Emergent Vehicular Communications: Applications, Standards and Implementation

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Outline

- **Vehicular Communications, an Introduction**
- **Applications and Services**
  - Safety services and timing characterization
  - Application scenarios
- **Standards**
  - IEEE Std 802.11 and 802.11p
  - WAVE (Wireless Access for Vehicular Environment)
  - Open Issues
- **Implementation**
  - Features and architecture, Prototype, Optimizations
  - Integration within vehicle and use
- **Conclusions and Future Work**

Vehicular Communications

- Significant increase in vehicular **Dedicated Short Range Communications (DSRC)** expected for the next years
  - safety, comfort, infotainment services.
- Vehicular DSRC protocols and technologies must allow:
  - Vehicle to Vehicle (V2V),
  - Vehicle to Infrastructure (V2I)
  - Infrastructure to Vehicle (I2V)
- Very heterogeneous vehicular scenarios:
  - High dependability and real-time features
  - To support safety critical services
  - Adequate levels of quality of service for the users

Applications and Services

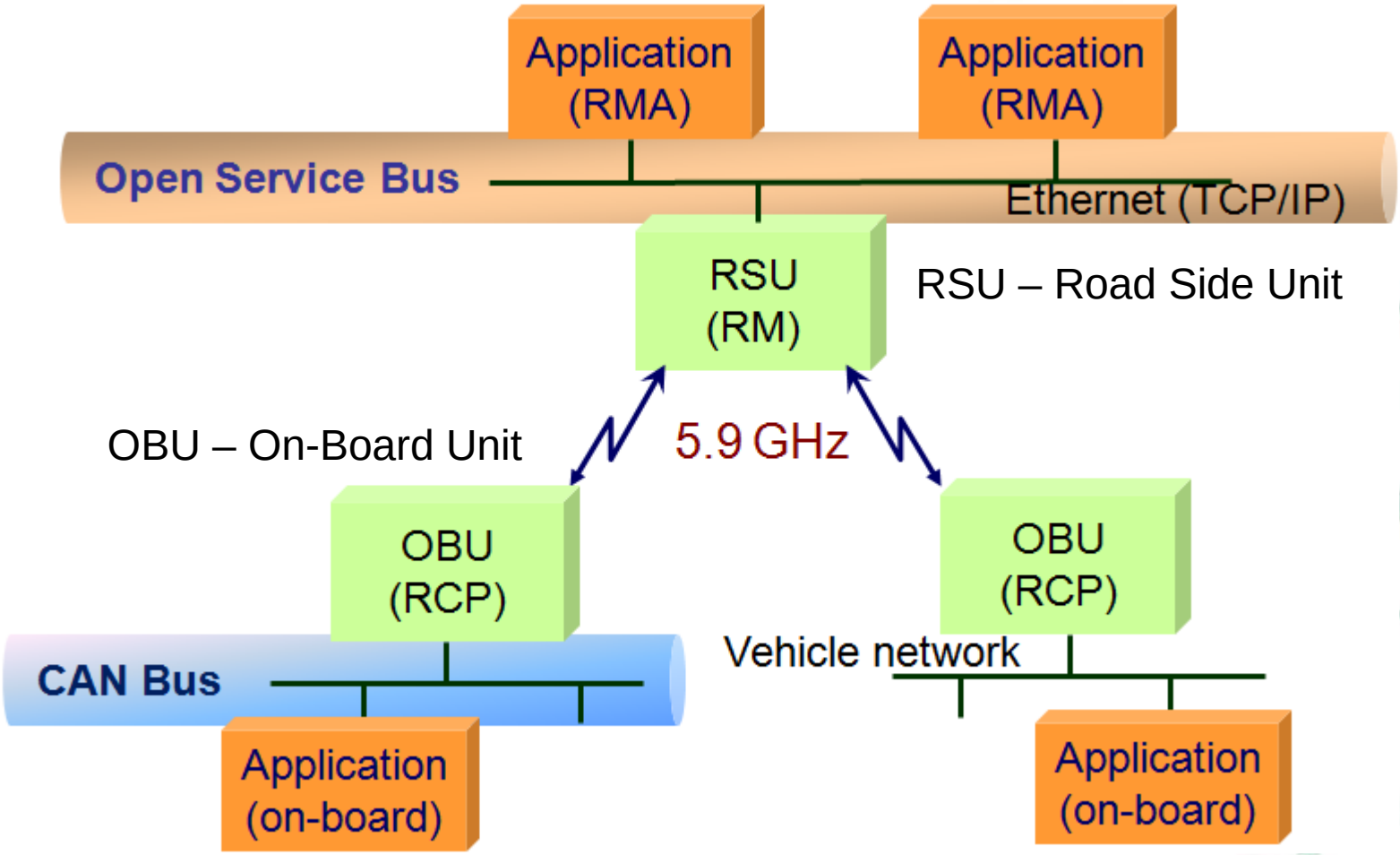
- Wireless communication systems, including 802.11p and WAVE, enable new ITS applications.
- Safety and comfort/infotainment applications.
- Safety applications:
  - **Emergency Electronic Brake Light,**
  - **Lane Change Assistance,**
  - **Post-crash Warnings,**
  - **Sign Extension Services,**
  - **Wrong Way Warning,**
  - **Road Blocked Warning,**
  - **Intersection Collision Warnings**,
  - …

