EURECOM
Sophia Antipolis

Challenges in Intelligent Transportation Systems

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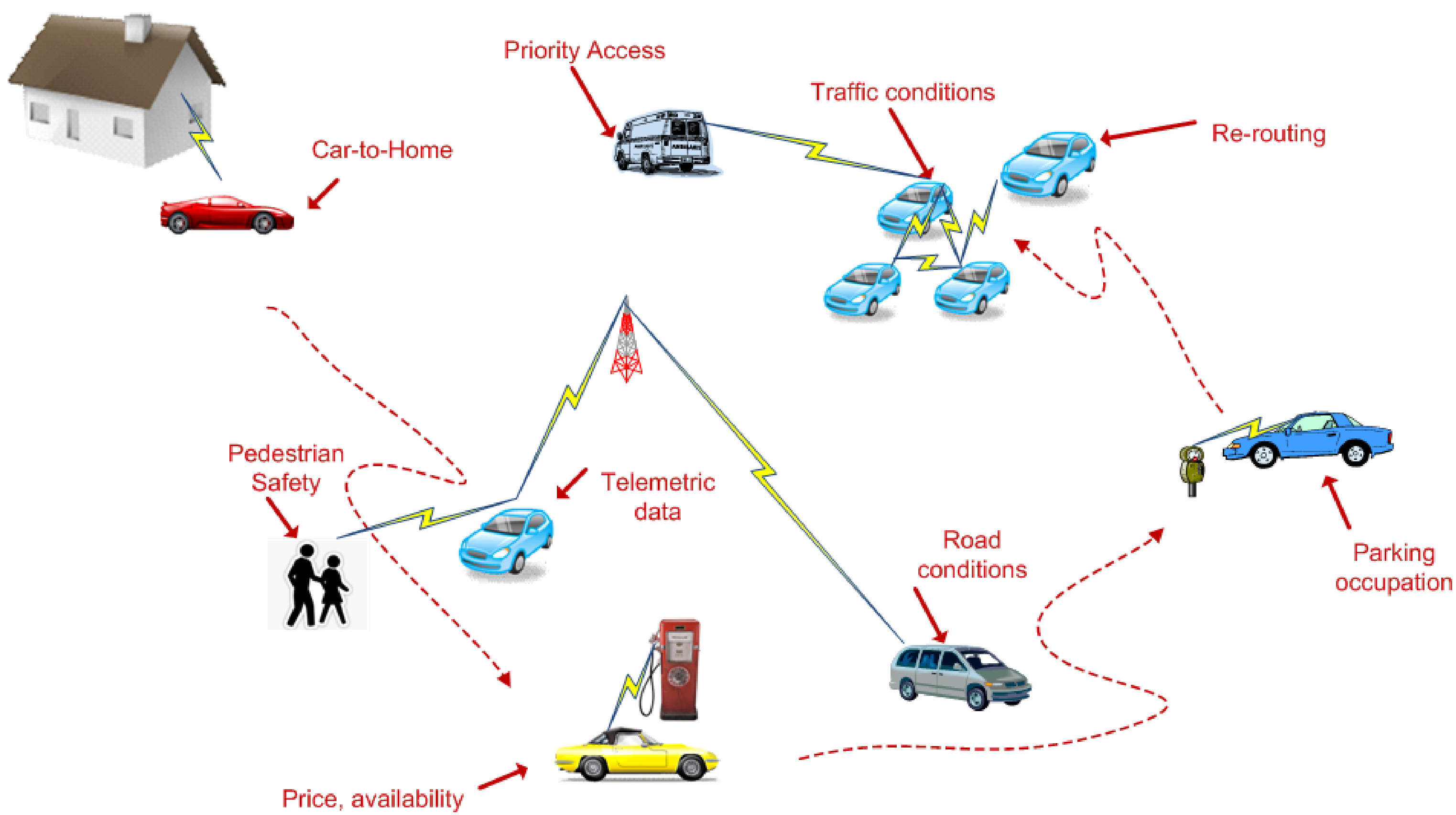
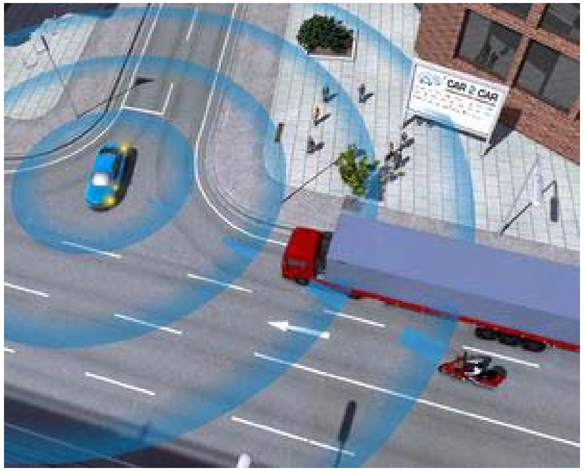
NTNU-EURECOM Workshop
Trondheim, Norway, September 22nd 2011

Intelligent Transportation Systems?



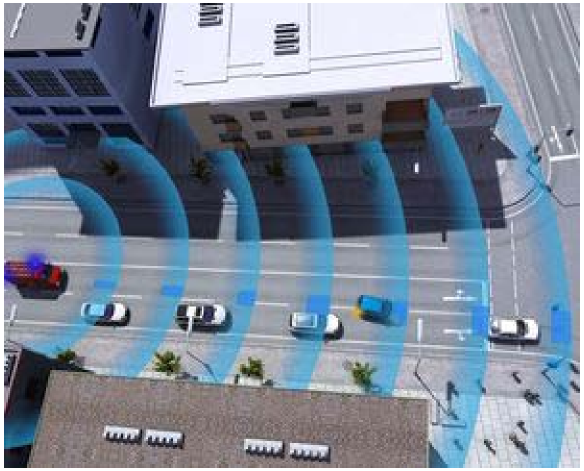
The Vision: Intelligent Vehicle / Transport



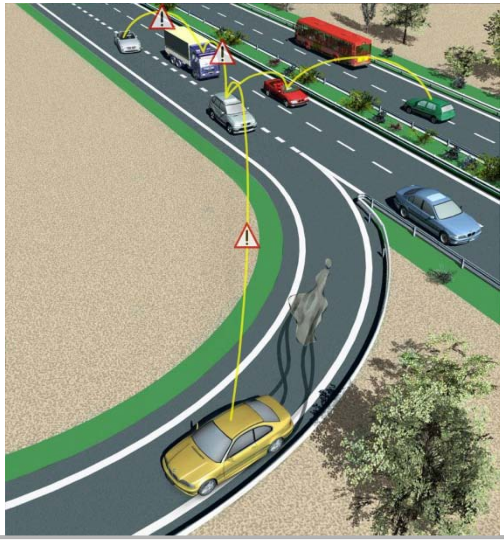
Motocycle Warning

Source:

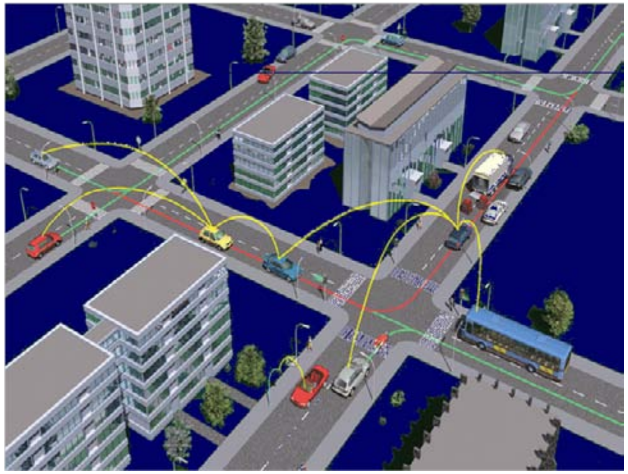
CAR 2 CAR COMMUNICATION CONSORTIUM



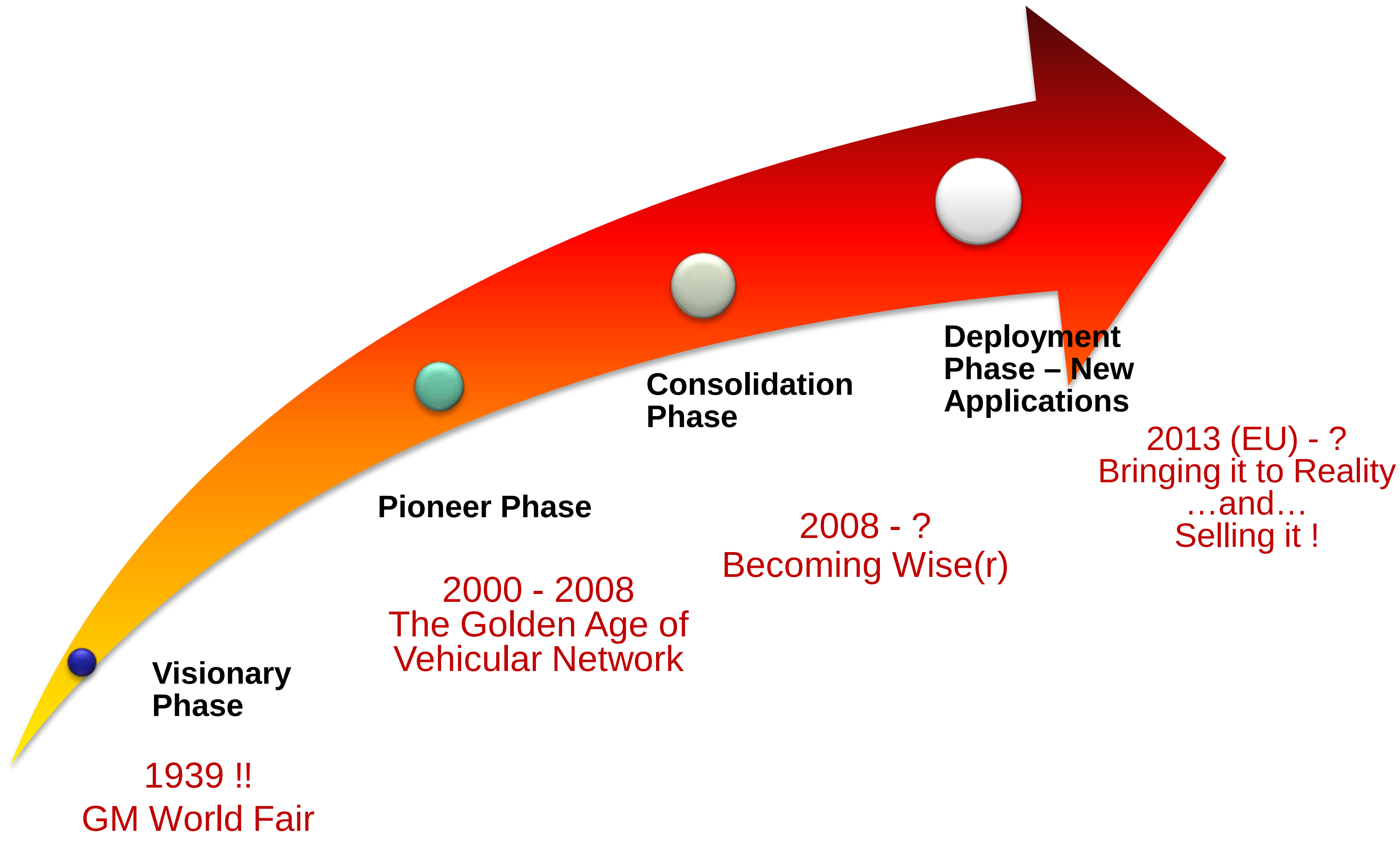
Emergency Vehicle



[Source: BMW F&T, for Network on Wheels]



Evolution Phases in Intelligent Transportation Systems



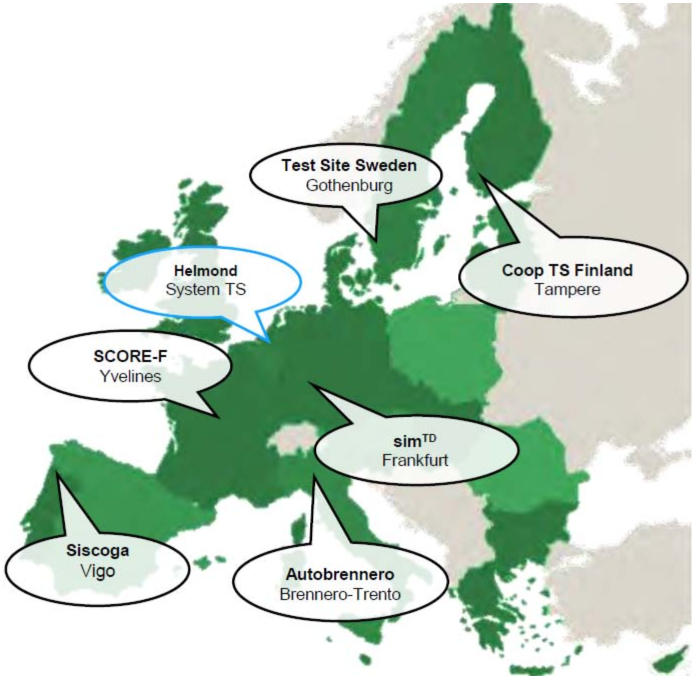
Visionary Phase…GM's FUTURAMA

Deployment Phase - 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
  - …

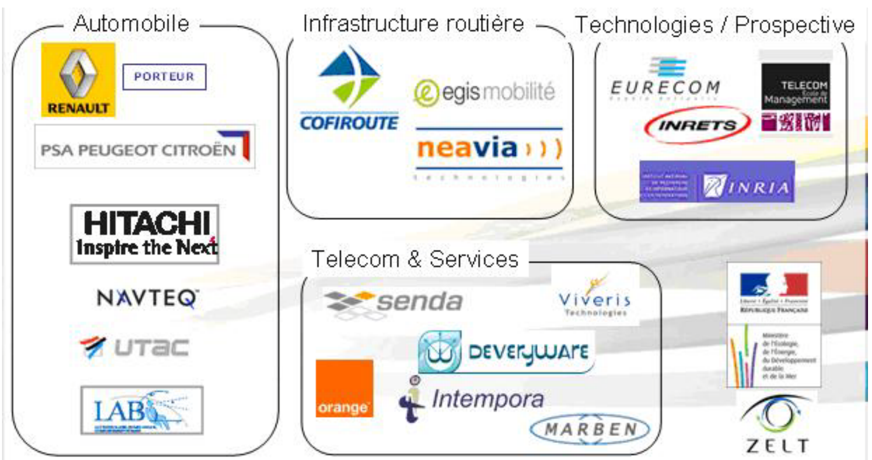


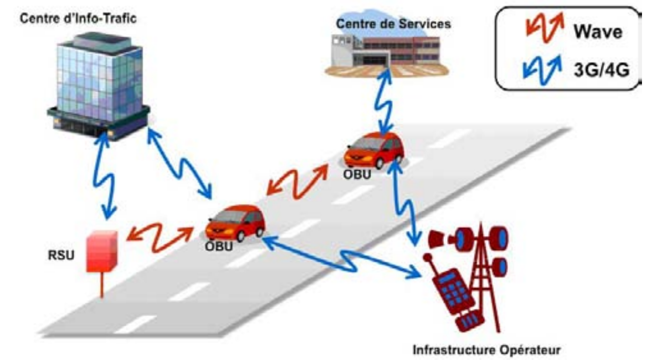
- **National FOTs**
  - French SCORE@F: http://blog.inria.fr/scoref/
  - German SIM-TD: http://www.simtd.org/

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

French FOT – SCORE@F

- **French FOT of cooperative road systems**
- **Project: 2010 – 2013**
  - Coordinator: Renault
- **National FOT, part of FP7 Drive C2X**
- **Contributions EURECOM**
  - Communication and Security Specifications
  - Heterogeneous Radio Access Specification
  - Use Case Evaluation
- **Partners:**





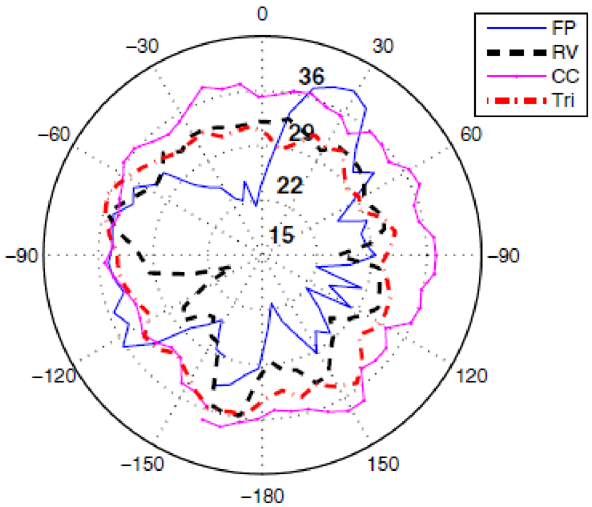
http://www.scoref.fr/

The world of Intelligent Transportation Systems

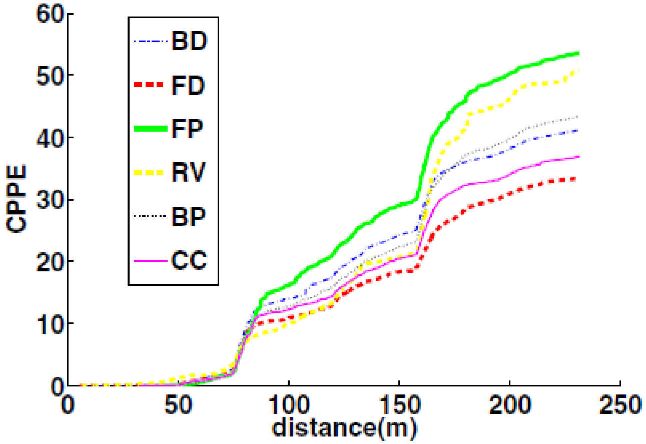
- **Not sounding too dramatic:**
  - Have we asked ourselves the right questions?
  - What will come next ?

Challenge 1:
Multiple Antenna Techniques and Testing

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



  - *Cumulative percentage packet error:*

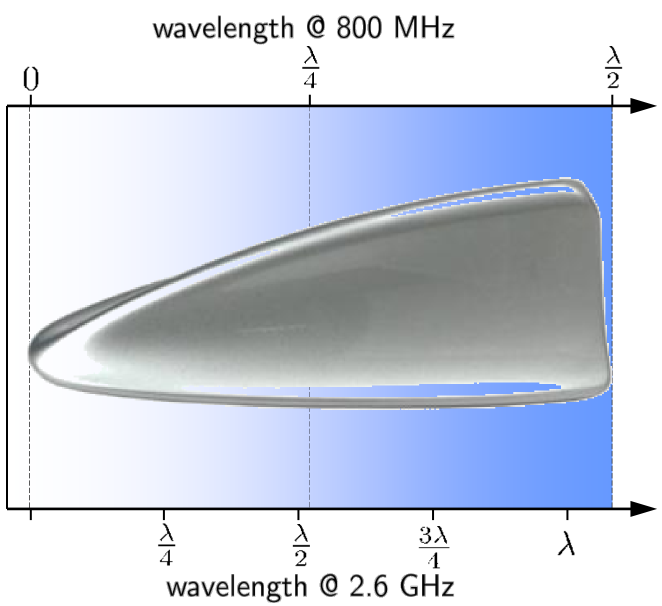


Legend:
- FP: Front Passenger
- FD: Front Driver
- BD: Behind Passenger
- CC: Car root center
- RV: Rear-view Mirror
- CC: Car-roof Center

