



Institut Mines-Télécom

# COMMUNICATIONS HÉTÉROGÈNES POUR LES ITS COOPÉRATIFS (C-ITS)



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# SOMMAIRE



1. URBAN ITS AND C-ITS
2. HETEROGENEOUS COMMUNICATION
3. INFRASTRUCTURE-BASED
4. CONCLUSION & PERSPECTIVES

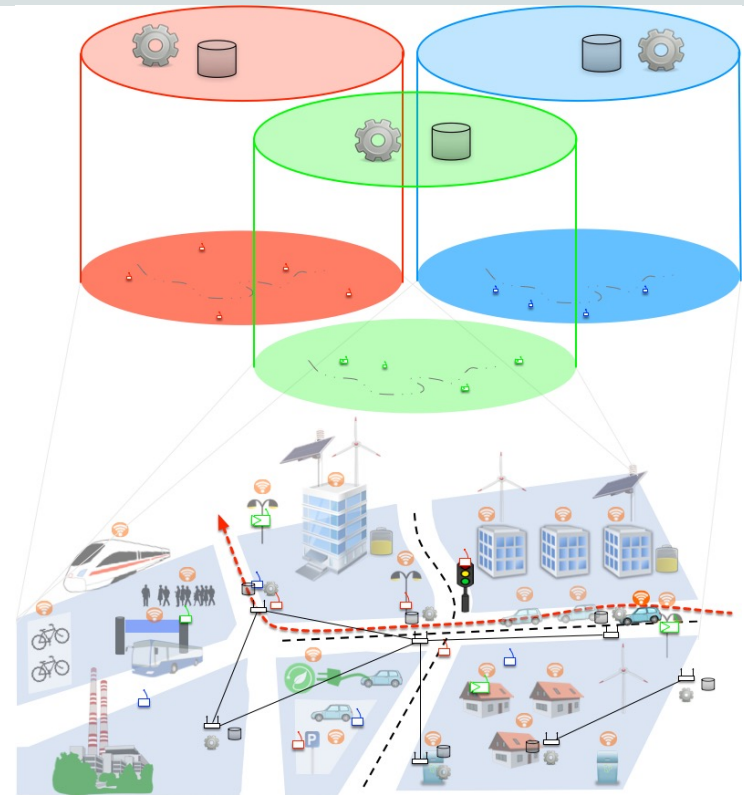


Each  
