Inter-vehicle communications - research report

Ana Roxin

Inter-vehicle communications – Research report

Ana ROXIN, UTBM

1 Vehicle communication - a definition

In order to define vehicle communications, one must first differentiate the different types of communication that may occur. Mainly, there are two types of vehicle communication:

- Intra-vehicle communication reference communications that occur within a vehicle.
- Inter-vehicle communication represents communications between vehicles or vehicles and sensors placed in or on various locations, such as roadways, signs, parking areas, and even the home garage.

In the rest of this paper, we will only focus on inter-vehicle communications. The primary modes of communication in this category are the following:

- Vehicle to/from roadside communication mode requires using roadside transponders. Vehicle to/from roadside communication supports both vehicle-specific data as well as locally relevant data broadcast to vehicles. This category is referred to as Vehicle-to-Infrastructure (V2I) communication.
- Vehicle to/from vehicle communication mode includes in-line communications with neighbouring vehicles (including those travelling in the opposite direction and those travelling in the same lane). This category is referred to as Vehicle-to-Vehicle (V2V) communication.

2 Inter-vehicle communication applications

For the concept of "intelligent vehicle" to be viable, a wide range of applications is needed, in order to lower the costs per application. Therefore, an extensive set of applications based on vehicle communications has been conceptualised. A sampling of these applications is given in the following table.

V2I Applications	**V2V Applications**
Curve speed warning	Emergency braking of forward vehicle
Optimal speed advisory	Pre-crash warning
Highway work zone warning	Driver advisories when making turns across traffic
Highway/rail crossing collision avoidance	Lane change warning
Traffic signal violation warning	Approaching emergency vehicle advisory
Low bridge warning	Stop sign movement assistance
Road condition warning	Road condition warning
Electronic toll collection	Cooperative adaptive cruise control

Wireless diagnostics	
Software "flashing"	
Commercial driver log information	
Vehicles acting as data probes for traffic and road information	
Real-time map/traffic updates	
Enhanced route planning and guidance	
Drive-through payment (gas, parking, fast food)	
Wireless transfer of digital entertainment (games, music, video)	
Data exchange for border clearance	

Table 1. Inter-vehicle communication applications.

3 Inter-vehicle communications

Over the past decade a considerable amount of research has occurred in the area of inter-vehicle communications oriented toward providing safety features and expanded capabilities to vehicles.

A first area of research is oriented toward the use of Mobile Ad Hoc Networking (MANET) for vehicle safety. The idea is to form groups of vehicles in order to allow relaying information from vehicle to vehicle.

A second area of research is oriented towards the concept of "intelligent road". The idea is to enable vehicles to seamlessly gather information from any combination of signs, displays, sensors, and transponders.

In the first section, we will describe vehicle-to-roadside communications. We will notably examine how vehicles can gain "intelligence" from highways, roads, and streets. In the second section, we will present vehicle-to-vehicle communications. We will notably discuss some of the applications that can be promoted by this type of communications.

3.1 Vehicle-to-Roadside communications

In this concluding section we will examine how vehicles can gain awareness about conditions they may encounter from highways, roads, and streets.

3.1.1 Roadside Design

In order to allow road infrastructure communicate with vehicles passing by, one must necessarily use either wireless access points or simple broadcast stations. Still, these equipments must be located at strategic locations in the road infrastructure. Table 2 lists some of these strategic locations from where information could be broadcasted.

Road element(s)	V2I Application
Lane markers	Lane markers mark the boundary of a road/highway. Lane markers represent a safety feature, since they prevent vehicle drift. Still, lane markers are passive devices. Improved with wireless transmitters, they could be used to communicate with a vehicle operator, resulting in an audio or visual warning when lane drift occurs.
Lane direction	Lane direction signs are generally placed at locations where any driver can see them. These signs have significantly reduced head-on collisions. Still, they are more difficult to identify by night or during bad weather (rain, snow). Lane direction signs represent another strategic location for broadcasting warning messages.
Road junction	A road junction is statistically a propitious spot for accidents. It is quite easy to imagine that in the (near) future vehicle-integrated electronics could automatically slow vehicle’s speed as it comes near the road junction.
Traffic light	Commonly, traffic lights are passive devices that simply switch from one colour to another. Nowadays, more and more traffic lights in urban areas integrate various electronic equipments in order to survey road traffic. We may cite video cameras placed at strategic locations to take photographs of drivers and license plates of vehicles that drive through red lights. We can easily imagine that in the (near) future the state of the traffic light could be broadcasted to approaching vehicles. Vehicle-integrated electronics could therefore automatically adjust vehicle’s speed (either slow down if the light changes from yellow to red or slightly accelerate if the light is green).
Road exit	Road exit is a strategic location for broadcasting information about the traffic exit, notably eventual obstructions. This way, the driver can be warned about proximity dangers. Another idea is to broadcast information about nearby facilities (such as gas stations or restaurants), so the driver can easily get his or her bearings.
Temporary obstacles	Temporary obstacles represent another strategic location where information broadcast could supplement conventional traffic signs. Indeed, a driver may encounter several obstacles on a road (lanes being resurfaced, potholes being filled, etc.). Having additional broadcasted information about the nature of the obstacle will definitely help the driver anticipate and prevent eventual accidents.

Table 2. Road strategic locations for vehicle information broadcasting.

3.1.2 Transmission Methods

In the following sections, we will present exiting standards and approaches that enable vehicle-to-infrastructure communication.

DSRC (Dedicated Short Range Communications)

DSRC is a communication protocol that is relatively short range (up to 1000m), line-of-sight, and based on a command-response control of communications between road infrastructure and vehicles. DSRC has also been identified with dedicated ITS spectrum allocations in various parts of the world.