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

Challenge 1:
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



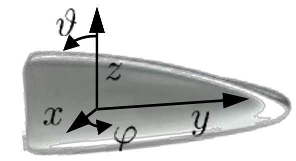


Fig. 3: Dielectric housing

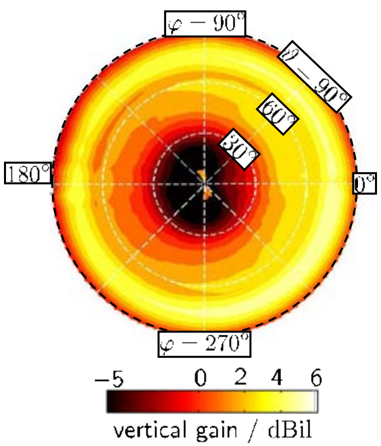


Fig. 1: Standalone Antenna

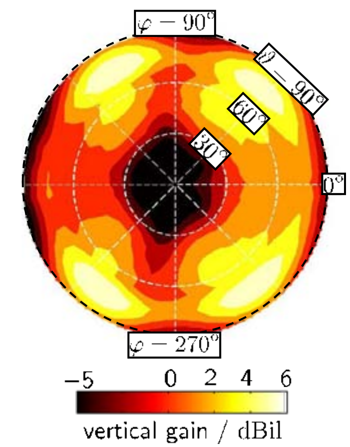
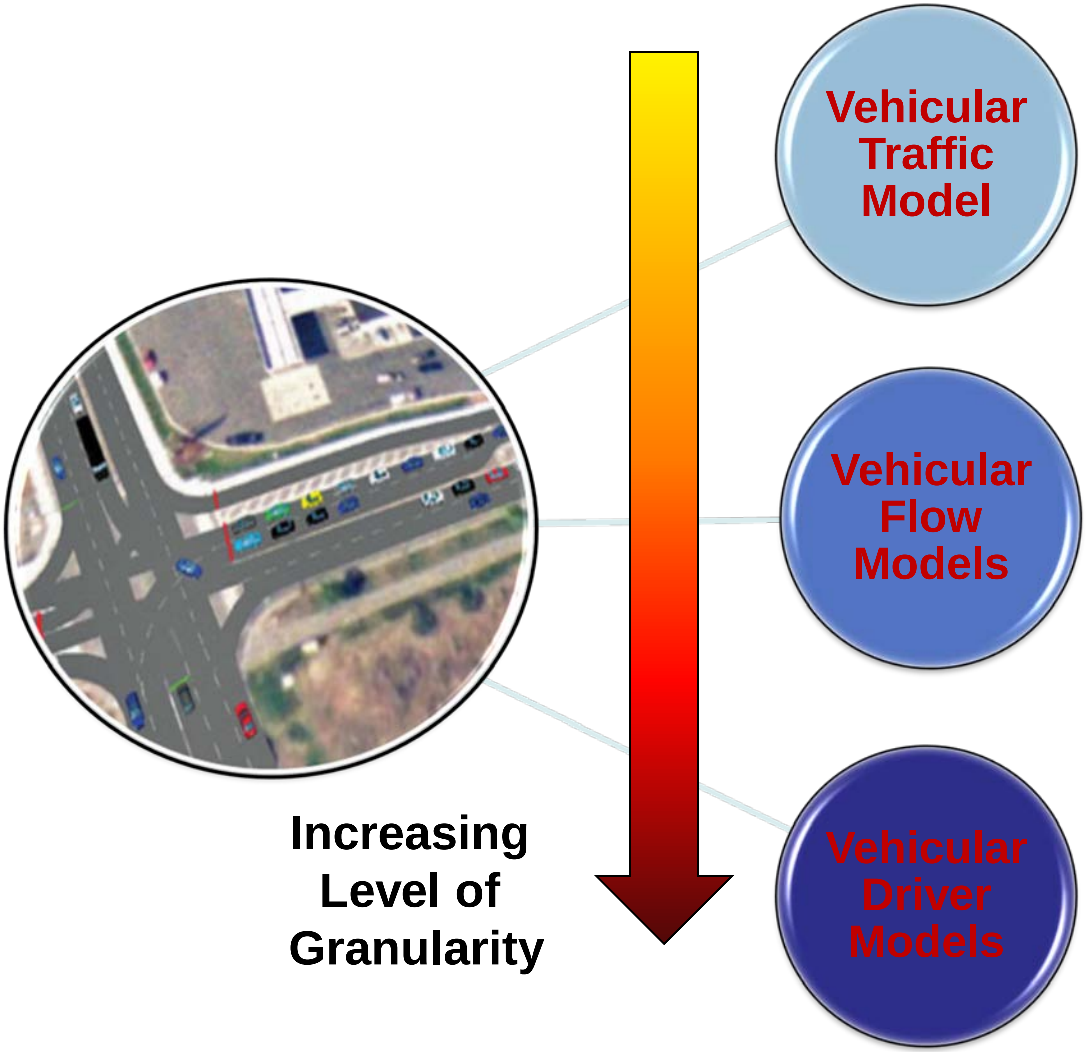


Fig. 2: Antenna with dielectric housing

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

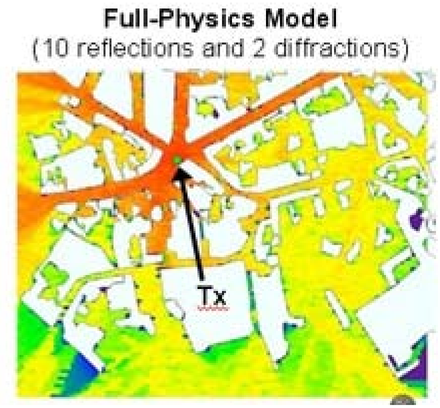
Challenge 2:
Multi-level Multi-Modal Mobility Modeling



- **Vehicular Traffic Models**
  - Represents the large scale trajectories employed by vehicles
- **Vehicular Flow Models**
  - Represent vehicular physical inter-dependencies
- **Vehicular Driver Models**
  - Represent the actions of breaks, turns etc.. on vehicles

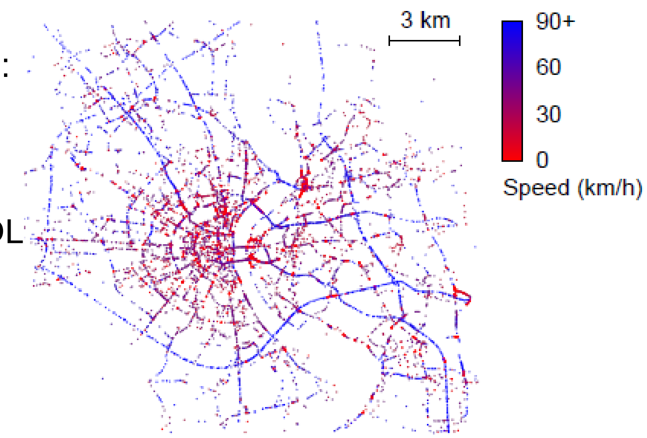
Challenge 3:
Large Calibrated ITS Scenarios

- **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

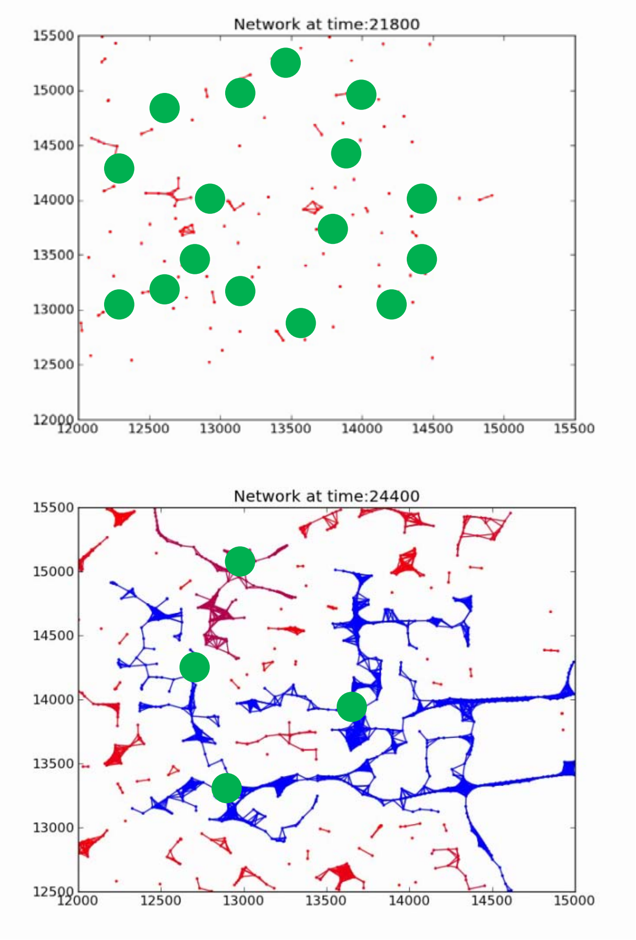
- **Current developments**
  - City of Zurich (MMTS traces)
    - Mesoscopic urban mobility
  - City of Karlsruhe, Germany (support: PTV, City of Karlsruhe, KIT):
    - Calibrated mobility and propagation of part of the city center
  - City of Braunschweig, Germany (support: city of Braunschweig, DL 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

Challenge 4: Vehicular Connectivity vs. Infrastructure Deployment

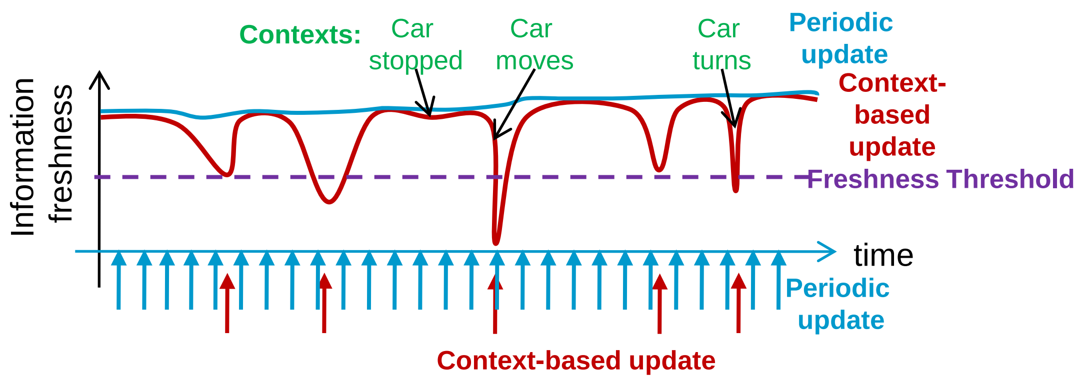
- **Sparse Initial Vehicular Network:**
  - Network strongly disconnected
    - Requires infrastructure assistance
- **Mature Vehicular Network:**
  - Network is clustered
    - Requires partial infrastructure assistance
- **Common Aspect:**
  - Deployment not based on coverage
    - Rather on context
      - Mobility, connectivity, degree..
- **Trade-off**
  - Optimizing connectivity: customer satisfied
  - Minimizing infrastructure size: provider satisfied