application/service

- in its own silo

- with its own partial  
perception

- and cloud services

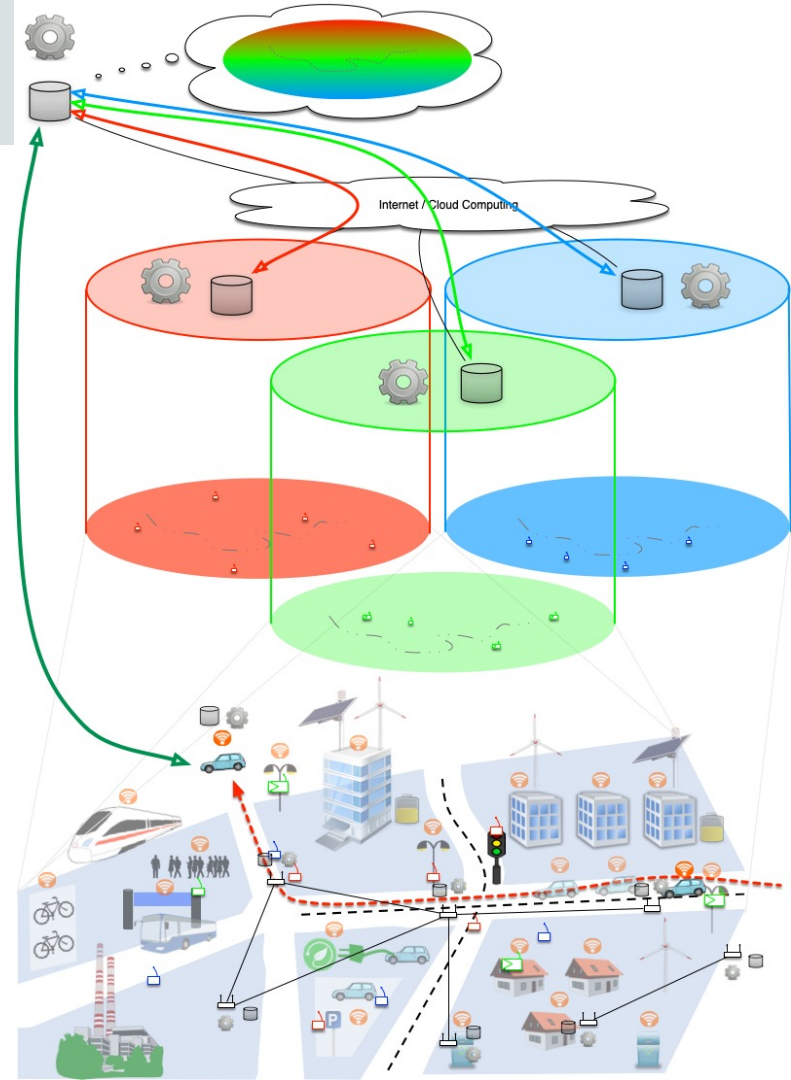


## DEPLOYMENT OF SERVICES IN A SILO MODE

(2/3)

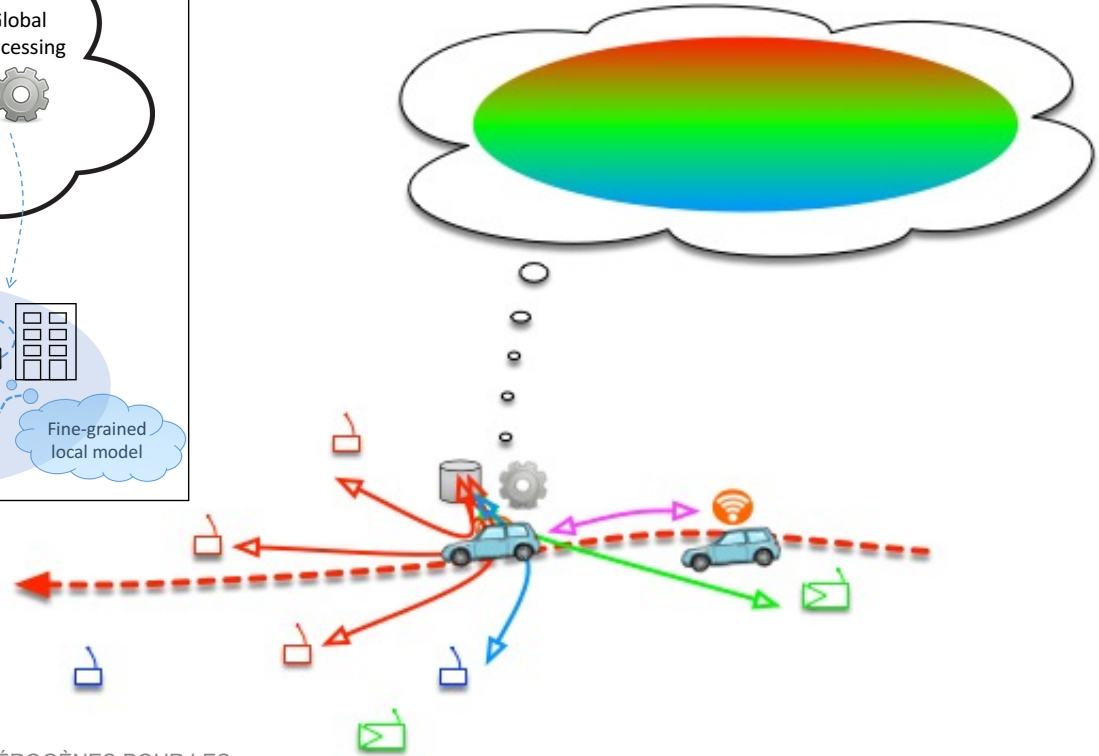
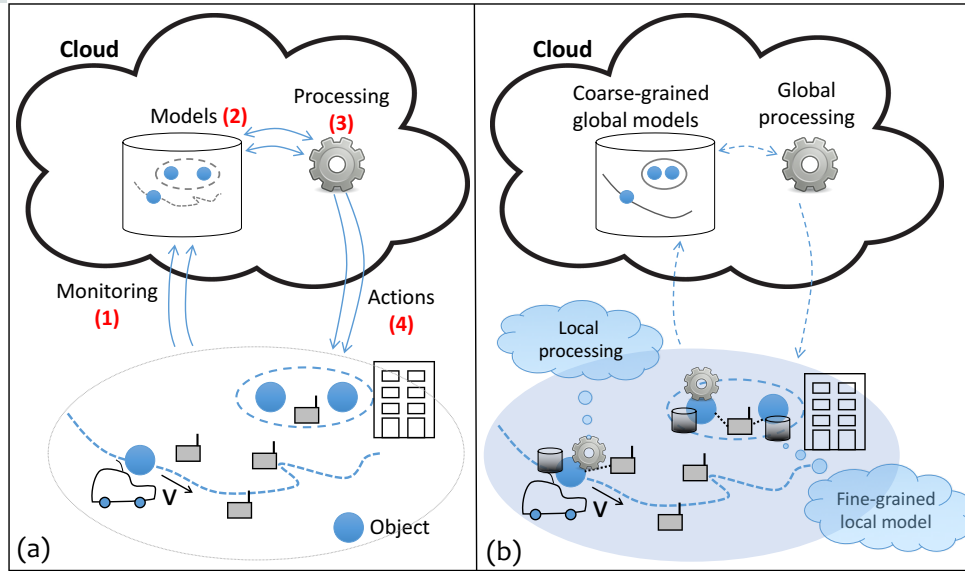
It becomes  
**complex** and  
**expensive**

