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Title

OPTIMIZATION OF VANET NETWORKS

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To the memory of my father

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Abstract

Currently, the Intelligent Transportation Systems (ITS) are increasingly studied as well in the community of research in industries (automobile, telecommunications, etc). Indeed, the implementation of ITS applications may in the short term to improve road safety, effectively increasing the use of roads, reduce congestion and traffic jams, reduce the impact of vehicles on the environment, etc.

However, several problems must be solved before being able to conceive such applications, among which the self-organization of inter-vehicles communications has a privileged place.

In this thesis, we focus on the optimization of VANET architecture. Initially, we are interested in two types of ad hoc networks WSN (Wireless Sensors Network) and VSN (Vehicular Sensors Network) where their main characteristics and applications are surveyed and a comparison between them is presented. Then, we tackle the principal constraint in the vehicular networks i.e. the mobility. In fact, the exact prediction of mobility of the nodes forming the network is very important in the simulation of VANET networks. Hence, a comparative study between two mobility models is made after a presentation of a set of related works dealing with mobility models in vehicular networks. Finally, we propose a self-organization mechanism called MCAV based on clustering, able to efficiently adapt to the vehicular network characteristics and applications. This advocated technique is evaluated by a combination of network simulator (NS-2) and a realistic mobility model VanetMobiSim.

Keywords: Vehicular Networks, VANET, self-organization, WSN, VSN, Mobility model, Clustering, VanetMobiSim.

Résumé

Actuellement, les systèmes de transport intelligent (STI) sont de plus en plus étudiés aussi bien dans la communauté de recherche que dans les industries (automobiles, télécommunications, etc.). En effet, la mise en place d’applications ITS peut à court terme améliorer la sécurité routière, augmenter efficacement l’utilisation des routes, réduire les congestions et les embouteillages, limiter l’impact des véhicules sur l’environnement, etc.

Cependant, plusieurs problématiques doivent être résolues avant de pouvoir concevoir de telles applications, parmi lesquelles les communications inter-véhicules ont une place privilégiée.

Dans cette thèse, nous nous concentrons sur l'optimisation de l'architecture des réseaux VANETs. Dans un premier temps, nous nous sommes intéressés à deux types de réseaux ad hoc WSN (réseau de capteur sans fil) et VSN (réseau de capteur véhiculaire). Leurs caractéristiques et leurs principales applications sont présentées et une comparaison entre eux est effectuée. Ensuite, nous abordons la principale contrainte dans les réseaux de véhicules à savoir la mobilité. En effet, la prédiction exacte de la mobilité des nœuds formant le réseau est très importante dans la simulation du réseau VANET. Ainsi, une étude comparative entre deux modèles de mobilité est faite après une présentation d’un ensemble de travaux portant sur les modèles de mobilité pour réseaux de véhicules. Enfin, nous proposons un mécanisme d’auto-organisation appelé MCAV basé sur le clustering capable de s’adapter efficacement aux caractéristiques et applications des réseaux véhiculaires. Cette technique préconisée est évaluée par une combinaison du simulateur de réseau (NS-2) et du modèle de mobilité réaliste VanetMobiSim.

Mots clés: Réseaux ad hoc de véhicules, auto-organisation, Réseau de capteur sans fil, Réseau de capteur véhiculaire, Clustering, modèle de mobilité, VanetMobiSim.

ملخص

حاليا، تدرس أنظمة النقل الذكية بشكل متزايد في البحوث العلمية والصناعية (السيارات, الاتصالات السلكية و اللاسلكية و غيرها). في الواقع، يمكن لتطبيقات هذه الأنظمة الذكية أن تحسن من أمن الطرقات، تزيد من استخدام الطرق بفعالية ، تحد من الازدحام والاختناقات المرورية، وتحد من تأثير السيارات على البيئة، الخ

و لكن، هناك العديد من الإشكاليات التي يجب حلها حتى نتمكن من تصميم مثل هذه التطبيقات، بما فيها التنظيم الذاتي للسيارات الذي يعتبر أكثر أهمية في شبكة المركبات.

