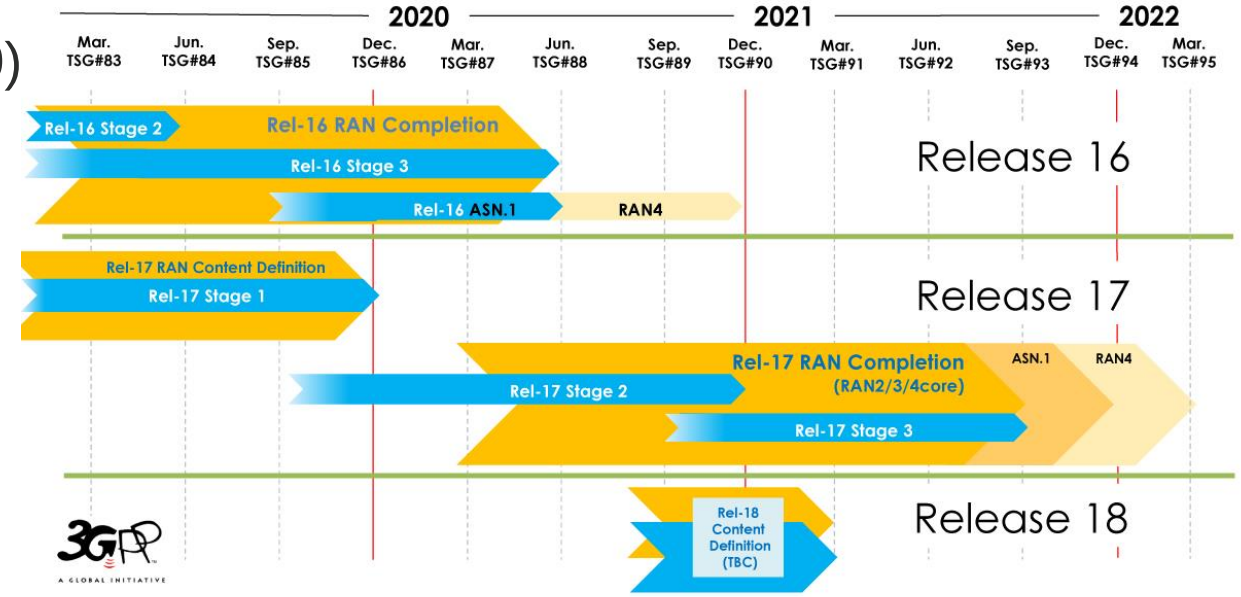
ITS use-cases
Intelligent Transportation Systems

Rolland Vida

C-V2x evolution

- LTE-D2D – Release 12 (2012)
- C-V2x Phase I– Release 14 (started in 2014, published in 2016)
  - V2V, V2I, V2N support
- C-V2x Phase II – Release 15 (published in 2018)
  - 5G support (called also 5G-V2x)
- C-V2x Phase III – Release 16 (expected for 2020)
  - Enhanced 5G support



Source: 3GPP TSG SA#87e, 17-20 March 2020, e-meeting document SP-200222

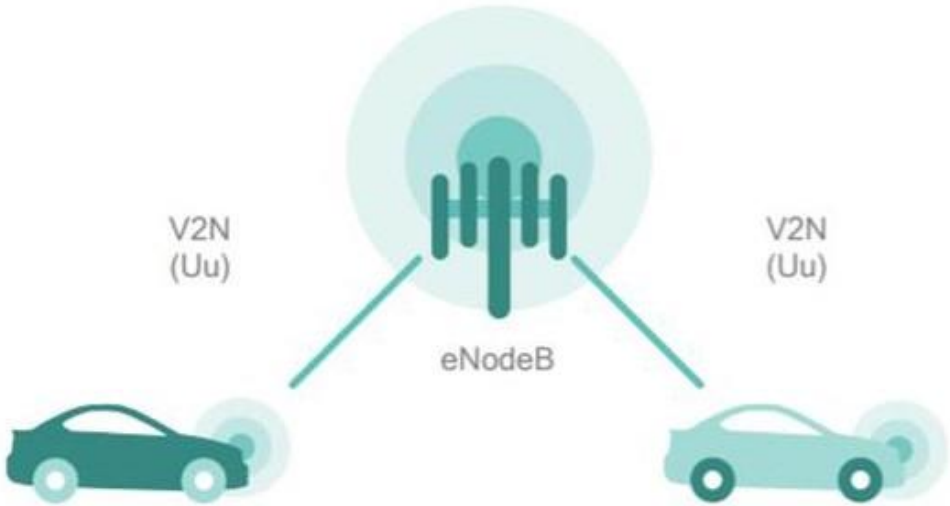
C-V2X defines two complementary transmission modes

Network communications

V2N on “Uu” interface operates in traditional mobile broadband licensed spectrum

Uu interface

e.g. accident 2 kilometer ahead



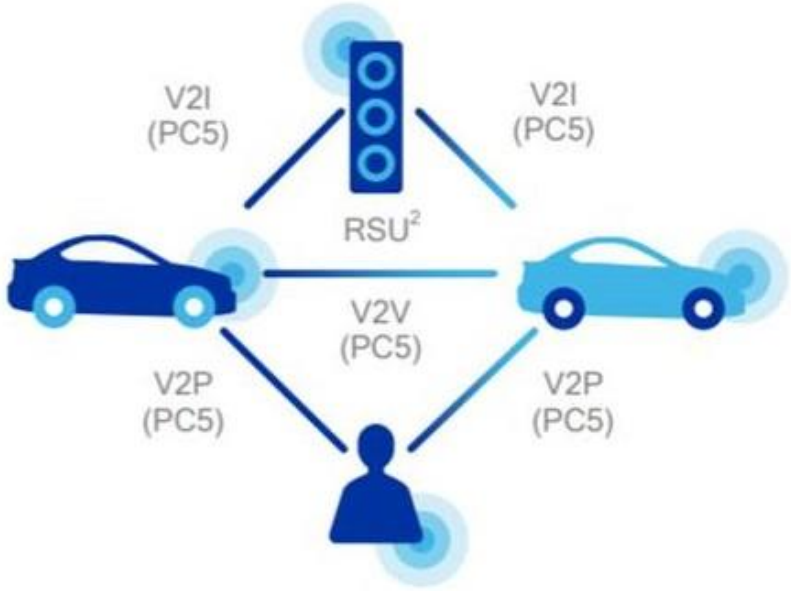
On the traditional cellular spectrum

Direct communications

V2V, V2I, and V2P on “PC5” interface[1], operating in ITS bands (e.g. ITS 5.9 GHz) independent of cellular network

PC5 interface

e.g. location, speed



On 5,9 GHz

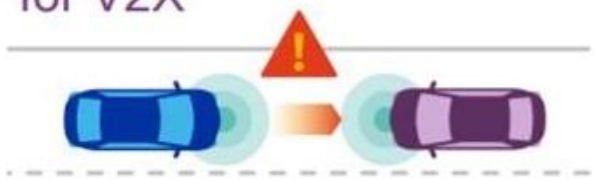
Continuous V2X technology evolution required

And careful spectrum planning to support this evolution

Evolution to 5G,
while maintaining backward compatibility

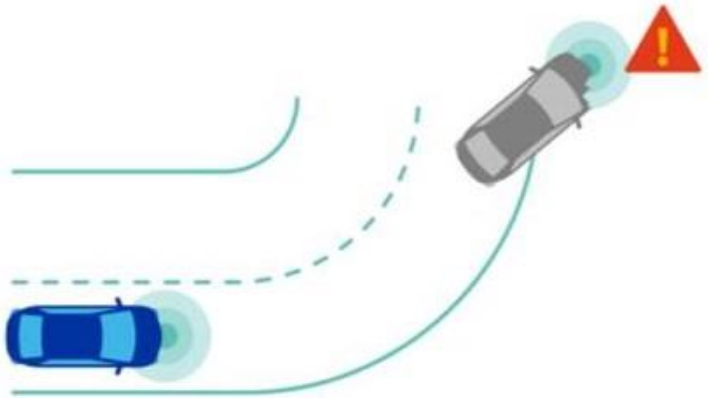
Basic safety
802.11p or C-V2X R14

Established foundation for V2X



Enhanced safety
C-V2X R14/15

Enhanced range and reliability



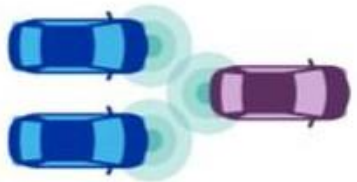
Advanced safety
C-V2X R16 (building upon R14)

