VANETs (cont.) & ITS use cases

Intelligent Transportation Systems

Vida Rolland

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)

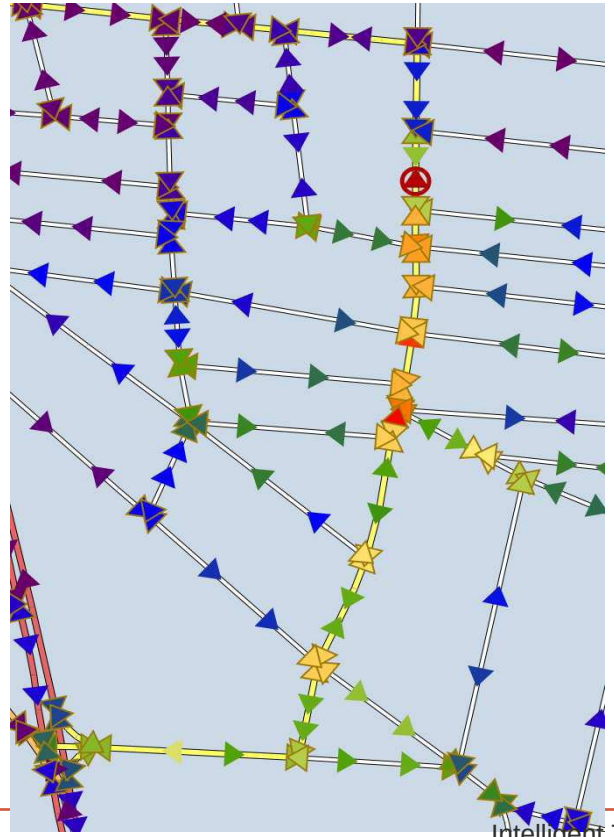
- **DECA: Density-Aware Reliable Broadcasting**
  - Does not use position information
  - Beacon messages sent to discover neighbors
  - Network load is minimized by chosing as next hop the neighbor that has most neighbors

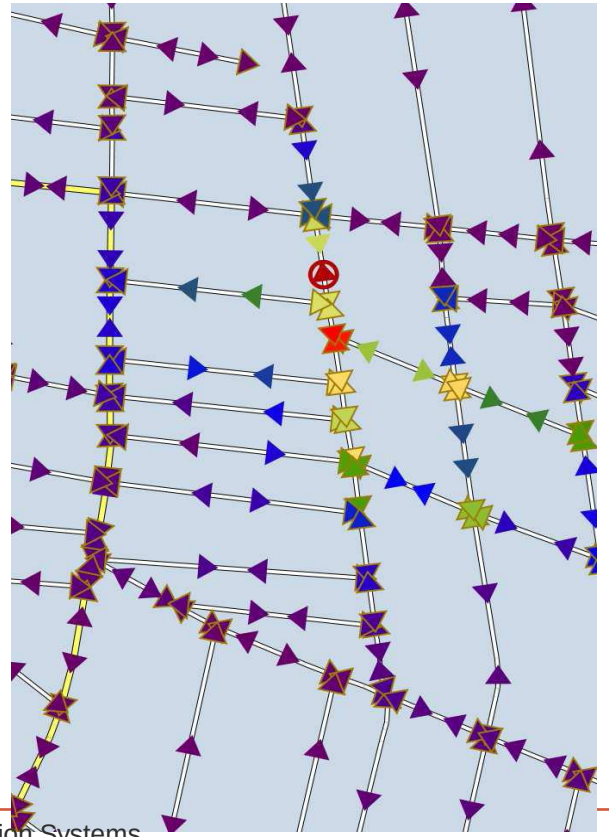
Intelligent flooding through gossiping

- 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

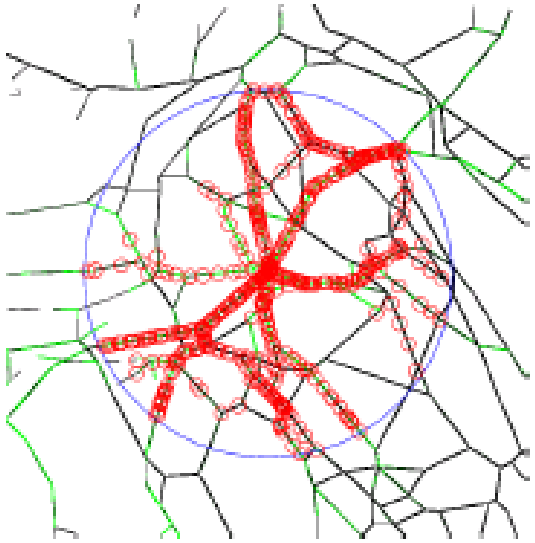
- Simulation results for the CLoUD protocol
  - Digital map of Budapest, warmer colors mean more messages received by that car
  - If the problem occurs on a main road (left), the message is spread more broadly
  - If the problem occurs on a side road (right), the flooding dies out fast

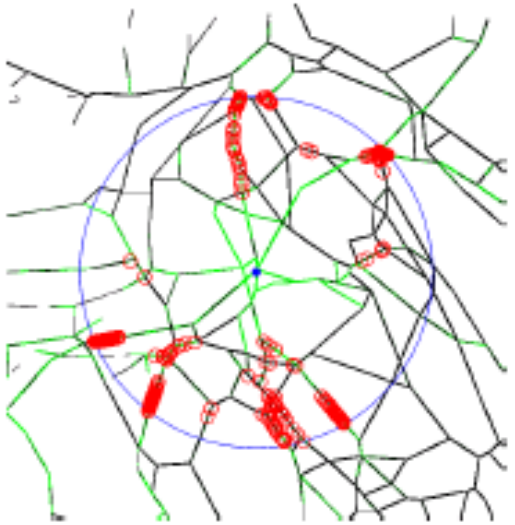




VANET Multicast protocols

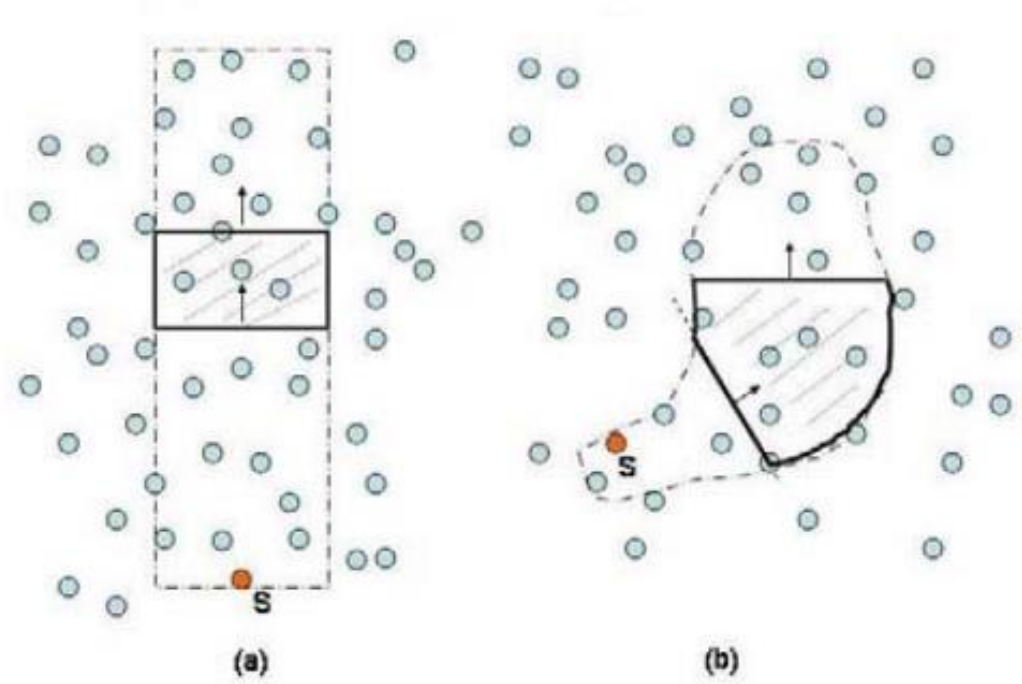
- There is a given area inside which all cars should receive the message (**Zone of Relevance**)
- The multicast group is implicitely defined by the position of the cars
- The source is not necessarily inside the ZOR, so first the packet should be delivered to the ZOR, through unicast routing, and then 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





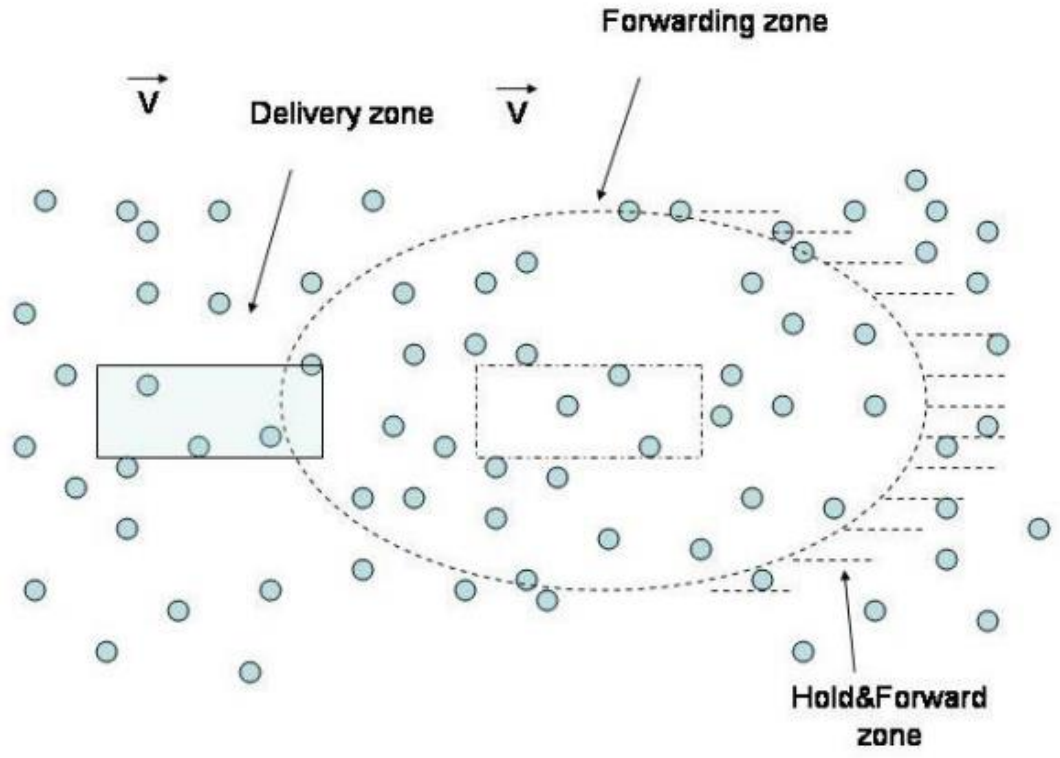
Mobicast

- **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 eneters the Delivery Zone should receive the message before it enters the zone, or just on entering the zone
-



