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ETSN11 - Introduction

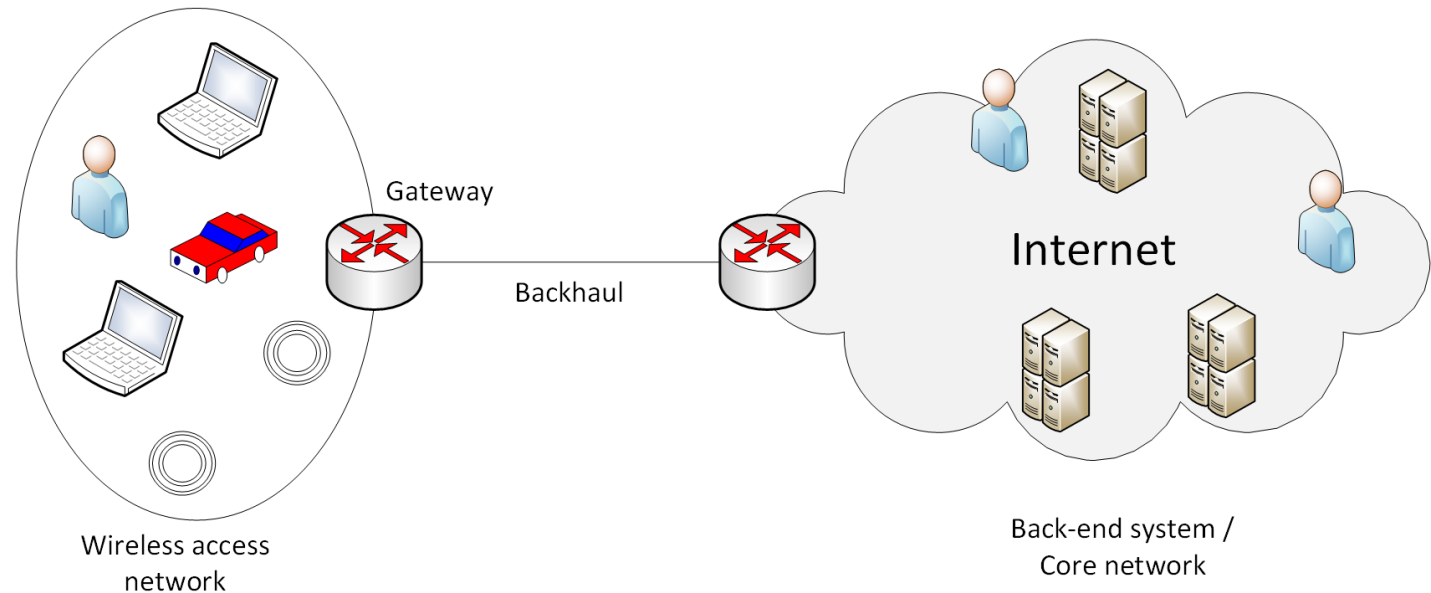
MARIA KIHLM



ETSN11 Wireless networks and applications – System design and Performance

- Advanced course for C, D, E, I, Wireless, and Exchange students.
- Network architectures for networked applications with wireless access.
- **Focus on "beyond ordinary Internet"**

Note: This course is in English.



Maria Kihl

- Affiliation
 - Professor in Internetworked systems at Lund University.
 - Assistant Head of Department for the Dept of Electrical and Information Technology.
 - Director for the Vinnova Competence center NEXTG2COM.
- Main research competences
 - Telecommunication architectures
 - Performance modelling and control of networked systems for mission-critical applications.
 - Cloud control, 5G, Industry 4.0,
 - Applied research with a strong foundation in theory.



Prerequisites

C, D, E, I programs

- Minimum 90 hp completed courses in your program
- Completed one basic math course (Endimensionell analys)
- If you cannot register to the course, you have not been admitted.
 - Contact me for more information

All students:

- Assumed prerequisites for this course are basic knowledge of **Internet protocols, Probability theory and Statistics**.
 - There is an online module on Canvas where you can test your background knowledge and review these parts.
- **The lecture on Wednesday 8-10** is a review on probability theory and statistics.
- Also, the **first tutorial** will include review exercises of the prerequisites.