M. Fiore, J. Härri, The Networking Shape of Vehicular Mobility, ACM Mobihoc 2008, Hong Kong, 2008
P. Cataldi, J. Härri, User/Operator Utility-Based Infrastructure Deployment Strategies for Vehicular Networks, IEEE WiVEC 2011, San Francisco, 2011

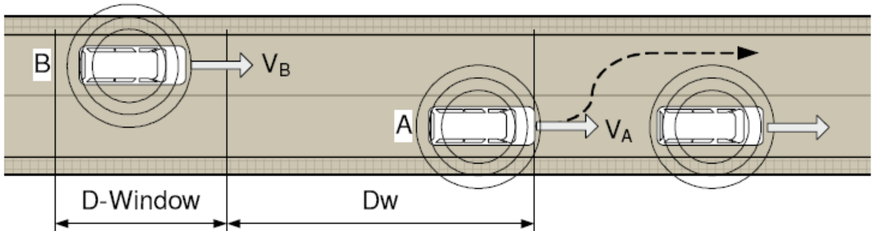
Challenge 5: Application(s)-centric - Information Relevance

- **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**"]

Challenge 6: Human Behaviors

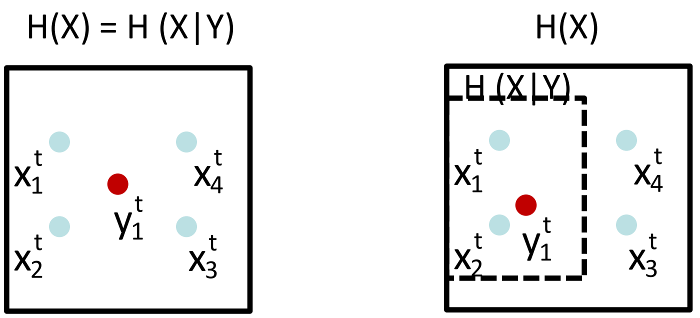
- **How to avoiding traffic accidents?**
  - Can only provide information
  - Cannot avoid stupidity !

- **What is creating the worst accidents**
  - On highway? - Overspeeding (french department Interior)
  - In urban environment? - Yield signs (City of Karlsruhe)

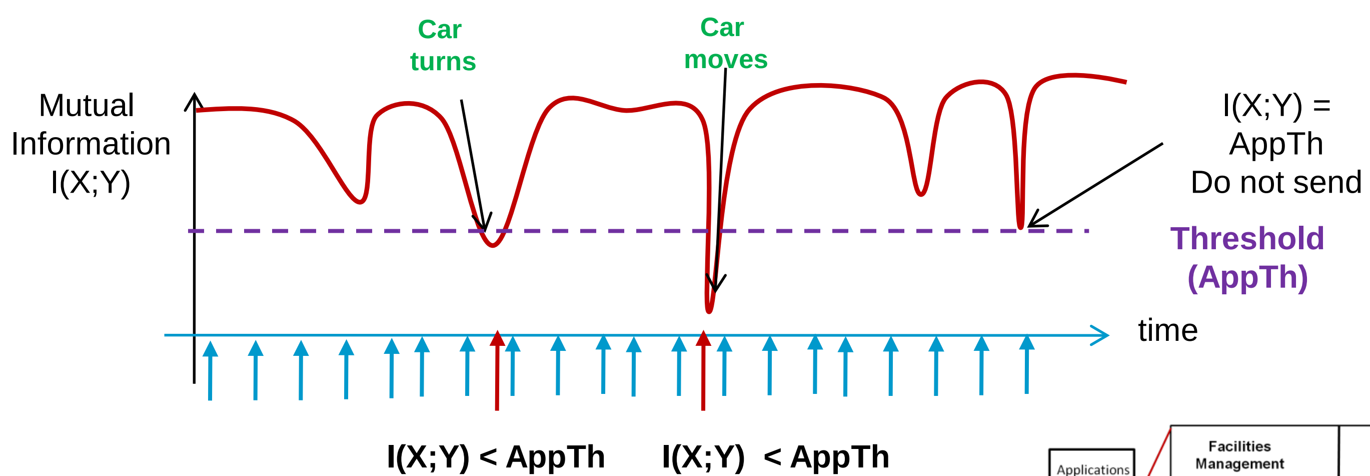
- **What are the ITS applications to limit:**
  - Over-speeding?
    - Hard to do: state still struggling with radars..
  - Yield Signs?
    - Most of the applications address traffic light violation
      - ☞ detecting a yield sign violation is very complex

Research Direction:
Tracking and Predicting Awareness

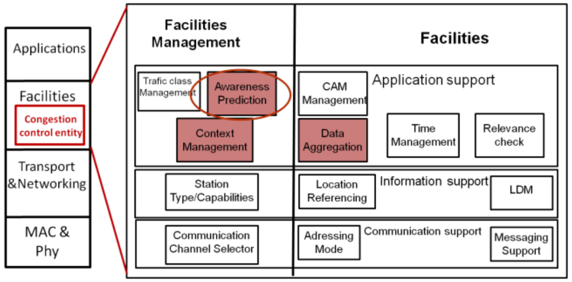
- **Cooperative Transmit Rate Control**
  - Entropy-based transmit decision
  - Enhanced particle filter tracking
  - Application-oriented requirements



- **Entropy-based transmit decision:**



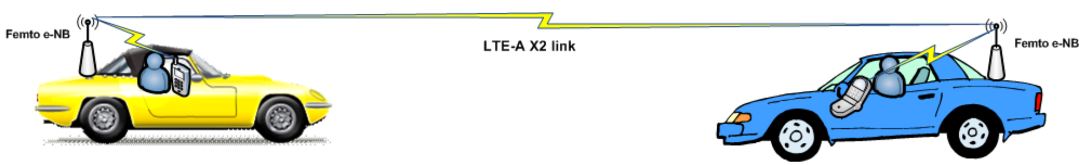
- **Generic Congestion Control Framework**



Research Directions:
Vehicular Relaying with LTE-A

- **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

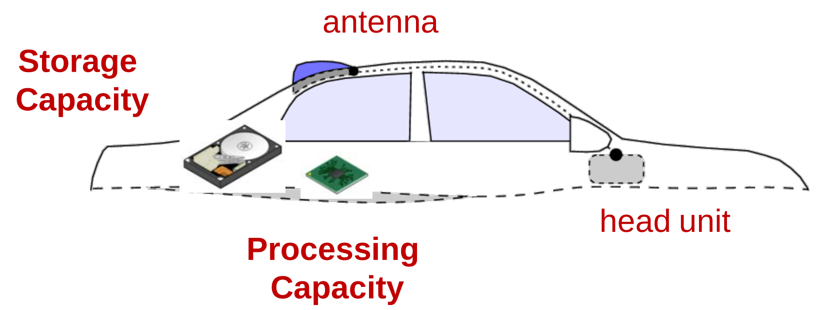


- **How will 802.11p and LTE-A RS/Femto coexist?**
  - Will share similar issues
    - Mobility, connectivity, scheduling, interferences

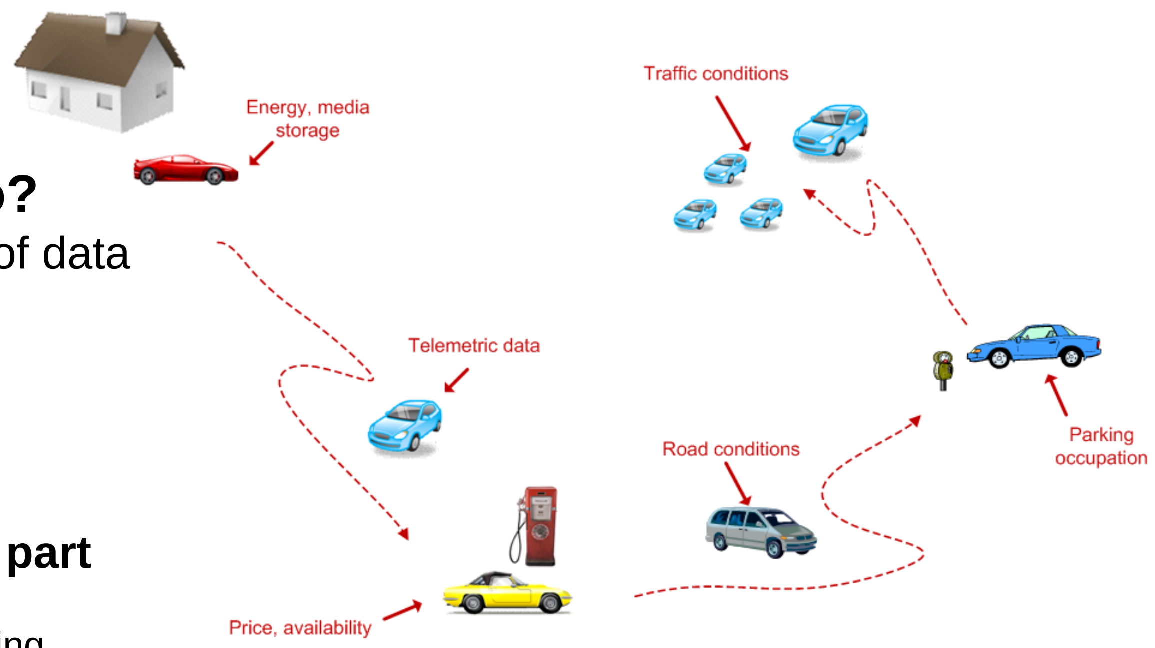
- **How to optimally use them?**

Research Directions:
Urban Sensing and Vehicular Clouds

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



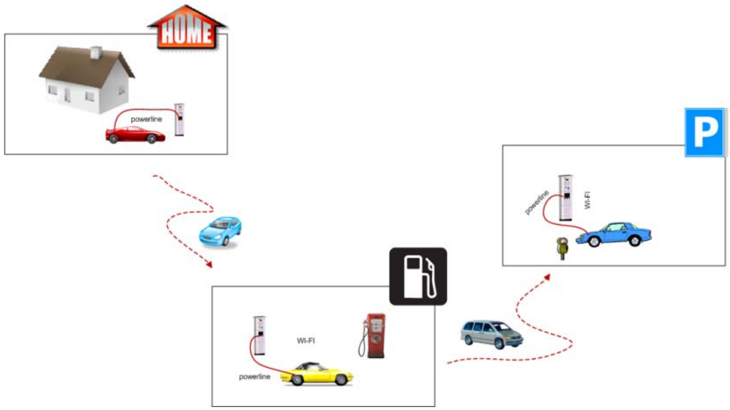
- **What does a vehicle do?**
  - Gathers a large amount of data
    - What to do with it?
    - Where to store it?
    - Where to process it?

