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Vehicular Wireless Networks: What should the future hold?

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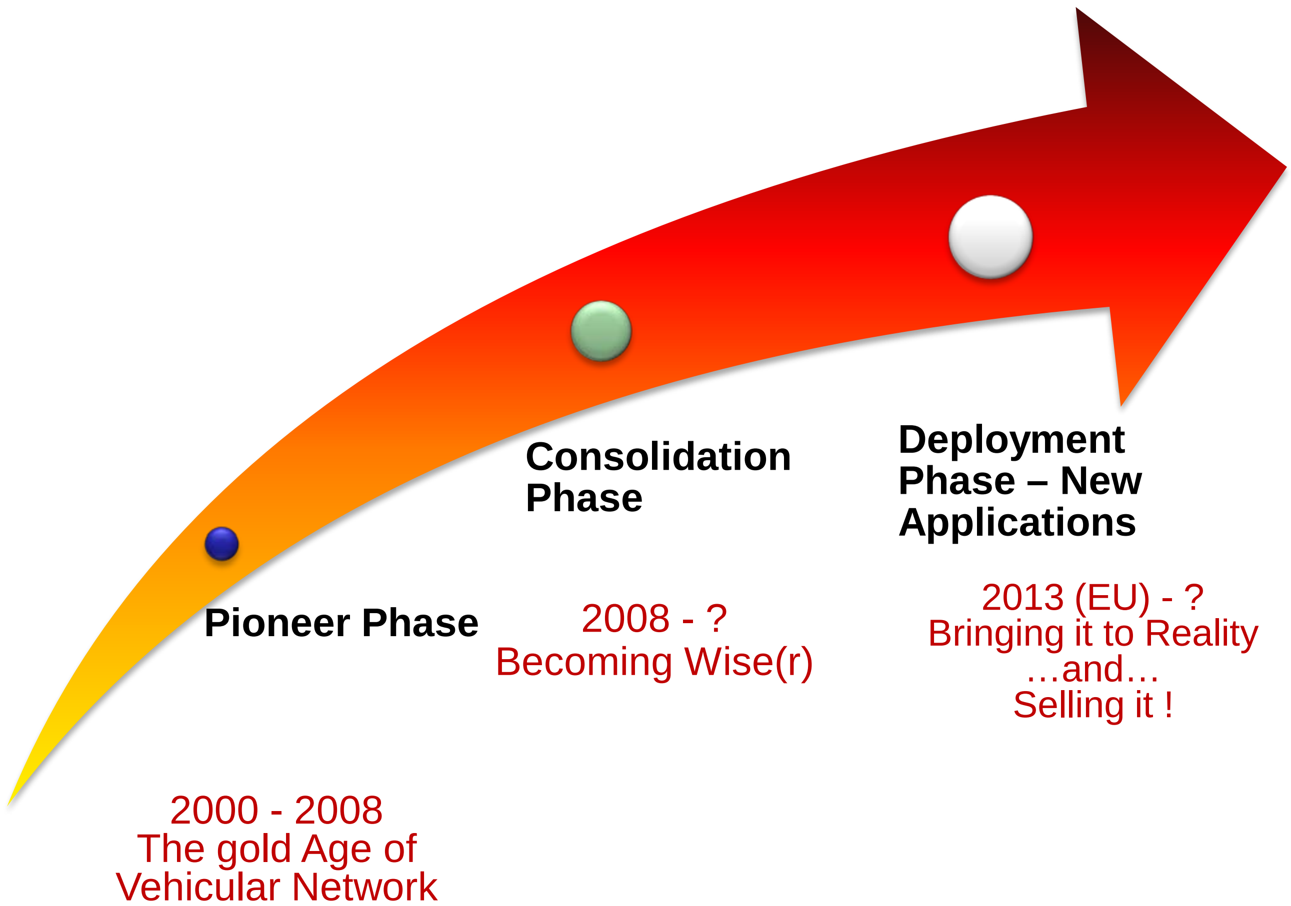
Evolution Phases in Vehicular Networks