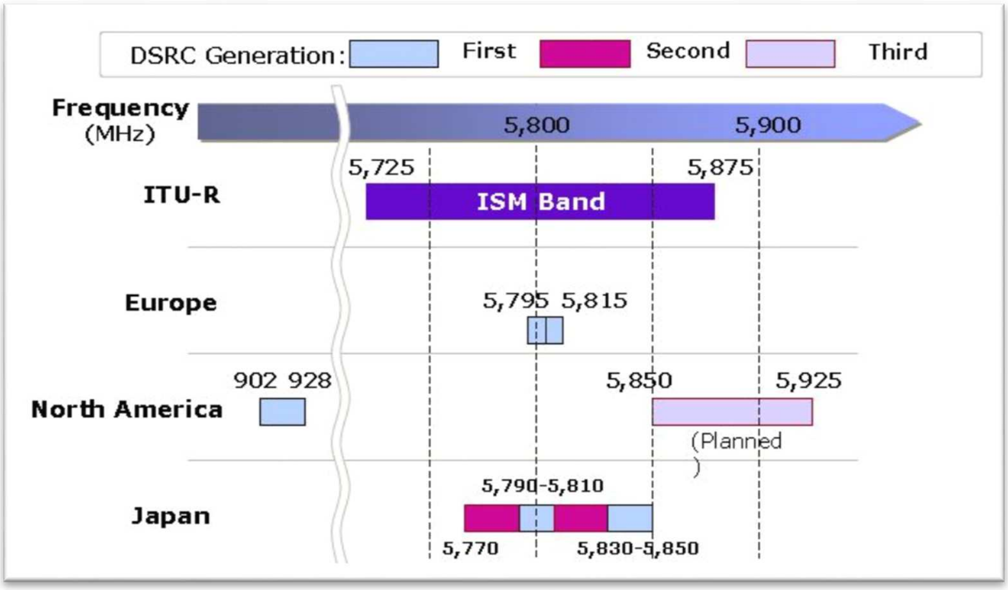

Figure 1. DSRC Spectrum Allocations [8].

North American DSRC implementation

The U.S. Federal Communications Commission (FCC) licensed, in 2003, 75 MHz of radio spectrum for DSRC in the 5.850–5.925 GHz band. This spectrum is provided specifically for ITS safety applications to avoid any interference from other users. This spectrum will be used to send short individual safety messages. Still a broadband allocation is required in order to handle the communications loading of many vehicles sending such short messages frequently.

The Vehicle Safety Consortium (VSC) performed an extensive evaluation of this DSRC band for "intelligent vehicle" systems applications. The project was conducted from 2002 to 2004, and several carmakers (BMW, DaimlerChrysler, Ford, GM, Nissan, Toyota, and Volkswagen) took part in the project. The VSCC-defined objectives were [1]:

- Identify key applications among communication-based vehicle safety applications;
- Estimate the benefits of these applications;
- Define the communications requirements for these applications;
- Identify and investigate specific technical issues that may affect the ability of DSRC to support these applications;
- Estimate the deployment feasibility of communications-based vehicle safety applications;
- Assess the ability of proposed DSRC communications protocol standards to meet the needs of safety applications.

At the end of this project (December 2004), VSCC did [1]:

- Confirmed DSRC communication as functional for vehicle safety applications at real intersections;
- Demonstrated vehicle-to-vehicle message exchange;
- Stated that 5,9 GHz DSRC communication protocol supports major vehicle safety applications' requirements

The VSC team identified over 80 applications that could be enabled by DSRC. Table 3 presents some of these DSRC-based applications for vehicle-to-infrastructure communication. The higher the applications are ranked in Table 3, the higher their safety benefit is [1]. The following communication parameters must be used for the implementation of the above-mentioned applications:

- One-way communication;
- Point-to-multipoint communication;
- Periodic transmission;
- 10 Hz minimum update rate;
- 100ms allowable latency;
- 250-300m communication range.

Application	**Function**	**Data communicated**
Curve speed warning	Aids the driver in negotiating curves at appropriate speeds, by using information communicated from roadside beacons located ahead of approaching curves.	• Curve location • Curve speed limits • Curvature • Super-elevation • Road surface condition
Stop sign movement assistance	Provides a warning to a vehicle entering an intersection after having stopped at a stop sign, to avoid a collision with traffic approaching the intersection.	• Vehicle position • Velocity • Heading • Warning
Traffic signal violation warning	Warns the driver to stop if a traffic signal is in the stop phase and the system predicts that the driver will be in violation, based on vehicle speed and braking status.	• Traffic signal status and timing • Traffic signal stopping location • Traffic signal directionality • Road surface condition • Weather condition
Intersection collision warning	Warns drivers when a collision at an intersection is probable.	• Traffic signal status • Timing • Directionality • Road shape • Intersection layout; • Vehicle position • Velocity • Heading
Stop sign violation warning	Warns the driver if the distance to the stop sign and the speed of the vehicle indicate that a high level of braking is required to properly stop.	• Stopping location • Directionality • Road surface condition • Weather conditions

Table 3. DSRC-enabled vehicle safety applications (communications between vehicle and infrastructure) [5].

At the end of this project, VSC recommended prototyping V2V and V2I DSRC-based safety applications, in order to determine their feasibility. Currently, the following application prototypes have been defined:

- Cooperative Intersection Collision Avoidance System (CICAS) [2]
- Emergency Electronics Brake Lights [1]

Currently, another project has been launched by the VSC, namely the VSC-A project [3]. This is a 3 year project, started in December 2006 and meant to end in November 2009. The main idea behind this project is to resolve current communication and vehicle positioning issues, in order to enable an interoperable deployment of DSRC and positioning-based safety systems. At the end of this project, the participants must determine if 5,9GHz-DSRC and vehicle positioning can:

- Improve autonomous vehicle safety systems
- Enable new communication-based safety applications

A second project, namely Cooperative Intersection Collision Avoidance Systems – Violations Project (CICAS-V) has been launched in May 2006, and is meant to last 4 years, until May 2010. The project's goal is the development of Cooperative Intersection Collision Avoidance Systems, that [4]:

- Prevent crashes between vehicles, due to traffic violations;
- Prevent crashes between vehicles, due to stop signs violations.

