OKOS VÁROS @ BME TMIT

VANETs

Intelligent Transportation Systems

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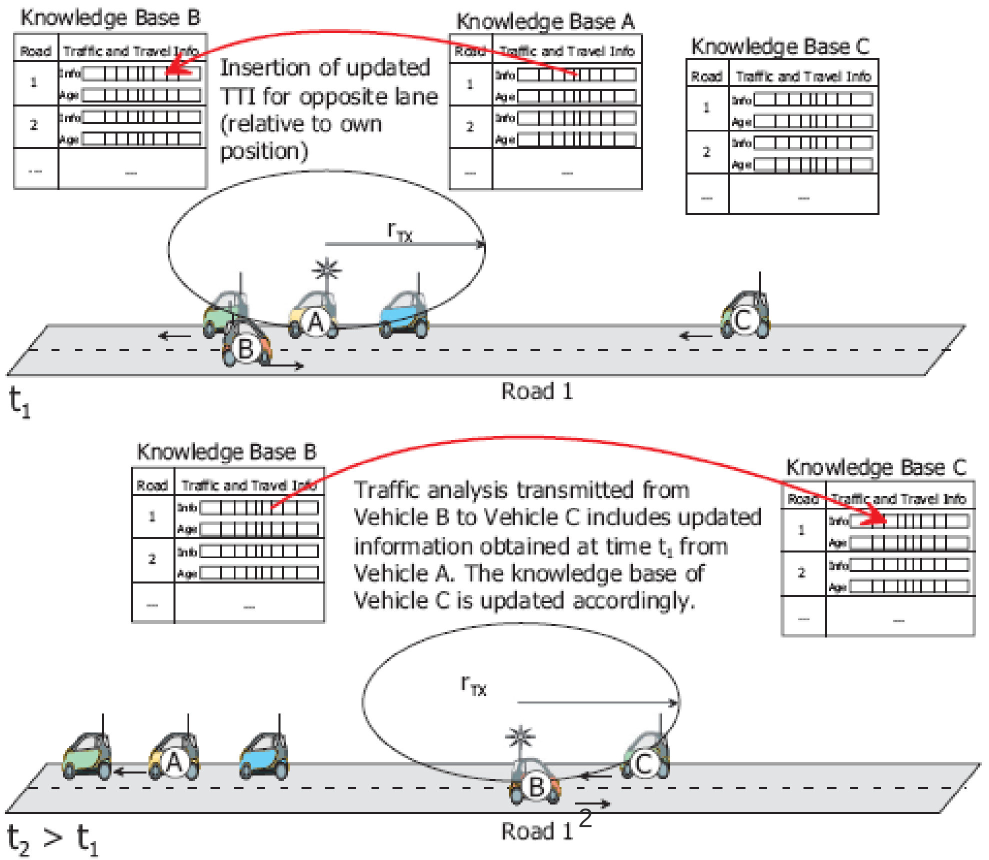
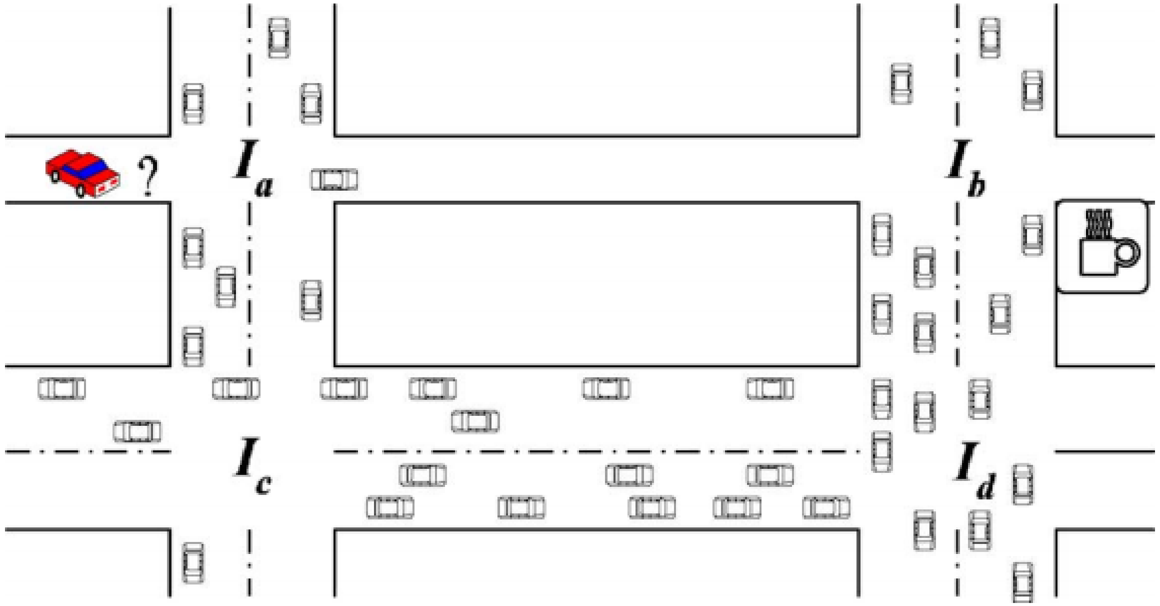
DTN: Delay Tolerant Network

