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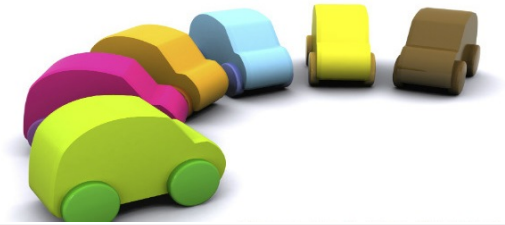
« Cooperative Connected Vehicles (C²V): where IoT meets C-ITS

Prof. Jérôme Härri

Visit to Prof. Fidler, TU Hannover

February 3rd 2016



Cti
Commission des Titres d'Ingénieur

Graduate school and research center in communication systems

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PRINCIPAUTÉ DE MONACO

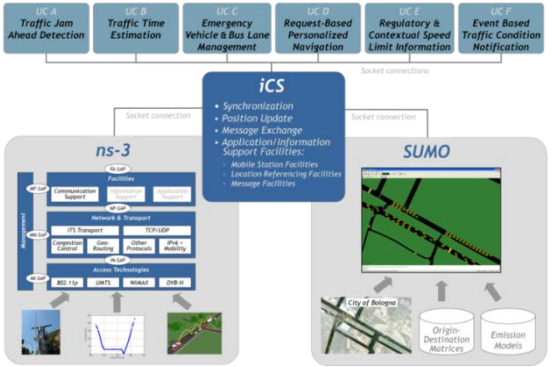
UN RÔLE À PART DANS LE MONDE.

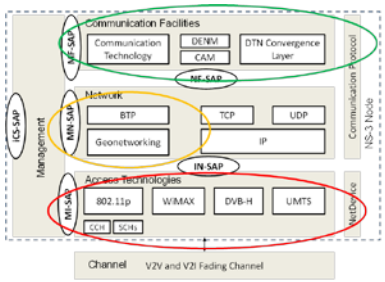
Focus on: Automotive Domain Activities

- **V2X Communications & Networking**
  - Dependable Vehicular Communication
    - 1-hop broadcast & congestion control
  - Contribution to the ETSI ITS, in particular DCC
    - C2C CC WG COM co-chair and subWG DCC chair
  - 5G extensions to automotive domain
    - LTE D2D for safety communication
    - Low latency LTE
- **Vehicular SDN & NFV**
    - IPv6 Vehicular Mobility Management
    - Mobility-aware Content storage and retrieval
    - Vehicular Fog-based processing
- **Vehicular IoX**
  - M2M-compliant IoT architecture for ‘connected cars’
  - Data-as-a-service architecture for vehicular & crowd sensing
- **Vehicular Communication Security**
  - Software designed security (security by design)
  - Embedded security

Focus on: Tools and Methodologies

- **Simulation Platforms**
  - iTETRIS Platform
    - http://www.ict-itetris.eu/
  - ns-3 with V2X extensions
    - *https://www.nsnam.org/*
  - SUMO
    - http://sumo.dlr.de
- **Emulation / Prototyping**
  - 5G OpenAirInterface
    - http://openairinterface.eurecom.fr/
  - V2X Prototyping

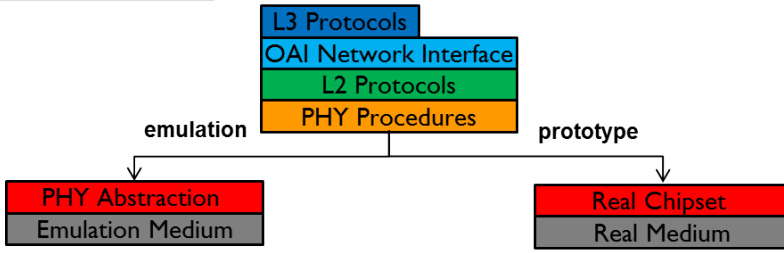




Intelligence in the Communication Stack

Position-based Geographic Routing

Heterogeneous Access Technologies



EURECOM – Teaching & Research

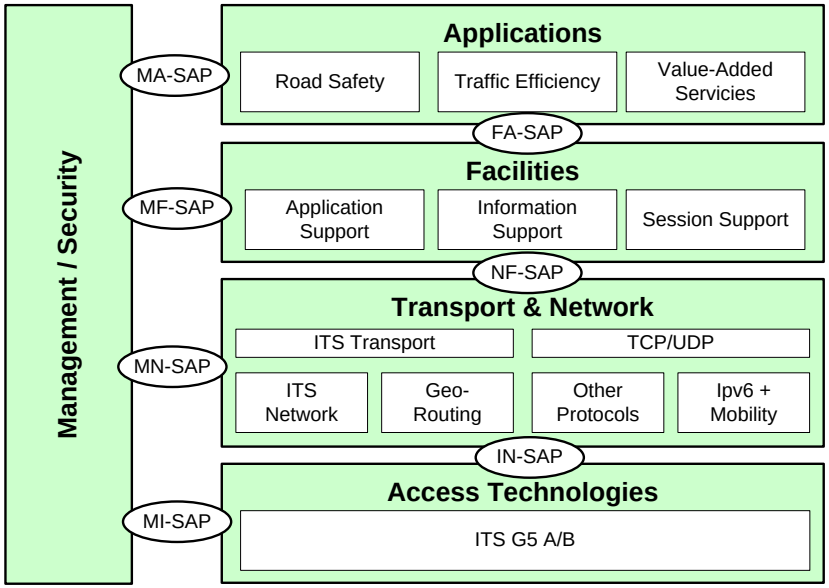
- **'Grande École' for Communication Systems**
  - Member of the Elite Cluster SCS
  - Architect and co-founder of Com4Innov

- **Research:**
  - Mobile & Network Communication – Massive MIMO, **connected vehicles**, **IoT**, WiFi, 5G, M2M, SDN
  - Data & Security – Big Data, Cloud computing, cryptography
  - Multimedia – Web Semantics, Open Data, Speech/video recognition

- **Teaching:**
  - Engineering Track - Telecom ParisTech
  - International Master Track – Mobile Communication, Data & Security, Multimedia
  - Post-Master Track – http://www.eurecom.fr/en/teaching/post-master-degree
    - **Cooperative Communications for ITS**
    - Security of Computer Systems

