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The Future of V2X: Where we are and where we are going

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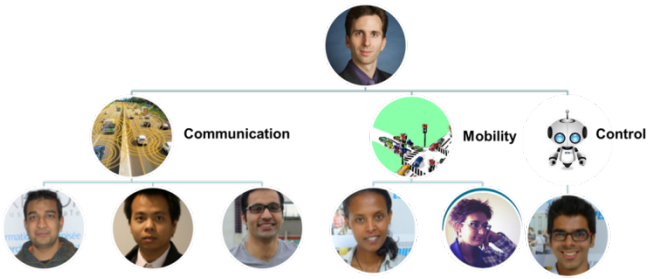
Cti
Commission des Titres d'Ingénieur

CATS Evolution: from Awareness to Autonomy

ICN, MEC,
SDN, Caching

Cooperative Communication

C-V2X, ITS-G5



CATS:
- Awareness
- Positioning
- Smart Traffic Lights
- Dynamic Navigation
- Autonomous Driving
- Vulnerable RU
- ..

VRU

Mixed Robots

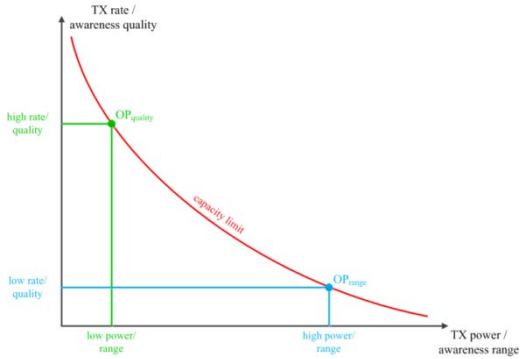
Cooperative Mobility

Cooperative Control

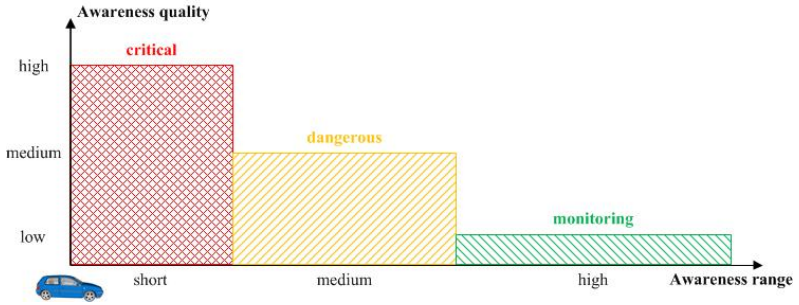
Cars

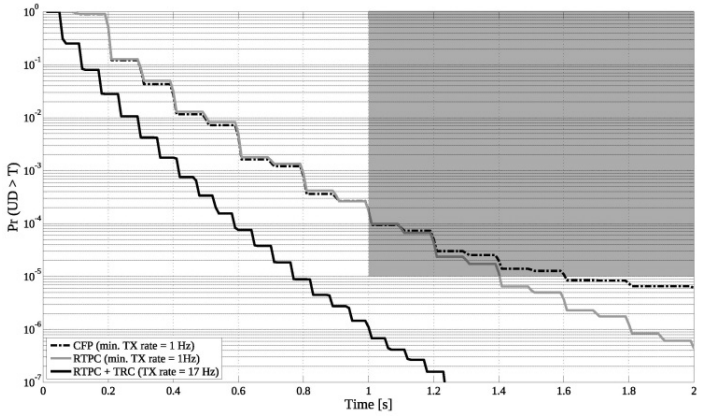
Cooperative Awareness – ITS-G5 and ITS-G5 rel. 2

- **Major CATS Building Block: Cooperative Awareness**
  - CATS need to be aware of their immediate surrounding
- **Finite Capacity V2X Channel Trade-off**
  - Can see far but not clearly
  - Can see clearly but only in short distance



- **Dependable 1-hop broadcast is critical**
  - Need smart Transmit Strategies / RRM

