1. What is the task of GeoNetworking?

   GeoNetworking is a network-layer protocol for mobile ad hoc communication which enables a communication over multiple wireless hops without the need for a coordinating infrastructure (e.g. road side unit)

2. List some properties of GeoNetworking

   - Works connectionless and fully distributed
   - Multi-hop dissemination of packets in geographical regions
   - Specific for highly mobile network nodes and frequent changes in the network

3. List the functions provided by GeoNetworking

   - Geographical addressing
   - Geographical forwarding

4. What distinguishes geographical addressing?

   - It enables the capability to send data packets to a node by its position or to multiple nodes in a geographical region
   - A station can select and specify a well-delimited geographic area to which messages should be delivered
   - Intermediate stations serve as message relays (forwarder)

5. List the state-of-the-art addressing modes and provide a brief definition of each

   Unicast (one-to-one) Packets are delivered to a single, specific node uniquely identified by a destination address

   Anycast (one-to-one-of-many) Packets are delivered to at least one member of a distinct group sharing common criteria

   Multicast (one-to-many-of-many) Packets are sent to all members of a group

   Broadcast (one-to-all) Packets are delivered to all nodes in a certain network

   GeoNetworking Packets are delivered to a group of destination nodes by their geographical locations

6. Explain briefly how geographical addressing works

   - When a node receives a data packet, it compares the geo-address in the data packet and the node's view on the network topology, and makes an autonomous forwarding decision
   - Every node required a partial view of the network topology in its vicinity

- Every packet carries a geographical address, such as the geographical position or geographical area as the destination

7. Explain briefly how geographical forwarding works

   - When a node receives a data packet, it compares the geo-address in the data packet and the node's view on the network topology, and makes an autonomous forwarding decision
   - Every node required a partial view of the network topology in its vicinity
   - Every packet carries a geographical address, such as the geographical position or geographical area as the destination

8. What is GeoNetworking beaconing?

9. Describe how the location table is built through GeoNetworking beacons

   - Beacons are used to build a Location Table which can be consulted at any time to know the neighboring nodes and their locations
   - Location Table is populated not only with information about direct neighbors, i.e. those that are located within one hop communication range but also with farther neighbors, i.e. those located at two-hops distance and more

10. What is the motivation behind the Single-Hop Broadcast (SHB)?

    SHB used by safety applications that require fast information dissemination in the surrounding space

11. What is the goal of Topological Scoped Broadcast (TSB)?

    TSB is used to reach a limited number of hops by rebroadcasting a packet from a source to all nodes in the n-hop neighborhood

12. How does TSB deals with duplicate packets?

    - Packet numbering (Sequence number) is used to detect duplicate packets
    - If as same packet reaches a destination or an intermediate node through different neighbors (i.e., different forwarders), only the very first packet is processed, and all the other duplicates are just dropped

13. Describe how GeoUnicast works. Draw a scenario where GeoUnicast could be applied

    - GeoUnicast addresses a single and specific station
    - A multi-hop communication based on GeoUnicast exchange of packets between a vehicle and a parking lot

14. List the steps performed by GeoUnicast until the packet reaches the destination node

- When a station wishes to send a unicast packet, it first determines the destination's position
- The data packet is forwarded to a station towards the destination
- Forwarders may in turn re-forwards the packet along the path until the packet reaches the destination

15. Outline the difference between a sender-based and a receiver-based forwarding approach
    - Sender-based: Explicit selection of a next hop by the current forwarder
    - Receiver-based: Implicit selection of a forwarder among all candidates through a decentralized coordination function

16. Describe how Greedy Forwarding (GF) algorithm works
    - Each station that needs to forward a packet explicitly selects the next hop among all its known neighbors
    - It selects the neighbor with the smallest geographical distance to the destination, thus providing the greatest progress when the packet is forwarded
    - If no neighbor with greater progress than the local forwarding station exists, the packet has reached a local optimum