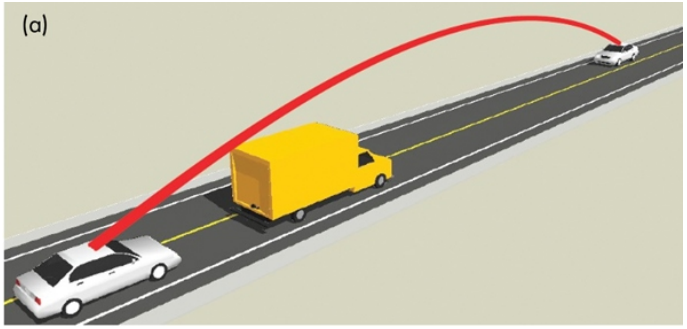
C-ITS Applications – Day 1
Architecture, Technologies & Applications

- **ETSI Technical Committee on ITS**



Source: C2C-CC

- **Applications**
  - Active Road Safety
    - Cooperative awareness
    - Hazard warning
  - Cooperative Traffic Efficiency
    - Adaptive speed management
    - Cooperative navigation



- **Technology**
  - ITS-G5
    - IEEE 802.11 for vehicular environment
    - a.k.a: 802.11p, DSRC

C-ITS Applications – DAY 2
Objective: Highly Autonomous Driving

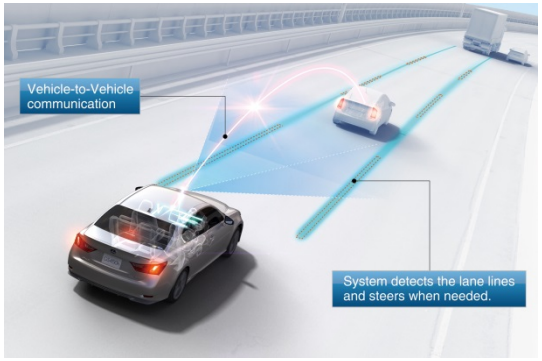
- **Not such a new idea**

- **A very marketized idea…**

Source: google

- **…yet a very ambitious idea**

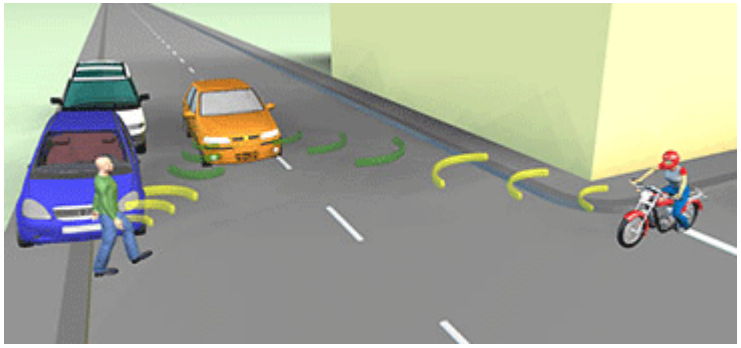
Source: US Peloton



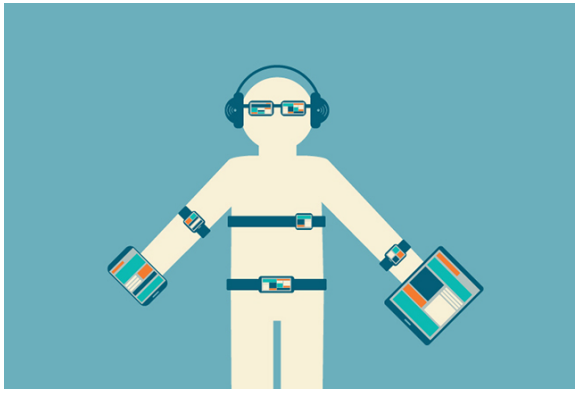
Source: toyota

C-ITS Applications – DAY 2
Objective: Vulnerable Road Users

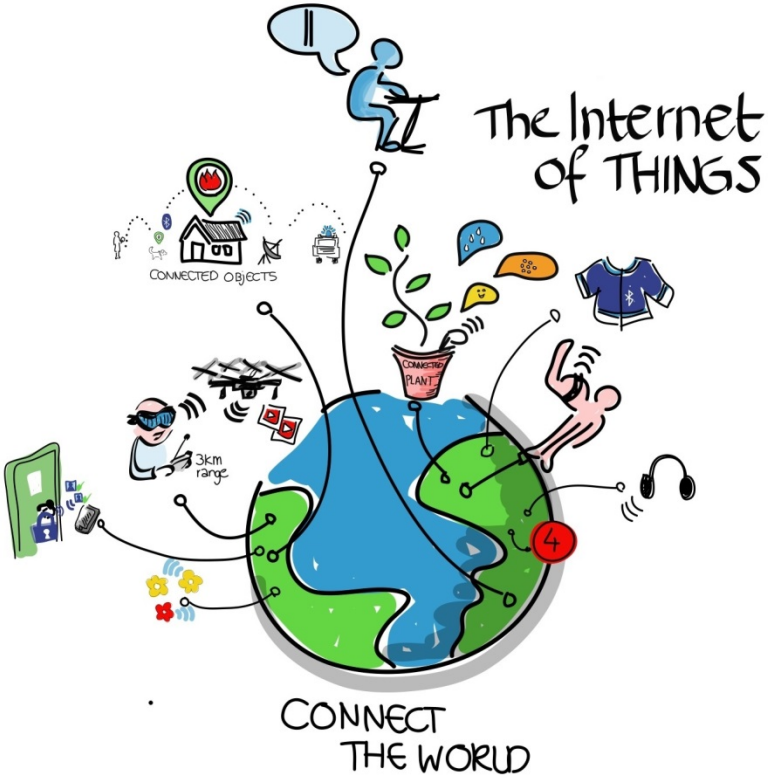
- **C-ITS not only between Vehicles**



- **C-ITS connects to wearable devices**



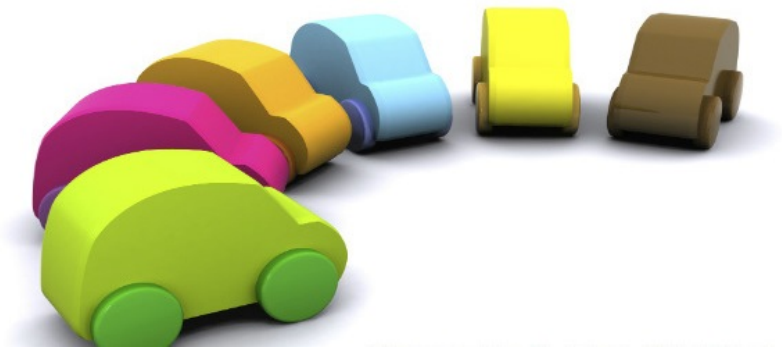
- **C-ITS is part of the Internet-of-things**



