

1. How does the cellular network work?
  - Cellular network divides the world into cells, each served by a base station. This allows frequency reuse in frequency division multiple access (FDMA) protocols by exploiting spatial diversity of the carrier used
2. What is the motivation behind frequency division duplex (FDD) and time division duplex (TDD)?
  - In FDD two separate frequencies are used, one frequency for uplink (from UE to base station) and one for downlink (from base station to UE)
  - In TDD the same frequency is used alternating between uplink and downlink
3. What is the role of multiple access scheme in cellular networks?
  - The multiple access scheme is used to further subdivide available resources into independent channels (e.g. for serving multiple users): FDMA, TDMA or CDMA
4. Provide a simplified architecture of the three generations of cellular network
  - See lecture slide 6
5. What is the task of the base station controller (BSC)?
  - The BSC serves all higher functions such as channel allocation and is connected to one and several hundred BTSs within GSM/GPRS network
6. What is the main task of the radio network controller (RNC)?
  - The RNC is responsible for scheduling decisions within the UMTS network
7. Which duplexing technique is used by GSM?
  - GSM employs FDD separate frequencies for uplink and downlink transmissions
8. How many communication channels could be achieved with GSM-900 (900 MHz band)?
  - 124 frequency bands per direction, each frequency band is subdivided into eight time slots leads to a total of 992 channels
9. What is the main motivation behind GPRS (General Packet Radio Service)?
  - GPRS provides packet oriented data transport over flexibly allocated channel on the air
10. What is the difference between circuit switching and packet switching?

- Circuit Switching establishes a physical path between the sender and receiver of the message before a message is delivered. It is inflexible as once a path is established for transmission, it doesn't change while the duration of the session leading to an inefficient use of resources as data connection would tie up resources by allocating a circuit irrespective of whether it is being used or not
  - Packet Switching is connectionless as it doesn't establish any physical connection before the transmission starts
11. Which multiple access technology is used by UMTS?
- UMTS uses pure CDMA dedicating the whole frequency band to all users simultaneously using static FDD or flexible TDD for uplink and downlink
12. How does LTE provide voice services to mobile phones?
- Voice over LTE that encapsulated such traffic for transport to new core network component
  - Voice over IP applications on the mobile device
  - Legacy fallback network like GSM or UMTS that a device may connect to for performing voice calls
13. What is the motivation behind the device-to-device (D2D) communication?
- D2D communication is a new cellular-based communication technology. It allows user equipments (UEs) in close proximity to communicate using a direct link without having their radio signal travel all the way through the base station (BS) or the core network
  - This might lead to low latency in communication due to a shorter signal traversal path
14. List the two main techniques used by D2D for coverage extension?
- Relaying: Relays are used to extend the coverage of cellular service and enable multi-hop communication
    - UEs close to the BS may act as a relay for UEs located at the cell edge which may encounter poor signal quality while connecting to the BS
  - Cooperative diversity techniques: Information is relayed via multiple parallel paths to boost signal strength at a receiver
15. Briefly explain how relaying work in D2D
- It used to extend the coverage of cellular service and enable multi-hop communication

- A UE (e.g., at the cell edge) may encounter poor signal quality while connecting to the BS and UE close to it that has, however, a better link to the BS may act as a relay

16. What is the difference between inband and outband D2D communication?

- Inband: Cellular and D2D communication use the same licensed spectrum which is either divided into non overlapping portions (overlay) or not (underlay)
- Outband: D2D communication uses unlicensed spectrum e.g 2.4 GHz ISM band or 38 GHz mmWave band

17. What the task of Proximity based Services (ProSe)?

- ProSe allows physically close devices to discover themselves and communicate via direct links

18. List the main challenges of D2D

- Device synchronization
- Peer discovery
- Mode selection
- Resource allocation
- Interference management

19. List some scenarios where the device synchronization might be challenging

In situations where

- UEs belong to different BSs that may not be themselves synchronized
- Some of the UEs are in the coverage of the network and some outside the coverage
- All UEs lie outside network coverage

20. How does D2D mode selection can be achieved?

The choice of an appropriate mode for D2D communication can be done based on following performance objectives:

- High spectral efficiency
- Low latency
- Low transmit power

21. How does D2D deal with the interference problem?

There are several centralized, distributed and hybrid algorithms proposed for interference management including

- Power control as interference can be reduced if UEs transmit at lower power levels
  - Careful scheduling of transmissions
22. List the two radio interfaces proposed by C-V2X
- Uu interface used to support vehicle to infrastructure communications (uplink and downlink)
  - PC5 interface used to support V2V communications based on direct LTE sidelink
23. What is the difference between mode 3 and mode 4 for C-V2X communication?
- In mode 3 the cellular network selects and manages the radio resources used by vehicles for their direct V2V communications
  - In mode 4 vehicles autonomously select the radio resources for their direct V2V communications
24. What resource management algorithm is used in C-V2X mode 4?
- In mode 4 a specific resource pool configuration and semi-persistent scheduling (SPS) - also known as sensing-based semi-persistent scheduling - is used to select and reserve resource for transmissions
25. How does sensing-based semi-persistent scheduling (SPS) work?
- See lecture slide 30-33
26. What is the motivation of using a reselection counter in SPS?
- To avoid consecutive packet collisions for the selected resource block
27. Why is the packet latency bounded in SPS?
- To support services requiring a deterministic latency
  - Packet latency is derived from the selection window and defined as the time window between the time the packet has been generated and the defined maximum latency (e.g. 100 ms for 10Hz)
28. Briefly explain the dilemma while dimensioning the selection window in SPS
- A shorter window provides a shorter latency but might increase the probability of collisions
29. How do packet losses occur with the semi-persistent scheduling (SPS)?
- When at least two vehicles transmit on the same resource (i.e. the same sub channel and sub frame) which might mainly depend on the traffic density

- When a packet which cannot be received because the vehicle is transmitting its own packet in the same sub frame
30. List the three main transmission errors which can occur in mode 4
- Errors due to half-duplex transmissions
    - A packet which cannot be received because the vehicle is transmitting its own packet in the same sub-frame e.g. two vehicles selecting the same sub-frame
  - Error due to received signal power below the sensing power threshold
    - It depends on the path loss (distance between transmitter and receiver) and sensing power threshold
  - Error due to packet collisions
    - It occurs when at least two vehicles transmit on the same resource (i.e. the same sub-channel and sub-frame) Mainly depends on the traffic density
31. List the two categories of resource management algorithm used in C-V2X mode 3
- Dynamic scheduling: Vehicles request sub channels to the eNB for each packet transmission. This leads to an increased cellular signaling overhead and packet latency
  - SPS: eNB reserves sub channels for the periodic transmissions like in mode 4 BUT it is up to the eNB to decide how long the reservation should be maintained
32. How does C-V2X decentralized congestion control work?
- The C-V2X DCC used following metrics to characterize the channel state:
- Channel busy ratio (CBR) is defined as the portion of sub channels in the resource pool whose RSSI measured exceeds a preconfigured threshold
  - Channel occupancy ratio (CR) is defined as the total number of sub channels used for its transmissions divided by the total number of sub channels in a predefined time window
- Whenever a UE measures a CR higher than the CR limit, one or several transmit adaptation mechanisms shall be performed as follow:
- Drop packet transmission: Simply drops the packet transmission
  - Adapt the data rate: Reduce the number of sub channels used for the transmission
  - Adapt transmission power: Reduce transmission power so that the overall CBR in the area will be reduced
33. List the main challenges faced by the C-V2X network
- Synchronization
  - Resource allocation
  - Long packet delays
  - Half duplex problem