VANETs
Intelligent Transportation Systems

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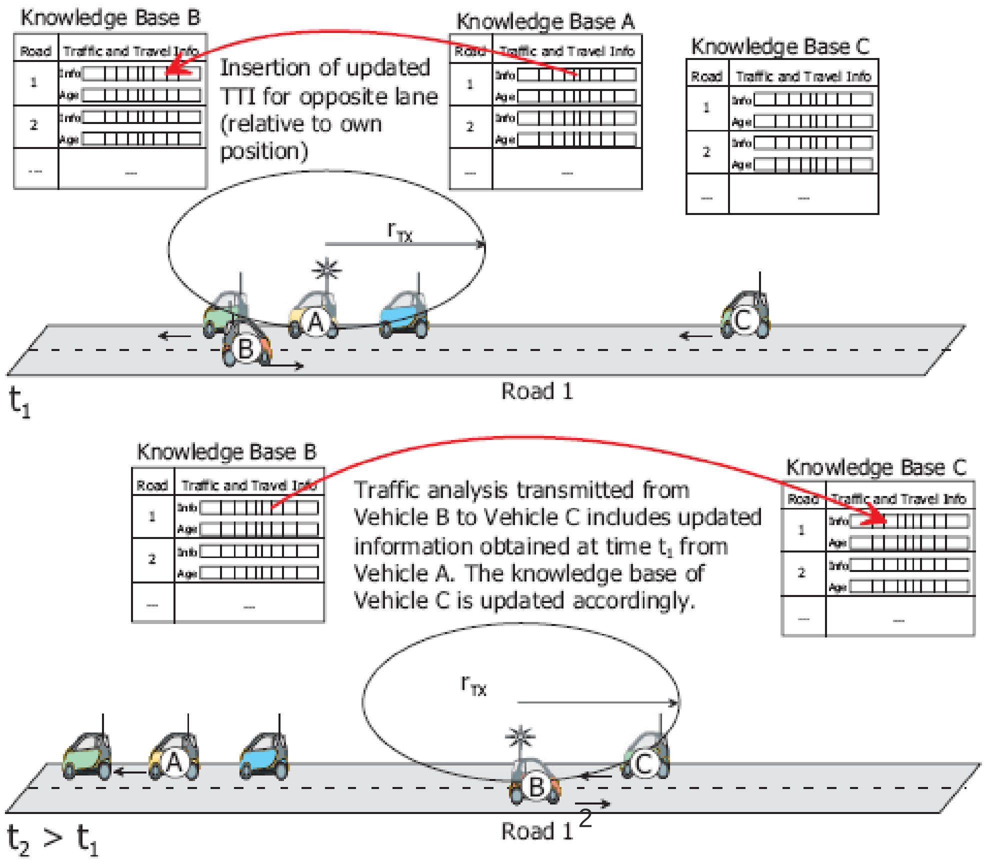
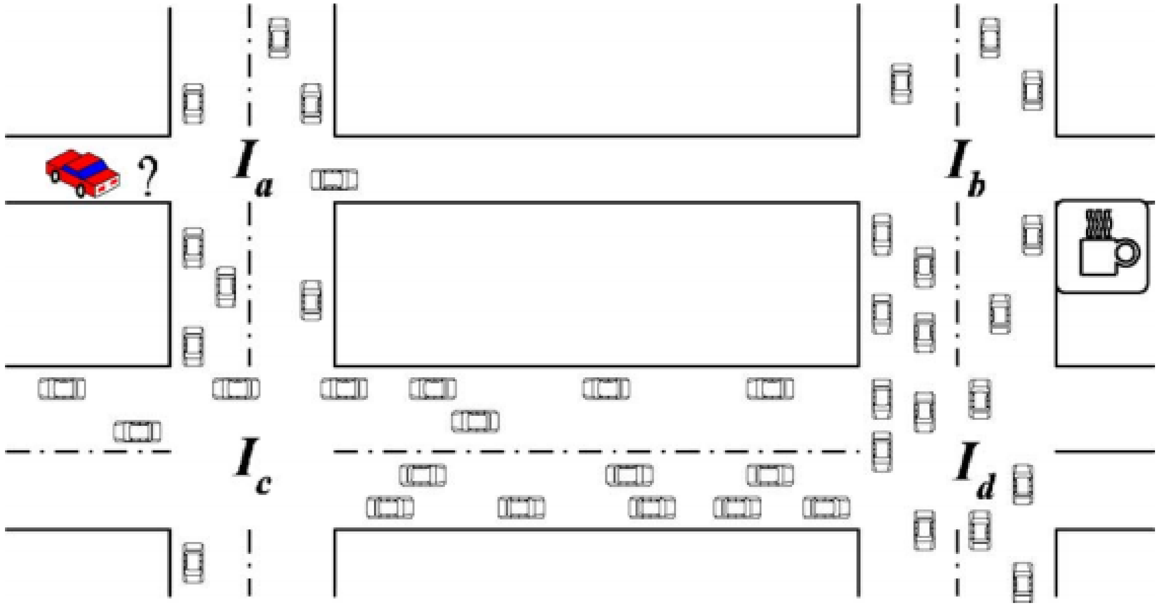
DTN: Delay Tolerant Network

