1. What is the motivation behind congestion control for V2X communication?

   - Ensure scalability in dense vehicle situations while fulfilling at the same time stringent application requirements
   - The aggregate of CAMs alone can exceed channel capacity with increasing vehicle density unless transmission parameters are adapted

2. What are the reasons of performance degradation?

   - Rapidly changing topology
   - Severe channel characteristics
   - Distributed medium access as stations share the same communication channel

3. List some performance degradations due to high channel load

   - Packet loss
   - Reduction of the effective communication range
   - Increased packet transmission delay

4. What is the main objective of congestion control?

   - Limit the observed load on the wireless channel for **all nodes** in order to provide fair and harmonized access to the wireless medium

5. What is the main objective of awareness control?

   - Adjust for example the power or rate of **only a selected subset of nodes**, with the objective of fulfilling the requirements of a particular application

6. Describe the transition phase from congestion avoidance to congestion control

   - Throughput increases with increasing load
   - Saturation point is reached when the load approaches network capacity
   - Throughput sharply drops to zero if load is further increased leading to a congestion collapse

7. Give a comparison of open and closed loop controller

   - Open loop controller: No need of feedback to correct and optimize the decisions made in the past. The robustness of the controller might depend on the accuracy of the system model used
   - Closed loop controller: Use a feedback path to determine how well the objective has been achieved at the cost of communication overhead

8. Briefly explain the aim of proactive congestion control

   - A proactive congestion control uses models that try to estimate transmission parameters which will not lead to congested channel conditions while at the same time providing the desired application level performance

9. Give a comparison of awareness control and congestion control

   - Awareness control: Adjust for example the transmission power or transmit rate of only a selected subset of nodes, with the objective of fulfilling the requirements of a particular application
   - Congestion control: Limit the observed load on the wireless channel for all nodes in order to provide fair and harmonized access to the wireless medium

10. What is flow control?

    - Scheme which protects the receiver of a flow of packets from being overwhelmed by too many packets sent from the source. It concerns only one source-receiver pair and has the objective to prevent the buffer at the receiver from overflowing

11. What is the aim of congestion avoidance?

    - Keep the network at its optimal operation point close the channel capacity

12. How does the TCP congestion detection work?

    - TCP uses an implicit feedback from the network to determine if congestion occurs
    - More specifically missing acks and timeout are used to trigger a packet retransmission

13. Explain the TCP rate adaptation

    - See lecture slide

14. What is the motivation behind the slow start in TCP?

    - Slow start is introduced to control the capacity of a network connection. It restricts how much data may be initially transmitted over a connection, then increases that capacity methodically. By doing so, it makes sure the system works prior to increasing the amount of data transferred

15. List four channel load measures

    - Communication density (CD)
    - Beaconing load (BL)
    - Channel load (CL)

- Channel busy ratio (CBR)

16. Consider a 4-lane highway scenario with a vehicle density of 20 veh/km/lane. Suppose each vehicle on the highway periodically transmits packets of length 800 Byte with a rate of 5 Hz over a broadcast channel of capacity $C = 6$ Mbit/s. Assume a carrier sense range of 800 meter.

    (a) Calculate the beaconing load (BL)

    - Beaconing load $BL = M \times r \times \rho \times 2d_{CS}$ in bit/s
    - $M = 800 \times 8 = 6400$ bits the packet size, $r = 5$ Hz the transmission rate, $\rho = 4 \times 20$ veh/km the vehicle density and $d_{CS} = 0.8$ km the carrier sense range
    - BL = 4.096 Mbit/s

    (b) Determine the channel load achieved in this scenario

    - Channel load $CL = \frac{4.096 \text{ Mbit/s}}{6 \text{ Mbit/s}} = 0.68$

    (c) Calculate the transmission rate generating a maximum channel load of 15%

    - Beaconing load $BL = 6 \text{ Mbit/s} \times 0.15 = 0.9 \text{ Mbit/s}$
    - Transmission rate $r = \frac{BL}{M \times \rho \times 2d_{CS}} = 1$ Hz

17. How to derive the channel busy ratio?

    - See lecture slide 22

18. Give the main causes of packet losses

    - Simultaneous sending
    - Single/Multiple hidden stations
    - Exposed station
    - Near Adjacent station

19. When does the exposed station problem lead to packet losses?

    - Packet loss implicitly occurs if the medium cannot be accessed in time. Many messages overcrowd the local message queue, so that messages have to be dropped before transmission

20. What is the purpose of Decentralized Congestion Control (DCC)?

    - Scheme proposed by ETSI utilizing multiple transmission parameters to control congestion aiming to maintain network stability, throughput efficiency and provide fair resource allocation to stations

21. Describe the role of Network Design Limits (NDL) in DCC

    NDL contains:

- Ranges of the controlled parameters: minimum and maximum value
- Default and target values of the controlled parameters
- Regulatory limits and device dependent parameters (e.g. max. transmit power)
- Model parameters, e.g. parameters of the transmit model , channel model and receive model
- Internal control loop parameters, e.g. signal level thresholds and time constants

22. How does the Transmit Power Control (TPC) work?

    - TPC adjusts the communication range and thus the amount of stations which will be able to receive the transmission by varying the transmission power

23. What is the side effect of increasing the transmission power?

    - In dense scenario, increasing the transmission power would lead to an augmentation of packet drops and packet collisions due to a large number of neighbor stations, which compete for the channel. On the other hand, increasing the transmission power would be beneficial in sparse conditions as the communication range is extended

24. Describe how the congestion control algorithm LIMERIC works

    - It adapts the periodic transmission rate of CAMs based on channel conditions
    - It uses the difference between the measured and the targeted channel load to adapt the transmission rate

25. List the three main states of DCC access control loop

    - Relaxed, active and restrictive