- to **reuse** objects already deployed
- to **maintain** the infrastructure
- to **take advantages of local knowledge**



# DEPLOYMENT OF SERVICES IN A SILO MODE

(3/3) From global to localized interaction

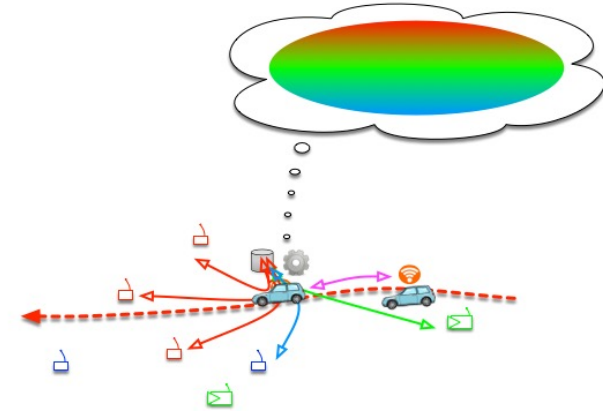


## Several verticals involved

- ▶ ITS, Energy, Surveillance, Utilities, Buildings, ...

## Heterogenous communication technologies

- ▶ Long range: Cellular (3/4/5G), LBWan (LoRA, ZigFox)
- ▶ Medium range: WiFi, G5, ...
- ▶ Short range: BlueTooth, IEEE 802.15.4, of coarse, but also, InfraRed, VLC, ...
- ▶ Very short range: NFC, RFID, ...



## TIC: an opportunity to blur the boundaries and mix the ecosystems

- ▶ But current open-data approaches, yet useful, come with concerns: privacy, sovereignty, scalability, response time, ...

## We are interested in interactions between vehicle and its environment

- ▶ Other vehicles, Roadside infrastructure, Pedestrian, ...



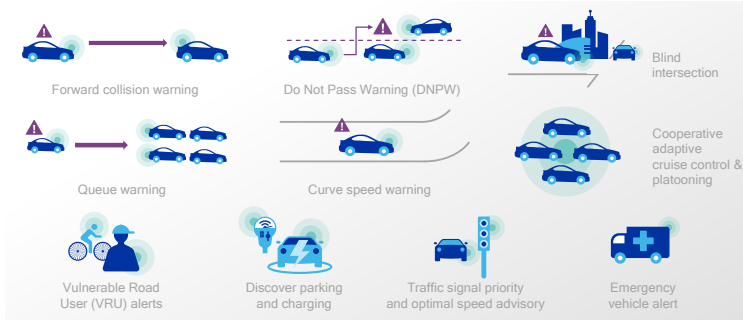
## Day 1

- Hazardous location notifications
  - Emergency brake lights
  - Emergency vehicle approaching
  - Slow or stationary vehicle(s)
  - Road works warning
  - Wether conditions
  
- Signage applications
  - In-vehicle signage
  - In-vehicle speed limits
  - Probe vehicle data
  - Shockwave Damping (ETSI local hazard warning)
  - Tradinc signal priority for designated vehicles
  - Green Light Optimal Speed Advisory (GLOSA)

## Day 1.5

- Information on fuelling & charging stations for alternative fuel vehicles
- Vulnerable Road User protection
- On street parking management & information
- Park & Ride information
- Connected & Cooperatibve navigation into and out of the city (1st and last mile, parking, route advice, coordinated traffic lights)
- Traffic information & Smart routing

[https://ec.europa.eu/inea/sites/inea/files/1\\_inea\\_cef\\_transport\\_info\\_day\\_its\\_2016\\_call\\_161021.pdf](https://ec.europa.eu/inea/sites/inea/files/1_inea_cef_transport_info_day_its_2016_call_161021.pdf)