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

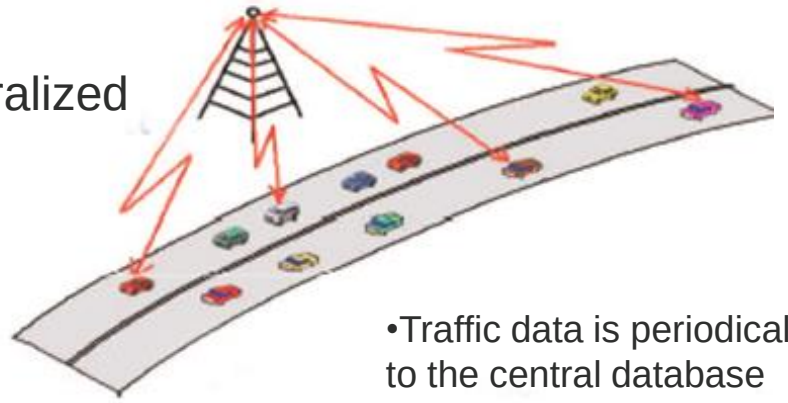


Communication architectures

- 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

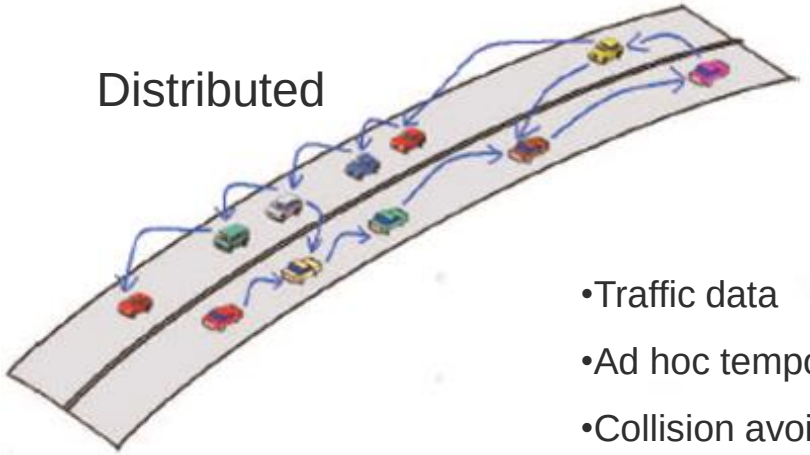
Communication architectures

Centralized



- Traffic data is periodically sent to the central database
- Cars receive traffic information from the central database

Distributed

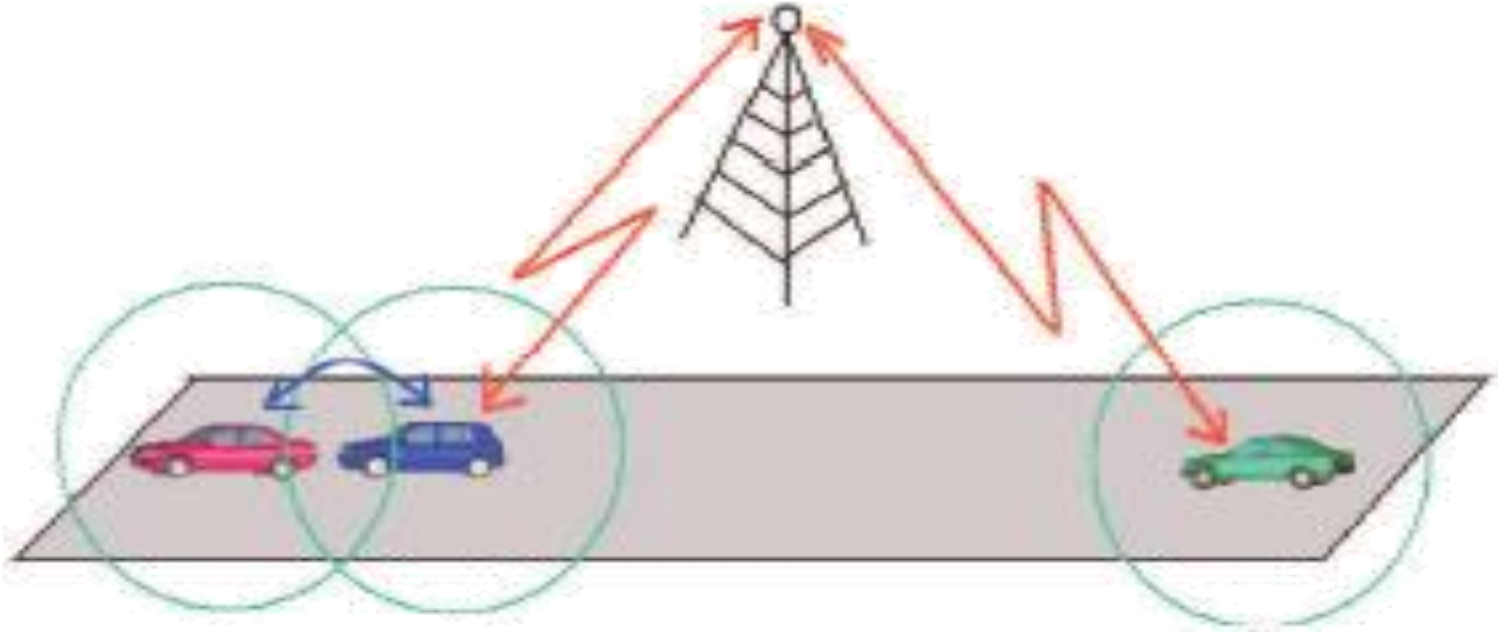


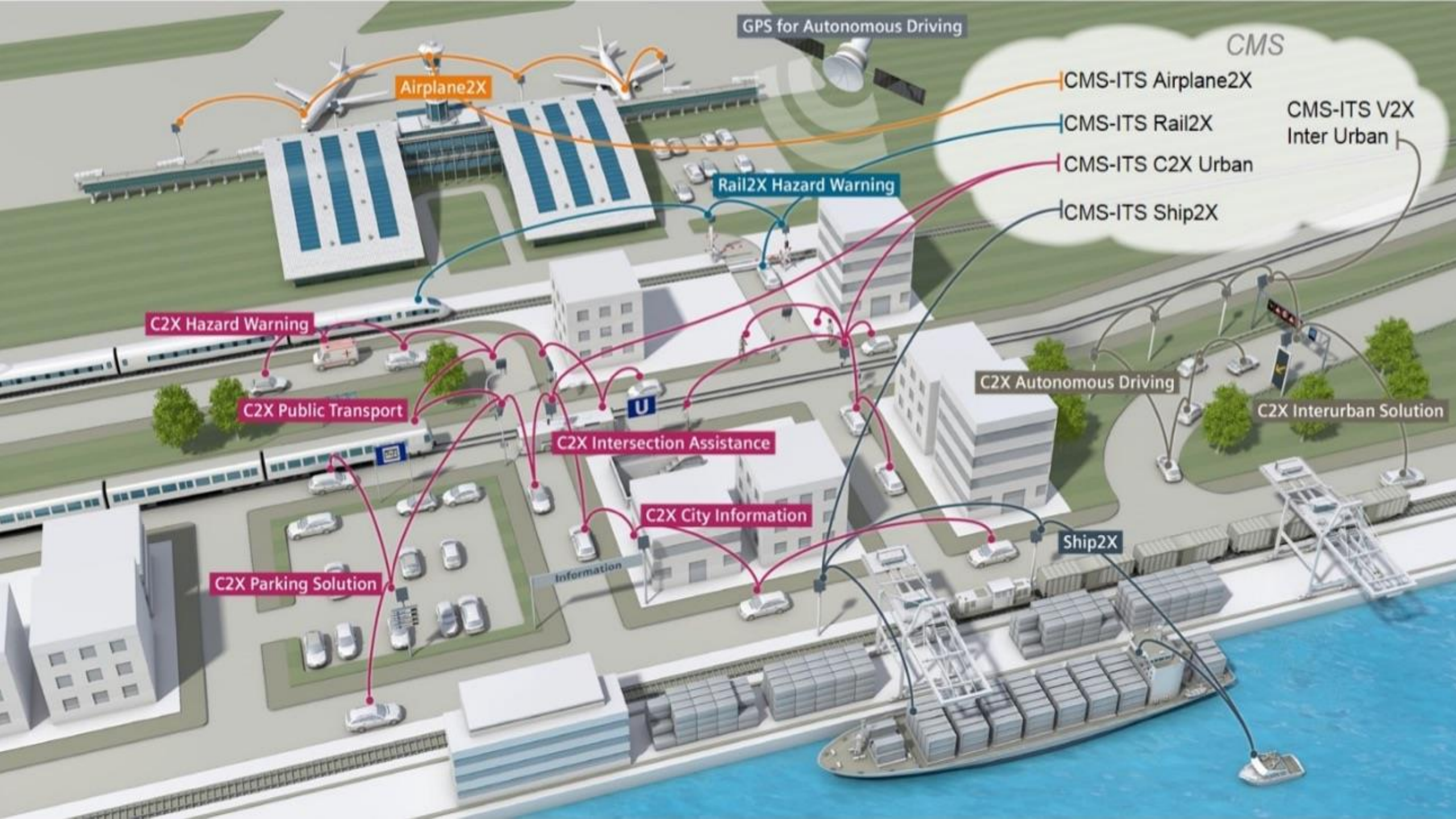
- Traffic data
- Ad hoc tempomat
- Collision avoidance