- 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

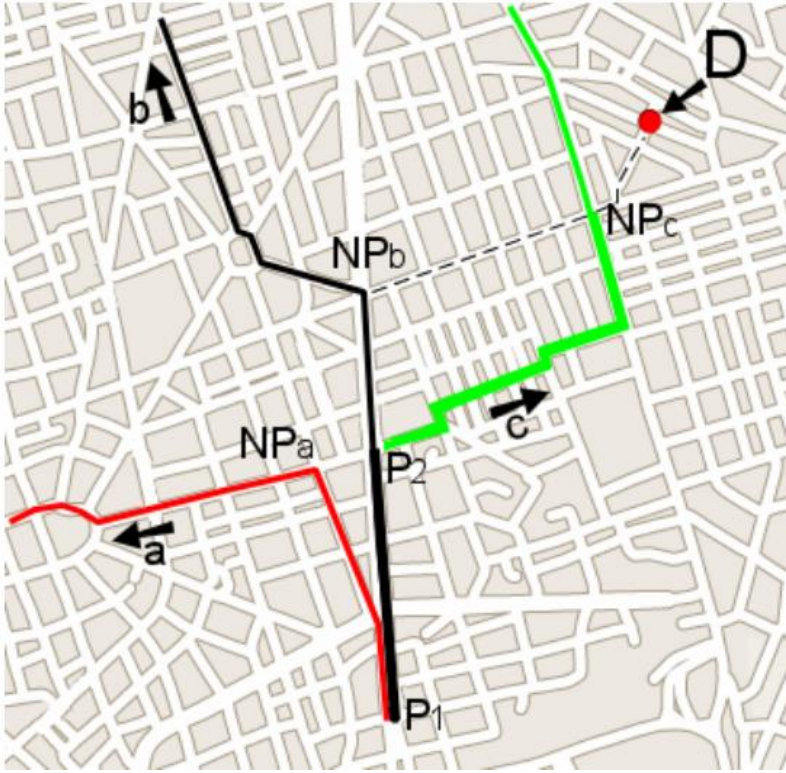
- Carry-and-forward, optimized to the lowest delivery delay
  - Prefers radio links, as they are faster than using data mule cars
  - If data has to be carried by a car, it chooses the fastest car that goes in the good direction
  - Dynamic routing step by step



  - **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)

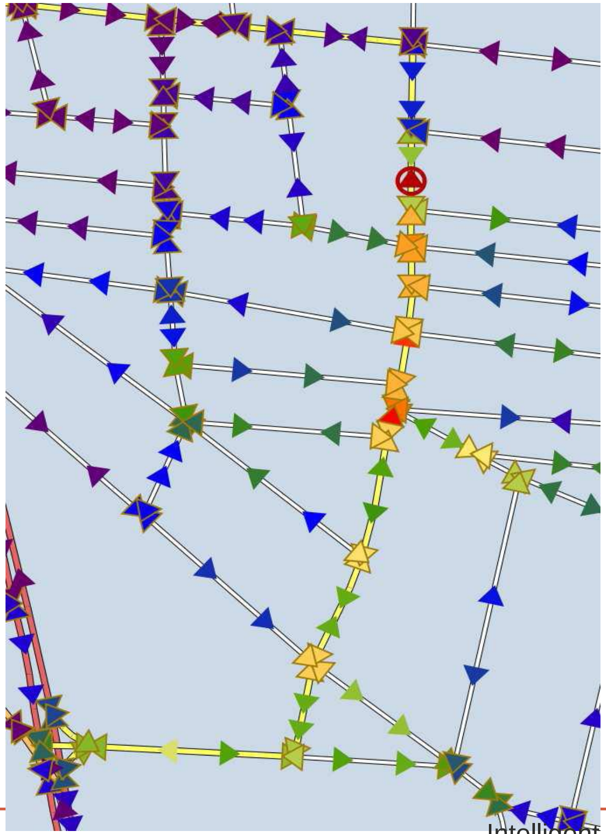
- **DECA: Density-Aware Reliable Broadcasting**
  - Does not use position information
  - Beacon messages sent to discover neighbors
  - Network load is minimized by chosing as next hop the neighbor that has most neighbors

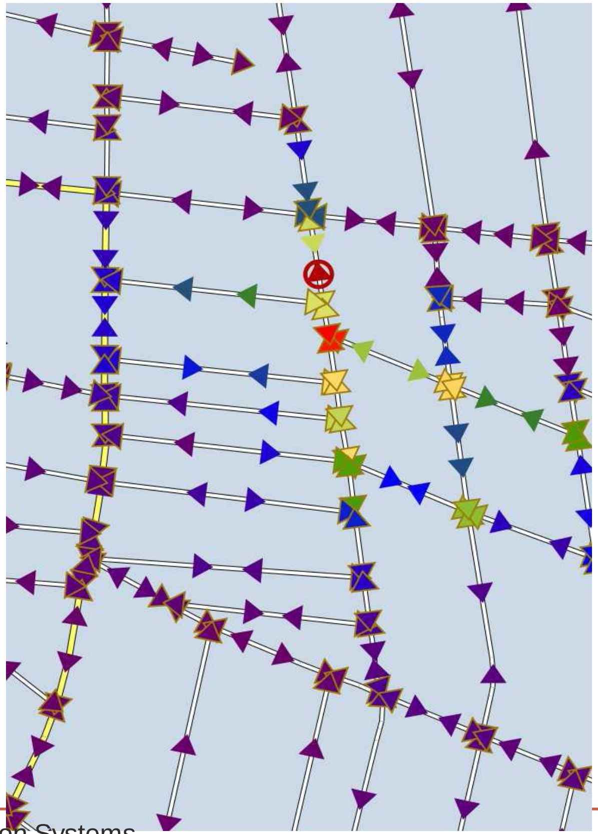
Intelligent flooding through gossiping

- 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

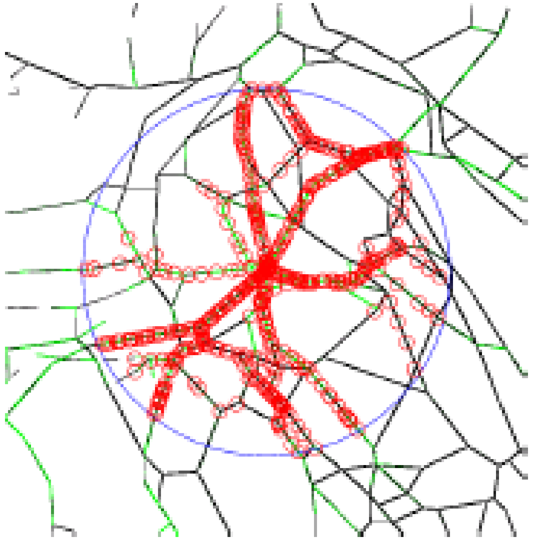
- Simulation results for the CLoUD protocol
  - Digital map of Budapest, warmer colors mean more messages received by that car
  - If the problem occurs on a main road (left), the message is spread more broadly
  - If the problem occurs on a side road (right), the flooding dies out fast

