Vehicular Communications

UTC

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Outline

- Vehicular networks
  - Definitions
  - Characteristics
  - Challenges
  - Actors
  - Applications and services
- Orange activities
  - Orange actual developments
  - Orange R&D activities
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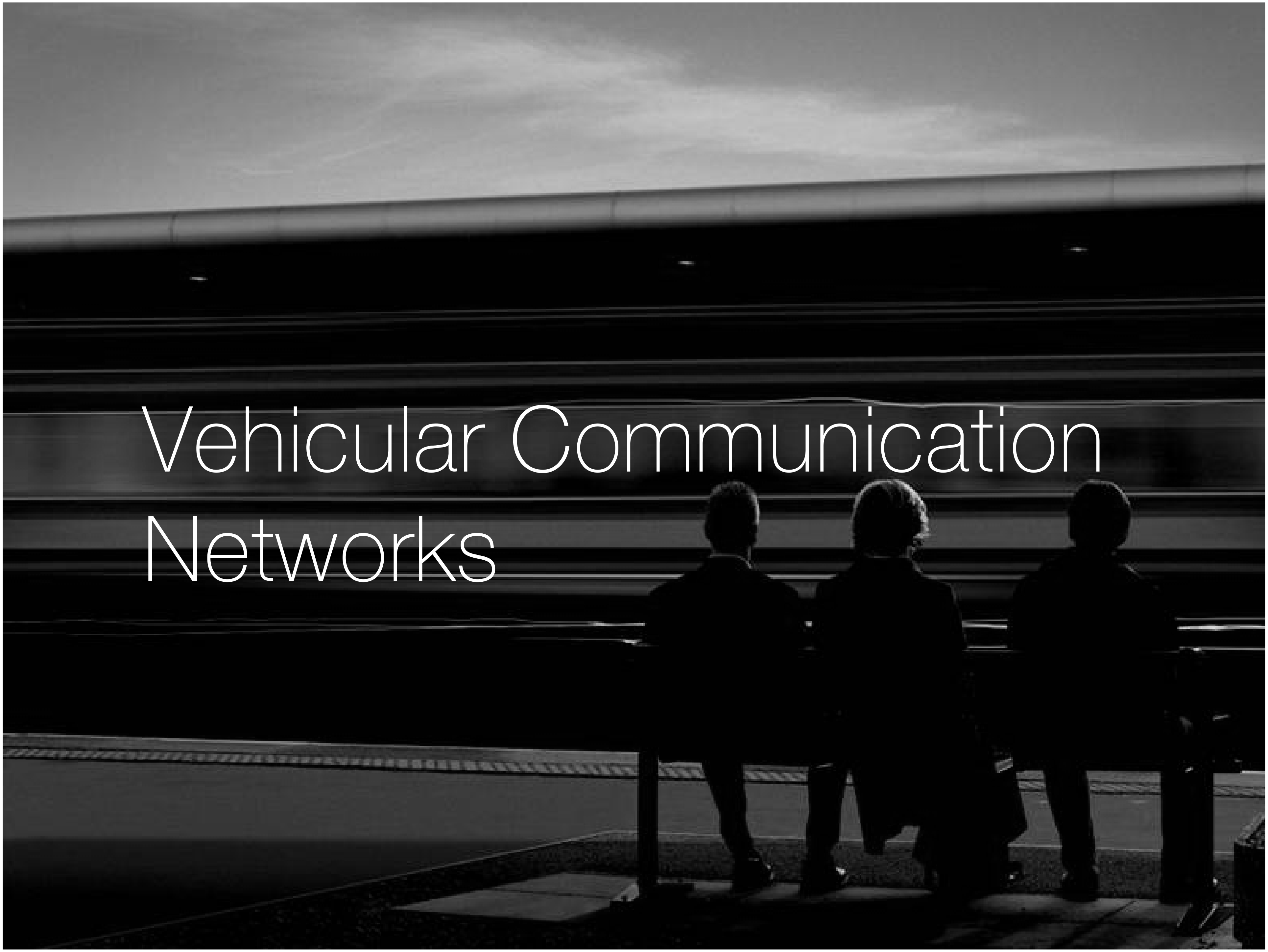
- References


Vehicular Communication
Networks

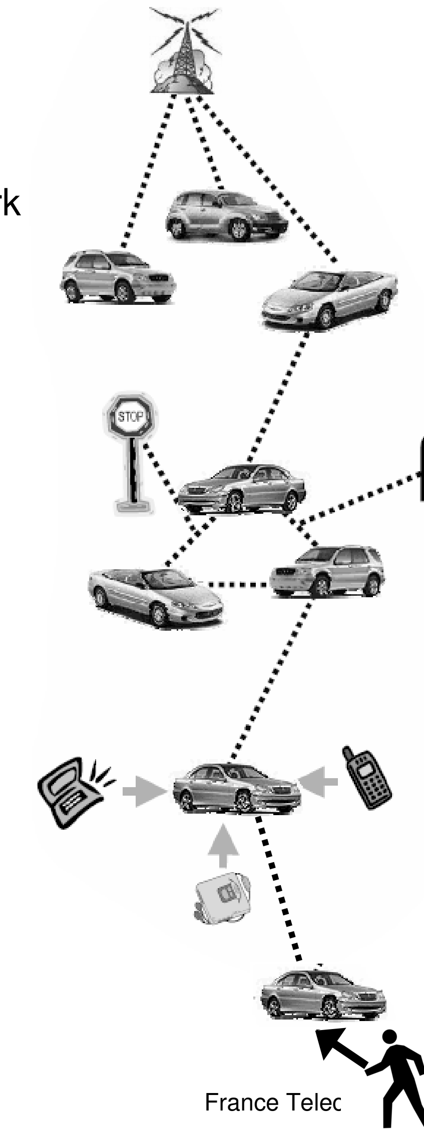
Vehicular networks: definitions

- Connecting vehicle to the infrastructure - V2I to be able to retrieve information (e.g. diagnostics data, **location**, **local traffic information**,…) from the vehicle or to allow vehicle to access network resources (e.g. **Internet access**, …)

- Connecting vehicles to each other - V2V and with the infrastructure allows them to share and exchange information and sensor data among each other and among them and the infrastructure (e.g. for **entertainment**, diagnostics, **safety**, probe data collection, etc.)

- Connecting portable devices to the vehicle allows us:
  - To enhance the vehicle's functionality (e.g. **digital address book as input to the navigation system**, MP3 player to play digital music)
  - To make use of vehicle resources on the portable device (e.g. **better connectivity**, audio system,…)

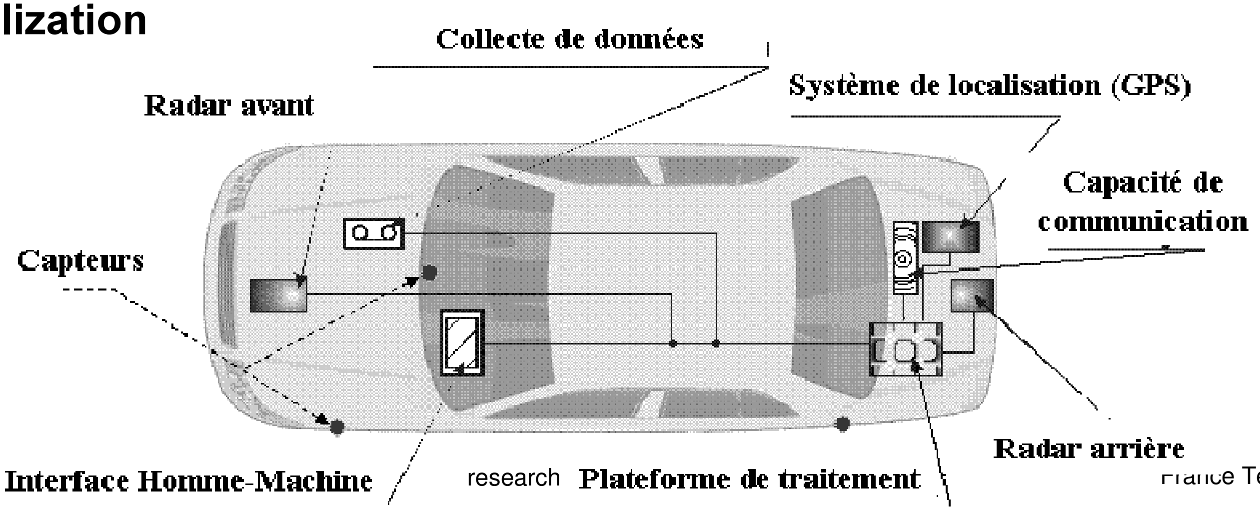
- Connecting vehicle to pedestrians – V2P (e.g. **pedestrian safety**, make contact between pedestrians desiring to go to a given destination and vehicles capable of transporting pedestrians to the destinations)



Adapted from W. Holfelder (DaimlerChrysler)

Vehicular networks: definitions

- Smart vehicle
  - **Sensing** and close environment perception using different sensors and cameras.
  - **Processing and storage** capacity on board permits to interpret the large collected information with the purpose of helping the driver to make a decision
  - **Communication** for information exchange and diffusion in the vehicular network itself or with other networks permitting to increase the perception perimeter of e vehicle
  - **Localization**



Vehicular networks: characteristics

- Vehicles have
  - Higher computational capability (+)
  - Almost unlimited energy sources (+)
- Mobility characteristics
  - Topology changes at a very high rate (-)
    - Challenges in all layers
  - Nodes move on predictable trajectories, usually 1-D (+)
- Connectivity
  - Much harder to assure connectivity (-)
  - Must be able to handle network partitions (-)
- Communication
  - Broadcast, multicast, group communication is more common than unicast communication (especially for C2C communications)

Vehicular networks: "challenged networks"

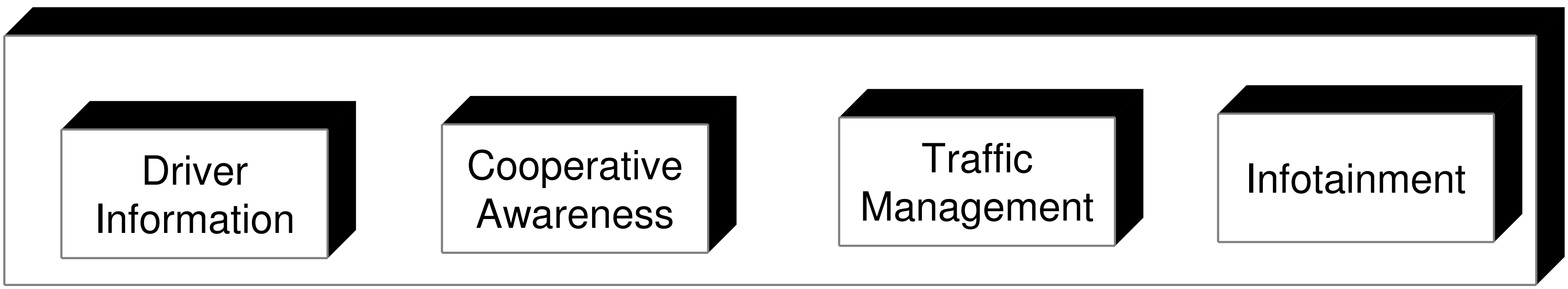
- Technical challenges
  - Mobile wireless environment challenges
    - Scalability will require robust
      - Dynamic channel congestion control methods (power and rate control)
      - Routing, broadcasting and information dissemination
      - Self-organization
    - Reliability and mobility will require robust
      - Handoff and mobility Mgt.
      - Routing and dissemination
      - Time-sensitivity
      - Self-organization
    - Authentication, Authorization and Accounting (AAA)
      - Authentication between participants
      - Access control and authorization for services' access
      - Accounting for the provided services
    - Secure communication
  - GPS technology challenges
    - Lane level accuracy at low cost will be an issue
    - Coverage (outages due to obstructions) will be an issue

Source: Car-to-car consortium

Vehicular networks: "challenged networks"

- Socio-economical/political challenges
  - Frequency allocation: is the allocated frequency sufficient?
  - Standardization development
  - Market introduction (laws, advantages)
  - Set up infrastructure
  - Economical models
  - Driver experience

Vehicular networks: applications and services



Vehicular networks: applications and services

Driver Information

Cooperative Awareness

Traffic Management

Infotainment

Examples:

- Hazard Warning
- Road Works
- Weather Information
- End of Traffic Jam

Communication Pattern / requirements:

- Event driven
- Many recipients
- Big target area
- Send and Route Sensor Data
- Physical Transport of Information
- Determine Validity of Data
- Ensure Integrity of Data
- Lower to medium penetration rate

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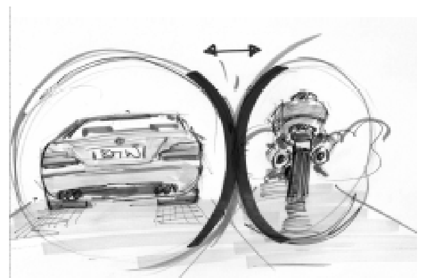
Vehicular networks: applications and services

Driver Information

Cooperative Awareness

Traffic Management

Infotainment



Examples:

- Mutual awareness
- Collision avoidance
- Merge assistance
- Intersection assistance

Communication Pattern / requirements:

- Low latency
- High reliability (high channel capacity, low packet loss)
- Very frequent messages (every few ms)
- Very high penetration
- Few recipients
- Small target area
- Many applications require same information but with different accuracy and update frequency

Vehicular networks: applications and services

Driver Information

Cooperative Awareness

Traffic Management

Infotainment

Examples:

- Real time traffic information
- Traffic management
- Traffic light assistance
- Intersection management
- Remote control and monitoring (fleet management)

Communication Pattern / requirements:

- Infrastructure support
- Small penetration rate required

Vehicular networks: applications and services

Driver Information | Cooperative Awareness | Traffic Management | Infotainment

Examples:

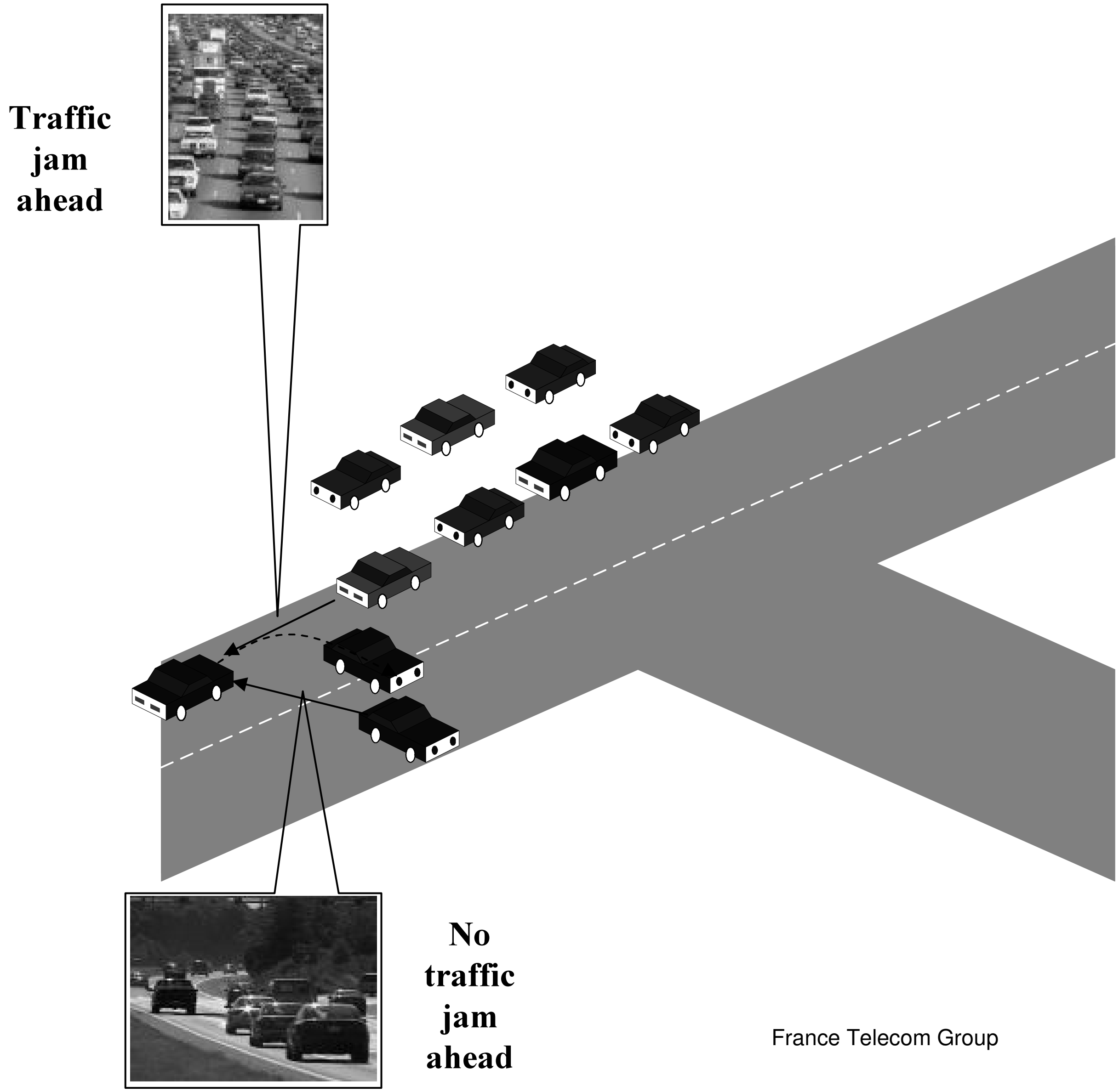
- Mobile office (Internet, email, file transfers ..)
  - Location based services and charging (parking, road usage, local restaurants and gas station, local traffic info, diverse advertising useful for passengers, dynamic map updates, car following ..)
  - Downloading: movie trailers, on-demand recorded radio programs, tourist information may be available on some hotspots and be downloadable to those on-board.
  - Entertainment (video-on-demand, games, chat ..)

Communication Pattern / requirements:

- IP Connectivity
- High bandwidth consumption

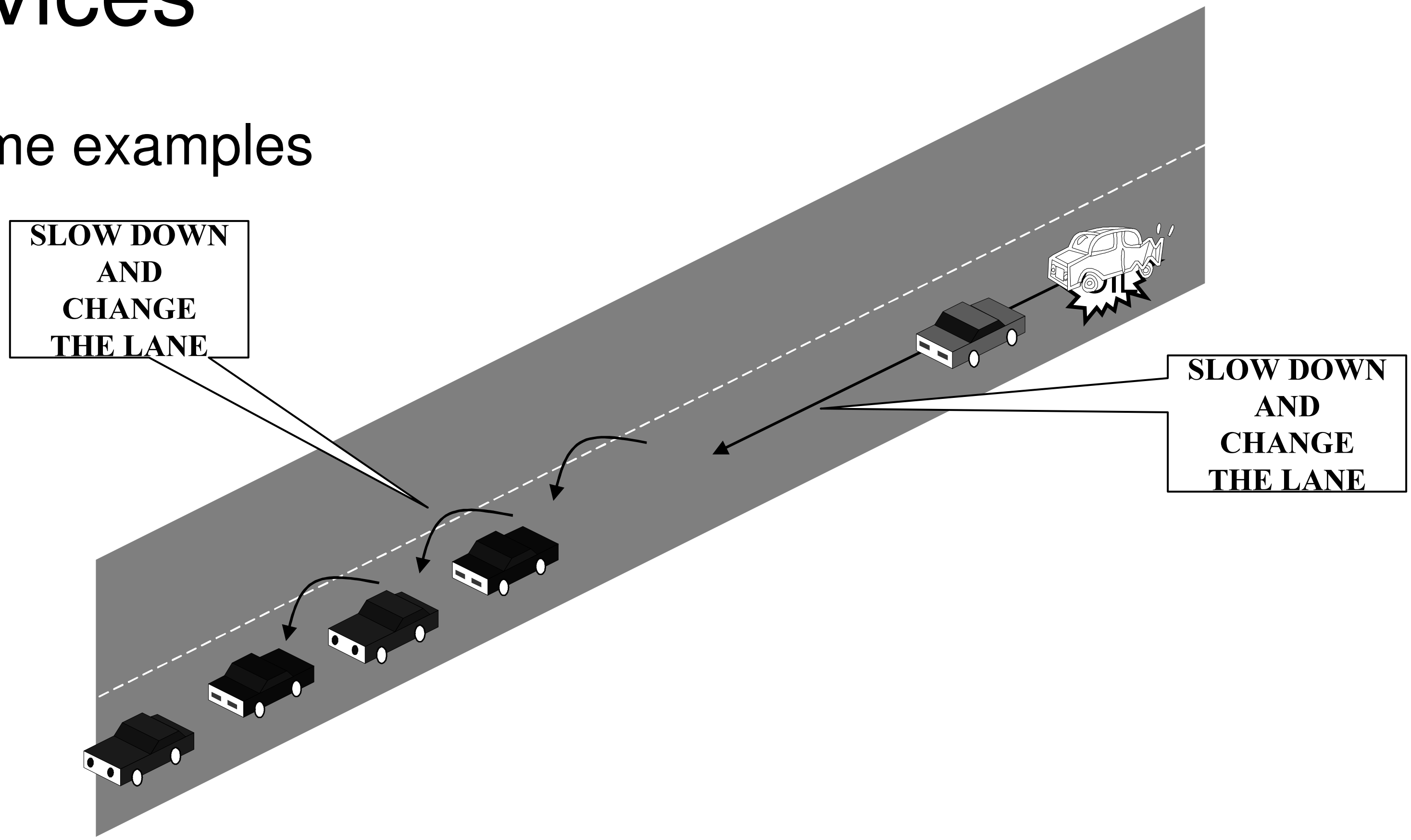
Vehicular networks: applications and services

■ Some examples



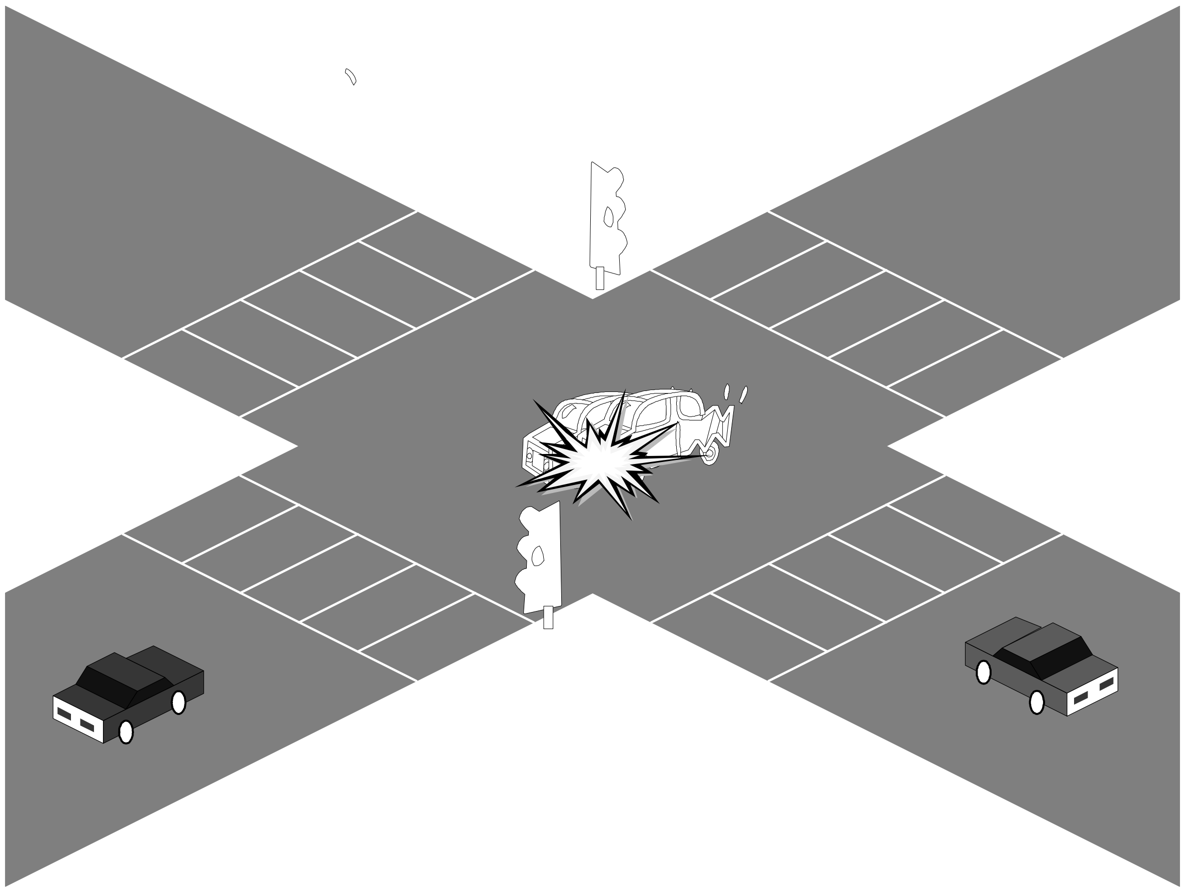
Vehicular networks: applications and services