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

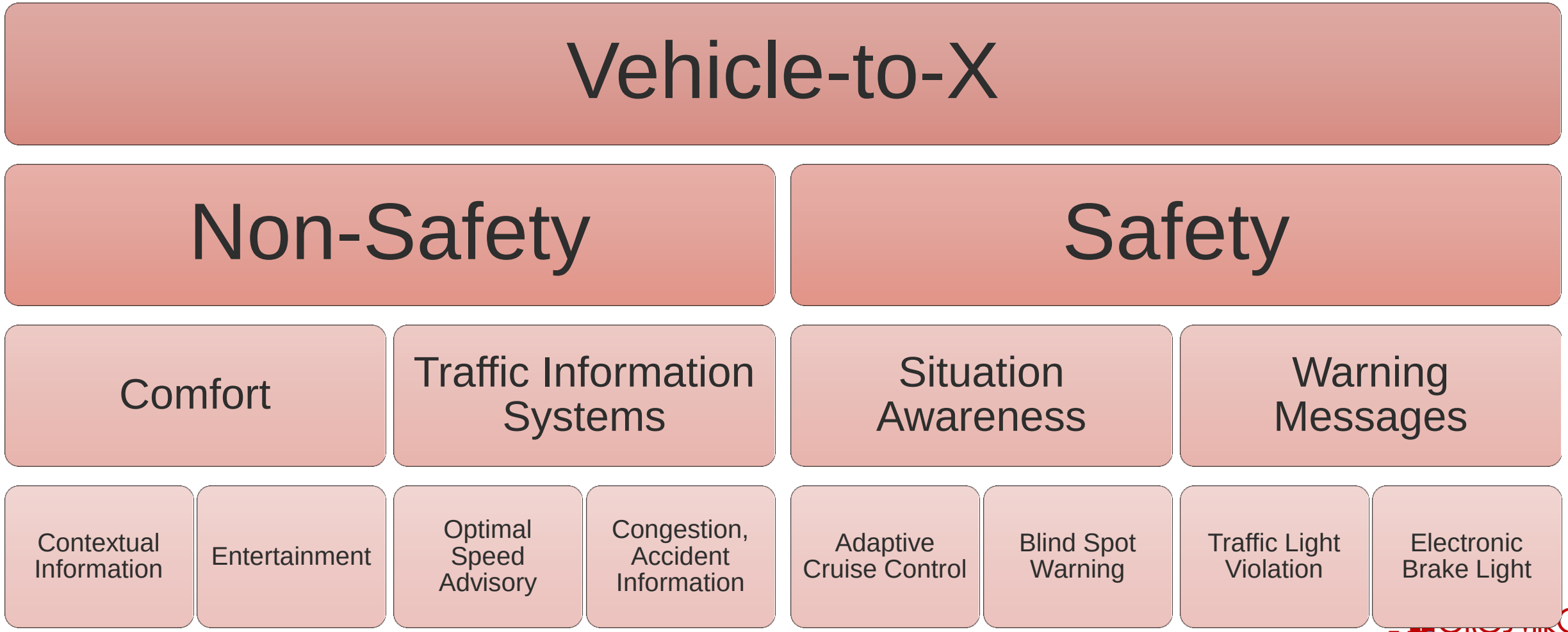
Hybrid solutions

- 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




GPS for Autonomous Driving
CMS
CMS-ITS Airplane2X
CMS-ITS Rail2X
CMS-ITS C2X Urban
CMS-ITS Ship2X
CMS-ITS V2X
Inter Urban
Airplane2X
Rail2X Hazard Warning
C2X Hazard Warning
C2X Public Transport
C2X Intersection Assistance
C2X City Information
C2X Parking Solution
C2X Autonomous Driving
C2X Interurban Solution
Ship2X
Information

Taxonomy of ITS Use Cases



Taxonomy of Use Cases

Vehicle-to-X

Non-Safety

Many messages

High data rate

Low latency demands

Low reliability demands

Safety

Few messages

Small packet size

High latency demands

High reliability demands

Diversity of requirements

Application	Latency	Reliability	# Vehicles	Area	Persistence
Information Query	★	★	★★★	★★★	
Hazard Warning	★★★	★★	★★	★★★	
ACC, el. Brake Light	★★★	★★	★	★	
Cooperative Awareness	★★	★★★	★	★	★
Intersection Assistance	★★	★★★	★★	★★	★
Platooning	★★★	★★★	★★	★	★

[1] T. L. Willke, P. Tientrakool, and N. F. Maxemchuk, "A Survey of Inter-Vehicle Communication Protocols and Their Applications," IEEE Communications Surveys and Tutorials, vol. 11 (2), pp. 3-20, 2009

Freeway ⇔ Urban

- 1D mobility
- Bimodal connectivity
  - Stable connection (vehicles on same lane)
  - AND
  - unstable connection (vehicles on opposite lane)
- High speed
- …

- 2D mobility
- Bipolar connectivity
  - Many neighbors (when standing)
  - OR
  - Few neighbors (when driving)
- Obstacles
- …

Convergence towards heterogeneous approaches

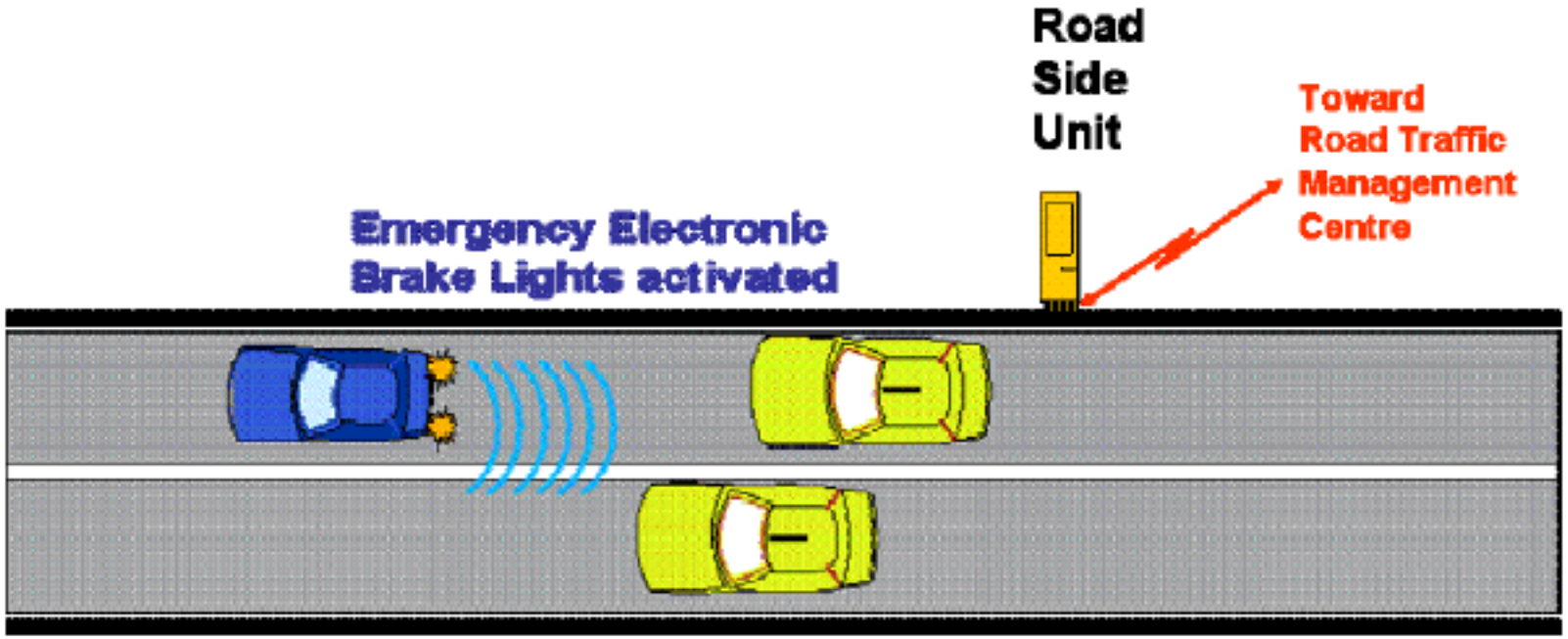
- Same system needs to work in multiple environments
  - Vehicle starts to drive in city with infrastructure support
  - Continues driving on freeway (still with infrastructure support)
  - Loses infrastructure support when turning onto local highway
  - Finishes driving in city without infrastructure support

ITS use cases

- Basic Set of Applications
  - Defined by ETSI (ETSI TR 102 638)