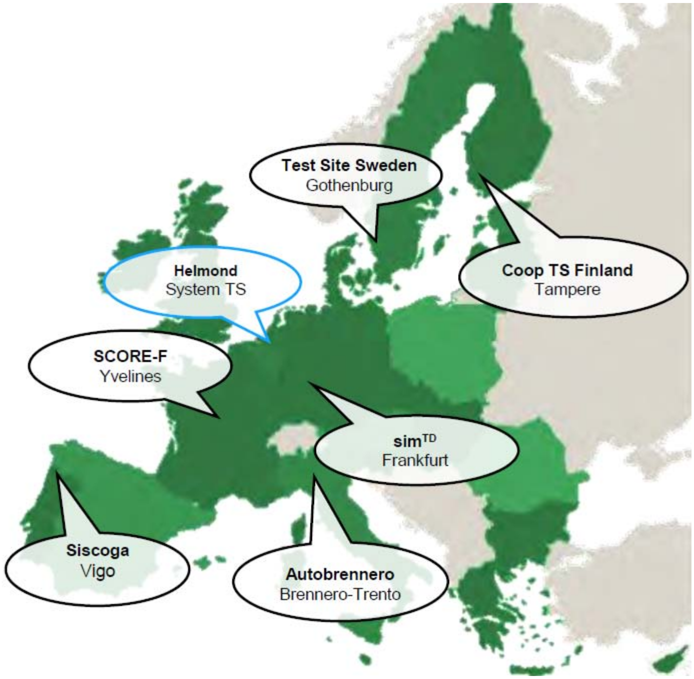


FP7 Drive CAR-2-X

- **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 i Europe.
  - Testing ~22 use cases in traffic safety/efficiency and comf 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/
  - German SIM-TD: http://www.simtd.org/

website: http://www.drive-c2x.eu/

The world of Vehicular Wireless Networks

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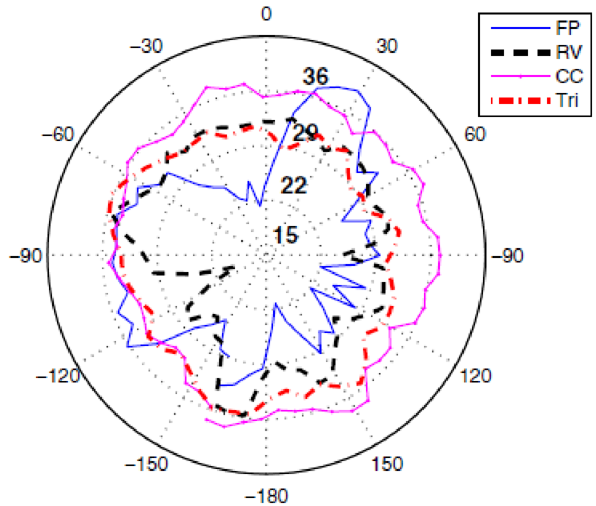
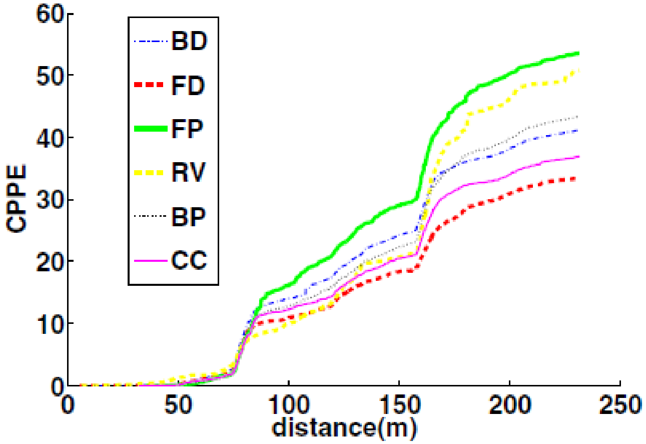
- **Not sounding too dramatic:**
  - Have we asked ourselves the right questions?
  - What will come next ?

Multiple Antenna Techniques and Testing

- **Impact of Antenna Placement on vehicles:**
  - Unidirectional Radiation:



  - *Cumulative percentage packet error:*

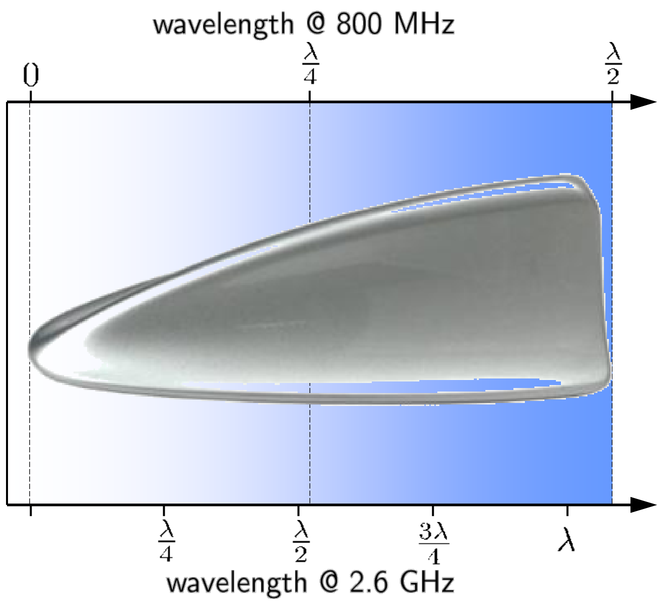


Legend:
- FP: Front Passenger
- FD: Front Driver
- BD: Behind Passenger
- CC: Car root center
- RV: Rear-view Mirror
- CC: Car-roof Center

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



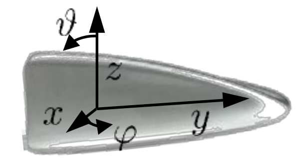


Fig. 3: Dielectric housing

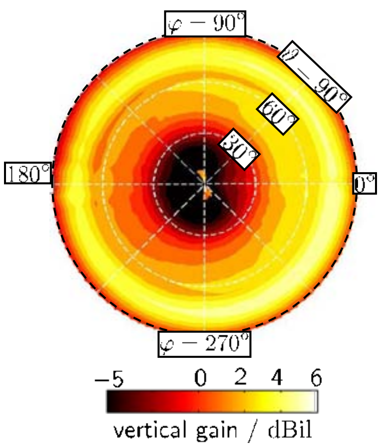


Fig. 1: Standalone Antenna

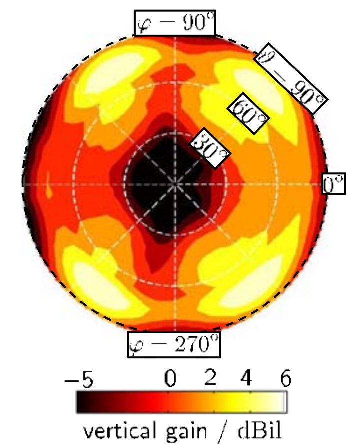
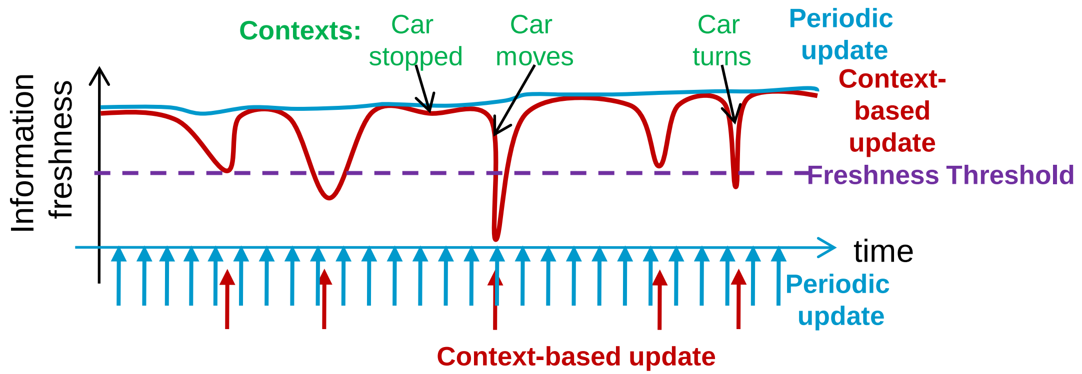


Fig. 2: Antenna with dielectric housing

Source: Oliver Klemp, BMW R&D, Munich, Germany, Oliver.Klemp@bmw.de

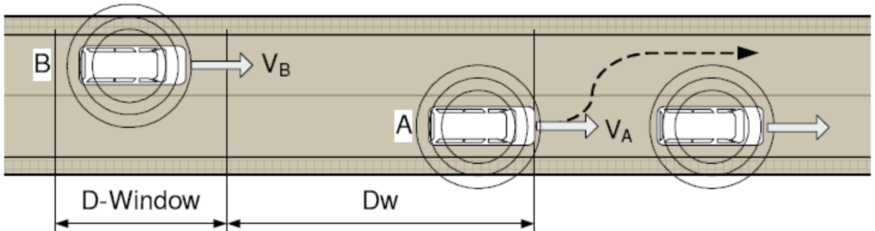
Application(s)-centric: Information Relevance