- Some examples

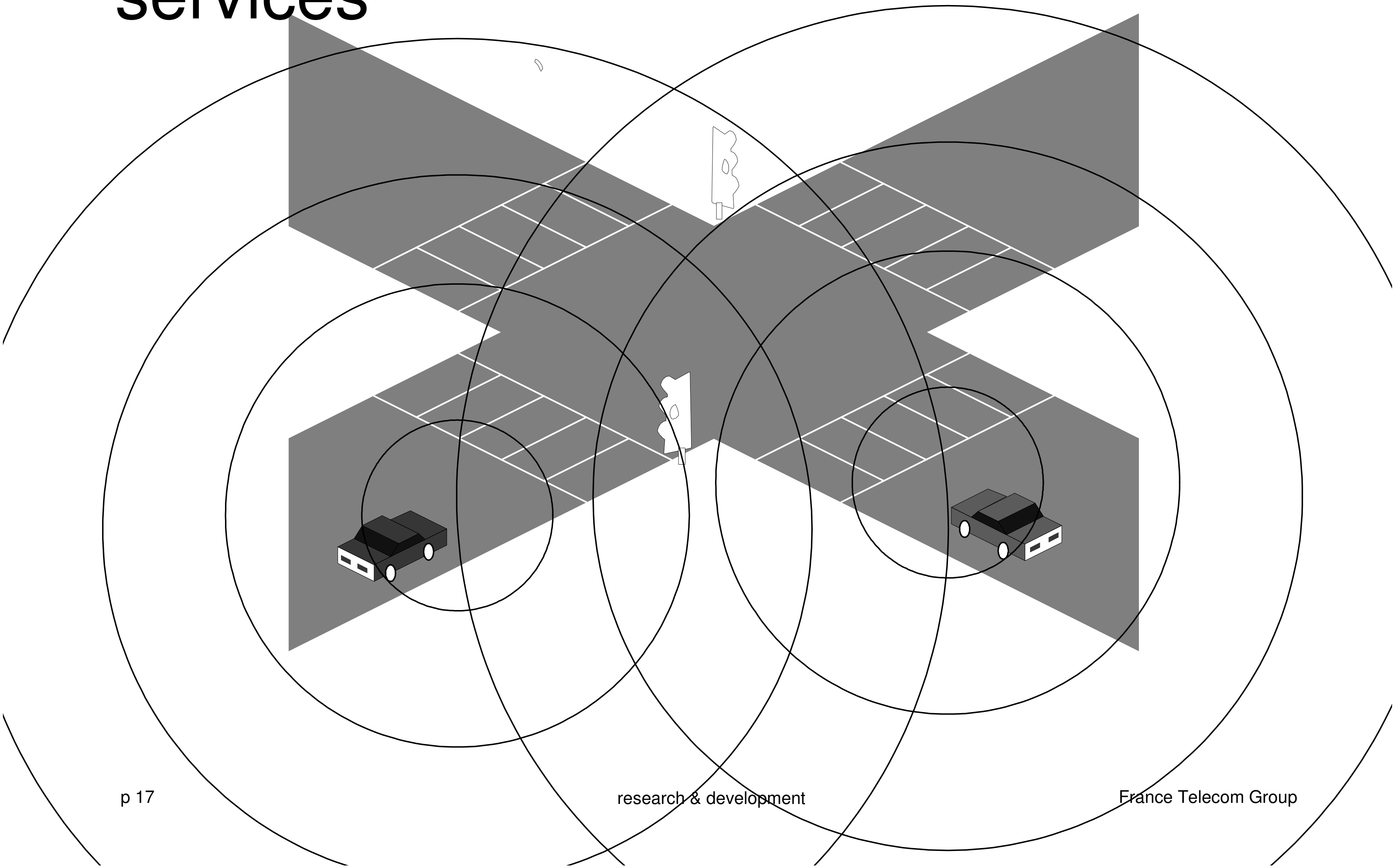


Vehicular networks: applications and services

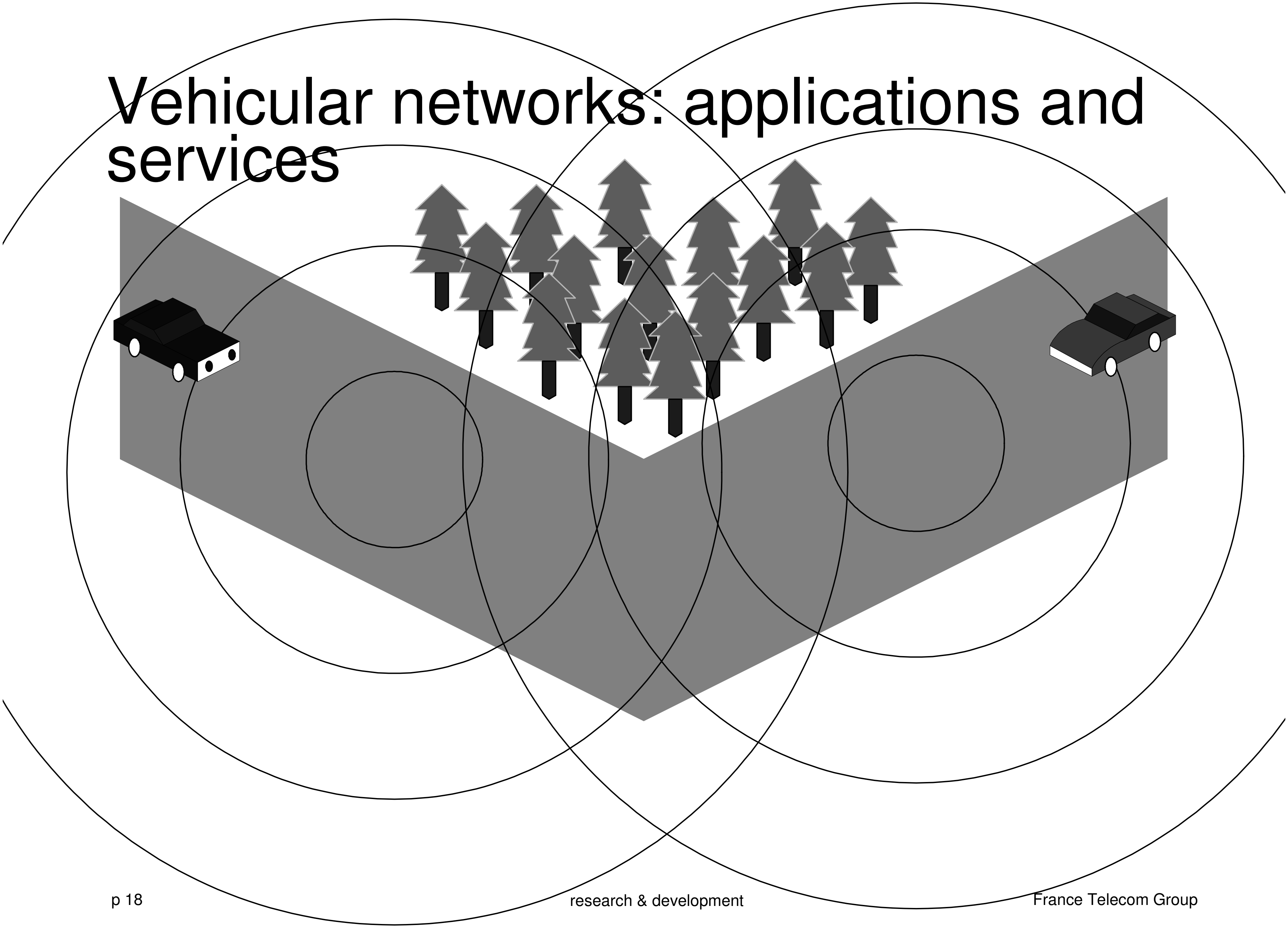
- Some examples



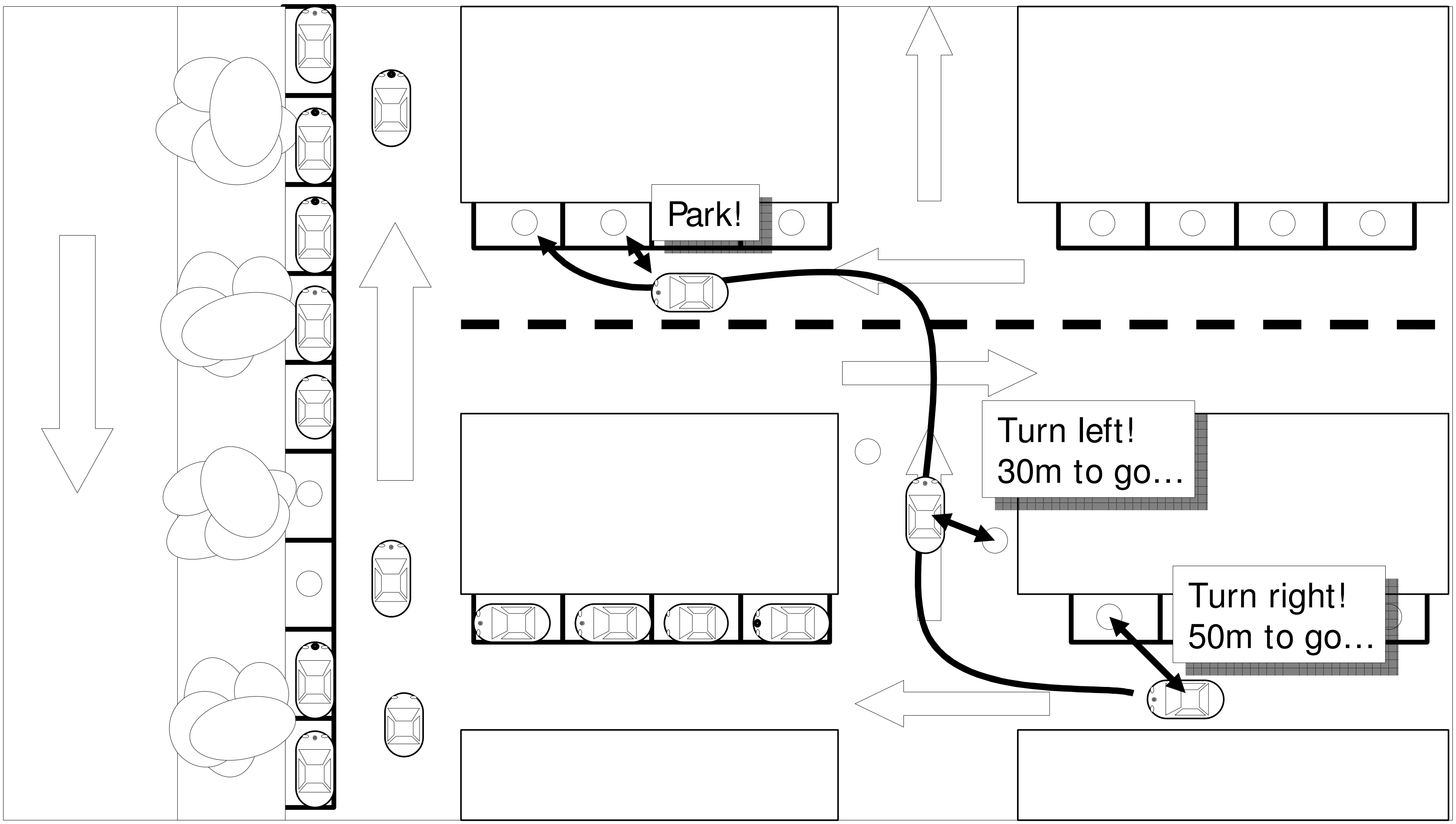
Vehicular networks: applications and services



Vehicular networks: applications and services



Vehicular networks: applications and services - SmartPark



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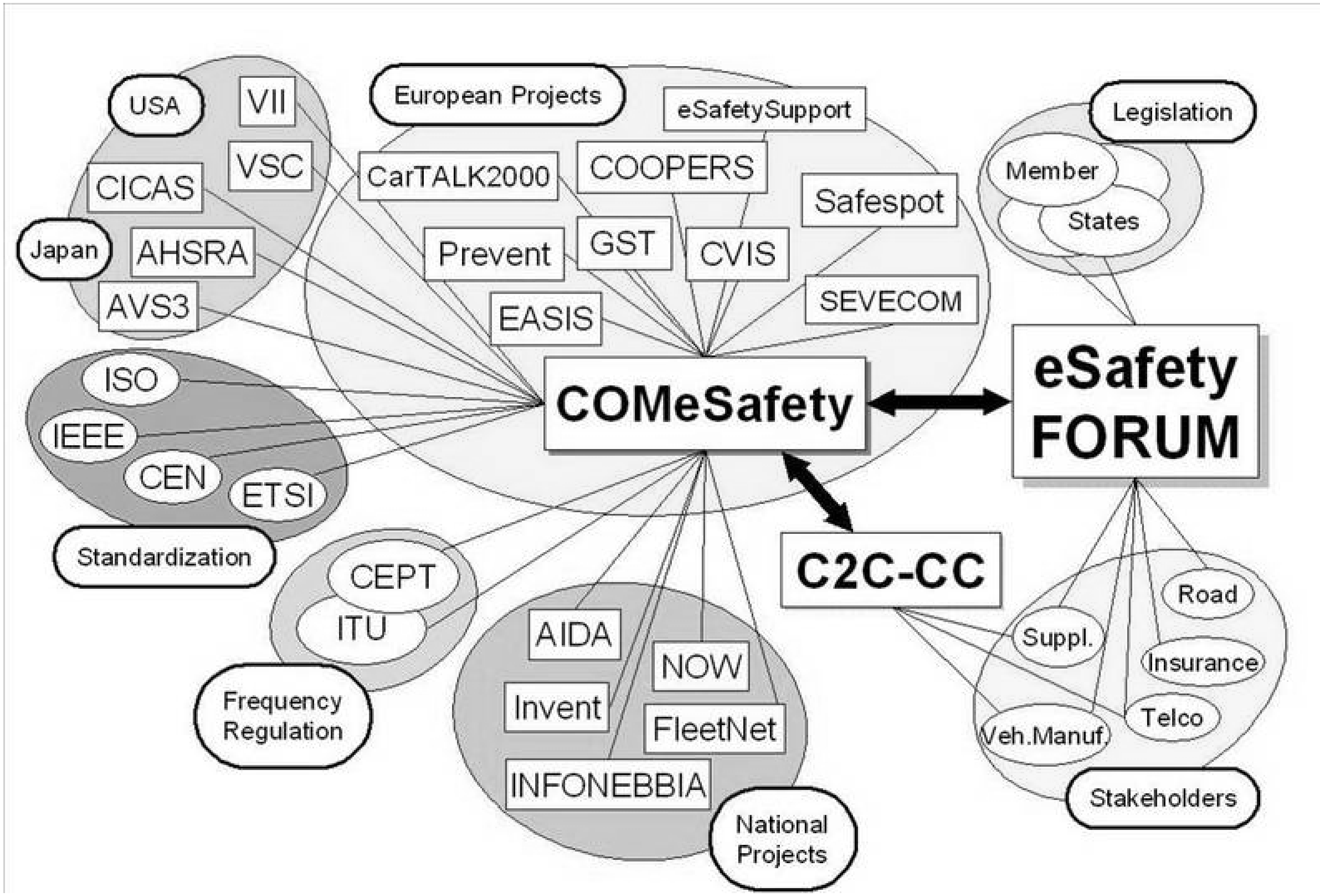
Courtesy: Matt Grossglauser, EPFL http://smartpark.epfl.ch

Vehicular networks: actors



Source : ComESafety website

Vehicular networks: some actors

- Governments
  - USDoT (*US Department of Transportation*) for example
- Industrials
  - Car manufacturers: BMW, Toyota, Chrysler, Daimler Benz, Ford, General Motors, Honda,
  - Manufacturers: NEC, Hitachi,
  - Operators: Orange labs, Deutsche Telekom, Telecom Italia, etc.
  - Software: Dash, Google, TomTom, Microsoft
- Universities
  - UCLA, University de Karlsruhe, University de Stanford, INRETS, etc.

US Research Projects

Old projects

- VSC (Vehicle Safety Communications)
  - DSRC (Dedicated Short Range Communications) for active safety applications

Current projects

- VII (Vehicle Infrastructure Integration) Initiative
  - Advanced v2v and v2i communications for safety and traffic efficiency
- CICAS (Cooperative Intersection Collision Avoidance System)
  - Intersection collision avoidance using v2v and v2i communication

EU Public Funded Projects

Old projects

- Aide
  - Driver Vehicle Interface
- EASIS
  - Electronic architecture
- PReVENT
  - Preventive Safety
- GST
  - On-line Safety service´s

Current projects

- SafeSpot
  - Cooperation for road safety
- CVIS
  - Cooperation for traffic efficiency
- Coopers
  - Seamless services along the travel chai
- SEVECOM
  - Security for cooperative systems
- COMeSafety
  - Coordination
- GeoNet
  - Geographic addressing and routing for vehicular communications

German Public Funded Projects

Old projects

- Fleetnet
  - Development and Demonstration of Car-2-Car communication protocols
- Invent
  - Intelligent traffic and user-friendly technology 3
- Network on Wheels (NOW)
  - Specification of Car-2-Car communication protocols

Current projects

- Aktiv
  - Adaptive and Cooperative Technologies for the Intelligent Traffic
- SIM-TD
  - German FOT

Industry Consortia

USA

- Vehicle Infrastructure Integration Consortium (VIIC)
- Collision Avoidance Metrics Partnership (CAMP)
- Targeted Applications
  - Safety
  - Traffic efficiency
  - Electronic Toll Collect (ETC)
  - Customer Relationship Management (CRM)

Europe

- Car 2 car Communication Consortium (C2C-CC)
- Targeted applications
  - Safety
  - Traffic Efficiency
  - Infotainment
- Note: Less roadside infrastructure expected than in the US

Standardization

- We need standards
  - uniformized vehicular cooperative systems (V2V & V2I)
  - uniformized exchange of information between vehicles and servers in the Internet
- AND ALSO
  - uniformized exchange with anything on the network anywhere Not only in the automotive sector: ITS is just one small portion of all data exchanges
  - Interoperability between communication systems developed in all sectors must be ensured
- The Internet Protocol (IP) is the de facto standard
  - ITS communication architectures must interoperate with it
  - IP provides an unification layer of underlying technologies
    - 2G/3G, 802.11 a/b/g, 802.11p, 802.16, satellite, ...