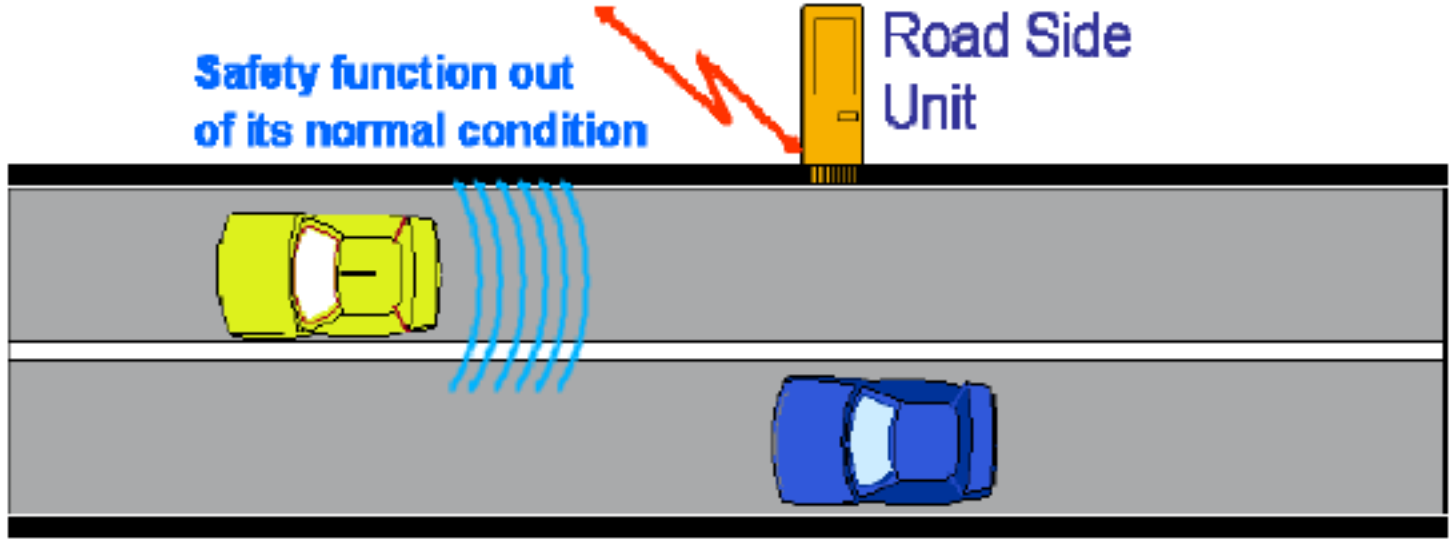
Vehicle Status Warnings

- **Emergency Electronic Brake Lights**
  - **Application name:** Road hazard warning.
  - A vehicle signals its hard braking to its local followers
  - Minimum frequency of periodic message 10 Hz



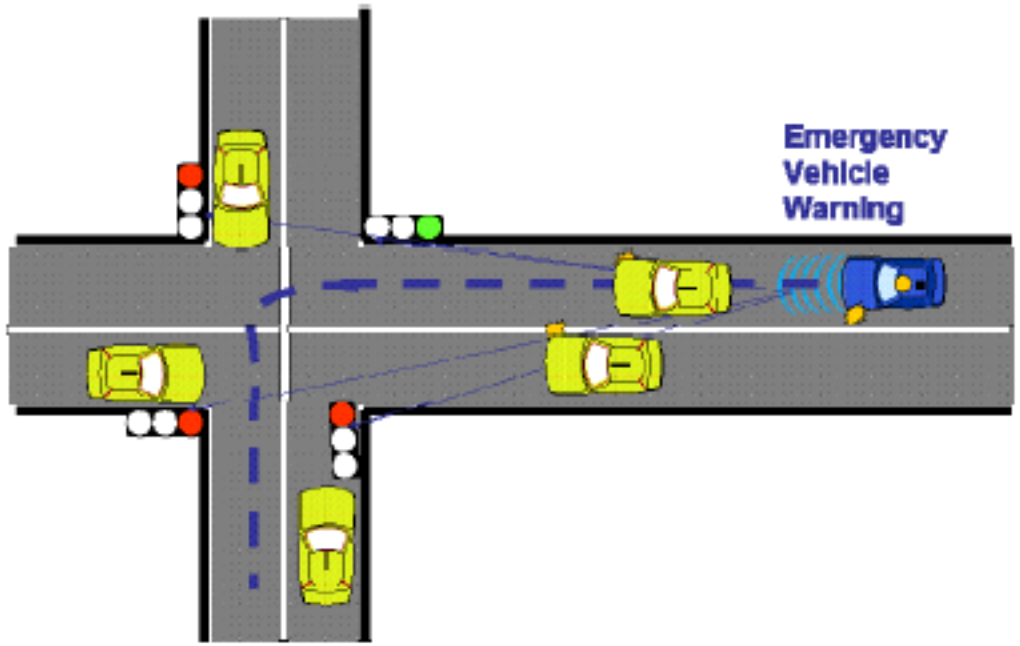
Vehicle Status Warnings

- **Safety function out of normal condition warning**
  - **Application name:** Road hazard warning.
  - a vehicle detecting a safety function (steering, braking, etc.) being out of its normal condition and presenting dangers to others to signal to them this abnormal vehicle state
  - Minimum frequency of periodic message 1 Hz



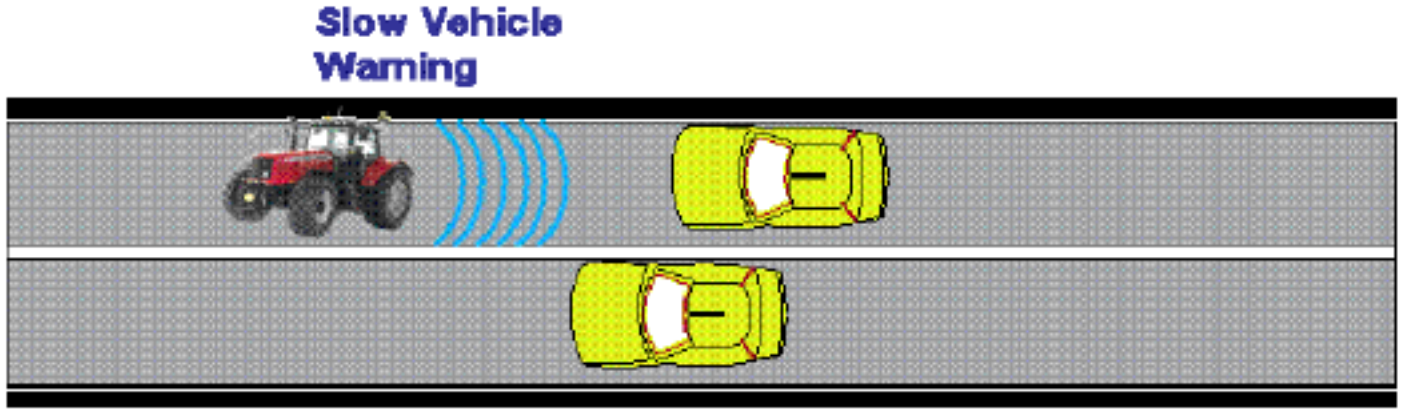
Vehicle type warnings

- **Emergency vehicle warning**
  - **Application name:** Co-operative awareness
  - Allows an active emergency vehicle to indicate its presence
  - Minimum frequency of V2X co-operative awareness messages issued by the emergency vehicle: 10 Hz
  - Specific use case security requirement: protection and authentication of the CAM message



Vehicle type warnings

- **Slow vehicle warning**
  - **Application name:** Co-operative awareness
  - any slow vehicle to signal its presence (vehicle type) to other vehicles
  - Minimum frequency of the periodic message: 2 Hz.

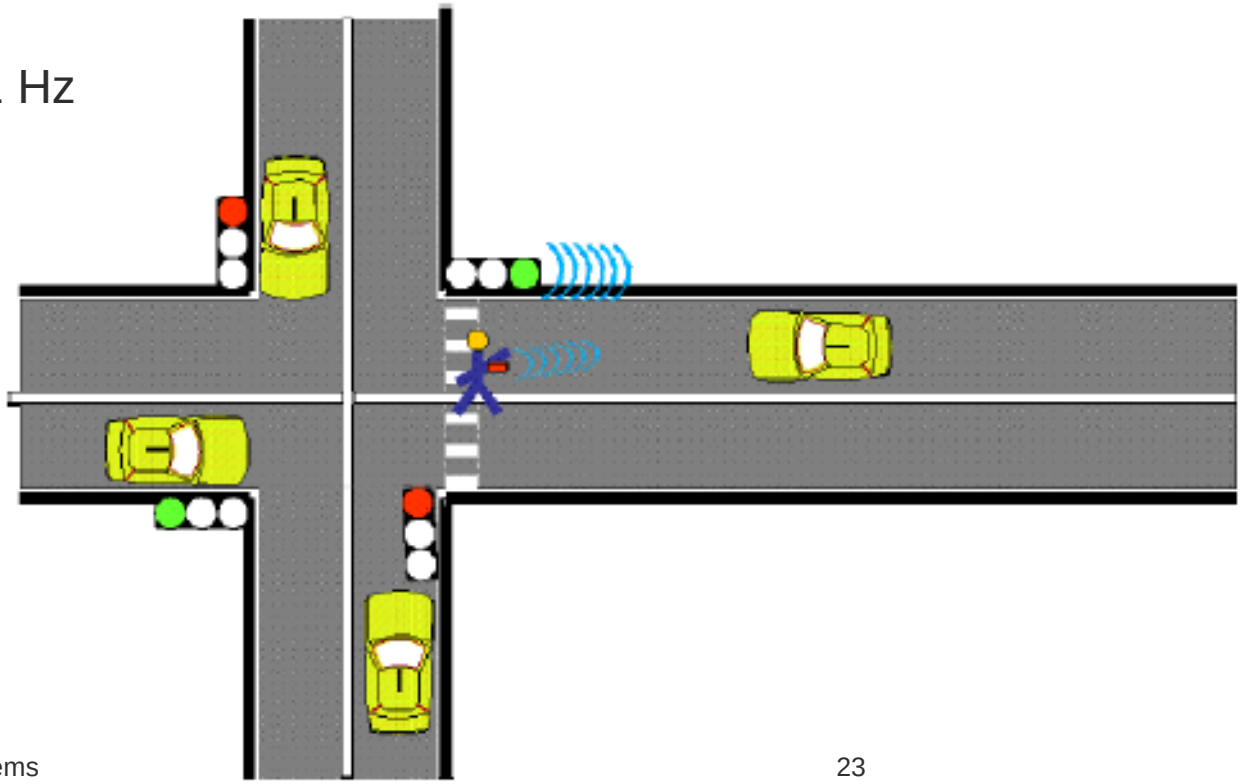


Vehicle type warnings

- **Motorcycle warning**
  - **Application name:** Co-operative awareness
  - Warn driver for arriving motorcycle. This is especially useful in case of reduced visibility
  - Road side unit to be installed if line of sight between vehicles is obstructed. RSU must be capable to relay signal or to detect and signal a collision risk.
  - Minimum frequency of V2V co-operation awareness messages: 2 Hz.