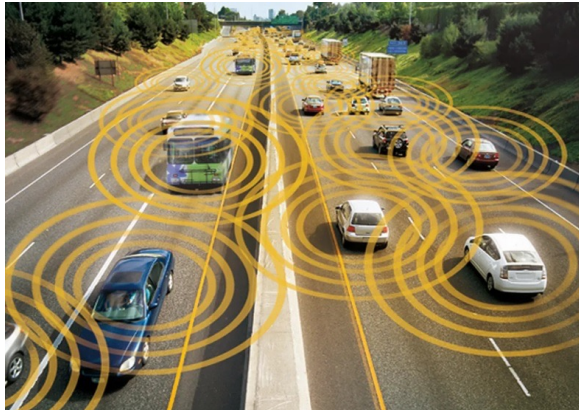


### One frequency (5Ghz), one technologie

- ▶ Everybody have to agree on one unique technologie
- ▶ One set of protocols everybody understand for safety-related services
- ▶ No addiction to the network (aka Internet) => local and direct interactions

### Two technology families

- ▶ ITS-G5 (an adaptation of WiFi)
- ▶ C-ITS (an evolution of LTE)
  
- ▶ Each of them as its own evolution
  - IEEE 802.11bd
  - NR-V2X (or 5G V2X)

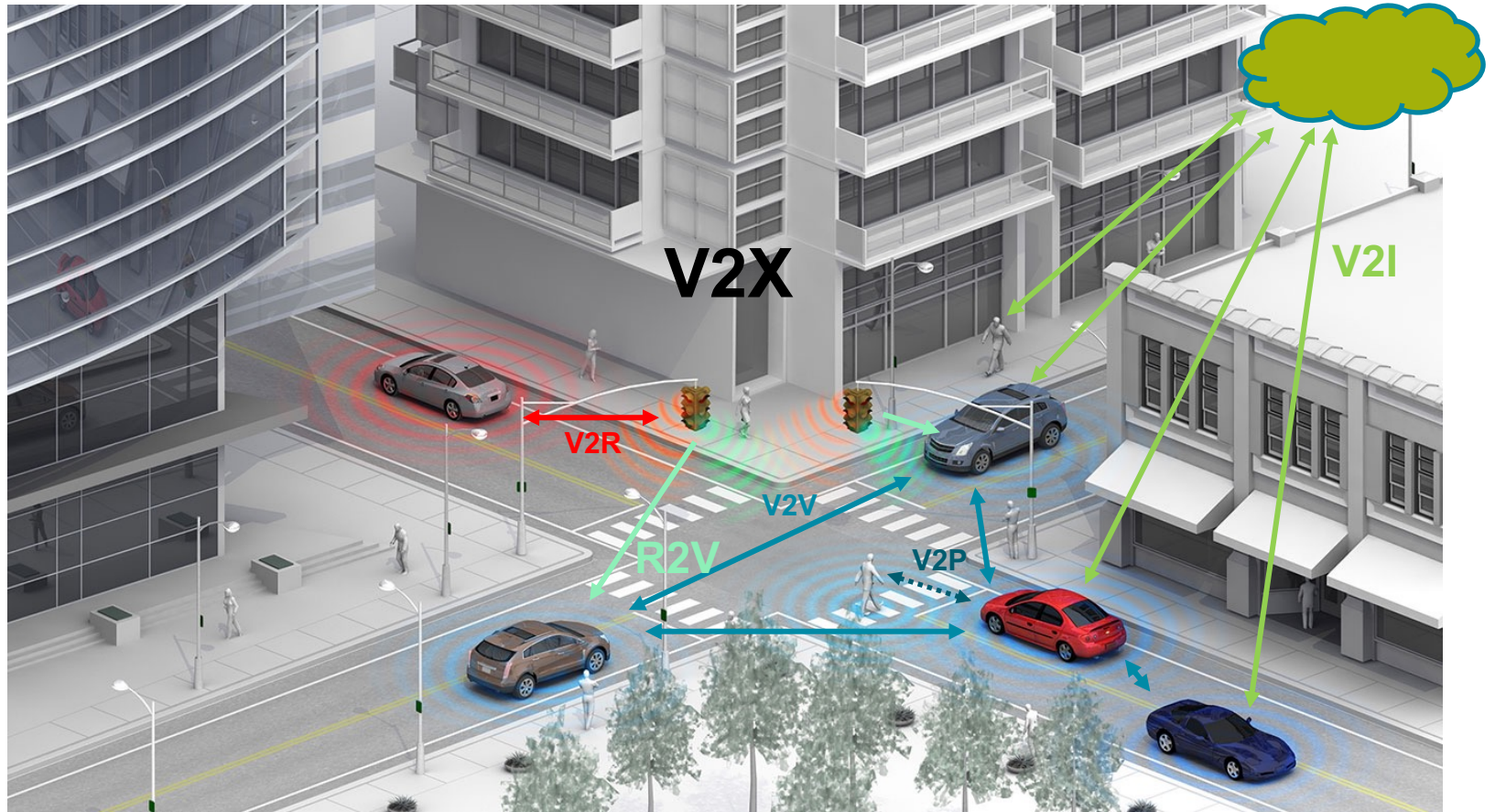


#### ITS-G5 (norme ISO/ETSI)

- Équivalent Européen de WAVE(US)
  - Basé sur 802.11p + services dédiés
  - Existe depuis + de 10 ans
- Mode IP: Internet
- Mode non-IP: pour V2V, V2I, V2x
  - Diffusion (broadcast) => pas d'ACK
  - Auto-organisé
  - Signé ou non
- Infra (option) pour
  - Internet
  - Infra routière active (PMV, feux, passage à niveau...)

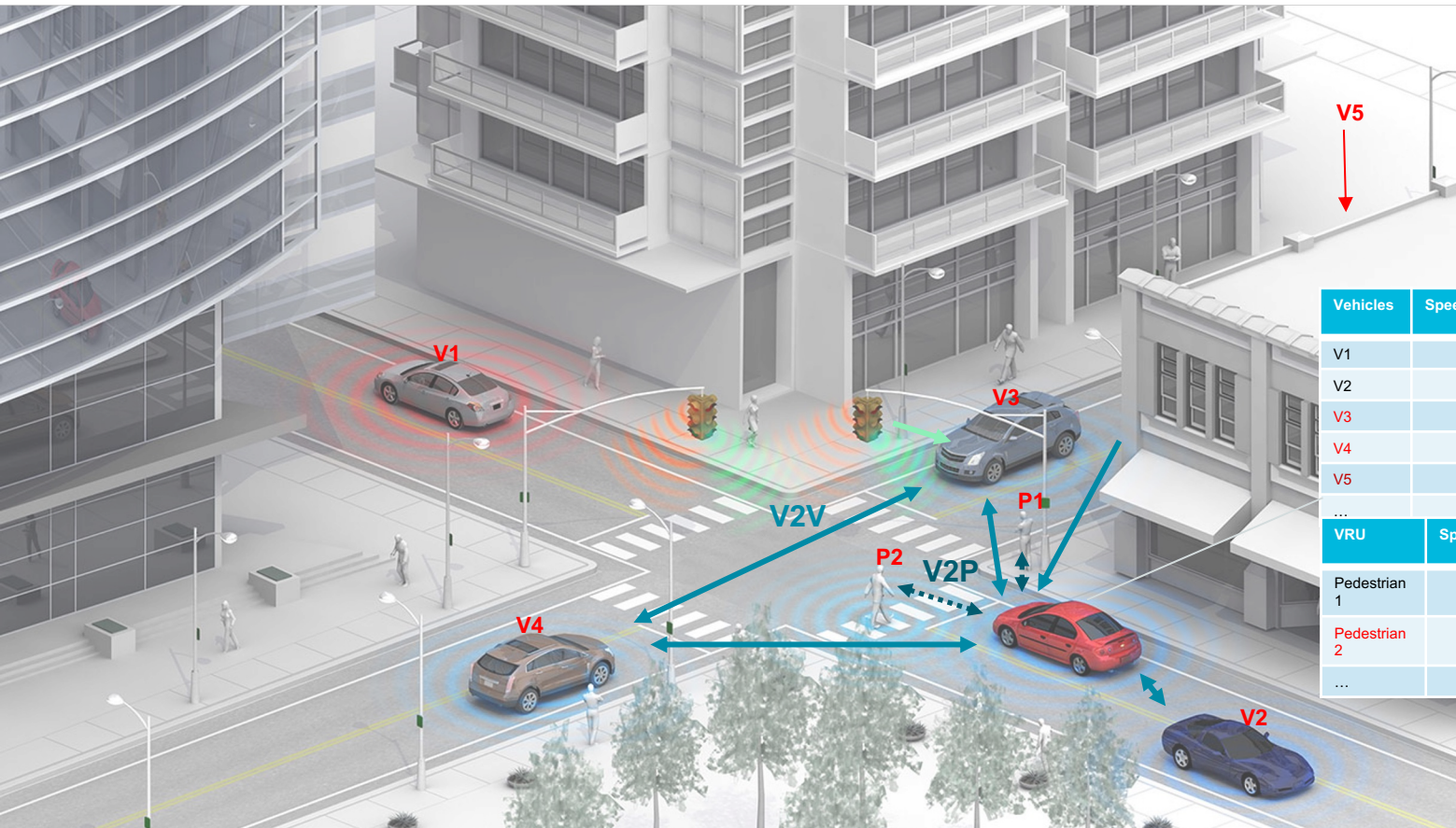
#### C-V2X (Cellular V2X / 3GPP)