From ‘Cooperative’ to ‘Connected’ - A Change in the Eco-System

- **Cooperative vehicle**
  - driven by car industry

DAIMLER BMW Audi Ford



- **Connected vehicle (things)**
  - driven by Internet & wireless industry

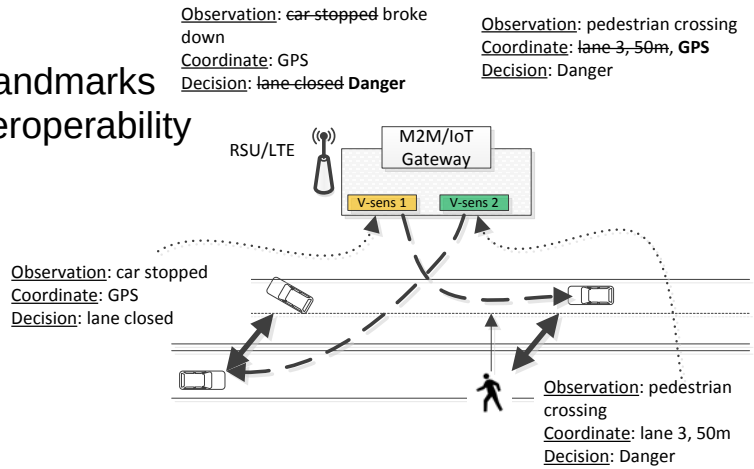
intel QUALCOMM HUAWEI Alcatel·Lucent ERICSSON

C²V Case Study: H2020 HIGHTS Project

- **HIGHTS: High Precision Positioning for Cooperative ITS**
  - Start: 1st May 2015
- **Topic:**
  - Cooperative Positioning providing sub-meter (<0.5m) precision
  - Positioning service for autonomous driving and vulnerable road users

HIGHTS
High precision positioning for Cooperative-ITS
http://hights.eu/

- **Situation:**
  - Ego localization with laser/radars/cameras show a high potential for self positioning, but..
    - not efficient in bad conditions (weather, traffic, curves, etc..), expensive, not interoperable
  - Objective: innovative use of C²V to
    - Cooperate to enhance positioning
    - Connect to an IoT to exchange navigation and landmarks
    - Unify landmark semantics for cross-platform interoperability



- **Partners:**

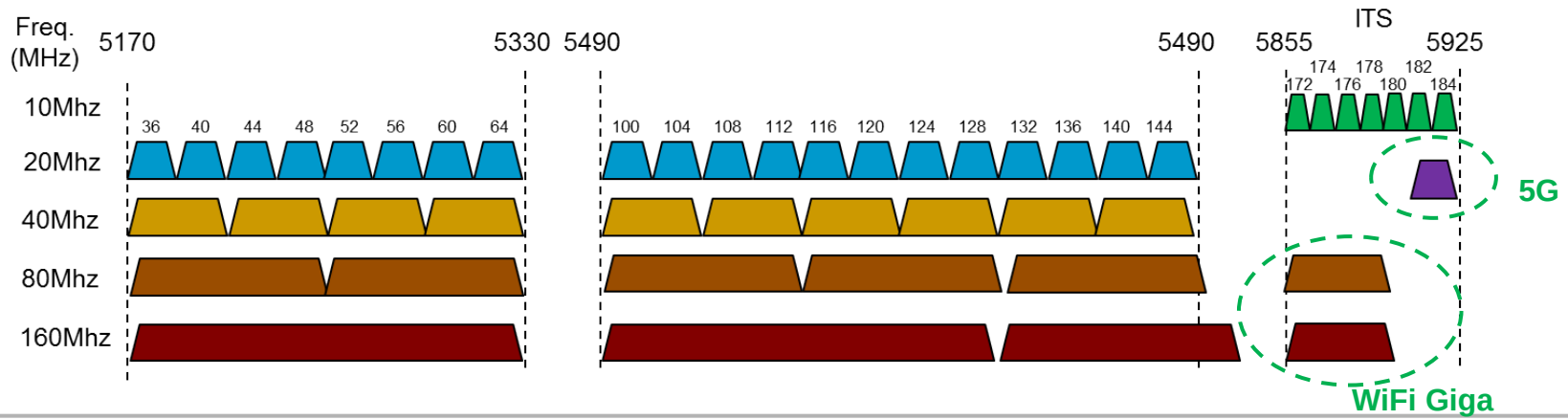
DLR, BOSCH Invented for life, cea leti, Jacobs University, Chalmers University of Technology, EURECOM, tass international, INNOTEC, FBConsulting, ZIGPOS, Be Spoon, objective, ibeo automotive, PAULs Consultancy BV

C²V: Cooperative Communication – G5 vs. 5G

- **Penetration rate**
  - Device Market Penetration:
    - G5: Enabled cars ➟ 50% in 15 years
    - 5G: Smartphones/things ➟ 50% in 2 years
  - Network:
    - G5: Road Side Units will be deployed in the next years
    - 5G: Network already available and in expansion