Standardization

USA

- IEEE 1609: Dedicated Short Range Communication (DSRC) –
  - Old name. Released in 2002 by ASTM (American Society for Testing and Materials)
- IEEE 802.11p: Wireless Access for the vehicular Environment (WAVE)
  - New name from 2003
  - Approved 802.11p amendment is scheduled to be published in July 2010

Europe

- Car 2 Car Communication Consortium (C2C-CC)
  - Car manufacturers
- ETSI ERM TG37 (TC ITS)

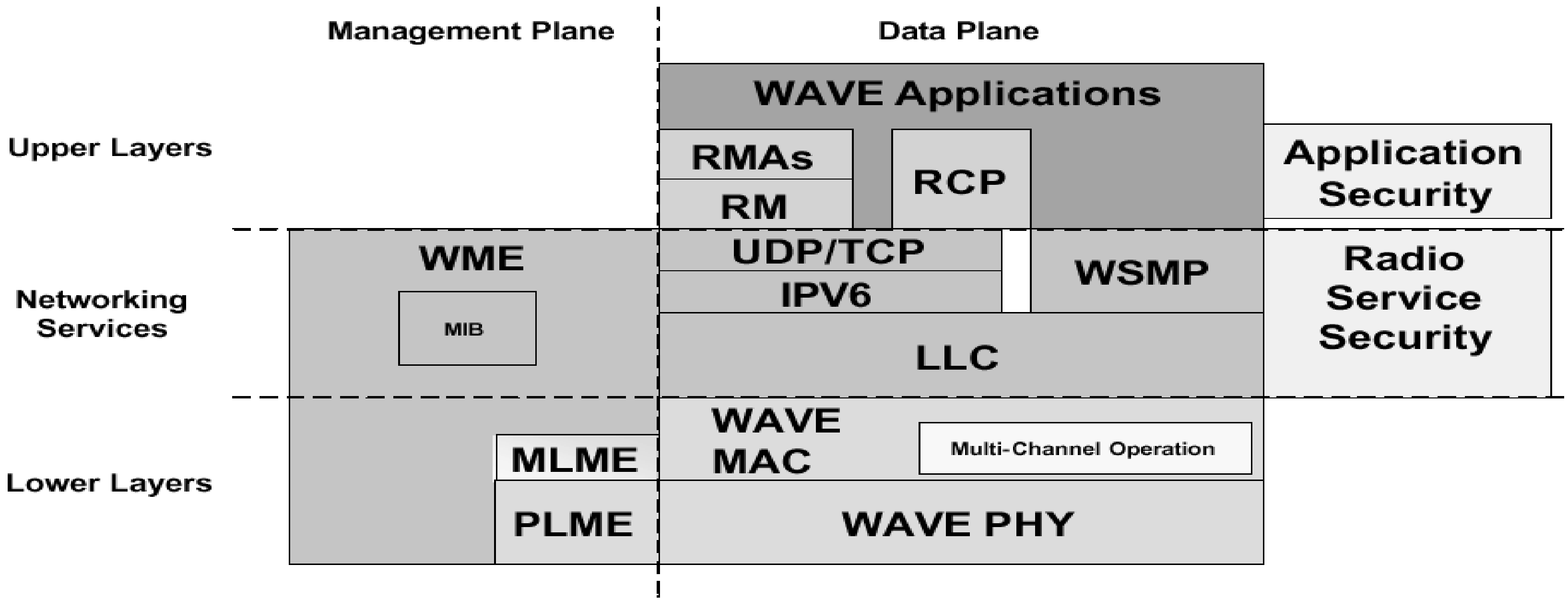
Worldwide Standardization:

ISO TC 204 WG 16 (CALM - Communications Air-interface, Long and Medium range)

COMeSafety and ETSI for coordination and harmonization

WAVE - 802.11p is a Common Radio Base System

Protocol Architecture: USA (ASTM)



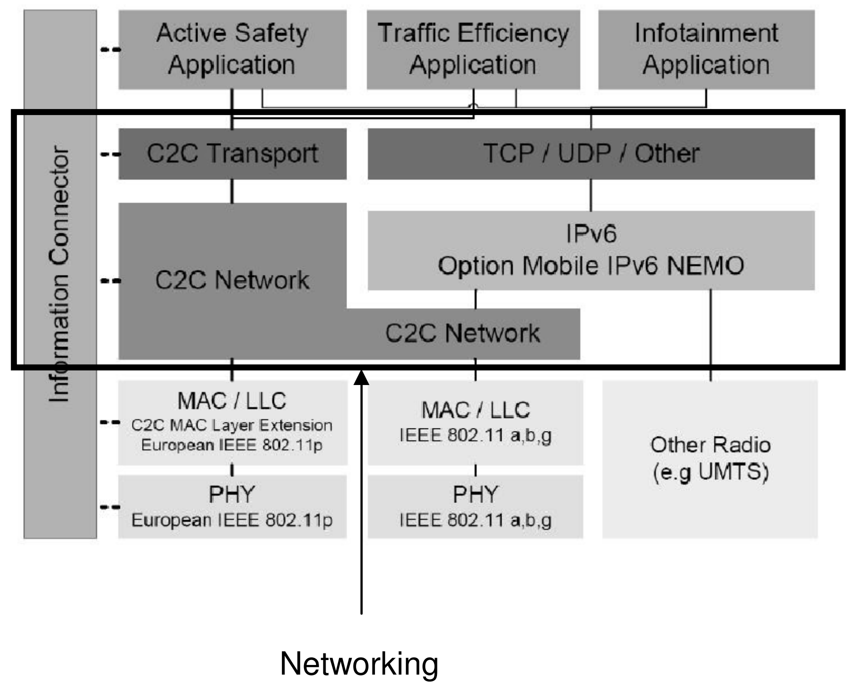
- IEEE P802.11p: WAVE PHY & MAC
- IEEE Std 1609.1: Resource Manager
- IEEE Std 1609.2: Security Services
- IEEE Std 1609.3: Networking Services
- IEEE Std 1609.4: Multi-channel Operation

Protocol Architecture: EU (C2C-CC OBU)

- Partial integration of safety and non-safety systems
- Specific features for each Double stack

  (Critical) Safety
  - non-IP
  - geographic distribution for event-driven messages
  - High-frequency beaconing
  - information-centric communication paradigm

  Infotainment
  - IPv6
  - IPv6 Mobility (NEMO) optional
  - Multiple physical interfaces



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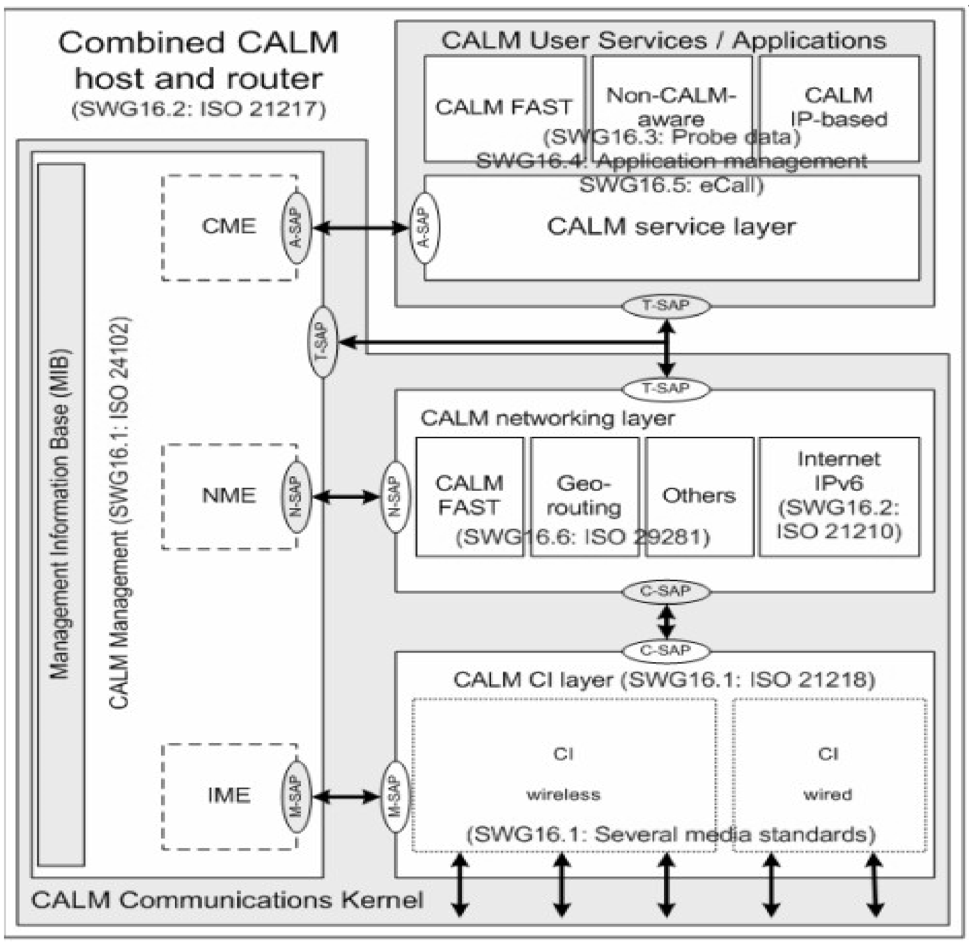
Protocol architecture: CALM

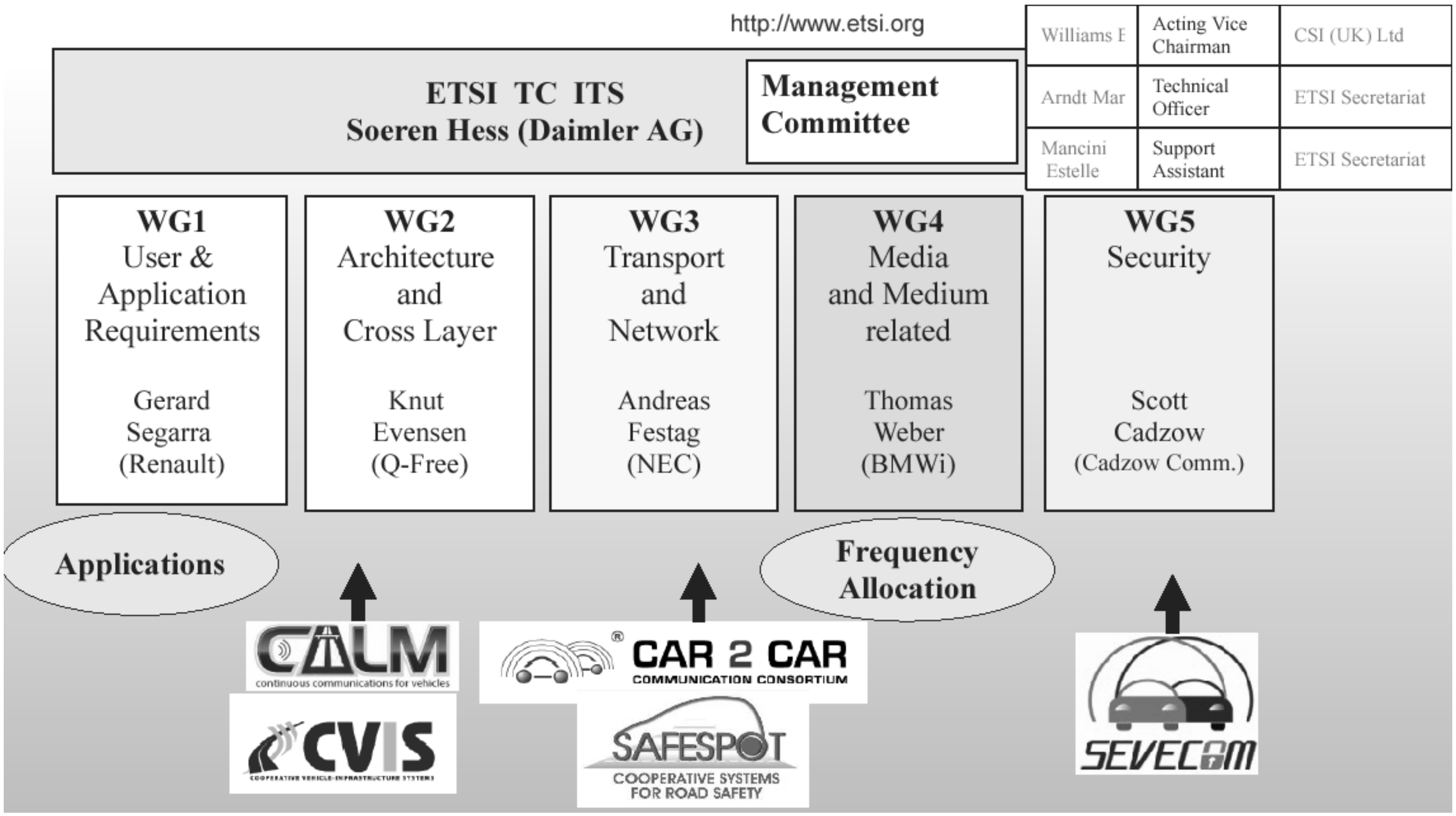
- Scenario diversity
  - Communication architecture allows V2V, V2I and continuous Internet access through multiple radio technologies (potentially used simultaneously)
- Media diversity
  - Cellular (CALM 2G/3G) – cf ISO 21212 & 21213
  - Infrared light (IR) – cf ISO 21214
  - Microwave (CALM M5 => 802.11p) – cf ISO 21215
  - Millimeter waves (CALM MM) – cf ISO 21216
  - Microwaves CEN DSRC
- Networking diversity
  - IPv6 (Internet connectivity, mobility management): ISO 21210
  - Non-IP networking (FAST => time critical applications): ISO 29281
- Medium Selection & Switching
  - Select most appropriate media based on 24102
- CVIS project is a proof of concept of CALM

Protocol architecture: CALM

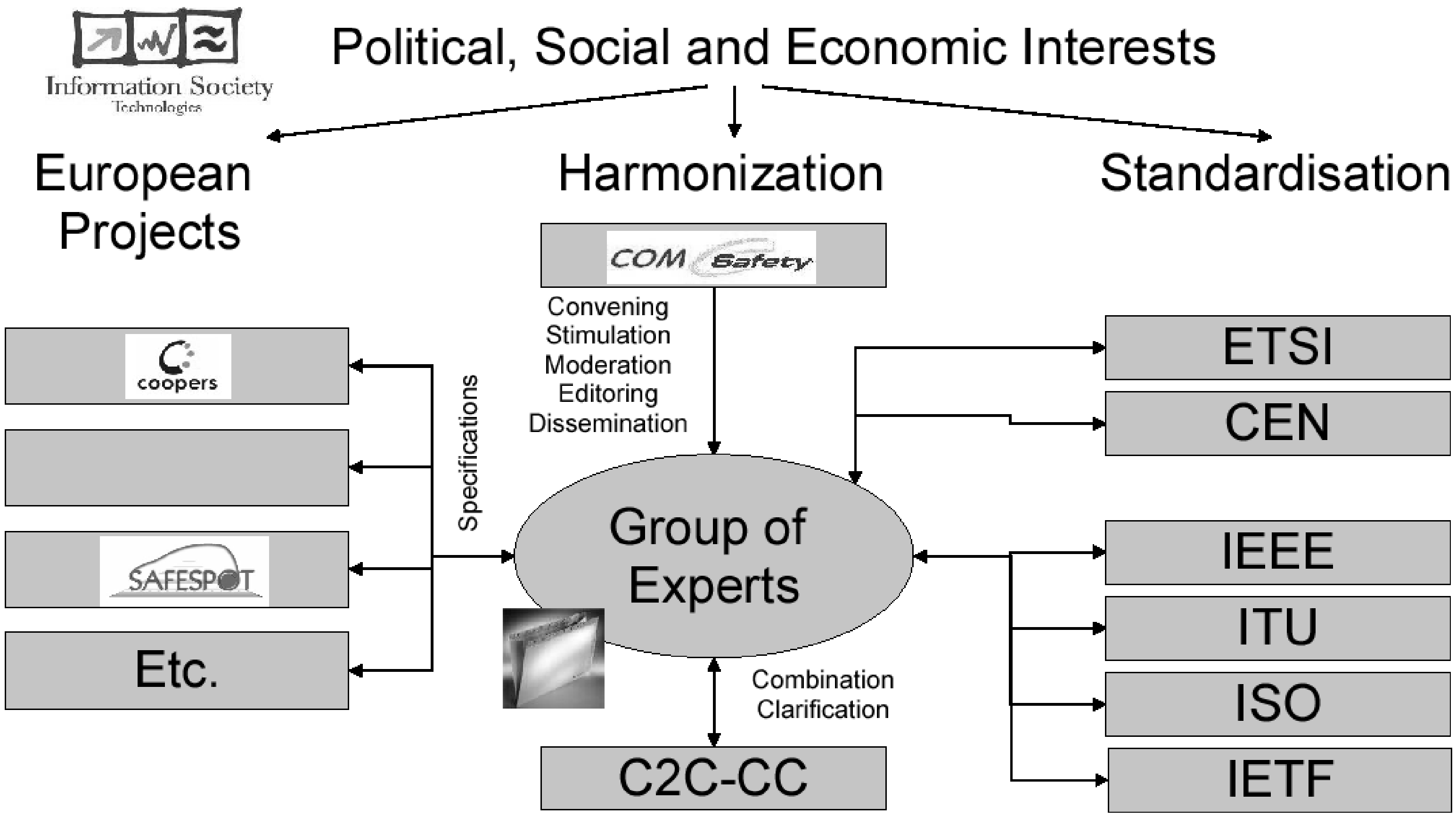


- SWG 16.0 Architecture
- SWG 16.1 Media
- SWG 16.2 Networking
- SWG 16.3 Probe Data
- SWG 16.4 Application Management
- SWG 16.5 Emergency Communications
- SWG 16.6 Non-IP Networking
- SWG 16.7 Security and Lawful Intercept