في هذه الأطروحة، نحن نركز على تحسين بنية شبكة المركبات. في البداية ، نقدم دراسة مقارنة لنوعين من الشبكات اللاسلكية، (شبكة الحساسات التقليدية وشبكة الحساسات المدمجة في المركبات) بذكر مجموعة مفصلة من خصائصها وتطبيقاتها الرئيسية. ثم نتطرق إلى العائق الرئيسي في شبكات المركبات ألا وهو الحركة المستمرة للسيارات التي تحتاج إلى تنبؤ دقيق و نماذج خاصة لمسايرتها,و في هذا

الصّدد, نقوم بالمقارنة بين نموذجين للتنقل بعد تقديم مجموعة من الأعمال التي تركز على هذه النماذج في شبكة السيارات.وفي الأخير نقترح خوارزمية التنظيم الذاتي(MCAV) التي تعتمد على التجميع و تتكيف بشكل فعال مع خصائص وتطبيقات شبكة المركبات، حيث يتم تقييم هذه التقنية باستعمال (NS-2) ونموذج لتنقل واقعي VanetMobiSim.

الكلمات المفتاحية: شبكات المركبات، أجهزة الاستشعار، شبكة الحساسات المدمجة في المركبات، خوارزمية التجميع، نموذج التنقل، VanetMobiSim.

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List of Abbreviations

Acronym	Definition
ASV	**A**dvanced **S**afety **V**ehicle
ASTM	**A**merican **S**ociety for **T**esting and **M**aterials
AODV	**A**d hoc **O**n **D**emand **D**istance **V**ector
AMACAD	**A**daptable **M**obility-**A**ware **C**lustering **A**lgorithm in vehicular networks
CAMP	**C**ollision **A**voidance **M**etrics **P**artnership
C2C-CC	**C**ar-**to**-**C**ar **C**ommunication **C**onsortium
CVIS	**C**o-operative **V**ehicle-**I**nfrastructure **S**ystems
COOPERS	**CO-OPE**rative Systems for Intelligent **R**oad **S**afety
CCH	**C**ontrol **Ch**annel
CSMA/CA	**C**arrier Sense Multiple Access with Collision Avoidance
CALM	**C**ontinuous **A**ir-interface, **L**ong and **M**edium Range
CityMob	**City Mob**ility
CBR	**C**onstant **B**it **R**ate
CH	**C**luster **H**ead
CAN	**C**ontroller **A**rea **N**etwork
DVB-S	**D**igital **V**ideo **B**roadcasting-**S**atellite
DSRC	**D**edicated **S**hort **R**ange **C**ommunication
DRiVE	**D**ynamic **R**adio for **I**P Services in **V**ehicular **E**nvironments
DAB	**D**igital **A**udio **B**roadcast
DVB-T	**D**igital **V**ideo **B**roadcasting-Satellite
DM	**D**owntown **M**odel

Acronym	Definition
ETSI	**E**uropean **T**elecommunications **S**tandards **I**nstitute
ECC	**E**lectronic **C**ommunications **C**ommittee
EU	**EU**ropean
ERMTG 37	**E**lectromagnetic compatibility and **R**adio spectrum **M**atters **T**echnical **G**roup **37**
FleetNet	**Fleet Net**work
FCC	**F**ederal **C**ommunication **C**ommission
GPS	**G**eographical **P**osition **S**ystem
GSM	**G**lobal **S**ystem for **M**obile **C**ommunication
GPRS	**G**reedy **P**erimeter **S**tateless **R**outing
GST	**G**lobal **S**ystem for **T**elematics
GeoNet	**Geo**graphical **NET**working
ITS	**I**ntelligent **T**ransportation **S**ystems
In-VANET	**In**telligent- **V**ehicular **A**d-Hoc **NET**work
IVC	**I**nter-**V**ehicle **C**ommunication
IEEE	**I**nstitute of **E**lectrical and **E**lectronics **E**ngineers
InV	**In**ter-**V**ehicle
IVI	**I**ntelligent **V**ehicle **I**nitiative
IPv6	**I**nternet **P**rotocol **v**ersion 6
ISO	**I**nternational **O**rganization for **S**tandardization
ID	**ID**entification
IDM	**I**ntelligent **D**river **M**odel
JARI	**J**apan **A**utomobile **R**esearch **I**nstitute
LAN	**L**ocal **A**rea **N**etwork
LLC	**L**ogical **L**ink **C**ontrol
LKS	**L**ane **K**eeping **S**upport