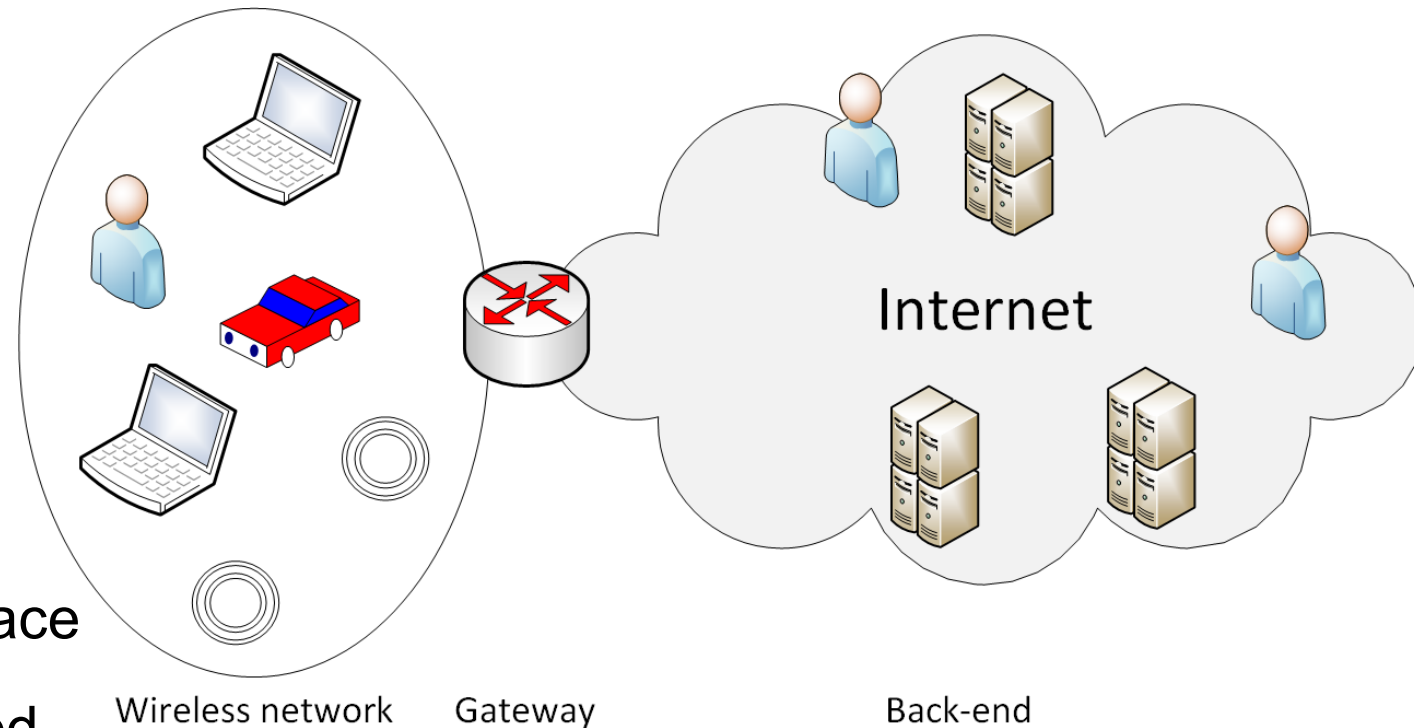
ETSN11 - Advanced course

You are expected to:

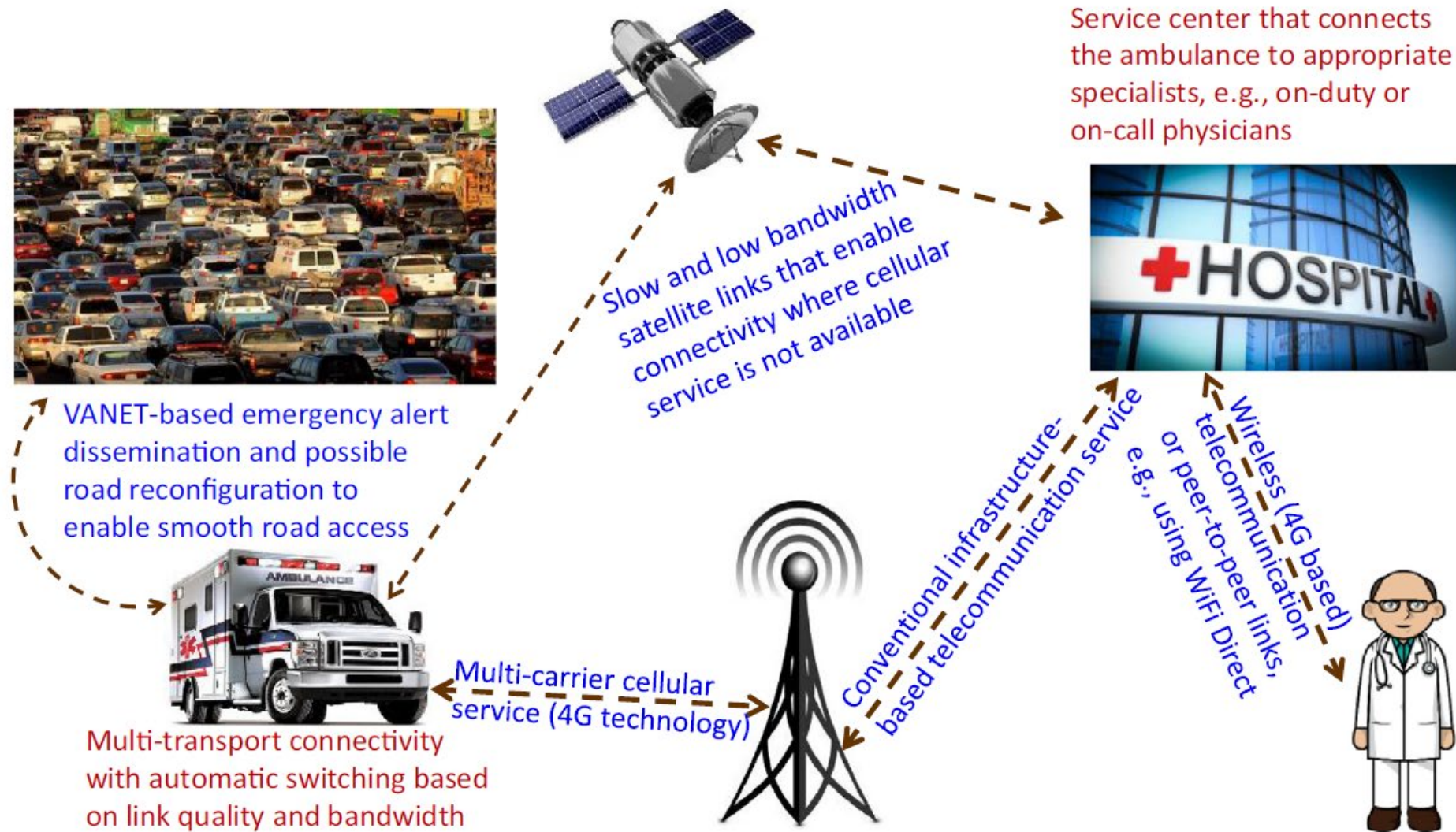
- work without close supervision.
- manage without a course book, the course literature is based on the slides + articles.
- know how to do team work and group projects.
- know how to write technical reports in English.
- know how to do proper literature searches.
- know the general rules for the use of AI tools.
- be able to not only learn the basic technologies, but also to understand how they can be used in complex scenarios based on reality.

