Challenges in Intelligent Transportation Systems

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Intelligent Transportation Systems?

- Car-to-Home
- Priority Access
- Traffic conditions
- Re-routing
- Pedestrian Safety
- Telemetric data
- Road conditions
- Parking occupation
- Price, availability
The Vision: Intelligent Vehicle / Transport

Motocycle Warning

Source: BMW F&T, for Network on Wheels

Emergency Vehicle

Source: CAR 2 CAR COMMUNICATION CONSORTIUM
Evolution Phases in Intelligent Transportation Systems

- Visionary Phase
- Pioneer Phase
- Consolidation Phase
- Deployment Phase – New Applications

- 2000 - 2008: The Golden Age of Vehicular Network
- 2008 - ?: Becoming Wise(r)
- 2013 (EU) - ?: Bringing it to Reality
  ...and... Selling it!

- 1939 !! GM World Fair
Visionary Phase...GM’s FUTURAMA
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/
- 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:

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

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

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

- 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
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

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M. Fiore, J. Härri, The Networking Shape of Vehicular Mobility, ACM Mobihoc 2008, Hong Kong, 2008
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

- Example: Cooperative Application-based TX Power control

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

[Source: Fatma Hrizi, Jérôme Hährri, Christian Bonnet, "Every Bit Counts: Tracking and Predicting Awareness"]
Challenge 6: Human Behaviors

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

- What is creating the worst accidents
  - On highway?
  - In urban environment?
    - Overspeeding (french department Interior)
    - 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:**

  ![Entropy-based transmit decision diagram]

  Mutual Information \( I(X;Y) \)

  - **Car turns**
    - \( I(X;Y) < \text{AppTh} \)
    - Do not send

  - **Car moves**
    - \( I(X;Y) = \text{AppTh} \)

- **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 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

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- **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
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/CVI S/SAFESPOT** (2006-2010)
- **CoCAR I and II** (2007-2011)
- **FleetNet** (2000-2003)
- **NoW** (2004-2007)
- **PreDrive** (2008-2010)
- **SIM-TD** (2008-2012)
- **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)

ITS Simulations – the iTETRIS Platform

- **UC A**: Traffic Jam Ahead Detection
- **UC B**: Traffic Time Estimation
- **UC C**: Emergency Vehicle & Bus Lane Management
- **UC D**: Request-Based Personalised Navigation
- **UC E**: Regulatory & Contextual Speed Limit Information
- **UC F**: Event Based Traffic Condition Notification

**ns-3**

**iCS**
- Synchronization
- Position Update
- Message Exchange
- Application / Information Support facilities:
  - Mobile Station Facilities
  - Location Referencing Facilities
  - Message Facilities

**SUMO**

Contact: [http://www.ict-itetris.eu/10-10-10-community/](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:**

![Partners logos]

22/09/2011 - Jérôme Härrri
NTNU-EURECOM Workshop
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 (gawworms) 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

- Operator Utility decreases with # RSU
- Joint User-Operator Satisfaction
  - ~8 RSU required in all approaches
  - Benefit: not the same RSUs’ locations !!
Impact of Static and Mobile Radio Obstacles

- Urban areas have location-specific propagation values (NLOS)
  - NLOS factor: $\alpha$
  - NLOS factor: $\beta$
  - NLOS factor: $\gamma$

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

- Not all vehicles are to be considered similar


Source: M. Boban et al., "Impact of Vehicles as Obstacles in Vehicular Ad Hoc Networks", IEEE JSAC 2010
Taming the Unknown: Connectivity Maps

**Situation:**

- **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

**Options:**

**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

![Rear mirror module](image1)

**Fig. 1:** Rear mirror module

![SDARS antenna](image2)

**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

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

- **FOT for Cooperative ITS Systems in France**
  - SCORE@F

- **PROTON-PLATA**
  - CALM
  - PHYS 802.11p
  - LTE

- **Open Source Hardware/Software Development Platform**

- **Field Operational Test**
- **System & Applications**
- **Security**
- **Experimental Platform**
- **Simulation**
- **Standardization**

- **Open Source Cooperative ITS Large-scale Simulation Platform**
- **iTETRIS**
- **NTNU-EURECOM Workshop**