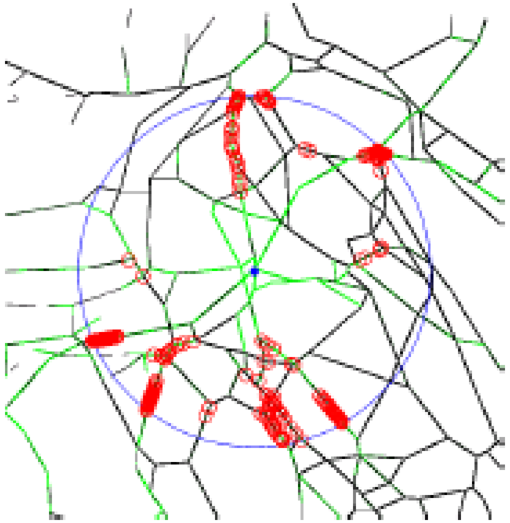




VANET Multicast protocols

- 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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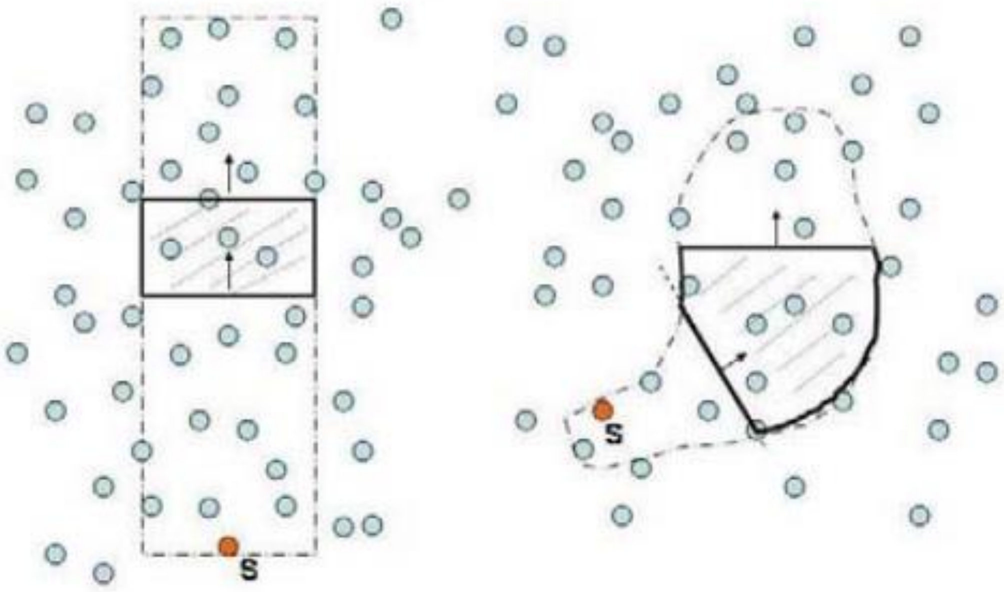
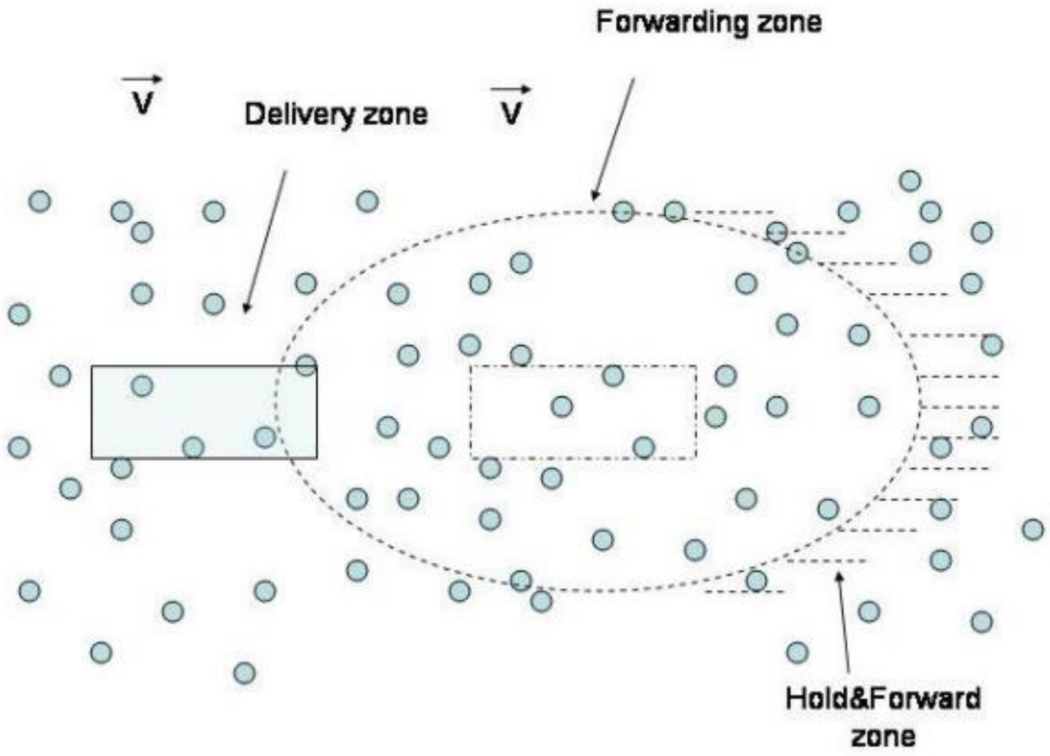


(a) (b)

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

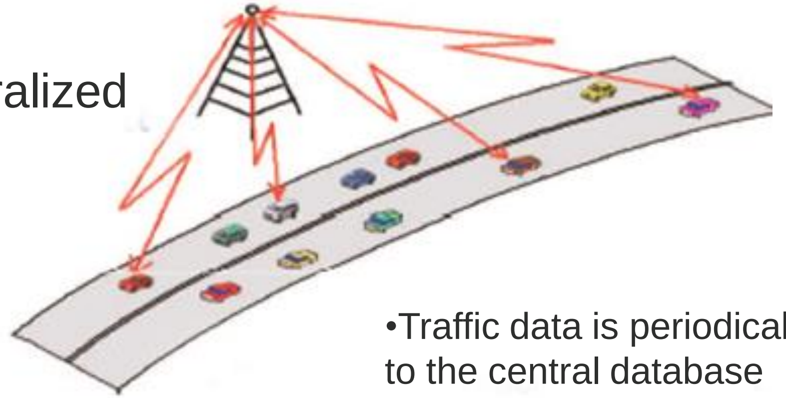
- Car-to-Car (C2C) or Vehicle-to-Vehicle (V2V)
  - Cars communicate directly among each other