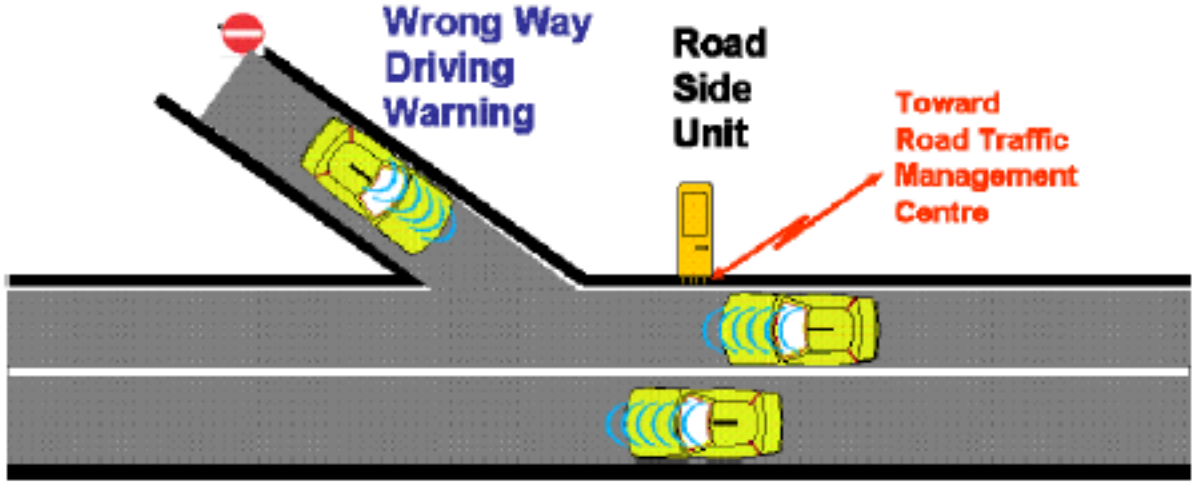
Vehicle type warnings

- **Vulnerable road user Warning**
  - **Application name:** Co-operative collision avoidance or mitigation.
  - Provides warning to vehicles of the presence of vulnerable road users, e.g. pedestrian or cyclist, in case of dangerous situation
  - Capability for a human equipped with relevant device or for a road side unit equipped with relevant system to broadcast I2V co-operative awareness messages providing information on the presence, trajectory and speed of a vulnerable road user.
  - Minimum CAMs frequency of the vulnerable user: 1 Hz



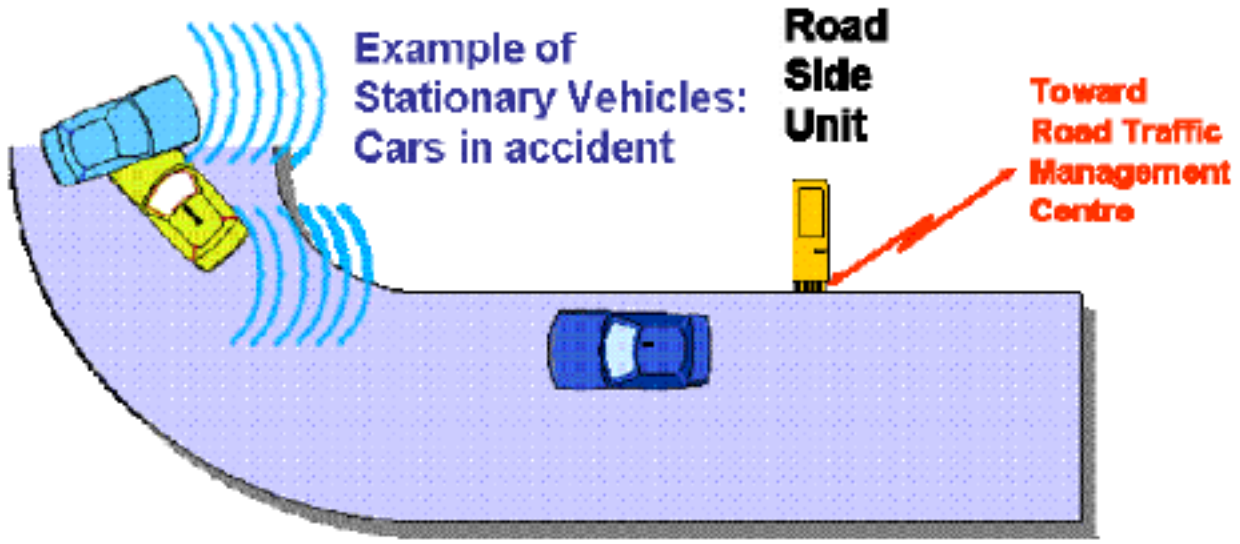
Traffic hazard warnings

- **Wrong way driving warning**
  - indicates to vehicles in the affected area that a vehicle is driving against the planned direction of traffic
    - This form of driver behaviour may be a violation of local laws and require identification of the vehicle and driver by the appropriate authority
  - Limit as much as possible frontal collisions due to wrong way driving.
  - Capability for a vehicle, to detect that it is driven in a wrong way and to broadcast in V2X decentralized environmental notification messages its current "wrong way heading" status
  - Minimum frequency of the periodic message: 10 Hz.



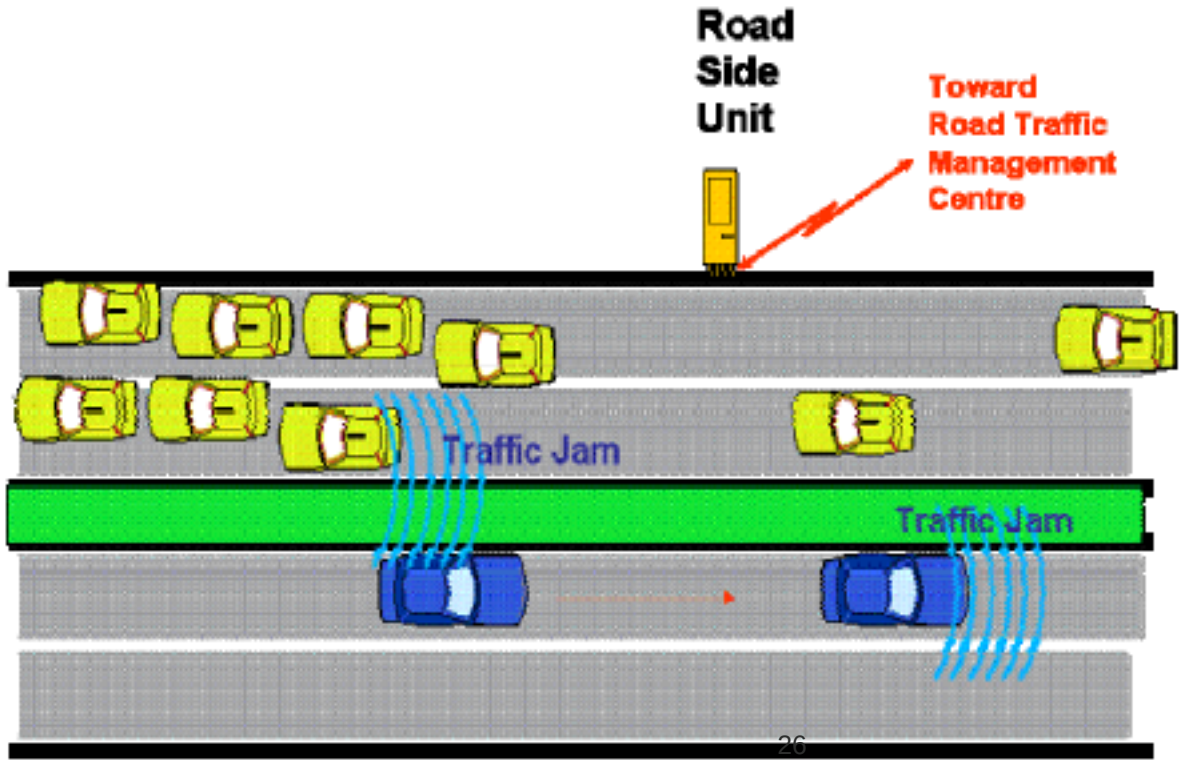
Traffic hazard warnings

- **Stationary vehicle warning**
  - Any vehicle being dangerously immobilized on the road (consecutive to an accident, a breakdown or any other reason) to alert other approaching vehicles of the risk for them associated to this dangerous situation
  - Minimum frequency of the periodic message: 10 Hz.