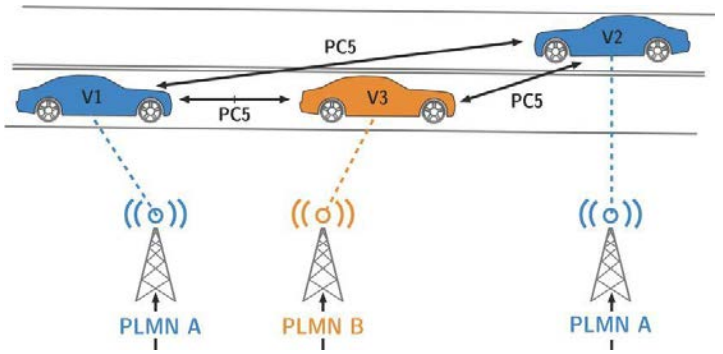




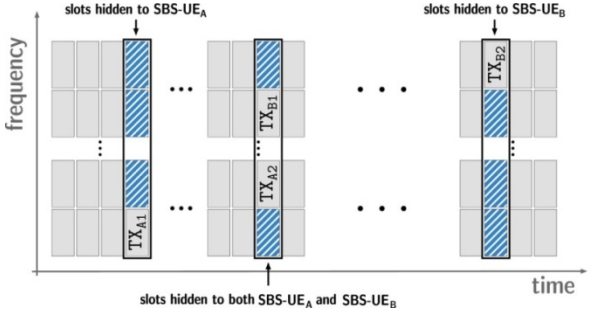
- **Selected Publications:**
  - Bernhard Kloiber, Jérôme Härri, Thomas Strang, Stefan Sand, Cristina Rico Garcìa, **Random Transmit Power Control for DSRC and its Application to Cooperative Safety**, *IEEE Transaction of Dependable and Secured Communication,* 2015
  - Bernhard Kloiber, Jérôme Härri, Thomas Strang, **Dice the TX power - Improving awareness quality in VANETs by Random Transmit Power Selection**, *IEEE Vehicular Networking Conference (VNC)*, 2012.
  - Fatma Hrizi, Jérôme Härri, Christian Bonnet, **Can Mobility Predictions be Compatible with Cooperative Active Safety for VANET?**, Prof of the *9th ACM Workshop on VehiculAr Inter-NETworking, Systems, and Applications (VANET)*, 2012.
  - Miguel Sepulcre, Javier Gonzalvez, Jérôme Härri, Hannes Hartenstein, **Contextual Communications Congestion Control for Cooperative Vehicular Networks**, *IEEE Transaction on Mobile Computing, 2011.*

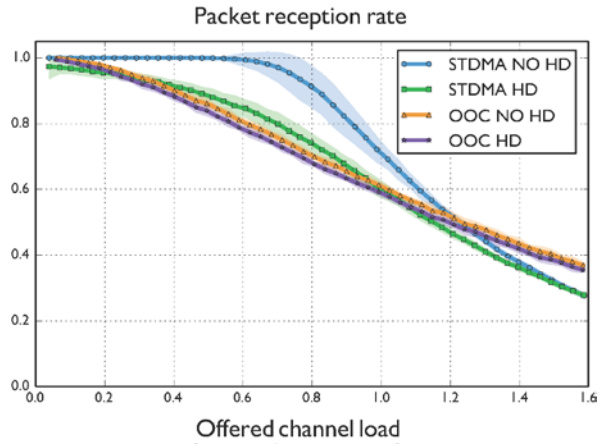
Cooperative Awareness– Cellular Ad-Hoc LTE-V2X

- **LTE-V2X Radio Resource Management**
  - Supervised: centralized RRM (eNB)
  - Unsupervised: distributed RRM
    - Challenge: avoid collision !!
  - Resource Allocation Mechanism:
    - Random – Optical Orthogonal Codes
    - TDMA – Self-Organized TDMA



- **LTE-V2X Mode 4 (unsupervised)**
  - Advantage:
    - Does not rely on any infrastructure
  - Drawback
    - Synchronization
    - Half-duplex
    - …