- **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 Härri, Christian Bonnet, " **Every Bit Counts: Tracking and Predicting Awareness**"]

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

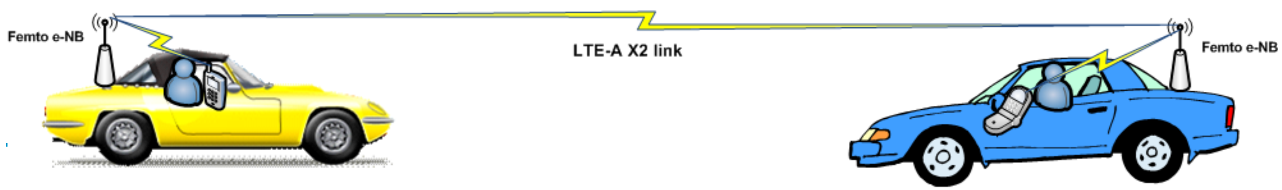


[Source: Miguel Sepulcre, Javier Gozalvez, Jérôme Härri and Hannes Hartenstein, " **Application-based Congestion Control Policy for the Communication Channel in VANETs**"]

LTE-Advanced for Vehicular Networks

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

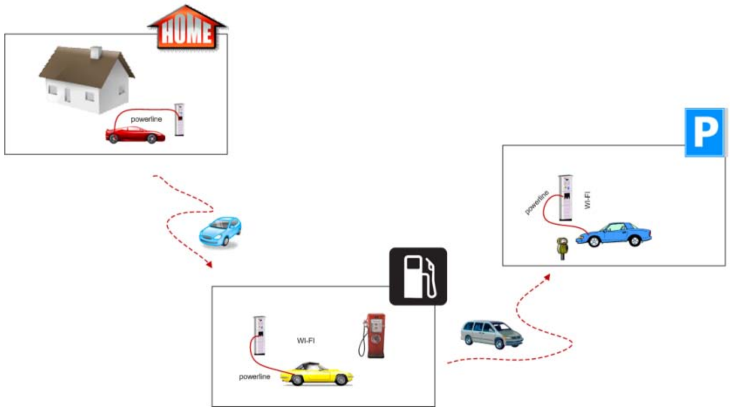
- **Both are expected to become part of vehicles**
  - The LTE-A X2 link provides a data link between Relay Stations



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

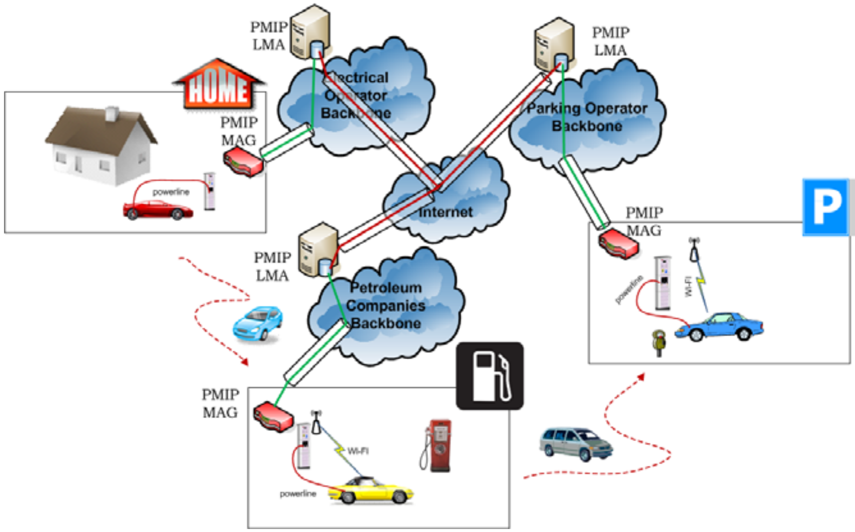
Electro-Mobility and Smart Grids

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



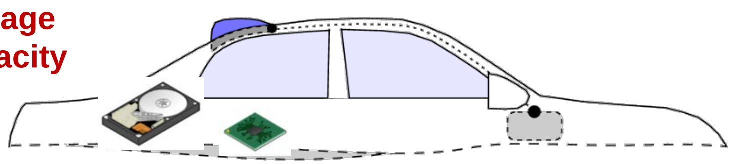
- **Designing the communication networks**
  - At the charging stations
    - Multiple interfaces
  - Between charging stations