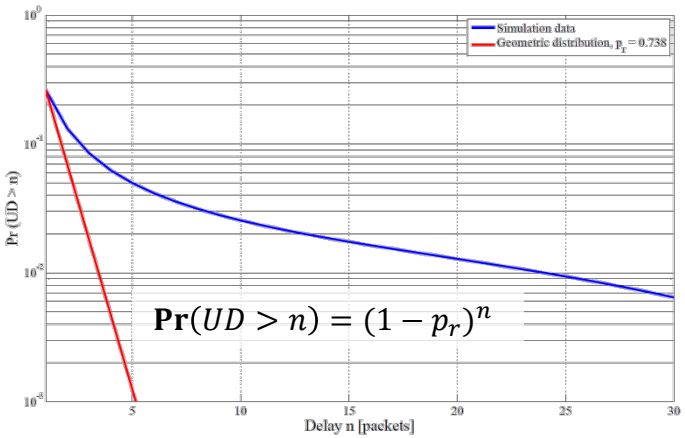
- **Ubiquity**

- **Frequency bands**

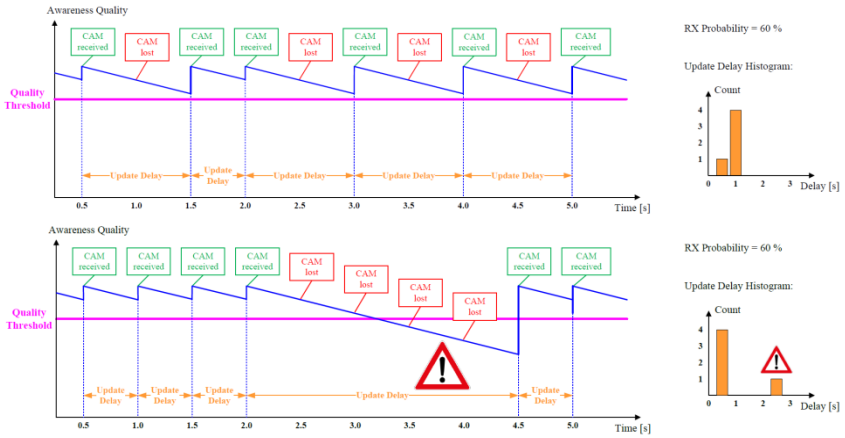


C²V: Cooperative Communication – G5 vs. 5G

- **G5 for Safety Automotive**

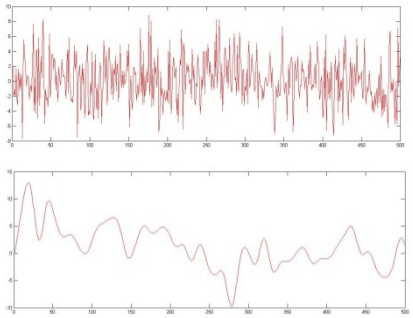


IRT shows signs of correlations (simulations)

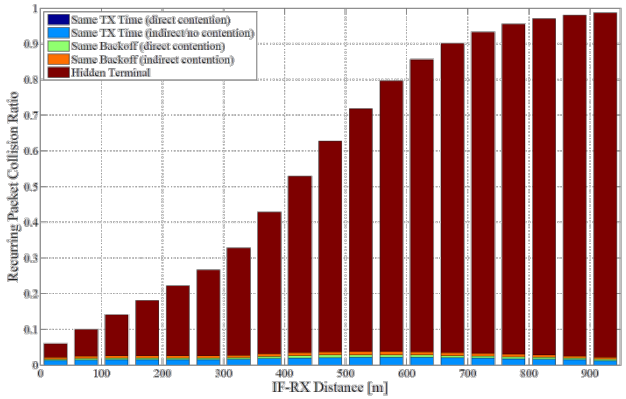


Correlated IRT has a bad impact on C-ITS at constant PRR

Correlated Shadowing

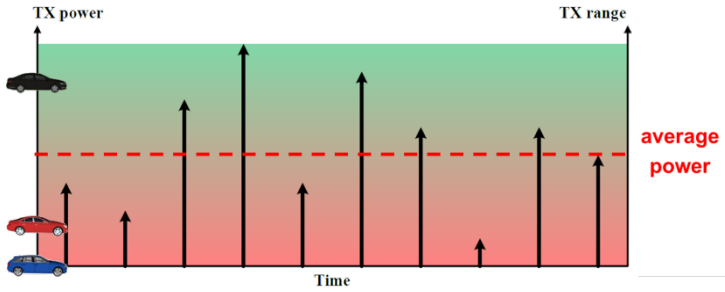


Correlated Mobility

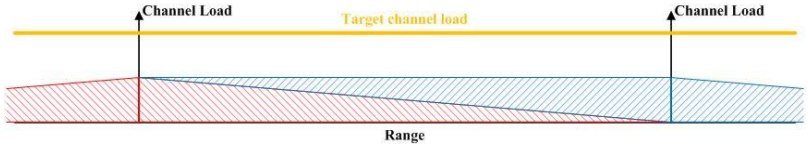


Correlated Hidden Terminal

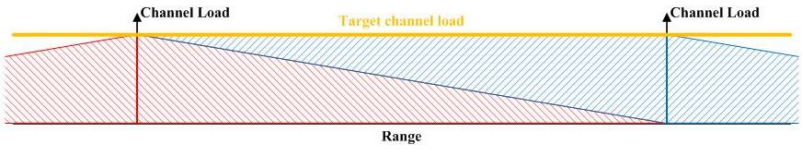
C²V: Cooperative Communication – G5 vs. 5G



Random Tx Power Control – reduces Channel Load

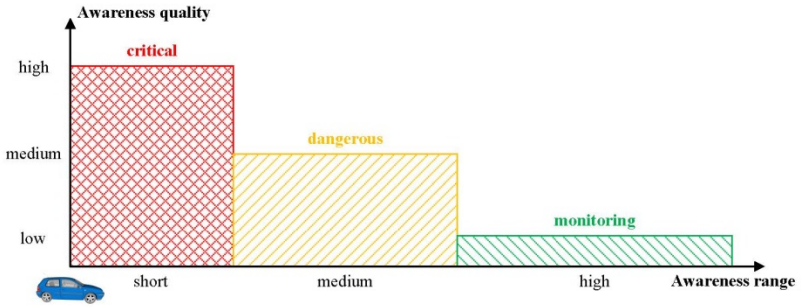


Tx Rate Control: Uses the 'leftover' channel load to increase awareness quality

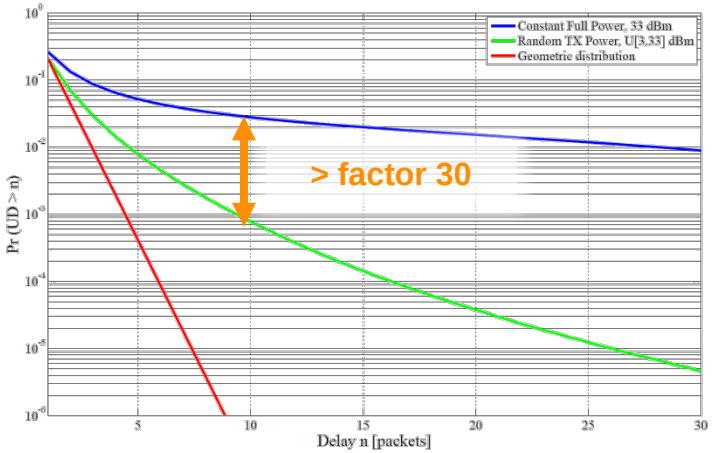


- **Fish-Eye Awareness Control**
  - Random Tx Power Control to mitigate correlated packet collisions
  - Tx Rate Control to increase awareness quality