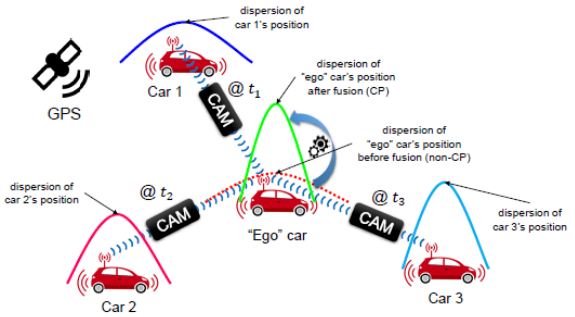


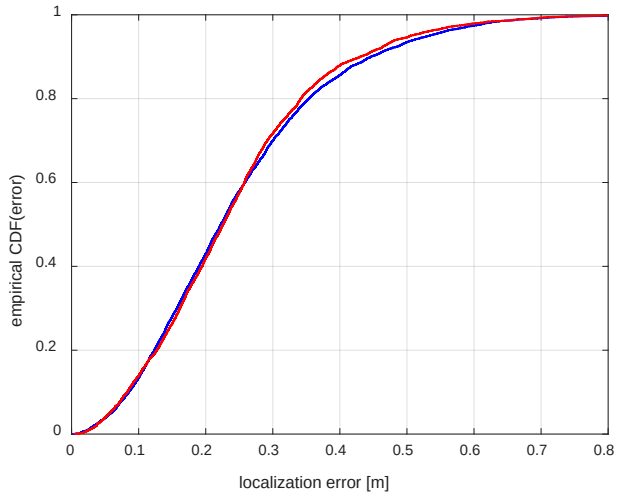


- **Selected Publications:**
  - Laurent Gallo, Jérôme Härri, **Distributed Radio Resource Management for Ad-Hoc LTE-V2X Automotive Safety Broadcast**, *Elsevier Vehicular Communications, 2017, under review.*
  - Laurent Gallo, Jérôme Härri, **Unsupervised LTE D2D -– Case Study for Safety-Critical V2X Communications**, *IEEE Vehicular Technology Magazine, 2017.*
  - Laurent Gallo, Jérôme Härri, **Analytical Study of Self-organizing TDMA for V2X Communications**, *1st IEEE ICC Workshop on Dependable Vehicular Communications*, 2015
  - Gallo, Laurent; Härri, Jérôme**, Short paper: A LTE-direct broadcast mechanism for periodic vehicular safety communications**, *IEEE Vehicular Networking Conference (VNC)*, 2013.

High Precision Positioning – Cooperative V2X 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 tessellation
- **Challenges -**
  - Asynchronous sampling
  - Not all neighbors are born identical
  - Correlation (space and time) in samples
  - Fusion of heterogeneous sensors



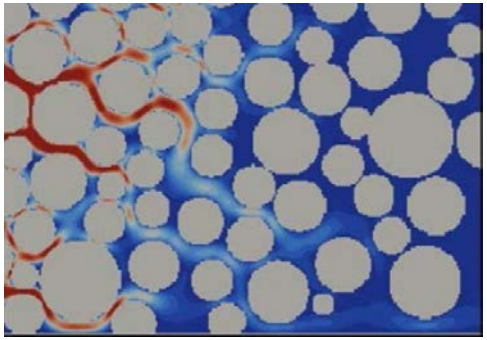


- **Selected Publications:**
  - Gia-Minh Hoang, Benoît Denis, Jérôme Härri, Dirk TM Slock, **Breaking the Gridlock of Spatial Correlation in GPS-aided IEEE 802.11p-based Cooperative Positioning**, *IEEE Transaction on Vehicular Technology*, 2016
  - Gia Minh Hoang, Benoît Denis, Jérôme Härri, Dirk TM Slock**, Select Thy Neighbors: Low Complexity Link Selection for High Precision Cooperative Vehicular Localization***, IEEE Vehicular Networking Conference (VNC)*, 2016, Kyoto, Japan
  - Minh Gia Hoang, Benoît Denis, Jérôme Härri, Dirk TM Slock, **Cooperative Localization in GNSS-Aided VANETs with Accurate IR-UWB Range Measurements**, 13th *IEEE Workshop on 13th Workshop on Positioning, Navigation and Communications (WPNC)*,

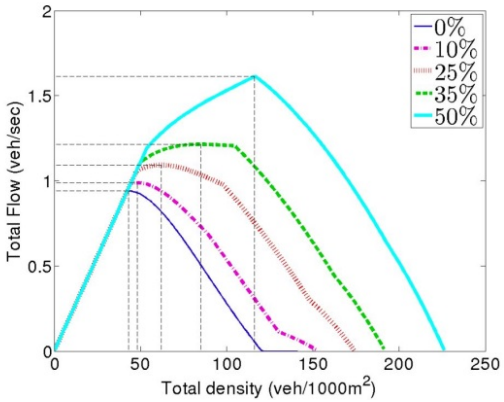
Cooperative (Automated) Powered-Two-Wheelers Future V2X

