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Assignment ALMA: WP 1 - Mapping of parallel/competitive projects and programmes

EXECUTIVE SUMMARY

Purpose:
This report studies the wireless communication in vehicular environment to supply ALMA steering group with relevant status of the on-going research. More specifically the standards-, parallel projects-, interest groups and existing commercial applications of wireless vehicular communication are discussed. Also the reliability for wireless communication research is reviewed. This report can be used to select standards and technologies that should be further investigated.

Methods:
The study is in a form of a literature review. First the biggest funders of vehicular communication were searched and relevant technologies concerning wireless vehicular communications were familiarized. After that the databases of the funders were used to search for relevant on-going projects. If there were many similar projects that had relevance to ALMA one of them was picked as a base example. After the ongoing projects were mapped, the search was extended to published material of several scientific article databases. These articles were used as a base of technology comparison, understanding the technical issues of upcoming standards and reliability analysis of the technologies. Lastly the existing commercial applications relevant to ALMA were searched using the information gained from the published papers and by trying to find suitable wireless replacements for fieldbus technology.

Results:
The report presents the most suitable communication technologies which should be considered as candidates for upcoming implementation tasks.

One of the main results of the study is the fact that there are no parallel projects that target exactly the same issues as ALMA. Previously the automated work sequences have been tested using crops harvesters or tractors, but the wireless *reliable* communication was not their target. Reliable wireless communication has not been studied much in vehicular environments, even though there are many projects that target wireless vehicular applications and their benefit to the driver.

The report identifies the five different fields of ITS research areas: (i) application development practices, (ii) security, (iii) simulations, (iv) testing and (v) new applications (e.g. safety applications). From these fields (i), (ii) and (iv) are very relevant to ALMA.

Conclusions:

- The most promising wireless technologies are NanoLOC, Certified Wireless USB (or similar development kits) and UTRA-TDD.
- For building of a fieldbus-wireless communication channel there exists commercial products utilizing different radios. Also VTT has developed its own version based on NanoLOC.
- The investigation of AUTOSAR for ECU abstraction is advisable before implementation starts. Possible interesting tool for engineering can be EAST-ADL2 description language refined in ATESST2 project. It has been harmonised for AUTOSAR.
- For video transmission UWB should be investigated, especially the new ECMA standard which uses very high frequency of 60GHz.

TABLE OF CONTENTS

EXECUTIVE SUMMARY
TABLE OF CONTENTS
LIST OF ABBREVIATIONS AND SYMBOLS
1 VEHICLE COMMUNICATION TECHNOLOGIES 5
1.1 IEEE 802.11p standard 5
1.2 IEEE 802.15.4a standard 5
1.3 IEEE 802.20 standard 6
1.4 UTRA-TDD 6
1.5 UWB Standardization 6
2 PARALLEL PROJECTS, PROGRAMMES AND OTHER INTEREST GROUPS 7
2.1 Vehicle-to-Vehicle and Vehicle-to-infrastructure communication 9
2.1.1 AKTIV 9
2.1.2 COM2REACT 9
2.1.3 CyberCars2 9
2.1.4 CVIS (Cooperative Vehicle Infrastructure Systems) 9
2.2 In-Vehicle communication 10
2.2.1 AUTOSAR (AUTomotive Open System ARchitecture) 10
2.2.2 FMS (Fleet Management System) and Bus-FMS standards 12
2.2.3 ISOBUS standard 12
2.3 Other related projects 13
2.3.1 ANEMONE (Advanced Next gEneration Mobile Open NEtwork) 13
2.3.2 ARCTIC (Antenna research and technology for the intelligent car) 13
2.3.3 ATESST2 14
2.3.4 EMMA (Embedded Middleware in Mobile Applications) 14
2.3.5 EVITA (E-Safety Vehicle Intrusion Protected Applications) 14
2.3.6 FESTA 14
2.3.7 iTETRIS 15
2.3.8 SAFETEL (Safe Electromagnetic Telecommunication on Vehicle) 15
2.3.9 SEVECOM (Secure Vehicle Communication) 15
2.3.10 TRACKSS 16
2.4 Interest groups and related work 17
2.4.1 CALM - ISO TC204: Working group 16 17
2.4.2 Car 2 Car consortium 18
2.4.3 CVTA (Connected Vehicle Trade Association) 19
2.4.4 ERTICO 19
2.4.5 eSafety Forum and its different working groups 20
2.4.6 EUCAR (European Council for Automotive R&D) 21
3 INTERESTING COMMERCIAL APPLICATIONS 22
3.1 ANEMONA 22
3.2 IXXAT CAN-bluetooth-CAN 22
3.3 Nanotron radio applications by VTT 23
3.3.1 SWOT of Nanotron 23
3.4 WISA (wireless interface for sensors and actuators) 23
3.4.1 SWOT of WISA 23
3.5 Certified Wireless USB chipsets 24
3.5.1 SWOT of Certified Wireless USB 24
4 RELIABILITY IN VEHICULAR WIRELESS COMMUNICATION 25
4.1 RFID 26
4.2 Zigbee 26
4.3 IEEE 802.11p (WAVE) 28
4.4 UTRA-TDD 29
5 DISCUSSION 31
6 REFERENCES 33
APPENDICES

LIST OF ABBREVIATIONS AND SYMBOLS

ARQ	Automatic Repeat Request
C2C	Car-to-car
C2I	Car-to-infrastructure
CALM	Communications Air Interface for Long and Medium range
CAN	Controller Area Network
CE	Consumer Electronics
CSS	Chirp Spread Spectrum
DSRC	Dedicated short-range communications
ECU	Electronic Communication Unit
FP	Framework Programme
GSM	Global System for Mobile communications
GPS	Global Positioning System
ICT	Information and Communication Technology
IEEE	Institute of Electrical and Electronics Engineers
Infotainment	Information and entertainment (data)
ITS	Intelligent Transportation System
ISM	Industrial, Scientific and Medical
IVC	Inter-Vehicle communication (vehicle-to-vehicle)
LAN	Local Area Network
LIN	Local Interconnect Network
LQI	Link Quality Indicator
MAC	Medium Access Control
MAN	Metropolitan Area Network
MCU	Microcontroller unit
OEM	Original Equipment Manufacturer
PAN	Personal Area Network
PER	Packet Error Rate
PHY	Physical communication layer
PRR	Packet Reception Rate
RSSI	Received Signal Strength Indicator
RTD	Research and Technology Development
RVC	Road-to-Vehicle communication
SNR	Signal to Noise Ratio
UMTS	Universal Mobile Telecommunications System
UTRA	UMTS Terrestrial Radio Access
UWB	Ultra Wide Band
TDD	Time Division Duplex
V2I	Vehicle-to-infrastructure
V2R	Vehicle-to-road
V2V	Vehicle-to-vehicle
VANET	Vehicular ad-hoc network
WAVE	Wireless Access in Vehicular Environments
Wi-Fi	Wireless Fidelity
WLAN	Wireless Local Area Network

1 VEHICLE COMMUNICATION TECHNOLOGIES

The purpose of this document is to review parallel projects where existing wireless communication technologies have been studied and utilized in vehicular environment. The technologies covered in this report are the main wireless technologies such as Bluetooth, IEEE 802.11 (Wi-Fi), ZigBee, IEEE 802.15.4a (NanoLOC PHY), UMTS and UWB (see Appendix 1: “Review, Radio Standards and Protocols” and Appendix 2: “Esiselvitys: Ajoneuvojen uudet väyläteknologiat” for more information of vehicular communication technologies). In addition, some wireless technologies are briefly mentioned while illustrating the on going research and standardization actions.

1.1 IEEE 802.11p standard

802.11p also known as WAVE (Wireless Access in Vehicular Environments) is still under development. It is especially interesting standard because it extends WLAN to meet the requirements of intelligent transportation systems (ITS). Originally 802.11p was initiated to fulfill the requirements of the US and therefore it was based on the US frequency allocation of 5 GHz (5.85-5.925 GHz). However, just recently European Comission decided to reserve 5.9 GHz frequency to ITS applications as well, so the standard can be utilized in Europe when it is complete. In the future, even though the initial design of 802.11p was initiated to serve the US purposes, the standard should be extended for international use as well. In Europe the standardization work is done in CALM M5 (ISO 21215) workgroup, where the target is to develop 802.11p to meet European legislation and supporting several different radio interfaces.

The main requirements of 802.11p is to support mobile devices moving up to 200 km/h when base station distances are less then 1 km. The deployment areas target V2I and V2V communication, where small latency, fast connecting and high mobility are key factors for good operability. 802.11p standard also defines mesh-type network support which is required in many ITS deployment areas e.g. local traffic information dissemination.

The strengths of IEEE 802.11p standard are high bandwidth, hardware availability with decent pricing, on-going development of the standard and good support in many application environments. Because WLAN technology is unlicensed its costs will be under control in the future as well. The weaknesses are fairly short range (~50m), high power consumption, poor quality of service and higher probability for channel noise as there is bound to be several devices using the same free frequency allocation. Also fast on-going development often leads to incomplete standards, which can be considered as a threat. The finishing date for 802.11p is still open. [1, 2]

1.2 IEEE 802.15.4a standard

IEEE 802.15.4 standard targets low powered devices with small to medium throughput. To achieve higher data rates and resistance to channel noise an alternative standard 802.15.4a was developed around different PHY. The first PHY in 802.15.4a is based on UWB whereas the other is based on CSS (chirp spread spectrum) technology developed by Nanotron. [3]

1.3 IEEE 802.20 standard

IEEE 802.20 is also known as Mobile Broadband Wireless Access (MBWA). Its goal is to enable worldwide deployment of affordable, ubiquitous, always-on and interoperable multi-vendor mobile broadband wireless access networks that meet the needs of business and residential end user markets. It supports various vehicular mobility classes up to 250 Km/h in a MAN environment and targets spectral efficiencies, sustained user data rates and numbers of active users that are all significantly higher than achieved by existing mobile systems. The operating frequency band is below 3.5GHz. The standardization process has been active since 2002. [4]

1.4 UTRA-TDD

UTRA-TDD (UMTS Terrestrial Radio Access – Time Division Duplex) is used in mobile phone networks. In vehicular environment its main usage has been the creation of (decentralized) ad-hoc networks where no base station would be required. This of course requires a modified protocol and effective radio channel management schema. The common factor of the proposed protocols has been the idea to use location data (GPS) to decide how the messages should be sent, but still there are several choices available. The greatest challenges are thought to be medium access control and fast connecting between devices in high speeds. Also excessive testing that is required has been problematic. Previously the UTRA-TDD has been tested for example in FleetNet project and it is one of the proposed standards for the ITS communication. The biggest advantages of UTRA-TDD over existing 802.11 standards are larger distances and robustness for high velocities. Also when dealing with dense traffic UTRA-TDD devices does not suffer from noise of other similar devices. The noise from similar devices is a drawback of 802.11, which all utilize the same ISM bandwidth. [5-7]