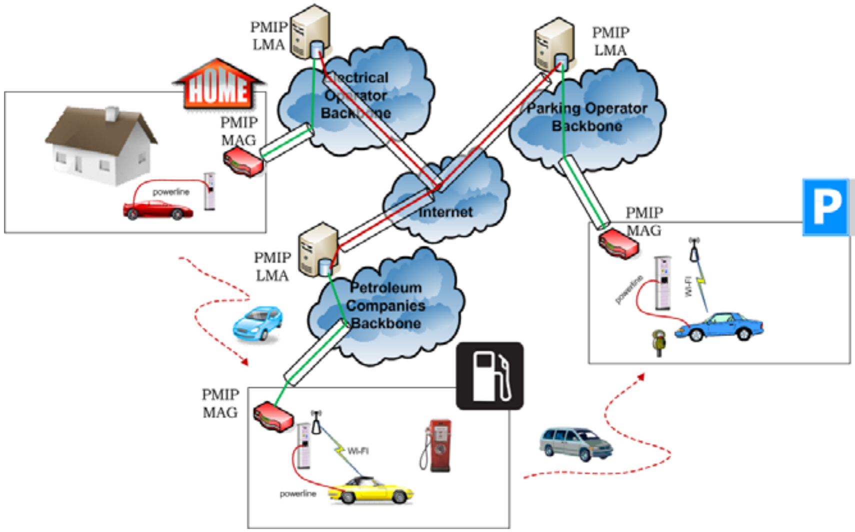


- **Vehicles are connected and part of a vehicular cloud**
  - Mobile storage, mobile processing…

Research Directions: 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





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 !**

Brief Summary

- **EURECOM is involved in two 'religions' for Intelligent Transportation Networks (but we are not exclusive)**
  - LTE-A
  - DSRC
- **Tools (Open-source):**
  - Large scale simulation platforms with iTETRIS
  - FOT and Emulation with OpenAir Interface
- **Involved in National and European Projects for ITS**
  - National:
    - SCORE@F / VELCRI / CORRIDOR / SYSTUF
  - European:
    - LOLA/EVITA/iTETRIS
- **Intelligent Transport Networks in EURECOM**
  - LTE-A for vehicular communications
  - DSRC-802.11p: 1-hop Broadcast/Multicast / congestion management
  - Infrastructure deployment Optimizations
  - Machine-2-Machine communications
  - IPv6 Mobility - Proxi-MIPv6
- **More Information:** its@eurecom.fr

  Jerome.Haerri@eurecom.fr

- **ITS Team**:
  - **Cross-department team**
- **MM Department**:
  - Prof. Benoît Huet
- **RS Department**:
  - Prof. Yves Roudier
- **CM Department**:
  - Prof. Bonnet
  - Prof. Knopp
  - Prof. Härri
  - Prof. Nikaein
  - Prof, Kaltenberger
  - Prof. Spyropoulos
  - M. Wetterwald

BACKUP SLIDES

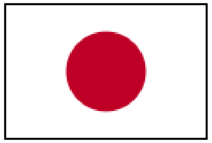
Vehicular networks: Yet another network?

- **Different from deployed networks**
  - Requires dedicated communications
  - Rely on the complex characteristics of the vehicular wireless channel at 5.9GHz
  - Lack of centralized management, coordinate
  - High and dynamic mobility
  - Significant concerns related to security and privacy

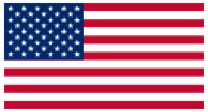
- **Socio-Economical Aspects**
  - Needs to evaluate the real benefits of vehicular networks in safety and traffic efficiency
    - Can it really help and at which cost?
  - How to handle early deployment
    - Connectivity will be sparse at the beginning
      - ☞ But the danger is the same

Non-exhaustive Overview of Projects

- **C2C-CC** (2001)
- **CarTalk** (2001-2004)
- **SeVeCom** (2006-2008)
- **ETSI ITS** (2009)
- **Drive** (2011-2014)
- **Chauffeur I and II** (1996-2003)
- **PreVent/WILL WARN** (2005-2008)
- **Coopers/CVIS/SAFESPOT** (2006-2010)
- **CoCAR I and II** (2007-2011)
- **FleetNet** (2000-2003)
- **NoW** (2004-2007)
- **PreDrive** (2008-2010)
- **SIM-TD** (2008-2012)



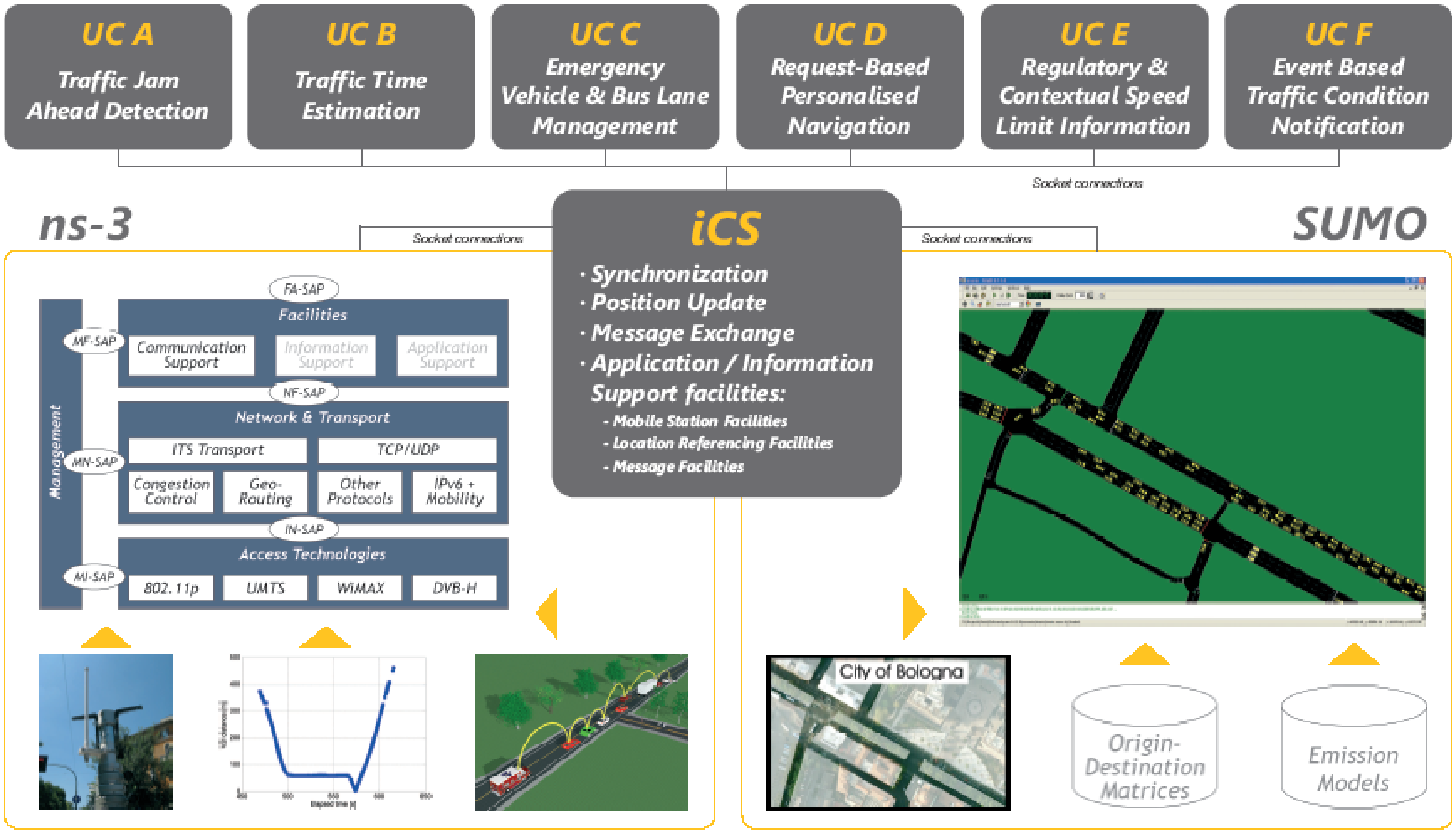
- **ASV I** (1991-1995)
- **ASV II** (1996-2000)
- **ASV III** (2001-2005)
- **ASV VI** (2006-2010)



- **PATH** (1986)
- **IVI** (1998-2004)
- **VII / IntelliDrive** (2004-2009)
- V2V Decision (2013)
- **DSRC** (1999)
- **WAVE** (2004)
- ***ITS Strategic Research Plan,*** (2010-2014)

[Partial Reproduction of : H. Hartenstein, *VANET: Vehicular Applications and Inter-Networking Technologies"*, Chapter 1 – Introduction, Wiley, 2010]