Applications and Services

- **Comfort / infotainment applications.**
  - Can provide some commodity to travelling car passengers
  - Will become a source of revenue to motorway and/or telecommunication operators.
- **Some Examples:**
  - **Tolling Services, Internet Access, Online Games,**
  - **Location Based Services** (e.g. traffic routing, tourist information)**, GPS Map Update, E-mail Servers,**
  - **Other multimedia services** (e.g. instant messaging, movies and music downloads)**,**
  - **Parking Spot Locator,**
  - **…**

Applications and Services

Main parts of a DSRC 5.9GHz WAVE infrastructure



Safety services and timing characterization

- Safety services in ITS have different requirements of **latency**, **range** and **type of communication.**
- Final report of the **Vehicle Safety Communications Project***:
  - Intersection Collision Avoidance,
  - Public Safety,
  - Sign Extension, Vehicle Diagnostics and Maintenance,
  - Information from Other Vehicles,
- Total of **36** different **safety applications.**
- Our work is focused on **motorway scenarios,**
  - **High travelling speed of the vehicles**

Safety services and timing characterization

SAFETY APPLICATIONS	Allowable Latency (msec)	Comm. Range (m)	Type
Emergency Electronic Brake Lights	100	300	V2V
Lane Change Warning	100	150	V2V
Cooperative Collision Warning	100	300	V2V
Event Warning (Accident, Traffic)	100	300-1000	I2V V2V

Safety services and timing characterization

Hard braking Warning scenario

Safety services and timing characterization

Accident Warning scenario

Safety services and timing characterization

Tolling application **scenario tested in Northwest Parkway Brisa's concession, in Denver, USA**