- **Powered-Two Wheelers (PTW):**
  - Increasing presence in road traffic
  - Lack of knowledge of their influence on traffic flows
  - Critical impact on Smart Cities and Road Automations
  - C-ITS applications are not adapted to PTW
    - New WG at CAR 2 CAR in 2016

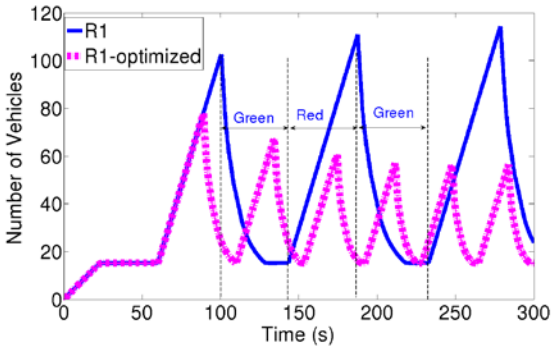
Porous Flow Modeling



Improved Road Capacity



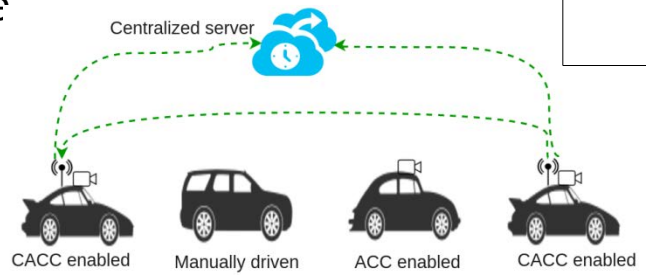
Optimized Traffic Lights



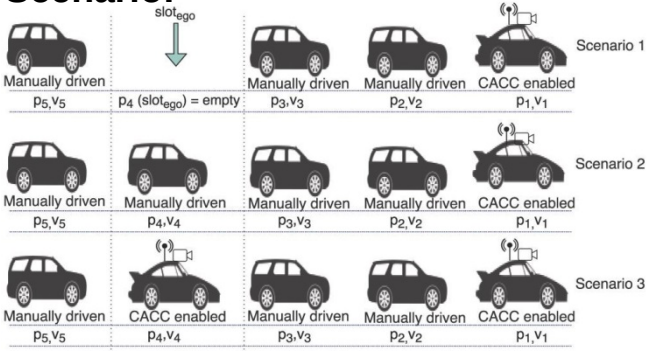
- **Selected Publications:**
  - Sosina Gashaw, Paola Goatin, Jérôme Härri, **Modeling and Analysis of Mixed Flow of Cars and Powered Two-wheelers**, *Elsevier Transportation Research Part C*, under review.
  - Sosina Gashaw, Paola Goatin, Jérôme Härri, **Analysis of the effect of Powered two wheelers on adaptive traffic signals operation,** *8th International Conference on Mobility and Transport (Mobil.TUM)*, TU Munich, Germany 2017.
  - Sosina Gashaw, Paola Goatin, Jérôme Härri, **Modeling and analysis of mixed flow of cars and powered two wheeelers**, *Transport Research Board (TRB) Annual Meeting*, Washington DC, 2017

Cooperative Control – Mixed Automated Vehicles at Low Penetration

- **Mixed Automated / Legacy Traffic:**
  - Automated vehicles represents the future of transportation
  - They will need to share road with legacy vehicles
  - Challenge: how can automated vehicle help avoid collision ?



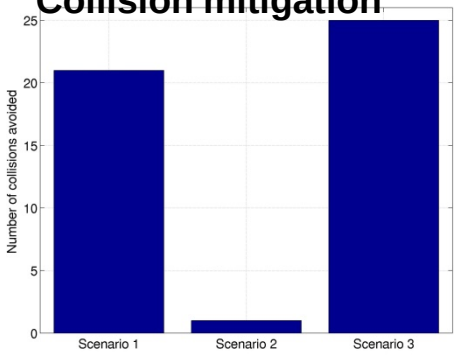
Scenario:



Benefits

- Automated vehicle allows capacity increase at no safety reduction
- Already at low penetration !!