Higher throughput

Higher reliability

Wideband ranging and positioning

Lower latency



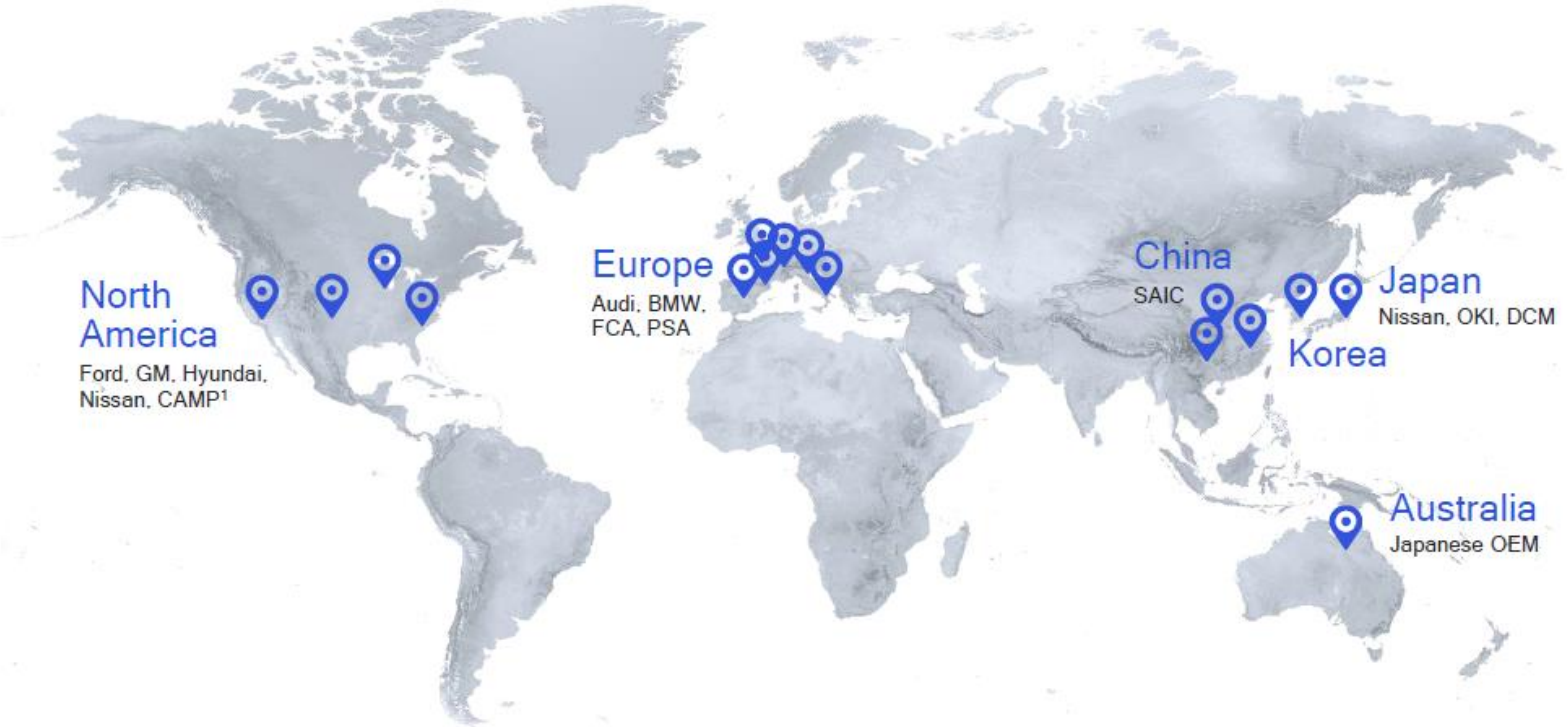
C-V2X

Rel 14/15 C-V2X established basic safety

Rel 16 NR C-V2X saw continued evolution for advanced use cases

- Release 14/15 C-V2X standards completed
- Broad industry support with 5GAA
- Global trials started in 2017; first commercial deployment expected in 2020
- Qualcomm® 9150 C-V2X chipset announced in September, 2017
- Integration of C-V2X into the Qualcomm® Snapdragon™ Automotive 4G and 5G Platforms announced in February, 2019

Driving C-V2X global presence with trials and demos



Gaining traction across numerous regions and industry sectors

From standards completion to independent field testing to initial deployments

1. CAMP = Crash Avoidance Metrics Partnership LLC and this project includes the listed OEMs and Qualcomm.

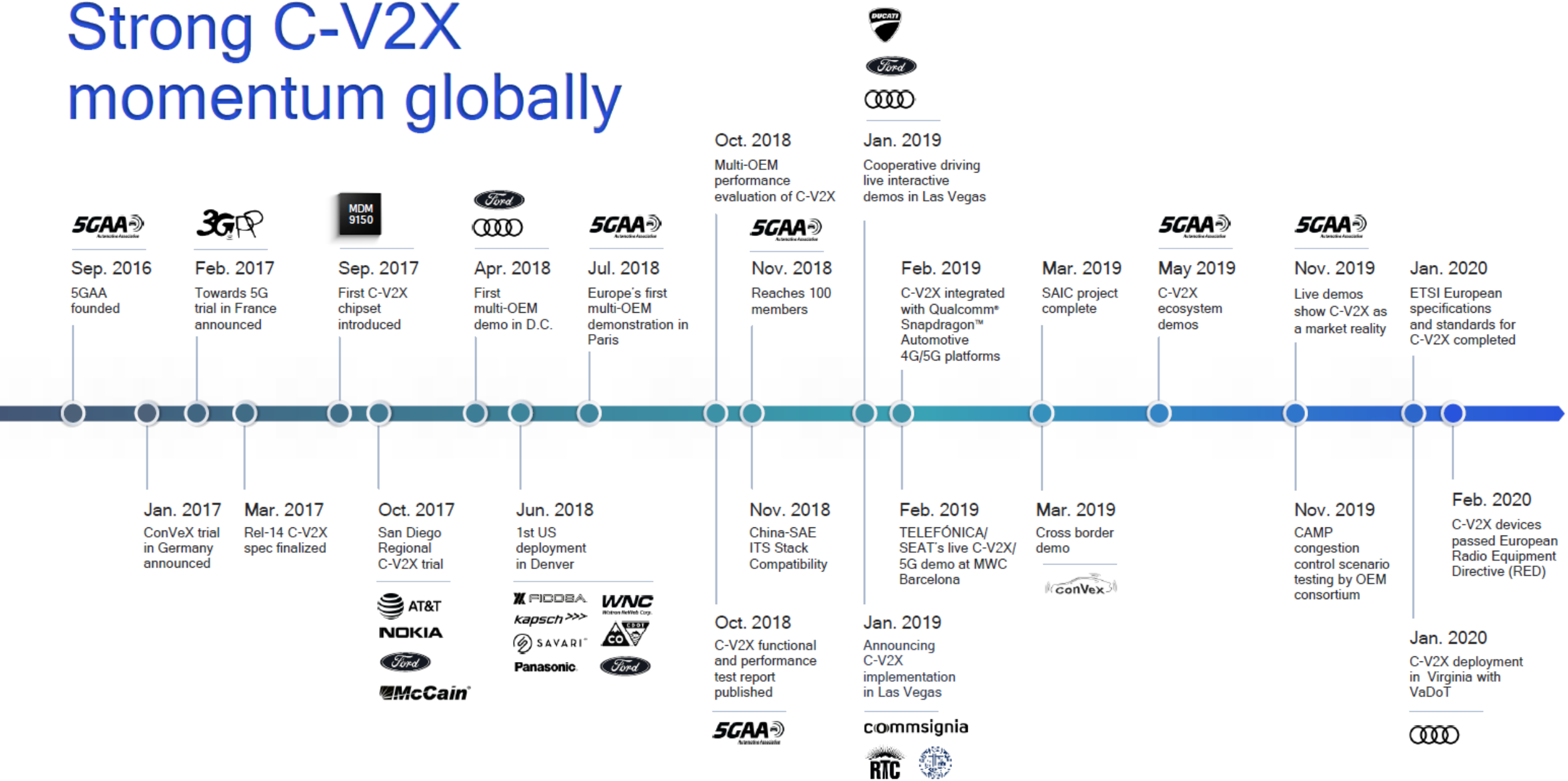
Collaborating with key ecosystem players

CAMP	Ford	Quectel	Kapsch
PSA	Lear	SWARCO	Neusoft Reach
BMW	Valeo	Commsignia	Simcom
Daimler	WNC	Genvict	Sasken,
SAIC	CMCC	Nebulalink	Thundersoft
Continental	AT&T	R&S	Telit
Bosch	NTT DoCoMo	Datang	Lacroix
LG	CMRI	Ficosa	And more…
ZTE	McCain	Savari	

5GAA Automotive Association

- 8 of the top 9 global automakers
- Top automotive Tier 1 suppliers
- 9 of the top 10 global telecommunications companies
- Top 3 global smartphone manufacturers
- Top global semiconductor companies
- Top 5 global wireless infrastructure companies
- Top global test and measurement companies and certification entities
- Global representation from Europe, China, US, Japan, Korea, and elsewhere