- Solution cellulaire
  - Infra portée par opérateurs
- Arrivée du D2D en 4G+/5G (PC5)
  - Avec/sans support de l'infra
  - Normalisation en cours
  - Début d'industrialisation
  - NR-V2X à venir
- Hybridation avec ITS-G5 ?
  - Partage de la couche facilities
  - Mais pb de signature
  - Projet SCOOP@F: serveur central + unicast (relayage applicatif)



# COOPERATIVE PERCEPTION

Using only direct communication (CAM/DENM messages)

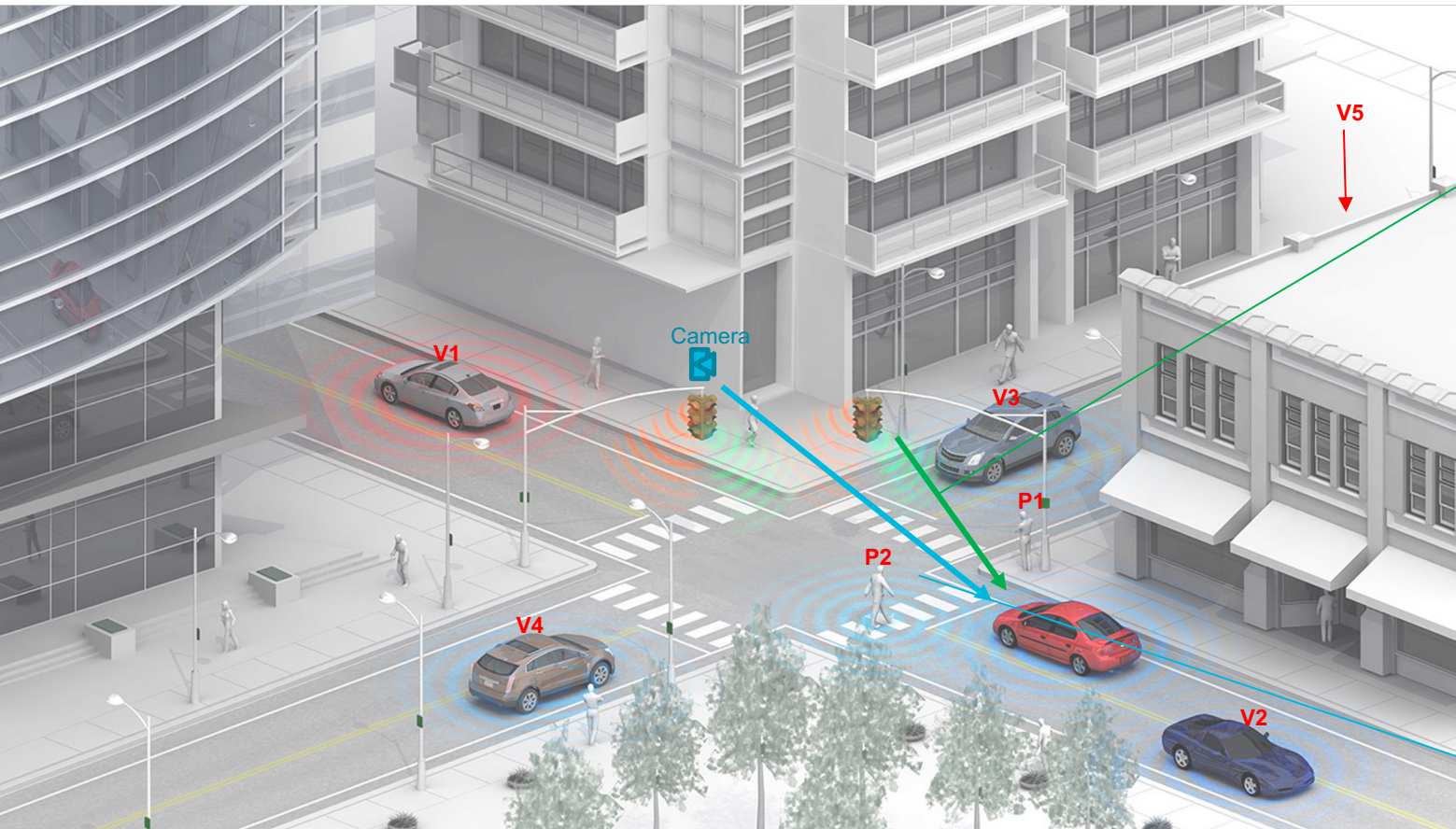


Vehicles	Speed	Direction	Position	Priority
V1				No
V2				No