Collision mitigation



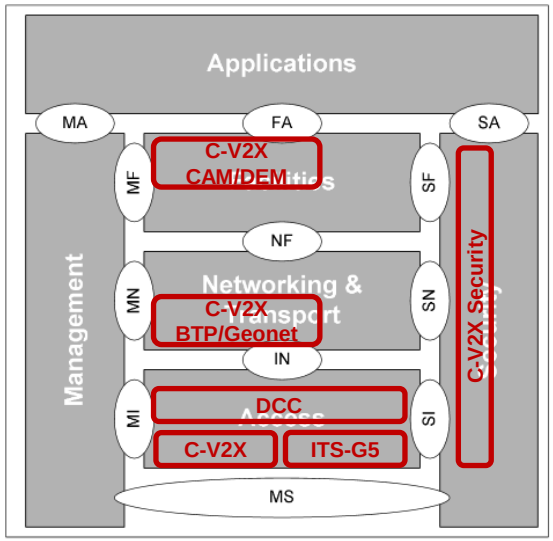
- **Selected Publications:**
  - Raj Haresh Patel, Jérôme Härri, Christian Bonnet, **Impact of localization errors on automated vehicle control strategies**, IEEE Vehicular Networking Conference, November 27-29, 2017, Torino, Italy
  - Patel, Raj Haresh; Härri, Jérôme; Bonnet, Christian, **A collision mitigation strategy for intelligent vehicles to compensate for human factors affecting manually driven vehicles**, ITSC 2017, IEEE 20th International Conference on Intelligent Transportation Systems, October 16-19, 2017, Yokohoma, Japan
  - Raj Haresh Patel, Jérôme Härri, Christian Bonnet, **Cooperative Braking in Mixed Traffic Scenario considering Imperfect Position Information,** *8th International Conference on Mobility and Transport (Mobil.TUM)*, TU Munich, 2017..
  - Raj Haresh Patel, Jérôme Härri, Christian Bonnet, **Braking strategy for an autonomous vehicle in a mixed traffic scenario,** accepted, *3rd IEEE Conference on Vehicle Technology and Intelligent Transport Systems*, 2017, Porto, Portugal.

PANEL STATEMENTS

Future V2X – Where we are !!

- **ITS-G5 Technology ready for deployment**
- **Initiating ITS-G5 rel. 2**
  - VHT & OCB
  - 5Ghz & 64GHz

- **3GPP specification freeze in July 2017**
  - Target: CAM/BSM communication
- **In October 2017, Cellular Stakeholders proposed multiple WI to ETSI ITS for LTE-V2X**
  - C-V2X is expected to be integrated in ETSI ITS in 2018
  - Access Technology -
    - LTE-V2X mode 3-4 rel.14 on PC5 for V2V
    - LTE-V2X on Uu for V2I/V2N communication

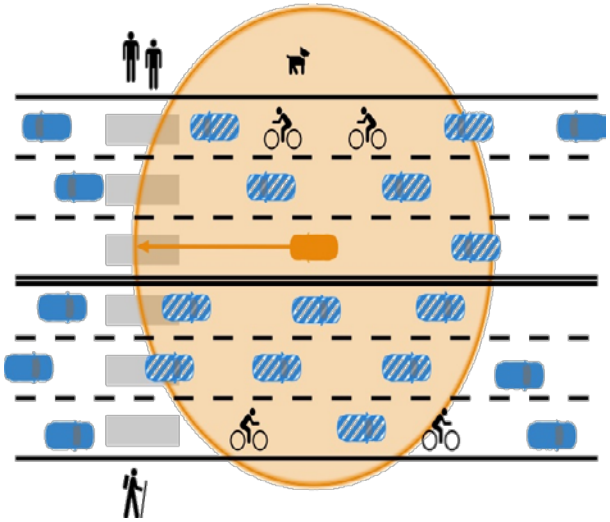


Future V2X – Think before talk and Understand what you need to say !!

- **V2X Communication stems from VANET**
  - Periodic GPS trasmission of ‘beacon’
  - It is not adapted to safety-critical C-ITS application

- **DAY 1 C-ITS**
  - Complex DCC mechanisms managed to adapt it to DAY 1 C-ITS applications

