Vehicular Wireless Networks: What should the future hold?

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Evolution Phases in Vehicular Networks

- **Pioneer Phase**: 2000 - 2008
  - The gold Age of Vehicular Network

- **Consolidation Phase**: 2008 - ?
  - Becoming Wise(r)

- **Deployment Phase – New Applications**: 2013 (EU) - ?
  - Bringing it to Reality
  - ...and...
  - Selling it!

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FP7 Drive CAR-2-X

- **Major European Field Operation Test**
  - Spans multiple national FOTs
  - 32 partners, 10 support partners and 18.9 million Euro budget

- **Objectives:**
  - Laying the foundation for rolling out cooperative systems in Europe.
  - Testing ~22 use cases in traffic safety/efficiency and comfort in real deployments
  - ETSI-compliant
    - Contribute or implement ETSI ITS standards

- **Challenges:**
  - Interoperability of hardware and Software
  - Data availability and data quality
  - Scalability of technical testing
  - …

- **National FOTs**
  - French SCORE@F: [http://blog.inria.fr/scoref/](http://blog.inria.fr/scoref/)
  - German SIM-TD: [http://www.simtd.org/](http://www.simtd.org/)

The world of Vehicular Wireless Networks

- Not sounding too dramatic:
  - Have we asked ourselves the right questions?
  - What will come next?
Multiple Antenna Techniques and Testing

- Impact of Antenna Placement on vehicles:
  - Unidirectional Radiation:
    - Cumulative percentage packet error:

Source: S. Kaul et al., “Effect of Antenna Placement and Diversity on Vehicular Network Communications”, ICC 2010
Multiple Antenna Techniques and Testing

- The antenna challenge
  - Multi-standard & multi-mode functionality
  - Integration of multiple antennas with **limited form factors**
  - Integrated into a dielectric housing

Source: Oliver Klemp, BMW R&D, Munich, Germany, Oliver.Klemp@bmw.de
Application(s)-centric: Information Relevance

- Information relevance communication
  - Information does not have the same worth/relevance in space or time
  - Not adapted to application requirements
  - **Channel Congestion**: cannot provide maximal freshness and coverage everywhere
    - But could adjust transmit profiles to provide it where and when needed

- **Example**: Cooperative Application-based TX Rate control

[Source: Fatma Hrizi, Jérôme Härr|, Christian Bonnet, "Every Bit Counts: Tracking and Predicting Awareness"]

- **Example**: Cooperative Application-based TX Power control

[Source: Miguel Sepulcre, Javier Gozalvez, Jérôme Härr|, and Hannes Hartenstein, "Application-based Congestion Control Policy for the Communication Channel in VANETs"]
LTE-Advanced for Vehicular Networks

- LTE-Advanced specifies extensions of the basic architecture to support
  - Relay Stations
  - Femto e-NBs

- Both are expected to become part of vehicles
  - The LTE-A X2 link provides a data link between Relay Stations

- How will 802.11p and LTE-A RS/Femto coexist?
  - Will share similar issues
    - Mobility, connectivity, scheduling, interferences
Electro-Mobility and Smart Grids

- Distributing the Charging station
  - In Points of Interests
  - As function of mobility

- Designing the communication networks
  - At the charging stations
    - Multiple interfaces
  - Between charging stations

- Objective Function of electro-mobility
  - Optimization of Energy
    - quick-load vs. long charge
    - Shortest path vs. least energy demanding path
    - Selling energy vs. using it
Urban Sensing and Vehicular Clouds

- **What does a vehicle contain?**
  - Antennas, head unit,…
  - Also: storage and processing capabilities
    - Could be used!!

- **What does a vehicle do?**
  - Gathers a large amount of data
    - What to do with it?
    - Where to store it?
    - Where to process it?

- **Vehicles are connected and part of a vehicular cloud**
  - Mobile storage, mobile processing…
Large Calibrated Vehicular Scenarios

- Evaluation of applications and protocols require reference scenarios
  - Need to be
    - Large scale topologies
    - Calibrated mobility and validated environment
    - Capable of various context
      - In space & in time
    - Widely accepted by the community

- Current developments
  - City of Zurich (MMTS traces)
    - Mesoscopic urban mobility
  - City of Karlsruhe, Germany (support: PTV, City of Karlsruhe, KIT):
    - Calibrated mobility and propagation of part of the city center
  - City of Braunschweig, Germany (support: city of Braunschweig, DLR, University of Hannover)
  - City of Cologne, Germany (support: INSA Lyon)
    - Calibrated 400km2 micro and macro mobility

Source: Sandesh Uppoor, Marco Fiore, "Vehicular mobility in large-scale urban environments", ACM Mobicom 2011, Poster Session
And what Future holds?

- This…

- Fully automated car
  - Awareness provided by
    - Sensors and radars
  - Google map-based navigation

- 1600 km automatic driving… 1 single accident!