- 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

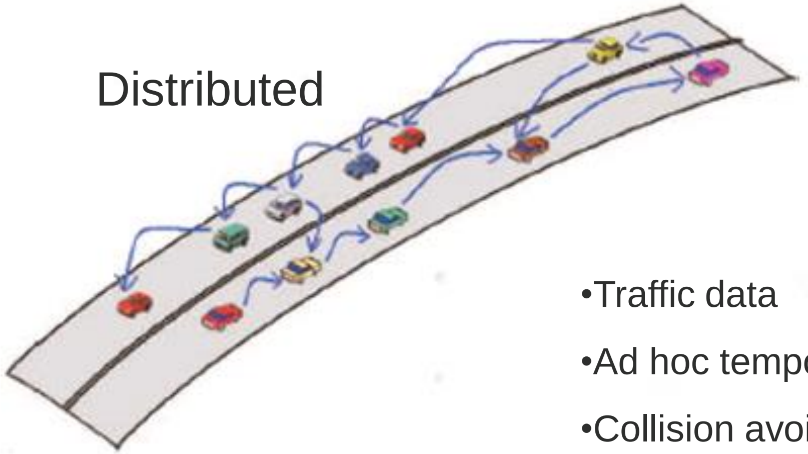
Centralized



•Traffic data is periodically sent to the central database

•Cars receive traffic information from the central database

Distributed



•Traffic data

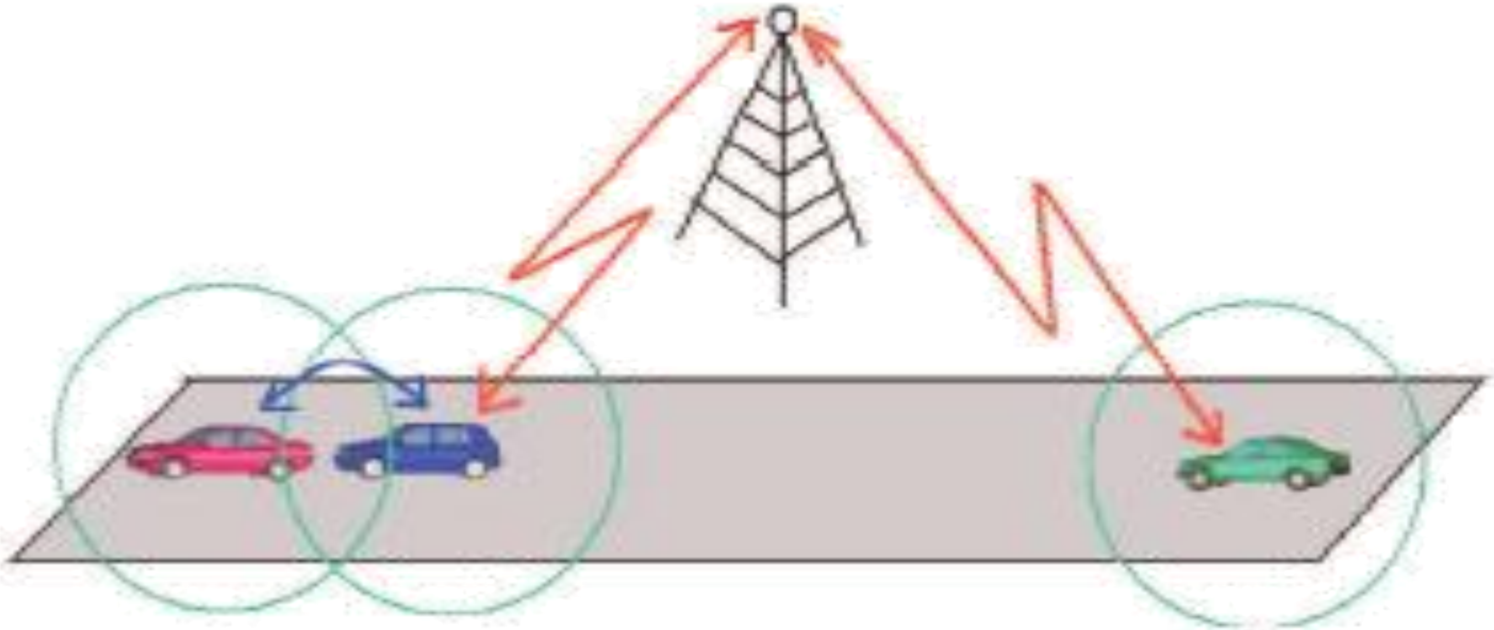
•Ad hoc tempomat

•Collision avoidance

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

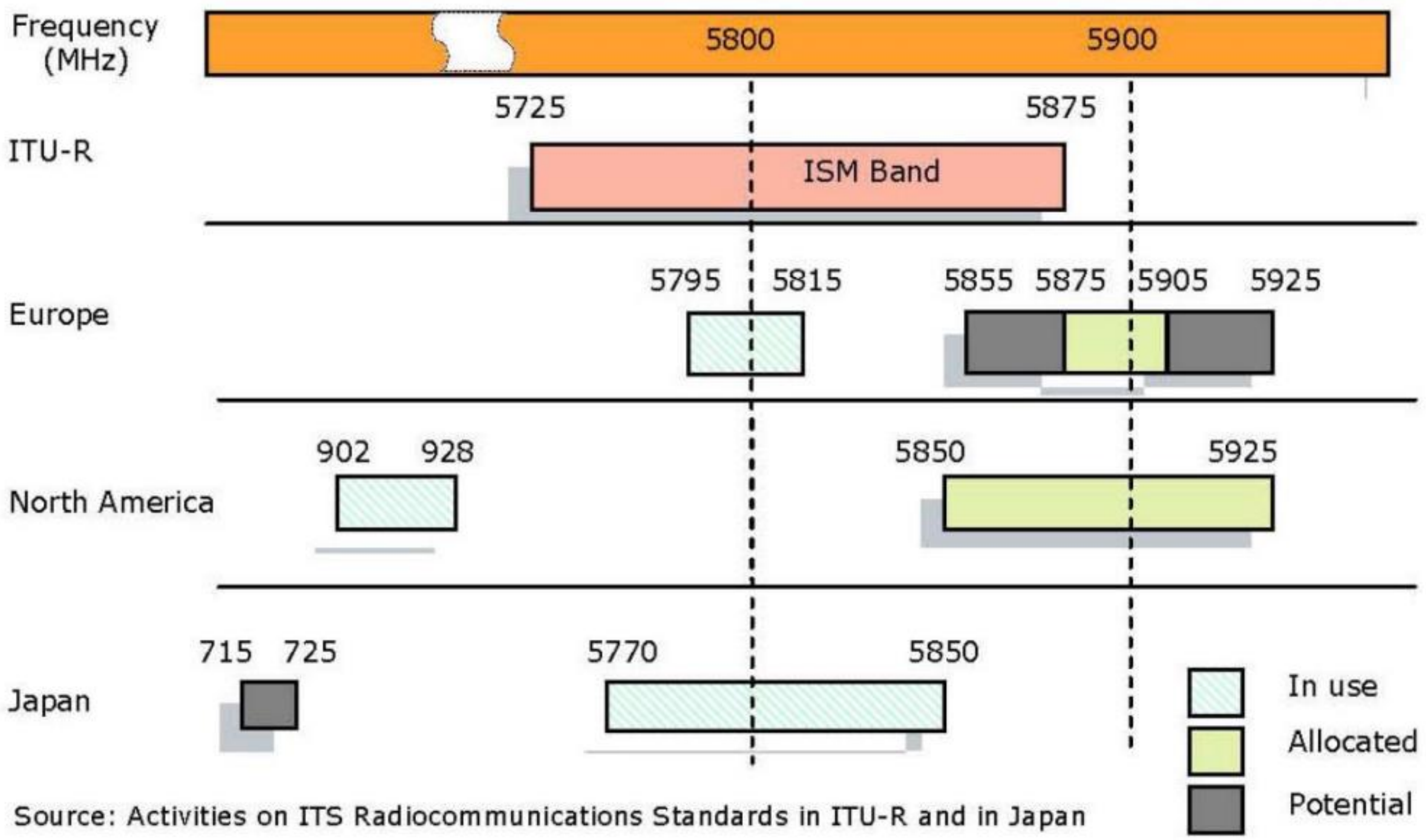
Hybrid solutions

- 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



DSRC – Dedicated Short Range Communications

- Dedicated in 1999 by the FCC (Federal Communications Commission) to vehicular communications
  - 75 MHz of spectrum in the 5.9 GHz band (5.850-5.925 GHz)