Fish-Eye Awareness



C²V: Cooperative Communication – G5 vs. 5G



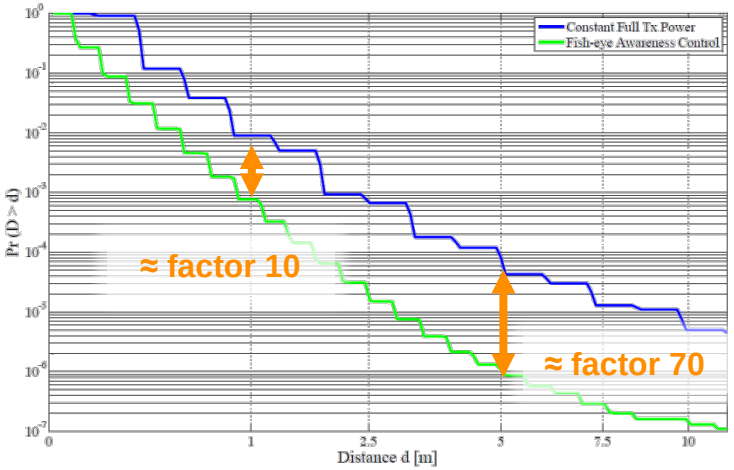
Fish-Eye Awareness on IRT

- Decorrelate hidden node-related collision
- Factor 30 improvement at 1Hz

Source: Volvo

Fish-Eye Awareness on position error

- Factor 10 at 1m
- Factor 70 at 5m

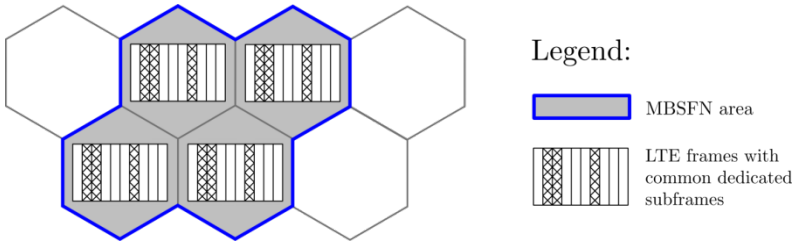


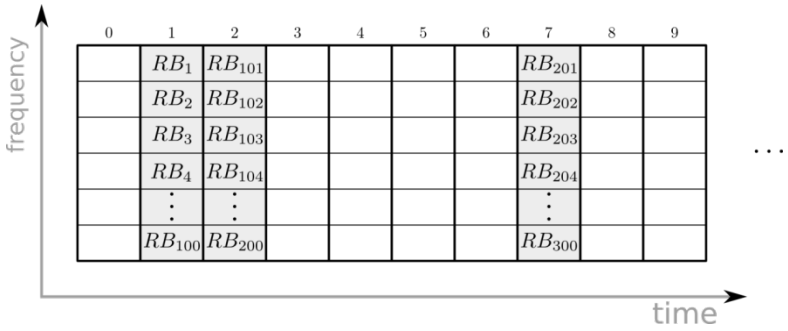
Reference: B. Kloiber, J. Härri, T. Strang, C. Rico Garcìa, **Random transmit power control for DSRC and its application to cooperative safety**, IEEE Trans. of Dependable and Secured Communication, Volume PP, N°99, 2015

C²V: Cooperative Communication – G5 vs. 5G

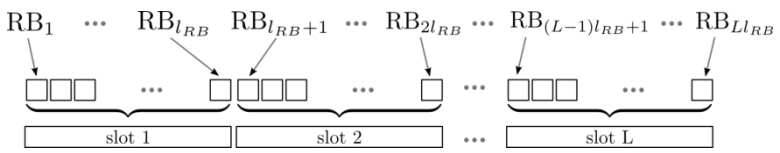
- **An alternate view - 5G for Safety Automotive**

  - Multi-cell / operator resource Allocation

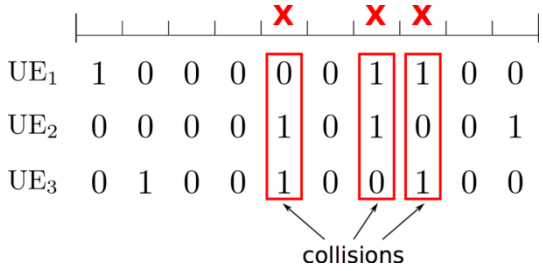




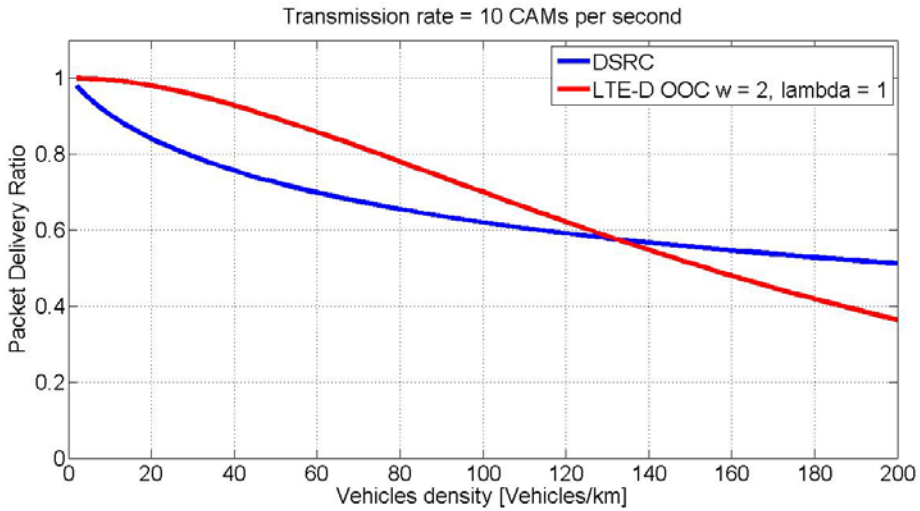
  - Fully distributed resource scheduling
    - Locally, vehicles group RBs into slots the size of one CAM packet



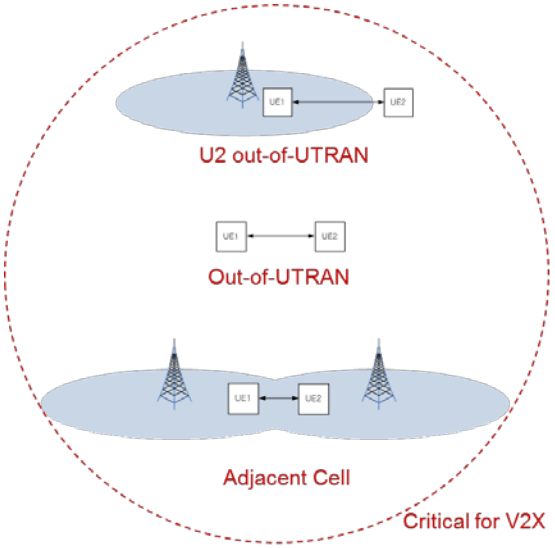
  - Challenge:
    - Select slots with minimum collision probability
      - ☞ Sounds familiar !!