- If nodes are sparse, the network connectivity can be broken
- Topology holes will appear
- This can be handled by the **carry-and-forward** method
  - **Data-mule**s
- It is possible if the message is still valid in spite of the delay
- Mobility prediction is very useful



VADD: Vehicle-Assisted Data Delivery in VANET

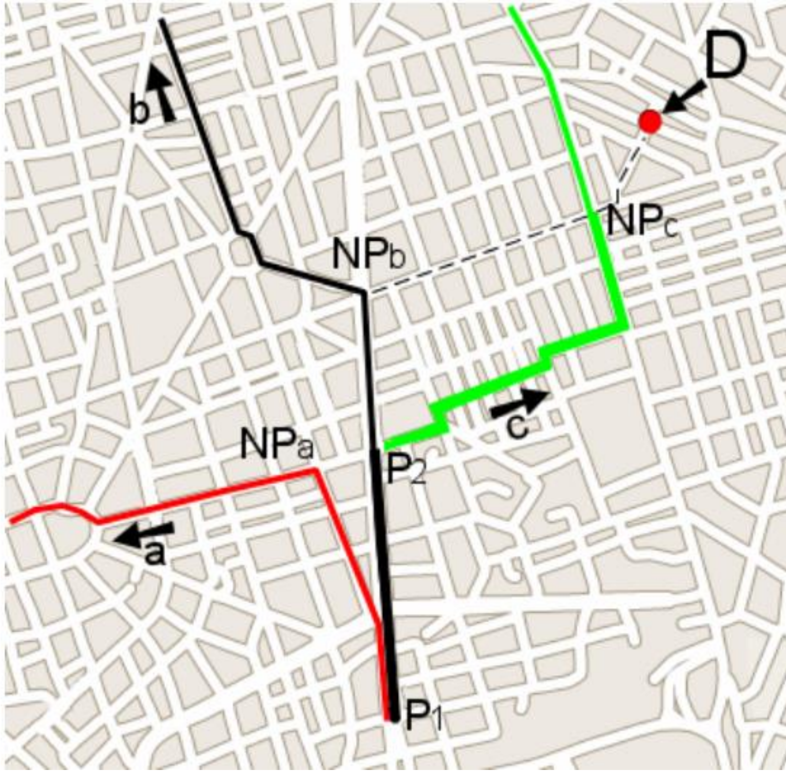
- Carry-and-forward, optimized to the lowest delivery delay
  - Prefers radio links, as they are faster than using data mule cars
  - If data has to be carried by a car, it chooses the fastest car that goes in the good direction
  - Dynamic routing step by step



  - **VADD delay model**
    - Distances between intersections
    - Average vehicle density on each segment
    - Average vehicle speed on each segment
  - **Stochastic model**
    - We cannot calculate in advance the entire path
    - It depends on whether in a given intersection, at a given moment there will be a car to forward the message in a given direction, or not
    - We can calculate probabilities