For more information concerning DSRC applications, one may refer to [5], which is the complete final report for the VSC initial project.

Japan DSRC implementation

In Japan, DSRC technology is already well implemented. Toyota announced this spring (February 2008) a new road-to-vehicle communication technology that uses both 5,8GHz-DSRC and UHF waves (774,5 MHz). The system allowed reaching transfer rates of 6 Mbps, with a communication range of about 100-200m [6].

This summer (July 2008), the Japanese company, Oki Electric Industry announced implementing DSRC in a gate management system for Electronic Toll Collection. DSRC is used by the system to communicate with vehicle on-board units. In this way, each vehicle is recognized based on the own unique ID of the on-board unit [7].

In Japan, several DSRC applications are planned for the years to come, notably regarding the following structures [9]:

- Parking management – the applications are planned for 400 public parkings and 6500 private parkings
    - Parking permission
    - Payment settlements system
    - Customers management (in/out control)
    - Car Ferry – automatic check-in and settlement
- Gas stations – the applications are planned for 58000 gas stations
    - Gas pumping stand
    - Information support system
    - Settlements system
- Convenience store – the applications are planned for 30000 stores
    - Information station
    - Settlements systems

Current Japanese applications of the DSRC protocol concern the following areas [9]:

- Information providing for high-speed driving conditions

  - Road & traffic information providing services
- Information providing for stationary conditions
  - Electronic advertisements
  - Paid contents delivery
- Zone tolling
- Driver support
- Logistics management
  - Trucks and trailers logistics management system
  - Taxies management system

WAVE (Wireless Access Vehicular Environment)

WAVE can be considered to be a superset of DSRC as it supports the traditional characteristics of DSRC but has some remarkable advantages. WAVE supports a longer operational range (over 1 km depending on environmental conditions), higher data transfer rates, and allows peer-to-peer communications [10].

WAVE is an adaptation of the IEEE 802.11a protocol and has received a tentative designation of 802.11p within this wireless interface standards family. The official IEEE 802.11 Work Plan predictions indicate that the approved amendment of the 802.11p standard will be published in April 2009 [11]. Within the IEEE 802 context, "Wireless Access in Vehicular Environments" (WAVE) refers to what was previously called Dedicated Short Range Communications (DSRC) [12].

The first international conference on WAVE is scheduled for this winter (December 8-9, 2008), in the USA. A first demonstration of the WAVE prototype has been demonstrated this summer (August 2008), and it proved that WAVE outperforms WiFi in a vehicular environment. The WAVE prototype demonstration video can be downloaded here [13]. The following figure illustrates the WAVE prototype:

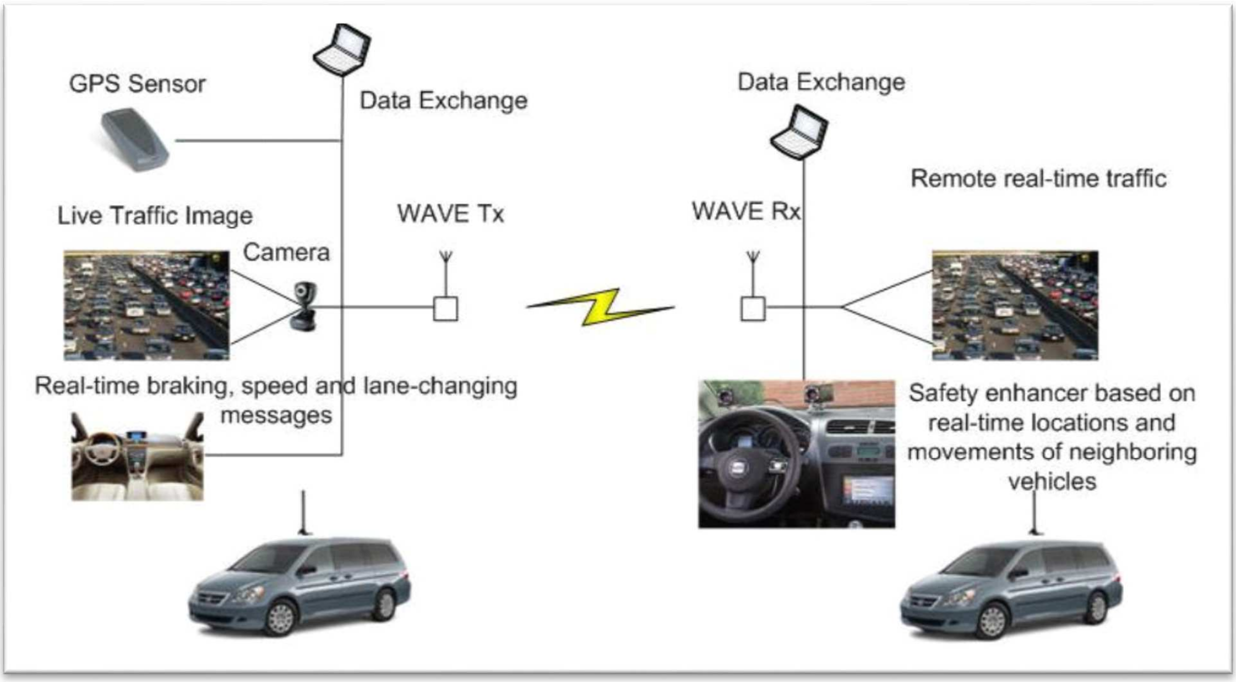

Figure 2. WAVE prototype [14]

For a complete overview of the family of standards for WAVE, that currently comprises 4 standards, one may refer to [15]. [16] gives a good overview of the progress of the standardisation activity for

IEEE 802.11p.