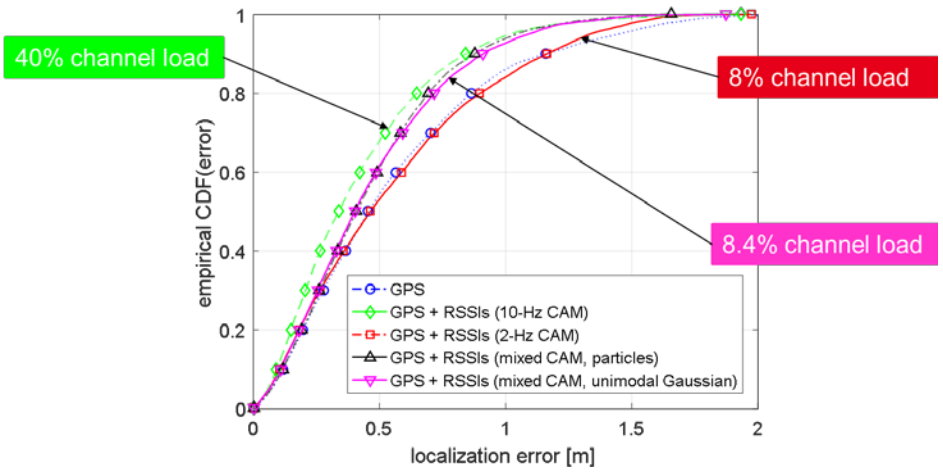
- **DAY 2 C-ITS**
  - Cannot ‘simply’ adapt….need to think differently
  - Not a technology issue:
    - ITS-G5 is certainly capable of matching DAY 2 C-ITS requirements
    - LTE-V2X is not the ‘white night’ going to save C-ITS…



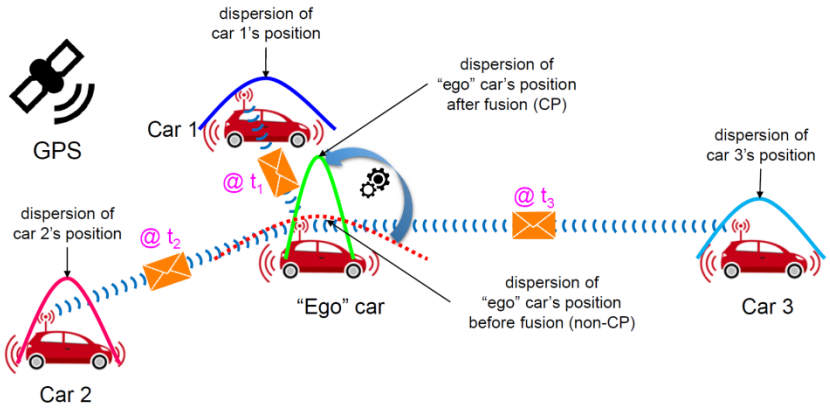
Now, more than ever, we need to first think what we need to transmit, not which technology to use !!!

Thinking before Talking – Example to High Precision Positioning

- **Precise Awareness Message (PAM) –**
  - Providing sub-meter awareness ‘precision’



Source: Minh Hoang, CEA - EURECOM



By transmitting the input of fusion filter instead of basic GPS, can save <u>significant channel resource</u> !!

Understand what you need to Say – Example to Automated Driving

- **Modeling of Highly Autonomous Driving**
  - Platoon control: time-based acceleration control
    - Need high update rate, vulnerable to packet losses
  - Trajectory control: Prediction and Anticipation
    - Model Predictive Control -
      - ☞ Optimize over a Predictive Horizon, but only implement the Control Horizon
        - Then re-optimize
        - If information is lost, apply the previous optimization
      - ☞ Less vulnerable to losses

Control inputs/indications might not be required as we expect – potential benefit to V2X

Designing future V2X will require the understanding on Control Mechanisms (..and traffic modeling)

Future V2X – Stop Fighting & Cooperate !!