- In Europe, ETSI allocated in 2008 30 MHz in the 5.9 GHz band for ITS
- Systems in US, Europe, Japan not really compatible with each other



Source: Activities on ITS Radiocommunications Standards in ITU-R and in Japan

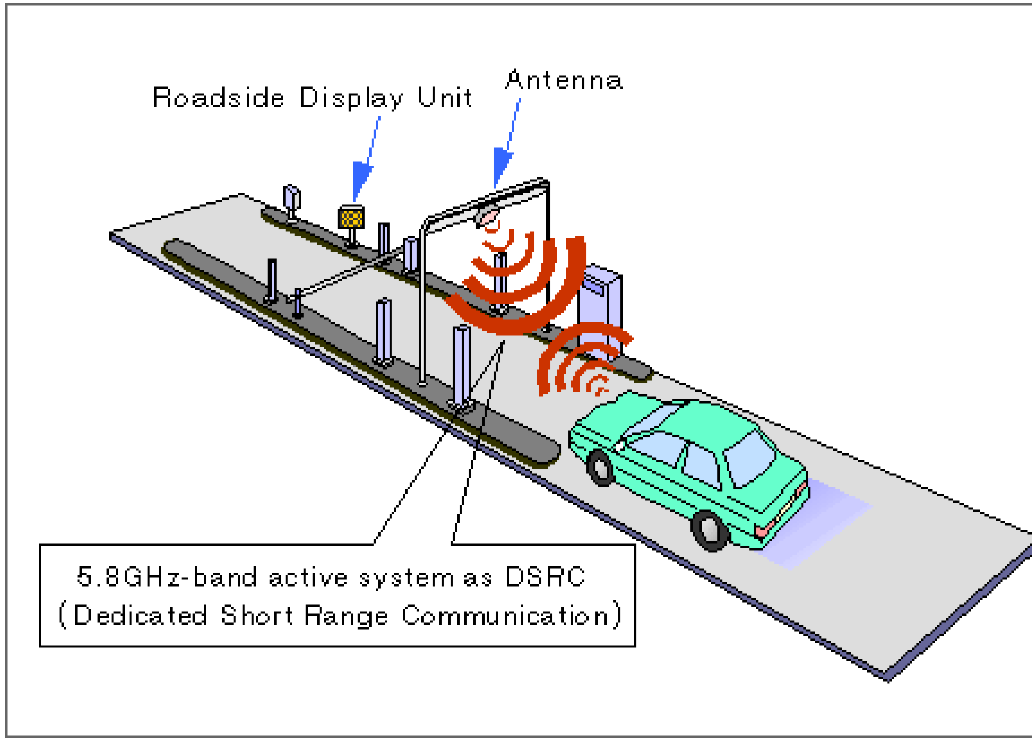
DSRC – Dedicated Short Range Communications

- Traditional ISM bands (Industry, Science, Medical) – 900 MHz, 2.4 GHz, 5 GHz
  - **Free, unlicenced bands**
  - Populated by many technologies – Wifi, Bluetooth, Zigbee
  - No restrictions other than some emmission and co-existance rules

- DSRC band
  - **Free but regulated spectrum**
  - Restrictions in terms of usage and technologies
  - All radios should be compliant to a standard