Acronym	**Definition**
MCAV	**M**obility and **C**onnectivity based **C**lustering **A**lgorithm for **V**ehicular networks
MANET	**M**obile **A**d-hoc **NET**work
MIMO	**M**ultiple **I**nput **M**ultiple **O**utput
MAC	**M**edia **A**ccess **C**ontrol
MM	**M**anhattan **M**odel
MOVE	**MO**bility model generator for **VE**hicular networks
Mobic	**Mo**bility **B**ased Metr**i**c for **C**lustering in Mobile Ad Hoc Networks
NoW	**N**etwork-**o**n-**W**heels
NS-2	**N**etwork **S**imulator **2**
OSI	**O**pen **S**ystems **I**nterconnection
OFDM	**O**rthogonal **F**requency **D**ivision **M**ultiplexing
OBU	**O**n-**B**oard **U**nit
PDA	**P**ersonal **D**igital **A**ssistant
P-Demo	**P**ath **D**emo
PATH	**P**artners for **A**dvanced **T**ransit and **H**ighways
PHY	**PHY**sical
PTSM	**P**robabilistic **T**raffic **S**ign **M**odel
PDP	**P**olicy **D**ecision **P**oint
PEP	**P**olicy **E**nforcement **P**oint
QoS	**Q**uality **o**f **S**ervice
RVC	**R**oadside-to-**V**ehicle **C**ommunication
RSU	**R**oad **S**ide **U**nit
R&D	**R**esearch and **D**evelopment
RMAC	**R**obust **M**obility **A**daptive **C**lustering

Acronym	**Definition**
SeVeCom	**Se**cure **Ve**hicular **Com**munication
SCH	**S**ervice **CH**annels
SDOs	**S**tandards **D**evelopment **O**rganizations
STRAW	**ST**reet **RA**ndom **W**aypoint
SSM	**S**top **S**ign **M**odel
SM	**S**imple **M**odel
SUMO	**S**imulation for **U**rban **Mo**bility
TCP	**T**ransmission **C**ontrol **P**rotocol
TC	**T**echnical **C**ommittee
TIGER	**T**opologically **I**ntegrated **G**eographic **E**ncoding
TLM	**T**raffic **L**ight **M**odel
UMTS	**U**niversal **M**obile **T**elecommunications **S**ystem
UWB	**U**ltra **W**ide **B**and
USB	**U**niversal **S**erial **B**us
US	**U**nited **S**tate of **A**merica
USDoT	**US D**epartment **o**f **T**ransportation
UDP	**U**ser **D**atagram **P**rotocol
USA	**U**nited **S**tate of **A**merica
VSN	**V**ehicular **S**ensors **N**etwork
VANET	**V**ehicular **A**d-Hoc **NET**work
V2V	**V**ehicle**-to-V**ehicle
V2I	**V**ehicle**-to-I**nfrastructure
VoIP	**V**oice **o**ver **IP**
VSC	**V**ehicle **S**afety **C**onsortium
VII	**V**ehicle **I**nfrastructure **I**ntegration
VICS	**V**ehicle **I**nformation and **C**ommunication **S**ystem
VanetMobisim	**V**anet **M**obility **S**imulator

Acronym	**Definition**
Wi-Fi	**Wi**reless-**Fi**delity
WiMAX	**W**orldwide **I**nteroperability for **M**icrowave **Acc**ess
WPAN	**W**ireless **P**ersonal **A**rea **N**etwork)
WLAN	**W**ireless **L**ocal **A**rea **N**etwork
WECA	**W**ireless **E**thernet **C**ompatibility **A**lliance
WAVE	**W**ireless **A**ccess in **V**ehicular **E**nvironment
WMAN	**W**ireless **M**etropolitan **A**rea **N**etwork
WWAN	**W**ireless **W**ide **A**rea **N**etwork
WLL	**W**ireless **L**ocal **L**oop
WG	**W**orking **G**roup

CHAPTER 1

GENERAL INTRODUCTION

I.1 Motivations

Wireless networks have become an integral part of daily life of businesses, individuals, industry and other organizations. They represent today one of the building blocks on which will be based the omnipresent intelligent systems (Ubiquitous intelligence) that will constitute one of the future technologies.

