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## External Lecture Assignment

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## **Clustered ad hoc networks**

Ad hoc networks are wireless networks that are set up spontaneously and without the use of a centralized access point or infrastructure. Since ad hoc networks do not require fixed infrastructure, they are easy to set up and can be used in various situations.

The different approaches to operate wireless ad hoc networks are centralized, flat and clustered networks. In a centralized network, a single controller handles the whole network by collecting information and distributing it to the network. In a flat network, every node collects information from the neighboring nodes and decides for itself. In a clustered network, nodes are gathered in clusters where one node is a cluster-head that is in charge of allocating radio resources.

### **Advantages**

The advantages of clustering come from the use of the “divide-and-rule” principle where the network is broken into smaller clusters that are responsible for managing their own data. This improves network scalability, reliability, performance, and security. The network can easily be expanded by adding nodes to clusters, the failure of one node does not affect the whole network, performance and security are high because of each node in the cluster being responsible for managing its own traffic and data.

### **Disadvantages**

The disadvantage of clustering is their difficult implementation since the network is more complex. First you either choose the cluster-heads and then add neighboring nodes to their cluster, or you associate nodes in clusters and choose the cluster-head among them. For every new cluster, you need to do frequency allocation. The complexity also makes it more difficult for all the processes to work simultaneously. Multiple clusters also leads to more power consumption and managing, meaning higher costs.

### **Most important information**

The most important piece of information that we took from the presentation was that clustered ad hoc networks perform better than centralized and flat ad hoc networks. We also learned how the network structure can be layered so that each layer performs a specific task. By cross-layer optimization, the layers can be optimized to coordinate together.

# Wi-Fi technology

## Advantages

One of the main advantages of Wi-Fi technology is its portability. Wi-Fi can be accessed from a variety of locations, allowing users to access the internet from any location that has a Wi-Fi network. Because Wi-Fi networks are widely available, users may locate a Wi-Fi network in their region, making it even easier to stay connected.

Another advantage of Wi-Fi is its high speed compared to other wireless networks. Wi-Fi uses faster data transfer rate, up to 600 Mbps. Additionally, Wi-Fi networks are generally more secure than other types of wireless networks, due to the use of authentication and encryption methods such as EAP and TKIP.

## Challenges

Wi-Fi networks' main challenges include interference from other wireless devices, and restricted range. Interference from other wireless devices can damage the Wi-Fi signal, resulting in slower speeds and worse dependability. Finally, Wi-Fi networks have a restricted range and can only reach regions within the same or adjacent buildings. Furthermore, due to the lack of authentication and encryption mechanisms in certain networks, Wi-Fi networks are vulnerable to security concerns.

The most important piece of information that we took out of this presentation was the recent evolution of Wi-Fi technology. More precisely, the features of Wi-Fi 6 and development towards Wi-Fi 7.

## Most important information

Wi-Fi 6 includes advanced features such as Orthogonal Frequency Division Multiplexing (OFDM). OFDM divides the available radio spectrum into many channels, which are subsequently assigned to different network devices. This lets multiple devices send and receive data at the same time, reducing interference between devices and increasing network overall speed.

Wi-Fi 7 is designed to offer even faster speeds than Wi-Fi 6 with the added benefit of increased coverage. Additionally, Wi-Fi 7 includes features such as coordinated OFDM and beamforming, which are designed to improve network reliability and reduce latency. Coordinated OFDM dynamically allocates channels to different devices on the network, which allows multiple devices to send and receive data simultaneously, while also minimizing interference between devices.