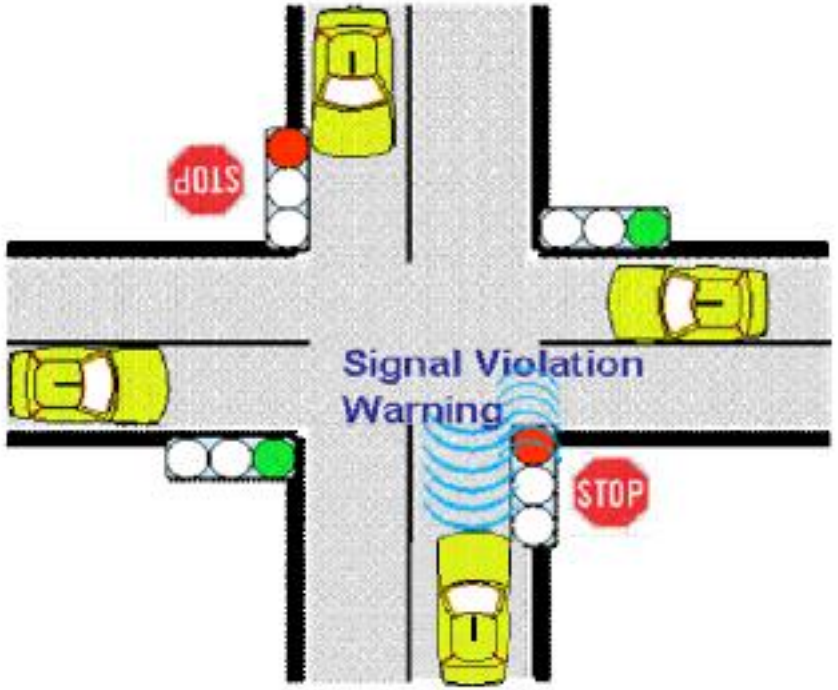
Traffic hazard warnings

- **Traffic condition warning**
  - Any vehicle or roadside station to signal to other vehicles the current traffic condition (e.g., traffic jam)
  - Such data may be propagated by the ITS network as authoritative traffic management messages in order to mitigate the impact of the traffic condition on traffic flow
  - Capabilities for all vehicles crossing the car signalling a traffic jam to store and forward received V2X decentralized environmental notification messages according to their geocasting parameters
  - Minimum frequency of the periodic message: 1 Hz.



Traffic hazard warnings

- **Signal violation warning**
  - allows a detecting ITS station (most likely a road side unit) to signal to affected users that a vehicle has violated a road signal and increased the risk of an accident
    - This form of driver behaviour may be a violation of local laws and require identification of the vehicle and driver by the appropriate authority.
  - Minimum frequency of C2X decentralized environmental notification messages: 10 Hz.



Traffic hazard warnings

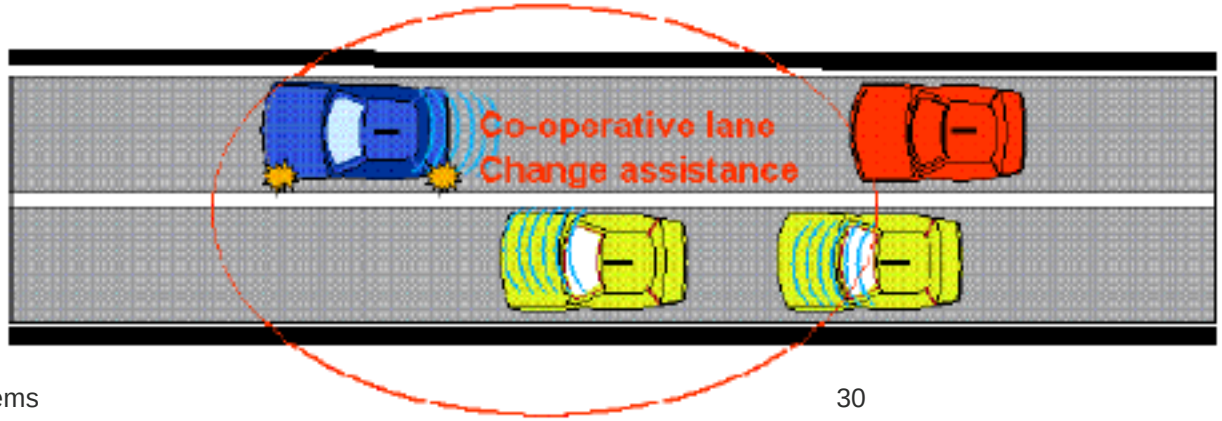
- **Roadwork warning**
  - Via road infrastructure to vehicle communication, provides information on current valid roadwork and associated constraints
  - Capabilities for concerned vehicles to store and forward according to geocasting messages cancel rules, I2V decentralized environmental notification messages
  - Minimum frequency of the periodic message: 2 Hz.

Dynamic vehicle warnings

- **Overtaking vehicle warning**
  - **Application name:** Co-operative awareness.
  - An overtaking (passing) vehicle signals its action to other local vehicles to secure the overtaking situation
  - Requires accurate positioning of vehicles on digital map
  - Minimum frequency of the periodic message: 10 Hz.

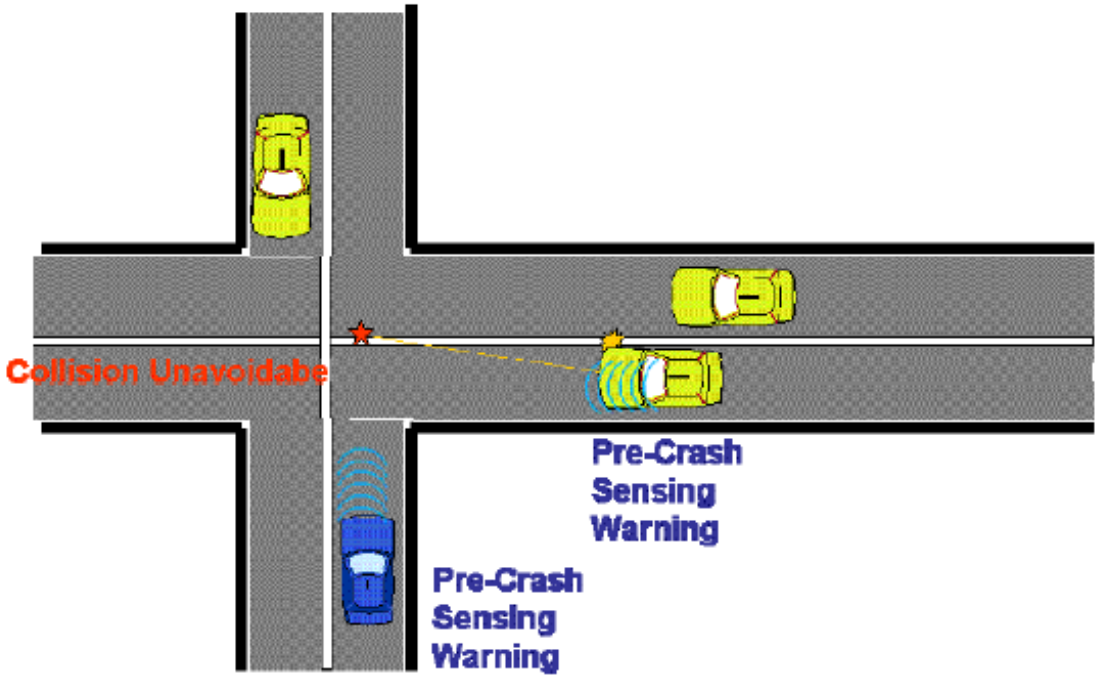
Dynamic vehicle warnings

- **Lane change assistance**
  - Provides the driver assistance by giving information about cars on the neighbouring lane and facilitating this change through V2V co-operation
  - Capability for a vehicle to broadcast V2X co-operative awareness messages indicating a lane change.
  - Capability for this vehicle to co-operate in some manner with other vehicles involved in a lane change situation.
  - Minimum duration of the total exchange: according to the respective vehicles speeds and transmission ranges.
  - Minimum frequency of V2V co-operation awareness messages: 10 Hz.
  - Vehicles relative positioning accuracy: at least equal to 2 m.



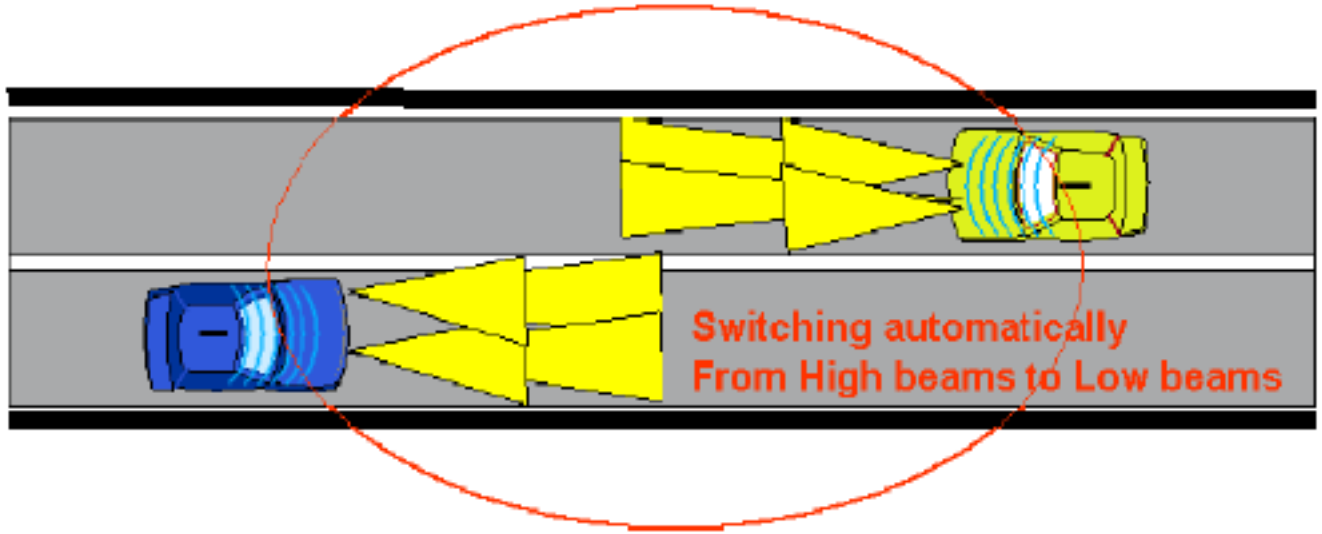
Dynamic vehicle warnings

- Pre-crash sensing warning
  - **Application name:** Co-operative collision avoidance or mitigation.
  - Prepare for imminent and unavoidable collision by exchanging vehicles attributes after unavoidable crash is detected
  - Minimum frequency of CAMs: 10 Hz.
  - Maximum latency time: 50 ms. (for the other applications is usually 100 ms)