- **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

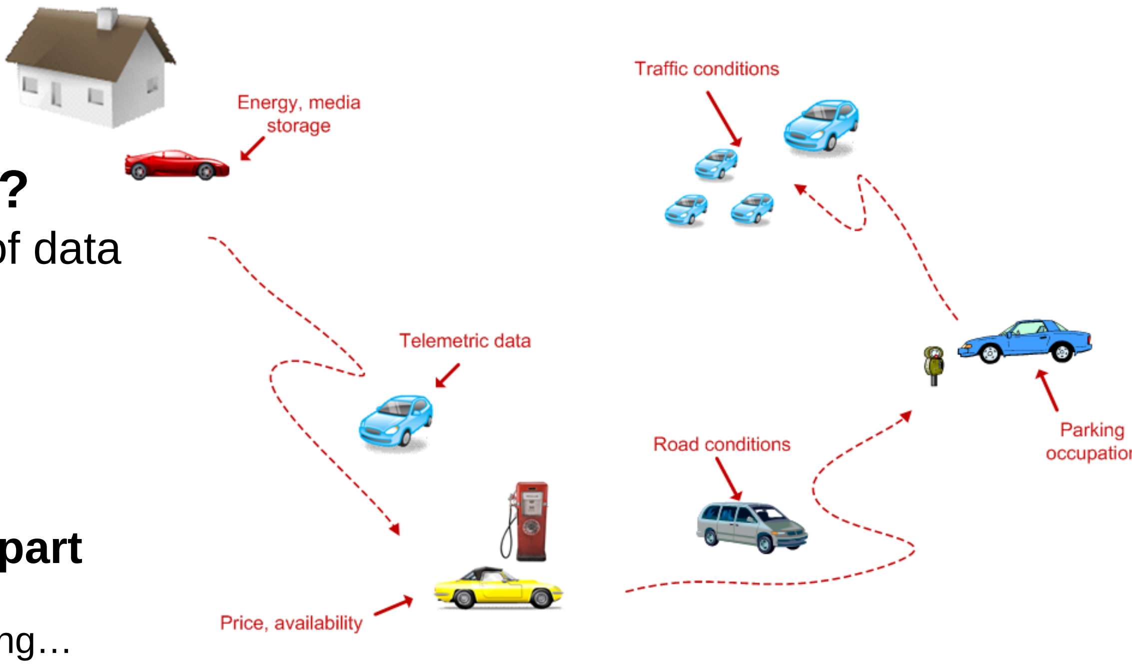


Urban Sensing and Vehicular Clouds

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



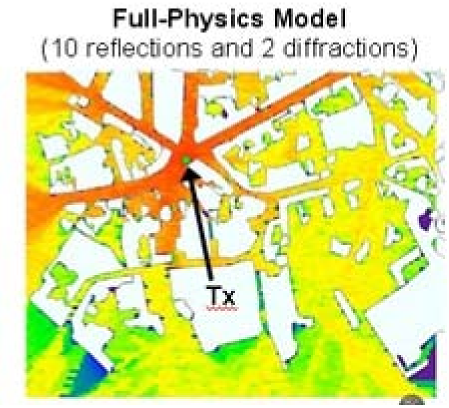
- **What does a vehicle do?**
  - Gathers a large amount of data
    - What to do with it?
    - Where to store it?
    - Where to process it?



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

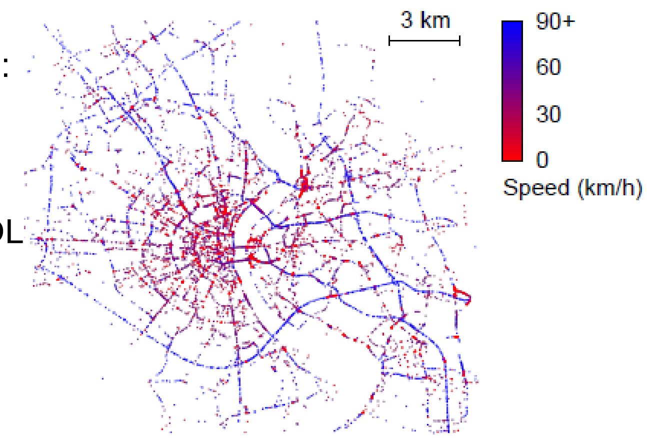
Large Calibrated Vehicular Scenarios

- **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



Source: AWE WinProp

- **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, DL 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~~ Google holds?

- **This…**

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

- **1600 km automatic driving… 1 single accident !**