# ***The Physical Layer of 5G and Beyond***

## ***The 5G standard***

The 5G standard aims to provide high-speed, low-latency, and more reliable connections than existing network standards. It uses a range of frequency bands, including sub-6GHz, mid-band, and mmWave spectrum, to achieve faster and more reliable connections. The 5G standard also includes massive MIMO, multi-user aspects, hardware impairments, full duplex, and other novel aspects such as waveforms, unified control and user plane separation, cloud/fog RAN, and applications of machine learning. The 5G standard is designed to provide enhanced mobile broadband, massive machine-type

## ***Spectrum and Frequency bands in 5G***

The spectrum and frequency bands used in 5G networks are divided into two categories: low-band and high-band. Low-band spectrum operates in the 600 MHz to 6 GHz range, while high-band spectrum operates in the 24 GHz to 52 GHz range. Low-band spectrum provides wider coverage and better penetration, while high-band spectrum provides higher data rates and more capacity. Additionally, 5G networks also use mmWave (millimeter wave) spectrum in the 28 GHz to 39GHz range, which provides the highest data rates.

- Low-band spectrum operates in the sub-6 GHz range, meaning frequencies below 6 GHz. This includes the 600 MHz, 700 MHz, 800 MHz, 900 MHz, 1.2 GHz, 1.7/2.1 GHz, and 2.6 GHz bands. It provides wider coverage and better penetration, but its capacity and data rate are limited.
- High-band spectrum operates in the 24 GHz to 52 GHz range and is also known as mmWave. It provides the highest data rates and more capacity, but it has a limited range and is easily blocked by obstacles such as buildings, trees, and hills.
- Finally, mmWave spectrum operates in the 28 GHz to 39GHz range. It also provides the highest data rates, but it is more susceptible to blockages and has a limited range.

## ***Massive MIMO***

Massive MIMO is an emerging technology in 5G that utilizes multiple antennas to increase spectral and energy efficiency. It enables a large number of users to be served simultaneously by a single base station. The components of Massive MIMO include antenna geometries and channel models, instantaneous Channel State Information (CSI) acquisition, and multi-user aspects. It has been shown to provide significant performance benefits in terms of throughput and latency. Additionally, Massive MIMO can also be used for Full Duplex communication, as well as for technologies such as mmWave and other novel aspects in 5G such as waveforms, Uplink/Downlink Coordination, Cloud/Fog RAN, and applications of Machine Learning.

***Antenna Geometries and Channel Models:*** Antenna geometries and channel models are essential components of Massive MIMO. They define the characteristics of the antennas such as their size, shape, and orientation, as well as the properties of the wireless environment in which they operate. By understanding the interactions between the antennas and their environment, Massive MIMO can be optimized to provide the best performance.

**CSI Acquisition:** Channel State Information (CSI) acquisition is the process of collecting and analyzing information about the channel in order to determine the best transmission and reception settings. This enables Massive MIMO systems to make decisions quickly and accurately in order to maximize the efficiency of their transmissions.

**Multi-User Aspects:** The multi-user aspects of Massive MIMO refer to the ability of the system to support multiple users simultaneously. This requires advanced algorithms and techniques to ensure that each user is served without interference from the other users.

**Full Duplex:** Full duplex is a communication method that allows for simultaneous transmission and reception on the same channel. This can be used to improve the performance of Massive MIMO systems by increasing their capacity and reducing interference.

**mmWave:** Millimeter Wave (mmWave) is a wireless communication

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### ***Other Novel aspects in 5G***

5G networks introduce a range of novel aspects such as waveforms, UCNC, CUPS, and Cloud/Fog RAN, which enable higher data rates, improved latency, and increased reliability. Waveforms are new modulation techniques that allow for higher spectral efficiency and increased data rates. UCNC is an architecture that combines multiple technologies to provide users with high-quality services with improved flexibility and scalability. CUPS is a new network architecture that makes use of centralized units to improve resource management and reduce latency. Cloud/Fog RAN enables distributed network architectures with the integration of cloud computing and radio access networks. All of these aspects increase the capabilities of 5G networks and enable new applications.