Protocol architecture: ETSI TC ITS

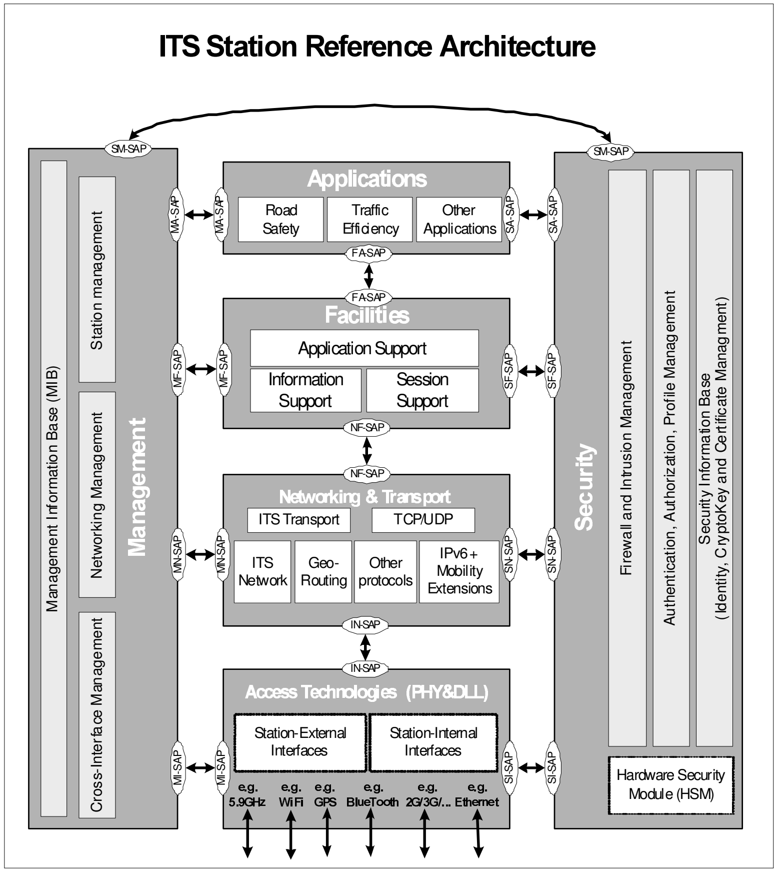


Protocol architecture: COMeSafety: Coordination

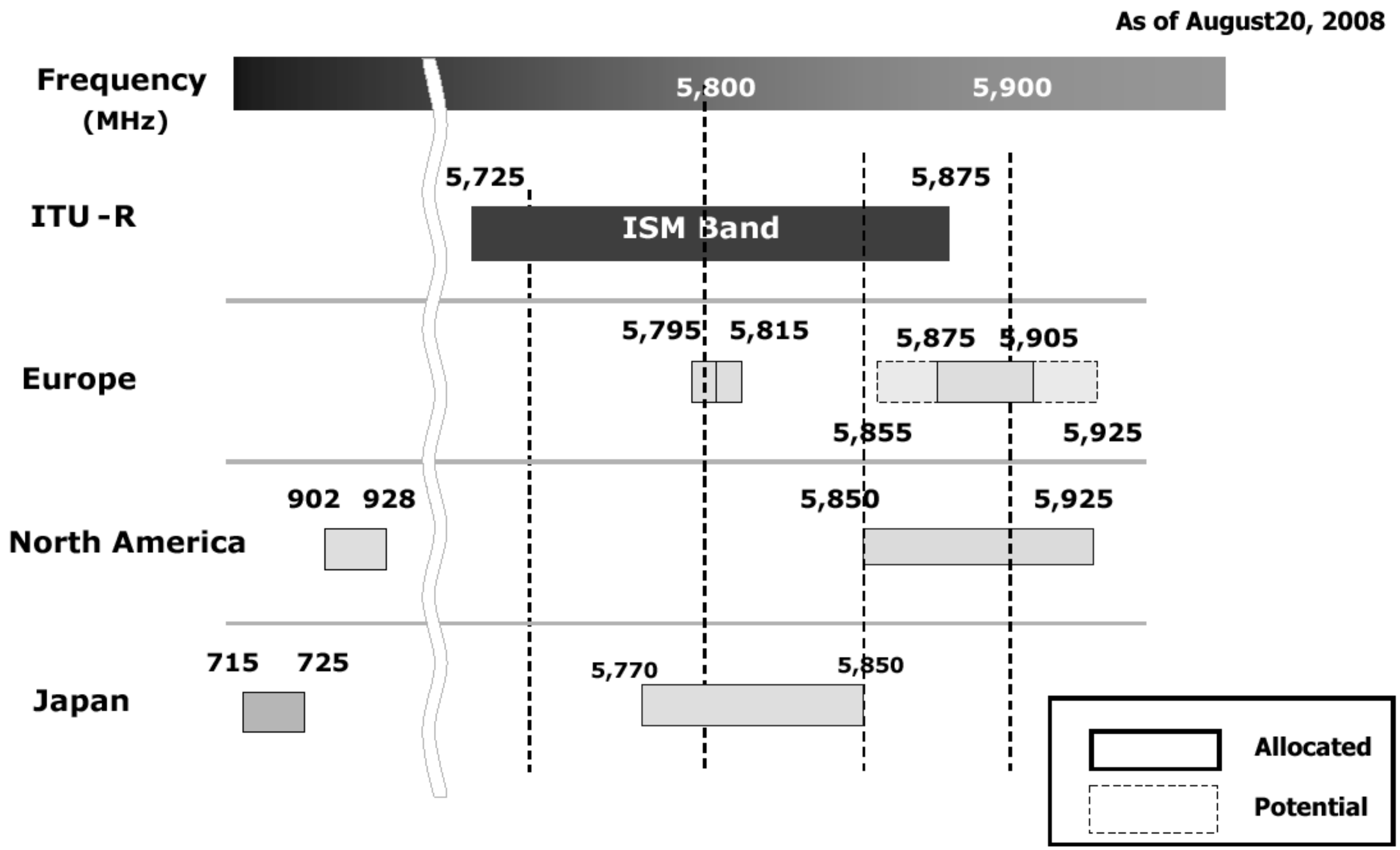


Protocol architecture: COMeSafety: Coordination

- Proposed European ITS Communication Architecture
  - Joint development: ETSI TC ITS COMeSafety+ R&D projects

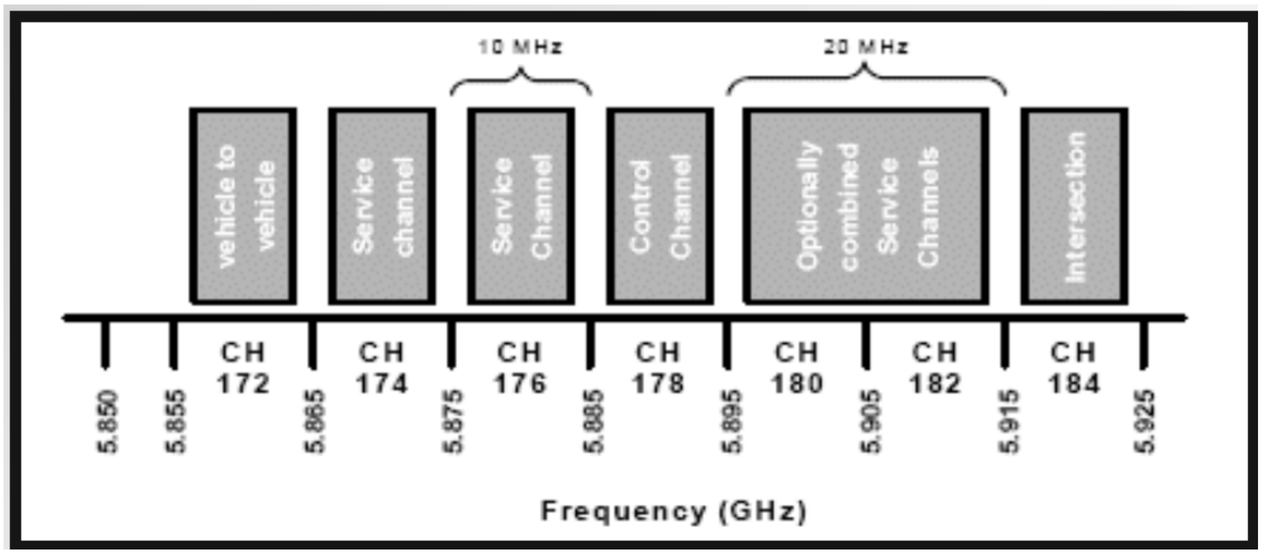


Spectrum allocations



IEEE 802.11p

- PHY/MAC Layers
  - The standard is based on IEEE 802.11a PHY layer and IEEE 802.11 MAC layer
  - Seven 10 MHz channels at 5.9GHz
    - one control channel and six service channels



IEEE 802.11p

- PHY/MAC Layers
  - 802.11a vs. 802.11p
    - 802.11a is designed for high data rate multimedia communications in **indoor** environment with **low user mobility**
    - DSRC PHY uses a variation of OFDM modulation scheme to multiplex data
      - high spectral efficiency, simple transceiver design and avoids multi-path fading
      - Data rates from 3 up to 27 Mbps
      - Transmit power level are changed to fit requirements of outdoor vehicular communications
      - **communication ranges up to 1000 meters**

Parameters	DSRC/802.11p	802.11a
Information data rate Mb/s	3, 4.5, 6, 9, 12, 18, 24 and 27	6, 9, 12, 18, 24, 36, 48 and 54
Modulation	BPSK, QPSK, 16-QAM, 64-QAM	BPSK, QPSK, 16-QAM, 64-QAM
Coding rate	1/2, 1/3, 3/4	1/2, 1/3, 3/4
Number of subcarriers	52 (=48+4)	52 (=48+4)
OFDM symbol duration	8µs	4µs
Guard time	1.6µs	0.8µs
FFT period	6.4µs	3.2µs
Preamble duration	32µs	16µs
Subcarrier frequency spacing	0.15625MHz	0.3125MHz

IEEE 802.11p

- PHY/MAC Layers
  - MAC layer of DSRC is inspired from the IEEE 802.11a and IEEE 802.11e
    - CSMA/CA
    - QoS issues included (4 classes)

IEEE 802.11p

- Proactive algorithms (table-driven)
  - better performance in terms of delay but they need a considerable amount of control traffic (e.g., OLSR)
- Reactive algorithms (on-demand)
  - minimize the number of broadcast packets by creating routes only on demand (e.g., AODV)
- Several studies demonstrate that neither of the two protocol classes outperform the other in every vehicular scenarios.

IEEE 802.11p

- Traditional MANETs routing protocols require an explicit route establishment phase before the data transmission begins

- They are not adequate to low delivery-latency requirement for safety applications

- Routing protocols for VANETs
  - should rely on packet forwarding based on geographic location of sender and receiver
  - should be broadcast oriented

IEEE 802.11p

- Position-based unicast routing (geographical forwarding)
  - these routing protocols exploit the availability of accurate location information
  - more suited to dense networks and to frequent network disconnections (e.g., GPSR)

- Geocast routing
  - a kind of multicast routing where the destination nodes are characterized by their geographical coordinates
  - in VANETs nodes interested in notifications of traffic congestions or warnings are located in the same place

IEEE 802.11p

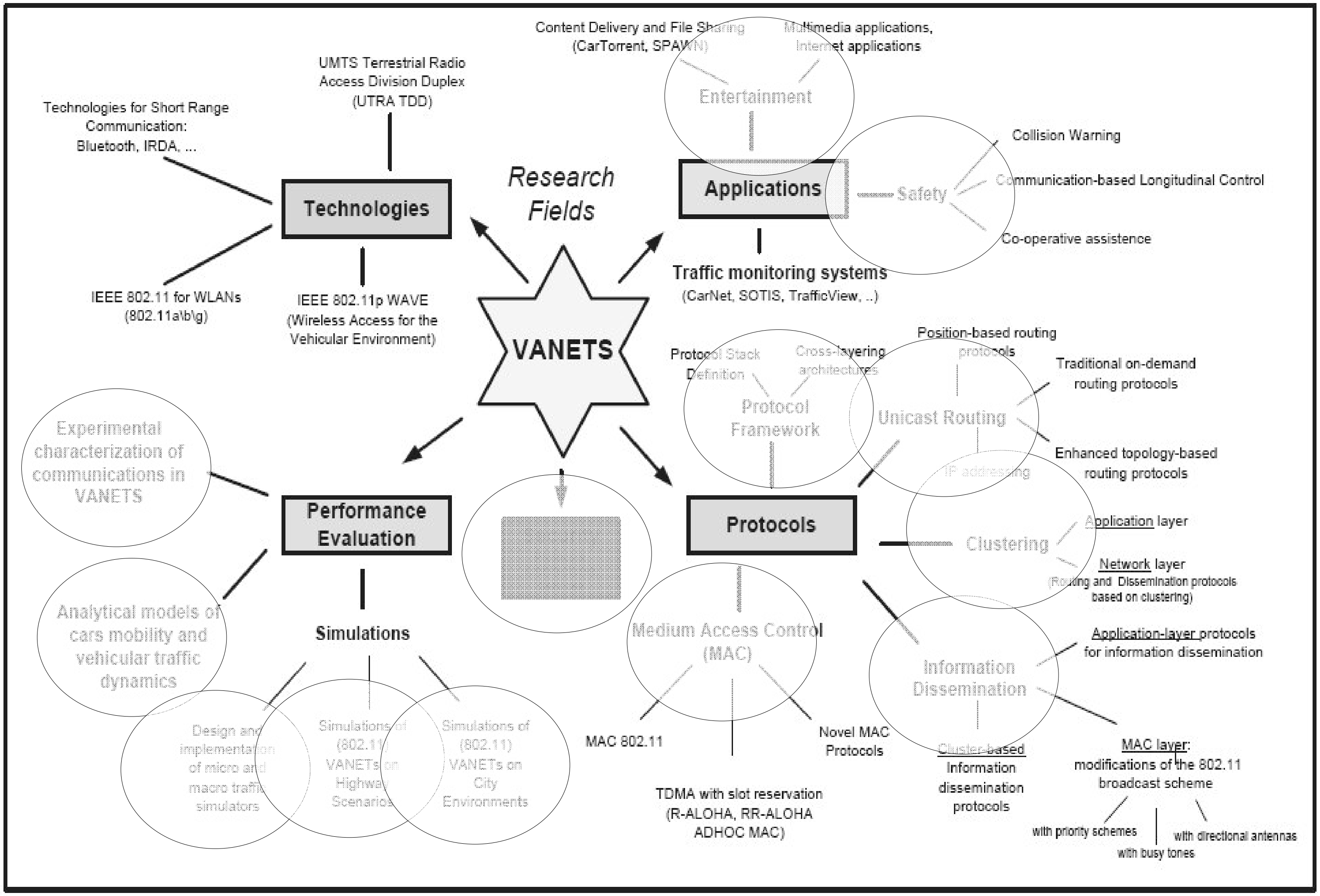
- Broadcast
  - Majority of applications for VANETs rely on broadcast dissemination of information in the applications area
  - Blind flooding is the first approach to achieve broadcasting since it does not require local or global topology information
  - Broadcasting has a strong influence on network performance
    - Serious redundancy, contention and collision problems can occur as a result of flooding
  - An efficient broadcast protocol should minimize the total number of packet retransmissions, while at the same time preserving network connectivity