Strong C-V2X momentum globally



NR C-V2X builds on LTE C-V2X

with advanced use cases

Safety use cases

Advanced use cases

Upper layers

Mapping use cases to transport profile

C-V2X

Rel 14/15 sidelink

Broadcast messages

NR C-V2X

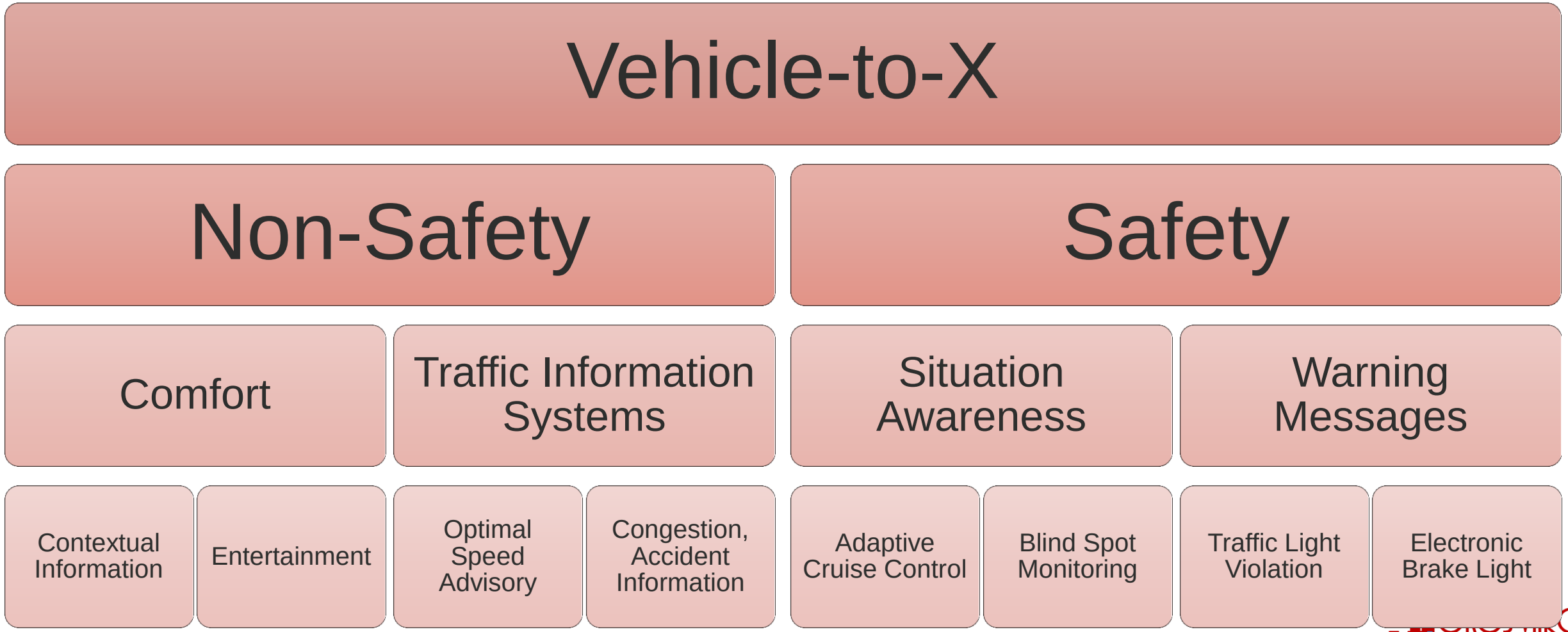
Rel 16+ sidelink

Multicast messages

5G C-V2X sidelink

NR C-V2X introduces complementary capabilities for advanced use cases

Taxonomy of ITS Use Cases



Taxonomy of Use Cases

Vehicle-to-X

Non-Safety

Many messages

High data rate

Not so strict latency demands

Low reliability demands

Safety

Few messages

Small packet size

Strict latency demands

High reliability demands

Diversity of requirements

Application	Latency	Reliability	# Vehicles	Area
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

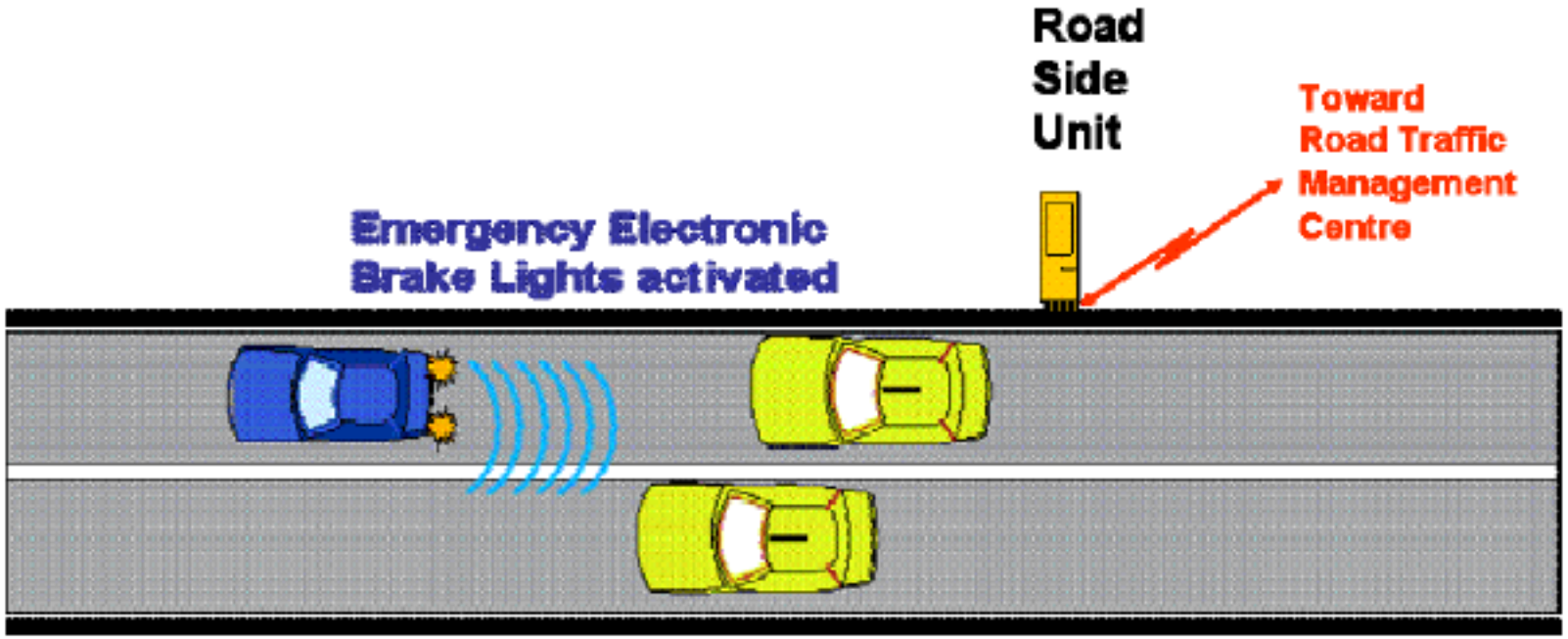
- Same system needs to work in multiple environments
  - Vehicle starts to drive in city with infrastructure support
  - Continues driving on freeway (still with infrastructure support)
  - Loses infrastructure support when turning onto local highway
  - Finishes driving in city without infrastructure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