CALM (Continuous Air interface Long and Medium range communications)

CALM is a framework that defines a common architecture, network protocols and air interface definitions for all types of current and (expected) future wireless communications [17]. These air interfaces are designed to provide parameters and protocols for broadcast, point-point, vehicle-vehicle, and vehicle-point communications.

CALM is being developed by Working Group 16 of the Technical Comittee 204 of the International Standards Organization (ISO). The standardisation work is closely coordinated with other organizations, such as ETSI, ITU or IEEE [19]. The WG16 is currently divided into 8 sub-working groups, all working on nearly 20 different CALM-related standards [20]:

- 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

These standards are designed to enable quasi-continuous communications between vehicles and service providers, or between vehicles. In particular, for medium and long-range high-speed V2I transactions, the functional characteristics of such systems require contact over a significantly longer distance than is feasible or desirable for DSRC, and often for significantly longer connection periods [20]. The following communication modes will be supported by CALM:

- Infrared
- GSM (until 3G cellular technology)
- DSRC
- IEEE 802.11 evolutions such as WAVE
- IEEE 802.16e (Mobile WiMax)
- Millimetre-wave (62 GHz)
- Satellite
- Bluetooth
- RFID

Some applications will have the need that communication sessions set up in an initial communications zone may be continued in following communication zones. CALM establishes the network protocols to support the handover of a session conducted between a landside station and a mobile station to another landside station using the same media or a different media, in whatever way is optimum for the application.

CALM also supports safety critical applications, such as those examined within VSC. In such cases, a handoff between media is unlikely as the messages will be short and quick. However, the CALM architecture allows for messages to be sent simultaneously on several media to improve quality of service (via redundancy).

The following figure provides the CALM architectural scheme at the highest level of abstraction:

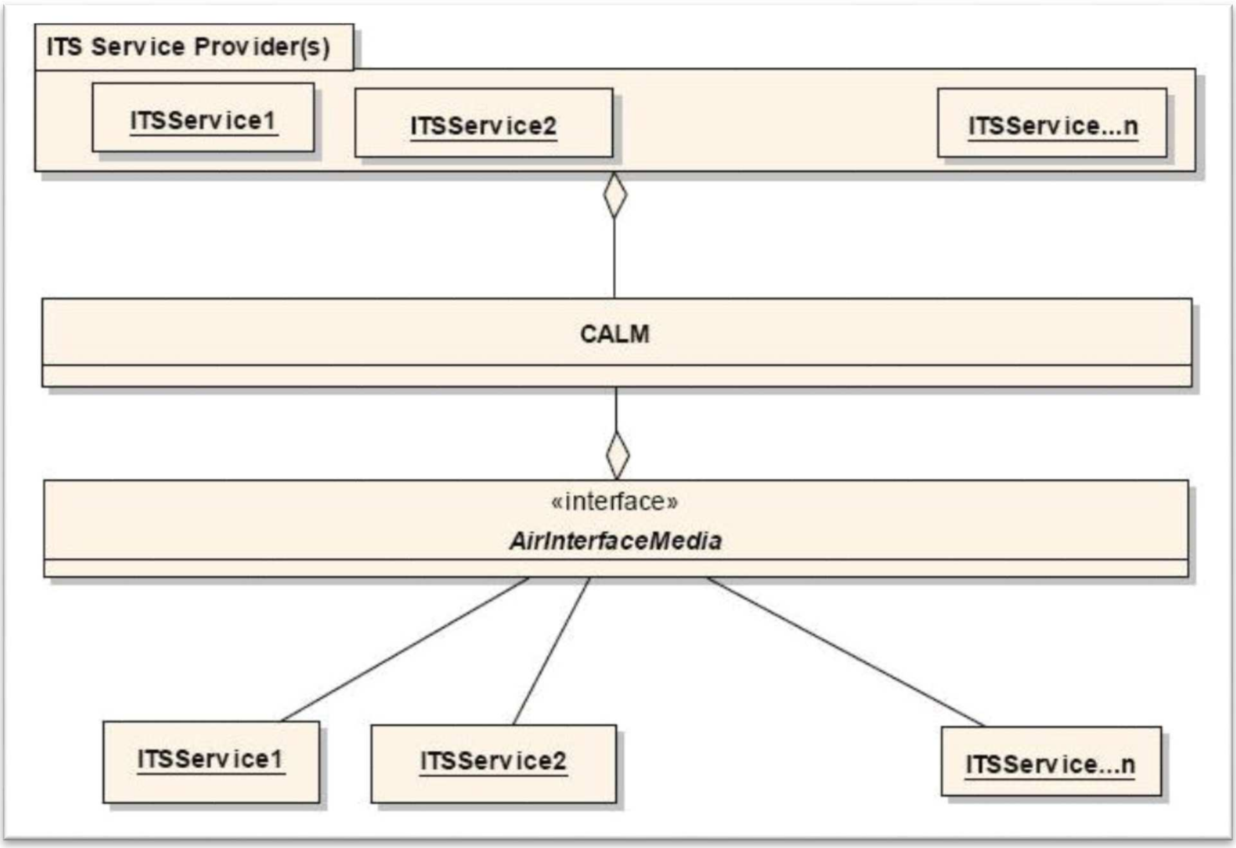

Figure 3. CALM architectural scheme [21].

The vehicle-to-infrastructure communication based on the ISO CALM standard will first be demonstrated on 10-11 December 2008 in Berlin, Germany [17].