IEEE 802.11p

- Broadcast
  - A trade-off between robustness and redundancy should be found
  - Different approaches:
    - probability-based
      - a node forwards the packet with a probability p which depends on network scenario
    - location-based location-based
      - the idea is to select as relays those nodes that permit to cover the widest additional area
    - neighbor-based neighbor-based
      - the nodes decide whether broadcasting the message or not on the status of their neighbors
    - cluster-based cluster-based
      - nodes are grouped into small clusters each one managed by a particular node called cluster-head which has the task of retransmitting broadcast messages


Orange R&D activities

Orange Labs activities



Orange Labs activities

1 ■ Mobility models and simulators

2 ■ GyTAR overview

3 ■ IFTIS overview

4 ■ GVI overview

5 ■ Vehicular communication security

6 ■ Experimental evaluation & characterization

1. Mobility models and simulators

- One key problem in the study of VANETs is the need to characterize vehicular nodes mobility and traffic patterns traffic patterns in order to produce mobility models that reflect as close as possible the real behaviour of mobile systems
- Mobility model affects the simulation results
- Based on a on a *level-of- detail* classification, traditionally, three types of approaches have been used:
  - Microscopic models
  - Macroscopic models

1. Mobility models and simulators

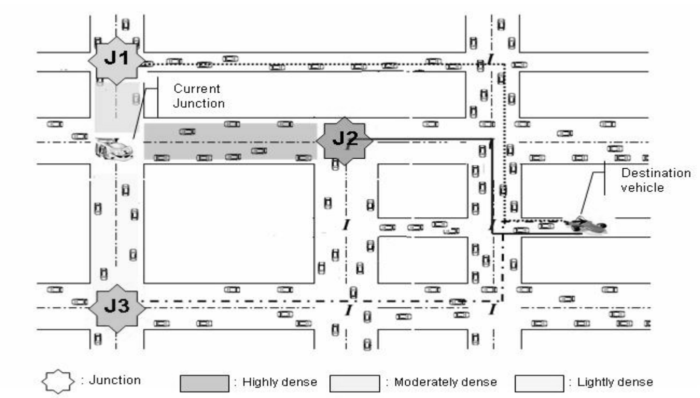
- Microscopic models
  - The most basic and detailed approaches are microscopic or car following models, modeling the actual response of individual vehicles to their predecessor
  - Each vehicle is described on the on “microscopic scale” by its space x(t) and speed v(t) coordinates at time t.
- Macroscopic models
  - Coarsest level of description
  - In most applications one is neither interested in the exact evolution of the singles vehicle nor in the in the distribution function *f*
  - Use fluid dynamic equations
  - Main quantities are the density, the mean speed and speed variance of vehicles

1. Mobility models and simulators

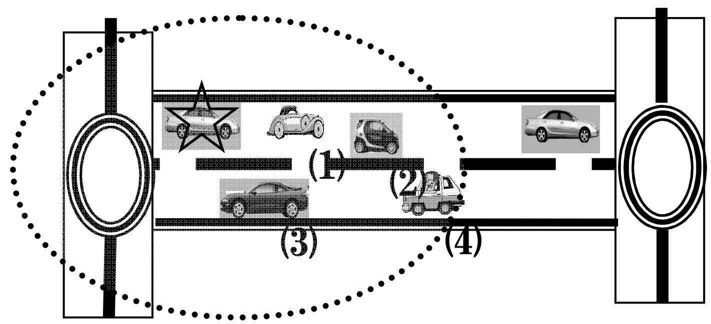
- Simulations are still commonly used as a first step in any protocol development for VANETs research
- Recently new open-source tools are available for generation of vehicular mobility patterns.
  - STRAW: The Street Random Waypoint tool provides road topology extraction from the maps of the TIGER database as well as micromobility support. The main drawback is that it **produces traces not usable by different well-known network simulators** but only by the SWANS platform on which it is based.
  - CanuMobiSim: is a for the generation of movement traces in a variety of conditions. Extrapolation of real topologies from detailed Geographical Data Files (GDF) are possible, many different mobility models are implemented, a GUI is present, a**nd the tool can generate mobility traces for *ns-2 or Glomosim (Qualnet)*** and other simulators. Micromobility is considered, implementing several car-to-car models.

2. GyTAR: An Improved Vehicular Ad Hoc Routing Protocol for City Environments

- GyTAR: Example of Position Based Routing Protocol
  - GyTAR is an intersection-based routing protocol
  - GyTAR is capable to find robust routes within city environments.
  - GyTAR Overview:
    - Dynamic selection of the junctions through which a packet must pass to reach its destination,
    - Improved greedy forwarding mechanism between two junctions

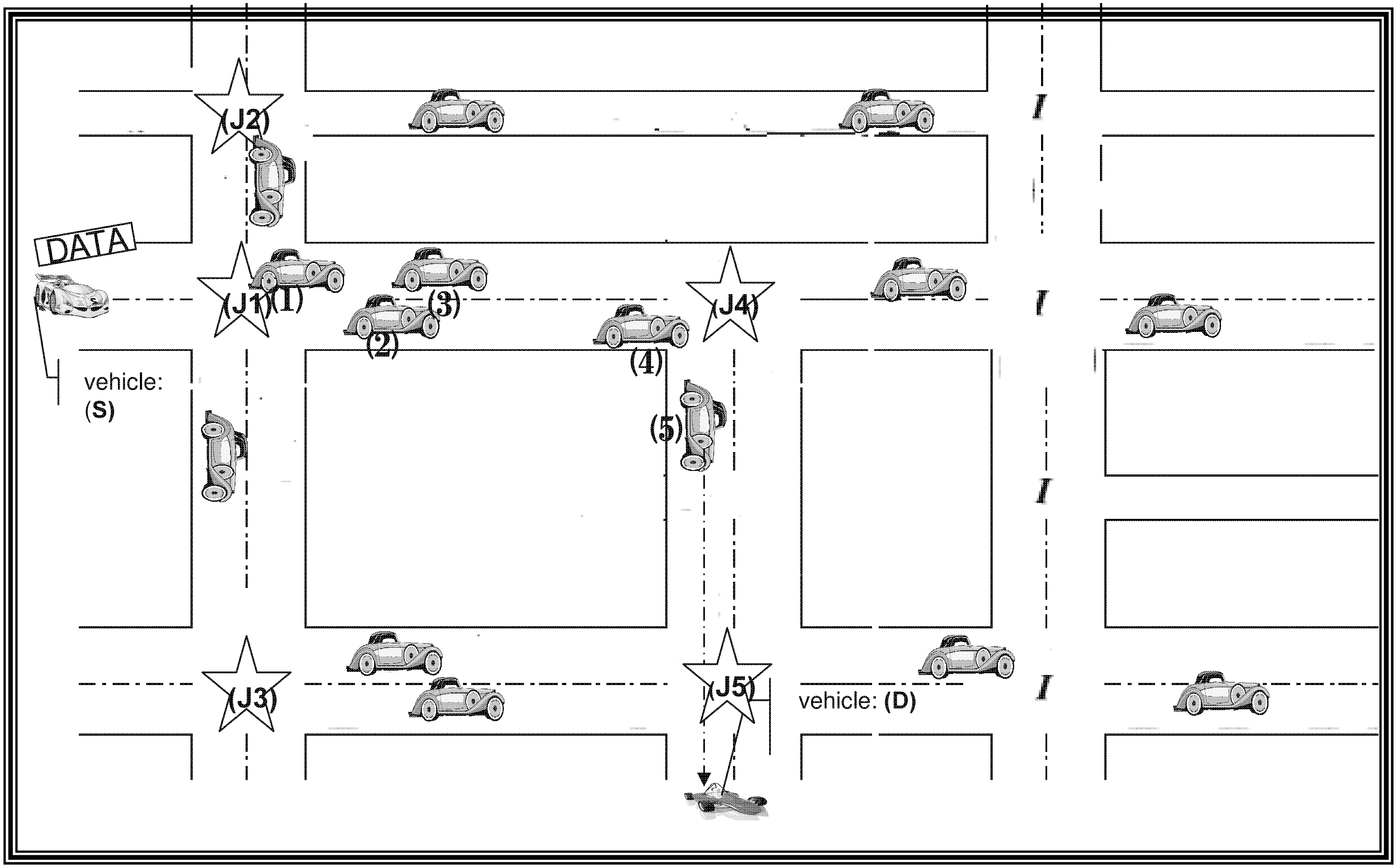


- Selecting junctions in GyTAR -



- Forwarding mechanism between two junctions-

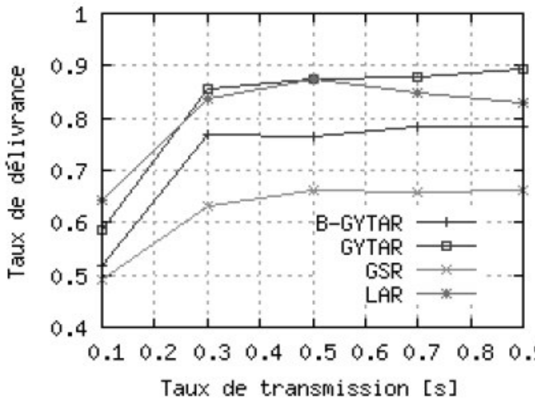
2. GyTAR Overview : How does it work?

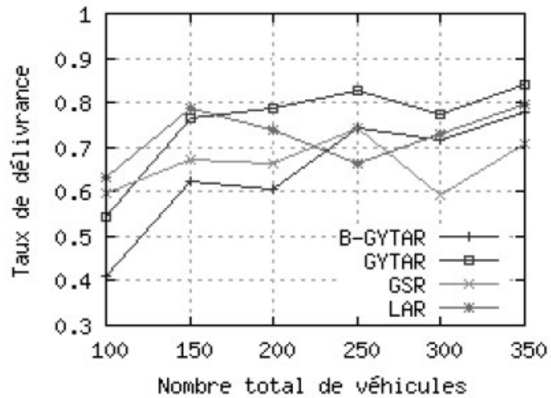


2. GyTAR Overview : Simulation results?

- Delivery ratio

300 noeuds

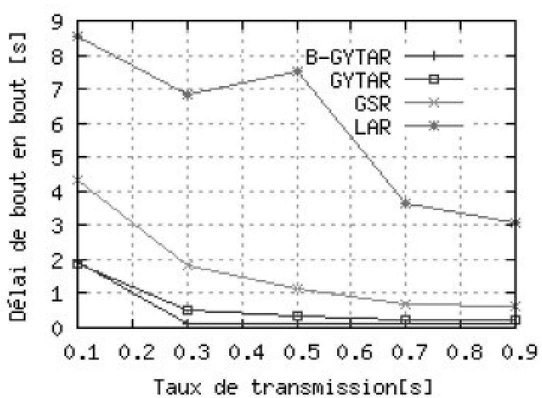


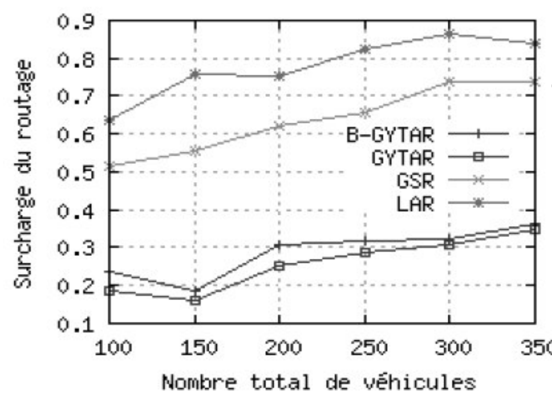


5 packets / sec

- Delay and overhead

300 noeuds





5 packets / sec

2. GyTAR : Applications

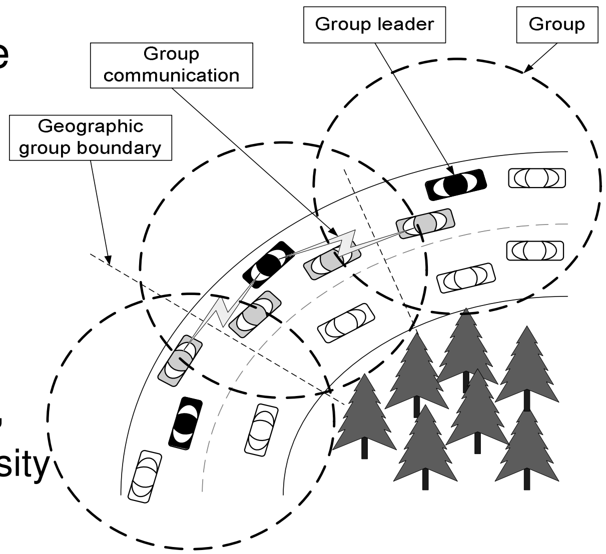
- GyTAR is conceived to relay data in the vehicular network for distributed infotainment applications and user services which require more than one hop communication

- GyTAR could be specifically adapted for:
  - Delay sensitive ad hoc applications like on-vehicle chat or gaming and equally applicable
  - **Infrastructure-related** delay tolerant applications like the accessing of info-mobility or infotainment services.
  - Service continuity and possible extension to the wired network.

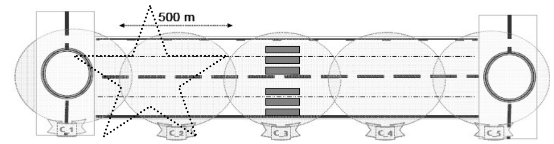
- Related publications
  - M.Jerbi, S.Senouci, R.Meraihi, Y.Ghamri-Doudane, "An improved Vehicular Ad Hoc Routing Protocol for City Environments", IEEE ICC 07, Glasgow, Scotland, Juin 2007.
  - M.Jerbi, S.Senouci, R.Meraihi, Y.Ghamri-Doudane, "GyTAR: Improved Greedy Traffic Aware Routing Protocol for Vehicular Ad Hoc Networks in City Environments", ACM/ VANET 06, Los Angeles, USA, September 2006.