ITS use cases

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

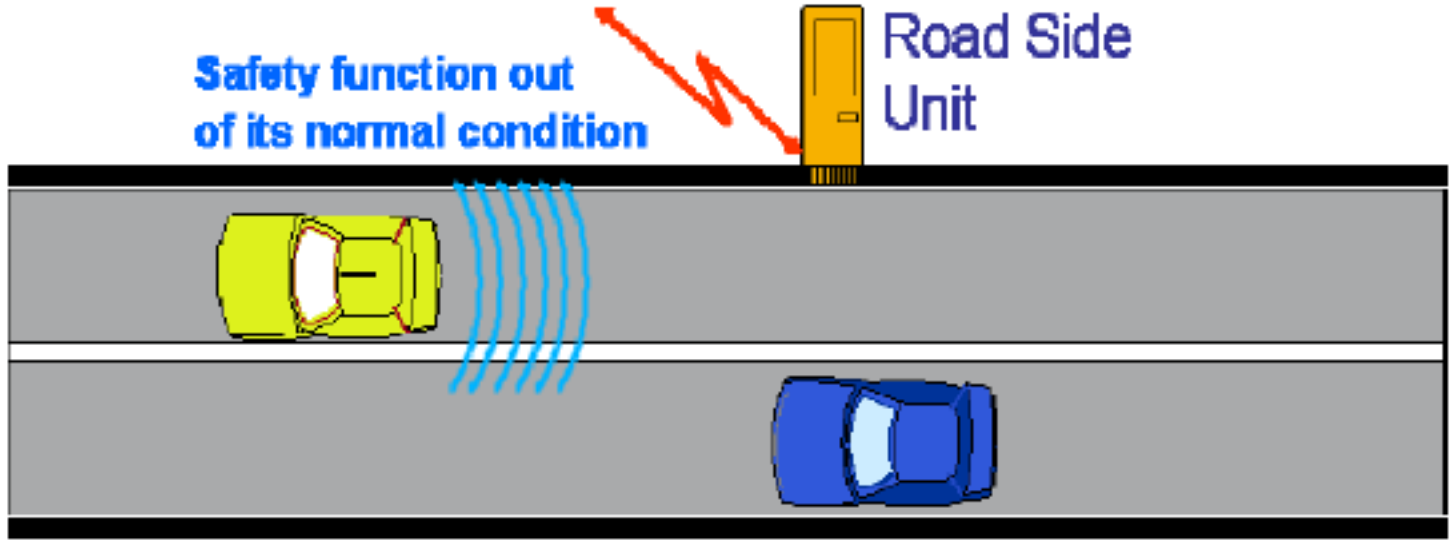
Vehicle Status Warnings

- **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



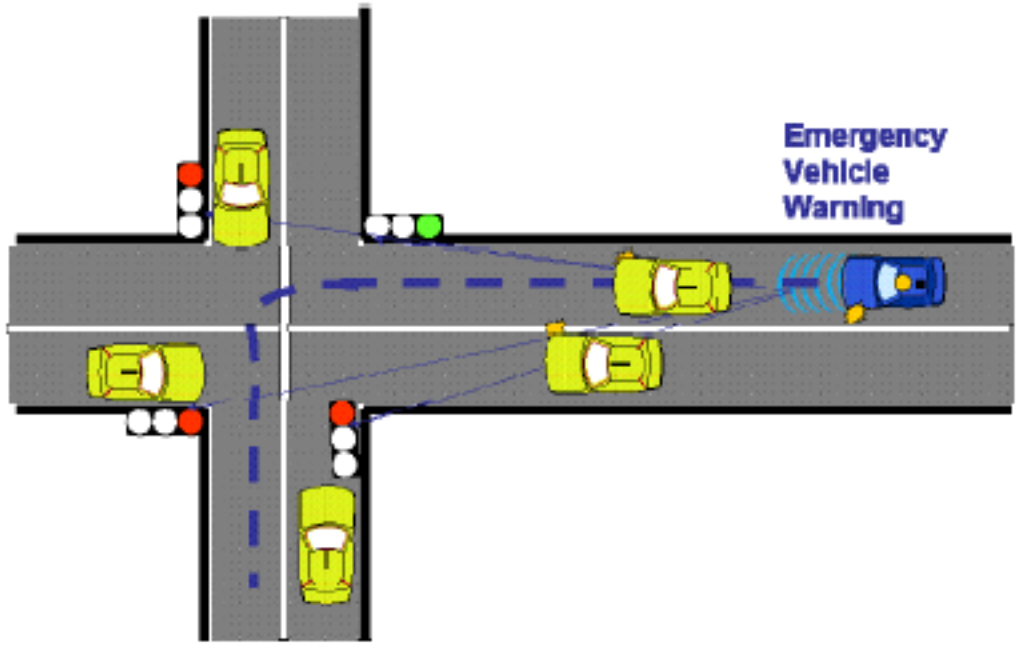
Vehicle Status Warnings

- **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



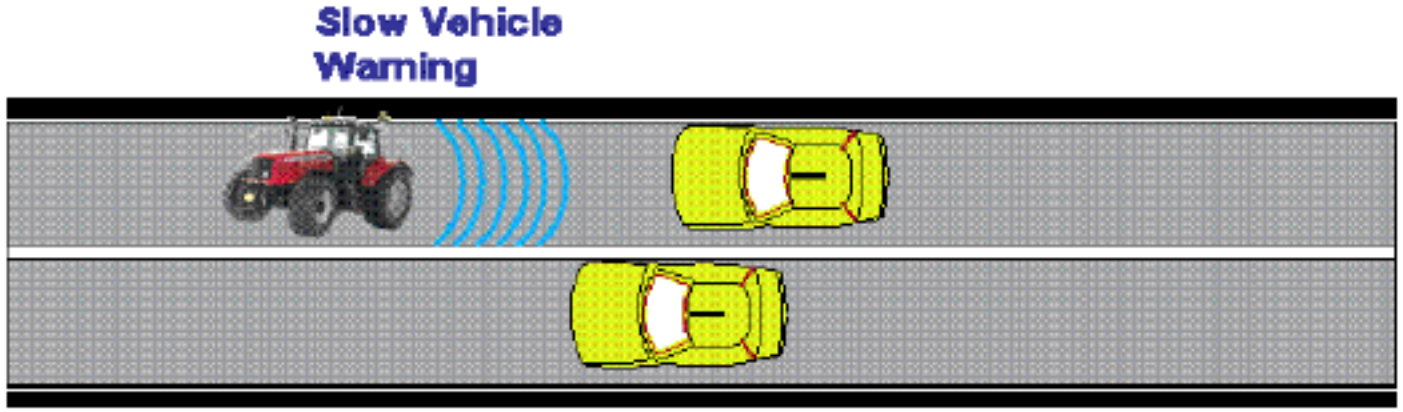
Vehicle type warnings

- **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.

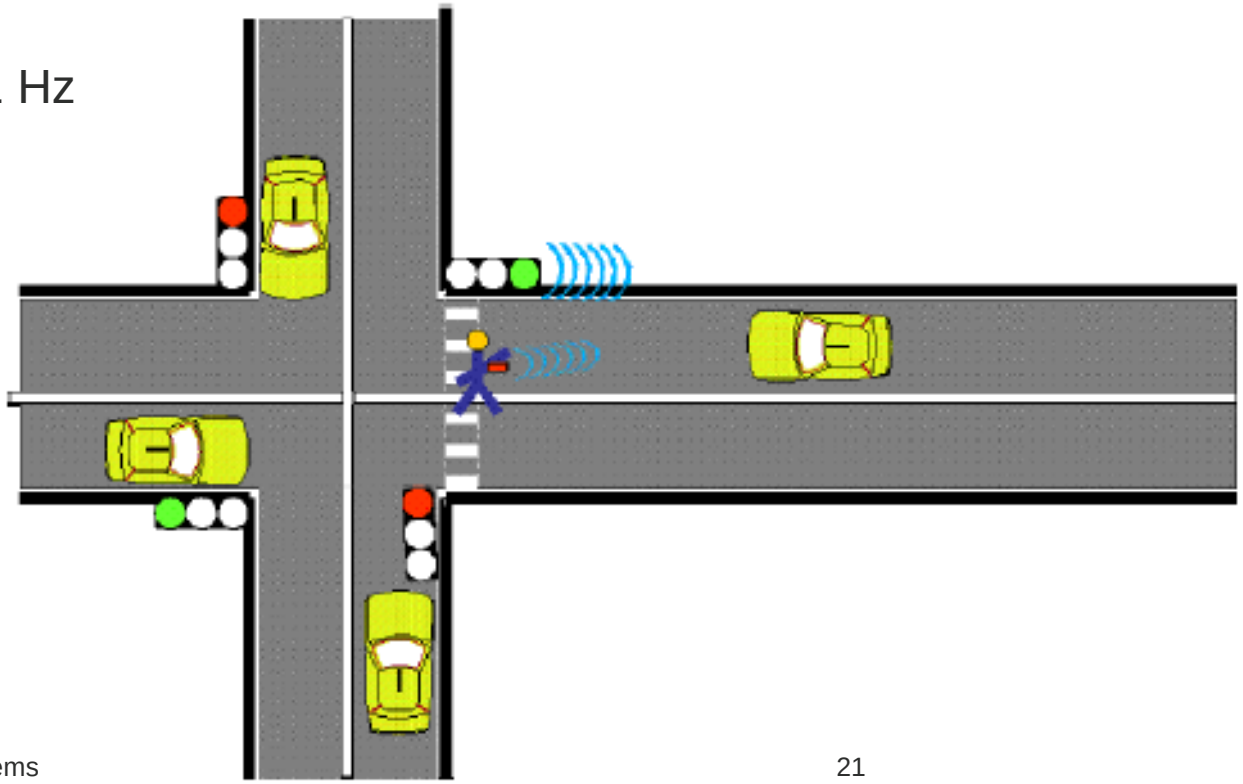


Vehicle type warnings

- **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.

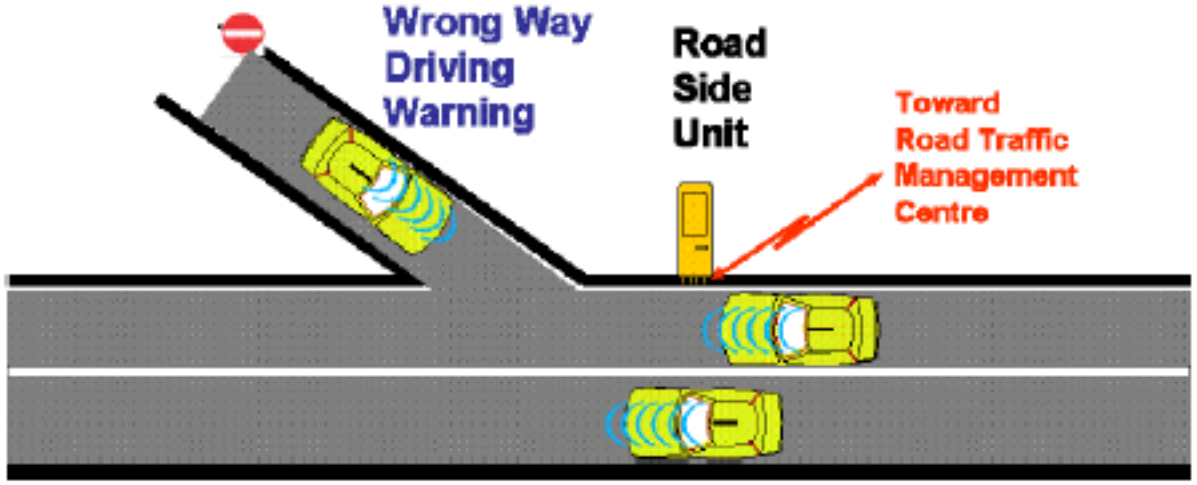
Vehicle type warnings

- **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



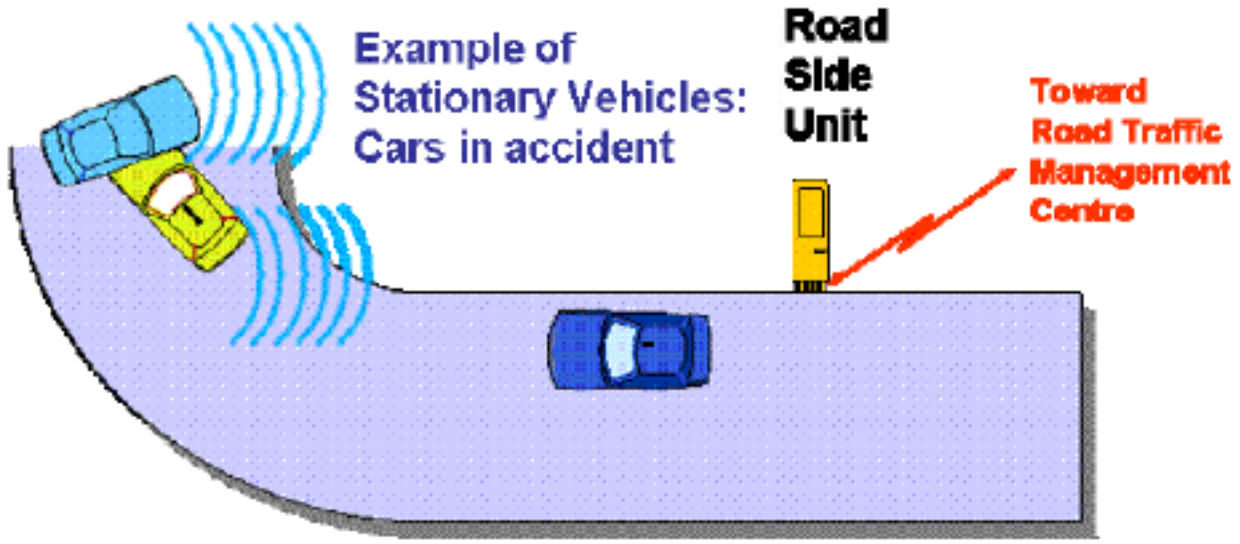
Traffic hazard warnings

- **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 (DENM) about its current "wrong way heading" status
  - Minimum frequency of the periodic message: 10 Hz.