3.2 Vehicle-to-Vehicle (V2V) communications

In this section we will focus our attention upon understanding what technologies enable vehicle-to-vehicle (V2V) communications and how this kind of communication functions.

3.2.1 Overview

In order to allow V2V communication, vehicles must form some kind of network. As vehicles are on the road and are moving, no available infrastructure can support a network deployment. The answer to this problem is ad-hoc networking.

An ad-hoc network is a network with either no infrastructure or a minimal infrastructure. An ad-hoc network is composed of nodes that come together to form a network. An ad-hoc network is self-organizing. Each node can function as a network router, data source, or data destination. Thus, when several (two or more) nodes come together into an ad-hoc network, they become capable of communicating with one another and therefore relaying information.

Based upon the preceding, a Vehicle Ad-hoc Network (VANET) is an ad-hoc network that has vehicles as network nodes. The nodes move relatively to one another, but within the constraints of the road. Figure 4 illustrates an example of such a network

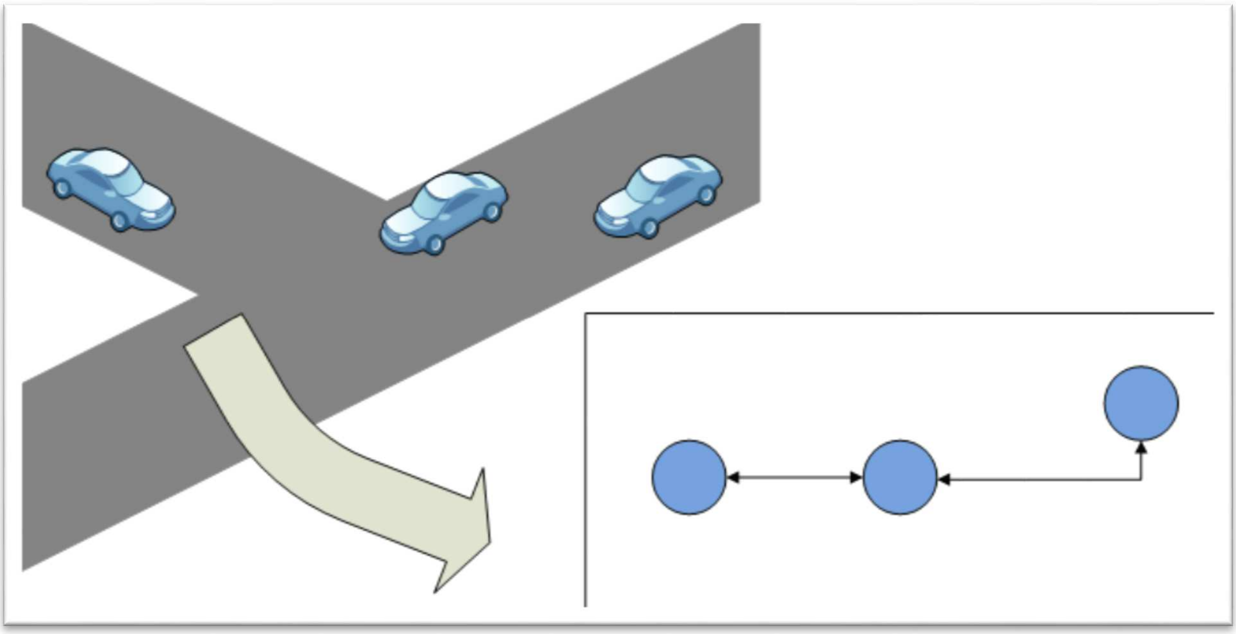

Figure 4. Illustration of a Vehicle Ad-Hoc Network (VANET).

3.2.2 Applications

The following table lists several V2V communication specific application areas.

V2V Application	**Description**
Vehicle traffic monitoring	By relaying information about traffic flow through certain intersections, vehicle operators can be notified of potential congested areas. If such information is used as an input into a vehicle navigation system, the system would be able to compute alternate routes. A second area concerning vehicle monitoring could include the transmission of certain types of vehicle information from vehicles on one side of a highway to vehicles on the other side of the highway (when approaching an accident, when approaching particular weather conditions, etc.).
Collision and congestion avoidance	Information about potential congested areas can be relayed from a vehicle to another, in order to warn the drivers of eventual accidents or traffic jams. Thus, members of that network could be notified that they are proceeding toward a location where an accident occurred or are in the path of approaching emergency vehicles. Again, if such information is used as an input into a vehicle navigation system, the system would be able to compute alternate routes.
Law enforcement	Information about missing persons or stolen vehicles could be broadcasted directly to every vehicle, located in a given area. In the future, it could be possible to integrate a stolen vehicle notification system that would enable law enforcement personnel to rapidly learn information about the stolen vehicle (its position, its heading, its speed, etc.).

Broadband transmission	If vehicles had broadband transmission capability, several applications would be enabled for vehicle’s passengers (for example real-time game playing or music download). This will increase the infotainment capacity of the vehicle. As a more critical application, one may think of using vehicle’s broadband capacity to obtain a connection to a nearby hospital in the event of a medical emergency, allowing a person’s vital information to be sent to the ER prior to the arrival of the patient.
Highway lane reservation	One of the more common driving situations many individuals remember is the rapid approach of an emergency vehicle or the sudden stop of a school bus. Both situations result in the modification of a vehicle operator’s routine, causing the operator to attempt to either move his vehicle into the slow lane or bring his vehicle to a complete stop. With V2V communication, designated vehicles (such as police cars, ambulances, and school buses) could send messages to either reserve highway lanes for their use or inform vehicle operators of their presence and the need of the driver to take some specific action, such as moving into the slow lane.
Emission control	When the density of vehicles in an area increases, the density of pollutants from the vehicles also increases. This represents a health hazard to drivers and passengers as well as to pedestrians in the area. Using power management techniques (such as those incorporated into notebook computers), vehicle congestion could be treated in a similar manner. A vehicle’s engine behaviour (adjustment of a vehicle’s idling speed, switching hybrid vehicles from gas to electricity) could be modified by the exchange of real-time information.