Main course content

- Network architectures and technologies
 - Fast-speed access networks
 - Internet of Things (IoT)
 - Ad-hoc networks
 - Sensor networks
 - Delay-tolerant networking
 - Underwater networks
 - Data communication in outer space
- Performance analysis of networked systems and application
- System design for real-world scenarios

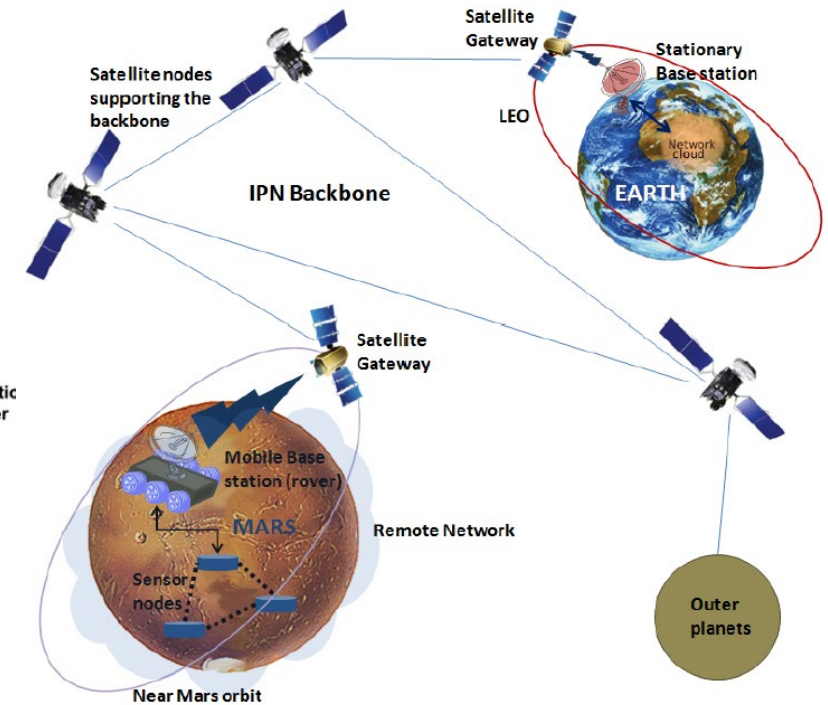
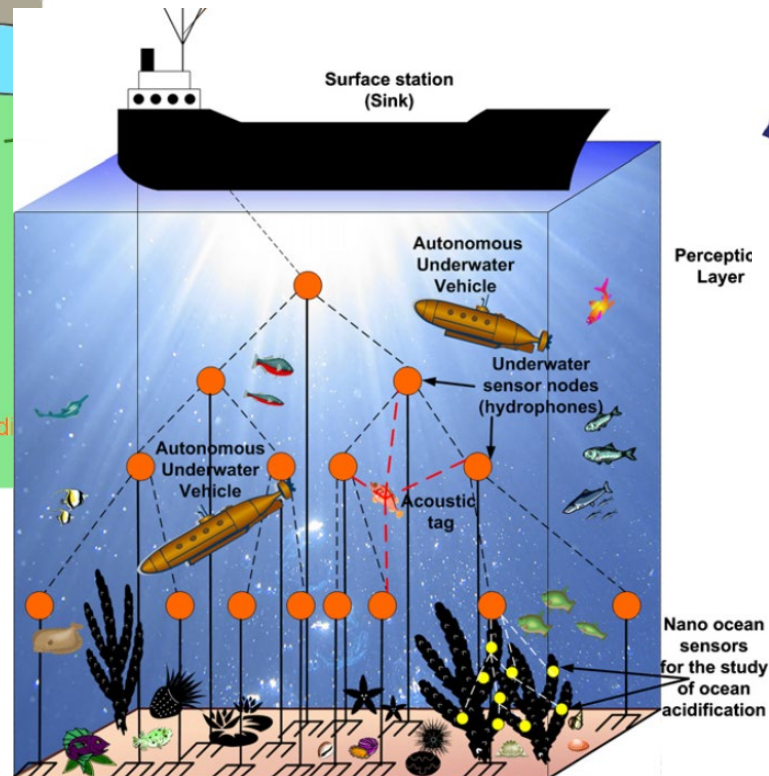
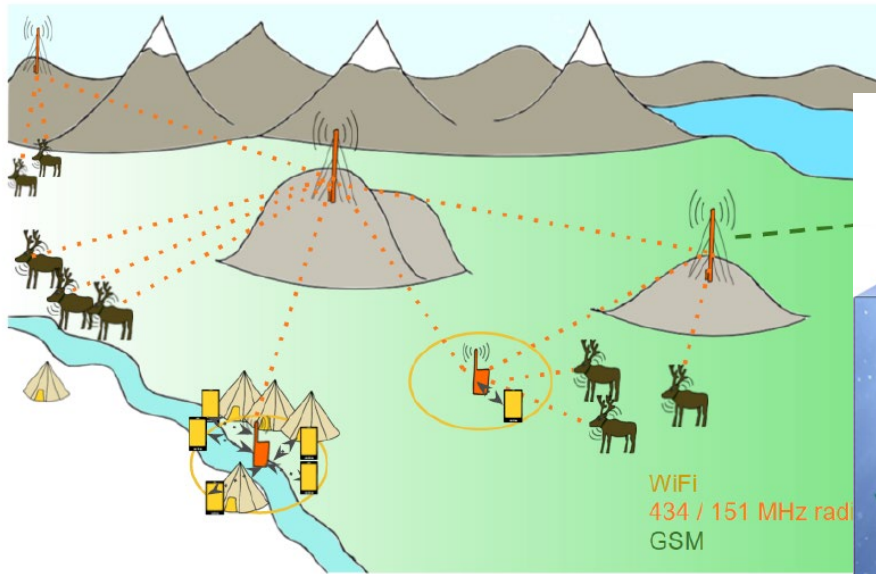


Going beyond ordinary Internet



Earth, Underwater, and Outer space

In the course, we will go beyond the ordinary Internet. We will discuss wireless network architectures both on Earth, Underwater, and in Outer space.



But you are of course welcome to use wired solutions if you believe that they are the best for a specific scenario 😊.