Indeed, computers, sensors, fleas, digital networks and other electronic systems will participate in a near future to the democratization of ubiquitous computing, i.e. the fusion of virtual worlds and the real world to create smart environments that can offer their users a multitude of highly available services (Intelligent transport systems, smart home, help and medical supervision, etc.) and the complexity of the implementation is invisible to these users.

A typical example of these applications is the intelligent transportation system (ITS), whose main objectives are: (i) improving of the displacements safety, (ii) improving the overall efficiency of the transport system by reducing travel time and congestion, and (iii) improving the user comfort by providing a variety of information services, decision support, guidance and access to the Internet. All this would also have like outlet the transports integration in sustainable development policy, in particular by reducing gas emissions for light vehicles or trucks and by optimizing infrastructure maintenance.

A key component of these systems ITS is the inter-vehicle communication. Indeed, communications involving vehicles will play an important role in the coming years, whether to communicate between vehicles or with the existing infrastructure. The cars of the future will not be satisfied any more to detect hazards through radar or cameras on roads; they will be able to receive alert messages sent by other users or infrastructure (signs, gantries, etc.) and transmit this information to other vehicles. The cars will be equipped with battery of various sensors (VSN, Vehicular Sensor Networks). Each will collect data and feed the network formed by the surrounding vehicles within a few kilometers.

Thanks to these communications capacity and embarked sensors, many innovative applications are possible. They range from safety to the traffic regulation through the transmission of information to the driver. One can even imagine network game applications among several passengers of different vehicles like games on internet. Given these potentialities, vehicular networks represent a new promising market in terms of network infrastructure deployment and provision of related services. However, they are only in experimental phase and several issues must be solved before being able to deploy such applications. Indeed, the applications of vehicular communications require in most cases a reliable communications, a minimum quality of service and also in some cases real-time communications. However, these contrast much with the highly dynamic nature of vehicular network (topology change, variable distance between vehicles, frequent loss of connectivity, no reliable communications, delay, etc).

I.2 Contributions of this thesis

Vehicles networks properties should remove important technological obstacles as channel access, routing and data dissemination, self-organization and addressing or safety. In this thesis, we attack one of these technological namely self-organization networks. Our goal is to propose a solution of self-organization based on clustering adapted to VANET environments.

In this thesis, we presented and surveyed the main characteristics and applications of two types of ad-hoc networks WSN and VSN, and we make a comparison between them. Our research is much focused on vehicular sensor networks (VSN); considerable efforts have emerged to introduce intelligence into transport systems to improve safety, efficiency and usability in road transport. These networks will play an important role in building the future internet, where they will serve as a support for various communication applications and integrated into our daily live.

The second problem, which we are interested in this thesis, is that the mobility in the vehicular networks which is the principal constraint met in the vehicular networks, therefore the performance investigation of VANET network routing requires the exact prediction of mobility of nodes forming the network, and this is realized by the good choice of the mobility model. A comparative simulation between two mobility models for VANET is made after presented a set of works deals with the mobility models for vehicular networks.

By considering a key parameter of the operation of vehicular ad hoc network, i.e. the network mobility and connectivity, we propose a new clustering approach to self –organize the vehicular networks. The main purpose of this technique is to propose an optimal architecture for data transmission within the vehicles in the road.

I.3 Organization of the thesis

This thesis deals with communication in vehicular networks. It is organized as follows:

In Chapter 2, we introduce the concept of vehicular networks. We describe the communication architectures and wireless technologies potential to such networks. We also describe the characteristics and various applications of vehicular networks. In the rest of this chapter, we present the main actors field and a project overview and standardization work.

In the chapter 3, we describe the characteristics and applications of the sensor networks (WSN and VSN), then we give a table of comparison study for the both networks.

Chapter 4 discusses a variety of synthetic mobility models for vehicular networks. We aim to illustrate that a mobility model has a large effect on the performance evaluation in simulation of VANET network by making a full simulation comparison between two mobility models.