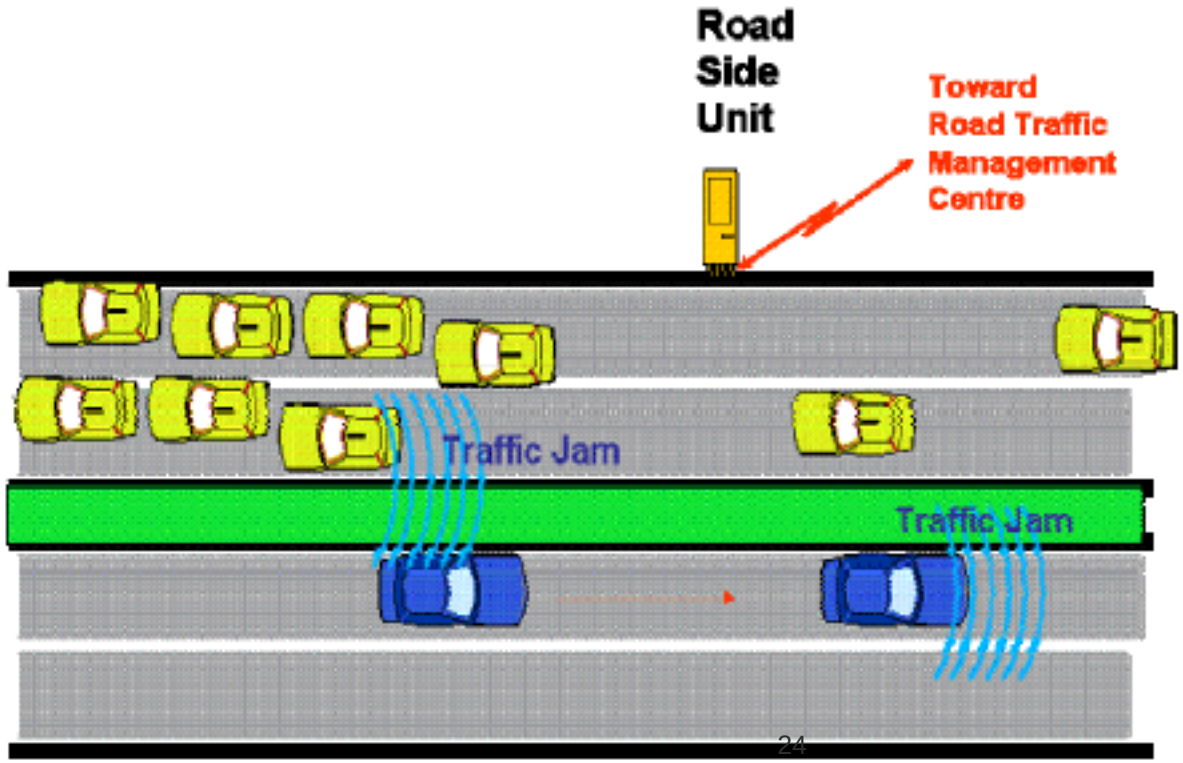
Traffic hazard warnings

- **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.



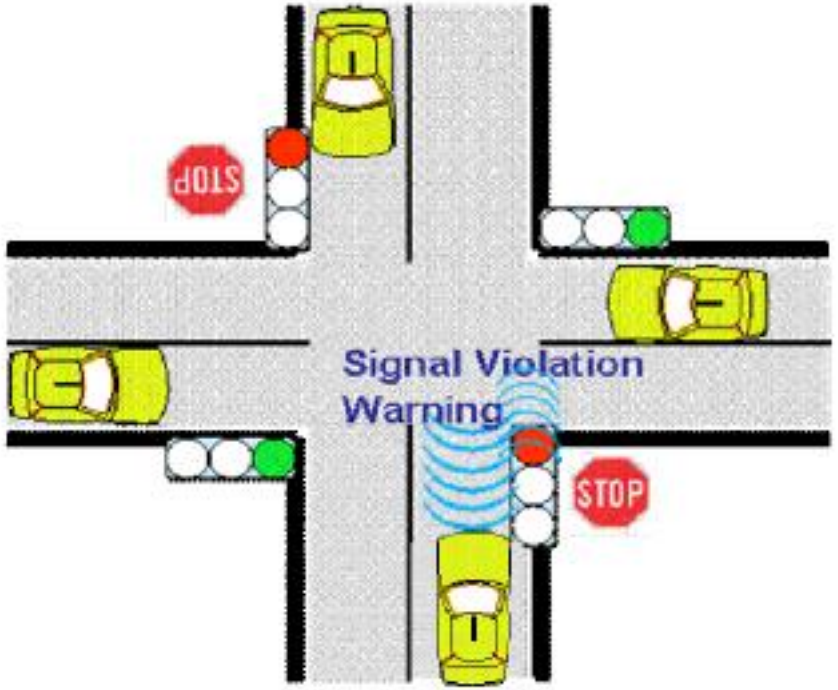
Traffic hazard warnings

- **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

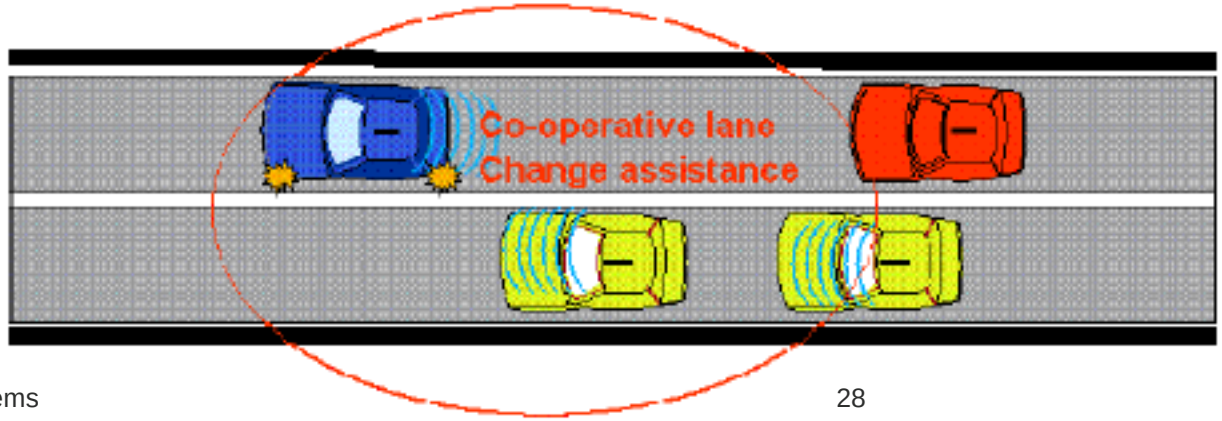
- **Roadwork warning**
  - Via road infrastructure to vehicle communication, provides information on current valid roadwork and associated constraints
  - Capabilities for concerned vehicles to store and forward according to geocasting messages cancel rules, I2V decentralized environmental notification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

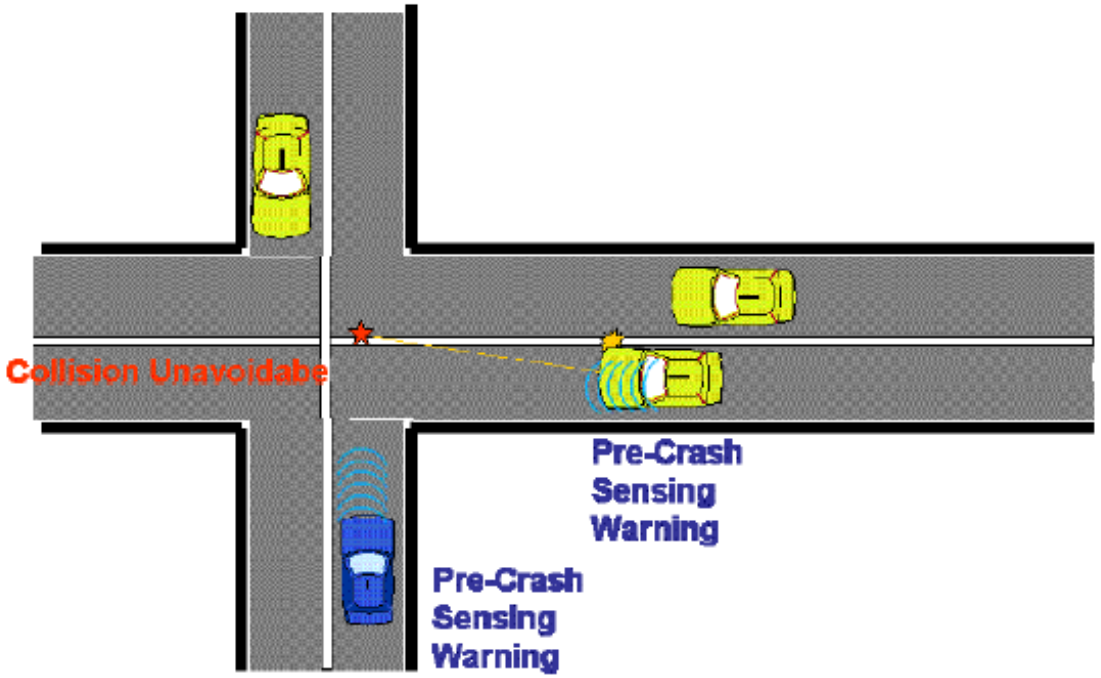
Dynamic vehicle warnings

- **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.