3. IFTIS Overview

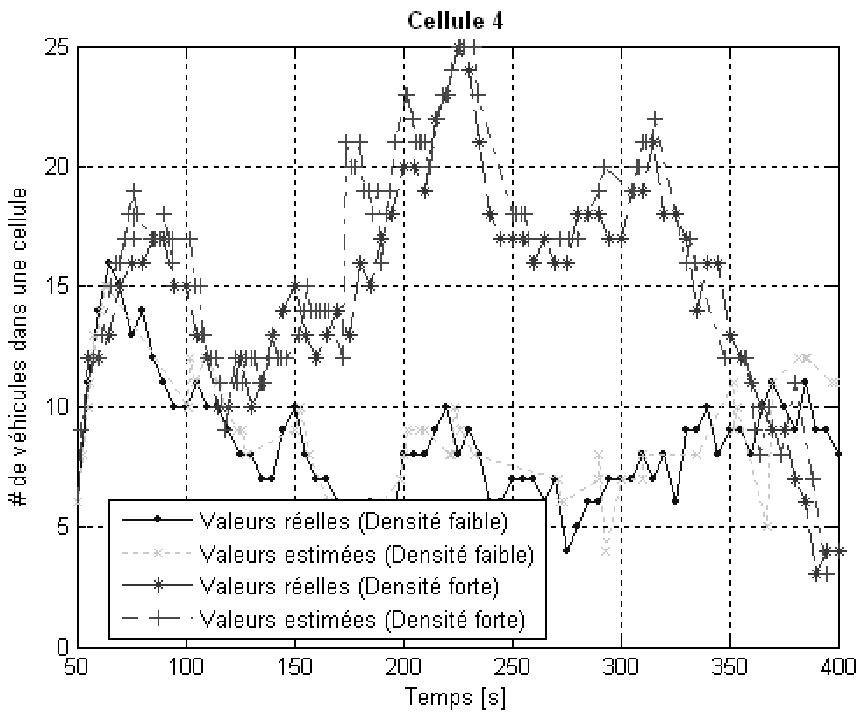
- **GyTAR assumes that every vehicle is aware of vehicular traffic**
  - **Solution: IFTIS**
    - A decentralized mechanism for the estimation of traffic density
    - The approach is based on the distributed exchange and maintenance of traffic information between vehicles traversing the routes.
    - IFTIS Overview:
      – Road is divided into cells,
      – Local density Information is relayed between groups,
      – Road density is estimated at junctions using the density of each cell.



3. IFTIS Overview: Simlation results

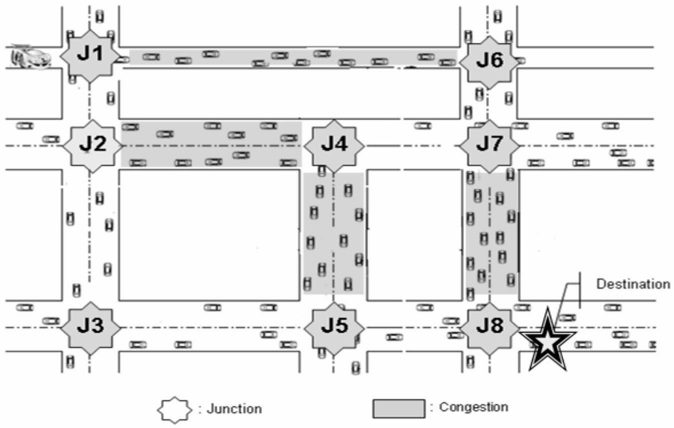


Précision dans l'estimation de la densité du trafic



3. IFTIS Overview: Scenario of use

- **Scenario of use :**
  - **Real-time traffic congestion Warning system** : To determine real-time traffic congestion for vehicular networks.



- Traffic warning system -

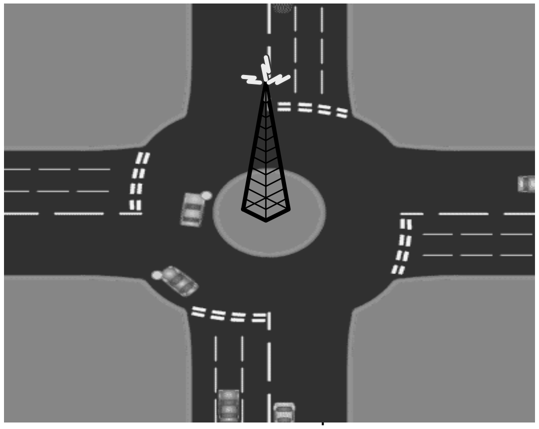
Roadside units installed at intersections for disseminating this information about congestion in nearby area.

- Related publications
  - M.Jerbi, S.Senouci, T.Rasheed, Y.Ghamri-Doudane,, "An Infrastructure-Free Traffic Information System for Vehicular Networks", IEEE WiVeC 07, Baltimore, USA, September 2007;

4. GVI overview: motivations

- Many of VANETs applications rely on distributing data.
- They may prove costly as they require the installation of new infrastructures on road network, especially if the area to be covered is large.

- Our main objective is to propose a mechanism based on inter-vehicle communications acting as ***virtual stationary infrastructure.***
  - The *geo-localized virtual infrastructure* broadcasts a message periodically.
  - The broadcasted message is virtually stationary within a region



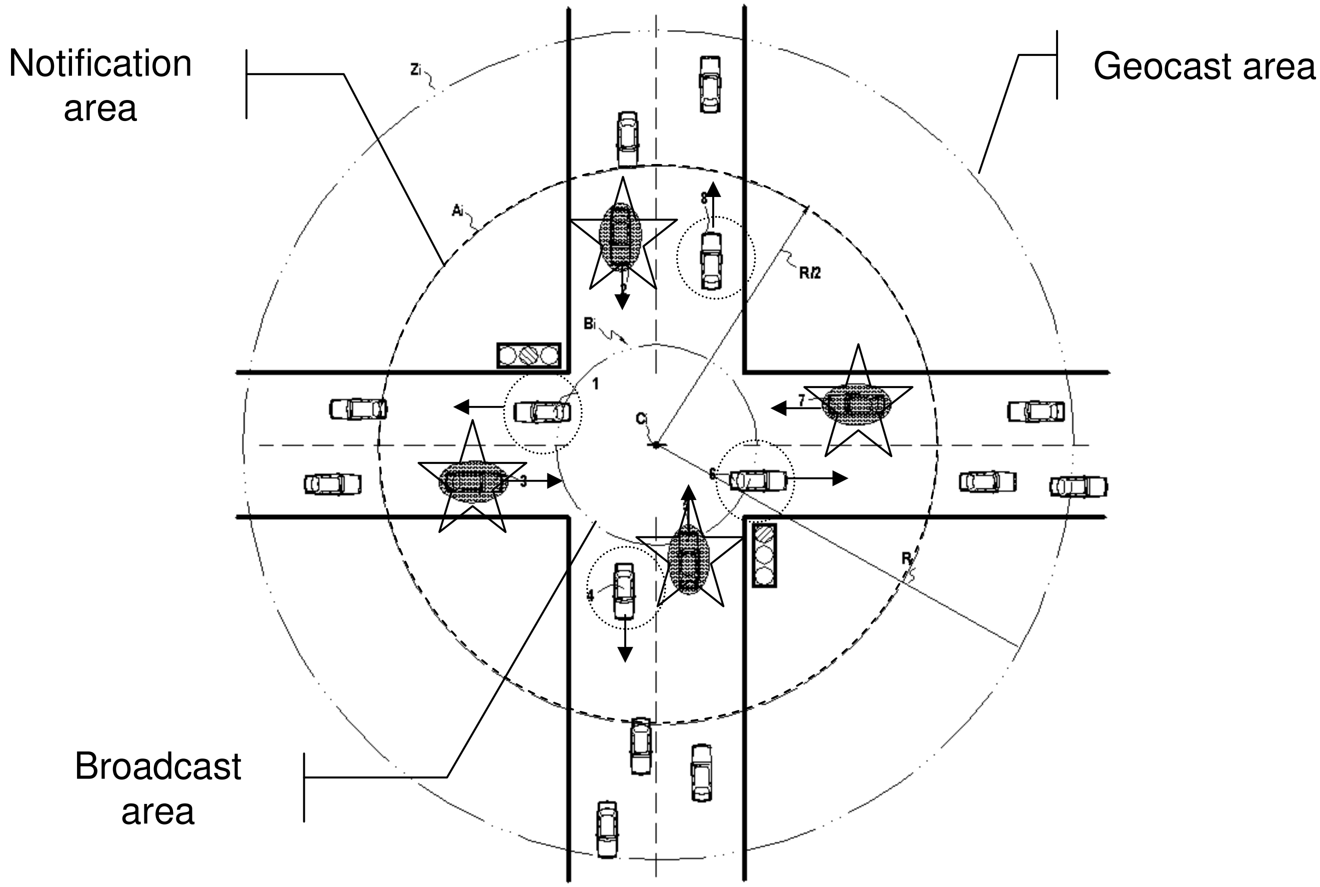
4. GVI Overview: What is GVI?

- The geo-localized virtual infrastructure mechanism consists on electing vehicles that will perpetuate information broadcasting within the intersection area.

- The GVI mechanism is composed of two phases:
  - (i) the first phase is selecting vehicles able to reach the broadcast area.
  - (ii) in the second phase, only one among the selected vehicles is elected as the local broadcaster. It will perform a local / single hop broadcast once it reaches the broadcast area.

4. GVI Overview : How does it work?

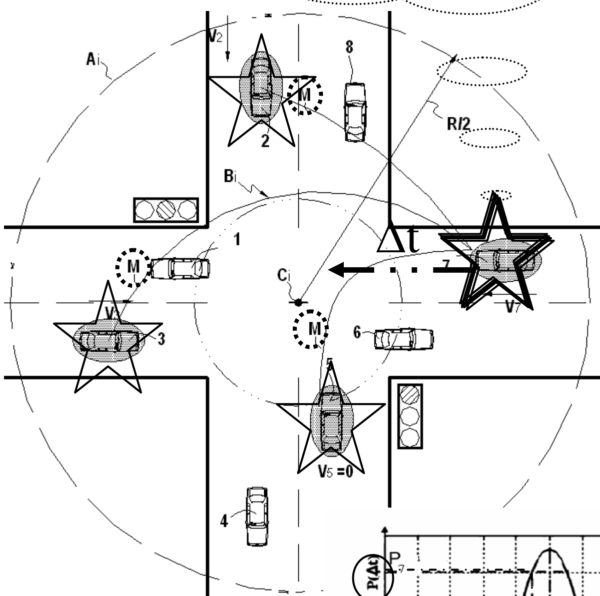
- 1st phase : Selecting vehicles candidates

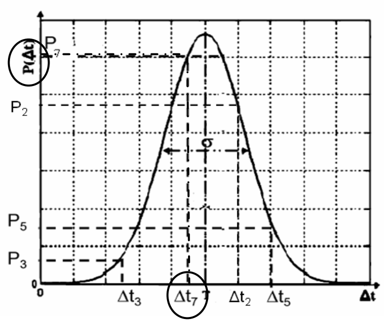


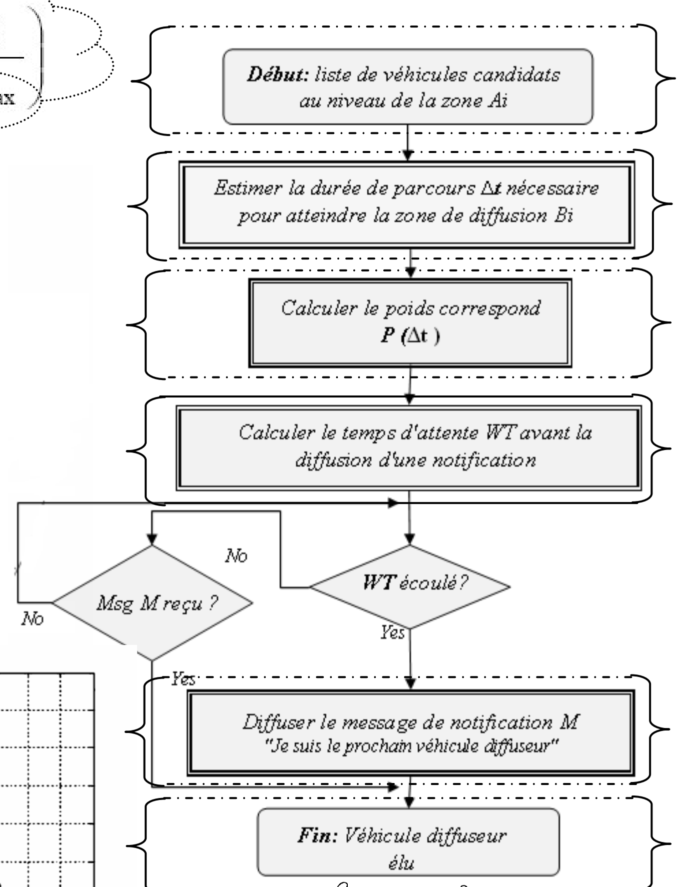
4. GVI Overview : How does it work?

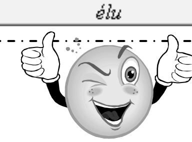
- 2nd phase : Electing local broadcaster vehicle

$$WT_i(P_i) = WT_{Max}\left(1-\frac{P_i}{P_{\max}}\right)$$



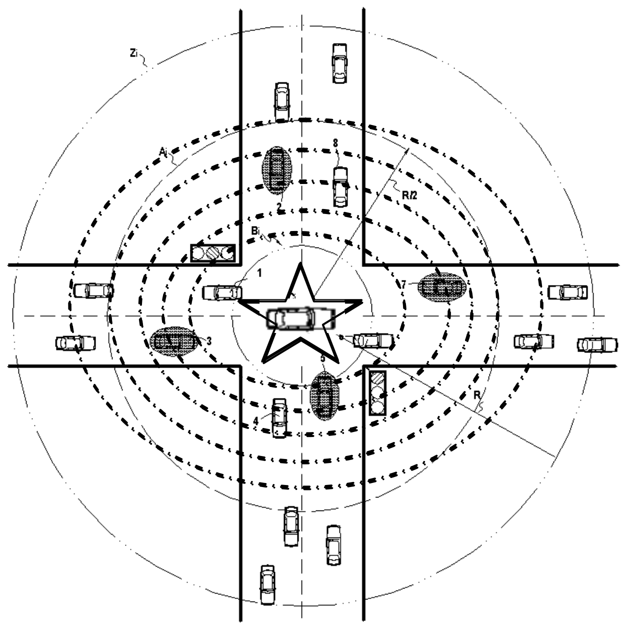






4. GVI Overview : How does it work?

- Summary

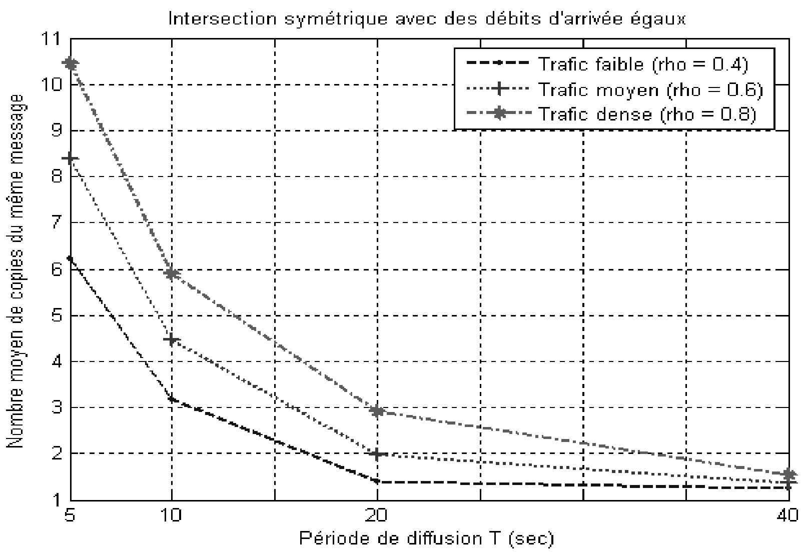


<u>1st phase:</u> Selecting vehicles candidates

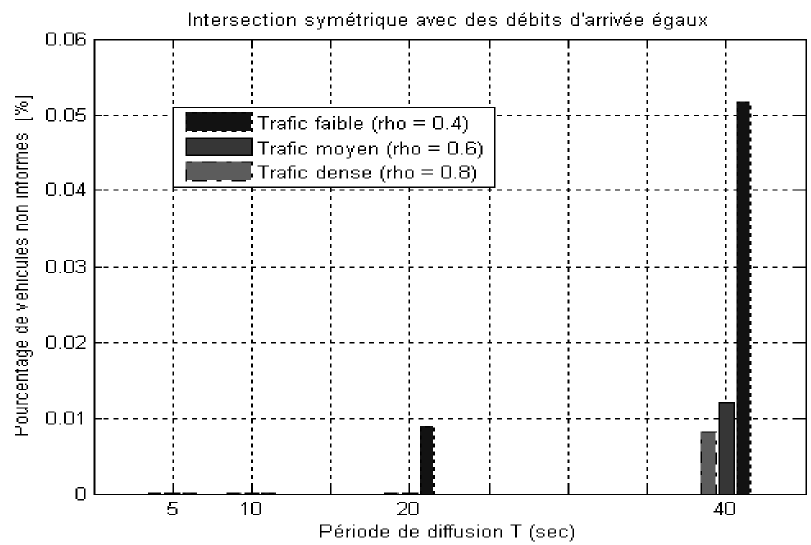
<u>2nd phase:</u> Electing local broadcaster vehicler