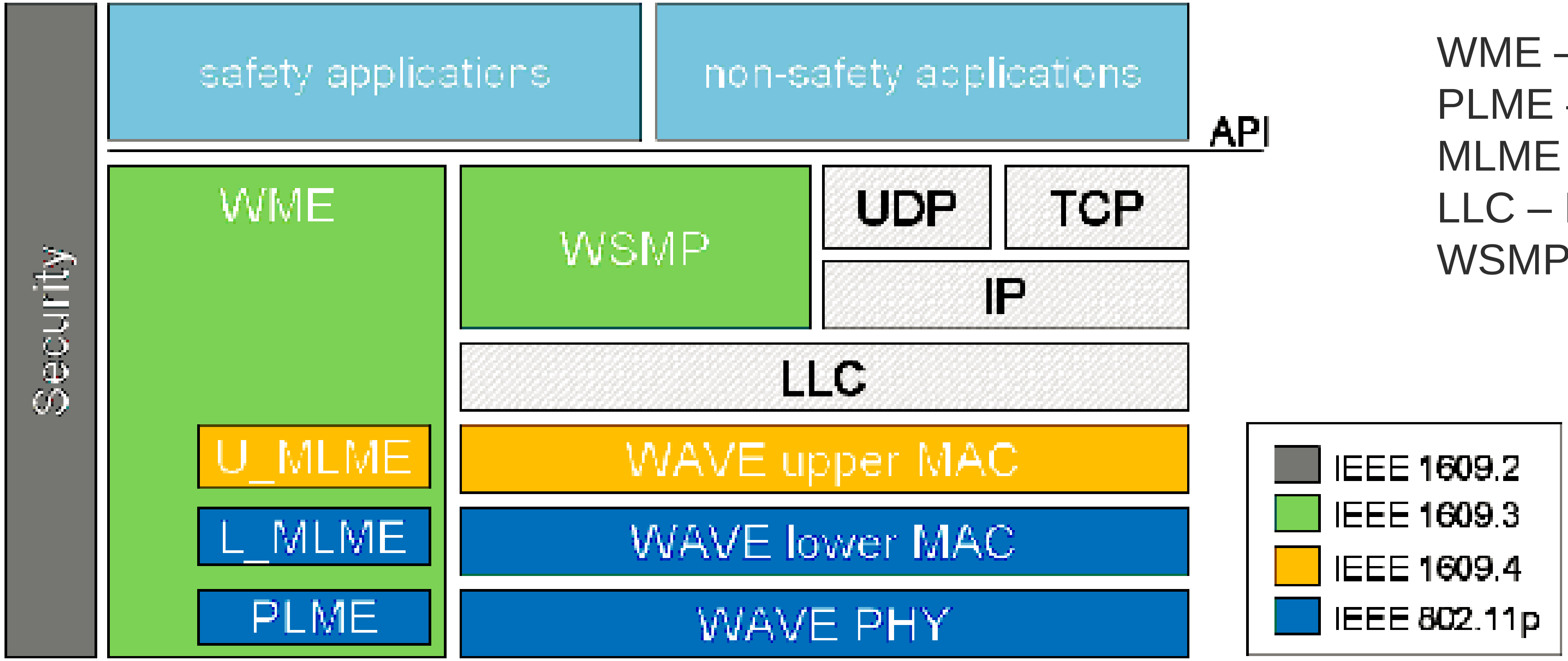
DSRC – Dedicated Short Range Communications

- **Basic goals of DSRC**
  - Support of low latency, secure transmissions
  - Fast network acquisition, rapid and frequent handover handling
  - Highly robust in adverse weather conditions
  - Tolerant to multi-path transmission
- **Mainly for public safety applications**, to save life and improve traffic flow
- Private services also permitted
  - Spread the deployment costs, encourage quick development and adoption
  - **Electronic Toll Collection (ETC)** was initially one of the main drivers



WAVE

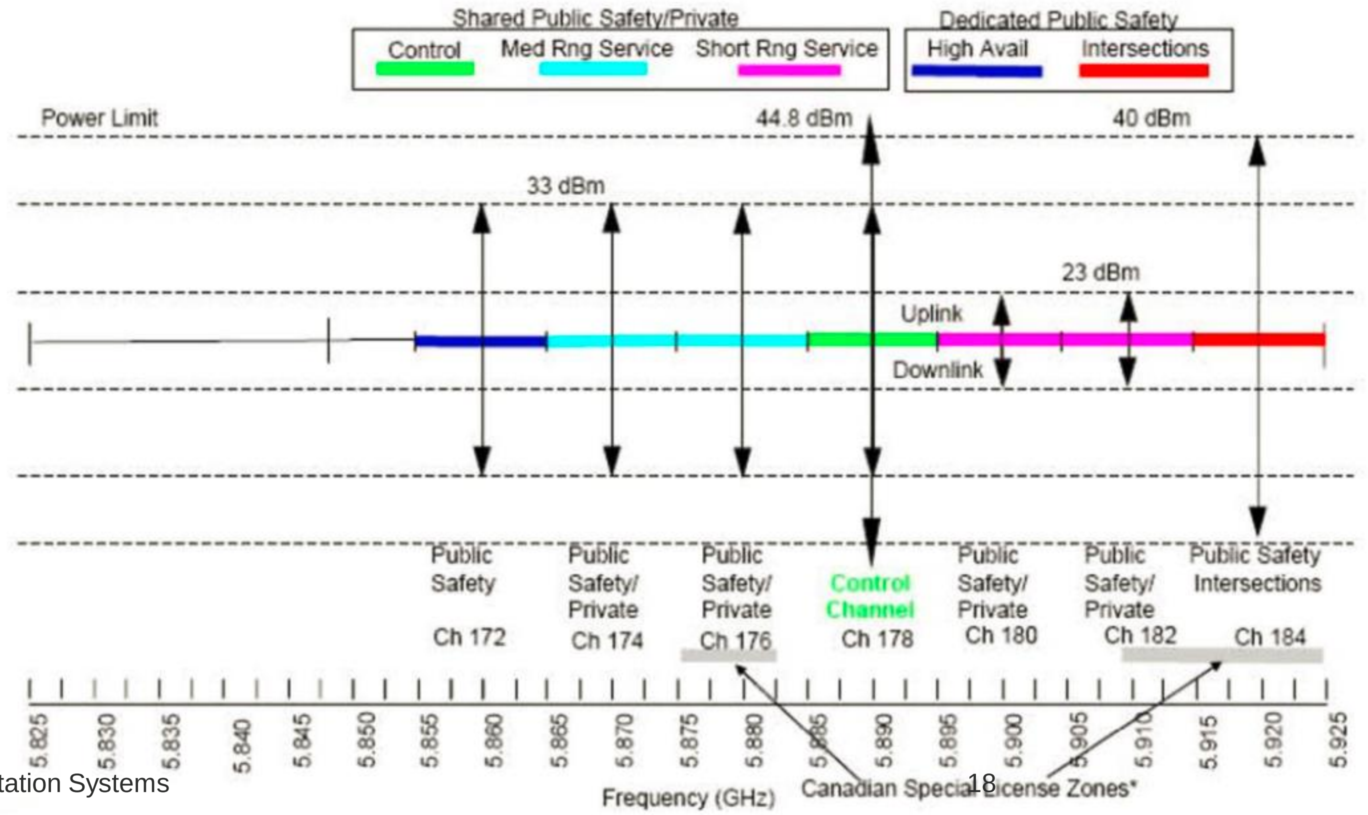
- IEEE 802.11
  - Collection of physical (PHY) and medium-access control (MAC) layer specifications for implementing WLAN
  - 802.11a (5 GHz, OFDM), 802.11b (2.4 GHz, DSSS), 802.11g (2.4 GHz, OFDM), 802.11n (2.4 and 5 GHz, MIMO-OFDM), 802.11ac (5 GHz, MIMO-OFDM)
  - **802.11p – part of WAVE (Wireless Access in Vehicular Environment)**