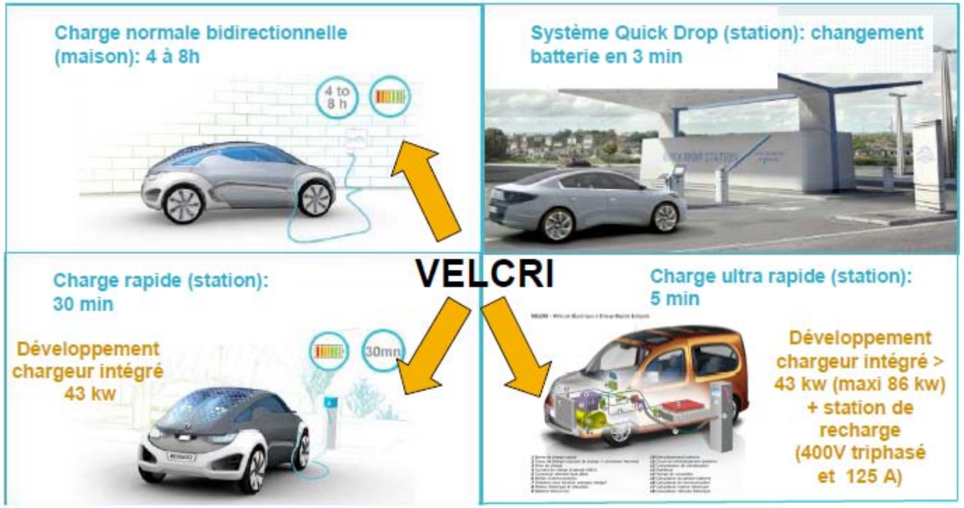
ITS Simulations – the iTETRIS Platform



- Contact: http://www.ict-itetris.eu/10-10-10-community/

VELCRI – Véhicule Electrique à Charge Rapide

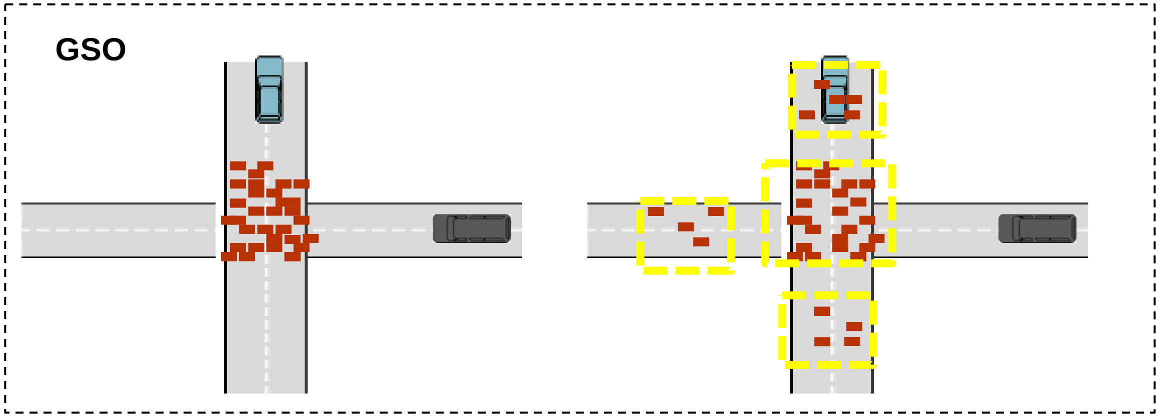
- **Fast Electrical Charging System**
  - Technical Development of fast and slow charging systems
  - 2-ways powerline communication at the charging stations
  - Smart Grid Optimization
- **National Project: 2010 – 2013**
- **Coordinator: Renault**
- **EURECOM Contribution:**
  - Network-controled IP Mobility
  - Multi-Interface Management
  - Charging station deployment plan

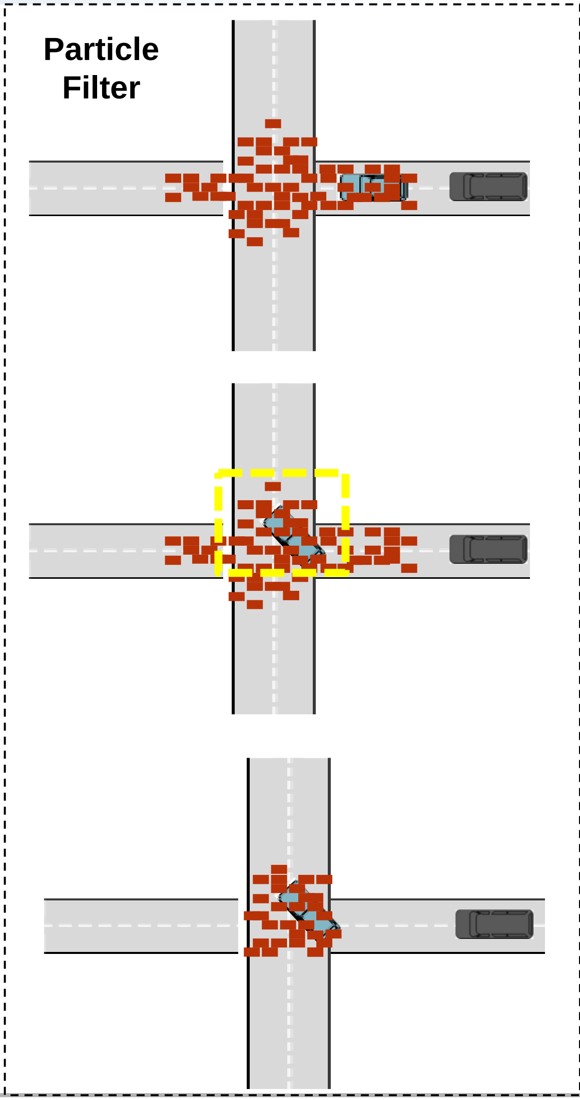


- **Partners:**

Every bit should count: Tracking and Predicting Awareness

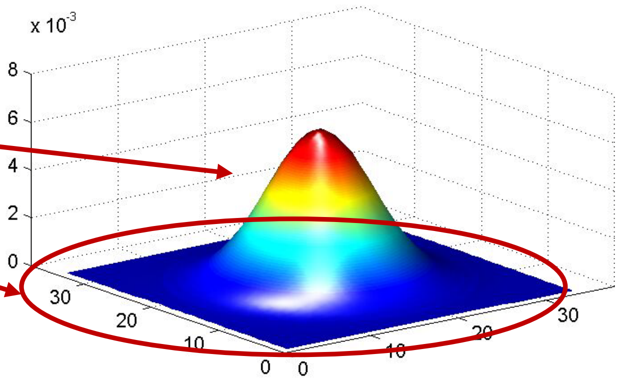
- **Enhanced Particle Filter**
  - Sequential Importance Resampling (SIR) filter
  - Resampling remains problematic
    - Sudden speed/trajectory change
  - Enhanced resampling:
    - Glowworm Swarm optimization (GSO)
      - Particles (glowworms) of brighter intensities attract glowworms that have lower intensity
      - Distant particles (gowworms) are discounted when a glowworm has sufficient number of neighbors
    - Approach allows to split the resampling of particles in different zones (different hypothesis where vehicle ' could be'

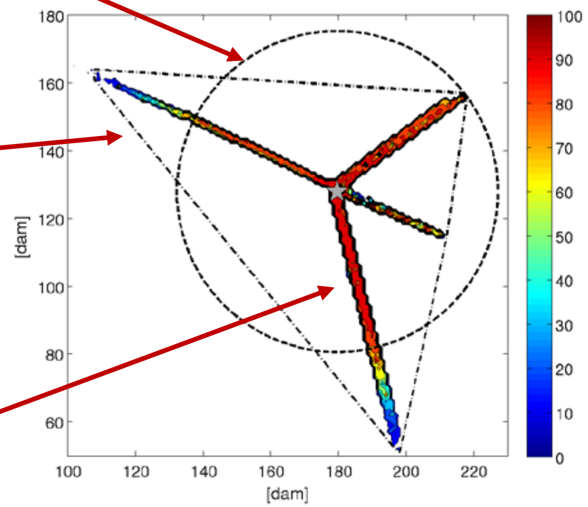




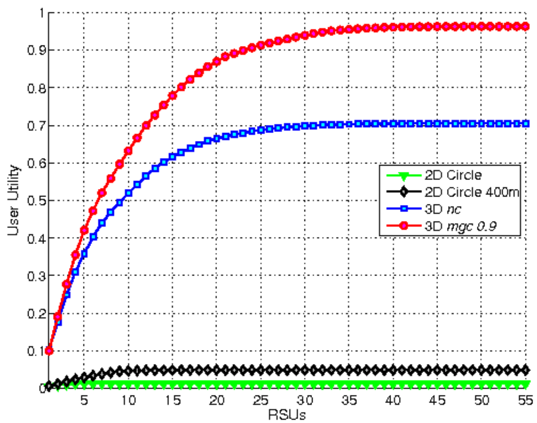
Infrastructure Connectivity vs- Coverage

- **Coverage does not reflect connectivity**
  - Intensity of the connectivity
  - Pure Coverage
- **Circular homogeneous coverage-based approach**
  - Does not reflect directional coverage
  - Over-estimates coverage, also where not possible/necessary
- **Convex Polygon-based coverage-based approach**
  - Reflects directional coverage
  - Still over-estimates coverage, also where not possible/necessary
- **Non-convex polygon-based coverage-based approach**
  - Reflects directional coverage
  - Manages to estimate coverage with more granularity