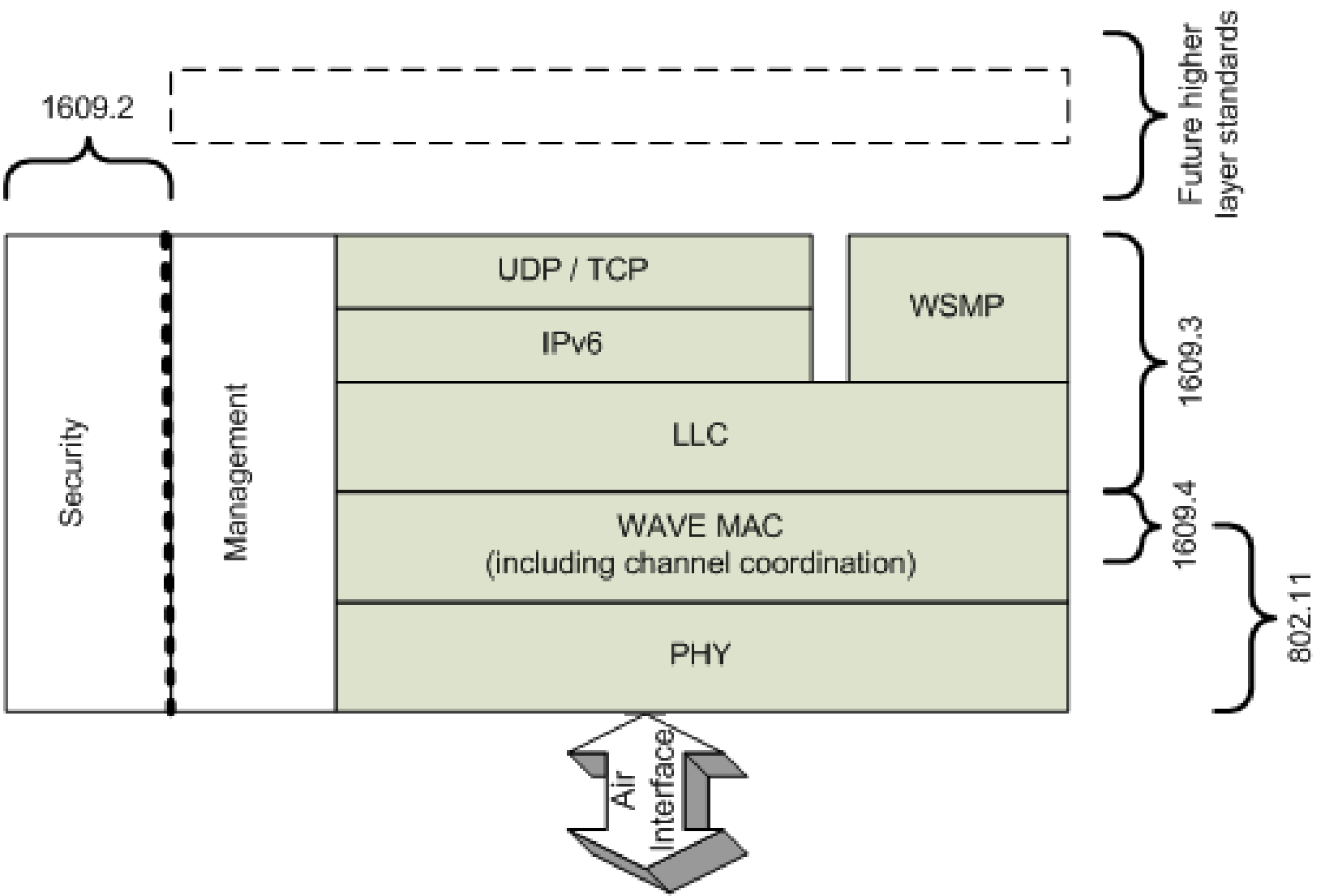
STANDARDS

- IEEE **802.11p** is an amendment of IEEE Std 802.11, specifying extensions to it.
- Laws and regulations for USA, Europe or Japan
- Most important parameters defined in 802.11p:
  - **Transmit power limits,**
  - **Channel spacing**
  - **Frequency bands** that may be used in each zone.
- Defines the functions and services for stations to exchange messages without joining a Base Station Subsystem (BSS);
- Signaling techniques and interface functions used to communicate outside the context of a BSS.

STANDARDS

- **WAVE** (**W**ireless **A**cess for **V**ehicular **E**nvironment)
  - Defines the **architecture** (complementary to 802.11p),
  - A standardized set of **services**
  - The **interfaces** that collectively enable secure V2V and V2I wireless communications.
- **IEEE 1609** consists of 4 trial standards (full use drafts)
  - **IEEE 1609.1-2006 – Resource Manager (RM)**
  - **IEEE 1609.2-2006 – Security Services for Applications and Management Messages**
  - **IEEE 1609.3-2007 - Networking Services**
  - **IEEE 1609.4-2006 – Multi-Channel Operations**
- Two unpublished standards under development.

STANDARDS


1609.2
Future higher layer standards
Security
Management
UDP / TCP
IPv6
WSMP
LLC
1609.3
WAVE MAC
(including channel coordination)
1609.4
PHY
802.11
Air Interface

STANDARDS

- **Application layer (based on 1609.1)**
  - Managing resources through Resource Manager
  - Interacting with a command processor on the OBU side.
  - Resource management applications may be in the same computer or distributed across the network.
- **Network layer (based on 1609.3)**
  - Network transportation services, addressing and data routing for data exchange among WAVE entities.
  - Management plane - WAVE Management Entity (WME), responsible to advertise the services,
  - MIB implemented centrally or in a distributed fashion with local sub-MIBs.
  - Data plane implements the IPv6 protocol as well as the WAVE Short Message Protocol (WSMP).