WME – WAVE Management Entity
PLME – Physical Layer Manag. Entity
MLME – MAC Layer Manag. Entity
LLC – Logical Link Control
WSMP – WAVE Short Message Prot.

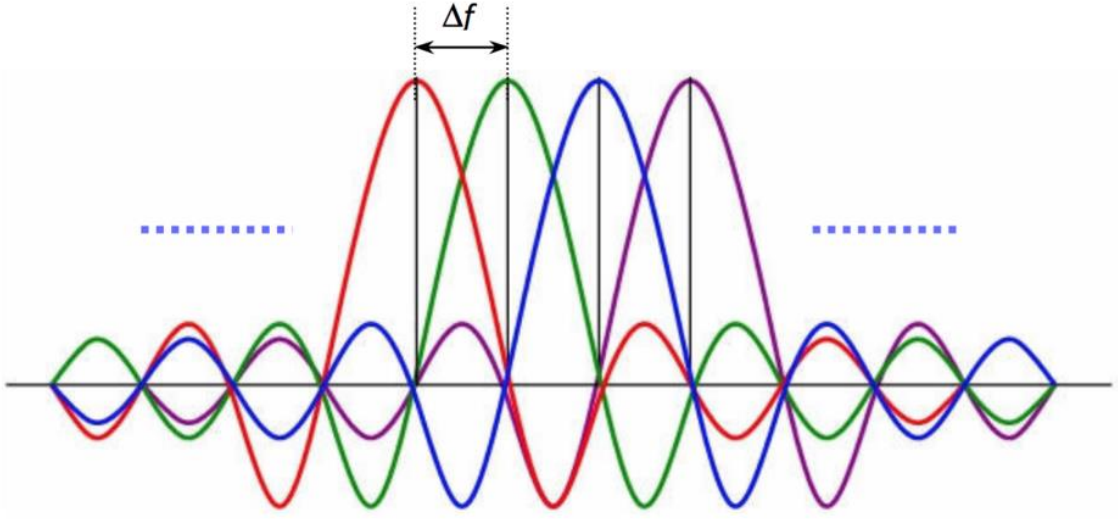
WAVE spectrum bands

- 75 MHz wide spectrum divided into 7x10 MHz wide channels, 5 MHz guard band
  - Channel 178 the **control channel (CCH) - t**ransmit WAVE Short Messages (WSM), announce services
  - Channel 172 reserved for **high availability applications (future use)**
  - Channel 184 reserved for **intersections**
  - The other channels shared between public safety and private uses
    - Channels 174-176 and 180-182 can be combined to form a 20 MHz channel
- In Europe the **ITS-G5 standard**
  - **ITS-G5B band**: 5.855 – 5.875 GHz
    - 172, 174 SCH – ITS non-safety app
  - **ITS-G5A band**: 5.875 – 5.905 GHz
    - 176, 178 SCH – ITS traffic safety app
    - 180 CCH
  - **ITS-G5D band**: 5.905 – 5.925 GHz
    - 182, 184 SCH – for future use