Table 4. V2V Applications.

3.2.3 Vehicle frequency utilisation

Integrating V2V communication equipments into a vehicle needs to be examined with respect to the frequency use of other applications that are already incorporated into vehicles. Thus, in this section we will discuss the operational frequency of wireless applications integrated into vehicles.

Table 5 lists wireless technology standards and applications that can be expected to be supported by future vehicles. Although it is not certain that each vehicle will support every entry in Table 5, due to the use of different frequencies by various applications and standards, it is imperative that evolving applications use standardized frequencies to minimize or avoid frequency interference issues.

Wireless technology	**Frequency spectrum**	**Description**
AM Radio	530 to 1710 kHz	Analogous modulation (AM) radio occurs in the medium waveband.
Bluetooth	2.4-GHz	As mentioned earlier in this book, Bluetooth represents a short-range, low-power wireless transmission technology. Although Bluetooth operates in the same frequency band as microwave ovens, most wireless LANs, and portable phones, its use of frequency hopping commonly minimizes interference between Bluetooth devices and other wireless devices operating in the same frequency band.

FM Radio	88- to 198-MHz	Frequency modulated (FM) radio occurs in the very high frequency (VHF) band.
GPS	1227.6 MHz 1575.42 MHz	GPS represents a low-power navigation signal that is commonly used in DVD-based navigation systems to show the location of a vehicle with respect to the display of a portion of a map of the area the vehicle is traversing. Due to the low power of GPS, it is a line-of-sight communications method that does not work if a vehicle is located in a garage or traversing a tunnel.
Satellite Radio	XM Radio (2332.50 to 2345.00 MHz) Sirius Satellite Radio (2320.00 to 2332.50 MHz)	One recent addition to the use of the frequency spectrum is satellite radio. Technically referred to as Digital Audio Radio Service (DARS), satellite radio is familiar to many new vehicle purchasers, who receive a free six-month or year subscription with their new vehicle. here are two major satellite radio operators, Sirius Satellite Radio and XM Satellite Radio, with both operators using the 2.3- GHz S-band. XM Radio uses two geostationary satellites and Sirius Satellite Radio uses three satellites.
Radar Detectors	K-band (24.05- to 24.25- GHz) Ka-band (34.2 to 36 GHz) X-band (10.5- to 10.55- GHz)	
Safety Radar	24 GHz	Allocated by the EU Commission for Driver Assistant Systems (DAS). Thus, the use of the 24-GHz frequency band could result in interference with radio applications that are already being used.
	35 GHz	FM continuous wave used for detecting intruders and moving vehicles, traffic monitoring and control.
	76.5 GHz	FM continuous wave prototype radar used for automobile collision warning, traffic monitoring and detection.

Table 5. Operational frequency of wireless applications integrated into vehicles.

3.2.4 Transmission Methods

The following sections present an overview of existing activities and approaches in the area of V2V communication.

DSRC (Dedicated Short Range Communications)

As presented earlier, the DSRC protocol allows very low latencies and also broadcasting. This creates a significant advantage of this protocol over other transmission methods like point-to-point wireless communications. The VSC team has defined several applications that could be enabled by the DSRC protocol. Communication parameters were defined for each application, notably [5]:

- Types of communication
- Transmission mode
- Update rate

- Allowable latency
- Data to be transmitted and/or received
- Required range of communication.

The following table presents some of the selected DSRC-based applications for vehicle-to-vehicle communications.

V2V Application	Function	Data communicated	Range (m)
Cooperative forward collision warning	Aids the driver in mitigating or avoiding a forward collision; data received from the forward vehicle is used along with host vehicle information as to its own position, dynamics, and roadway information to estimate collision risk.	• Vehicle position • Velocity • Heading • Yaw rate • Acceleration	150m
Emergency electronic brake light	When a forward vehicle brakes strongly, a message is sent to other vehicles following behind to provide advance notification even if the radar sensors or the driver’s visibility is limited by weather or other vehicles	• Vehicle position • Heading • Velocity • Deceleration	300m
Road condition warning	Marginal road conditions are detected using onboard systems and sensors and a road condition warning is transmitted to other vehicles via broadcast. This information enables the host vehicle to generate speed recommendations for the driver	• Vehicle position • Heading • Road condition • Parameters	400m
Lane change warning	Warns the driver if an intended lane change may cause a crash with a nearby vehicle by processing information sent from surrounding vehicles and estimating crash risk when the driver signals a lane change intention	• Vehicle position • Heading • Velocity • Acceleration • Turn signal • Status	150m

Table 6. VSC selected V2V applications [5].

Ad-hoc networking

In contrast to the DSRC command-response approach between communication partners, several European research projects have explored the potential of ad-hoc communication networking techniques for vehicle communications.

The CarTALK and Fleetnet projects in Europe have explored in depth the potential of ad-hoc communication networking techniques for vehicle communications.

FleetNet-Internet on the road

Within the FleetNet project an ad-hoc radio network supporting V2V communications has been developed. The air interface uses UMTS Terrestrial Radio Access Time Division Duplex (UTRA TDD) standard [30].

The driver-assistance safety applications are based on short messages being passed from car to car in efficient ways so that drivers can get information on obstacles or traffic jams ahead, beyond the view of the driver's vision or the range of vehicle sensors.

FleetNet researchers had the following objectives [22]:

- Development of communication protocols for the organization of the ad-hoc radio network;
- Development of routing algorithms for multihop data exchange, for forwarding between vehicles and between vehicles and stationary gateways;
- Access mechanisms for the radio channel that ensure good quality of service in terms of delay and error rates.