17. Draw two scenarios with GF reaching a local minimum as well as a local maximum
    - Local minimum, see lecture slide 19
    - Local maximum, see lecture slide 20

18. Describe briefly the function of Contention-based Forwarding (CBF)
    - CBF enables an implicit forwarding of a packet by the optimal station using a timer-based re-broadcasting with overhearing of duplicates
    - Receiver decides to be a forwarder of a packet

19. List the steps performed by the CBF
    - Forwarding node transmits the packet as a single-hop broadcast to all neighbors
    - All neighbors, which receive the packet, process it
    - The packet is buffered in CBF packet buffer and a timer is started
    - Upon expiration of the timeout, the forwarding station re-broadcasts the packet

20. How does the CBF avoid packet duplications?

    If a forwarding receives a duplicate of the packet from an another forwarding station before its timer expires, it will stops its timer and drop the packet from the packet buffer

21. Provide a brief comparison of GF and CBF

    - See lecture slide 24

22. What is the role of the Location Service (LS)?

    LS is used whenever a forwarder needs to determine the position of another forwarder. This is the case when a GeoUnicast packet is sent from the source to the destination, and the source does not have the position information for the destination in its location table

23. Describe briefly two mechanisms used by LS

    - Reactive: Location service request is triggered whenever needed (on-demand)
    - Proactive: Location information of relevant nodes (or destinations) is kept updated locally through periodic exchange of control packets

24. What is the task of GeoBroadcast? Draw a scenario where GeoBroadcast could be applied

    - GeoBroadcast addresses all (broadcast) stations within a specific destination area
    - Roadwork warning application which triggers a GeoBroadcast communication to disseminate the area surrounding the segment of road which is relevant to the road work

25. Why is the location service not required for GeoBroadcast?

    A location service to calculate the location of the destination nodes is not required, as the information of the destination area is known at source node

26. List two GeoBroadcast forwarding algorithms and describe their functions

    - Simple GeoBroadcast forwarding algorithm: The packet is re-broadcasted when the forwarder is inside or at the border of the area otherwise the GF algorithm is used to forward the packet until the destination area is reached
    - Advanced GeoBroadcast forwarding algorithm is based on a mix of CBF and GF in order to decrease the forwarding delay

27. What is the task of GeoAnycast?

    - GeoAnycast addresses only one node within the destination area
    - The packet is forwarded till it reaches a first node inside the destination area (so far similar to GeoBroadcast), and then stops at that first node as it is considered as the destination node

28. What is the role of packet data rate control?

    It limits the forwarding of packets by evaluating the quantity of generated packets by each neighbor

29. Consider the following vehicular network topology shown in Figure 1. A GeoUnicast packet is sent from the originating vehicle S to the destination vehicle Z. The distance between Z and each vehicles in the network is given in table 1. The circles are representing the communication range.

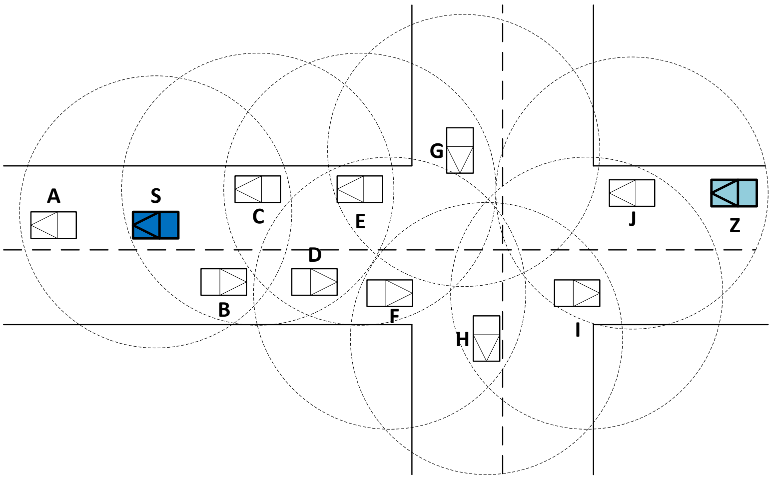

Figure 1: GeoUnicast Scenario

	S	A	B	C	D	E	F	G	H	I	J
Distance to Z [meter]	95	105	85	80	75	70	65	55	50	30	20

Table 1: Distances from vehicles to the destination vehicle Z

(a) Use the Greedy forwarding algorithm (GF) to compute the path from vehicle S to destination Z.