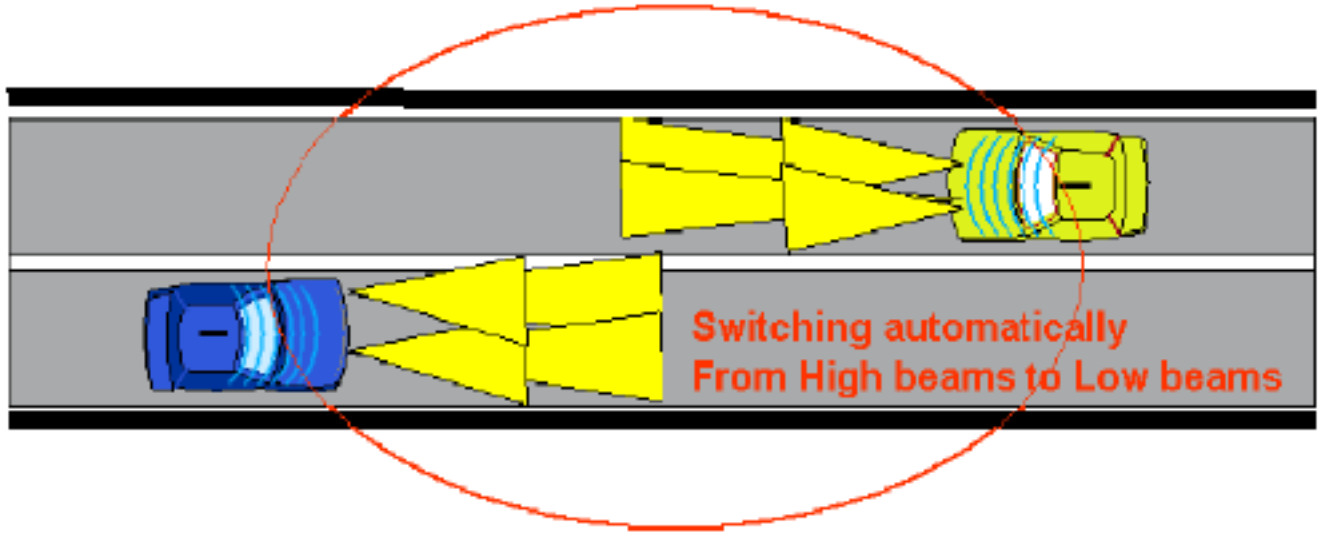
Dynamic vehicle warnings

- 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)



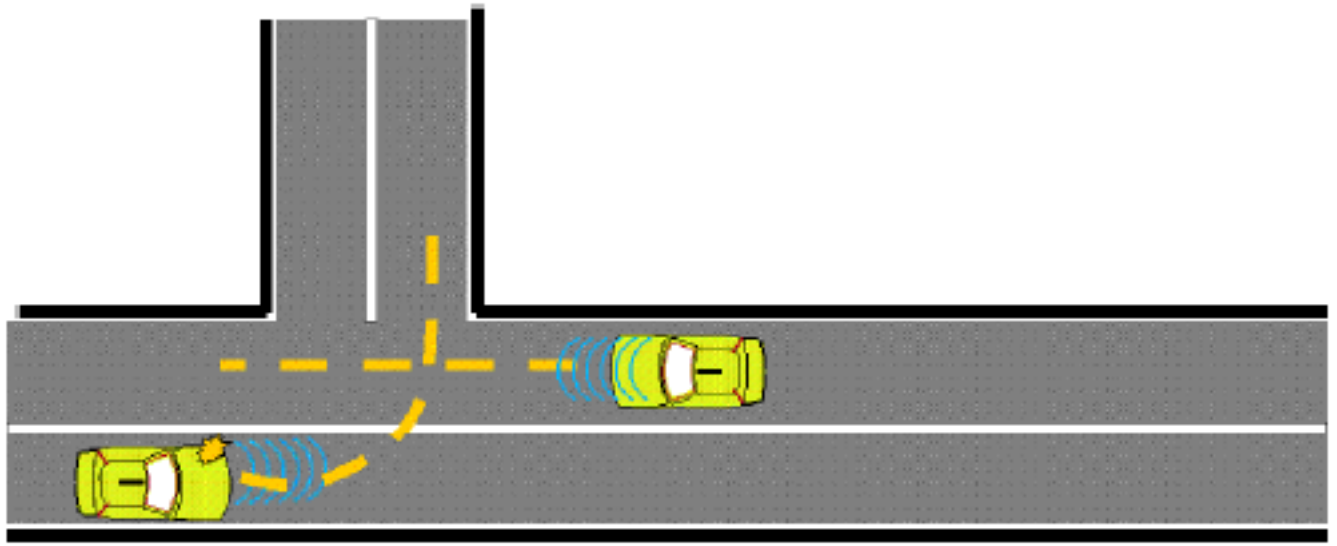
Dynamic vehicle warnings

- **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



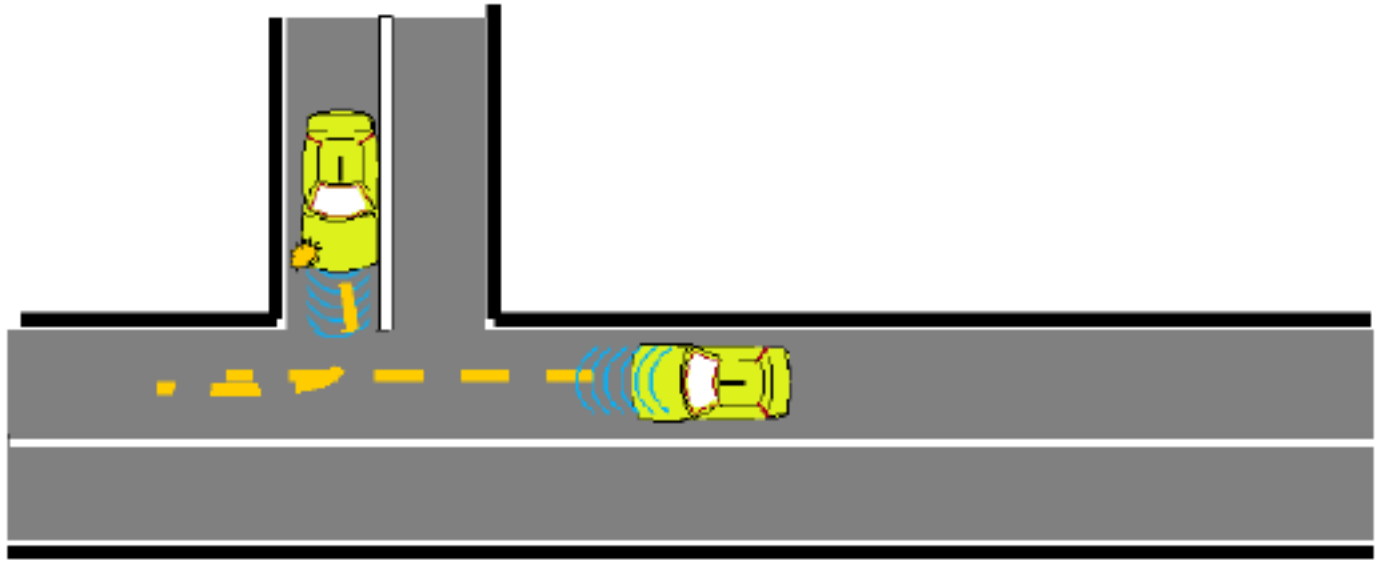
Collision Risk Warning

- **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.