GeOpps: Geographical Opportunistic Routing

- Assumes that cars know in advance their trajectory
  - Using some navigation, travel planner software
- Next hop selected in three steps:
  - Each neighbor calculates for its trajectory the closest point to the destination
  - It calculates how much time it takes to that closest point
  - If the trajectory of one of the neighbors gets closer to the destination than that of the current node, then the packet is taken over
- If the car changes its trajectory, everything should be recalculated



VANET broadcast protocols

- We have a target zone, within which all the vehicles should receive the message (Broadcast Domain)
  - However, the load on the network should be minimized, (avoid broadcast storms)

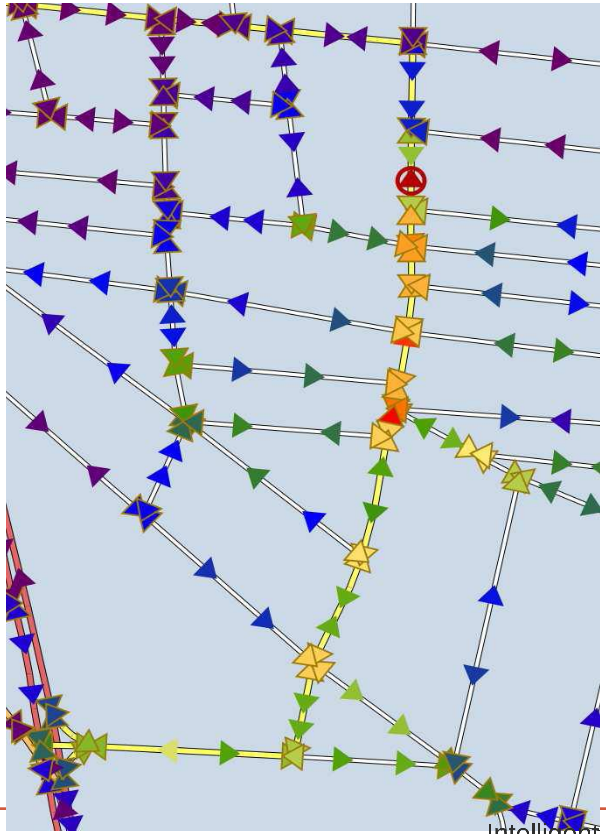
- **DECA: Density-Aware Reliable Broadcasting**
  - Does not use position information
  - Beacon messages sent to discover neighbors
  - Network load is minimized by chosing as next hop the neighbor that has most neighbors