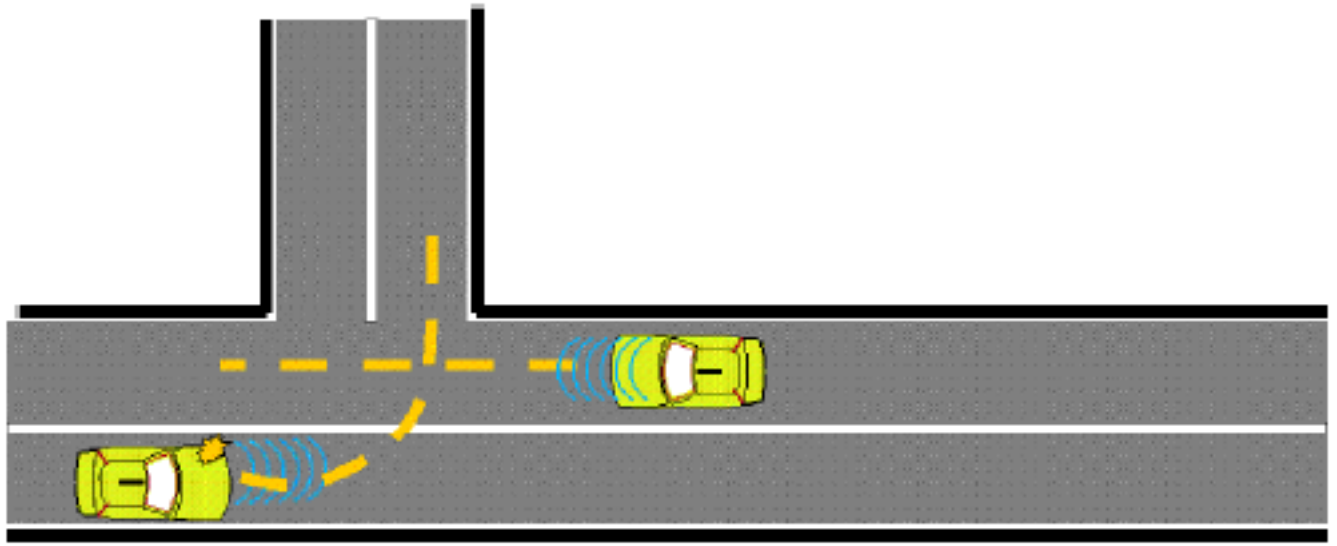
Dynamic vehicle warnings

- **Co-operative glare reduction**
  - **Application name:** Co-operative awareness.
  - Enable a capable vehicle from automatically switching from high-beams to low-beams when detecting a vehicle arriving in the opposite direction
  - Minimum frequency of V2V co-operation awareness messages: 2 Hz
  - Vehicles relative positioning accuracy: at least equal to 20 m



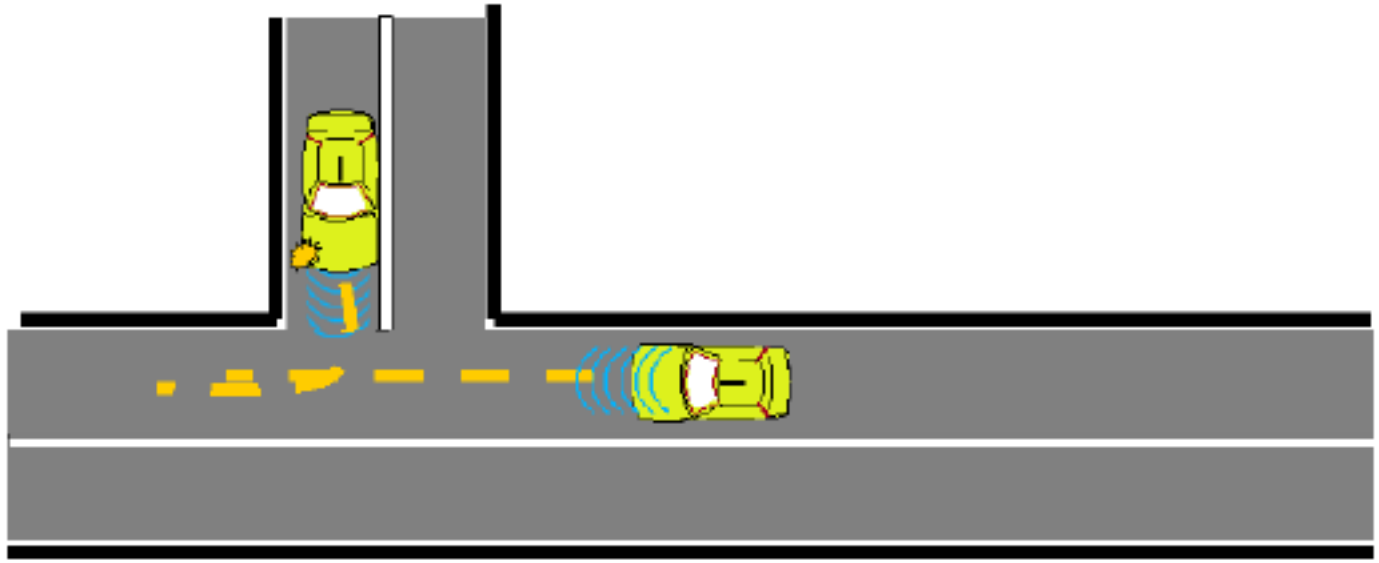
Collision Risk Warning

- **Across traffic turn collision risk warning**
  - **Application name:** Co-operative collision avoidance or mitigation.
  - inform approaching vehicles that a vehicle (the transmitting vehicle) is intending to turn across traffic
  - An indication of turning does not authorize the turning vehicle to turn and national laws will apply.
  - Minimum frequency of the CAMs: 10 Hz.



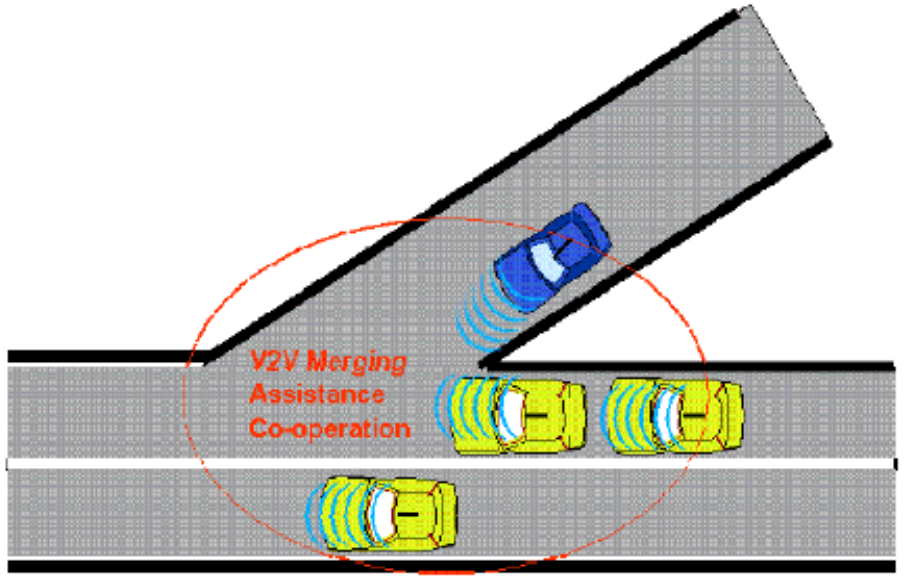
Collision Risk Warning

- **Merging Traffic Turn Collision Risk Warning**
  - **Application name:** Co-operative collision avoidance or mitigation.
  - Provide information of presence, position and movement of incoming vehicles from left side, turning right.
  - Road side unit to be installed if line of sight between vehicles is obstructed. RSU needs to be capable to relay signal or to detect and signal a collision risk
  - Minimum frequency of the CAMs: 10 Hz.