C²V: Cooperative Communication – G5 vs. 5G



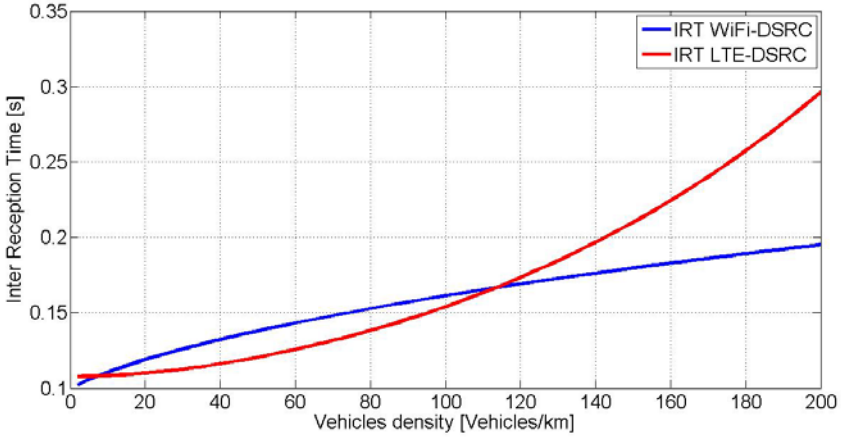
PRR



IRT

Performance metric:

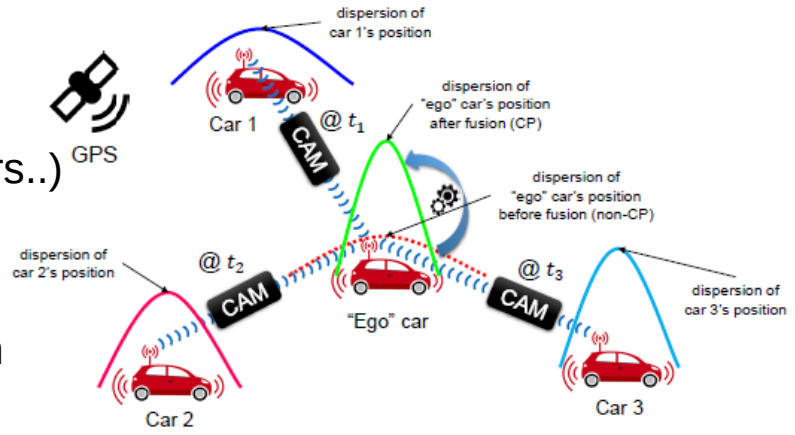
- TX-centric - probability of successful packet reception (PRR) (packet delivery rate)
- RX-centric – Inter-reception Time (IRT) between two successive CAM

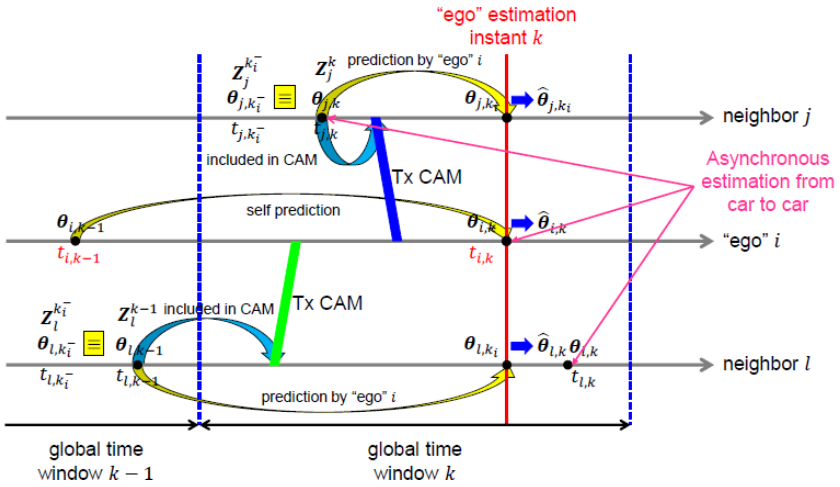


Reference: Laurent Gallo, Jérôme Härri, "**Dedicated Short Range LTE for V2X Direct Broadcast Communications**", IEEE Transaction on Vehicular Technology (to be submitted), 2016

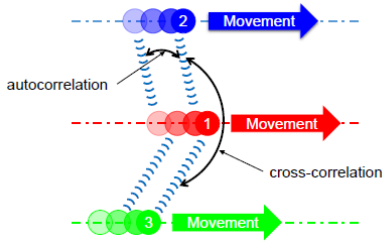
C²V: Cooperative Localization

- **Non-cooperative Localization:**
  - Use of GPS and known fixed anchors
  - Use on-board devices (laser scanners, radars..)
- **Cooperative Localization:**
  - Use Cooperating vehicles as landmark
  - Neighbor selection for optimal multilateration



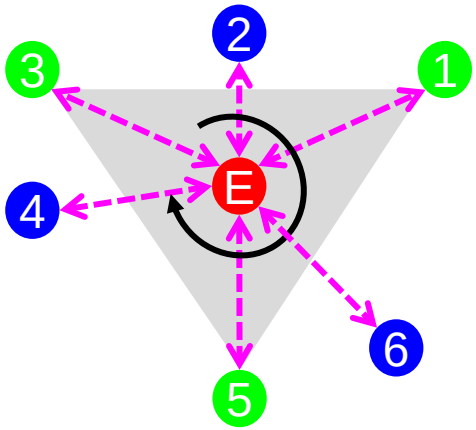


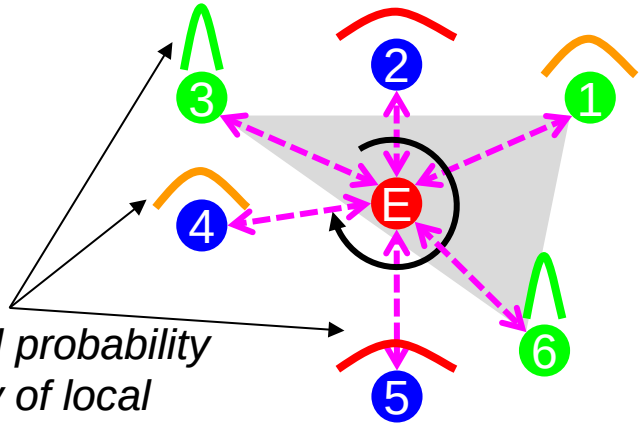
- **Challenges of Cooperative Communications**
  - Asynchronous sampling
  - Not all neighbors are born equal
    - Various GPS quality
  - Correlation (space and time) in samples