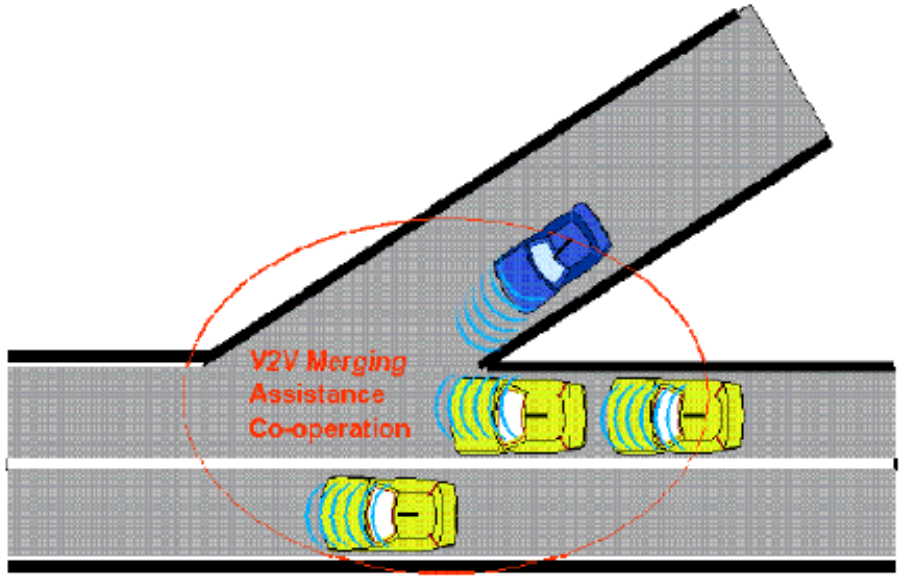
Collision Risk Warning

- **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.



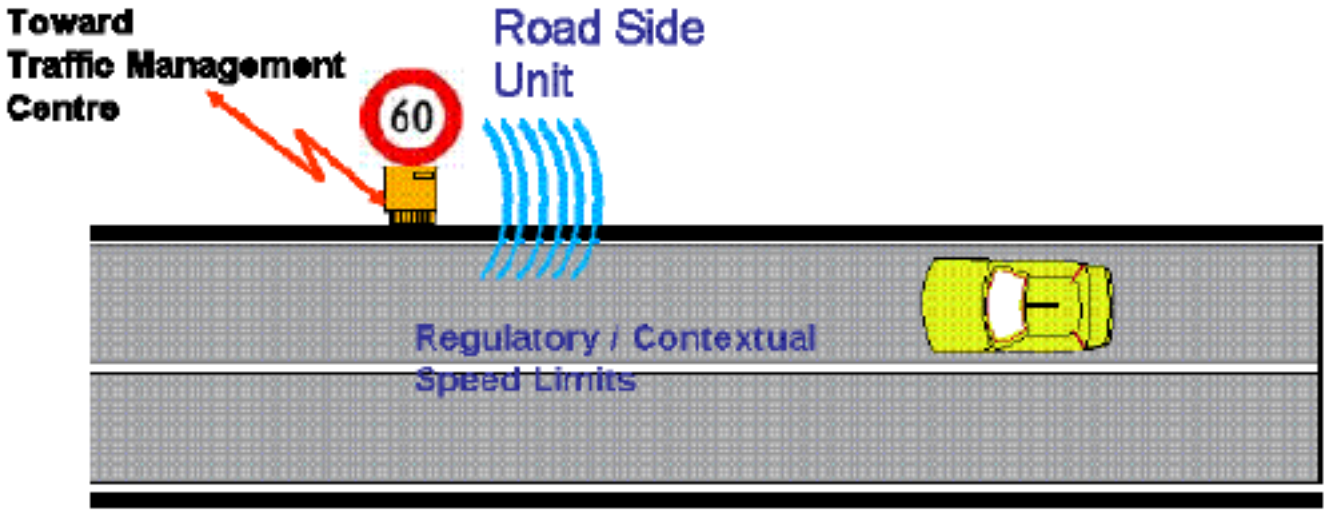
Collision Risk Warning

- 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



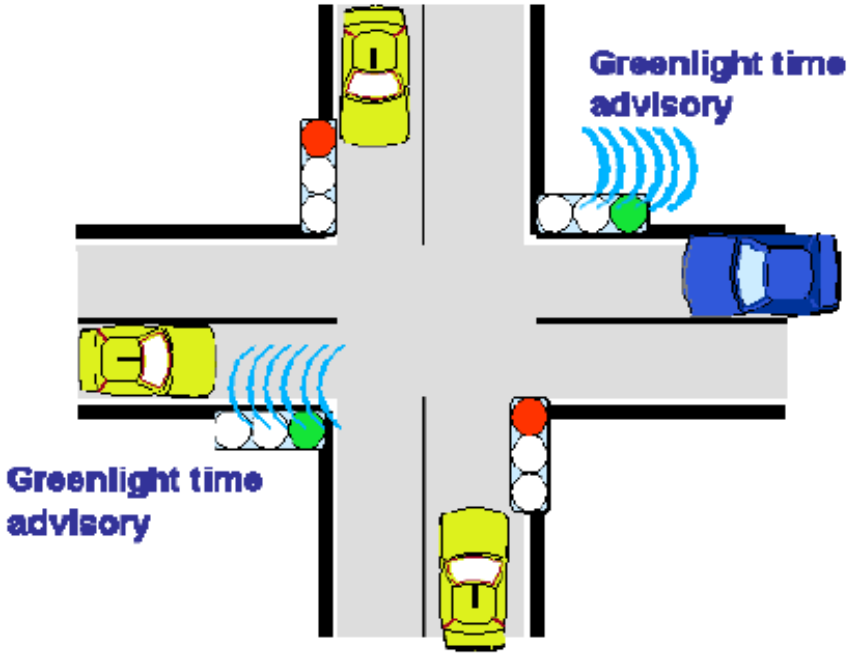
Traffic Efficiency

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



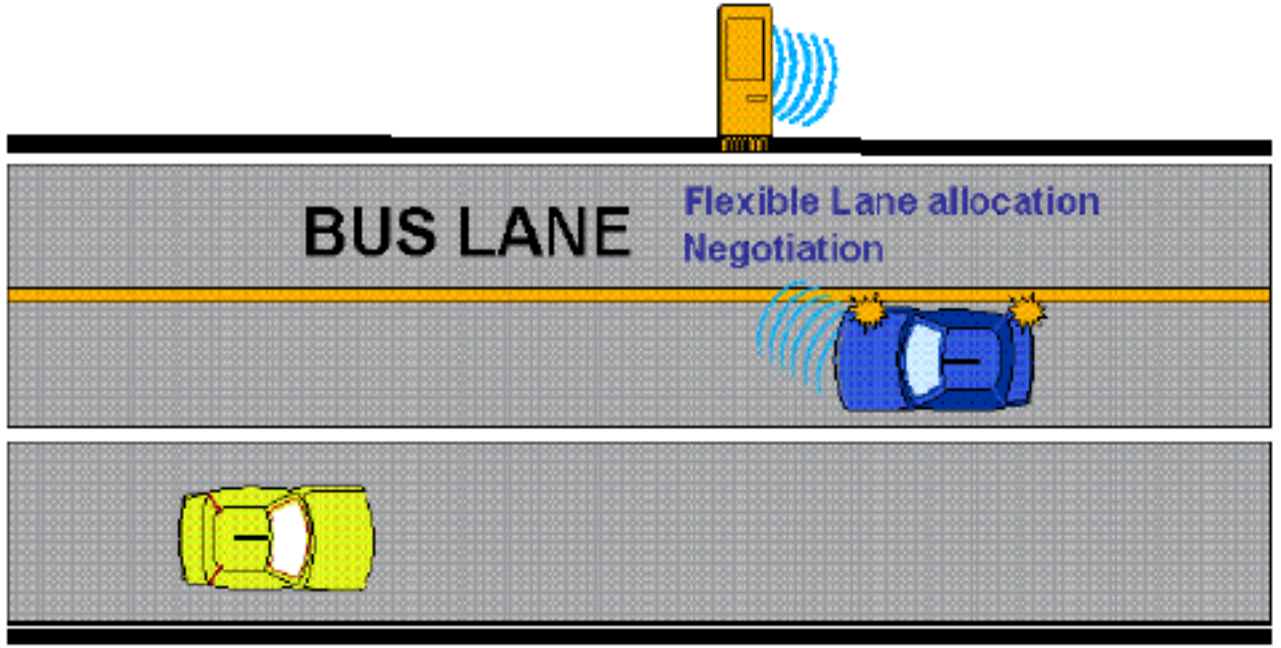
Traffic Efficiency

- **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.



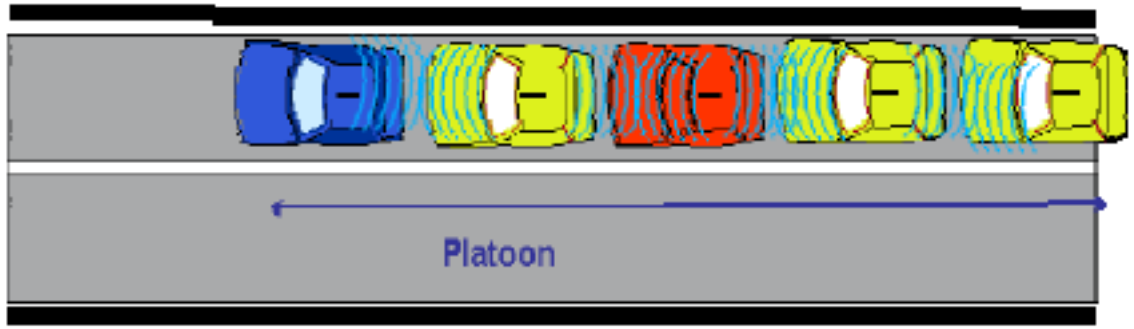
Traffic Efficiency

- **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



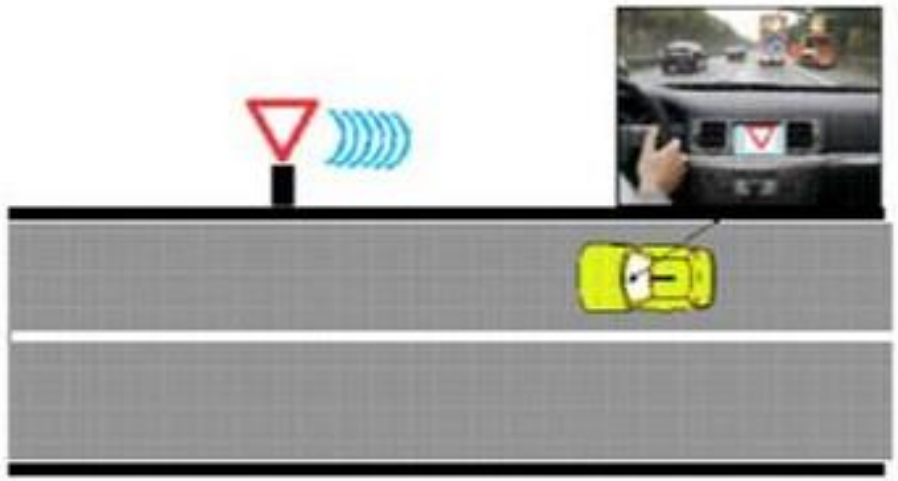
Traffic Efficiency

- **Co-operative 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.