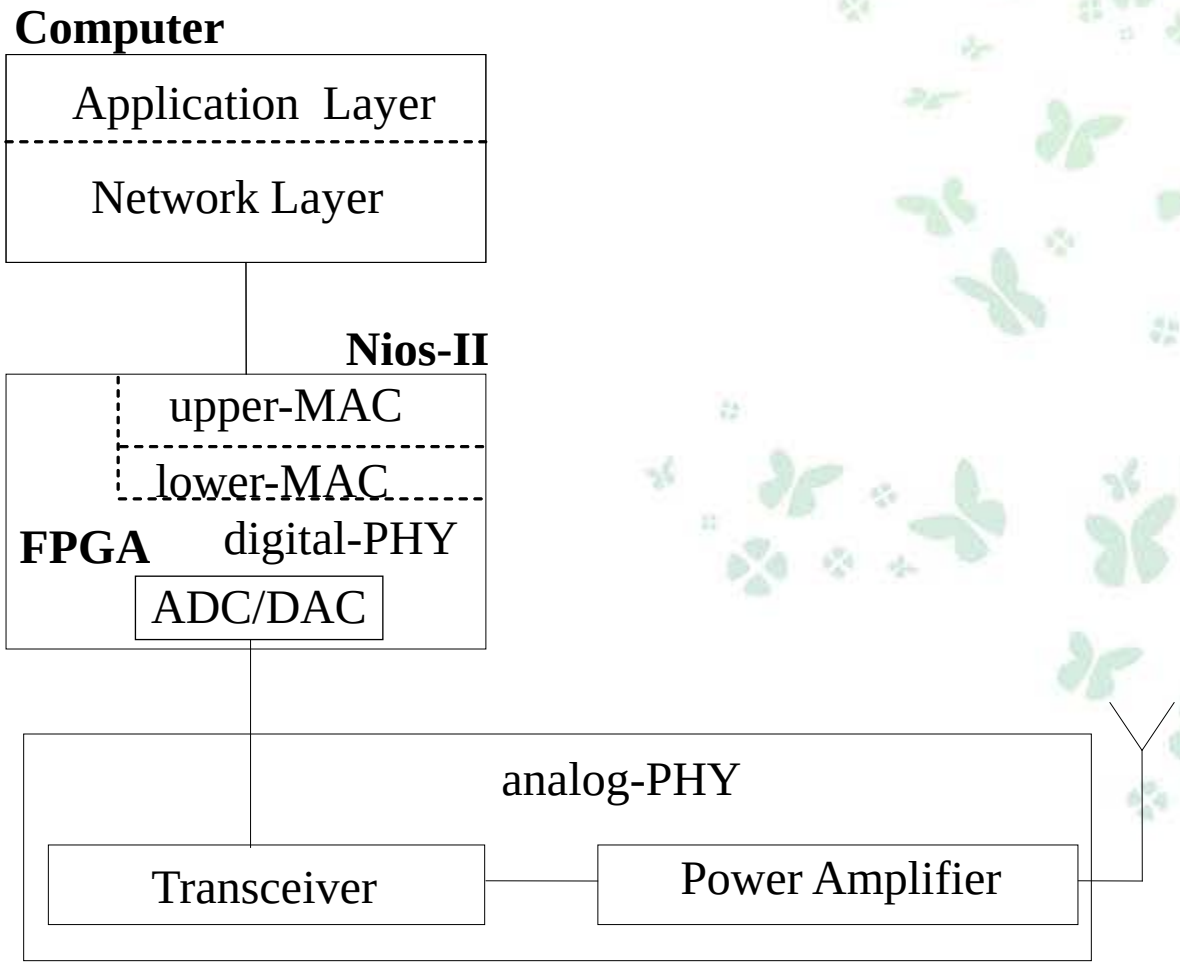
STANDARDS

- **MAC layer (based on 1609.4, IEEE802.11p)**
- Manag. plane (MAC Layer Management Entity - MLME)
  - Coordinates switching between Control CHannel (CCH) and Service CHannels (SCHs).
  - Queues service advertisements.
- Data plane.
  - Deals with IPv6 and WSMP frames,
  - Queues frames for transmission on the correct channel
  - Manages messages priority using the Enhanced Distributed Channel Access (EDCA) mechanism
- Synchronization:
  - UTC generator (e.g., GPS), or Timing Advertisement frames.