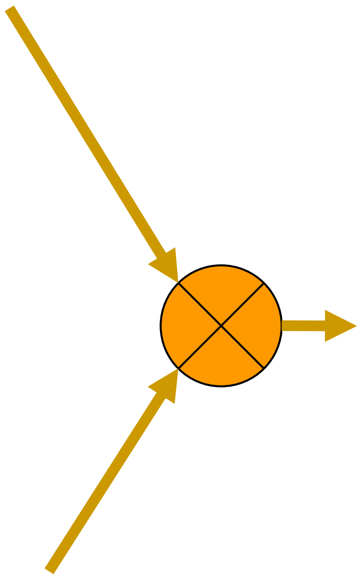


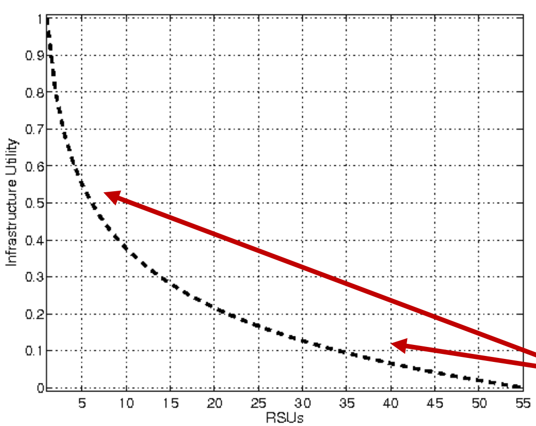


Provider Satisfaction and Joint Optimization



User Utility



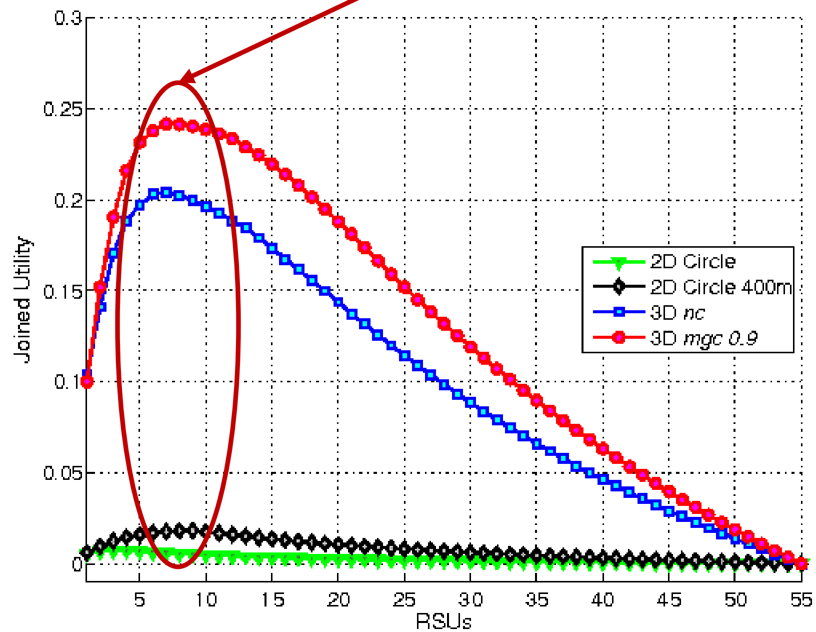


Operator Utility

Operator Utility decreases with # RSU

~8 RSU required in all approaches

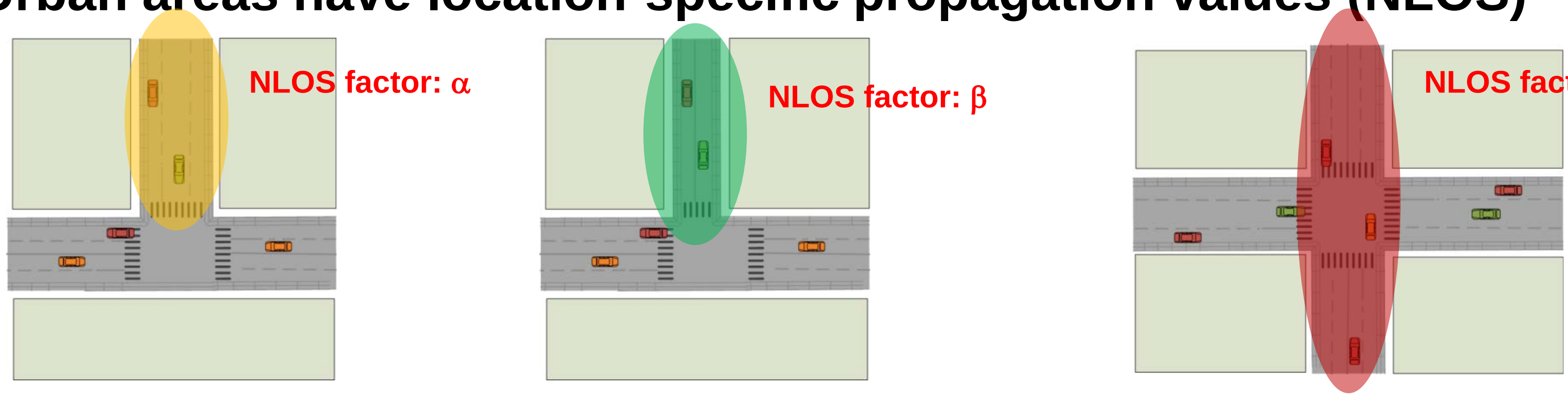
<u>Benefit</u>: not the same RSUs' locations !!



Joint User-Operator Satisfaction

Impact of Static and Mobile Radio Obstacles

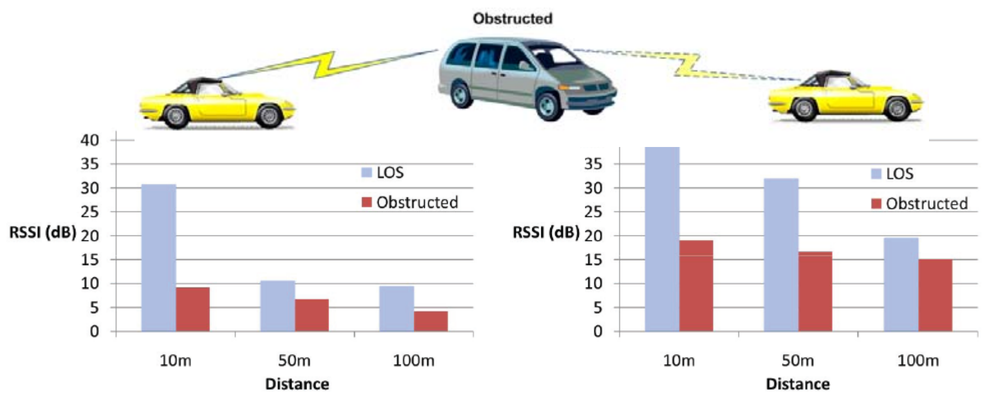
- **Urban areas have location-specific propagation values (NLOS)**



3-leg | 3-leg narrow | 4-leg

Source: T. Mangel et al., “**Vehicular Safety Communication at Intersections: Buildings, Non-Line-Of-Sight and Representative Scenarios**”, IEEE WONS 20

- **Not all vehicles are to be considered similar**

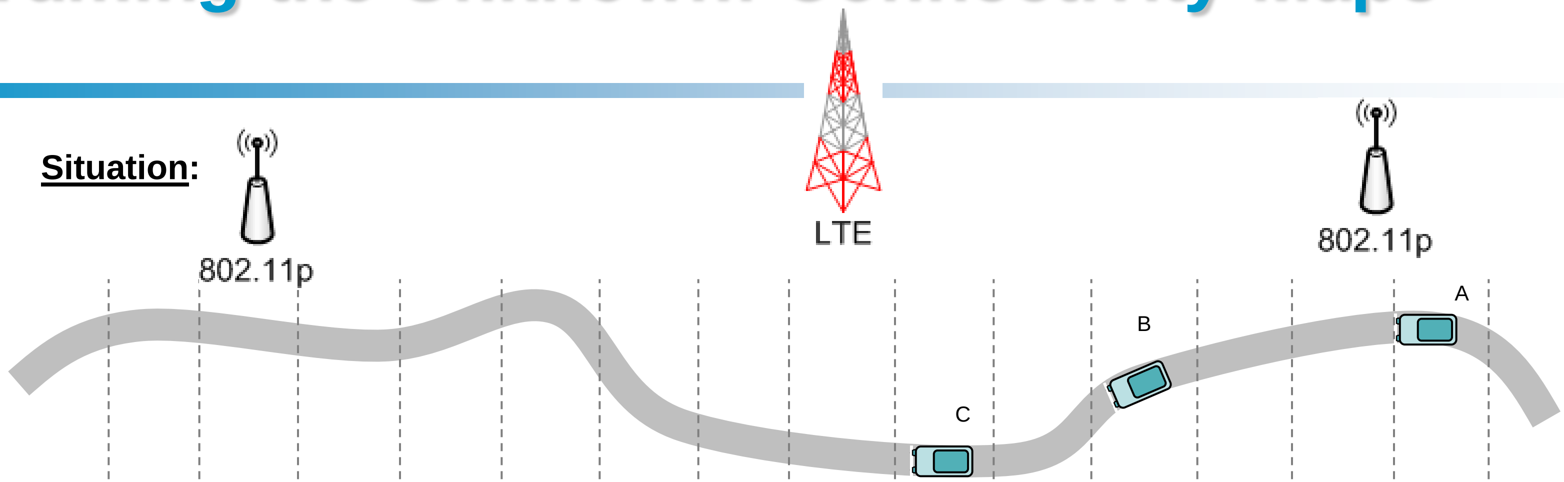


(a) 2.4 GHz. (b) 5.9 GHz

Source: M. Boban et al., “**Impact of Vehicles as Obstacles in Vehicular Ad Hoc Networks**”, IEEE JSAC 2010

Taming the Unknown: Connectivity Maps

- **Situation:**



	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
Bandwidth LTE	13	12	4	7	3	0	12	3	9	20	8	6	12	1	5	20
Bandwidth 802.11p V2I	1	15	43	21	9	0	0	0	0	0	0	0	0	21	52	70
Bandwidth 802.11p V2V	0	0	0	0	0	0	0	0	0	25	3`	40	0	21	52	70

- **Options:**
  - Vehicle A:
    - Low LTE bandwidth at position 2 !
      - Wait for pos 4/7
      - Transmit and adapt transmission parameters??
      - Use 802.11p in pos 4 instead?
  - Vehicle B:
    - Low LTE Bandwidth at position 5, pos 7 high bandwidth..
      - Wait for pos. 7
      - Use vehicle C at position 7 as relay; V2V bandwidth between pos. 5 and 7 is high