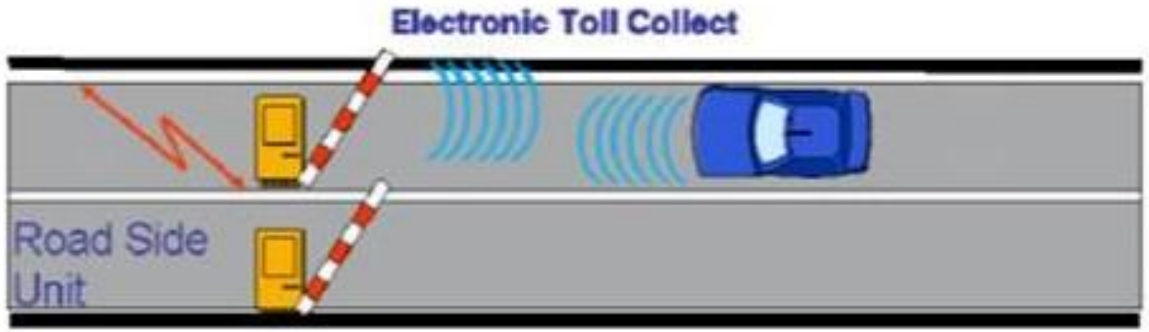
Traffic Efficiency

- **In-vehicle signage**
  - Capability for an RSU to broadcast periodically messages providing the traffic sign type and status
  - Capability for vehicles to receive and process messages and inform driver of the decoded traffic sign
  - Minimum frequency of the periodic message: 1 Hz.
  - Maximum latency time: 500 ms..



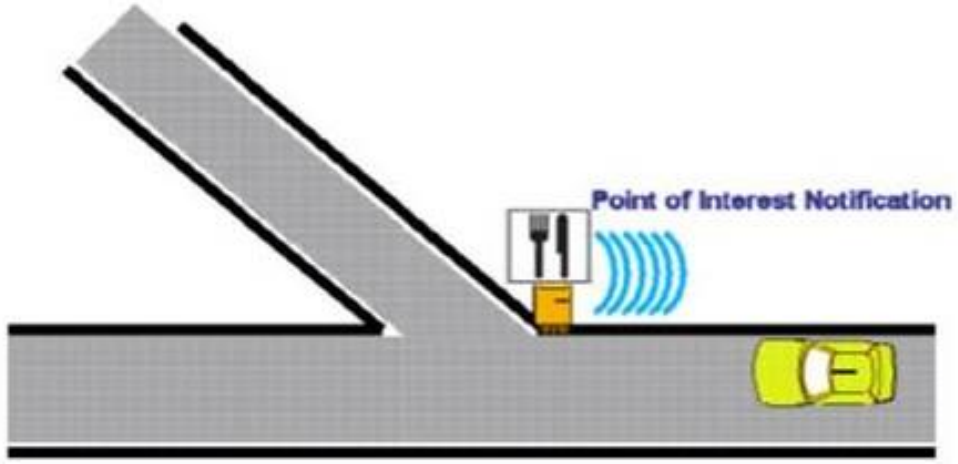
Traffic Efficiency

- **Electronic toll collect**
  - Capability for an RSU to broadcast its electronic toll payment capabilities and active state. Capability to process the electronic toll collect from a given vehicle
  - I2V CAMs frequency: 1 Hz.
  - Maximum latency time: 200 ms..



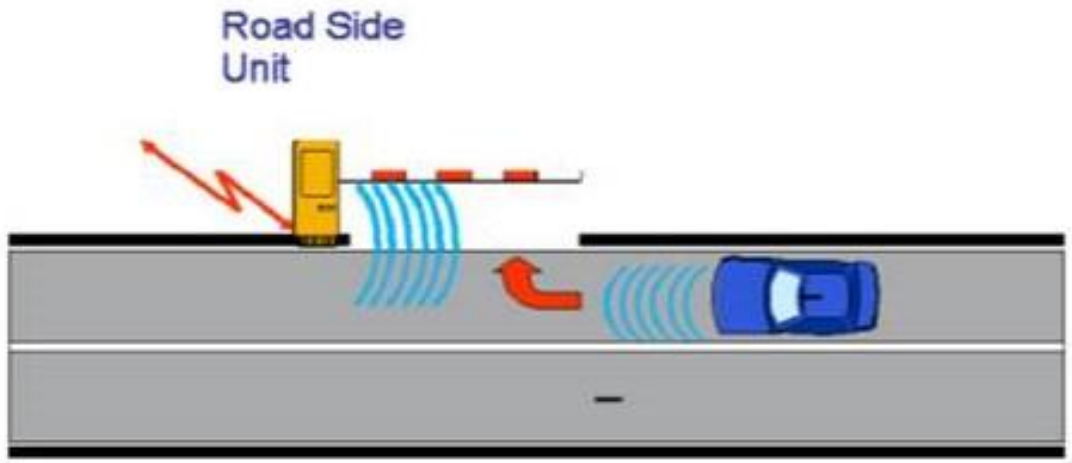
Other use-cases

- **Point of interest notification**
  - **Application name:** Comfort and entertainment
  - Informs about the presence of locally based services or/and Points of Interest. Can provide some dynamic information such as the opening hours, prices, waiting time, available room, promotions etc.
  - Capability for a road side unit to broadcast I2V CAM messages to announce some locally based services/PoI information.
  - Capability for the road side unit to establish a P2P session with any requesting vehicle, to provide detailed POIs information
  - Minimum frequency of the periodic message: 1 Hz.



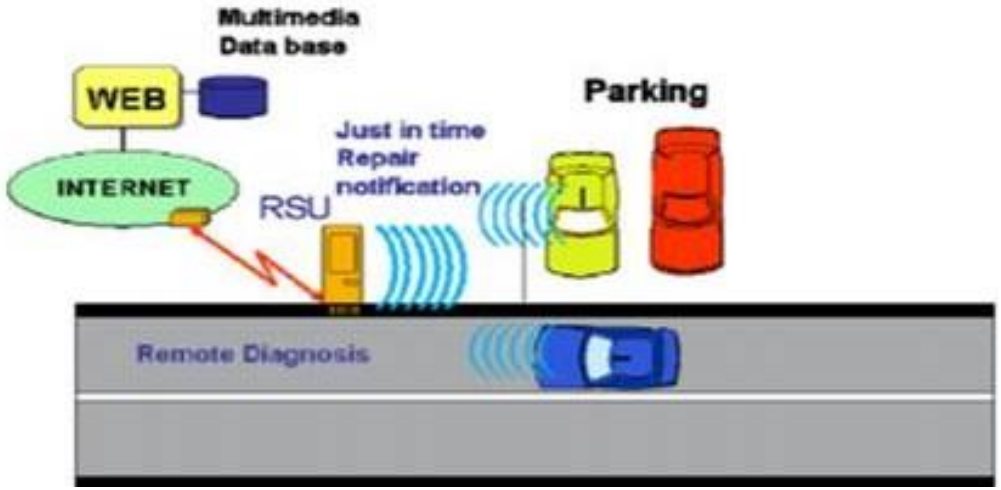
Other use-cases

- **Automatic access control/parking access**
  - **Application name:** Comfort and entertainment
  - Upon signalization of an access controlled area (e.g. a private or public parking), a concerned vehicle entitled to access this area will supply its identity to the road side unit to obtain the right to access the area.
  - Minimum frequency of the periodic message: 1 Hz.
  - Maximum latency time: 500 ms.



Other use-cases

- **Media downloading**
  - **Application name:** Comfort and entertainment
  - Accessing/purchasing, downloading multimedia content from a local RSU which may offer some Internet access to a dedicated web site
  - IPv6 is required. For broadcast-based services, link-local addressing is enough. For unicast-based services IPv6 globally valid addresses need to be provided.
  - The RSU can act as an IPv6 router or a network bridge. Purchasing and delivery need to be secured.
  - I2V minimum CAMs frequency: 1 Hz, maximum latency time: 500 ms..



Other use-cases

- Map download and update
- Vehicle software update
- Eco-driving assistance
- Instant messaging support
- SOS service
- Stolen vehicle alert
- Fleet management
- Stb…