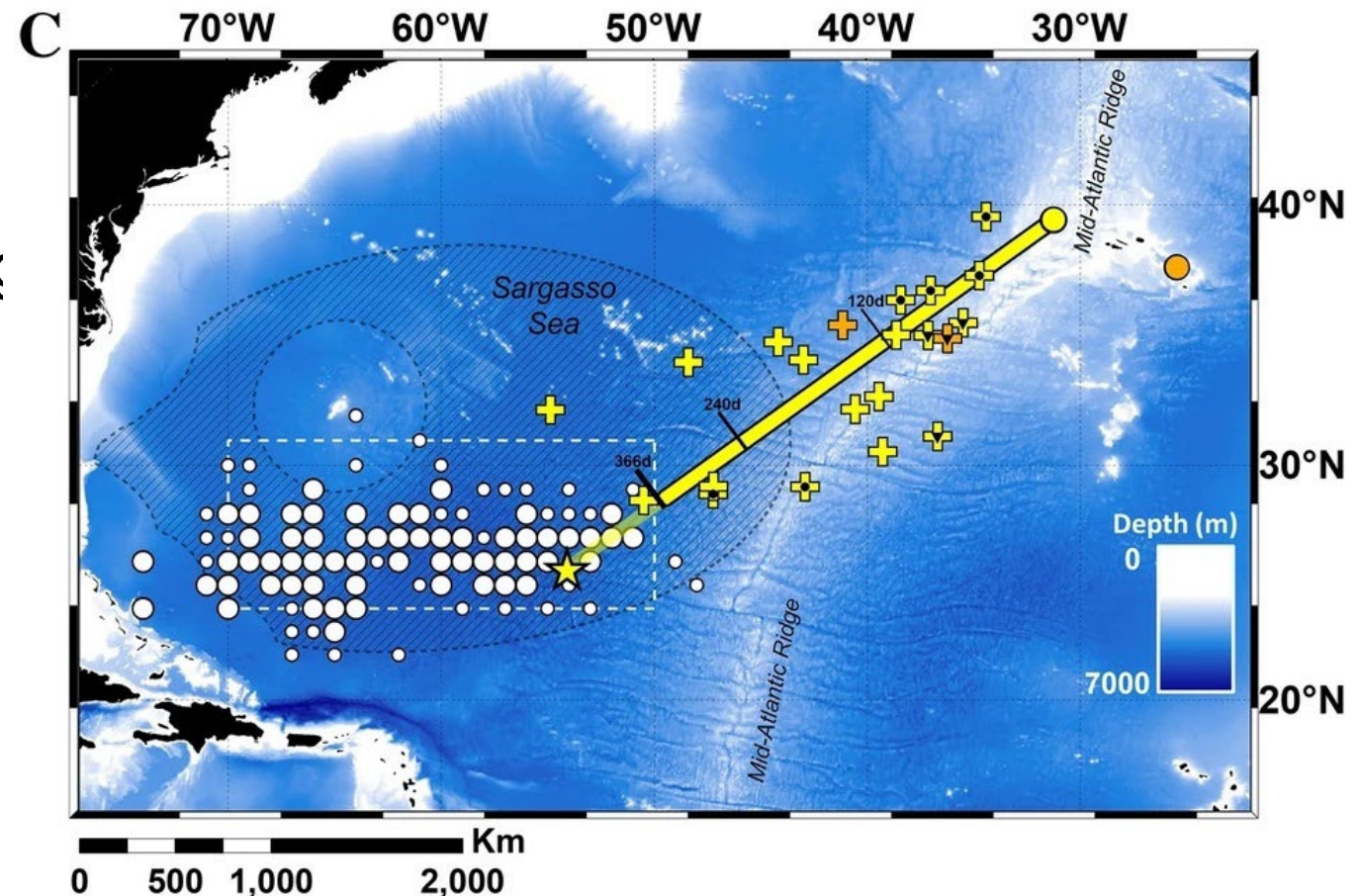
Real-world example: Connected drones for rescue operations at sea

The Swedish Sea and Rescue society (SSRS) and the Swedish coast guard develop connected drones for rescue operations at sea. The drone can find a person at sea, stream a live video, and register the position. The rescue ship can then go to this position and rescue the person.



Real-world example: Tracking eels to the Sargasso sea

- Female silver eels were tagged with **pop-up Argos satellite tags** and released from Azores islands' shore in November and December 2018 and 2019.
- Twenty-one tags detached after more than 40 days (up to one year, about six months on average) and recorded substantive data along the way.
- The locations at tag release along the way confirmed that they were going towards the Sargasso Sea.



Real-world example: NASA LunaNet

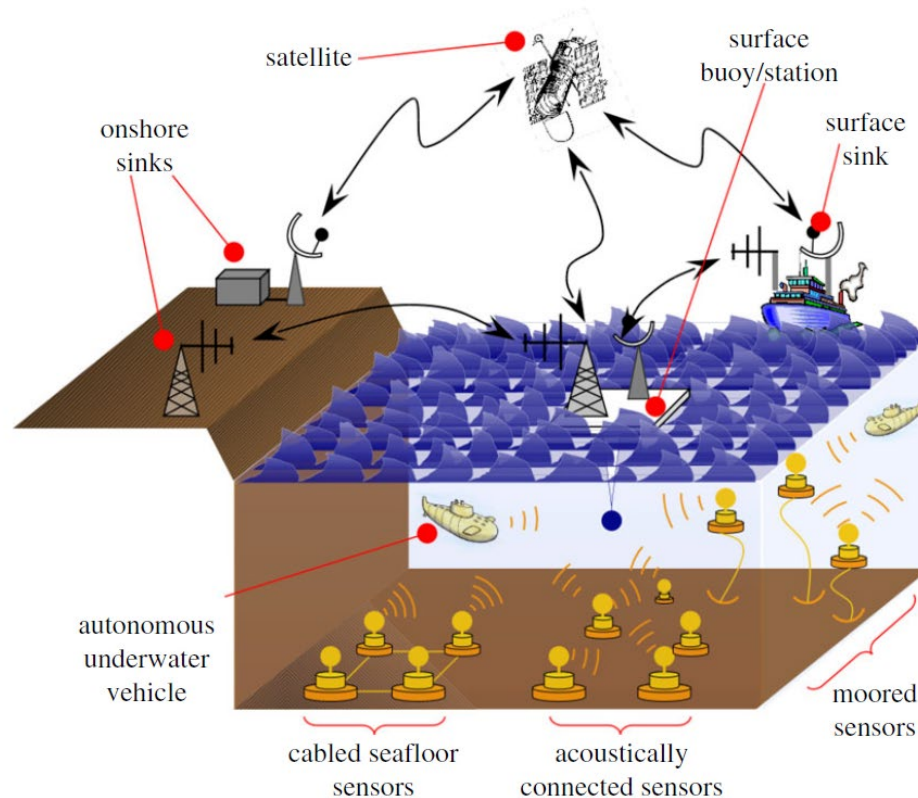
LunaNet is planned to provide Internet-like capabilities to the Moon for the NASA mission Artemis, bringing people to the Moon.