V3				No
V4				No
V5				Yes
...				
VRU	Speed	Direction	Position	Priority
Pedestrian 1				No
Pedestrian 2				Yes
...				

Only see vehicles and VRU sending CAM and DENM messages

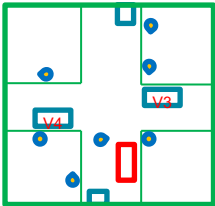
# COOPERATIVE PERCEPTION

With the support of the infrastructure (sensor, actuator, ...)



Signal Phase and Time (SPAT)  
=> Status of the traffic light, next signal stage change

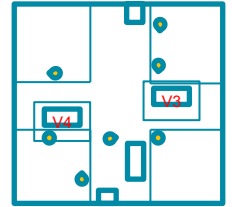
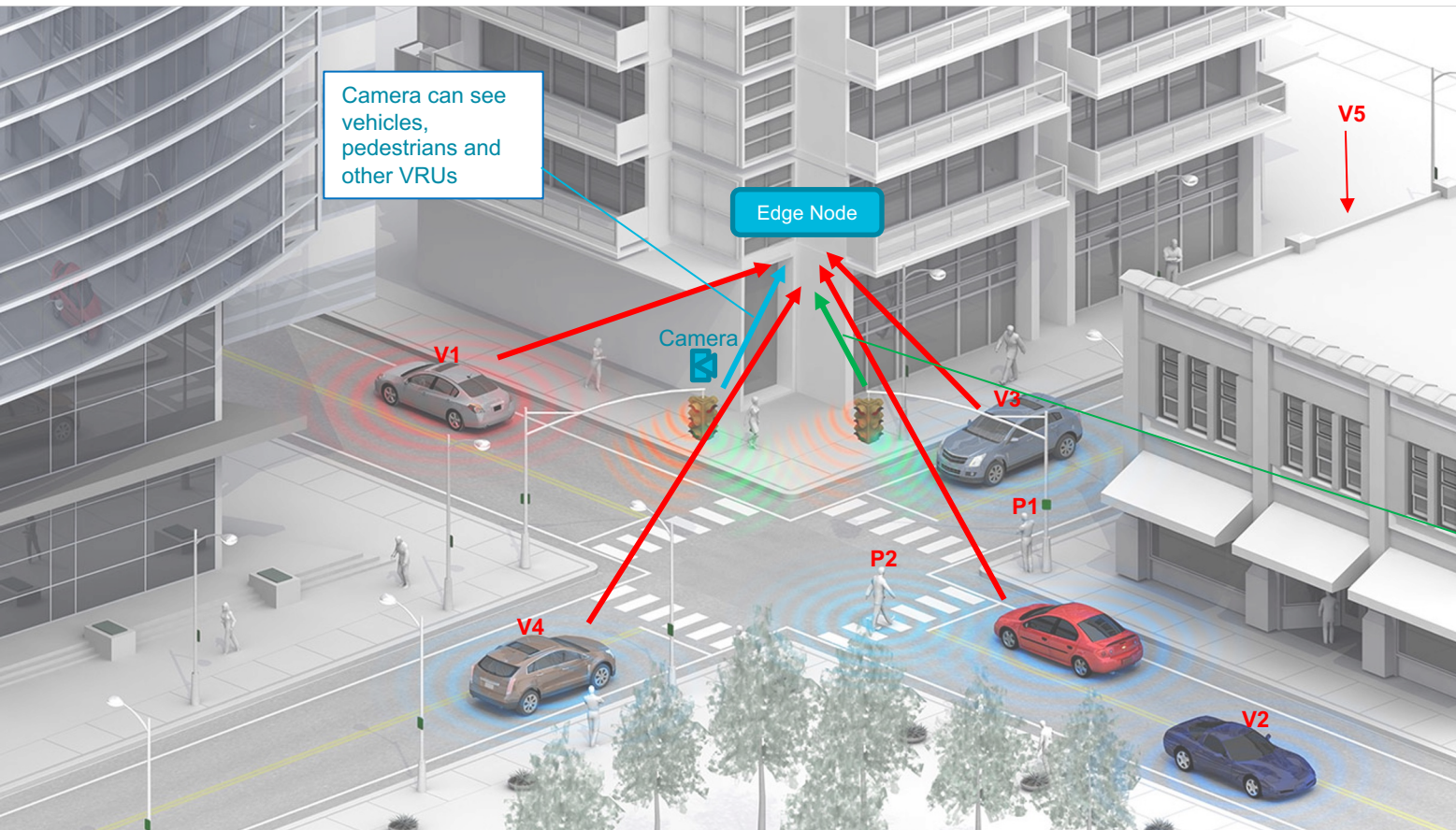
Map Data (MAP)  
=> Physical geometry of the intersection