Satellite positioning systems played a key role in the FleetNet approach. FleetNet uses this information to better organize the ad-hoc radio network. Radio routing protocols use of the knowledge of the position of other cars within communications range, and a geo-addressing technique is used to connect with cars based on their positions. Position-based communications addressing is important, as the requirement is to communicate only with the car in front or behind in longitudinal emergency braking scenarios, for instance [29]. The following figure illustrates the unicast position-based routing logic used for the FleetNet project.

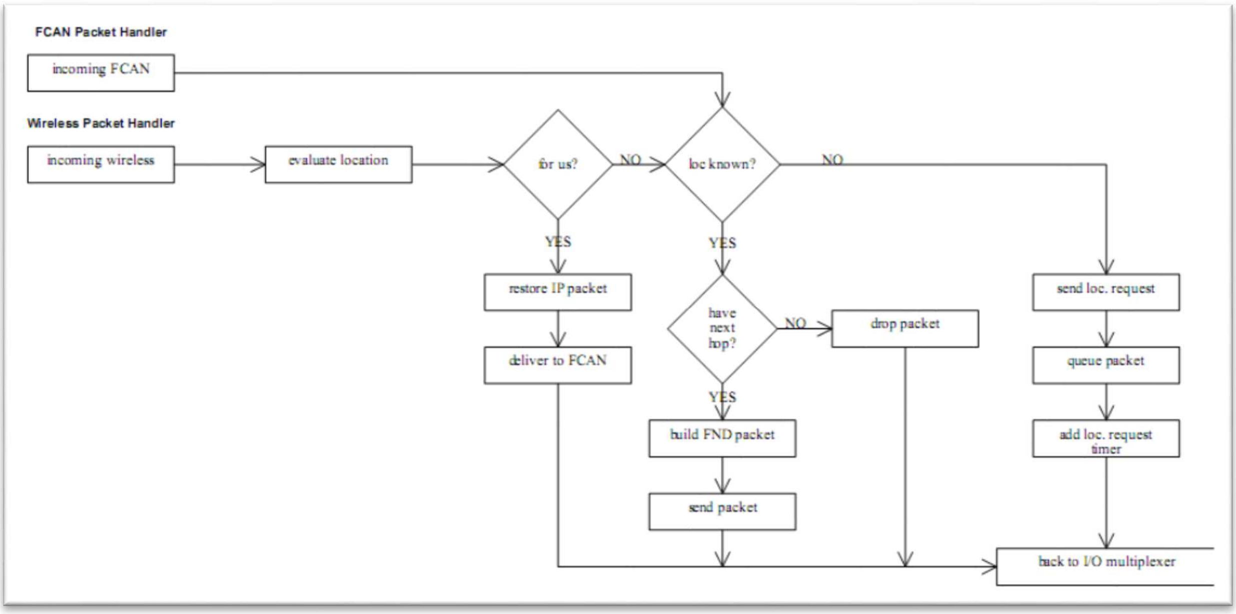

Figure 5. Unicast position-based routing logic [29].

FleetNet prototypes implementing these services were successfully demonstrated at the DaimlerChrysler research centre (Ulm, Germany) in November 2003. For more information about the FleetNet projet, one may refer to the project's official webpage: http://www.et2.tu-harburg.de/fleetnet/index.html.

CarTALK

The CarTALK included many of the FleetNet organizations and was also focused on applying VANET technologies for V2V communications. The main idea for this project was to test and evaluate a cooperative driver assistance system based upon V2V communications [23].

CarTALK explored both direct and multihop V2V communications. Direct communications allow extending the information horizon through upstream communications with following vehicles. The coverage range depends upon the network topology and the vehicle density. This is overcome with a multihop approach: traffic from the opposite lane "grabs" the signal and travels onward for some distance before transferring it back over to the lane of interest. CarTALK techniques use position awareness and spatial awareness to perform these data transfers efficiently.

CarTALK demonstrated selected applications in six test vehicles.

For more information regarding CarTALK, one may refer to [24].

Radar-based communications

ACC radars generate radio signals for forward sensing. By adding a communications channel, one could get dual use out of the same hardware. This added-value concept is driving ongoing work by researchers. Such an approach allows for simultaneous sensing and information relay. The available data rate is relatively high due to the bandwidth used by the radar systems. By the nature of radar sensing, real time operation is guaranteed and sharp directivity is assured. In fact, individual vehicles can be selected for communications based on the radar beam steering.

Just a few days away (October, 8th, 2008), ford unveiled its radar-based collision warning with brake support system. If the system detects an obstacle in-front of the vehicle, it first activates an alarm sound and an alarm light. It then "pre-charges" the brakes and activates a break-assist function. Ford announced that this technology will be integrated on several Ford and Lincoln models in 2009. For more information about this system, one may refer to [25].

Last year (March 2007), it's the Automotive systems Division of continental AG that announced the implementation of radar sensors for better proximity control. Radar sensors will allow obtaining a more precise analysis of the vehicle's close surrounding, for a better Adaptive Cruise Control (AAC). The system will be introduced in 2009 and will be able to determine the exact position of the roadside. The system will also be able to categorize any objects it perceives [26].

Communication using millimetre-wave frequencies

Millimetre-wave (MMW) communications in the 60 GHz range offer several advantages for broadband data downloads to vehicles:

- Large (license-free) bandwidth that allows achieving high data rates;
- Short wavelength that leads to small antenna dimensions;
- No interference with existing radio systems.

In Germany, Fraunhofer-Institüt for Nachrichtentechnik HHI develops solutions based on broadband millimetre-wave transmission in the 60-GHz [27].

Researchers at Denso in Japan have developed new millimetre-wave radar for AAC systems (September, 19th, 2008). The new radar is half the volume and the price of the previous model. The radar measures the distance to the vehicle in front. Therefore it allows maintain safe following distances, even if the vehicle isn't moving at a constant speed [28].