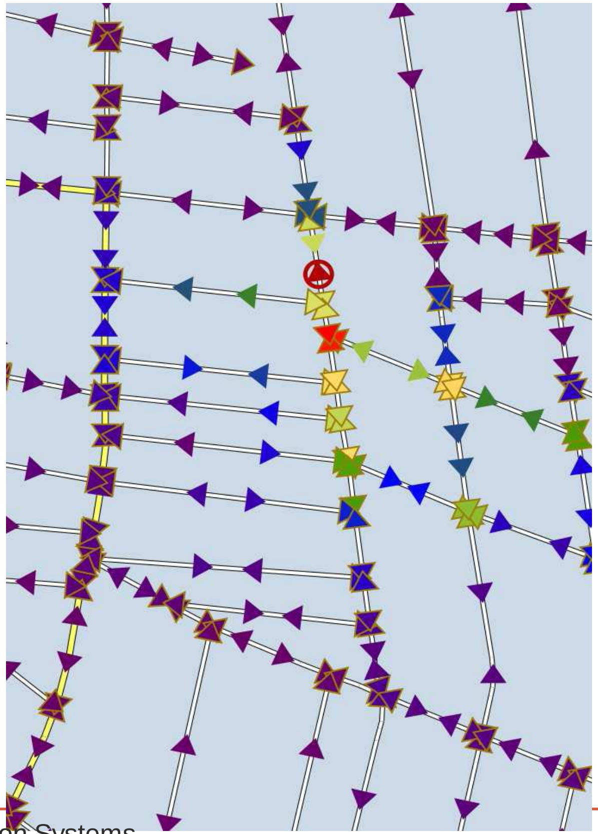
Intelligent flooding through gossiping

- Messages are rebroadcast or dropped with a given probability *p*
  - **Carefully Localized Urban Dissemination (CLoUD)**
- The drop probability on a given road segment depends on the probability of cars on that segment heading towards the source of the flooding (where the danger was detected)
- Needs a traffic database
  - Turn probabilities at each intersection
  - Stop probability on each segment
  - Average traffic density in different periods of the day
- Increasing reliability with a voting mechanism
  - The message is dropped only if there are sufficent votes to drop it
- Miklos Mate, Rolland Vida, „Reliable Gossiping in Urban Environments”, in Proceedings of 72nd IEEE Vehicular Technology Conference VTC-Fall, Ottawa, Canada, September 2010.

Intelligent flooding through gossiping

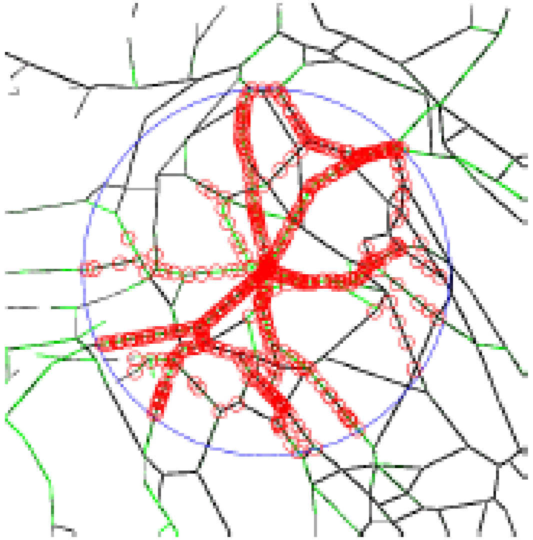
- Simulation results for the CLoUD protocol
  - Digital map of Budapest, warmer colors mean more messages received by that car
  - If the problem occurs on a main road (left), the message is spread more broadly
  - If the problem occurs on a side road (right), the flooding dies out fast

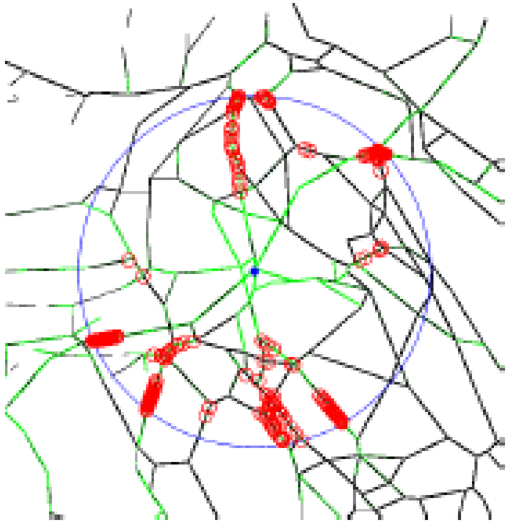




VANET Multicast protocols

- There is a given area inside which all cars should receive the message (**Zone of Relevance**)
- The multicast group is implicitely defined by the position of the cars
- The source is not necessarily inside the ZOR, so first the packet should be delivered to the ZOR, through unicast routing, and then flood the ZOR
  - E.g., information about traffic jam is not interesting for those already in the jam
  - The alert should be sent to those who can still avoid it





