-driving trucks cooperate, thereby allowing them to drive with very small distance between each other, see an illustration in the image below. A vehicle platoon is always controlled by the leader vehicle, and other vehicles can "connect" behind the leader. Your task is to help Scania with a network system solution for their vehicle platoons. The company will then perform test drives in a secured test area outside of the city of Södertälje (south of Stockholm). The vehicle platoon should have one leader vehicle, and maximum four following vehicles.



- 17.** Your task is to help the polar research station NIPR, placed in the small town of Ny-Ålesund in Svalbard. NIPR wishes to monitor the waters around North Pole, and in particular, monitor the North Pole ice cap. Since the North Pole covers a very large area, NIPR wishes to use the waters just north of Svalbard as a test site. Your task is to propose a suitable network architecture for this monitoring system. The system should continuously monitor the environment, and collect data of the ice cap, water temperatures and salinity. NIPR has access to a cloud server, where all data should be stored. Below is a map showing the location of Svalbard.