### ***Towards 6G***

6G is the upcoming sixth-generation mobile telecommunications technology, which is expected to be available in the near future. It is anticipated to be a revolutionary development that will provide faster speeds and better connectivity than 5G technology, with ultra-high data rates and ultra-low latency. 6G technology will also provide improved coverage, scalability and enhanced security. 6G will also bring a number of new applications and services, such as virtual and augmented reality, autonomous driving, and the Internet of Things (IoT). 6G technology is expected to use multi-band or millimeter-wave (mmWave) frequencies, which will allow for faster data transmission and shorter range than 5G. 6G is expected to be the first generation of mobile technology to use artificial intelligence (AI) to help make decisions and optimize the performance of the network. 6G will also make use of advanced technologies such as quantum computing, distributed ledger technology, and edge computing. 6G technology is expected to be the foundation of the next generation of wireless networks, paving the way for new and innovative applications and services.

## ***Towards 6G***

Machine Learning is a rapidly growing field with a wide range of applications. It is used in a variety of industries including healthcare, finance, retail, manufacturing, and transportation. It is used to improve decision making, automate tasks, and predict outcomes. Machine Learning algorithms can be used to identify patterns in data, detect anomalies, and develop personalized models. In healthcare, Machine Learning is used for diagnostics, image recognition, and disease prediction. In finance, Machine Learning is used for risk management, fraud detection, and portfolio optimization. In retail, Machine Learning is used for demand forecasting, product recommendation, and customer segmentation. In manufacturing, Machine Learning is used for process optimization, anomaly detection, and predictive maintenance. In transportation, Machine Learning is used for route optimization, traffic prediction, and autonomous vehicles. Machine Learning has the potential to revolutionize many different fields and has already had a considerable impact on our daily lives.

# ***Positioning and Relevant use cases in automotive***

## ***Introduction***

The topic of positioning in vehicles is an important one, as it has implications for the safety, efficiency, and overall experience of using vehicles. With the advent of connected and autonomous vehicles, the importance of accurate and reliable positioning has become even greater.

## ***Why is positioning important in the vehicle?***

Positioning is critical in vehicles because it enables the vehicle to determine its location, orientation, and velocity. This information is used for a variety of purposes, including navigation, obstacle detection and avoidance, and collision prevention. It is also used to support other advanced features such as lane departure warning, adaptive cruise control, and autonomous driving.

## ***Introduction of few use cases:***

There are many different use cases for positioning in vehicles, including in-car navigation systems, real-time traffic updates, and accident avoidance systems. In autonomous vehicles, positioning is used to ensure the vehicle stays on the correct path, avoids obstacles, and makes safe decisions in real-time.

## ***Vehicular communication: what it is and why positioning is important?***

Vehicular communication refers to the exchange of data between vehicles and between vehicles and other entities, such as infrastructure and cloud-based services. Positioning information is a key component of vehicular communication, as it provides the necessary context for the exchange of information and enables vehicles to interact with each other and with the environment.

## ***Autonomous Driving:***

Autonomous driving refers to the ability of a vehicle to operate without human intervention. Accurate and reliable positioning is a critical component of autonomous driving, as it enables the vehicle to determine its location, orientation, and velocity, and to make safe and effective decisions.

## ***Overview of the technology:***

There are many different technologies used for positioning in vehicles, including GPS, inertial navigation systems, and vision-based systems. Each of these technologies has its own advantages and disadvantages, and the choice of technology will depend on the specific requirements of the application.

## ***Different way to achieve accuracy and some results:***

To achieve high levels of accuracy, multiple positioning technologies may be combined, and various methods may be used to improve accuracy, such as data fusion and Kalman filtering. In recent years, there have been significant advances in the accuracy of positioning systems, with some systems achieving sub-meter accuracy in real-world conditions.

## ***What is safety and integrity:***

Safety and integrity refer to the ability of a positioning system to operate correctly and provide reliable information, even in challenging conditions. This is particularly important in safety-critical applications, such as autonomous driving, where incorrect positioning information could have serious consequences.

***Conclusion:***

In conclusion, positioning is a critical component of the modern vehicle, and is increasingly important as vehicles become more connected and autonomous. With the continued development of positioning technologies and the integration of multiple sources of information, it is likely that the accuracy and reliability of positioning systems will continue to improve in the coming years.