Mobicast

- **Mobile Just-in-time Multicasting**
- The Zone of Relevance, or **Delivery Zone**, moves with a given speed
  - E.g., give way to the ambulance
- We should ensure that within some space-time coordinates, each car that enters the Delivery Zone should receive the message before it enters the zone, or just on entering the zone
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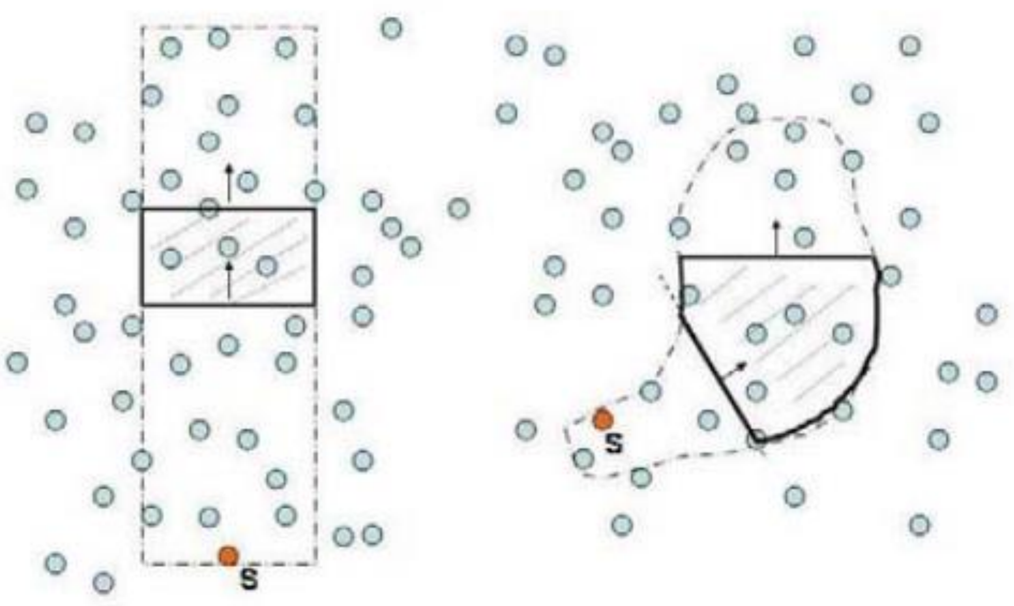
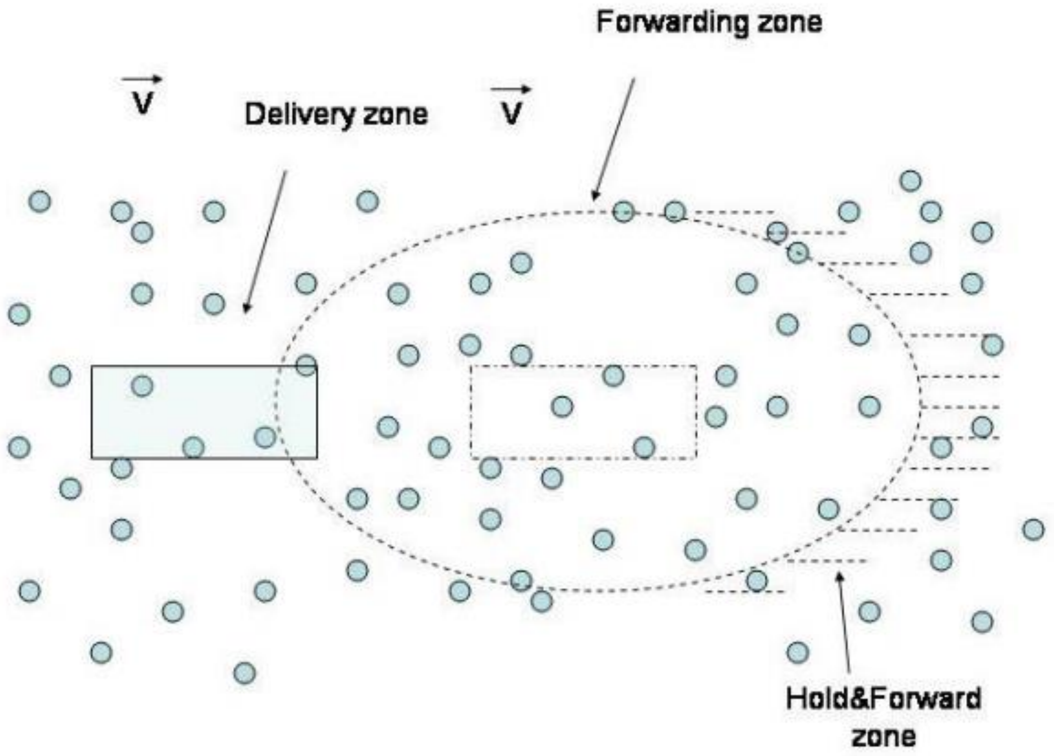