C²V: Cooperative Localization

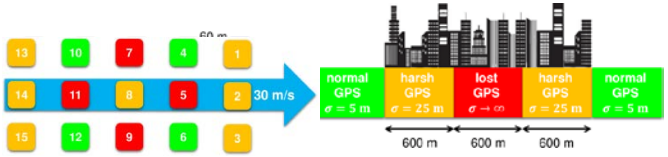
- **Bayes Link Selection Criterion**
  - Link Selection - General goals
    1. ↓ (reduce) computational complexity
    2. ↓ (reduce) communication loads
  - Non-Bayesian CRLB criterion
    1. Radio link quality
    2. Geometry of reference vehicles
  - Bayesian CRLB criterion
    1. Radio link quality
    2. Geometry of reference vehicles
    3. Uncertainty of neighbors' estimated positions



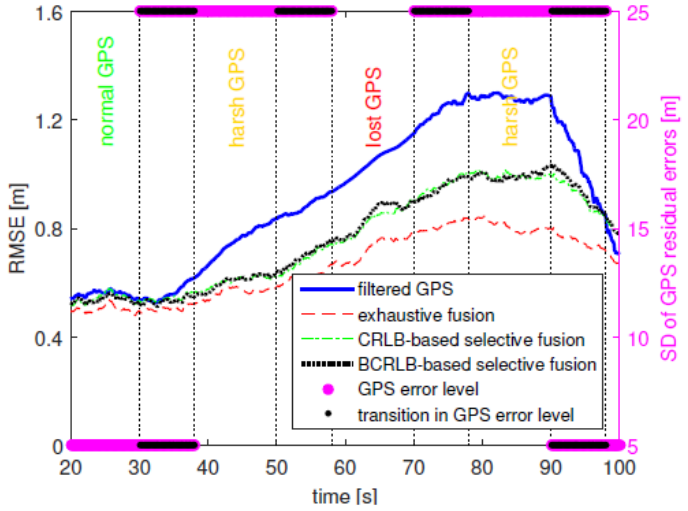


Presumed probability density of local position estimates (possibly transmitted also in CAMs)

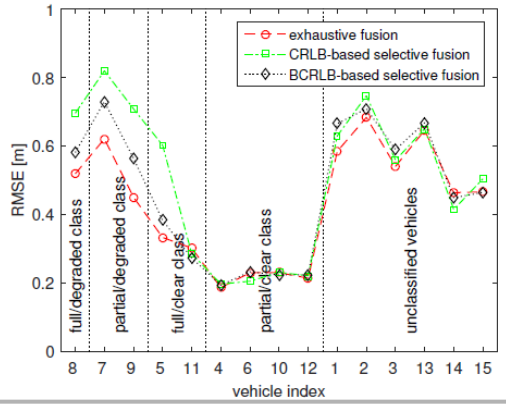
C²V: Cooperative Localization



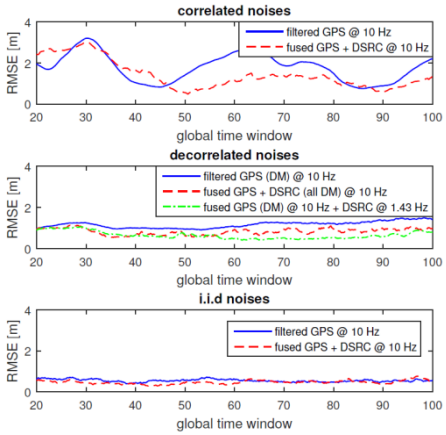
- **Cooperative Localization**
  - Benefits:
    - Helps in degraded GPS conditions
  - Drawback:
    - Complex fusion; careful neighbor selection



- **Challenges:**
  - Heterogeneous Neighbor Quality



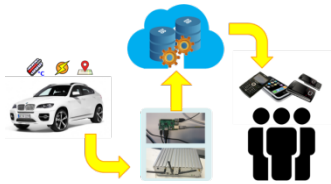
  - Correlated Localization



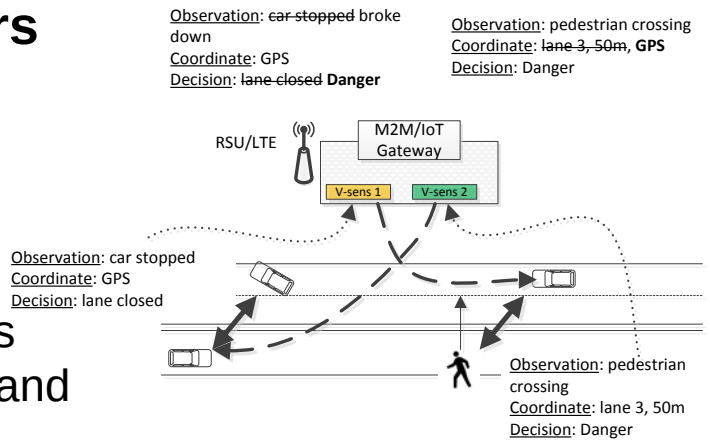
  - References

- M. Hoang, B. Denis, J. Härri, D. Slock, **Select Thy Neighbors: Low Complexity Link Selection for High Precision Cooperative Vehicular Localization**, IEEE Vehicular Networking Conference
- M. Hoang, B. Denis, J. Härri, D. Slock, **Breaking the Gridlock of Spatial Correlation in GPS-aided IEEE 802.11p-based Cooperative Positioning**, under revision, IEEE Transaction on Vehicular Technology