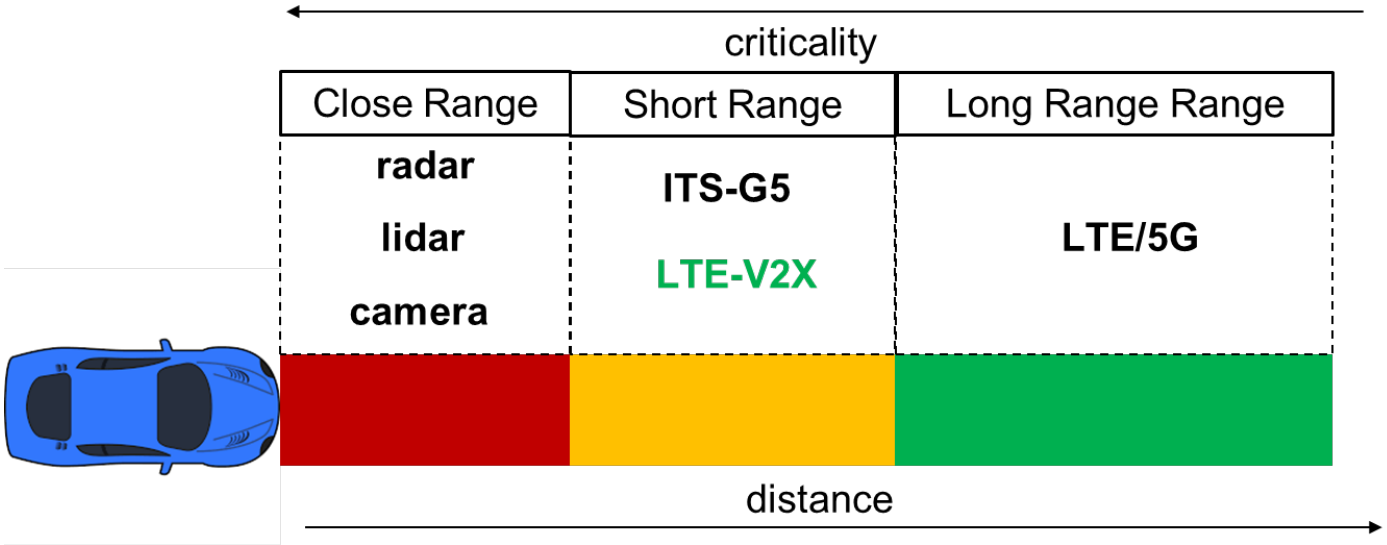
- **Future HAD will be critically based on V2X communication**
  - So far, one technology only (ITS-G5) !
    - can fail, can be hacked, can be jammed

- **Parallel to Avionics**
  - Redundant Paths – each communication path is redundant !!
  - Functional Redundancy – each function is redundant !!
    - Example: Speed measurement: 3 probes from at least two constructors
  - Design Diversity – different computer design, different software development tools, etc…

- **What about future Autonomous Cars (cars in 'autopilot') ?**
  - Will also need similar strategies….

- **LTE-V2X and ITS-G5 two different technologies aiming at providing a similar service…**
  - Friends or Foes ?

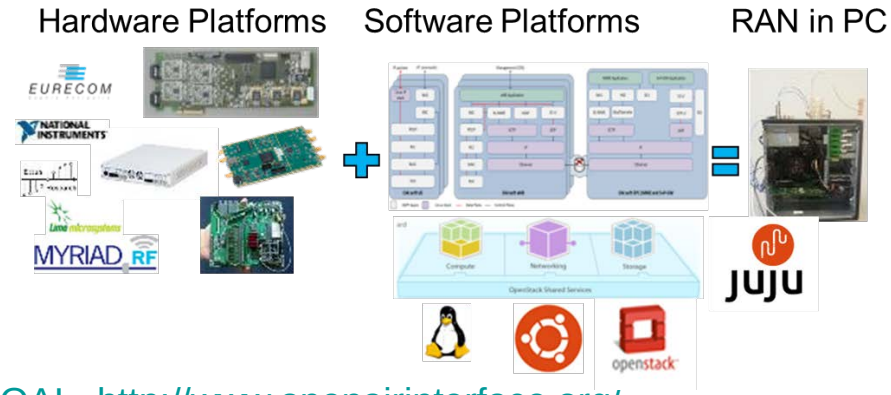
Future V2X – Stop Fighting & Cooperate !!



<u>Two technologies are an advantage</u>: can provide redundancy and be more resilient to failure and attacks !!