IMPLEMENTATION

- WAVE prototype focused on safety critical applications
  - WSMAC layer (based on 1609.4, IEEE802.11p)
  - IPv6 will be added later if required.
- Mix of hardware
- Analogue components and multiple processors, general purpose and specialized.
- Software on general-purpose processors
  - WSMP network, LLC and upper MAC
- Specialized hardware:
  - Lower MAC and PHY layer, computationally intensive with time critical functionalities (e.g. MAC layer's synchronization and channel coordination)
  - Bit oriented operations (e.g. CRC calculation)

IMPLEMENTATION



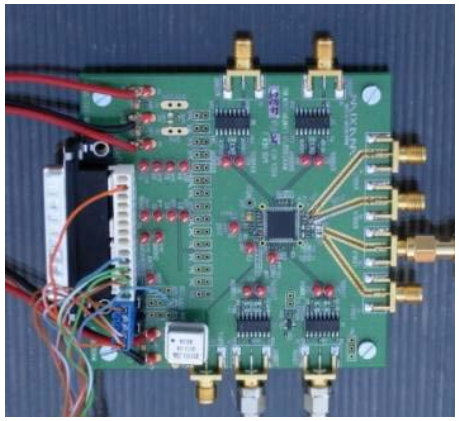
IMPLEMENTATION

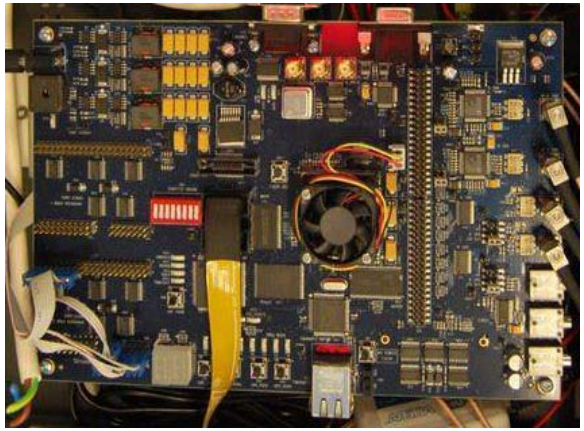
- First prototype based on the following equipment:
  - A mini car-PC; n Altera Stratix II FPGA development kit;
  - A Maxim transceiver; a power-amplifier; an appropriate antenna.
- FPGA used to implement both PHY and MAC
  - Hardware blocks in VHDL: scrambling, encoding, interleaving, mapping, IFFT and cyclic redundancy insertion
  - Upper MAC layer using the embedded processor Nios II.
- Networking services and upper layers
  - Implemented in JAVA and running in the mini car-PC.
  - Connection between the mini car-PC and the FPGA currently performed by a serial link.

IMPLEMENTATION

- On-going optimization
  - cost, size, resource usage, performance and power efficiency.
- Shrinking:
  - Tighter integration of the system modules.
  - Application, Network, Upper MAC, Lower MAC, Physical (digital), as well as the Management and Security cross layers, in independent processors or functional units running on FPGA and communicating through custom parallel high speed buses or point-to-point links.
  - Reduction of the intra node communication latencies
  - Mixed signal and analogue components (ADCs, DACs, RF transceiver and power amplifier implemented in a custom board.

IMPLEMENTATION





IMPLEMENTATION

- Interfaces required to integrate WAVE box within a vehicle:
  - Vehicle devices and user/driver)
- Power supply and ignition connector
- Antenna connector for the DSRC 5,9 GHz band.
- OBD-II to get information from the vehicle
  - speed, status, error codes, ...
- USB and/or Bluetooth interface
  - With devices for displaying data, configuration and update.
  - Specific display with touch capabilities or
  - An Embedded or Portable Navigation Device (PND)

CONCLUSIONS AND FUTURE WORK

- Vehicular high speed wireless communications will enable a new set of services
  - safety, comfort and infotainment
  - Delivered through the road infrastructure and other users.
- Ongoing work on the WAVE standards (IEEE 1609.x), allowed the construction of a working prototype
  - Proof of concept and demonstration of a basic set of services.
- WAVE compliant and embeddable device soon (1 year?).
- Future work in another line consists in evaluating the system performance and communication efficiency under dense scenarios (traffic jams or accidents).