1.5 UWB Standardization

UWB stands for Ultra WideBand, which means the frequency range is large, even more than 1GHz. There are several existing standardizing actions for UWB as it provides high data rates and tolerance to the channel noise. IEEE 802.15.3a would use UWB as PHY, but consensus has not been found between the two proposals: multiband promoted by WiMedia Alliance and single band led by UWB Forum. However, UWB Forum is now defunct as several large companies have resigned. ISO has approved WiMedia Alliance’s proposal as MAC and PHY for its standard. ECMA International (non-profit industry association for standardizing ICT and CE) has also been developing standard for 5 GHz UWB but also their last proposal was withdrawn. [3]
In this month ECMA released their own standard, which uses very high frequency (60GHz) band and the transfer rate of 200 Mbps was achieved over distance of three meters. The standard specifies four frequency channels of 1.728 MHz. The maximum distance specified in the standard is 10 meters. Because the high bandloss when line-of-sight is blocked the standard especially defines relay device. The standard’s target is video streaming applications in CE where very high throughput is required. [8]

2 PARALLEL PROJECTS, PROGRAMMES AND OTHER INTEREST GROUPS

There has not been any noticeable research activity considering the topic of ALMA “wireless sensor platforms for reliable autonomous work-sequences” until now. The nearest correspondence projects can be found from the Intelligent Transportation System (ITS) - projects. The common factor in current ITS projects are the wireless sensors, which have been developed and evaluated for safety and infotainment purposes of vehicles, trains, freights etc. However, wireless sensors have not been used for safety critical or vehicular control applications but rather safety improving informative systems for the driver. Therefore it must be emphasized that knowledge of reliability issues of wireless sensors in vehicles is not satisfactory. Also most of the current ITS research essentially targets vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) which usually require longer communication distances and effective mesh-type network protocols. In ALMA the main target is intra-vehicle point-to-point communication. Requirements for such communication are small pre-known network latency and acceptable throughput when common noise sources of heavy-duty vehicle environment are present.

On the European level there are more than 60 ongoing ITS projects at the moment [9, 10]. The total budget for intelligent cars (i2010 intelligent car initiative for cleaner and safer transport) in EU FP7 programme was more then 100 M€ [11]. There are also many national projects targeting local issues. On the global level the most active players in ITS field along the Europe are the US, Japan and South Korea whose research organizations have participated in some European projects as well. Figure 1 shows some of the current key projects/interest groups within USA, Japan and Europe.

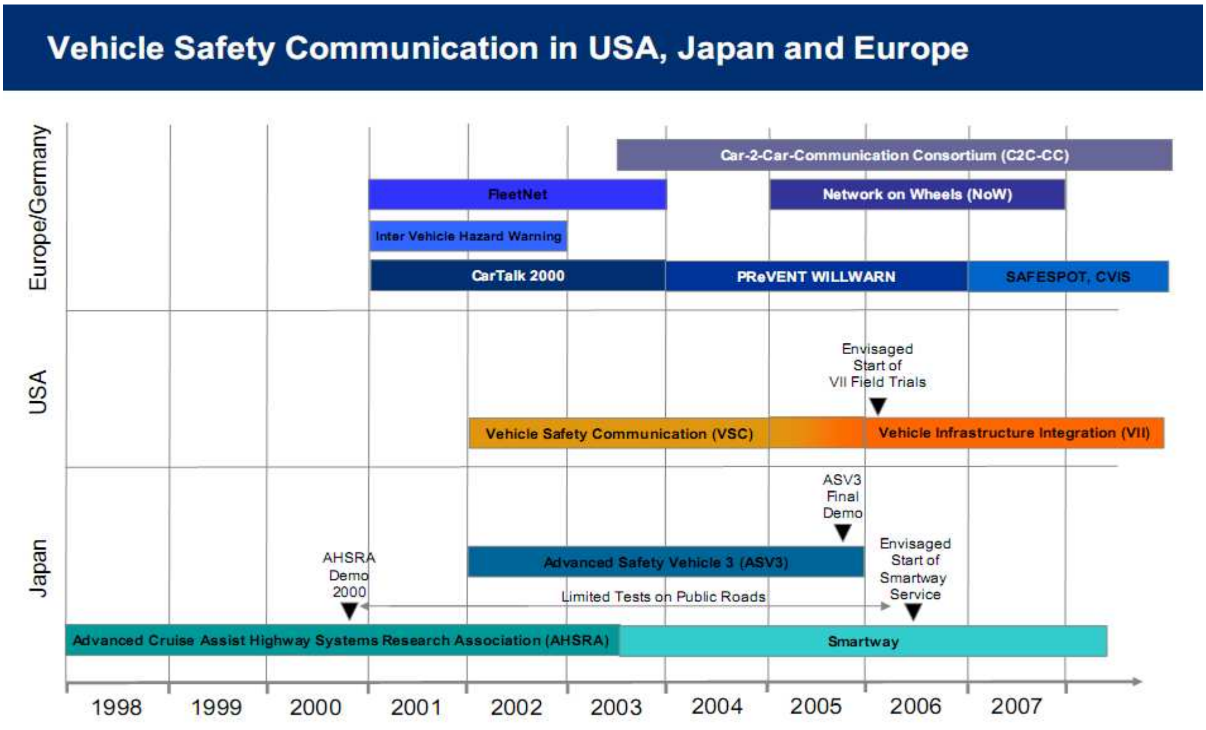

Figure 1. Some essential ITS projects/interest groups of the three biggest global players [12]**.**

In the US, Federal ITS program funds the research with 110 M$ annually till the fiscal year 2009 [13]. In South Korea the ITS research has mainly targeted safety and electronic payment, where the current government is planning to invest 3.2 billion US$ from 2007 to 2020 [14]. In Japan the ITS research is currently concentrated under the principal project Smartway, which had the estimated budget nearly 960M$ in 2001 [15]. In addition to this there are plenty of industrial projects contributing to this field.

The focus of the public funded ITS research in respect to communication has been V2V and V2I communication whereas (wireless) in-car communication has been mostly covered by industrial consortiums. The main target of in-car communication research has been standardization, in order to allow 3rd party device development and new applications within vehicles. Application wise, the target of the wireless in-car communication research has been mostly for infotainment purposes. The main cause for this is that the control applications communicate via well known and standardized fieldbus technology. Also legislation does have impact on the selected technologies when safety applications are considered.

Intelligent transportation tries to answer to a wide variety of issues regarding safety, environmental friendliness and cost effectiveness of transportation. The development areas of ITS can be roughly divided between intelligent infrastructure development and intelligent vehicle development. The general deployment areas of ITS are:

- **Road/Highway management** (surveillance, lane control, speed limits and law enforcement)
- **Weather management** (monitoring/prediction, information dissemination, traffic control, response treatment)
- **Fleet management** (computer aided dispatch, maintenance, service coordination)
- **Crash prevention and safety** (obstacle detection, route planning, intersection detection, lane change/keep assistance, roll stability, vision enhancement, driver monitoring, environmental hazard detection)
- **Emergency management** (tracking, advanced automatic collision notification, telemedicine, response management)
- **Electronic payment/pricing** (toll collection, transit fare payment, parking payment)
- **Infotainment** (navigation, tourism related info)
- **Commercial vehicle operations** (electronic registration/permitting, on-board monitoring, automated inspection, weight screening, border clearance, credential checking, traveler information, asset tracking, remote unauthorized operation prevention systems)

As many of the above mentioned deployment areas require wireless communication, it is useful for ALMA to study the current ITS projects, to highlight the technologies that are tested in vehicular environments. This also introduces the interest groups, which act as possible sources of information and cooperation in the future.

2.1 Vehicle-to-Vehicle and Vehicle-to-infrastructure communication

V2V, V2I and V2R are the main research fields for car communications. The goal is to prevent accidents on the road (European eSafety initiative) and also to make traffic flow more efficient and thus pollute less. As was mentioned above, there are numerous projects utilizing wireless technologies. In this section a few example projects are presented based on the technologies they are utilizing. This way a technology cross-section of the current research can be obtained. (see: Appendix 3: “List of ICT for transport FP6 RTD Projects” and Appendix 4: “List of ICT for transport FP7 RTD Projects” for more complete list of ITS projects).

2.1.1 AKTIV

AKTIV (Adaptive und Kooperative Technologien für den Intelligenten Verkehr) has three sub-projects targeting safety, communication with intelligent infrastructure and communication protocols. The technologies for communication are cellular mobile communication technologies such as UMTS. [16] AKTIV has 29 partners - automobile manufacturers and suppliers, electronic, telecommunication and software companies as well as research institutions. The four-year cooperation will continue through 2010.

AKTIV project will design, develop, and evaluate:

- Driver assistance systems with a main focus on safety relevant applications.
- Knowledge and information technologies
- Solutions for efficient traffic management; and
- C2C and C2I communication

2.1.2 COM2REACT

Objective of COM2REACT (COoperative CoMmunication System TO Realise Enhanced Safety And EffiCiency In European Road Transport) is to establish scalable cooperative system for V2V and V2I. The main technology will be ad-hoc Wi-Fi network using existing Optimized Link State Routing Protocol (OLSR). The project uses 802.11b/g technology, but plans to replace it with the new 802.11p in the future. [17]

2.1.3 CyberCars2

The project is based on a vision that Cybernetic Transport Systems based on fully automated urban vehicles will be seen on city roads. Such systems have been developed and evaluated in the scope of previous project Cybercars (www.cybercars.org) and Cybermove (www.cybermove.org). The technology that is used will be same as in CALM architecture. [18]

2.1.4 CVIS (Cooperative Vehicle Infrastructure Systems)

In CVIS the 2.5G(GSM)/3G(UMTS) cellular phone and WLAN is used for V2V and V2I communication. The consortium consists of 60 partners, among which vehicles manufacturers, suppliers and other industries, universities, research institutes, national road administrations and representative organizations from the European member states, including some of the newly joined member states. [19]

The CVIS objectives are:

- to create a unified technical solution allowing all vehicles and infrastructure elements to communicate with each other in a continuous and transparent way using a variety of media and with enhanced localization;
- to enable a wide range of potential cooperative services to run on an open application framework in the vehicle and roadside equipment;
- to define and validate an open architecture and system concept for a number of cooperative system applications, and develop common core components to support cooperation models in real-life applications and services for drivers, operators, industry and other key stakeholders;
- to address issues such as user acceptance, data privacy and security, system openness and interoperability, risk and liability, public policy needs, cost/benefit and business models, and roll-out plans for implementation.

2.2 In-Vehicle communication

Because there are no noticeable wireless in-car communication projects going on, other related work is discussed here. One of the activities considering in-vehicle communication is the standardization procedure between application and sensor interfaces. Also the existing standards for sensor and actuator communication in heavy-duty vehicle are briefly presented.