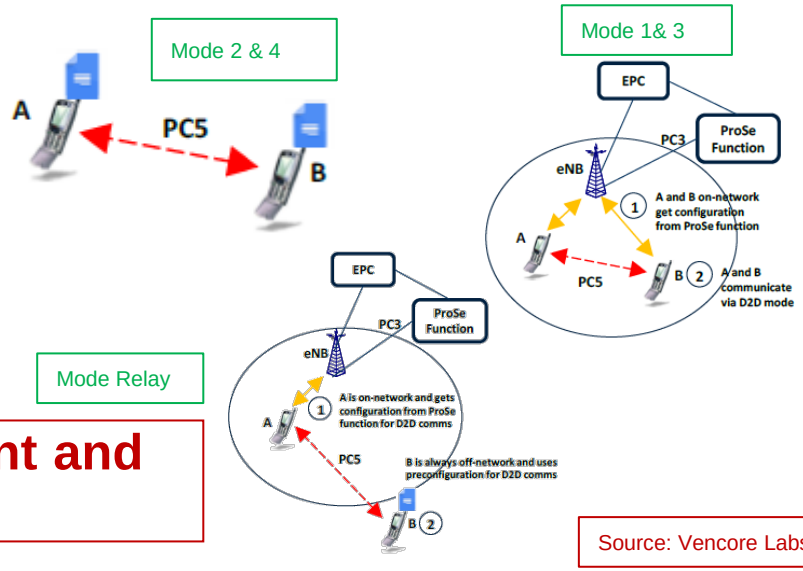
Future V2X – Speak Openly !!

- **Extension of OAI for Slidelink communication**
  - LTE Rel.14 compliant
  - Supporters:
    - EURECOM (FR)
    - Orange Labs (FR)
    - Vencore Labs (US)
  - Objective: 1st Open V2X/D2D Platform



OAI - http://www.openairinterface.org/

- **Architecture:**
  - Operation Mode:
    - LTE Prose Public Safety
      - Mode 1 & 2
      - LTE Relay mode
    - LTE-V2X
      - Mode 3 & 4



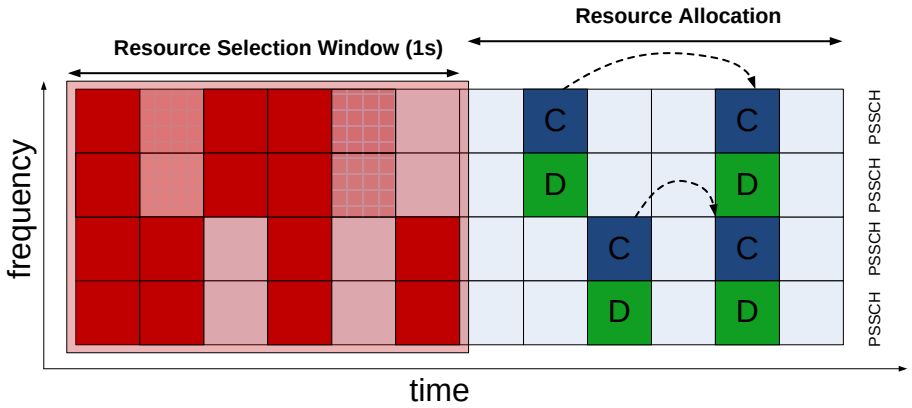
- **First prototype to be ready early 2018 !**

Open Platforms allow faster development and cooperation !!

Source: Vencore Labs

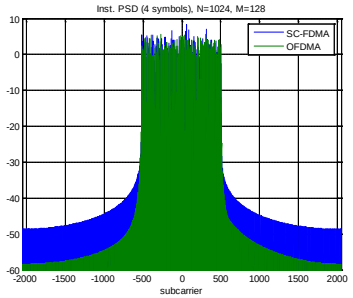
Cellular V2X Challenges (some)

- **3GPP rel.14 mode 4 Resource Allocation proposal:**
  - Semi-Persistent Scheduling
    - UE reserves RB over consecutive Sub-frames
  - Listen-before-Talk access
    - RSSI-based resource selection
      - 1s monitoring windows
      - Selection of the 20% RB with lowest RSSI



- **Challenges**
  - Resource Selection Window
    - Must listen a (random) time to get the statistics of the SL-Resource pools
    - Challenging in highly dynamic networks and highly spontaneous communications
  - Half-Duplex
    - Two UE cannot simultaneously TX and RX on the same SF
  - PAR and adjacent RB power leakage
    - A UE should RX all RX in same SF at ‘similar RX power
    - Adjacent RBs might experience power leakage
  - These aspect leads to performance degradation not sufficiently investigated

Cellular V2X Challenges - Coexistence



- **EU Rule - Technology neutrality of the ITS-G5 band**
  - Both ITS-G5 and LTE-V2X can be granted access
  - Must not alter one-another performance !!

- **Challenge:**
  - ITS-G5 is currently using the ITS-G5 spectrum
  - Can LTE-V2X use the ITS-G5 bands without interfering with ITS-G5 technology?
    - SC-FDM has a larger out-of-band spectrum emission…

source: