Chapter 12

Vehicle-to-Vehicle Communications: Applications and Perspectives

12.1. Introduction

The objective of ambient intelligence is to create an intelligent daily space, which is immediately usable and integrated into our homes, our offices, our roads, our cars, and everywhere. This new concept must be invisible; it must blend in with our normal environment and must be present when we need it.

One of the applications of this concept consists of providing our cars and roads with capabilities to make the road more secure (information about the traffic, accidents, dangers, possible detours, weather, etc.) and to make our time on the road more enjoyable (Internet access, network games, helping two people follow each other on the road, chat, etc.). These applications are typical examples of what we call an Intelligent Transportation System (ITS) whose goal is to improve security, efficiency and enjoyment in road transport through the use of new technologies for information and communication (NTIC).

Traditional traffic management systems are based on centralized infrastructures where cameras and sensors implemented along the road collect information on density and traffic state and transmit this data to a central unit to process it and make appropriate decisions. This type of system is very costly in terms of deployment and is characterized by a long reaction time for processing and information transfer in a context where information transmission delay is vital and is extremely important in

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this type of system. In addition, these devices placed on roads require periodic and expensive maintenance. Consequently, for large scale deployment of this type of system, important investment is required in the communication and sensor infrastructure. However, with the rapid development of wireless communication technologies, location and sensors, a new decentralized (or semi-centralized) architecture based on vehicle-to-vehicle communications (V2V) has created a very real interest these last few years for car manufacturers, R&D community and telecom operators. This type of architecture relies on a distributed and autonomous system and is made up of the vehicles themselves without the support of a fixed infrastructure for data routing. In this case, we are talking about a vehicular ad hoc network (VANET), which is no more than a specific application of traditional mobile ad hoc networks (MANET)[1]. An example of an urban VANET network is illustrated in Figure 12.1.

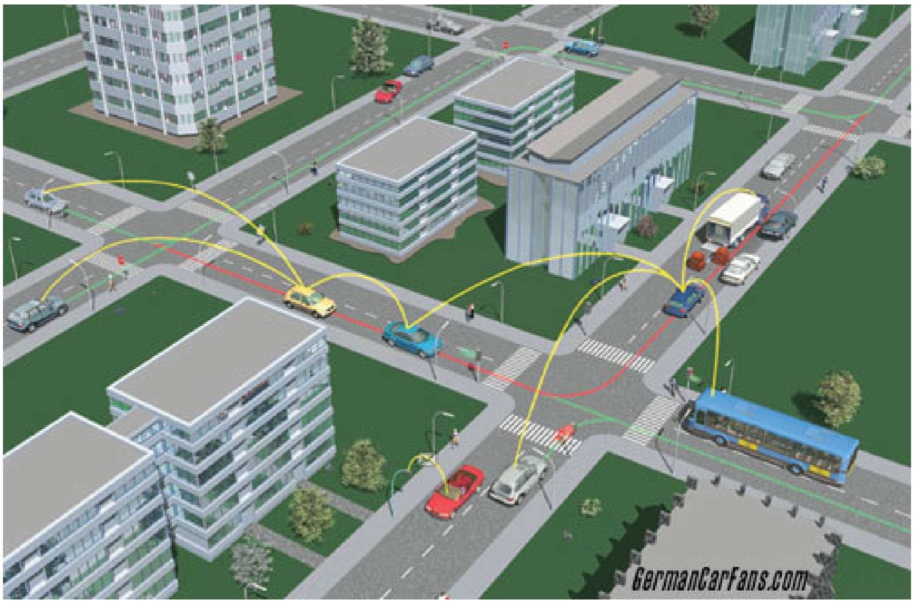

Figure 12.1. *Example of VANET network [KOS 05]*

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1 A mobile ad hoc network (MANET) is an autonomous system made up of mobile stations interconnected by wireless connections without the management of a centralized infrastructure. Following existing communications in the network,The mobile stations (or nodes) can assume also the role of router to relay data.

In this chapter, we focus on the study of the main component in ITS systems which is inter vehicle communication (IVC) and its related services. For road safety services, the information on potential dangers (weather conditions, state of the road, operational state of a vehicle, etc.) can be exchanged in real time between vehicles to inform the drivers. Examples of services are not limited to road safety applications but exist for other types of applications as well, specifically comfort applications (mobile Internet access, convoy of cars, games, etc.) offering interesting perspectives for telecom operators looking for new service niches. The rest of this chapter is organized as follows: in section 12.2 we present a detailed description of the different vehicular communication characteristics, features and applications. As well as a presentation on existing projects in this field, section 12.3 will discuss the state of the art and the related work proposed in the literature to face the dynamics and constraints related to vehicular networks. In particular, the following problems will be addressed: routing, data dissemination, mobility models, medium control and security. Section 12.4 will provide the conclusion.

12.2. Properties and applications

12.2.1. *Properties of VANETs*

As an integral part of an ITS system, IVC combines the following technologies and disciplines, as represented in Figure 12.2:

– Sensing and close environment perception: by using different sensors (weather conditions, state of the road, state of the vehicle, pollution and others) and cameras, the driver have a certain amount of information and a better visibility inside his vehicle, enabling him to react appropriately to changes in his immediate environment;

– processing: with a large processing capacity on board, vehicles nowadays are intelligent and are able to *interpret* the collected information with the purpose of helping the driver to make a decision (particularly in driver assistance systems);

– storage: a large storage space is required in this context in order to store different classes and types of information. These data structures are updated via events and decisions from the communication system. We should note that in a network of vehicles, energy and storage space are sufficiently available;

– routing and communication: for information exchange and diffusion in the vehicular network itself or with other networks (IP or cellular for example). This permits to increase the precaution perimeter with the help of an extended perception of the environment and thus give a more accurate prediction of driving problems.

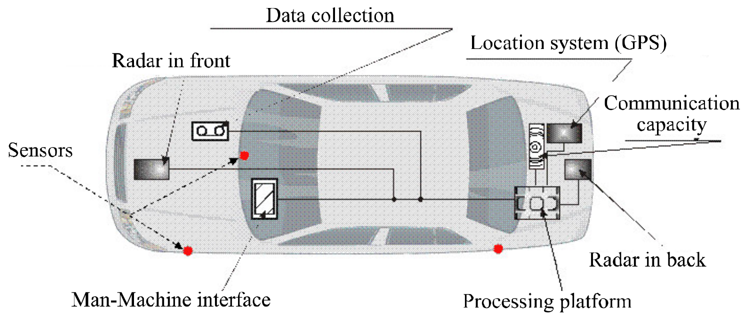


Figure 12.2. *Intelligent vehicle [HUB 05]*

These different technologies are present in all environments where IVC technology can be applied. Nevertheless, depending on the application sectors, the environment and its characteristics can differ: free, rural, semi-urban, urban space, tunnels; wireless communication properties, radio range and capacity can also be contrasted. In an an architecture view, inter-vehicle communication system can be either pure ad hoc vehicle-to-vehicle, or hybrid using gateways to other networks and services.

As previously mentioned, a VANET network represents a specific aspect of MANET networks. Nevertheless, research works studied and carried out in the field of MANETs cannot be applied directly in the context of vehicular networks because of the characteristics of VANET networks making the application of ad hoc network protocols and architectures inappropriate. In the following, we present a few properties and constraints related to the environment of vehicular networks which sets them apart from ad hoc networks:

– processing, energy and communication capacity: contrary to the context of mobile ad hoc networks where energy constraint for example represents one of the problems discussed in the literature, vehicles in a VANET have no limit in terms of energy, have large processing capability and can have several communication interfaces (Wi-Fi, Bluetooth [BLU 01] and others);

– environment and mobility model: environments considered in ad hoc networks are often limited to open spaces or indoors (as in the case of a conference or within a building). Vehicle movements are connected to road infrastructures, on highways or within a metropolitan zone. The constraints imposed by this type of environment, such as radio obstacles (for example, because of buildings) and multipath and fading effects, considerably affect the mobility model and radio transmission quality to consider in proposed protocols and solutions. Besides, mobility is directly connected to driver behavior;

– type of information transported and diffusion: since one of the key vehicle network applications is prevention and road safety, the types of communications will focus on message broadcast from a source (or a point) to several recipients. Nevertheless, the vehicles concerned by such diffusion depend on their geographical location and their degree of implication in the launched event. In such situations, communications are mainly unidirectional;

– network topology and connectivity: contrary to ad hoc networks, VANET networks are characterized by high mobility linked to car speed, which is very faster on highways. Consequently, an element can quickly join or leave the network in a very short period of time, which makes topology changes frequent. In addition, problems such as network clustering can appear frequently, mainly when the IVC system is not widely used and set up in the majority of vehicles. Solutions proposed must then consider this spatio-temporal constraint where connectivity is one of the key parameters. The heterogeneity of nodes in terms of speed (cars and buses: buses have a regular, slower speed) offers additional information to consider in the development of solutions and architectures for vehicle networks. One of the constraints and parameters to be closely studied is the VANET network fragmentation problem because of spatio-temporal conditions, specifically when the market penetration rate of these networks is low. This implies weak connectivity and very limited road life. In addition, properties inherent to VANET networks, especially in terms of size, raise scaling problems and require a complete revision of existing solutions;

– from the point of view of sensor networks, a node (vehicle) in the network can be considered a high capacity sensor, equipped with various functions, or a local network made up of existing terminals in the vehicle. In addition the information collected by sensors in a vehicle can be combined to eliminate redundancies and decrease the number of transmissions. The energy constraint and mobility factor clearly differentiate sensor networks from vehicle networks, designed for different sectors of application. Moreover, information collected by sensors in vehicles is used in the operation of protocols and can generally affect network behavior.

12.2.2. *VANET applications*

The main IVC network applications can be classified into three categories: 1) road safety applications, 2) driver assistance applications, and 3) comfort applications. In what follows, we explain these categories in more detail and then give examples of applications:

– road safety applications: road safety has become a priority in most developed countries. This priority is motivated by the increasing number of accidents on roads due to the increasing number of vehicles. In order to improve safety in travel and cope with road accidents, IVCs offer the possibility of preventing collisions and road work, of preventing obstacles (fixed or mobile) and of distributing weather information;

– applications to driver assistance systems and cooperative vehicles: to facilitate autonomous driving and bring support to the driver in specific situations: help in vehicle passing, prevention of straight or curved lane exits, etc. We can also mention the case of trucking companies using IVC for productivity to decrease gasoline consumption;

– comfort applications for the driver and passengers: user information and communication services in particular, such as mobile access to the Internet, electronic messaging, inter-vehicle chat, network games, etc.

In what follows, we limit ourselves to the description of a few services and examples of vehicle-to-vehicle communication system applications.

12.2.2.1. *Alert in case of accidents*

This service alerts vehicles driving towards the scene of an accident that traffic conditions have been modified and that it may be necessary to be more vigilant. It is also necessary in case of reduced vehicle density to be able to retain the message in order to retransmit it if another vehicle enters the retransmission zone. Safety messages will have to be transmitted at regular periods. Thus, the node(s) designated to retransmit messages will transmit alert messages at regular moments. Messages will have to be short to be transmitted quickly. Messages will also need to have accident scene coordinates and retransmission zone parameters.

12.2.2.2. *Alert in case of abnormally slow traffic (traffic jam, road work, bad weather, etc.)*

This service alerts car drivers of particular traffic situations. The driver is informed that it is necessary to slow down regardless of the nature of the traffic problem. The alert message is transmitted by a vehicle detecting traffic problems. An official vehicle doing road work can also trigger an alert message (see Figure 12.3). As with the alert message informing of an accident, the alert message informing of a slow down must be transmitted to other vehicles efficiently and quickly.

12.2.2.3. *Collaborative driving*

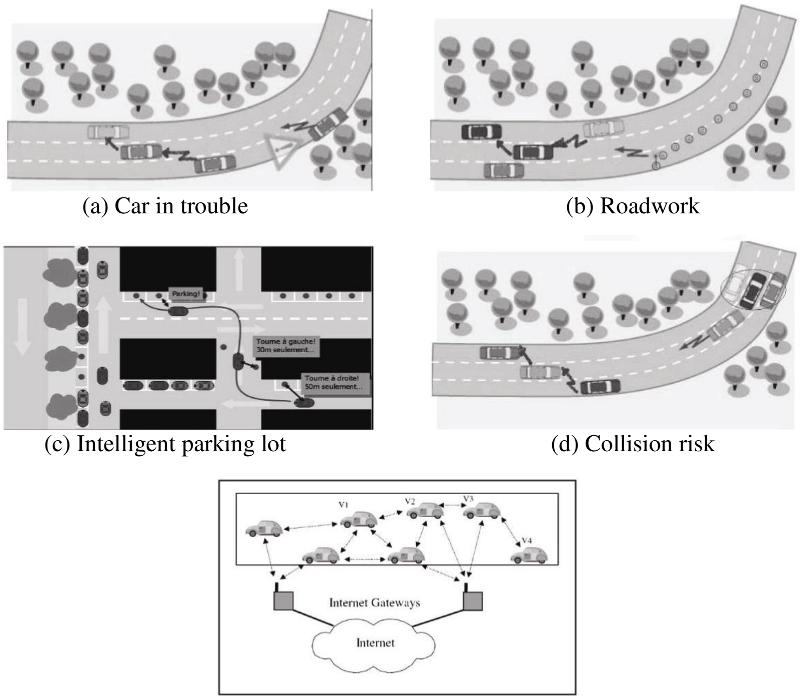
Collaborative driving is a concept that considerably improves road transport safety in addition to decreasing the number of victims in accidents involving automobile vehicles. This innovation is based on information exchanged between vehicles equipped with instruments (for example, sensors) enabling them to perceive what surrounds them and to collaborate in dynamically formed groups. These groups of vehicles, or localized networks, can develop a collective driving strategy which would require little or no intervention from drivers. In the last few years, different automated vehicle architectures have been proposed, but most of them have not, or almost not, tackled the inter-vehicle communication problem.

12.2.2.4. *Highway hot spot*

Today people can access websites from a public area (stations, airports), for example to download movies. In the car, we can imagine buying an Internet content from a station or even from the highway (going from one car to another to the closest access point to join the wired network). Car passengers will be able to play network games, download MP3 files, send cards to friends, etc.

12.2.2.5. *Parking management*

This service assembles information on space availability in parking lots and coordinates between cars in order to guide them to find free spaces (SmartPark project [SMA 05]).



(a) Car in trouble (b) Roadwork

(c) Intelligent parking lot (d) Collision risk

(e) Internet access

Figure 12.3. *VANET network application scenario examples*

12.3. State of the art and study of the existing

12.3.1. *Projects and consortiums*

The first IVC studies have emerged at the beginning of the 1980s in Japan (for example: Association of Electronic Technology for Automobile Traffic and Driving) with the increase of people or merchandise traveling, thus stimulating the exploration of new solutions such as automatic driving, intelligent road planning, etc. Several government institutions throughout the world have led an exploratory phase from different worldwide projects, involving a large number of research units. These projects have led to the definition of several possible prototypes and solutions, based on different approaches. In this way, traffic management systems were installed in large Japanese cities and on most urban and intercity highways.

The Japanese have made large investments in the development of driver information systems. In the case of a highway, the system electronically monitors the speed and volume of traffic and gives drivers instant warnings on accidents and delays. Warnings and other information for drivers are displayed on different variable message signs. In the Japanese AHS (Automated Highway System) project, the goal was to design an automated highway system for autonomous driving: control of the vehicle is assumed by a computer on board. In the USA, there is the Intelligent Transportation Society of America (ITS America), which is a group of manufacturers, government agencies, universities and other enterprises. This group focuses on research, promotion and development and deployment coordination of ITS applications throughout the USA. As in Japan, the American government also implemented the NAHSC (National Automated Highway System Consortium) in 1995. In Europe, the PROMETHEUS (PROgraM European Traffic with Highest Efficiency and Unprecedented Safety) project began in 1986 and included over 13 vehicle manufacturers and several universities from 19 European countries. In this context, several approaches and solutions concerning ITSs have been developed, implemented and demonstrated.

The results of this first step were a detailed analysis of the problem and the development of a feasibility study to achieve a better understanding of the conditions and possible effects of applying the technology. Later, and with the technological advancement of communication, calculation and location equipments, other projects were carried out and have paved the way for some IVC applications. Because of the importance of this field, new projects were initiated throughout the world.

In Europe, a certain number of large scale projects have recently emerged focusing on problems related to IVC systems. Most of these projects were introduced in the context of research programs from the European Community (5th

and 6th PCRD). However, a large majority of these projects focus on the exclusive use of existing infrastructure for implementing the IVC system, which can be extremely expensive. Drive [DRI 99] and GST [GST 05] projects are excellent examples of these projects. DRiVE (Dynamic Radio for IP Services in Vehicular Environments) is meant to work on the convergence of different cellular technologies and high throughput networks (GSM, UMTS, DAB and DVB-T) in order to implement the necessary foundation for the development of innovative IP services for vehicles. The GST (Global Systems for Telematics) [GST 05] project is also intended for applications related to road safety. However, this project focuses on the use of the GSM network. It focuses on problems in relation with securing the network and service infrastructure, operation security and billing.

In what follows, we will review a few consortiums and projects undertaken in the last few years on V2V communications:

– the FleetNet (Internet on the road) project is a German project introduced by a consortium of six manufacturers and three universities [FLE 00]. FleetNet's objective was to develop a communication platform for vehicle networks, to implement a demonstrator, and to standardize the proposed solutions in order to ensure better security and comfort for driver and passengers. The FleetNet architecture is based on a routing mechanism based on a system of location and navigation, and also considers vehicle to infrastructure communications in order to provide Internet access service;

– the Car2Car [CAR 05] communication consortium was launched by six European automobile manufacturers, and was open to providers, research organizations and other partners. The Car2Car consortium has established its objective of improving road safety and efficiently managing traffic using IVCs. Its main missions were as follows: 1) the creation of an open European standard for V2V communications based on wireless LAN components, 2) developing V2V system prototype demonstrators for road safety applications, 3) promoting the allocation of a free exclusive frequency band for Car2Car applications in Europe, and 4) developing deployment strategies and economic models for market penetration;

– the European IST project CarTalk2000 [CAR 01] (coordinated by the Daimler Chrysler manufacturers between 2001 and 2004) was intended to develop cooperative aid to driving systems and implement a pure, self-organized wireless ad hoc network. The UMTS radio access technology was adopted as part of a multihop routing protocol based on localization. Besides technological aspects, the project studied factors related to strategies of market introduction including cost analyses and legal aspects;

– the NOW (Network-on-Wheels) project [NOW 04] (2004-2008) is a German project from the federal education and research government, founded by automobile manufacturers, telecommunication operators and academia. NOW supports and strongly cooperates with the Car2Car consortium. The communication protocols developed for the project are dedicated for security applications as well as for entertainment applications and provide an open communication platform for a large range of applications. One of NOW's main objectives is the implementation of communication protocols and data security algorithms in vehicle networks. Considering the wireless IEEE 802.11 technology and location based routing in a V2V or vehicle to infrastructure communication context, the goal is to implement a system of reference and to contribute to the standardization of such a solution in Europe in collaboration with the Car2Car consortium. Aspects concerning vehicle antennae are also addressed;

– the integrated European PReVENT project [PRE 04], co-financed by the European Commission, was introduced to improve road safety by developing and demonstrating preventive road safety technologies and applications. Its objective is to reduce the number of accidents by 50% by 2010, as indicated in the eSafety action [ESA 05] for European Union road transport. PReVENT allow to: 1) study and evaluate preventive safety applications using sensors, positioning and communication technologies integrated in embedded systems for driving assistance, 2) contribute in the technological development and integration, and 3) contribute to a quick market introduction;

– on the French side, the MobiVip project [MOB 05] from the PRéDIT3 program is one of the most recent in the field. It focuses on research and experimentation of key technological bricks for the integrated deployment of mobility services in urban areas based on a "public individual vehicle" transport system and an information system which integrates into the policy of global traffic management on the city scale. The goal is the creation of new tools for multi-modality (hardware, software and model technological bricks) based on integration, in the juncture between assisted and automatic driving, telecom, transport modeling and service evaluation. However, studies carried out in MobiVip do not focus on the network aspect.

12.3.2. *Study of the existing*

In this section, we will present a few propositions relative to VANET networks. They are, however, only at the proposition stage and no standard has yet been developed.

12.3.2.1. *Routing*

Before addressing routing tasktask in vehicle networks, we will briefly recall a few principles and studies surrounding routing in mobile ad hoc networks (MANET).

12.3.2.1.1. Routing protocols in MANET

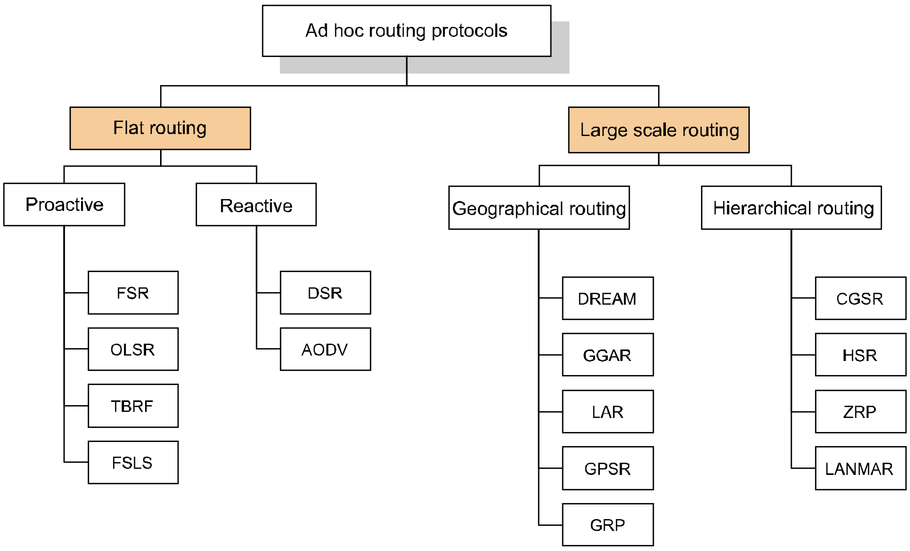


Figure 12.4. *Classification of ad hoc routing algorithms*

As illustrated in Figure 12.4, there exist two classes of MANET routing protocols: the flat and the large-scale routing protocols.

– we start with the first protocol class, flat routing can be divided into two subsets: on one side proactive protocols (FSR [GER 01], OLSR [CLA 03], TBRPF [OGI 04]) and on the other reactive protocols (DSR [JOH 04], AODV [PER 03]). A proactive protocol will keep all possible routes for each destination in the network. The route will then be instantly available. Conversely, reactive protocols will determine a route only when requested. A period of time is therefore necessary for a route search;

– the large scale class includes geographical routing protocols and hierarchical routing protocols:

- *geographical routing*: routing technique based on location information. All protocols in this group share the excessive usage of geographical position information, implicitly raising the need for a global location service providing this information such as GPS, Galileo, ZigBee [ZIG 05],. Also, a source node needs to know the current position of a desired communication partner. Generally, this information is assumed to be provided by a location service. Geographiacal protocols can be further subdivided into two categories 1) enhanced-topological and 2) position-based. The first one uses location information to enhance exiting topological-based protocols to make them more suitable. These improvements are mainly focused on the number of route discovery messages sent. In this way, the use of route discovery algorithms become more relevant in certain areas of the network than in others. The position determination technology will make it possible to mark a perimeter of research in which the route discovery protocol will be more efficient. An example of this strategy is the Location Aided Routing (LAR) protocol [KOY 98], a protocol based on DSR. The second category of geographical algorithms such that GGAR [NAV 97], GPSR [KAR 00] and GRP [JAI 01] reside in their capacity to find the best possible geographical route for each transmitted packet, while having a restricted view of the network or only having partial location information;

- *hierarchical routing*: finally, the large-scale class includes the subclass of protocols that rely on hierchical approaches. The main objectif is to partition the network into clusters to provide better routing information dissemination. Clustering consists of classifying network nodes in a hierarchical way following specific parameters: address, geographical zone, capabilities, etc. A subset of nodes is elected in a completely distributed way to assume the role of local coordinator. This type of hierarchical routing approach (for example, CBRP [MIN 99]) is intended to reduce the size of the routing table which is based on the clustering structure used. A clustering algorithm is based on the following steps: clusterhead formation (election), communication between clusterheads, and their maintenance.

Routing based on location is known for its robustness in terms of network size scalability. It is a good candidate for VANET networks. A few studies such as that from [SEN 05] have well demonstrated this. The authors have evaluated the performance of three ad hoc routing protocols (AODV, DSR, and LAR). Simulation results have shown that LAR is more powerful in terms of end-to-end delay and network overload in an IVC environment.

12.3.2.1.2. Routing protocols for VANET

Different solutions for routing in IVCs were proposed. We describe them below.

A-STAR (Anchor-based Street and Traffic Aware Routing) [LIM 05] is a position-based routing protocol for a metropolitan IVC environment. It mostly uses information on the itinerary of city buses to identify an anchor route with high connectivity for packet transmission. A-STAR is similar to the GSR protocol since it adopts an anchor-based routing approach considering roads topology.

However, contrary to GSR, it calculates anchor paths according to traffic (bus traffic, vehicle traffic, etc.). A weight is assigned to each street according to its capacity (a wide road or a small road served by a different number of buses). Route information provided by buses gives an idea of the traffic load in each street. This provides an image of the city vehicular traffic at different times. We find that one of the perspectives of this study consists of giving a dynamic weight that would change based on this retrieved information and of traffic at a given time in order to provide better anchor calculation quality. For performance studies, the M-Grid mobility model was used to describe vehicles movement within a city.

The authors of [BLU 03] propose a clustering algorithm (Clustering for Open IVC Networks – COIN) adapted to IVC networks which improves cluster stability. The clustering mechanism used is designed in a way that enhance scalability. Cluster selection is based on nodes mobility, driver behavior and distance between cars. With a reduced additional control load, this protocol gives clusters a time to live that is approximately twice as long and decreases changes in cluster affiliation by at least 46%.

The reactive routing protocol proposed in [LOC 03] is based on location information. It uses the city map to facilitate the routing function. The authors use the reactive location service to know the position of another vehicle. It is the equivalent of a route discovery procedure for routing protocols based on topology. The authors are currently working on expanding the solution to minimize overhead generated by diffusions.

12.3.2.2. *Data dissemination and diffusion*

Dissemination of information consists of forwarding data from a source to one or more destinations, by ensuring a reduced transmission delay, strong reliability and better resource usage. Destination nodes concerned by the dissemination mechanim can be characterized by their positions, IP address, geographical region, etc.

In a MANET network, broadcasting protocols use flooding for route construction and maintenance. Flooding is the most naive protocol , consisting on rebroadcasting the received packet by all the nodes. The problem (also known in [TSE 02] as the broadcast storm problem) is that this systematic rebroadcast uselessly causes excessive bandwidth usage since each node will receive the same information from many times.

In addition, with dense ad hoc networks, the fact that each node systematically rebroadcasts generates a large number of collisions that will not be corrected by the

MAC layer (absence of ACK during diffusion). This decreases the efficiency and reliability of diffusion. However, other types of diffusion better adapted to IVC environments are now possible, notably multicast and geocast.

Multicast is used by applications wishing to transmit information to more than one destination. A node that wants to receive data must first join a multicast group. Messages sent are then received by all members of the group.

Geocast adopts the same operating principle with the difference that instead of explicitly joining a multicast group, nodes are implicit members of the same group if they are in the same geographical zone. In this case, the group becomes a geocast group. In this type of protocol, the following terminology is used: 1) geocast group: members of a group are defined by their geographical location; 2) geocast zone: the geographical area where all mobile node members of a geocast group are located. Entering the zone is the same as joining the group and vice versa; and 3) forwarding zone: the zone where data packets are forwarded. Each geocast group has a forwarding zone, and only nodes that are inside can forward packets. A geocast zone is included in a forwarding zone.

Below, we will briefly present a few data dissemination solutions in vehicular networks. In fact, because of the challenges of road safety applications, vehicular networks must integrate data dissemination mechanisms which are efficient and.reliable.

MDDV (Mobility-Centric Data Dissemination Algorithm for Vehicular Networks) [WU 04] is a diffusion algorithm which considers that vehicles do not have the positions of their surrounding vehicles, contrary to other geographical algorithms. The road system is modeled as a directed graph where nodes represent intersections, and connections road segments. A weight is associated with each connection to reflect corresponding traffic density and distance. MDDV uses a forwarding path specified as the route with the smallest sum of weights from a source to a "destination region" in the directed graph.

The Urban Multi-Hop Broadcast Protocol [KOR 04] is a broadcast algorithm modifying the 802.11 access layer to adapt it to the IVC context with the goal of reducing collisions and efficiently using bandwidth. It includes two phases: the first one is called directional broadcast where the source selects the furthest node in the diffusion direction to perform data forwarding with no topology information, and the second is the intersection broadcast, which disseminates packets in all directions using repeaters installed at intersections..

In RBM (Role-Based Multicast) [BRI 00], the authors propose a multicast protocol where each node maintains two lists: a list of neighbors and a list of transmitting nodes. Depending on the contents of these two lists, a node decides whether or not to rebroadcast the message after a certain period of time. In other words, this approach allows nodes to wait with rebroadcasts until new neighbors move into their vicinity.

In [SUN 00] dissemination protocols called TRADE (TRack DEtection) and DDT (Distance Defer Time) were proposed. For TRADE, the objective is to guarantee better reliability with a limited number of rebroadcasts. A vehicle must designate among its neighbors those ensuring retransmission of messages based on their movements. DDT uses a defer time before rebroadcasting a received message and if during this time it receives the same message from another vehicle, it does not rebroadcast it again.

IVG (Inter-Vehicle Geocast) [BEN 04] is a new dissemination mechanism wich generalizes the previous methodes (TRADE and DDT) in order to overcome network fragmentation, reliability and neighbors determination. Dynamic relays are introduced to periodically rebroadcast alert messages. These relays are selected according to the relative distance to the source vehicle. A simulation study showed that IVG outperforms TRADE and DDT in terms of reliability.

Other geocast solutions can also be found in [SUN 05] or [MAI 05].

12.3.2.3. *Mobility models for vehicular networks*

Simulations play an important role in the validation of new protocols as they allow hypothesis to be tested in a relatively low-time consuming manner. An important aspect of simulations in MANETs in general and VANETs in particular is the definition of movement of the nodes in the simulated area. It was recognized that movement patterns greatly influence simulation results. Consequently, particular attention must be given to the development and definition of a mobility model, considering the characteristics and constraints of the modeled environment.

For mobile ad hoc networks, the Random Way Point (RWP) model [JOH 96] is one of the most widely used mobility models in simulations. In this model, each node individually chooses a random destination in the network's geographical limit and also chooses a random movement speed (between a minimum and a maximum). Once the node reaches its destination, it makes a pause during a time period. Then, the node repeats the process by choosing a different destination and random speed. In this case, mobile nodes move randomly and independently from roads topology. There are other mobility models [CAM 02] called "group mobility models" which represent mobile nodes where movements are mutually dependent and which are adapted to applications involving group communications.

These mobility models for MANET suffer from a few limits such as convergence of nodes to the center of the network's surface over time, which gives inadequate node distribution [BET 04]. These models can not be directly used in vehicle networks where movements and speeds are delimited and predefined by routes and driver behavior. In order to design an appropriate realistic mobility model for IVCs, we have to take into account the environment characteristics:

– highway: open environment characterized by a fast movement speed (with limits: minimum and maximum speed), cars acceleration and deceleration, and nodes density based on the time of day;

– city: moderate speed with a higher intersection probability. There are stop lights, a large vehicle density, and the existence of roads busier than others (main roads, commercial or tourist areas, for example);

– open countryside: characterized by slower speeds with lower car density.

Road traffic modeling is a research subject where several studies have been carried out in the field of intelligent transport systems. A variety of simulation tools such as PARAMICS [CAM 96], CORSIM [COR 96] and VISSIM [VIS 05] were developed to analyze micro and macro mobility features. For example, CORSIM [COR 96] is a microscopic traffic simulator developed by the Federal Highway Administration in the USA and widely used in ITS. In CORSIM, nodes mobility is determined considering driver behavior, vehicles characteristics and restrictions from the road and surrounding vehicles. However, few efforts are spent in the integration of techniques and communication scenarios.

A few studies on mobility models have been proposed recently. For example, [SAH 04] proposed a mobility model based on vehicle movements following real and specific road plans. A comparison with the RWP model was conducted. Developed for the NS-2 simulator [FAL 05], this model is available and can be freely used for vehicular network simulations. However, aspects such as wait time at intersections or the existence of busier streets have not been considered in the model. In [LEB 05], a generic mobility model based on the Random Trip Mobility model family was studied. Simulations using city maps were performed. In [KAR 05], a tool called MOVE based on SUMO [SUM 05] was developed to generate mobility trace files usable with NS-2 or Qualnet [QUA 05]. In STRAW (STreet RAndom Waypoint) [CHO 05], movement of nodes is restricted to streets defined by data from real city maps and their mobility is limited according to road congestion. The model is divided into components: intra-segment mobility, inter-segment mobility, and a road management and execution component. In [MAN 05], a simulation tool called GrooveSim was developed. It integrates a set of mobility, communication, traffic and path models. It represents one of the rare tools to propose a mobility model to be tested on a geographical dissemination protocol for vehicular networks. Developed in C++ for Linux platforms, it offers four basic mobility models: uniform speed model with a minimum and maximum speed; 4-state Markov-based probabilistic model; load-based model; and street map-based maximum speed. GrooveSim generates street maps from anywhere in the USA by importing TIGER/Line-type files [TIG 04] that are freely available in the USA. Nevertheless, with this type of format, information provided in TIGER files do not offer specific information on the number of lanes per road, one way systems, and contain no road signs. Because GrooveSim offers basic models, it should be expanded to support more realistic communication models and more appropriate traffic models.

Mobility models generally proposed are quite recent and mainly tested with ad hoc routing protocols (DSR, AODV, etc.). It would be more suitable to use them with (routing or other) protocols specific to IVC constraints. It would also be appropriate to combine the approaches used in road traffic simulators with communication simulators (CORSIM and NS-2, for example).

12.3.2.4. *MAC and physical layers*

Currently, there are two main approaches for the design of MAC protocols specific to IVC networks. They differ depending on the radio interface used. The first approach is based on WLAN physical layers, such as IEEE 802.11 and Bluetooth. The alternative approach consists of enhancing 3G cellular telephony layers such as CDMA with decentralized access. On one hand, the advantage with the first approach is the distributed coordination support in ad hoc mode, but the flexibility of resource allocation and transmission throughput is low. On the other hand, 3G extensions provide higher throughput and more flexible resource allocation, but are badly affected by complexity linked to the coordination function developed in distributed mode. We will now discuss a few propositions which attempt to improve certain aspects of existing norms.

The authors of [KAT 03] proposed a distributed access protocol called LCA (Location-based Channel Access). Based on location information, the LCA protocol divides a geographical surface into cells with one channel per cell. In each cell, any multiple access protocol such as CSMA or CDMA can be used. We nevertheless think that a set of simulations in the vehicular context is necessary to evaluate the validity of this type of solution in a network as dynamic as IVC networks.