Source: J. Yao, S. Kanhere, M. Hassan, "**Improving QoS in High-speed Mobility Using Bandwidth Maps**", IEEE TMC 2011

Multiple Antenna Techniques and Testing

- **Alternative mounting spaces**
  - Rear-mirror antennas
  - Inherent diversity efficiency, LTE 700 MHz
  - Comparatively large mounting space
  - Conformal design

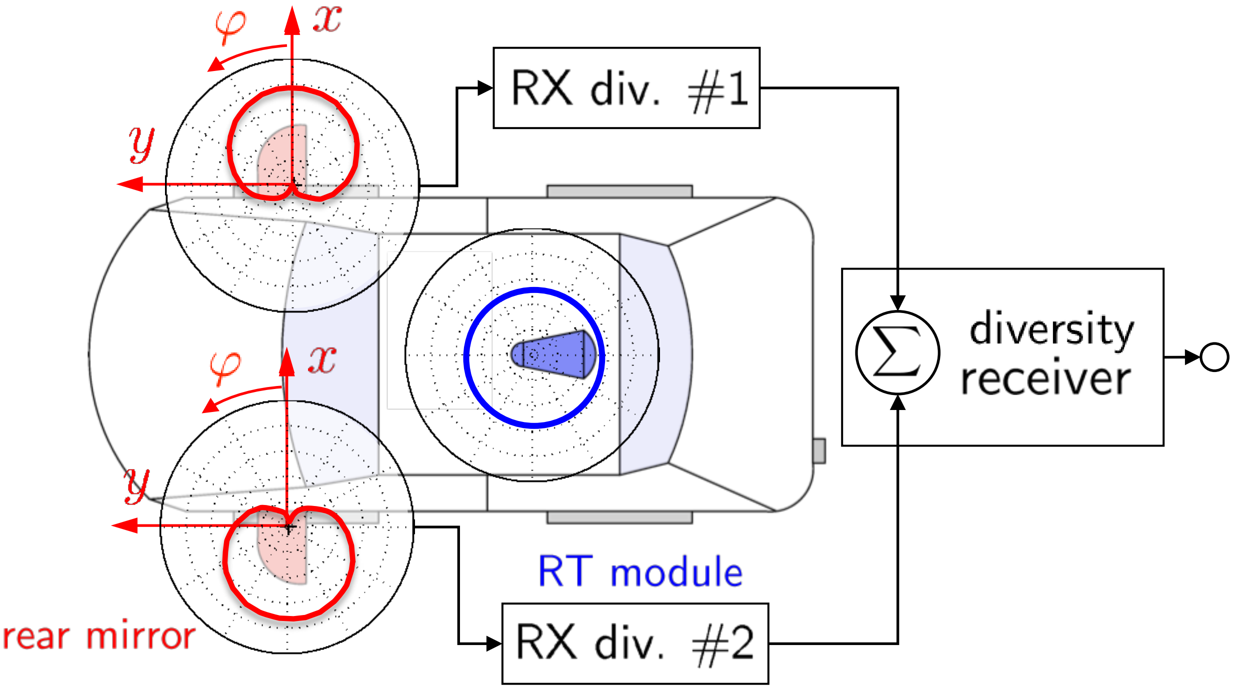


Fig. 1: Rear mirror module

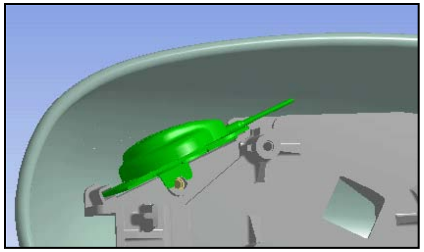
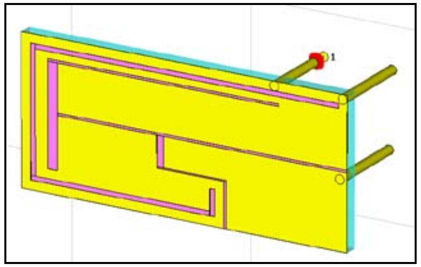


Fig. 2: SDARS antenna



Source: Oliver Klemp, BMW R&D, Munich, Germany

Multiple Antenna Techniques and Testing

- **Path loss in different antenna positions**
  - cc-scenario: **monopole** antennas at **Pos. 2**
  - ll-scenario: **patch** antennas at **Pos. 1**

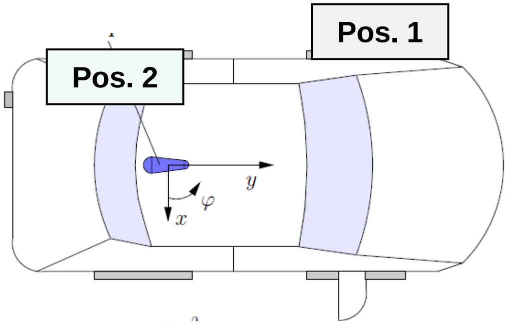
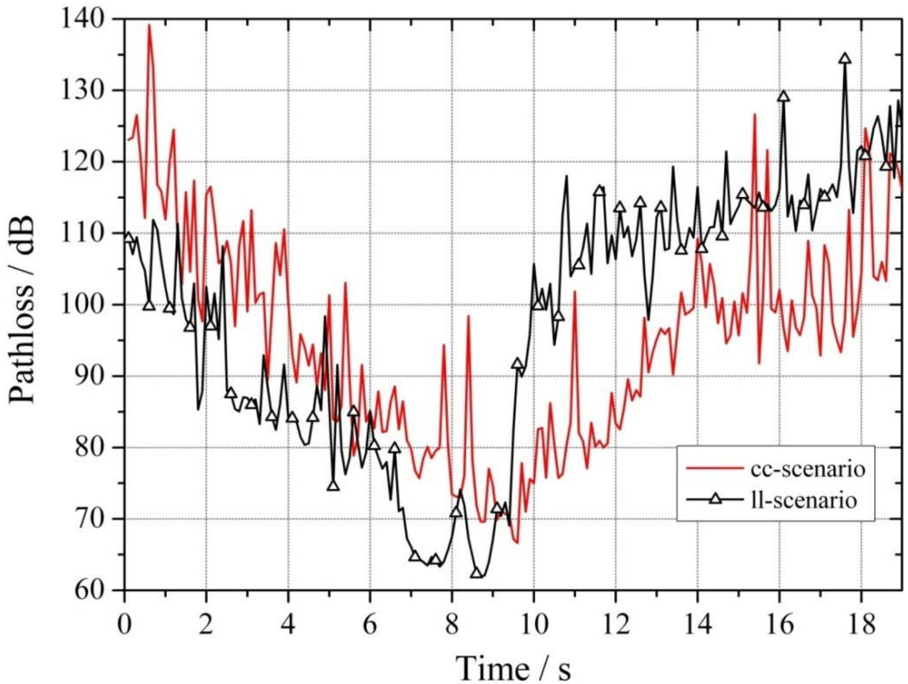
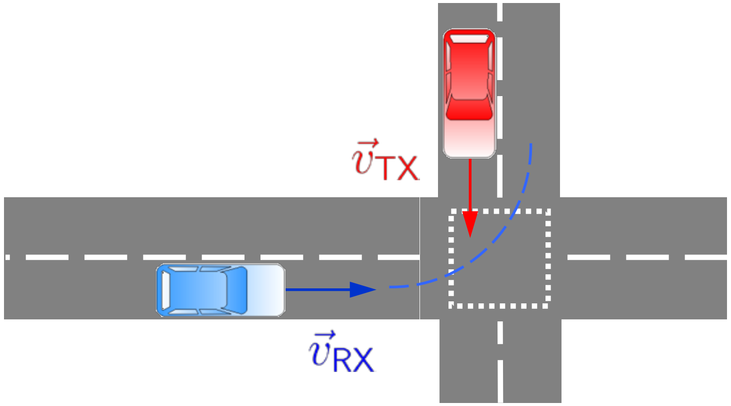


Fig. 1: Antenna setup

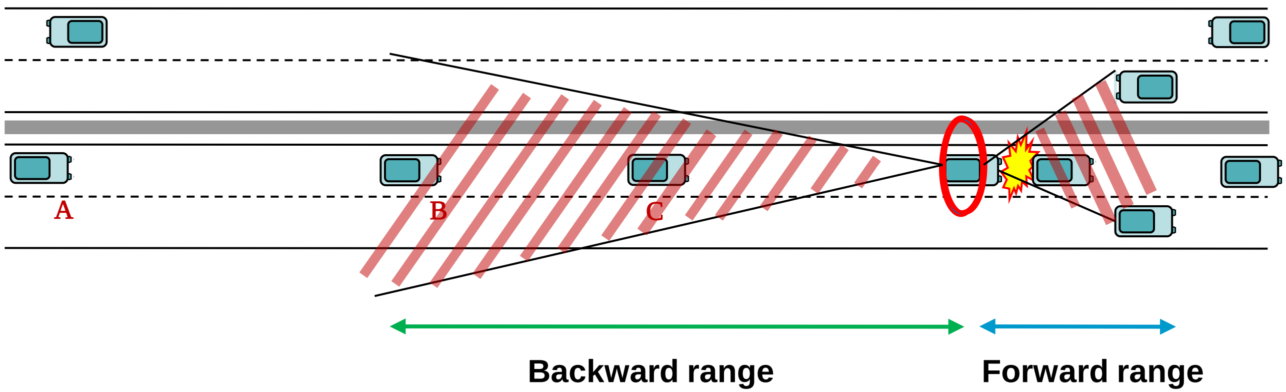




[2] Kornek, Schack, Slottke, Klemp, Rolfes, Kürner: Effects of Antenna Characteristics and Placements on a Vehicle-to-Vehicle Channel Scenario, ICC 2010

Applications of Information Pertinence

- **Directional Antenna:**
  - Direct information flows where needed



- **Cooperative Transmit Rate Control**
  - Let vehicles cooperate in predicting contexts
    - Transmit only upon unpredicted context changes

EURECOM ITS R&D Life Cycle