Camera can see vehicles, pedestrians and other VRUs

# COOPERATIVE PERCEPTION

With the support of the infrastructure (Edge Computing)



Signal Phase and Time (SPAT)  
=> Status of the traffic light, next signal stage change

Map Data (MAP)  
=> Physical geometry of the intersection

## Uniformity

All devices use the same frequency and the same technologie

## Diversity

Each de device as a subset of communication technologies / fréquences

- ▶ How to organise the discovery?
- ▶ Delay? Not suitable for safety-related services

## Organised diversity

Some devices have multitechno-capabilities

- ▶ Could be in the infrastructure when taking into account multiple type of users
- ▶ Could be in vehicle: how to provide guarantees?
- ▶ Still necessary to organize service discovery.

## SCOOP@F phase 2 : (Eu, 2016-2020)

- ▶ Cooperative ITS, Hybrid communication, Mobile IP, V2X security

## InDiD (Eu, 2019-2023)

- ▶ Urban ITS, IP-based local interactions, V2X security

## SIMEHet (YoGoKo, 2015-2019)

- ▶ Extended connectivity, Hybride communications

## Chantier 3.0 (Région, 2019-2020)

- ▶ Vehicle – Pedestrian interactions using mass-market communications technologies (BLE, WiFi)

## X2Rail (Eu/IP2, 2017-)

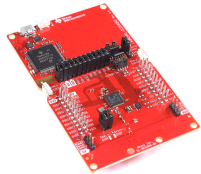
- ▶ Security architecture

## TAXIRail (PiA, 2022-2025)

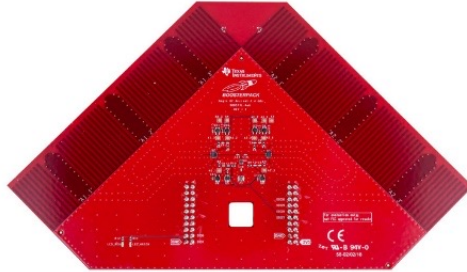
- ▶ Security architecture, V2X in railway context, extended connectivity



## 2 localization antennae (TI BOOSTXL-AOA)



CC2640R2  
Bluetooth 5.1 MCU



## Reference positioning system

- ▶ Marvelmind (up to 2cm precision) / Camera

## Data collection & Scenario replay

- ▶ Robot-based (TurtleBot3)
- ▶ Antomation software

## Environment

- ▶ Dedicated Room / Faraday cage



## No way to pass by 5G

	DSRC ITS G5	3GPP C-V2X (R14)	3GPP 5G C- V2X (R15, R16)
Out-of-network operation	Ok	Ok	Ok
V2V, V2I	Ok	Ok	Ok
Safety-critical uses	Ok	Ok	<b>R16</b>
V2P	Ok (?)	Ok	Ok
V2N	Limited	Ok	Ok
Multimedia	No	Ok	Ok
Network coverage	Limited	Ok	Ok
Regulation/testing efforts	Ok	Limited	Ongoing
Very high throughput	No	No	Ok
Very high reliability	No	No	Ok
Positioning	No	No	Ok (10cm VRU, 30cm V)
Very low latency	No	No	Ok (1-5 ms)

### For V2X communication

- ▶ Characterisation of 5G-NR for V2X communications
- ▶ Adaptation of C-ITS protocols to non-broadcast communications (beam forming)
- ▶ Interaction vehicles - pedestrians (VRU)
- ▶ Hybridation of ITS-G5 – 5G-V2X and other technologies
- ▶ Adaptation V2X security in 5G context

### For AGV and robotics in industry

- ▶ Private 5G infrastructure and URLLC communications
- ▶ Hybridation with other communication technologies

### Use of MEC in Urban ITS scenari

### Multi-operators V2X slicing

# QUESTIONS / COMMENTS ?