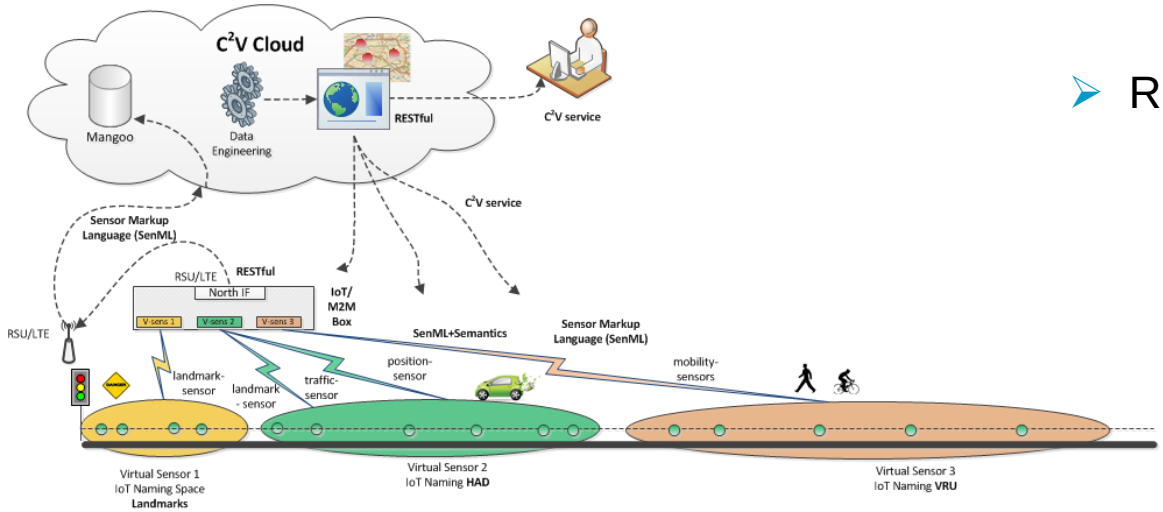
C²V: Connected Services



- **C²V data as a 'Service' to data consumers**
  - C²V Data needs to be discovered
  - C²V Data needs to be processed
  - C²V Data is shared by C-ITS services
- **Initial architecture specification**
  - IoT/M2M for cooperative localization/landmarks
  - Adapted to Highly Autonomous Driving (HAD) and Vulnerable Road Users (VRU)

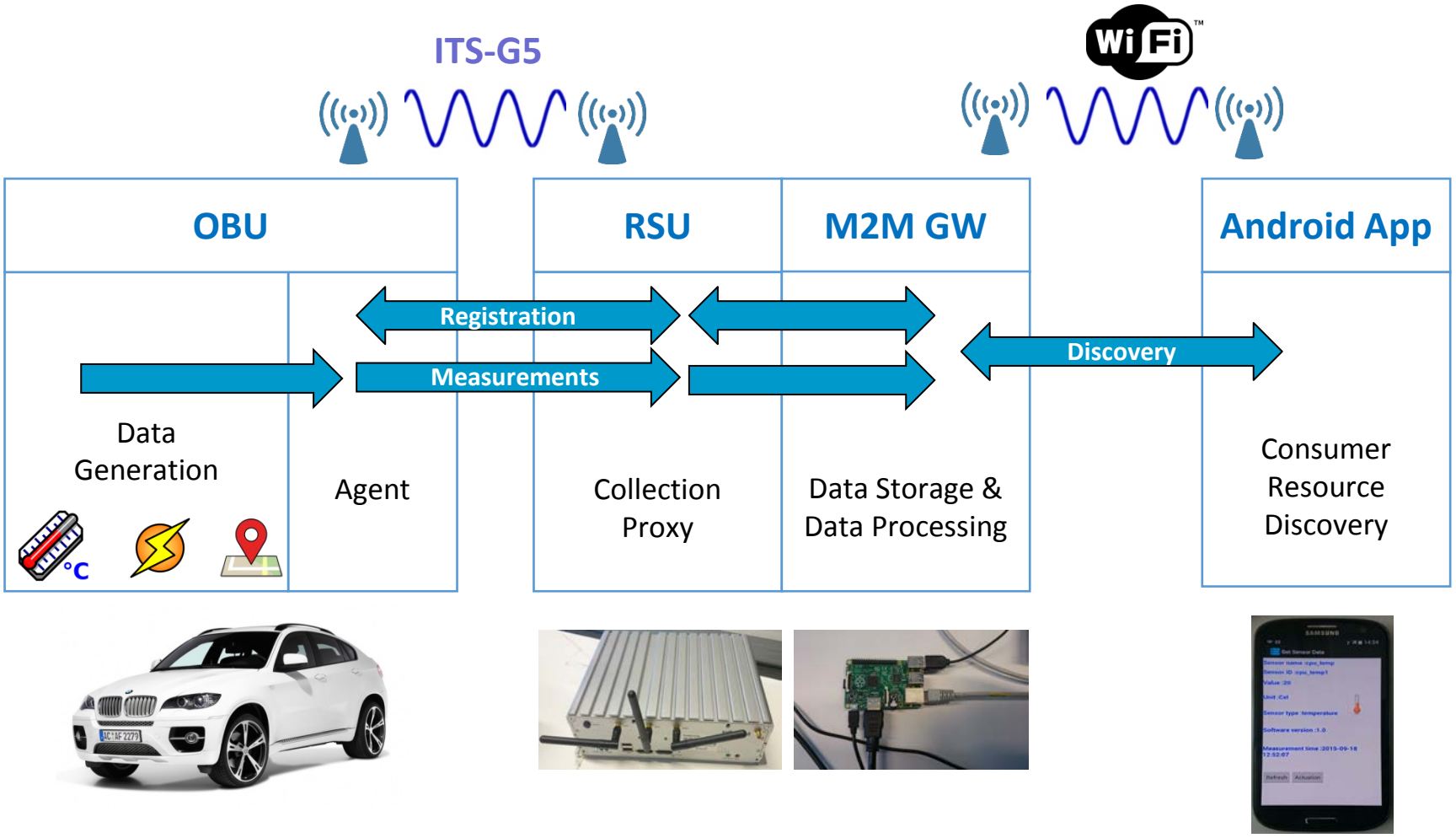


- **IoT/M2M architecture for C²V Services**



- Reference
  - Datta, Soumya Kanti; Bonnet, Christian; Härri, Jérôme **Fog computing architecture to enable consumer centric Internet of Things services**, IEEE ISCE 2015, 19th IEEE International Symposium on Consumer Electronics, June 24-26 2015, Madrid, Spain

C²V – Connected Services



Cooperative Connected Vehicles (C2V): where IoT meets C-ITS

- **C²V – bridging two eco-systems**
  - Automotive & Wireless Industry
  - Different operations:
    - C-ITS – horizontal
    - IoT – vertical

- **IoT in C-ITS – Cars as Connected Objects**
  - Ubiquitous IoT/M2M architecture
  - Local resource discovery through C-ITS communication
  - Unified Services
- **IoT / M2M architecture in C-ITS domain**
  - Transparent to C²V technology (5G or G5)
  - Extensible to different IoT domains
    - Smart Driving
    - Smart City / Traffic
    - Electro-Mobility
    - …

Jérôme Härri
Jerome.Haerri@eurecom.fr