(a) (b)

Mobicast

- **Forwarding Zone**
  - Preceeds the Delivery Zone
  - Nodes in this zone rebroadcast the message
- **Hold&Forward Zone**
  - They only store the message, and retransmit it only when entering the Forwarding Zone

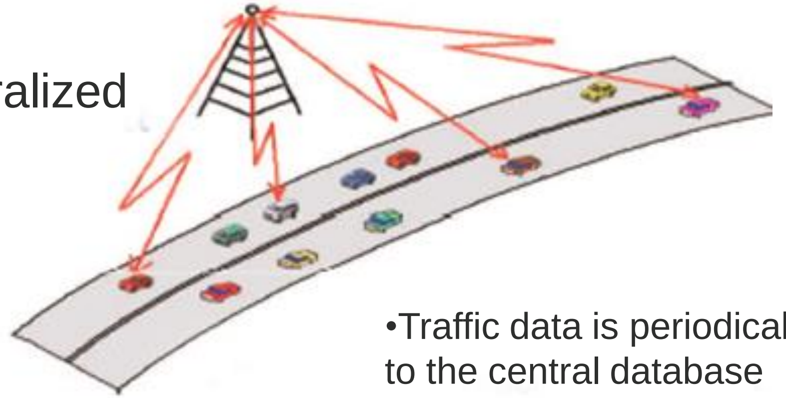


Communication architectures

- Car-to-Car (C2C) or Vehicle-to-Vehicle (V2V)
  - Cars communicate directly among each other
- Car-to-Infrastructure (C2I) or Vehicle-to-Infrastructure (V2I)
  - Communication among cars and the deployed infrastructure
  - Mobile base stations
  - Sensors, data storage, gateways deployed next to the road
    - RSU – Road Side Unit
- Car-to-Pedestrian
  - In between C2C and C2I
    - Different mobility models

Communication architectures

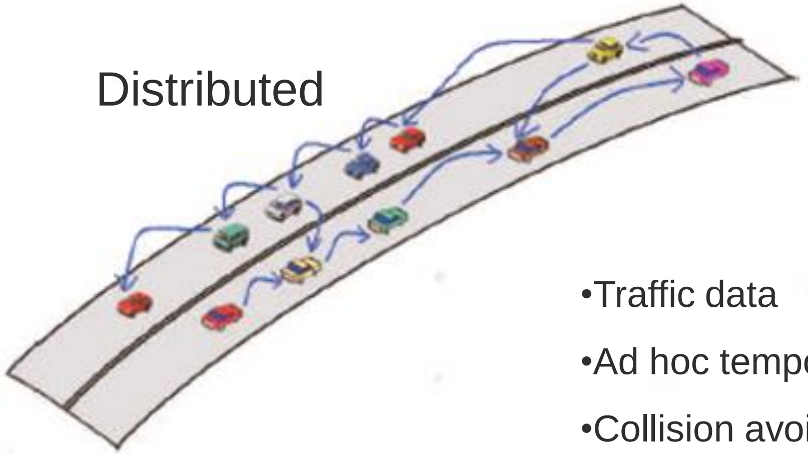
Centralized



•Traffic data is periodically sent to the central database

•Cars receive traffic information from the central database

Distributed



•Traffic data

•Ad hoc tempomat

•Collision avoidance

	Centralized	Distributed
Coverage/ range	☺ Complete	☹ Low, separated islands
Speed	☹	☺
Reliability	☺	☹ collisions, interferences
Capacity	☹ limited	☹ limited
Price	☹ yes	☺ no

Hybrid solutions

- Some cars can communicate with the central entitty, through the mobile network
  - E.g., LTE
- Others communicate only with each other
  - They can not, or do not want to communicate with the central entity