2.2.1 AUTOSAR (AUTomotive Open System ARchitecture)

AUTOSAR is open and standardized automotive software architecture. With AUTOSAR hardware and software will be independent on each other. This helps development of vehicular software and user interfaces and simplifies software management. The AUTOSAR scope includes all vehicle domains. AUTOSAR consortium includes over 130 partners and members including big car manufacturers and tier-1 suppliers.[20]

The AUTOSAR project provides abstraction level for MCU and ECU, provide uniform interface for different fieldbus technologies (LIN, CAN, Flexray) and also upper level software interface for communication between different modules. In addition to this AUTOSAR should take into account function and timing requirements for handling complex sensors and actuators.[21]

AUTOSAR project objectives and main working topics [20]:

- Implementation and standardization of basic system functions as an OEM wide "Standard Core" solution
- Scalability to different vehicle and platform variants
- Transferability of functions throughout network
- Integration of functional modules from multiple suppliers
- Consideration of availability and safety requirements
- Redundancy activation
- Maintainability throughout the whole "Product Life Cycle"
- Increased use of "Commercial off the shelf hardware"
- Software updates and upgrades over vehicle lifetime

Although the first version of AUTOSAR was released in May 2005, the integration of AUTOSAR compatible products to mass produced vehicles are still few years away, as can be seen from the roll-out plan in Figure 2.

The AUTOSAR Roll Out Plan (2008 - 2012)

Core Partner	2008	2009	2010	2011	2012
BMW Group	■ ≈10 AUTOSAR BSW modules as part of Std Core in vehicles, tool / serial support in place			■ Powertrain-, Chassis-, Safety-, Body- ECUs use AUTOSAR architecture	
BOSCH	■ Body Computer with subset of AUTOSAR specs incorporated ■ Instrument Cluster with subset of AUTOSAR specs incorporated	■ ACC ECU using AUTOSAR architecture. ■ Powertrain EDC/ME(D)17 ECUs using AUTOSAR architecture ■ Domain Control Unit using AUTOSAR BSW	■ Chassis ECU using AUTOSAR architecture ■ Body Computer using AUTOSAR architecture		
Continental		■ Body ECU using AUTOSAR architecture ■ Powertrain ECUs using AUTOSAR architecture	■ Powertrain- ,Chassis- ECU using AUTOSAR architecture		
DAIMLER		■ First usage of AUTOSAR modules in vehicles	■ First AUTOSAR compa-tible ECUs in vehicles	■ Introduction of AUTOSAR architecture and methodology in vehicles	
Ford		■ 1-2 AUTOSAR conformant ECUs; first use of conformant tools/methodology	■ Continuous roll-out of ECUs into vehicle architecture increased use of conformant tools / methodology		
Opel			■ First usage of AUTOSAR modules	■ First use of AUTOSAR architecture ECU	
PSA PEUGEOT CITROËN		■ Powertrain ECU using AUTOSAR architecture	■ Body ECU using AUTOSAR architecture		
TOYOTA			■ First usage of AUTOSAR modules		■ AUTOSAR Architecture ECU
VOLKSWAGEN AG		■ First AUTOSAR modules in series production		■ First complete ECUs in series production	

Figure 2 AUTOSAR Roll Out Plan [22]**.**

Even so, car manufacturers like BMW and Audi have tested solutions which comply with AUTOSAR concept (e.g. shock absorber control) [23, 24]. Also Huyndai Motor Company recently announced development of AUTOSAR-based ECU and they view AUTOSAR as an emerging global standard [25]. This implies that current status of the AUTOSAR, which is shown in Figure 3, is mature enough for product development.

For creation of AUTOSAR products, AUTOSAR development software has been made available for example by Carnica Technology, dSpace, Elektrobit and ETAS [26-29]. Especially Elektrobit has made joint ventures with MCU manufacturers like Fujitsu and Freescale who have developed low-level software to optimize microcontrollers for AUTOSAR [30, 31].

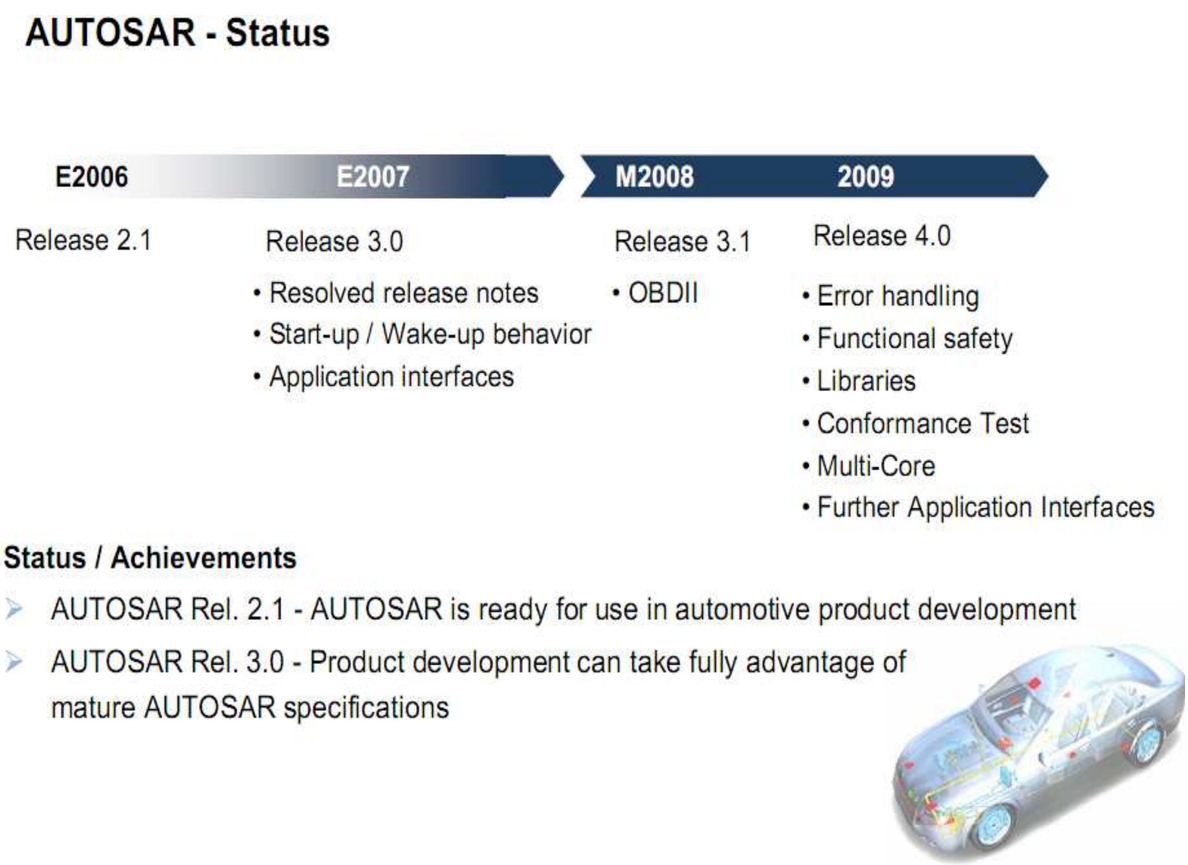

Figure 3. Autosar Status [22]**.**

2.2.2 FMS (Fleet Management System) and Bus-FMS standards

FMS is an open standard for truck manufacturers [32]. It has been extended in 2006 to cover buses and coaches as well [33]. To allow third parties to access vehicle data, an open standard called Fleet Management System was introduced. The FMS interface connects to the CAN bus of the vehicle and thus increases safety, as direct connection could interfere with the correct functionality of the truck systems. A new extension to the standard is planned for wireless transmission mainly to cover digital tachograph data collection [34].

Currently the standardization is done in heavy truck electronic interface group. The group belongs to ACEA (European automobile manufacturer’s association) and it consists of Daimler, MAN, Scania, DAF Trucks, IVECO, Volvo trucks and Renault trucks.

2.2.3 ISOBUS standard

ISO11783 is based on CAN 2.0B specification. The purpose is to provide an open interconnected system for electronic communication units (ECUs). ISOBUS standard specifies a serial data network for control and communications on forestry or agricultural tractors, mounted, semi-mounted, towed or self propelled implements. The standard describes a 250 kbits/s twisted non shielded quad cable Physical Layer. [35]

2.3 Other related projects

Besides wireless vehicular communication projects there are different projects that aim to improve the testing methods, security or development of wireless communication systems. Also new vehicular sensors are being developed, which in some cases require wireless communication link.

2.3.1 ANEMONE (Advanced Next gEneration Mobile Open NEtwork)

The ANEMONE project will realize a large-scale testbed providing support of mobile users and devices and enhanced services. In Finland ANEMONE testbed is located in Oulu where WLAN, WiMax and UMTS networks are available. [36]

Services of ANEMONE are the following:

- Mobility Service: Operational (MIPv6, NEMO BS, MCoA, Flow Bindings)
- Voice over IP: Operational
- Video on Demand: Operational
- IPv6 Camera: Operational
- IPv6 Weather Station: Operational
- AAA: Not yet operational
- Testing Service: Not fully operational (only IPv6 Core Protocol)

2.3.2 ARCTIC (Antenna research and technology for the intelligent car)

ARTIC is focused on intelligent car cooperative systems to improve efficiency in transport system, safety of all road users and make mobility more comfortable. ARCTIC provides support for radio links in in-vehicle wireless sensor networks including nomadic or brought-in wireless devices. [37]

ARCTIC has noted the need to fully utilize antenna technologies including:

- millimeter wave integrated antennas;
- small antenna & sensors;
- wideband antennas;
- array antennas; and
- smart antennas

Also project's goal is to adapt the best practices for new kind of antenna measurements for near and far-field measurements, along with comparative investigations of different techniques, to the measurement of vehicles antenna parameters.

ARCTIC will contribute to the three pillars of the Intelligent Car Initiative (ICI):

- **Pillar 1:** homogenization of the technical solutions by the sharing of the knowledge on antenna technology at European level
- **Pillar 2:** open new capabilities in transport research, by providing state-of-the-art solutions in co-operative systems for future smart cars
- **Pillar 3:** raise awareness on innovative communication capabilities, both at industrial and at citizen level, by the ARTIC Virtual Centre.

2.3.3 ATESST2

ATESST2 (Advancing Traffic Efficiency and Safety through Software Technology, Phase 2) aims to improve development practices for automotive systems. EAST-ADL2 is a description language which serves as a template language of how engineering information is represented. In this project EAST-ADL2 is refined to better support automotive systems. Especially EAST-ADL2 is harmonized together with AUTOSAR models. The project has started on July 2008 and is scheduled to July 2010. [38]

2.3.4 EMMA (Embedded Middleware in Mobile Applications)

The project aim is to deliver a middleware to hide the complexity of the underlying infrastructure whilst providing open interfaces to 3rd parties enabling the faster, cost-efficient development of new cooperative sensing applications. This end-product will be accompanied by a publicly available specification that will help to facilitate its wider adoption. [39]
The project was started on May 1, 2006, and its expected duration is 2,5 years (until October 2008) [40].

2.3.5 EVITA (E-Safety Vehicle Intrusion Protected Applications)

EVITA will provide a base for the secure deployment of electronic safety aids based on car-to-car and car-to-infrastructure communication. The objective is to prevent tampering with on-board systems in order to prevent the transmission of corrupted data to the outside. EVITA will release the secure on-board architecture and protocol specifications as open specifications. Project duration is from June 2008 to July 2011. [41]

2.3.6 FESTA

FESTA (from November 2007 – June 2008) main purpose was to create a methodology for field operational tests. Field Operational Tests (FOT) consists of a comprehensive programme of research to assess the impacts of ICT systems on driver behavior, both in terms of individual (safety) benefits and larger scale socio-economic benefits. The design and implementation of these FOTs must be carefully thought out to include the best possible result. FESTA aims to help this process by facilitating the coordination of expert knowledge in order to create a handbook of best practice for FOT implementation [42].

The objectives of FESTA:

- Facilitate the stakeholders' expertise and experience to provide a best practice handbook for the design and implementation of FOTs
- Provide additional guidance on how these activities should be undertaken and reported
- Involve major stakeholders (automotive industries, equipment suppliers, telecoms, academic institutions) to provide a common vision to the work

2.3.7 iTETRIS

V2V-V2I communication technologies can improve traffic management through real-time exchange of data among vehicles and with road infrastructure. Routing and data dissemination policies suited to the wireless vehicular environment operational characteristics need to be designed and optimized.

iTETRIS (An integrated wireless and traffic platform for real-time road traffic management solutions) project develops of advanced tools coupling traffic and wireless communication simulators. This will enable large scale computing analysis and development of adequate protocols and algorithms, overcoming the limitations of current data dissemination and routing proposals; characterized by over-simplistic wireless conditions. The project time frame is July 2008 to December 2010. [43, 44]

2.3.8 SAFETEL (Safe Electromagnetic Telecommunication on Vehicle)

SAFETEL aim was to improve the design standards of equipment and systems in automotives in cases of electromagnetic disturbances. The goal was to achieve higher levels of safety than imposed by current standards for internal and external EM environments. Also a simulation and test strategy was to be defined and an advanced set of design tools provided in order to guarantee the proper functioning of the electronic equipment in the presence of new complex receivers and transmitters such as GPS, GSM, Bluetooth and Time Modulated Ultra Wideband. The project lasted from Januray 2004 to January 2007. [45]

2.3.9 SEVECOM (Secure Vehicle Communication)

SEVECOM focuses on security requirements for vehicular communications [46].

The main goals of SEVECOM:

- Identification of the variety of threats: attacker's model and potential vulnerabilities; in particular, study of attacks against the radio channel and transferred data, but also against the vehicle itself through internal attacks, e.g., against TCU (Telematics Control Unit), ECU (Electronic Control Unit) and the internal control bus.
- Specification of architecture and security mechanisms which provide the right level of protection. It will address issues such as the apparent contradiction between liability and privacy, or the extent to which a vehicle can check the consistency of claims made by other vehicles. The following topics will be fully addressed: Key and identity management, Secure communication protocols (including secure routing), Tamper proof device and decision on crypto-system, Privacy. The following topics will be investigated in preparation of further work: intrusion detection, data consistency, secure positioning, secure user interface.
- The definition of cryptographic primitives which take into account the specific operational environment. The challenge is to address (1) the variety of threats, (2) the sporadic connectivity created by moving vehicles and the resulting real-time constraints, (3) the low-cost requirements of embedded systems in vehicles. These primitives will be adaptations of existing cryptosystems to the VC environment.

2.3.10 TRACKSS

TRACKSS (Technologies for Road - Advanced Cooperrative Knowledge Sharing Sensors) develops different sensory technology for transportation. In-vehicle sensor development tries to achieve advanced ice detection, high-dynamic high-resolution CMOS camera with subwindowing technique (detect only relevant regions), pedestrian detectors and smart dust utilization in transport. The infrastructure sensing technologies concentrate on vehicle detection e.g. induction loops to detect and analyze passing vehicles, laser scanners for vehicle recognition and smart CCTV for traffic management. TRACKSS also tries to integrate knowledge sharing capabilities into these sensors to enable their optimal integration into the Cooperative Transport Systems environment. [47]

TRACKSS goals are:

- To push forward the state of the art in infrastructure and in-vehicle sensing technologies for more safety and efficiency in road transport, improving their performance and cost-efficiency
- To implement advanced knowledge sharing capabilities in infrastructure and in-vehicle sensors, making them cooperative entities
- To enable improved situation awareness for all key players – humans and systems- involved in transport
- To pave the way to a new generation of Cooperative Transport Systems

2.4 Interest groups and related work

There exist several organizations and groups that are connected to political decision making, initiating new research projects, developing standards and promoting new ITS technology. In this section some interest groups are presented which are contributing to wireless vehicular communication or in-car communication.

2.4.1 CALM - ISO TC204: Working group 16

WG 16 is working on the standardization of the "CALM – continuous communications for vehicles" concept. The scope of CALM is to provide a standardized set of air interface protocols and parameters for medium and long range, high speed ITS communication using one or more of several media, with multipoint and networking protocols within each media, and upper layer protocols to enable transfer between media [2]. Examples of CALM air interfaces can be seen in Figure 4.

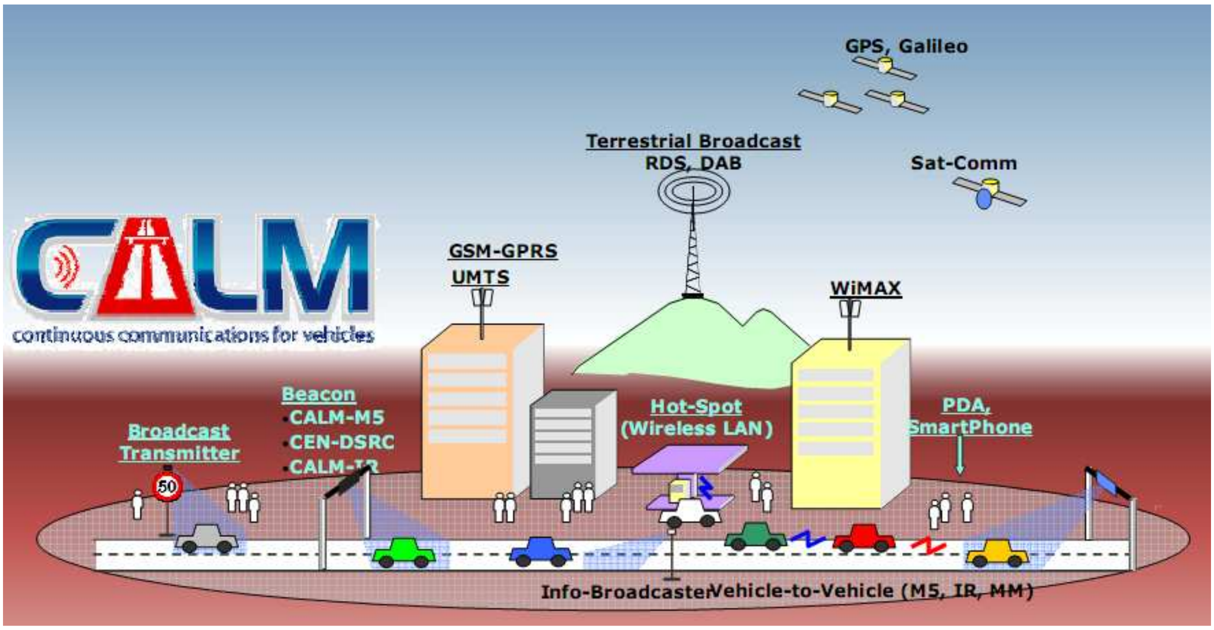

Figure 4 Examples of CALM air interfaces [48]**.**

In Figure 5 the general structure of CALM is illustrated. As can be seen in Figure 5 the structure is divided between the sub-groups of the Working group 16. The different sub-groups are:

- 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

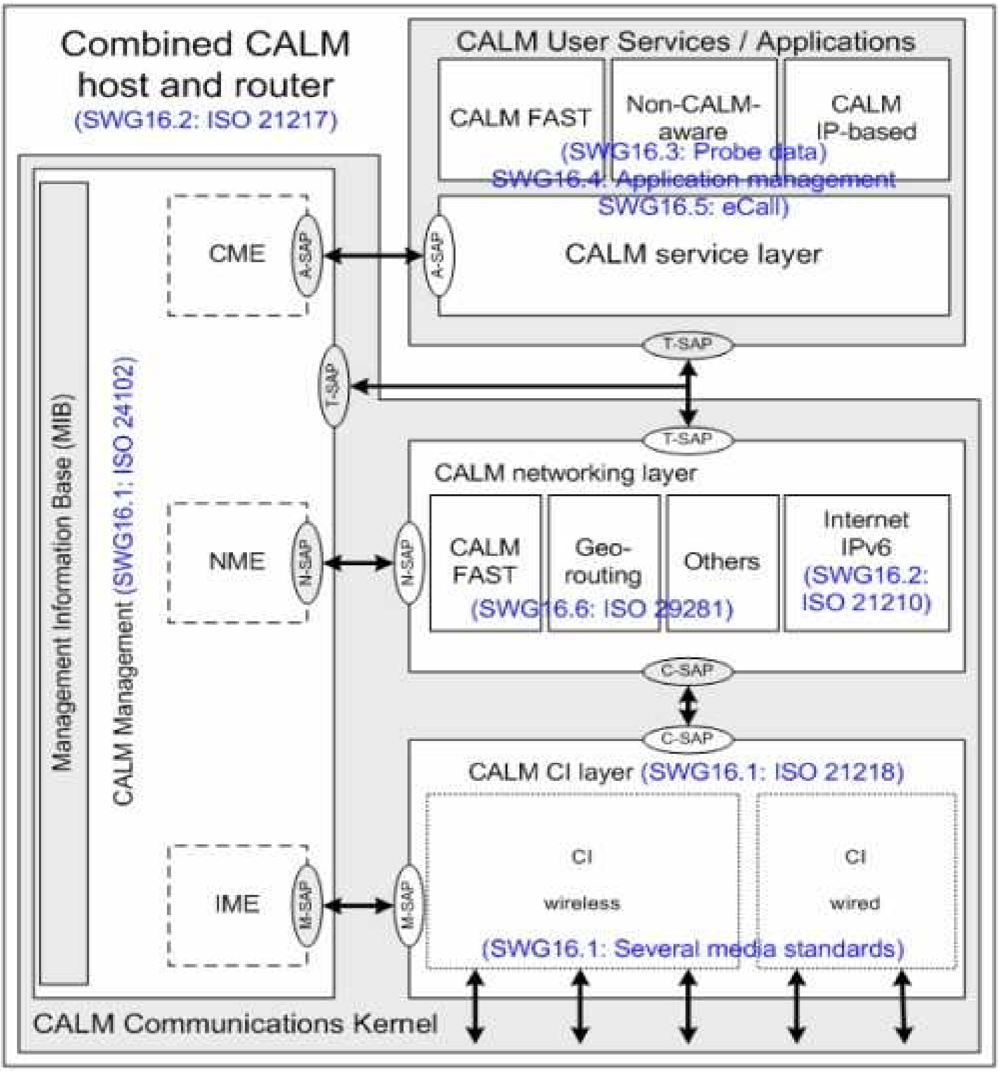

Figure 5 General Structure of CALM [2]**.**

2.4.2 Car 2 Car consortium

The CAR 2 CAR Communication Consortium is a non-profit organization initiated by European vehicle manufacturers, which is open for suppliers, research organizations and other partners. [49]

The mission and the objectives of the CAR 2 CAR Communication Consortium:

- To create and establish an open European industry standard for CAR 2 CAR communication systems based on wireless LAN (802.11 –technology) components and to guarantee European-wide inter-vehicle operability
- To enable the development of active safety applications by specifying, prototyping and demonstrating the CAR 2 CAR system
- To promote the allocation of a royalty free European wide exclusive frequency band for CAR 2 CAR applications
- To push the harmonization of CAR 2 CAR Communication standards worldwide
- To develop realistic deployment strategies and business models to speed-up the market penetration

2.4.3 CVTA (Connected Vehicle Trade Association)

Non-profit business league established to facilitate the interaction, and advance the interests, of the entities involved in the vehicle communication environment. [50]

Vision is to create:

- A vibrant economy surrounding the products and services that arise when the vehicle can interact with the external environment.
- Increased opportunity and an enhanced ability for participants to access opportunities in the Connected Vehicle space.
- Solid architectural and implementation consensus across all elements of the public and private Connected Vehicle value chain.

Objectives:

- Facilitate the engagement, collaboration and consensus building required to leverage resources, refine technological approaches, improve safe vehicle operation and advance business opportunities.
- Provide a robust and useful means of testing, evaluating, and demonstrating the enabling technologies, and provide a unified and trusted voice to communicate this information equitably and universally.
- Participate in industry activities as ambassadors to promote Connected Vehicle concept and market.
- Provide web based registry and program support for industry, organizational and governmental participants.

2.4.4 ERTICO

ERTICO was set up in 1991 at the initiative of leading members of European industry, Ministries of Transport and the European Commission. ERTICO is a professional body that represents the interests and combined skills of the European ITS community. Among its membership ERTICO now counts the key players from the ITS Industry, Infrastructure Operators and Users, as well as EU Member States. [51]

ERTICO is currently focused on:

- Improving the safety of road users.
- Making transport more efficient across all modes.
- Enhancing the security of all transport.
- Strengthening national and international cooperation on ITS.

2.4.5 eSafety Forum and its different working groups

Established in early 2003 by the European Commission in close co-operation with the industry, industrial associations and public sector stakeholders, the eSafety Forum is a joint platform involving all road safety stakeholders. It manages several working groups which deal with different areas of intelligent integrated road safety systems. eSafety forum also contributes to the i2010 Intelligent Car Initiative. [52] Considering ALMA the most important WGs would be Communications and eSecurity.

Currently there are 14 working groups and a steering group from which 6 are currently active:

Accident Causation Data	Concluded
Communications	Active
Digital Maps	Concluded
eCall Driving Group	Concluded
Heavy Duty Vehicles	Concluded
Human-Machine Interaction	Concluded
ICT for Clean and Efficient Mobility	Concluded
Implementation Road Maps	Active
International Co-operation	Active
Real-Time Traffic and Travel Information	Concluded
Research and Development	Active
eSecurity	Active
Service Oriented Architectures	Active
Steering group	--
User Outreach	Concluded

Working Group **Communication** especially focuses on [53]:

- Spectrum issues, helping the Commission with CEPT and Radio Spectrum Committee (RSC)
- Standardization, working together with Intelligent Transportation Systems Steering Group (ITSSG) towards ETSI, CEN and ISO
- International cooperation, i.e. establishing contacts to similar groups in the US and Japan to coordinate international issues in the WG-C work areas

The Communication working group has also suggested the spectrum shown in Figure 6 reserved to ITS purposes. It shows also the control channel which clearly indicates that there will be effort in the future to apply wireless communication for safety critical vehicular functions.

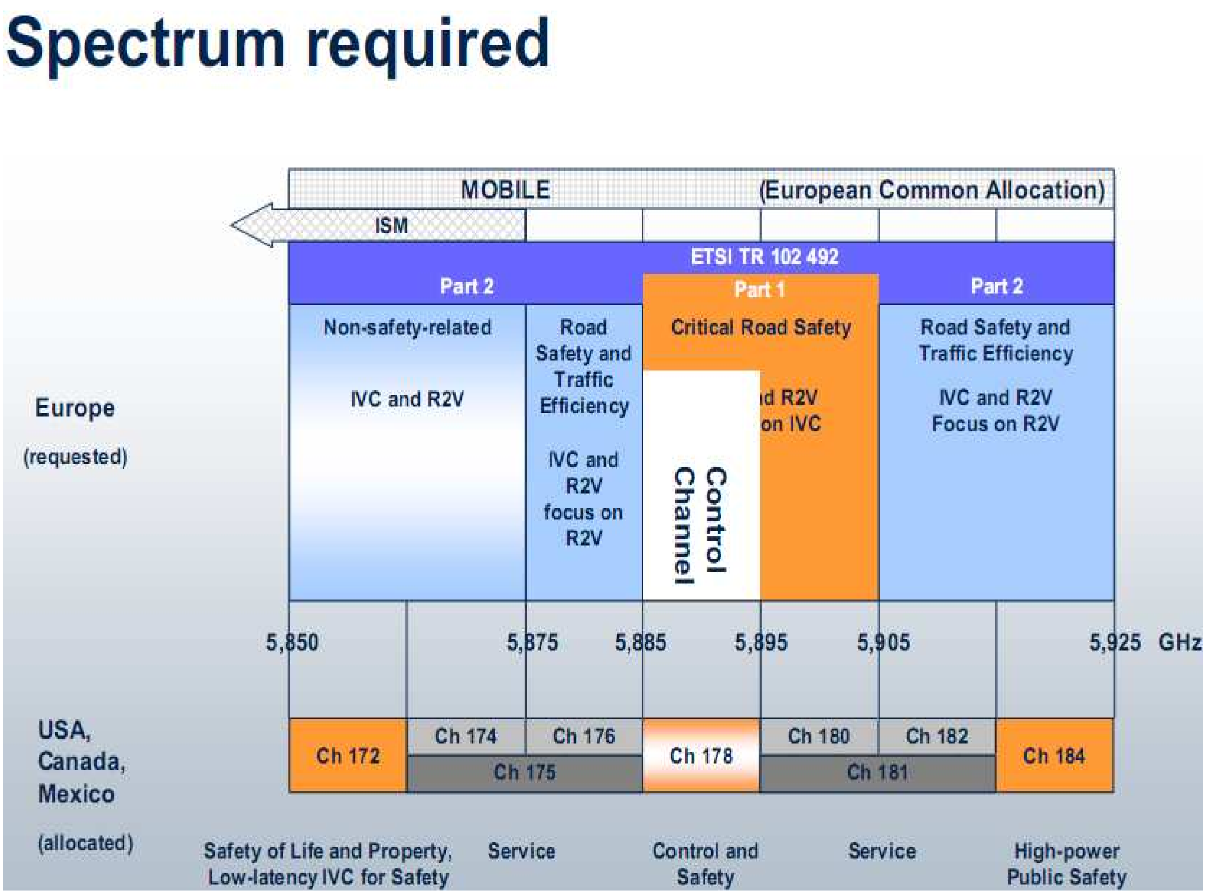

Figure 6. Suggestion from the Communications working group for reserved spectrum [54]**.**

Working Group **eSecurity** initial topics comprise [55]:

- Protection against unauthorized mobile remote access and wired access on networked vehicles including the full electronic system and its components and data against manipulation and subsequent misuse (e.g. wired & tele- data / software transfer)
- Protection of electronic motor vehicle components against e-assaults (e.g. viruses, trojans, spy-ware, spam, etc.) and of digital data stored in the motor vehicle and road infrastructure against unauthorized access and manipulation
- Protection of motor vehicles, fleets and road infrastructure by securing telematics and co-operative system applications
- Establishment of the legal requirement catalogue on necessities in MS and European legislation, certification, and inspection procedures next to the eSecurity Standards survey

2.4.6 EUCAR (European Council for Automotive R&D)

EUCAR evolved from the Joint Research Committee (JRC) of the European motor vehicle manufacturers. It then began to foster strategic cooperation in R&D activities concerning automobiles. EUCAR provides a platform for its members (big car manufacturers) so they have a better way to channel their technology needs in the up-coming R&D projects. [56]

3 INTERESTING COMMERCIAL APPLICATIONS

In this chapter, some interesting in-car communication products are presented. Also, as the target of ALMA was autonomous operations via wireless sensors, it was justified to search for products aiming to automate heavy-duty vehicles as well.

3.1 ANEMONA

Robosoft proposes Autonomous Heavy Vehicle Operation, which enables double mode of use manual and/or automatic for existing heavy vehicles (e.g. tractor). The product is a robotic kit, which have been tested in real scale demonstration workshops. Performance or evaluation data of the autonomous vehicle was not published. [57]

3.2 IXXAT CAN-Bluetooth-CAN

- CAN-Bluetooth-CAN Bridge and
- CAN-Bluetooth Module with ASCII Protocol

The bridge mode allows the user to set-up a CAN-Bluetooth-CAN bridge by using two CANblue/Generic devices. Message exchange occurs on layer 2 and is transparent [58].

Technical Data

Bluetooth interface	Bluetooth specification V2.0, Class 1 / +16,9 dBm (49 mW), 100m
Microcontroller	Infineon C161U, 36 MHz
Memory	256 k Flash, 128 k RAM
CAN controller	SJA1000
CAN bus interface	ISO 11898-2 and ISO/IS11898-3, switchable, Sub D9 plug according to DS102, galv. decoupled
Voltage supply	9 - 30 V DC, 2.5 W
Temperature range	-20 ºC ... +70 ºC

Certification	CE, FCC
Housing	stable metal housing
Size	85 x 72 x 35 mm

3.3 Nanotron radio applications by VTT

Nanotron radio has been applied by VTT to various applications. In train wheel measurement application the radio was utilized to perform online analysis of the rotating wheel. The system was able to measure four wheel disks (80 channels) simultaneously when speed exceeded 300 km/h.

In heavy-duty vehicle monitoring, wireless torque measurement of the wheel loader's cardan axle was developed successfully. Also with passenger car the radio was used successfully, when inertial measurement unit for car tires' winter testing was developed. In this application the data was sent to the car cabin wirelessly thus enabling fast installation of the unit.

Considering wireless bus architecture solutions, Nanotron radio was integrated to board containing FPGA module, which connects to different buses (e.g. CAN). [59]

3.3.1 SWOT of Nanotron

The strengths when using Nanotron is the existing know-how of its capabilities, several tested applications in vehicular environments and the availability of components. There are also some properties in the radio which are beneficial such as the CSS (tolerant for noise) and long communication distance. The weakness of Nanotron is its maximum throughput of 2 Mbps. The opportunities when utilizing Nanotron lies in the VTT developed applications and currently tested case scenarios, where NanoLOC radio was tested for location measurement. The threats are low scalability of the radio for different purposes when the need of transferred data growing. Also for the use of Nanotron in control applications new reliable protocol with pre-known latency is required. Development of such protocol can face difficulties which should be analyzed carefully.

3.4 WISA (wireless interface for sensors and actuators)

WISA, developed by ABB, is intended to provide wireless communication on factory floors. It has been in use for ABB applications for more than four years. In WISA the sensors are powered by magnetic coupling while the real-time wireless communication uses Bluetooth (IEEE 802.15.1). To ensure reliability, time division multiple access (TDMA) protocol with Frequency Hopping (FH) has been used. [60-62]

This comparatively low transmit power is appropriate and sufficient for a range of 5–10 m. For WISA a maximum message transmission delay of 15 ms is specified. The probability of failing to deliver a message within this time frame is less than 1×10-9. [61]

In WISA the Bluetooth radio was selected because at development time of WISA it was the only radio that was able to meet the requirements of multiple connections and low power consumption. Also the short communication range was seen as a benefit rather than disadvantage, as the product was designed especially for industrial manufacturing cells.

3.4.1 SWOT of WISA

The strengths of WISA are the support for existing fieldbus technologies (CAN, Profibus, DeviceNet), tested real-time protocol that meets the requirements of high node density (hundreds of nodes), high reliability, low latency (ms resolution) and low power consumption. The weaknesses are fairly short communication range (3-10 m), additional testing required for vehicular environment and relatively small data throughput (1 Mbps). Also WISA is proprietary technology, so it can be costly to integrate it into commercial systems. Also there might be some closed parts in WISA because licensing and patents might prevent their modification. According to ABB, there are also projects where WISA technology is inserted into third party products and some (but not all) WISA principles might be usable if other radio PHY would be used.

The use of WISA would be an opportunity if ABB would be willing to let us study their technology without additional costs. The biggest threats are unknown disturbances in vehicular environments (industrial shop floor differs from a heavy-duty vehicle) and the communication range which is required to be 10 meters. These matters require testing with real data in real environment. Also the licensing and the patents regarding WISA can be a threat if it is not taken care of in the beginning.

3.5 Certified Wireless USB chipsets

There exists quite a few chipsets and development kits for Certified Wireless USB e.g. Wisair [63]. Even though Certified Wireless USB is based on WiMedia Alliance's UWB radio, UWB standards should not be mixed with wireless USB. The current UWB standards are not complete, but for example ISO has accepted WiMedia's PHY and MAC, so similarities between Certified Wireless USB and upcoming UWB standards are expected. The Certified Wireless USB was designed for 3.1-10.6 GHz frequency band and it should be able to send 110Mbit/s up to distance of 10m. The current version of Certified Wireless USB 1.0 and it was released in May, 2005. [64]

3.5.1 SWOT of Certified Wireless USB

The strengths for Certified Wireless USB are:

- sufficient throughput for video streaming
- robustness for channel noise
- large amount of devices connected to the bus
- supposedly good security

The weaknesses are:

- the new – still immature technology
- low knowledge level of developers
- poor availability of devices before mass production starts
- short communication range.

There has not been much discussion of the power consumption of Certified Wireless USB so it might become a bottleneck in some applications. Because new technology always creates interest commercially it should be thought as an opportunity if end-products are developed. The integrated UWB radio gives an opportunity to get acquaintance of its characteristics before the UWB standards are finalized.

4 RELIABILITY IN VEHICULAR WIRELESS COMMUNICATION

Although many car manufacturers have PAN network installed for infotainment purposes (usually via Bluetooth+WLAN) the interest for in-car wireless safety critical sensors have not been high within the end-products [65, 66]. One reason for this is the dominating fieldbus technologies. Another reason is the challenging measurement setup required to analyze the reliability and performance of a wireless connection. Still, wireless reliability is an interesting topic and there has been some effort to validate wireless connection so safety applications could be produced. One validation method is to describe the threats and consequences of wireless communication and check the proposed method against these threats. Table 1 gives an overview of the basic threats.

Table 1 Basic threats and their consequences of wireless communication [67]

Basic threats	Consequences
The transmission fades because the distance between sender and receiver increases	Signal level is low. Bit error rate increases. Data is corrupted or lost.
The signal fades because of obstacles	Signal level is low. Bit error rate increases. Data is corrupted or lost.
Transmission signal fades because of environment conditions	Signal level is low. Bit error rate increases. Data is corrupted or lost.
Transmission signals are reflected from surfaces resulting in echoes and interference, or signal appears because of reflections from long distances	Signal level is low. Bit error rate increases. Data is corrupted or lost. Inserted new messages.
Two or more signals interfere with each other and cause proper signal for another receiver	Bit error rate is high and therefore an acceptable transient signal can be initiated.
Receiver is too sensitive.	Signal is generated out from noise. Short message can appear.
Poor capability of a relaying station.	The signal can be delayed e.g. due to heavy traffic or extra signal processing in relaying stations.
The nodes understand the network state or configuration differently at the same time.	Consistency and stability problems especially when nodes are moving. Radio B can hear radio C and A, but radio A cannot hear radio C. This may cause confusion
Nearby wireless network is using similar communication protocol.	One node is substituted intentionally or unintentionally with another node
Security; intentional penetration to wireless network	New messages may be inserted
Systematic failure, characteristics of wireless communication is not considered	Almost any of the above mentioned consequences may result
Sleeping nodes in low power networks. Some nodes can be ordered to sleep to lower power consumption i.e. longer battery life.	There is no communication through a sleeping node until the node awakes.

To understand the threats displayed in Table 1 the wireless communication faults can be further divided into transmission failures and communication system faults. These faults depend on the used hardware, software and environment. In short, the safety and reliability of a system has to be proven in the environment where the communication takes place e.g. in vehicular environment where typical disturbances are present. Also the use of statistical methods to measure reliability of the system is imperative.

Only few case studies of wireless reliability in vehicular environment have been published so far [68-71]. The technologies which have been studied are RFID, ZigBee, WLAN and UTRA-TDD.

4.1 RFID

RFID was studied in vehicular environment in a test setup where reader was positioned in above driver’s seat and RFID tags were placed:

- on the hood, (H)
- in the trunk, (TR)
- in the engine compartment and (IE)
- under the engine compartment (UE)

thus forming four different communication channels. First the multipath effect was studied by measuring the power delay profiles of all channels using a vector network analyzer and two omni-directional antennas. The results show that on the hood (H) is the best power delay profile, while under the engine compartment (UE) and in the trunk (TR) are the lowest. The power loss in the UE channel was measured to be more than 80dB, which is quite large.

In the passive RFID reading experiment only the tag residing on the hood could be recognized. In the second experiment the most powerful directional antenna that could be reasonable fit into car was tested, but still the passive RFID tags could not be read. The authors discuss of the possibility of routing the data with multiple readers and the use of active RFIDs instead of passive. These ideas were not tested. [72]

4.2 Zigbee

One purely theoretical study states that most demanding sensors in a vehicle require less than 1ms of latency and the least demanding sensor 50 ms latency. In this study the focus was mathematical feasibility analysis of IEEE 802.15.4 (ZigBee) radio as vehicular control channel, but also 802.15.4a (NanoLOC) was considered to support the results. The analysis revealed that up to 40 nodes could be supported if latency less than 100 ms was required. The minimum calculated latency was 15.9 ms, so it implies that IEEE 802.15.4 cannot be utilized if 1 ms latency is the target. Also, there were several assumptions made for the calculations so actual simulated or tested results should reveal even longer latencies. [73]

Another study, where four ZigBee sensors were placed in the different sections of a passenger car as illustrated in Figure 7, provided more reliable results. The test consisted of five different scenarios, which are listed in Figure 8. The error sources in different scenarios were WLAN, Bluetooth hands-free, car engine, car radio, other vehicles and people inside and outside of the vehicle. The study concentrated only on the PHY layer and the authors acknowledge the fact that taking other factors into account e.g. MAC might give different results. [74]

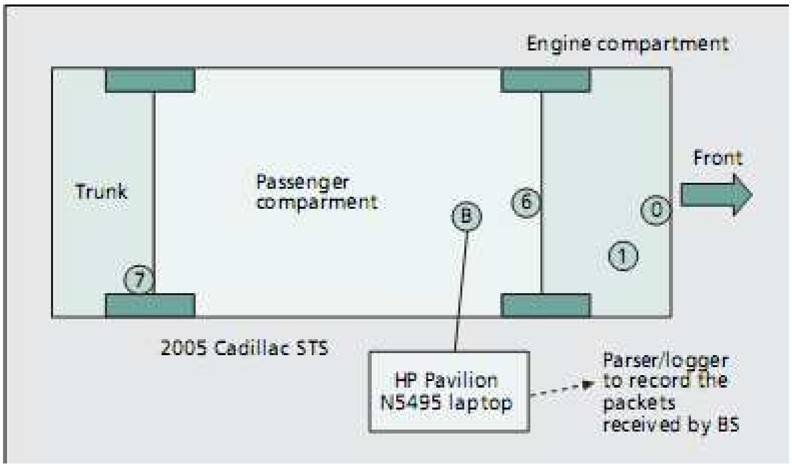

Figure 7. ZigBee test where four sensor nodes (0-7) were placed around a car [74]**.**

Scenario	Location	Driver	Engine
1	Maintenance garage	Present	On
2	Maintenance garage	Not present	Off
3	Corporate parking lot	Present	On
4	Corporate parking lot	Not present	Off
5	On the road	Present	On

Figure 8. Performed test scenarios [74]**.**

The main results of the study:

- Location of a sensor node will affect greatly on the link quality.
- The usage of Bluetooth hands-free caused 3-40 % decrease in throughput.
- Engine noise can increase Received Sensitivity Threshold of PRR and PER by 2-4dB
- RSSI and LQI can be used in link quality evaluation
- PRR drops from 1 to 0 when transmitting power fades to -91-94 dBm, also 802.11b/g and movement of the driver affects the throughput of the ZigBee.

Compared to RFID (see section 4.1) the following advantages were noted:

- Powerloss problem observed with passive RFID was not present with active ZigBee
- ZigBee can be deployed with off-the-self components, RFID requires modifications
- ARQ method and adaptive power increasing are possible with ZigBee for increasing link quality

Disadvantages of ZigBee compared to RFID:

- ZigBee is more expensive
- ZigBee battery will deplete in time

4.3 IEEE 802.11p (WAVE)

Although the standard is not yet complete (see section 1.1) some research have been conducted based on the published draft versions. One interesting feature of 802.11p is the multi-channel concept, which priorizes messages between safety related and information messages. Messages are categorized in different Access Classes (ACs) and each AC has its own message queue. Eventhough this should guarantee high priority safety message throughput, it was shown with mathematical analysis and simulations that the safety messages become unreliable when many nodes are present [75]. However, more nodes do not significantly affect the low priority messages as their wait time is longer by default. Also, because the non-safety messages take listening time from the potential receiver there might not be a suitable listener even if the control channel would be free [76]. These problems raise the questions of protocol efficiency (which also prevents collisions and helps to recover if channel becomes saturated) and the need of dedicated radio which receives and sends only control messages using different bandwidth.

Practical tests with traffic safety improving applications show that there is much potential in 802.11p communication. The tests were carried out using three passenger cars loaded with GPS and several applications which use the car break/acceleration data and range-finder sensor data. The reliability issues were divided between communication reliability and application reliability. The communication reliability was measured with two different methods: Packet Delivery Ratio and Distribution on consecutive packet drops. The application reliability was measured with T-window. These metrics are described in next paragraphs. [77]

Packet Delivery Ratio measures the throughput, while the consecutive packet drops measures how many ‘bursts’ of packet drops exist. Bursty packet drops means short and uneven spurs of dropped packets. The tests show that consecutive packet drops occur seldom, even when environmental conditions are harsh such as freeway. The most limiting factor in these tests was found to be distance. However, one can argue that three vehicles were not enough to test the impact of heavy traffic with lots of competitive messages.

The application reliability measurement with T-window is a statistical method. T-window is defined as the probability of receiving at least one packet during tolerance window T. If the packet was received, the application can be said to be reliable. This gives a better reliability performance analysis, as V2V or V2I communication does not require that every packet is received. Better yet, this opens the possibility to replace some of the packets by estimates from algorithms, which can predict the outcome even when few packets were lost.

The end result was that most of the time the safety applications would receive the amount of data they require for operating. The key factor is how to determine the time required for each application (T-window) and also whether to use more then one radio to improve the safety message throughput. Example values have been suggested in Table 2 which is being used in the IEEE 802.11p standardization process as well.

Table 2 Examples of DSRC Applications and Requirements [76]

Application	Packet size (bytes) / Bandwidth	Allowable latency (ms)	Network traffic type	Communication range (m)	Priority
Intersection collision warning / avoidance	~100	~100	Event	50-300	Safety of life
Cooperative collision warning	~100 / 10Kbps	~100	Periodic	50-300	Safety of life
Work zone warning	~100 / 1 Kbps	~1000	Periodic	50-300	Safety
Transit vehicle signal priority	~100	~1000	Event	300-1000	Safety
Toll collection	~100	~50	Event	<15	Non-safety
Service announcements	~100 / 2 Kbps	~500	Periodic	0-90	Non-safety
Movie download (2h of MPEG 1) 10min download time	>20 Mbps	N/A	N/A	0-90	Non-safety

4.4 UTRA-TDD

Reliability of UTRA-TDD has been tested in FleetNet project where it was compared with IEEE 802.11b [78]. UTRA-TDD is interesting choice for ITS in Europe as the required bandwidth has been available for quite some time. The requirements in FleetNet project were:

- Support for various bit rates (safety message vs. internet access)
- Robustness in difficult propagation situations (e.g. vehicles driving opposite directions on highway; in urban areas Non-line-of-sight situations and large channel tap delays are present)
- Support for large transmission range (helps to make the system useful even when there are few cars equipped with ITS technology)
- Support for single burst transmission (guarantee low latencies for high priority data packets)

There are several differences with UTRA-TDD and 802.11b which makes their comparison difficult, as every parameter needs to be optimized to get the best performance. It is also problematic that for UTRA-TDD the ad-hoc connectivity is not inherit which is readily available for IEEE 802.11. This means alterations needs to be made before UTRA-TDD can be utilized in ITS. The technology comparison was based on the ratio of energy per useful bit (E_b) to the noise spectral density (N_0). The results can be seen from Figure 9 where two different scenarios of “Urban” and “Highway” are presented for both technologies. The figure shows that for “Urban” scenario the 802.11b does not achieve 1% loss rate. The authors tracked the problem of 802.11b bad performance to the large channel tap delay. Because 802.11b does not utilize any equalization or channel coding this combination leads to bit errors. The target loss rate of 1% in “Highway” scenario was obtained by 802.11b with an E_b / N_0 of 11dB. With UTRA-TDD ad-hoc it was 8.5dB. As a conclusion multipath effects prevent 802.11b to meet required reliability of 1% loss rate. On both scenarios UTRA-TDD outperformed 802.11b.

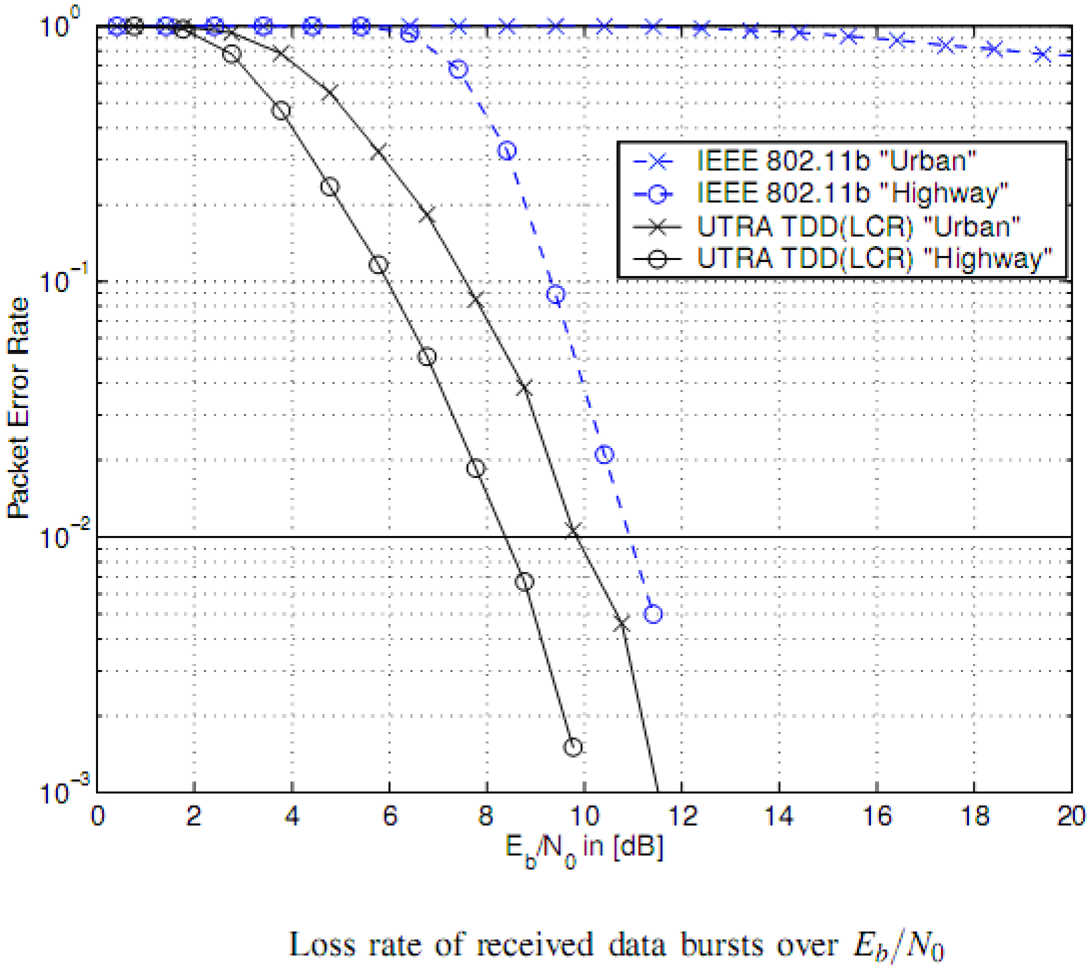

Figure 9 Comparison of UTRA-TDD and IEEE802.11b in two scenarios “Highway” and “Urban” [78]**.**

5 DISCUSSION

There are many proficient technologies for communication between mobile terminals (vehicle-to-vehicle) and are significant to our work. These technologies have been utilized in various projects or in case of upcoming standards they have been simulated and analyzed mathematically to measure their performance.

In technology wise the best opportunities lie within the technologies that are nearly or just standardized and have high impact on the current research such as IEEE 802.11p and UWB. If a successful implementation is created based on the draft version of the standard the know-how exists to modify them later to match with the complete standard. The strengths are large data rates and with UWB the tolerance with channel noise. Also IEEE 802.11p especially targets vehicles which makes it very interesting standard. The weaknesses are fairly short communication range. The risks with them are the incomplete draft versions, which most likely lead to problems. One possibility to explore the upcoming standards is to utilize development kits such as those based on Certified Wireless USB, which utilizes the same PHY defined in ISO standard of UWB.

If the target is to get decent applications using mature technology there are several technological options e.g. IEEE 802.11a/b/g, NanoLOC, ZigBee and Bluetooth. Alternatively, for communication between vehicles, the UTRA-TDD has shown to outperform some of its competitors (for example 802.11b), but these applications have been developed under various research groups which requires cooperation. The strength with UTRA-TDD would be its multi-usage as the same radio could connect to a GSM base station. Example projects that have utilized UMTS for ITS are AKTIV, CVIS and FleetNet.

The IEEE 802.11a/b/g has been the dominant technology in ITS pilots (e.g. COM2REACT) due to its inherit ad-hoc connectivity, cheapness and well-known standard. The biggest obstacle with IEEE 802.11 is the interference with other devices working on the same channel and fairly short communication range.

NanoLOC and ZigBee have been successful when utilized to low-power applications. NanoLOC has much longer communication range and data rate then ZigBee. Also NanoLOC is more tolerant to the multipath effect and noise which means it is more reliable. Because of general good performance of NanoLOC, it has been utilized by VTT in various vehicular communication projects.