There are several propositions for the use of R-ALOHA[2] (Reservation ALOHA) for a distributed channel allocation [BOR 02, BOR 03, HAL 01, RUD 03]. For example, in [BOR 02], the authors proposed the RR-ALOHA (Reliable R-ALOHA) protocol [BOR 02] based on UTRA TDD. In this new protocol, additional information concerning the status of each slot is transmitted to all nodes thus avoiding that the same reservation occurs. There are also a few MAC protocols for ad hoc networks combining CDMA with random access to the channel. As an example, we can site RA-CDMA (random access CDMA) [SOU 88] where transmitting stations begin their transmission immediately and independently from the state of the channel. One of the improvements of RA-CDMA is CA-CDMA (channel-adapted CDMA) [MUQ 03]. This uses a modified RTS/CTS reservation mechanism where the channel is divided into control and data channels. RTS/CTSs are sent to control channels in order to inform interfering nodes of the state of the channel (but contrary to protocol IEEE 802.11, interfering nodes can transmit simultaneously, although only under certain conditions). Throughout simulation results (in particular the comparison between CA-CDMA and IEEE 802.11), it was demonstrated that this protocol is promising for ad hoc networks. However, other dedicated studies involving an IVC environment are necessary.

Even though some MAC protocols have been proposed, more attempts are needed to put them into practice. Currently, IEEE 802.11b is the most widely used for demonstrations [FUB 03], and IEEE 802.11a is chosen by ASTM (American Society for Testing and Materials) to serve as a foundation for the DSRC[3] (Dedicated Short Range Communication) standard [DSR 03].

12.3.2.5. *Security in vehicular networks*

Communication transmitting in a vehicle network and information about vehicles and their drivers must be protected and secured to ensure the proper operation of an intelligent transportation system. Data sensitivity transmitted over a VANET network demonstrates a high need for security. In fact, the importance of security in this context is vital because of the critical consequences resulting from a violation or attack. In addition, with a highly dynamic environment characterized by almost instant arrivals and departures of cars, and short connection times, the deployment of a security solution must cope with specific configurations and constraints, even though the need for secure solutions for data transmission in VANET was known from the beginning. Only recently has this problem aroused interest, and a few

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2 R-ALOHA is a random access protocol with reservation and which is totally distributed. R-ALOHA is based on Slotted ALOHA with regular slot allocation. If a station succeeds in transmitting to a given slot, it will reserve the same slot in the next frames. This slot reservation reduces contention.

3 DSRC communication standard using the 5.850–5.925 GHz band in the USA. It is a variation of the IEEE 801.11a technology for V2V and V2I communications.

solutions have been developed. A brief description of some of these propositions follows.

The authors of [GOL 04] proposed a model to evaluate validity level of data circulating in the VANET network. In [RAY 05], the authors provided a detailed analysis of the different attacks in vehicular networks and propose a security architecture where protocols are described and evaluated. In addition, they show that cryptography based on public key is adapted for VANET networks. In [BLU 04], the authors presented the SecCar architecture which relies on a public key infrastructure to offer security solutions in IVCs. The use of digital signatures is studied and discussed in [LUT 02]; it is also supported by Zarki *et al.* [ZAR 02] who discuss security requirements for a system using a public key infrastructure in a VANET environment.

The approach implemented for the NOW project [NOW 04] consists of the construction of attack trees. From a generic model, an attack tree is built based on security requirements of the system and the different vulnerabilities related to proposed services. First, the focus is on general attacks such as the insertion of false messages, DOSs (Denial Of Service), and privacy violation. Authors of [DUR 02] focus on privacy guarantee and data integrity in application telematics. They in fact present a solution for data protection by using solutions based on standards such as SSL or IPSec.

There are also other propositions which are nevertheless limited to specific and limited aspects of vehicle networks without proposing a solution with global visibility for the vehicular network context.

12.4. Conclusion

In the last few years, the development of new technologies has sparked an incredible evolution of the transportation system. This evolution is intended to make networks more secure, efficient, reliable and ecological without necessarily having to modify the hardware of the existing infrastructure. The range of technologies involved includes information and sensor technologies, control and communication systems; it touches disciplines such as transportation, engineering, telecommunications, computing, finances, electronic commerce and automobile manufacturing.

The main objectives of an intelligent transportation system include: 1) the improvement of trip security, 2) the improvement of global efficiency of the transportation system by reducing travel time and congestion, 3) the integration of transportation in a durable development policy, particularly by reducing gas emissions for light vehicles and heavy trucks and by optimizing maintenance of the infrastructure, and 4) the improvement of user comfort by providing him with a selection of information, decision support, guidance and Internet access services.

The main goal of this chapter is to provide a better understanding of one of the main components of these ITS systems, that is, inter-vehicular communication (IVC) or what we call mobile inter-vehicular ad hoc networks (VANET), which are a particular class of MANET. The characteristics and applications of these systems, as well as a group of projects and research studies relating to this field, were presented. Even though they are similar to the mobile ad hoc network environment, problems inherent to vehicle networks must be closely studied and some existing ad hoc network solutions must be revised and adapted. In this chapter, we also presented some recent propositions concerning routing and data dissemination, mobility models, channel access layer, and aspects linked to security. These studies, although few in number, attempt to respond to environment characteristics and constraints.

We think that particular attention must be given to mobility models for a better representation of the real context (parameters such as lane changes, traffic lights, high influence areas, and the use of topographical information provided by maps). These models are necessary for testing these large scale communication systems by simulation. In addition, traffic models and the interconnection with other networks must be considered and taken into account in studies carried out for vehicular networks.

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