- Path is (S – C – E – G). Z is not reachable as we end up in an dead-end situation aka local minimum
- For these three hops, the packet latency is 3 ms

(b) Use the contention-based forwarding algorithm (CBF) to compute the path from vehicle S to destination Z.

- S – C – E – F – H – I – J – Z

(c) What is the packet latency needed to disseminate the packet from the originating vehicle S to the destination Z using both algorithms? Consider following assumptions:

- An additional packet latency per hop of 1 ms

- The minimum and maximum timeout for CBF are 0 ms and 20 ms, respectively
- The maximum communication range $d_{\max} = 200$ m
- For GF the overall packet latency is only the one hop latency of 3 ms
- For CBF: S $\xRightarrow{1\text{ms}}$ C $\xRightarrow{8\text{ms}}$ E $\xRightarrow{7\text{ms}}$ F $\xRightarrow{6.5\text{ms}}$ H $\xRightarrow{5\text{ms}}$ I $\xRightarrow{3\text{ms}}$ J $\xRightarrow{2\text{ms}}$ Z which implies an overall packet latency of 38.5 ms inclusive a total per hop latency of 7 ms (7×1ms)

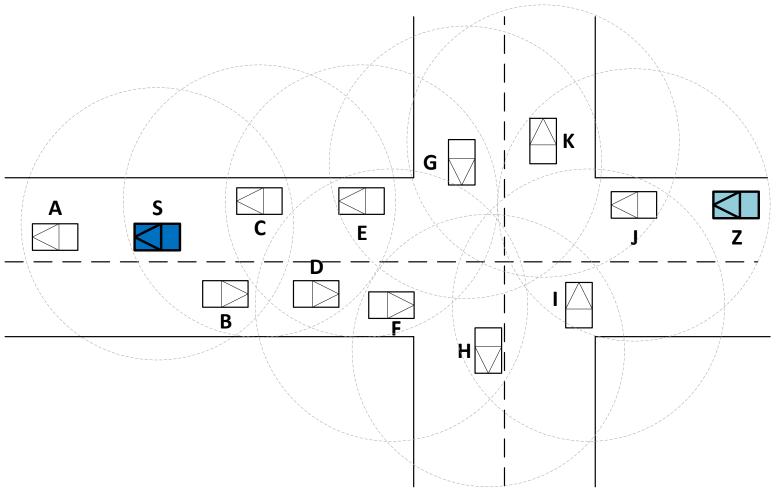

Figure 2: Updated GeoUnicast Scenario

(d) Now suppose a new vehicle K is added in the network as shown in Figure 2. The distance between vehicle K and vehicle Z is 40 meter. Calculate again the path as well as the packet latency when sending a GeoUnicast packet from S to Z using both forwarding algorithms.

- GF: S $\xRightarrow{1\text{ms}}$ C $\xRightarrow{1\text{ms}}$ E $\xRightarrow{1\text{ms}}$ G $\xRightarrow{1\text{ms}}$ K $\xRightarrow{1\text{ms}}$ J $\xRightarrow{1\text{ms}}$ Z which implies an overall hop-by-hop packet latency of 6 ms (6×1ms)
- For CBF: S $\xRightarrow{1\text{ms}}$ C $\xRightarrow{8\text{ms}}$ E $\xRightarrow{7\text{ms}}$ G $\xRightarrow{5.5\text{ms}}$ K $\xRightarrow{4\text{ms}}$ J $\xRightarrow{2\text{ms}}$ Z implying an overall packet latency of 32.5 ms inclusive a total per hop latency of 6 ms (6×1ms)