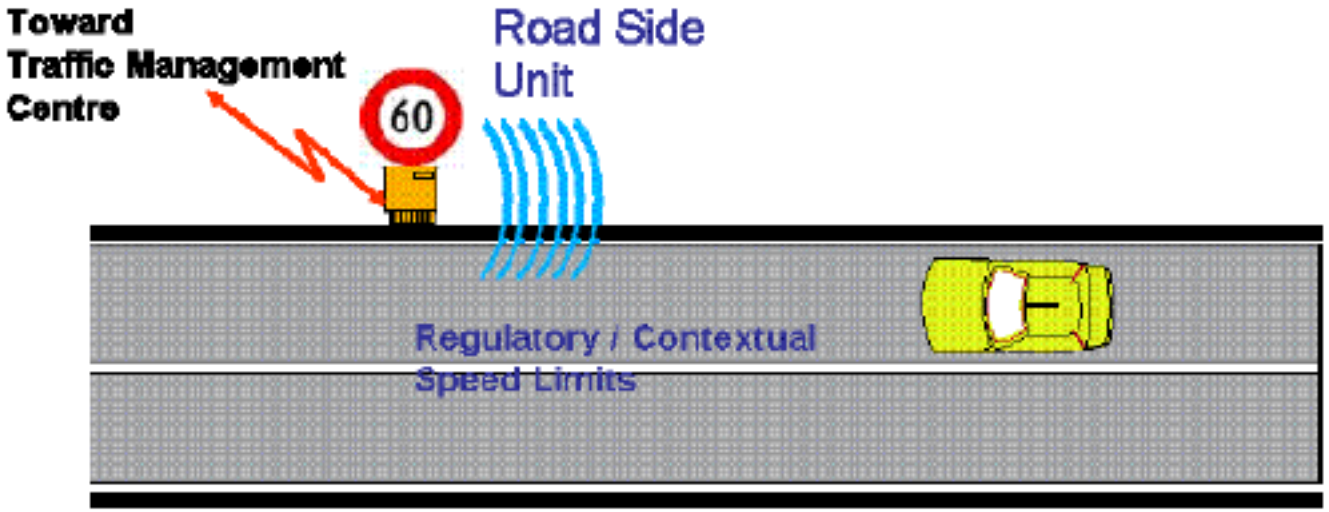
Collision Risk Warning

- Co-operative merging assistance
- **Application name:** Co-operative awareness.
- Vehicles involved in a merging negotiate together the merging process to avoid collision
- Road side unit to be installed if line of sight between vehicles is obstructed. RSU needs to be capable to relay signal or to detect and signal a collision risk.
- Minimum frequency of V2V Co-operation Awareness messages: 10 Hz
- Vehicles relative positioning accuracy: at least equal to 2 m



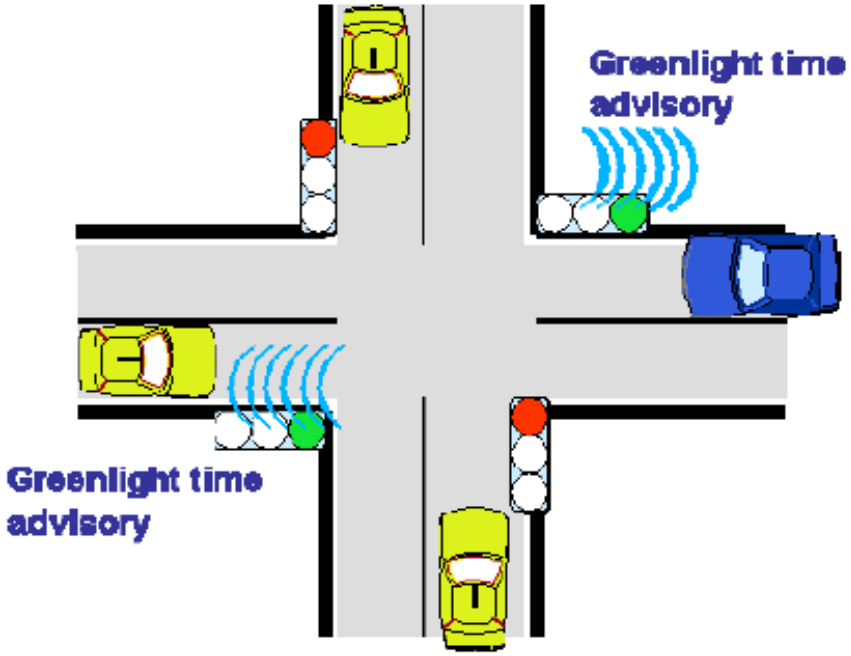
Traffic Efficiency

- Regul**atory/contextual speed limits**
  - **Application name:** Co-operative traffic management.
  - A capable Road Side Unit to broadcast at a given frequency the current local speed limits (regulatory and contextual)



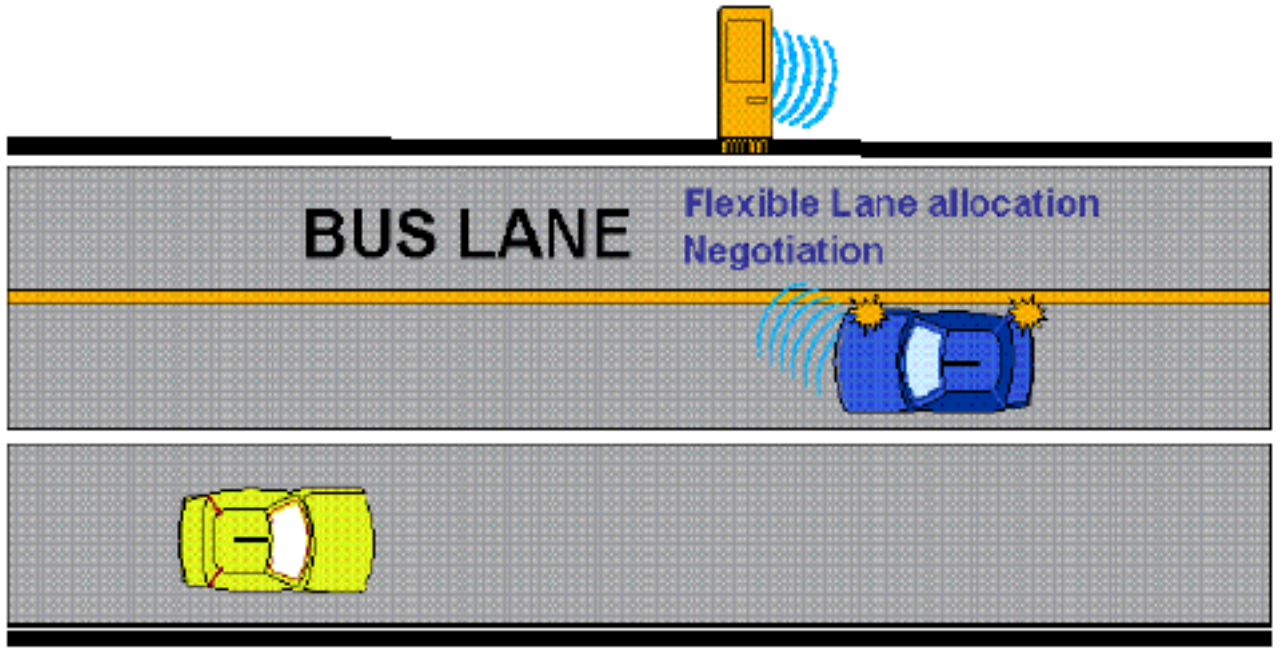
Traffic Efficiency

- **Traffic light optimal speed advisory**
  - **Application name:** Co-operative traffic management.
  - a traffic light to broadcast timing data associated to its current state (e.g. time remaining before switching between green, amber, red).
  - Minimum frequency of the periodic message: 2 Hz.
  - Minimum duration of the Reception: according to the vehicle speed and transmission range
  - Minimum positioning accuracy: better than 5 m.



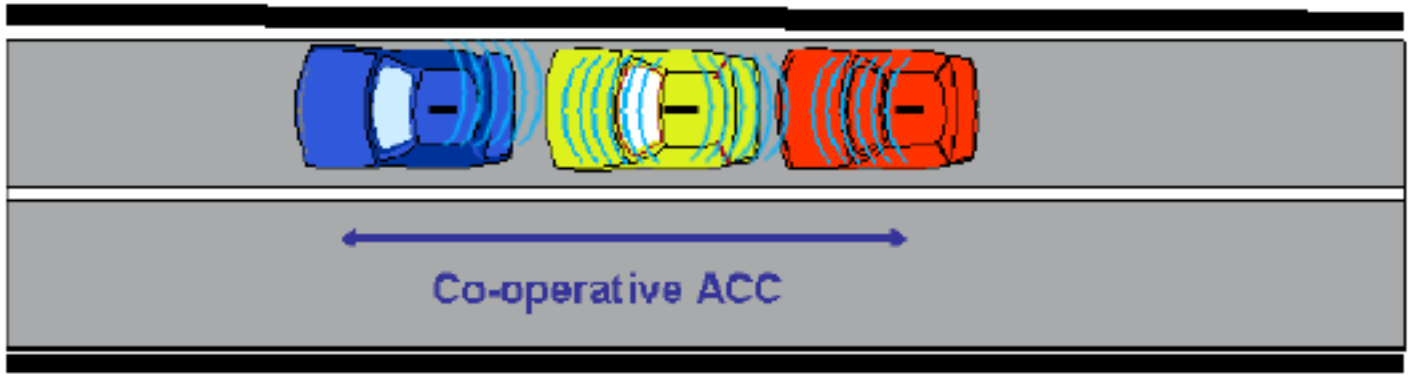
Traffic Efficiency

- **Co-operative flexible lane change**
  - considers the flexible allocation of a dedicated lane (e.g. reserved to public transport) to some vehicles which get a permanent or temporary access right under specific conditions (e.g. if no bus is present).
  - Capability for vehicles to receive and process messages and signal to its driver if can use or not the local specific lane (e.g. according to its vehicle type, its propulsion energy, its number of occupants, its mission, etc.).
  - Maximum latency time: 500 ms.
  - Minimum frequency of V2V co-operation awareness messages: 1 Hz



Traffic Efficiency

- **Co-operative adaptative cruise control**
  - the use of V2X co-operative awareness messages and unicast exchanges to obtain lead vehicle dynamics and general traffic ahead in order to enhance the performances of current ACC
  - Maximum latency time: 100 ms.
  - Minimum frequency of V2V co-operation awareness messages: 2 Hz.



Traffic Efficiency

- **Co-operative vehicle-highway automation system (Platoon)**
  - the use of V2X co-operative awareness messages and unicast exchanges for vehicles to operate safely as a platoon on a highway or specific lane.
  - Movement of a platoon of vehicles without drivers (only the leading one). A good example is the transfer of electrical shared vehicles from one place to another at low speed.
  - Minimum frequency of V2V co-operation awareness messages: 2 Hz.
  - Vehicles relative positioning accuracy better than 2 m.