Bluetooth is mainly utilized in vehicular PAN networks for infotainment transfer, but also some high reliability applications exists such as ABB’s WISA concept. In WISA the Bluetooth PHY is utilized for industrial manufacturing cell sensor/relay control and the wireless nodes are connected to regular fieldbus such as DeviceNet, Profibus or CAN. Even though WISA is thoroughly tested within industrial applications its vehicular performance remains untested. Also as the WISA is proprietary technology its costs can be high when applied commercially.

Other interesting areas in vehicular wireless communication projects relate to (i) application development practices, (ii) security, (iii) simulating, (iv) testing and (v) new applications.

For application development practices (i) there have been efforts to abstract the different levels of in-vehicle communication. This would definitely be useful as 3rd parties could access the ECUs inserted to the vehicles and develop their own applications for them. Example projects are AUTOSAR and EMMA, but their scope is bit different. It is easy to see that at least AUTOSAR standard should be further investigated. Also ATESST2 could provide useful information as the description language EAST-ADL2 that has been developed for representing engineering information is harmonized for AUTOSAR.

For security (ii) related information EVITA, SAFETEL and SAVECOM should be familiarized. EVITA provides the base to prevent the tempering of the onboard systems. SAFETEL concentrates on blocking electromagnetic disturbances that will hinder the operation of wireless communication device. SAFETEL tries to find methods to prevent outside attacks that will hinder the communication and performance of the device.

The simulation (iii) in vehicular wireless communication is not nearly as good as it could be. To get better performance of traffic simulations and wireless communication simulations iTETRIS is producing tools to couple them together. This enables large scale analysis and development of protocols and algorithms which better characterize wireless conditions in vehicles.

The testing (iv) related research has been conducted for example in ANEMONE, FESTA and ARCTIC projects. To support general testing of intelligent car applications ANEMONE project has produced test-beds around the Europe (one resides in Oulu) which provide different mobile communication possibilities for road users. The FESTA project tries to produce a common methodology for field operational tests (FOTs) on driver behavior. This contributes of measuring individual safety benefits and larger scale socio-economic benefits. In purely technology development aspect ARCTIC provides measurement and testing knowledge of vehicle antennas. Their goal is to share antenna technology on European level.

New applications (v) for intelligent vehicular environment have been designed in various projects e.g. in TRACKSS. Unfortunately, these applications are not very relevant considering ALMA. However, other interesting applications which do have some significance to ALMA are the commercial automation-kit for tractor (ANEMONA) and different commercial wireless links that provide connection between two fieldbuses (e.g. IXXAT CAN-Bluetooth-CAN). Also there have been some research projects in the past that have automated tractors or crops harvesters based on GPS data and simple work sequences.

The reliability of different communication methods was also studied, but only very few published results exists. The technologies that were evaluated are RFID, ZigBee, IEEE 802.11 and UTRA-TDD. The two former were tested for in-car communication and the latter were studied for vehicle-to-vehicle communication. The tests show that RFID does not qualify at all and ZigBee will take serious interference from Bluetooth handsfree, WLAN stations, movement of the driver etc, but it still functions somewhat. As for UTRA-TDD the simulations reveal that it outperforms IEEE 802.11b in both “urban” and “highway” scenarios. The reliability of UTRA-TDD was shown to reach at least 1% of packet loss.

The interest groups of ITS development were also studied as part of this report. One significant interest group in technology point of view is ISO TC204 nicknamed by their concept “CALM". CALM aims, for example, to provide upper level protocols so change between different transfer mediums would be possible. This would enable continuous air transmission. One of their current objectives is to make unfinished IEEE 802.11p to match European legislation and enable the utilization of different radio standards with it. The CALM concept has been adopted by at least one ITS project CyberCars2.

In legislation point of view the most noticeable technology oriented group in Europe is the eSafety forum. It was appointed by EU Commission to support their decision making. For example the bandwidth for the control channel was suggested by eSafety *Working Group* (WG) *communications*. This implies that safety critical wireless applications will be introduced to vehicles at some point. The interest groups presented in this report is not nearly complete. Only some of them were introduced usually based on the technology they were developing or promoting.

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APPENDICES

Appendix 1: Review, Radio Standards and Protocols, 38 p.

Appendix 2: Esiselvitys: Ajoneuvojen uudet väyläteknologiat, 41 p.

Appendix 3: List of ICT for transport FP6 RTD Projects

Appendix 4: List of ICT for transport FP7 RTD Projects

Appendix 3: List of ICT for transport FP6 RTD Projects

AIDE (Adaptive Integrated Driver-Vehicle Interface)
www.aide-eu.org/

AIRNET (Airport Network for Mobiles Surveillance and Alerting)
www.airnet-project.com

ATESST (Advancing Traffic Efficiency and Safety through Software Technology)
www.atesst.org

COM2REACT (COoperative CoMmunication System TO Realise Enhanced Safety And EffiCiency In European Road Transport)

COMeSAFETY (Encompasses five main activities dedicated to cooperative safety systems)
www.comesafety.org/

COOPERS (Co-operative Systems for Intelligent Road Safety)
www.coopers-ip.eu

COVER (Semantic driven cooperative vehicle infrastructure systems for advanced eSafety applications)
www.ist-cover.org

CVIS (Cooperative Vehicle-Infrastructure Systems)
www.cvisproject.org

CYBERCARS2
www.cybercars.org

EASIS (Electronic Architecture and System Engineering for Integrated Safety Systems)
www.easis.org

eIMPACT (Socio-economic Impact Assessment of stand-alone and co-operative intelligent vehicle safety systems (IVSS) in Europe)
www.eimpact.info

eSAFETYSUPPORT
www.esafetysupport.org

ESCOPE (eSafety Observatory)
www.escope.info

EU-INDIA (Cooperation between Europe and India on eSafety)
www.euindia.info

EURAMP (European Ramp Metering Project)
www.euramp.org

FEEDMAP (Technical and commercial feasibility assessment of map data feedback loops applied to the ActMAP framework)

FRICTION (On-board Measurement of Friction and Road Slipperiness to Enhance the Performance of Integrated Cooperative Safety Systems)
friction.vtt.fi

GOODROUTE (Dangerous GOODs Transportation ROUTing, Monitoring and Enforcement)
www.goodroute-eu.org

GST (A Global System for Telematics enabling on-line safety services)
www.gstforum.org/

HIGHWAY (breakthrougH Intelligent maps & GeograpHic tools for the context aWAredeliverY of e-safety & added-value services)
www.ist-highway.org

HUMANIST (Human Centred Design for Information Society Technology)
www.noehumanist.org

IM@GINE-IT (Intelligent Mobility AGents,Advanced Positioning and Mapping Technologies INtEgration Interoperable MulTimodal, location-based services)
www.imagineit-eu.com

ISHTAR (Industrial Stimuli for the HarmonisaTion of EuropeAn Research in the area of Location Based Services)

ISMAEL (Intelligent Surveillance and Management Functions for Airfield Applications Based on Low Cost Magnetic Field Detectors)
www.ismael-project.net

I-WAY (Intelligent co-operative system in cars for road safety)
www.iway-project.eu

MORYNE (EnhanceMent of public transpORt efficiencY through the use of mobile seNsor nEtworks)
www.fp6-moryne.org

PREVENT (PReVENTive and Active Safety Applications)
www.prevent-ip.org/

REPOSIT (RElative POSitioning for collision avoidance sysTems)
www.ist-reposit.org

SAFE-AIRPORT (Development of an Innovative Acoustic System for the Improvement of Co-operative Air Traffic Management)
www.safe-airport.com/Home_vera.htm

SAFESPOT (Co-operative Systems for Road Safety “Smart Vehicles on Smart Roads”) www.safespot-eu.org

SAFETEL (Safe Electromagnetic Telecommunication on Vehicle)
www.safetel-project.com

SAFETY TECHNOPRO (Training System on New Safety Technologies for Road Transport Addressed to Professional Bodies of the Automotive Sector)
www.safety-technopro.info

SEiSS (Exploratory study on the potential socio-economic impact of the introduction of intelligent safety systems in road vehicles)

SEVECOM (SEcure VEhicle COmmunication)
www.sevecom.org/

SPARC (Secure Propulsion using Advanced Redundant Control)
www.sparc-eu.net

TRACE (TRaffic Accident Causation in Europe)
www.trace-project.org

TRACKSS (Technologies for Road Advanced Cooperative Knowledge Sharing Sensors)
www.trackss.net

WATCH-OVER (Vehicle-to-vulnerable road user cooperative communication and sensing technologies to improve transport safety)
www.watchover-eu.org/

Appendix 4: List of ICT for transport FP7 RTD Projects

ADOSE (Reliable application specific detection of road users with vehicle on-board sensors)

ARTIC (Antenna Research and Technology for the Intelligent Car)

ATESST2 (Traffic Efficiency and Safety through Software Technology - Phase 2)

E-FRAME (Extend FRAMEwork architecture for cooperative systems)

EURIDICE (European inter-disciplinary research on intelligent cargo for efficient, safe and environment-friendly logistics)
www.euridice-project.eu

EUROFOT (European Field Operational Test on Active Safety Functions in vehicle)
www.eurofot-ip.eu

eVALUE (Testing and evaluation methods for ICT-based safety systems)
www.evalue-project.eu

EVITA (E-safety Vehicle Intrusion proTected Application)

FESTA (Field opErational teSts supporT Action)
www.festaproject.eu

FESTA

FNIR (Fusing Far Infrared and Near Infrared Imaging for PedestriTITLEan Injury Mitigation)
www.fnir.eu

FOT-NET (Field Operational Tests Networking and Implementation)
www.fot-net.eu

GEONET (Geo-addressing and geo-routing for vehicular communications)

HAVE-IT (Highly automated vehicles for intelligent transport)

IFM-PROJECT (Interoperable fare management project)
www.ifm-project.eu

INTERSAFE 2 (Cooperative Intersection Safety)
www.intersafe-2.eu

iTETRIS (An Integrated Wireless and Traffic Platform for Real-Time Road Traffic Management Solutions)
www.ict-itetris.eu

NEARCTIS (A Network of Excellence for Advanced Road for cooperative traffic management in the Information Society)

PRECIOSA (Privacy Enabled Capability In co-Operative systems and Safety Applications)

PRE-DRIVE (PREparation for DRIVing implementation and Evaluation
of C-2-X communication technology)

ROADIDEA (Road Map for Radical Innovations in European Transport Services)
www.roadidea.eu

ROSATTE (Road safety attributes exchange infrastructure in Europe)

SAFERIDER (Advanced telematics for enhancing the SAFEty and comfort of motorcycle RIDERs)

SCVP (Smartest Cars Video Project)
www.thinkingcars.com

SMARTFREIGHT (Smart freight transport in urban areas)
www.smartfreight.info

SMART-VEI (The Smart-Vehicle)

TELEFOT (Field Operational Tests of Aftermarket and Nomadic Devices in Vehicles)
www.telefot.eu

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	VTT / Register Office	Original