4 Conclusion

As a conclusion, we will turn towards the future "intelligent vehicle". We present here the communications electronics that will eventually be contained in the future "intelligent vehicle". Table 7 lists these components.

Component	Description

Microprocessor	The microprocessor receives input from the various communications devices. Such input is used to display warnings and other information on a display, via an audio alarm, and perhaps eventually via a voice synthesis system. Another function of the microprocessor will be to operate any routing protocol selected for the formation of a VANET. Thus, vehicle manufacturers could elect to use one high-performance processor or subdivide work by using two or more microprocessors.
Wireless networking transmitter /receiver	The wireless network transmitter/receiver enables the vehicle to receive roadway broadcasts as well as relay such broadcasts if the vehicle is within range of other VANET-compatible vehicles.
Forward-looking radar	Forward radar will be used to detect any forward obstacles at distances up to 120-150m, depending upon the terrain. The radar may operate in the unlicensed wideband (UWB) frequency range in the 60-GHz spectrum and will be integrated into a vehicle’s braking system.
Side radar	The purpose of side radar is to detect the presence of vehicles in a vehicle’s blind spots. Because the primary purpose of side radar is to look for obstacles in the blind spots of a vehicle, it will operate on low power and have a transmission range of less than 3m. As an alternative to the use of side radar, it is possible that future vehicles will be equipped with miniature cameras or use ultrasonic sensors. At the present time, vehicle manufacturers are testing all three technologies.
GPS	GPS will be used to provide a vehicle’s location. Through the microprocessor GPS will be integrated to the navigation system as well as crash sensors, enabling the deployment of an air bag to be transmitted to a monitoring station.
Cellular transmitter /receiver	The cellular transmitter can be viewed along with the GPS subsystem as part of a vehicle’s telemetric system. Here the deployment of an air bag would automatically result in a cellular call to a monitoring location, to include the GPS position of the vehicle. In addition, by pressing a button on the console, the vehicle operator can use a concierge service to request the location of a vehicle repair shop or ask another query without having to enter information into a navigation system while driving.
Event data recorder	The event data recorder is used in vehicles to store all important parameters, such as acceleration, position, velocity, and status of subsystems, to include tire pressure. By examining the contents of the event data recorder, it may be possible to determine the cause of vehicle problems ranging from a collision to the failure of an engine to start.

Table 7. Communications-related components of an “intelligent” vehicle.

As indicated in this section, the use of applicable transmitters along roadways, along with the emerging communications capability of the smart vehicle, can be expected to provide a significant enhancement to both road safety and driver and passenger requests for information. Although we are a few years away from the true “intelligent vehicle”, and at the present time do not know the exact components of the vehicle of the future, we can be assured that its benefits will result in its eventual deployment.

5 References

[1] www.car-to-car.org/fileadmin/dokumente/pdf/security_2006/sec_06_04_laberteaux_CAMP.pdf

[2] http://www.its.dot.gov/cicas/

[3] http://www.dsg.cs.tcd.ie/PerTrans2007/Communication%20Topics%20in%20Information-Rich%20Vehiclar%20Safety%20Systems.pdf

[4] http://www.ieeevtc.org/plenaries/vtc2007fall/15.pdf

[5] http://www-nrd.nhtsa.dot.gov/pdf/nrd-12/060419-0843/Index.htm

[6] http://techon.nikkeibp.co.jp/english/NEWS_EN/20080227/148143/

[7] http://findarticles.com/p/articles/mi_m0EIN/is_/ai_n27912642

[8] http://www.itu.int/ITU-R/study-groups/seminars/rwp8a-new-tech/docs/presentations/S4-2.pdf

[9] http://www.itu.int/ITU-R/study-groups/seminars/rsg8-tech-innov/docs/1.3-advances-in-its-telematics.ppt

[10] http://en.wikipedia.org/wiki/IEEE_802.11p

[11] http://grouper.ieee.org/groups/802/11/Reports/802.11_Timelines.htm

[12] http://standards.ieee.org/board/nes/projects/802-11p.pdf

[13] http://www.vehi-com.com/files/download/WAVE_Demo_2008.wmv

[14] http://www.vehi-com.com/

[15] http://www.standards.its.dot.gov/fact_sheet.asp?f=80

[16] http://grouper.ieee.org/groups/802/11/Reports/tgp_update.htm

[17] http://en.wikipedia.org/wiki/Communications,_Air-interface,_Long_and_Medium_range

[18] http://www.cvisproject.org/en/news/product_launch_event_2008.htm

[19] http://www.itu.int/ITU-T/spd/docs/002-tw-CALM.pdf

[20] http://www.calm.hu/

[21] http://www.isotc204wg16.org/images/CALM_Concept_Figure4.jpg

[22] http://www.et2.tu-harburg.de/fleetnet/english/objectives1.html

[23] http://www.nelisse.org/cv/publicat/pdf/2003its_cartalk_pa.pdf

[24] http://www.cvisproject.org/en/links/cartalk_2000.htm

[25] http://www.autoblog.com/2008/10/08/ford-unveils-radar-based-collision-warning-with-brake-support-sy/

[26] http://www.prnwire.com/cgi-bin/stories.pl?ACCT=104&STORY=/www/story/03-06-2007/0004540439&EDATE=

[27] http://www.hhi.fraunhofer.de/en/departments/broadband-mobile-communication-networks.html

[28] http://www.traffictechnologytoday.com/news.php?NewsID=7897

[29] http://www.et2.tu-harburg.de/fleetnet/pdf/PWC03-FleetNetRouting.pdf

[30] http://www.et2.tu-harburg.de/fleetnet/pdf/VTC03_Ebner.pdf