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

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CATS Evolution: from Awareness to Autonomy

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

ICN, MEC, SDN, Caching

C-V2X, ITS-G5

VRU

Mixed Robots

Cooperative Mobility

Cooperative Control
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 Härrri, 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 Härrri, 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.
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:**
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, *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

- **Selected Publications:**
  - Sosina Gashaw, Paola Goatin, Jérôme Härrri, *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.

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Porous Flow Modeling

Improved Road Capacity

Optimized Traffic Lights
Cooperative Control – Mixed Automated Vehicles at Low Penetration

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

- **Scenario:**
  - **Scenario 1:** CACC enabled
  - **Scenario 2:** Manually driven
  - **Scenario 3:** CACC enabled

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

- **Selected Publications:**
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 transmission 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’

By transmitting the input of fusion filter instead of basic GPS, can save significant channel resource!!
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 ?
Two technologies are an advantage: 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

- **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 !!
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