- With LunaNet in place, users will experience an operational environment similar to that experienced by Internet users on Earth.



In this course: Wireless = not wired!

In, for example, underwater networks, acoustic and/or optical data transmission may be a better choice than radio.



Types of exercises you will work with

- **Theory questions**
 - Questions about the network architectures and technologies described in the lectures.
- **Performance analysis problems**
 - Performance analysis of wireless networks and systems
 - Given a specific problem, perform an analysis using mathematical modelling and analysis.
 - **Main toolbox:** Probability theory and statistics
- **System design problems**
 - Based on realistic scenarios with networked applications.
 - For this scenario, suggest a suitable network architecture.
 - **Main toolbox:** The network architectures and technologies described in the lectures.

Theory question, example (251030)

Which of the following statements are true for **ad-hoc networks**? (5p)

- a) They require contention-free MAC protocols.
- b) They require contention-based MAC protocols.
- c) They can use centralized network architectures.
- d) They can use decentralized network architecture.
- e) They can be used for time-critical applications.
- f) They can be used for non-critical applications.
- g) They can have a DTN architecture.
- h) They require low communication error rates.
- i) The nodes in an ad-hoc network always require low energy consumption.

Theory question, example (251030)

Describe the main functions for **DTNs** and describe an example of a network system based on a DTN architecture. (5p)

Performance analysis problem, example (231025)

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.

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.

(8p)

System design problem, example (231025)

The Skåne University Hospital (SUS) in Lund wants you to design a 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 stories 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 shows a typical cart for medical equipment.



ALL Course Information

<https://canvas.education.lu.se/courses/43015>

Schedule:

<https://cloud.timeedit.net/lu/web/lth1/ri11566055000YQQ57Z7557007y4Y3143gQ7g0X6Y65ZQ176.html>

Course responsible and project supervisor: Maria Kihl

Project supervisor: Habtegebrel Kassaye Haile

Course literature

- There is NO textbook.
- **The slides will define the course content.**
- For each theory lecture, there is a list of reading material, which may include articles with specific reading instructions. The slides are always part of the reading material. **The slides defines the content (nothing else will be in the exam).**
- Also, for each theory lecture, there is a list of **Other relevant articles**. I have used these articles when preparing the lectures, and they may be **relevant to your project**.

Lectures (preliminary plan)

The lectures will on campus in room **E:1406**. Note: For this year, I have re-organized my slides and lecture topics. Therefore, the following plan is preliminary.

- 31/8: Introduction
- 1/9: Networks and applications – basic concepts
- **2/9: Review of probability theory and statistics (Optional, not part of the course)**
- **7/9: Lecture about the project**
- 8/9: Users and back-ends
- 9/9: Network architectures
- 14/9: Cellular Mobile Networks and IEEE 802.11 (WiFi)
- 16/9: Low-Power Wireless Networks (LPWAN) and Personal Area Networks (PAN)
- 21/9: Satellite Networks and Delay-tolerant networking (DTN)
- 23/9: Interplanetary networks and Underwater networks

Tutorials

Wednesdays 10-12 in E:2517 (from week 2)

- 9/9: Review of Probability theory and Statistics
- 16/9: Data transmission
- 23/9: Arrival processes and queues
- 30/9: Wireless access
- 7/10: Network systems

Project

- The project will be conducted in groups of 3-4 and it is worth 2.5 credit points.
- **Your group will perform a larger system design based on a specific scenario.**
- The solution will require you to study network technologies and protocols, as well as performance analysis, in order to determine how well your system will meet the system design requirements.
- The project consists of both **individual and group components**. You must pass all tasks in both components in order to pass the project as a whole.
- All information on Canvas in the document "**Project 2026**".

Project presentations on Friday October 16

- On **Friday October 16**, the projects are presented and evaluated.
- **You are required to attend!**
 - Some flexibility regarding time schedule if needed (please contact course responsibility as soon as possible).
 - Only for **extraordinary circumstances**, online attendance can be arranged after specific approval by course responsible.

Exam

- The exam is on **Friday Oct. 30, 8-13 in Sparta.**
- The exam digital using the **Inspera platform.**
 - You need to bring a laptop to the exam.
 - Requires a SafeBrowser mode.
 - More information on Inspera:
<https://www.campusonline.lu.se/en/digital-tools/inspera/>
- More information will come later.

Project week 1: Scenario Selection

Week 1: Scenario selection

- You must fill in the **Project Scenario selection form** by the end of **Thursday Sept 3**.
- Link to Project Scenario selection form (the form opens after this lecture):
<https://forms.gle/puVNdFTaNa53qS939>
- There are 13 available scenarios, described in the document "**Project Scenarios**".
- You are welcome to register a friend that you want to do the project with. You and your friend needs to select the same scenarios, in the same order.
- **All other information will come on the project lecture next Monday.**

Level of complexity - Explanation

For each scenario, there is a Level of Complexity:

Low: Your system design solution for this scenario can to a large extent be based on network technologies included in this course. However, your project must adapt these technologies for this specific scenario.

Medium: This scenario will partly require technologies that are not directly included in this course, but are part of the general scope of the course. Therefore, your project will have to find suitable technologies for this specific scenario.

High: This scenario will to a large extent require technologies that are not directly included in this course, but are part of the general scope of the course. Therefore, your project will have to spend time on investigating suitable technologies and adapt them to this scenario.

Scenario 1: Drones for medical transports

Summary: This scenario investigates self-service health cabins in rural areas. In a self-service health cabin, a patient can do some medical tests and provide samples (i.e blood, urine etc). Also, they can pick up medicine. The results of the medical tests should be sent digitally to the hospital in Storuman.

The samples and medicine should be transported to and from the hospital, using connected remote-controlled drones. Your project should result in a connectivity solution for the self-service health cabins, and a solution for how to deploy the connected remote-controlled drones that provide safe and secure transport of medical samples and medicine.

Level of complexity: Low



Scenario 2: Battlefield communications

Summary: This scenario investigates next-generation communications solutions for soldiers on the battlefield. The communication solution should allow infantry soldiers to communicate with each other and the command centre during battle. The communication must be secure, so that an enemy cannot listen in to the communication.

Your project should provide a secure and robust communication solution for soldiers on the battlefield. A battlefield is a tough environment for electronics, so the devices used must be robust, but also be small and light enough to easily fit in each soldier's kit.

Level of complexity: Medium



Scenario 3: Cattle monitoring

Summary: This scenario investigates communication solutions for remote monitoring of cattle and vehicles on a cattle station. The cows' location and general health status should be monitored from the homestead. Also, the location of all various vehicles (trucks, bikes etc.) should be tracked.

Your project should provide a complete communication system solution for the cattle station. Your solution should allow for infrequent maintenance of network devices (ideally only once every few months). Also, the solution must have a communications range covering the entire cattle station.

Level of complexity: Low



Scenario 4: High-density Internet Access

Summary: This scenario investigates a high-speed wireless network system solution to serve the spectators on Eleda Stadion in Malmö during football matches. The system should provide Internet access as well as private services, including instant replay video streaming, uploading and streaming of spectator videos, and messaging between spectators at the match.

Your project should provide a network solution with a wireless access network and a proper back-end system, which provides high-speed Internet access to all spectators during a match, also when the Stadion is full.

Level of complexity: Low

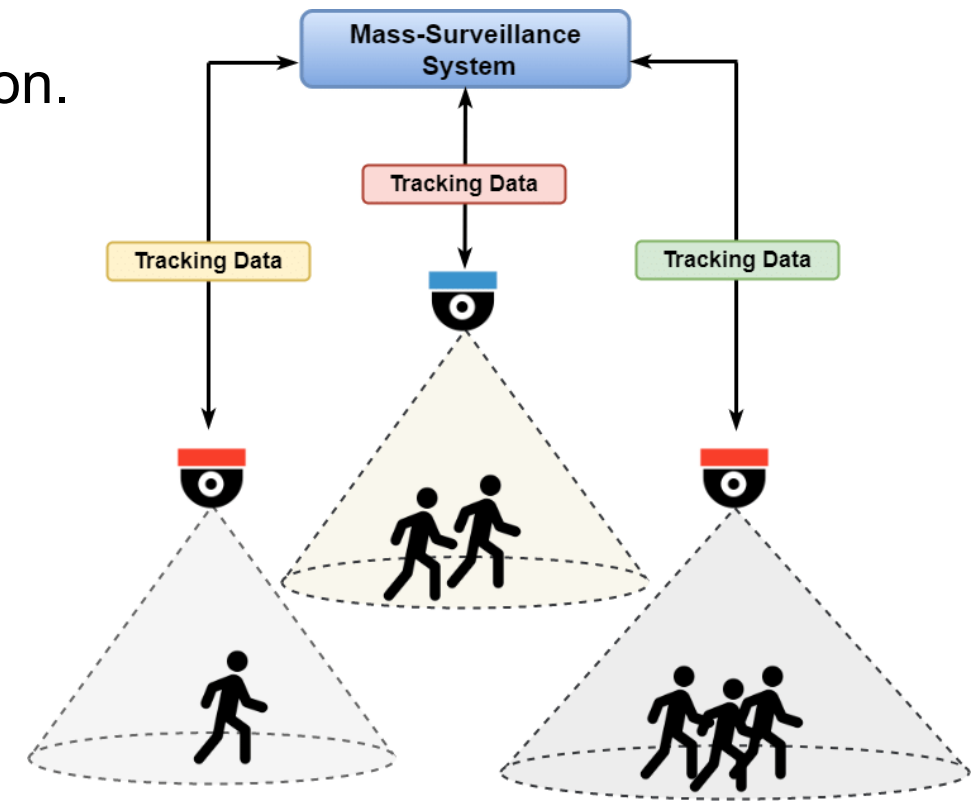


Scenario 5: Mass surveillance system

Summary: You are not reading this document. The scenario investigates a system that collects a high volume of data from diverse networks throughout Europe. The data needs to be passed through secret data centers, which you may assume are placed in capital cities in each state, where it will be processed in real time. All data should be securely always encrypted.

Your project should provide a complete network solution. The system should have real-time processing of text, voice and video data across Europe. Also, it should provide collection, collation and long-term storage of diverse data sources from different networks and locations. The system must provide high levels of encryption and information security at all stages.

Level of complexity: High



Scenario 6: Multi-player online game

Summary: This scenario investigates network system architectures for a massive multi-player online game. The game has real-time multiplayer battles and login and account management services. The game has become extremely popular and as a result, the back-end game servers have been frequently unavailable due to a high volume of requests per minute.

Your project should design an authentication and game server architecture for up to 4 million players in Europe simultaneously. Also, it should include mechanisms to gracefully handle excessive traffic. There should be synchronization between different servers, so that game state is consistent for different players in the same areas.

Level of complexity: Medium



Scenario 7: Internet access in rural areas

Summary: This scenario investigates Internet access in rural areas of Botswana. The fixed-line infrastructure in these areas is minimal, and the program does not have funding to build major new infrastructure. Basic Internet access is very important for the local business, for example to get weather reports, for wholesaling connections, and financial transactions.

Your project should develop a connectivity solution for a targeted area in Botswana. The system should provide basic Internet access in remote areas, to improve the conditions for both the local businesses and private users. There should be minimal new infrastructure to keep the costs low.

Level of complexity: Medium

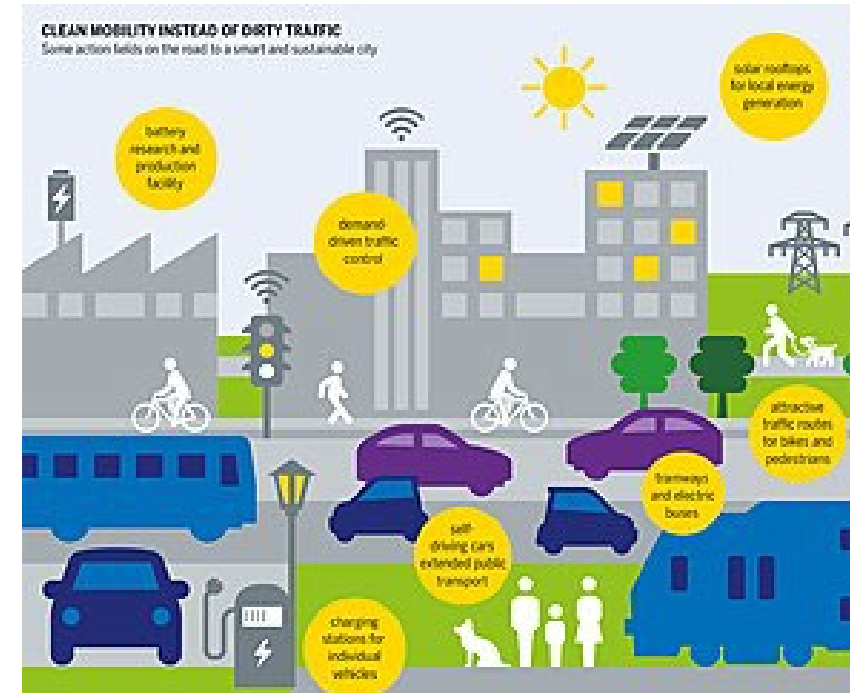


Scenario 8: The smart city

Summary: This scenario investigates a smart city communication infrastructure in Malmö, which include connected traffic lights and connected public service vehicles such as buses, garbage trucks, snowplows, and all types of emergency vehicles. The main aim is to provide safe and fast roads for safety-critical vehicles, such as ambulances, fire trucks and police vehicles.

Your project should develop a network system solution that provides reliable coverage across Malmö city. The system should include connected traffic lights that give priority to safety-critical vehicles, such as ambulances, to provide high reliability for them. Also, municipality owned vehicles and safety-critical vehicles driving in the city should be connected to the system.

Level of complexity: Low

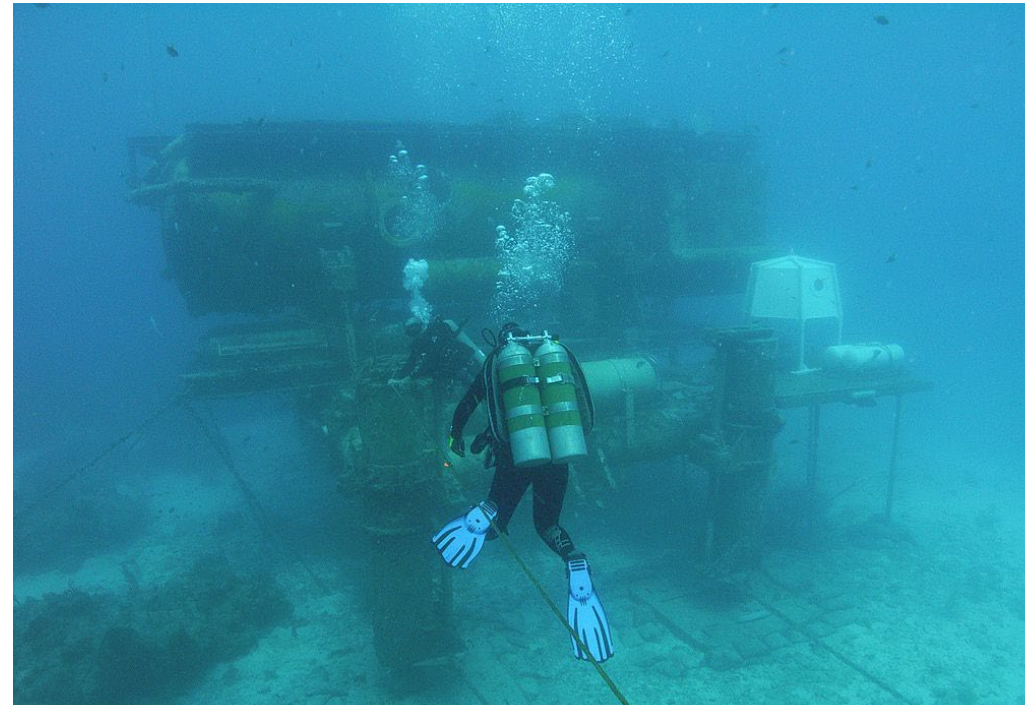


Scenario 9: Underwater communication

Summary: This scenario investigates a semi-autonomous underwater habitat placed in the Pacific Ocean outside the coast of California, approximately 50 meters below the surface and about 1 km from the shore. The researchers living at the habitat need Internet access. Also, the researchers will participate in diving operations, exploring the ocean. During these operations, the divers need to communicate both with the habitat and with each other.

Your project should develop a complete network system solution for the habitat. Since the habitat is semi-autonomous and located far out in the ocean, it is important that your solution is both resilient and robust to weather disturbances.

Level of complexity: High



Scenario 10: Internet on Mars

Summary: This scenario investigates communication solutions for future space missions for colonization of Mars. The residents of a Mars colony will require Internet access. Also, all spaceships will need to communicate with Earth, Mars and with each other.

Your project should develop a network system solution that provides Internet access for the residents of the Mars colony. Also, the system should provide data communication between spaceships, Mars and Earth. Further, you should develop a power supply solution for the network infrastructure on Mars.

Level of complexity: High



Scenario 11: Mobile live streaming

Summary: This scenario investigates an entertainment system based on body cameras for Malmö Arena during ice hockey matches. There will be one body camera per player on the ice in the hockey game, and each camera will be able to record and send high-quality live videos. The live videos should be broadcast on the Internet, so that anyone can follow their favorite player during the game.

Your project should provide a network system solution for this entertainment system. Also, your project should suggest, if possible, commercial cameras that are suitable for the scenario.

Level of complexity: Medium

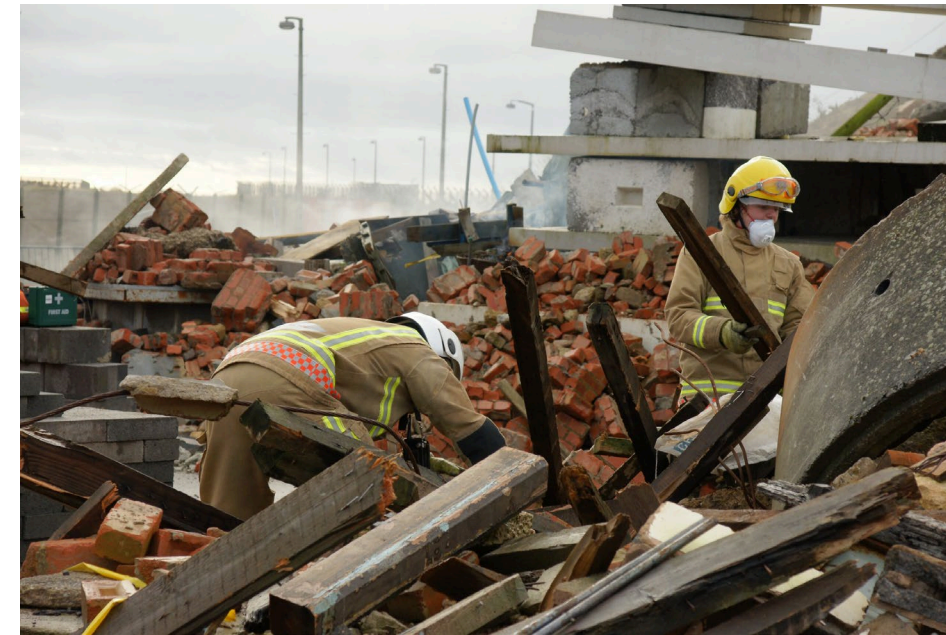


Scenario 12: Humanitarian emergencies

Summary: This scenario investigates communication infrastructures in disaster areas. After a disaster, for example an earthquake or a war zone, the fixed infrastructure often is damaged and not operational. It is therefore important to deploy temporary communication infrastructures for wireless Internet access in this areas, both for humanitarian organizations and the people that live in the area.

Your project should develop a communication infrastructure for basic Internet access for a targeted area in Pakistan. Your solution should provide basic Internet access and communication services to people and emergency organizations. The project focuses specifically on the city Quetta in Pakistan, which is located in a high-risk earthquake zone.

Level of complexity: Medium

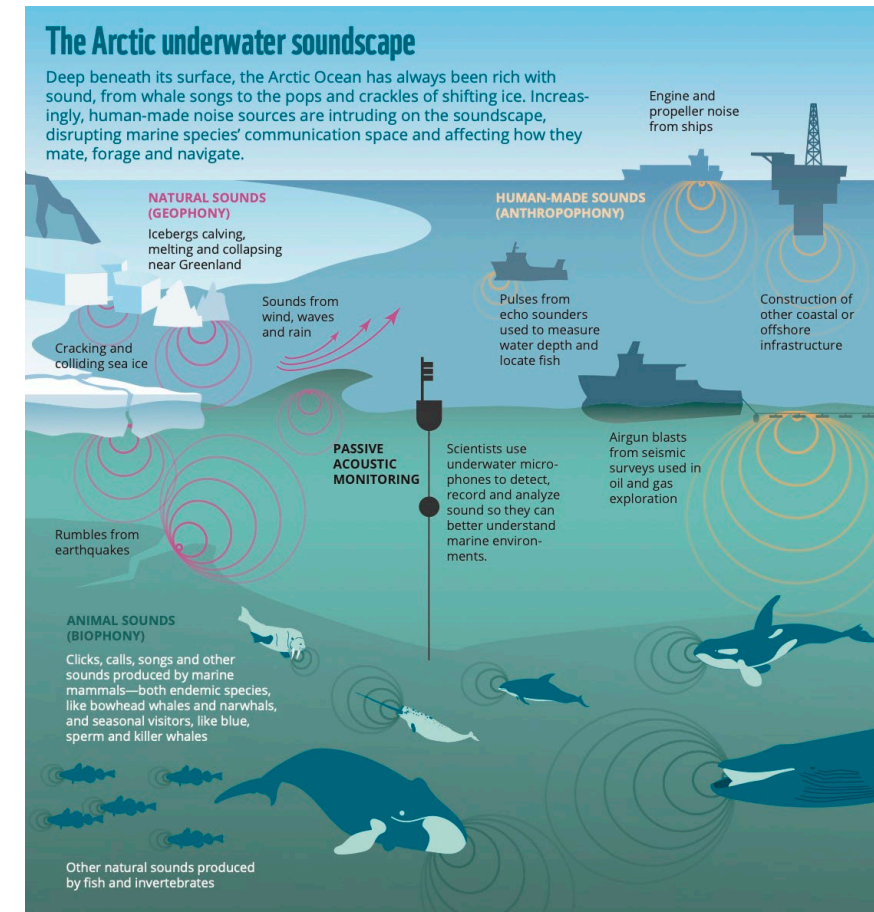


Scenario 13: Underwater environmental monitoring

Summary: This scenario investigates networked systems for underwater environmental monitoring in the Arctic region, specifically focused on the underwater region right below the North Pole. Underwater environmental monitoring has become an important application for tracking aquatic health and climate changes. Both Antarctica and the Arctic region are important for monitoring both general aquatic health and climate changes.

Your project should develop a communication infrastructure for underwater environmental monitoring of the waters below the North Pole. Your solution can include collaborations with other ongoing activities in the Arctic region.

Level of complexity: Medium



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