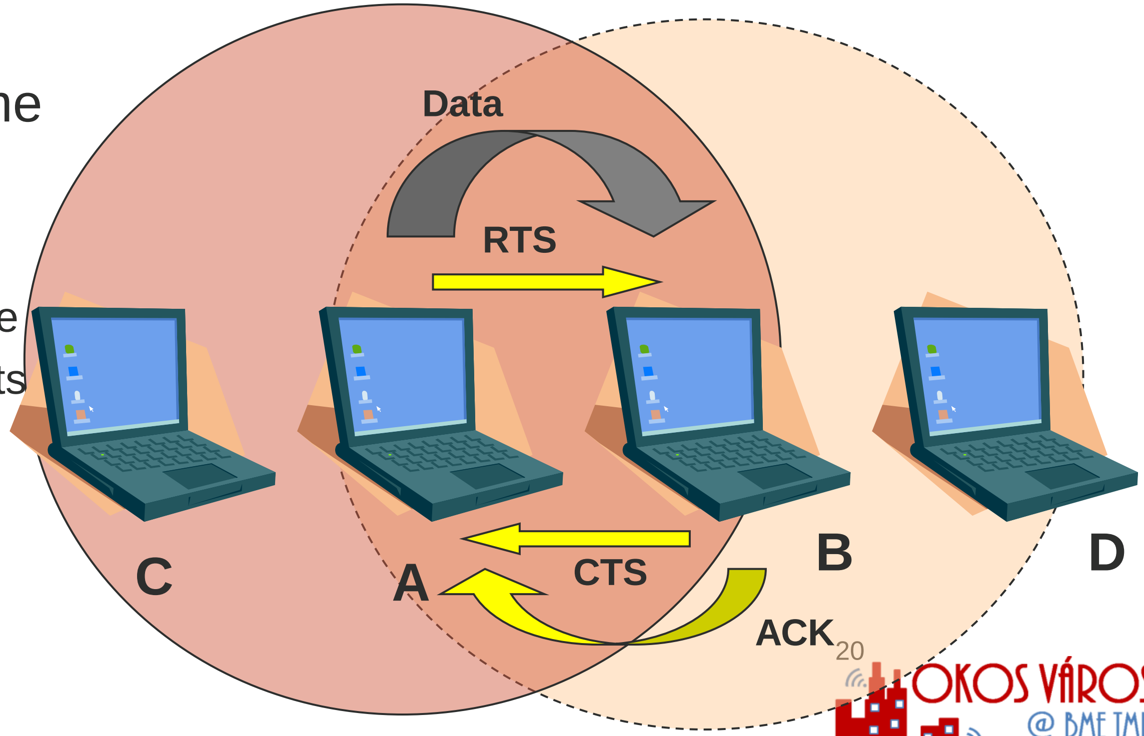
WAVE (802.11p) vs IEEE 802.11

- 10 MHz channels instead of 20 MHz
- 3-27 Mbps instead of 6-54 Mbps
- Same modulation schemes (BPSK, QPSK, 16QAM, 64QAM)
- Carrier spacing reduced to 0.15625 MHz from 0.3125 MHz
    - 48 data subcarriers for both



Traditional IEEE 802.11 MAC (DCF)

- **MAC – Medium Access Control**
  - Who has access to the medium (radio channel) and when?
  - Avoid many users speaking in parallel
- **DCF – Distributed Coordination Function**
  - A sends an RTS frame to B, asking the permission to send a data frame
    - **Request To Send**
  - If B gives the permission, it sends back a CTS frame
    - **Clear To Send**
  - A sends the data frame, and starts an ACK timer
    - If B receives the packets in order, it replies with an ACK frame
    - If the timer expires without receiving an ACK, everything starts from scratch



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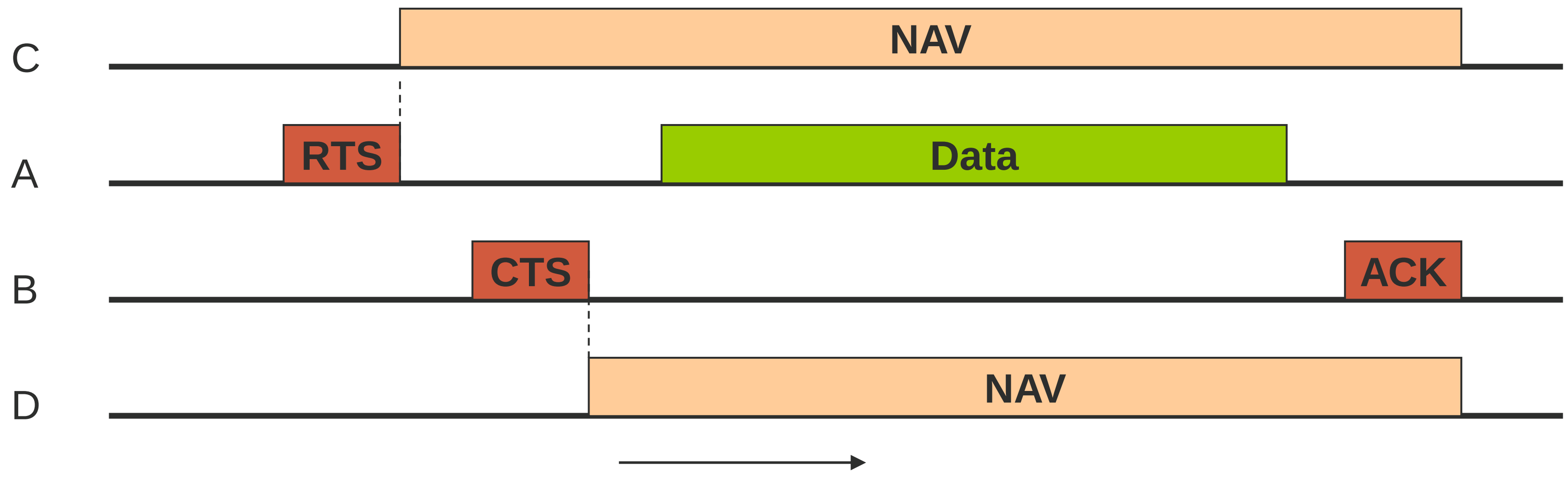
Traditional IEEE 802.11 MAC (DCF)

- C hears A, receives the RTS frame
  - Deduces that in the next moments someone will start to send data
  - It stops its own transmission, while the other conversation is not finished
    - Knows when it ends from the ACK timer, included in the RTS frame
  - It sets an internal reminder to himself, saying that the channel is virtually occupied
    - NAV – Network Allocation Vector
- D does not hear about the RTS, but hears the CTS
  - Also sets a NAV for himself



802.11p beaconing

- In traditional IEEE 802.11 multiple handshakes to ensure distributed medium access
  - If the channel is not free, backoff – the contention window doubles
- In 802.11p nodes exchange beacons using the **Wave Short Message Protocol (WSMP)**
  - To create cooperative awareness
  - Information on speed, position, acceleration, direction
  - Sent at regular intervals (e.g., 10 Hz – 100 ms)
- Sent on the CCH, no ACK
  - After the channel is sensed free for a given interval
  - If not free, backoff for the size of a Contention Window, and try again
  - No doubling of the contention window
- As opposed to data sent on SCH, where ACK should be sent
  - If no ACK received, collision occured, contention window doubled

IEEE 1609.x

- IEEE 1609.2 – security services
- IEEE 1609.3 – management services
  - Channel usage monitoring
  - Received channel power indicator (RCPI)
  - Management parameters
- IEEE 1609.4 – QoS and multi-channel access