4. GVI Overview : Simulation results?

Nombre moyen de copies du même message reçu



Pourcentage de véhicules non informés



- Related publications
  - M. Jerbi, A.L. Beylot, SM. Senouci, Y. Ghamri-Doudane “Geo-localized Virtual Infrastructure for VANETs: Design and Analysis”, IEEE Global Communications Conference (GLOBECOM' 2008), New Orleans, LA, USA.
  - M. Jerbi, SM. Senouci, Y. Ghamri-Doudane, A.L. Beylot, “Geo-localized Virtual Infrastructure for Urban Vehicular Networks”, in Proceedings of IEEE Intelligent Transport System Communication (ITST'2008), Phuket, Tailand, 22-24 October 2008.

5. Security Challenges in Vehicular Communication

- Securing vehicular communication is a great research challenge.
  - Direct impact on future deployment of vehicular networks and their applications.

- Commercial deployment of services in VANETs necessitates a number of security requirements.
  - Authentication, access control , services' authorization.
  - Trust between the communicating entities and confidential transfer.
  - Non-traceability
    - Certain authorities should be able to trace vehicles as a mean of security.
    - The non-traceability of vehicles with respect to each other should be assured.

5. Security Architecture for Inter-Vehicle Communication on Highways

- Inter-vehicle communication on highways.
  - Deployment architecture allowing Inter-vehicles data transfer/safety messages diffusion and vehicles' Internet access.

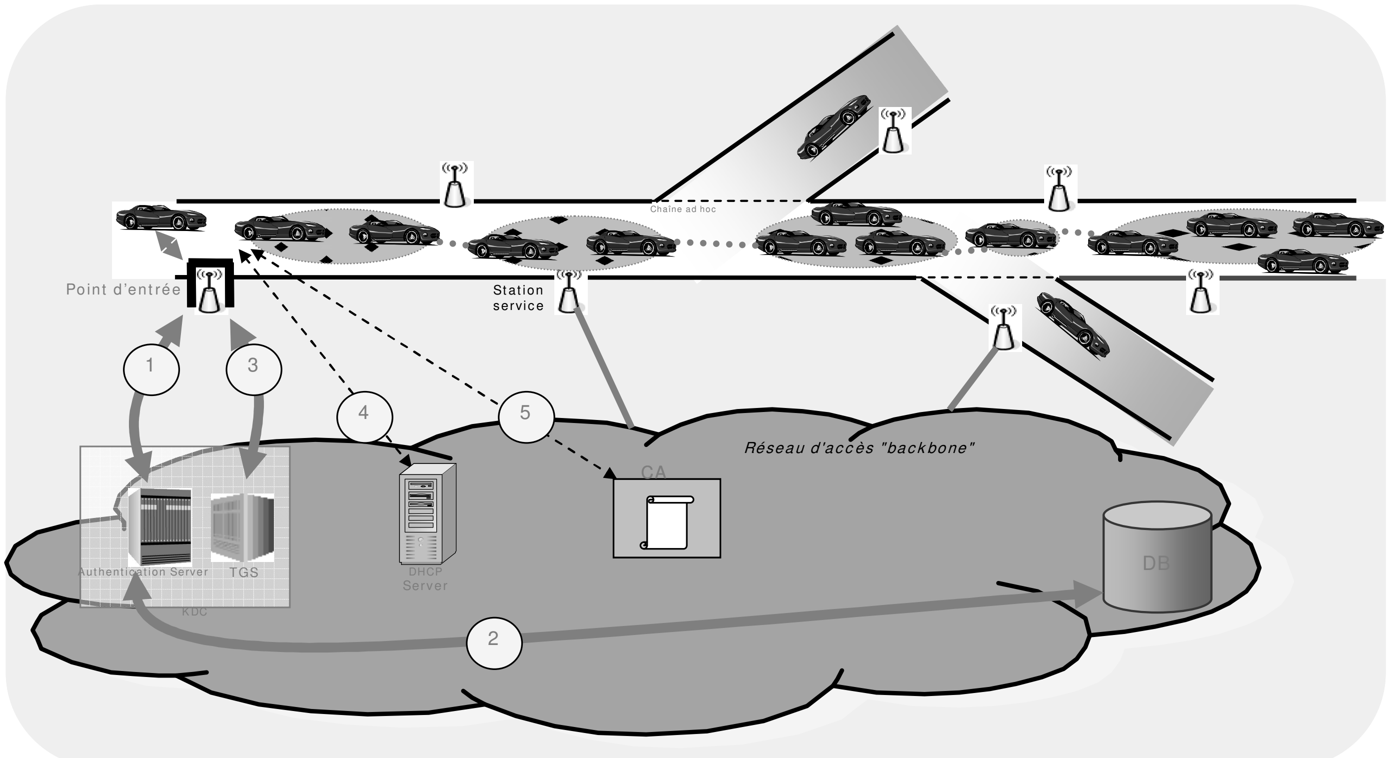
- Secure communication/participants' authentication.
  - Authenticating participants (mobile users) at highways entry points.
  - Authentication between participants during the voyage.

- The operator/service provider is the core for the AAA process.
  - AAA at entry points: Clients w.r.t. service provider.
  - Authentication and Confidentiality: Per link (client-client)/(client-AP)

- Adapting 802.11i for VN (AAA and communication privacy) using

1. Kerberos authentication server at entry points: Authenticating clients w.r.t. SPs.
   - 802.11i employing EAP-Kerberos.
   - Authorization for channel access.
   - Authorization for services access (certificates and IP configuration).
2. EAP-TLS between vehicles during the voyage.
   - Adapting 802.11i to the multi-hop ad hoc mode.
   - No communication with the centralized server: using the previously obtained certificates instead.
   - Encryption keys generation and utilization assuring confidential transfer.

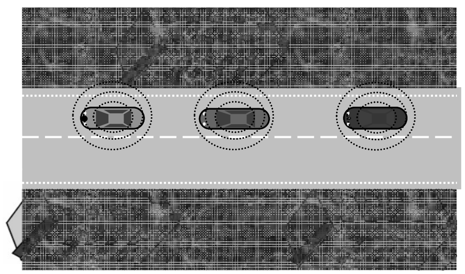
5. Security Architecture for Inter-Vehicle Communication on Highways



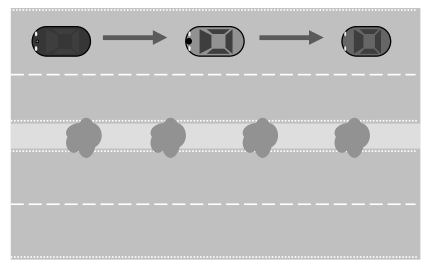
- Related publications
  - Hassnaa Moustafa, Gilles Bourdon, and Yvon Gourhant, "AAA in Vehicular Communication on Highways with Ad hoc Networking Support: A Proposed Architecture", ACM VANET 2005.
  - Hassnaa Moustafa, Gilles Bourdon, and Yvon Gourhant", Providing Authentication and Access Control in Vehicular Network Environment ", IFIP SEC 2006.

6. Experimental Evaluation & Characterization

- **Our Goal:** we investigate the usability of providing network connectivity to mobile users for different scenarios

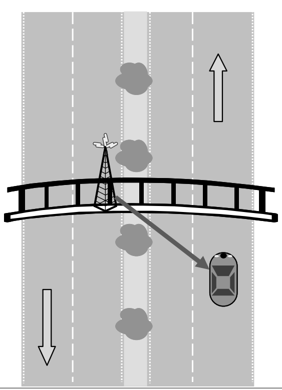


Static Scenario (6 vehicles)

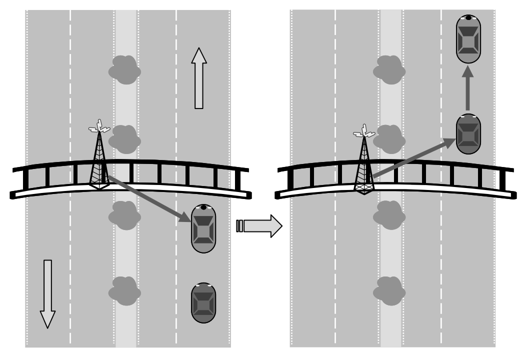


Following Scenario (6 vehciles)

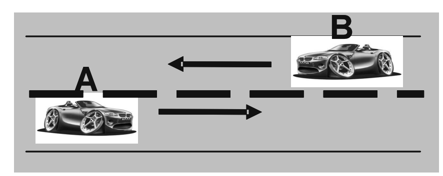
Round about



Single vehicle/ Single AP



Two vehicles/ Single AP



Crossing

6. Experimental Evaluation & Characterization

- Some results and analysis

Network connection time		
	high speed	low speed
Total	**81**	**140**

Amount of data		
	high speed	low speed
Total	**59,195**	**98,86**

– Network connection time (s) and amount of data (Mb) for scenario one car/one AP-

Network connection time		
	high speed	low speed
direct	66	143
multihop	25	27
Total	**91**	**170**

Amount of data		
	high speed	low speed
direct	54,247	106,452
multihop	9,813	9,519
Total	**64**	**116**

– Network connection time (s) and amount of data (Mb) for scenario two cars/one AP -

- The ad hoc network (cooperation)
  - Enlarges the service area and the connection time (**>16%**).
  - Increases the amount of data that the car can acquire through AP (**>10%**).

- Related publications
  - M. Jerbi, M. Al Haj and S.M. Senouci, "Extensive Experimental Characterization of Communications in Vehicular Ad Hoc Networks within Different Environments" – *IEEE VTC 07*, Dublin, Ireland, April 2007.
  - M. Jerbi, P. Marlier and S.M. Senouci, "Experimental Assessmnet of V2V and I2V Communications", *MoVeNet 07*, IEEE MASS 07, Pise, Italy, October 2007.

7. SOFT MAC

- Static slot assignment for high-priority traffic and dynamic assignment for the low-priority traffic
- Idea under patent

Conclusions

❖ Roadmap technologique

- Une décision de la Commission Européenne pour désigner le spectre est prévu que cette année 2008.
- Le standard IEEE 802.11p destinée aux applications ITS est en cours de normalisation et il est prévu qu'il soit disponible en 2010.
- Le gouvernement américain et les industriels regroupés dans le consortium VII démarrent une phase de test sur un réseau de type DSRC.
- Au japon la technologie DSRC est déjà déployée (ETC)
- Le système sera commercialisé à partir de 2010 pour le marché américain en premier. Le déploiement des RSU et des centres de contrôle sur nos routes (urbaines, interurbaines) est prévu aussi en 201x (max 2015) par les gestionnaires d'autoroutes/autorités publics.

Some references

- M.Jerbi, S.Senouci, R.Meraihi, Y.Ghamri-Doudane, "An improved Vehicular Ad Hoc Routing Protocol for City Environments", ***IEEE ICC 07****, Glasgow, Scotland, Juin 2007.*
- M.Jerbi, S.Senouci, R.Meraihi, Y.Ghamri-Doudane, "GyTAR: Improved Greedy Traffic Aware Routing Protocol for Vehicular Ad Hoc Networks in City Environments", ***ACM/ VANET 06****, Los Angeles, USA, September 2006.*
- M. Jerbi, and S.M. Senouci, M. Al Haj "Extensive Experimental Characterization of Communications in Vehicular Ad Hoc Networks within Different Environments" – ***IEEE VTC 07****, Dublin, Ireland, April 2007.*
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- M.Jerbi, S.Senouci, Y.Ghamri-Doudane,, "Towards Efficient Routing in Vehicular Ad Hoc Networks", *UBIROADS 07, Marrakech, MOROCCO, July 2007.*
- M. Jerbi, M. Al Haj and S.M. Senouci, "Extensive Experimental Characterization of Communications in Vehicular Ad Hoc Networks within Different Environments" – ***IEEE VTC 07****, Dublin, Ireland, April 2007.*
- M. Jerbi, P. Marlier and S.M. Senouci, "Experimental Assessmnet of V2V and I2V Communications", ***MoVeNet 07, IEEE MASS 07****, Pise, Italy, October 2007.*
- C. Tchepnda, H. Moustafa, H. Labiod, G. Bourdon, "Securing Vehicular Communications: An Architectural Solution Providing a Trust Infrastructure, Authentication, Access Control and Secure Data Transfer," ***IEEE Autonet 2006*****.**
- Hassnaa Moustafa, Gilles Bourdon, and Yvon Gourhant, "AAA in Vehicular Communication on Highways with Ad hoc Networking Support: A Proposed Architecture", ***ACM VANET 2005*****.**
- Hassnaa Moustafa, Gilles Bourdon, and Yvon Gourhant", Providing Authentication and Access Control in Vehicular Network Environment ", ***IFIP SEC 2006*****.**
- C. Tchepnda, H. Moustafa, H. Labiod, G. Bourdon, "A Layer-2 Multi-hop Authentication and Credential Delivery Scheme for Vehicular Networks ", IEEE ICC 2008 (Submitted)
- Moez Jerbi, Sidi-Mohammed Senouci, Tinku Rasheed, Yacine Ghamri-Doudane, "Towards Efficient Geographic Routing for Vehicular Networks in City Environments", Computer Communications Journal - Special Issue on Mobility Protocols for ITS/VANET. (Submitted)
- C. Tchepnda, H. Moustafa, H. Labiod, G. Bourdon, "Performance Analysis of a Layer-2 Multi-hop Authentication and Credential Delivery Scheme for Vehicular Networks ", IEEE VTC-fall 2008 (Submitted)

Thank you

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