The fifth chapter describes our contribution consisting of a clustering algorithm (MCAV, *Mobility and Connectivity based Clustering Algorithm for Vehicular networks*).The performances of this solution like re-affiliations rate , elections rate , average lifetime of cluster head and average number of clusters were evaluated via simulations using NS-2 simulator and vehicular traffic model VanetMobiSim. This study is followed by a discussion of the results.

To conclude, a general synthesis that takes back the whole important contributions of this research work was presented in Chapter 6. In addition, some perspectives were cited.

CHAPTER 2

INTRODUCTION TO VEHICULAR AD HOC NETWORKS

II.1 Introduction

Communications involving a vehicle will play an important role in the future, either to communicate with another vehicle or with the existing infrastructure. Indeed, tomorrow's cars no longer be content to detect hazards through radar or cameras, they will be able to receive alert messages sent by other motorists or infrastructure (roadsign, gantries, etc) and to pass this information to other vehicles. Such is certainly the ambition of vehicles networks that researchers want to implement.

These vehicular networks have moved from simple curiosity to coat today some interest both from the point of view of the automotive industry and operators of networks and services and the research community. These vehicular networks are indeed an emerging class of wireless networks for the exchange of data between vehicles and between vehicles and infrastructure. They have been extensively studied in Europe, Japan and North America to provide new technologies that improve the safety and efficiency of road transport.

The rest of the chapter is organized as follows: in section 2 we present a definition and a detailed description of architectures and various services and applications of vehicular communications as well as potential wireless communication technologies of such networks. In addition to a presentation of the main actors involved in vehicle networks, Section 3 presents some recent projects for these networks. In Section 4, we present a detailed description of the characteristics and challenges related to vehicular networks. Section 5 concludes this chapter.

II.2 Introduction to VANET

After a brief definition of vehicular networks (VANET, In-VANET), this section describes the services and applications of these networks, and then shows the possible communication architectures and potential wireless communication technologies for vehicular networks.

II.2.1 Definition of Technology

- ***VANET***

Vehicular Ad-Hoc NETwork (VANET) is a form of Mobile Ad-hoc NETworks (MANET), to provide communications in a group of vehicles within reach each other and between the vehicles and fixed equipment in range, usually called the road equipment.

The main objective of VANET offers safety and passenger comfort. To this end, a particular electronic device will be placed inside of each vehicle that provides ad-Hoc network connectivity for passengers. This network tends to operate without any infrastructure or legacy and client-server communication. Each vehicle equipped with a VANET device will be a node in the ad-hoc network and can receive and transmit other messages through the wireless network (collision warning, alarms, road sign...).These messages will give to the driver the essential tools to determine the best path along the road.

Most areas of interest of MANET are also for VANET. Rather than move randomly, vehicles tend to move in an organized manner. Interactions with road equipment can similarly be characterized fairly accurately. And finally, most vehicles are limited in their range of motion, for example by being forced to follow a paved road. There are also multimedia facilities and Internet connectivity for passengers, all provided in the wireless coverage of each car. Automatic payment for parking lots and toll are other examples of opportunities in VANET inside.

Vehicular networks (Figure 2.1) are a projection of intelligent transportation systems (ITS). Vehicles communicate with each other via the inter-vehicle communication (IVC: *Inter-Vehicle Communication*) as well as with road equipments (RSU[1]: *Road Side Unit*) through the equipment-to-vehicle communication (RVC: *Roadside-to-Vehicle Communication*). The optimal goal is that vehicular networks will contribute to safer and more efficient routes in the future by providing timely information to drivers and interested authorities [1].

- ***In-VANET***

In-VANET (Intelligent Vehicular Ad-hoc NETwork) defines a smart way to use Networking vehicles. In-VANET integrates on ad-hoc multiple technologies of network such as Wi-Fi IEEE 802.11 b / g, IEEE 802.16 WiMAX, Bluetooth, IRA, ZigBee for easy communication, accurate, efficient and easy between vehicles on the dynamic mobility. Effective measures such as the means of communication between vehicles can be activated both methods to track motor vehicles is also preferred.

In-VANET helps to define security measures in vehicles, streaming communication between vehicles, infotainment and telematics [2].

[1] Denomination suggested by the C2C-CC consortium.

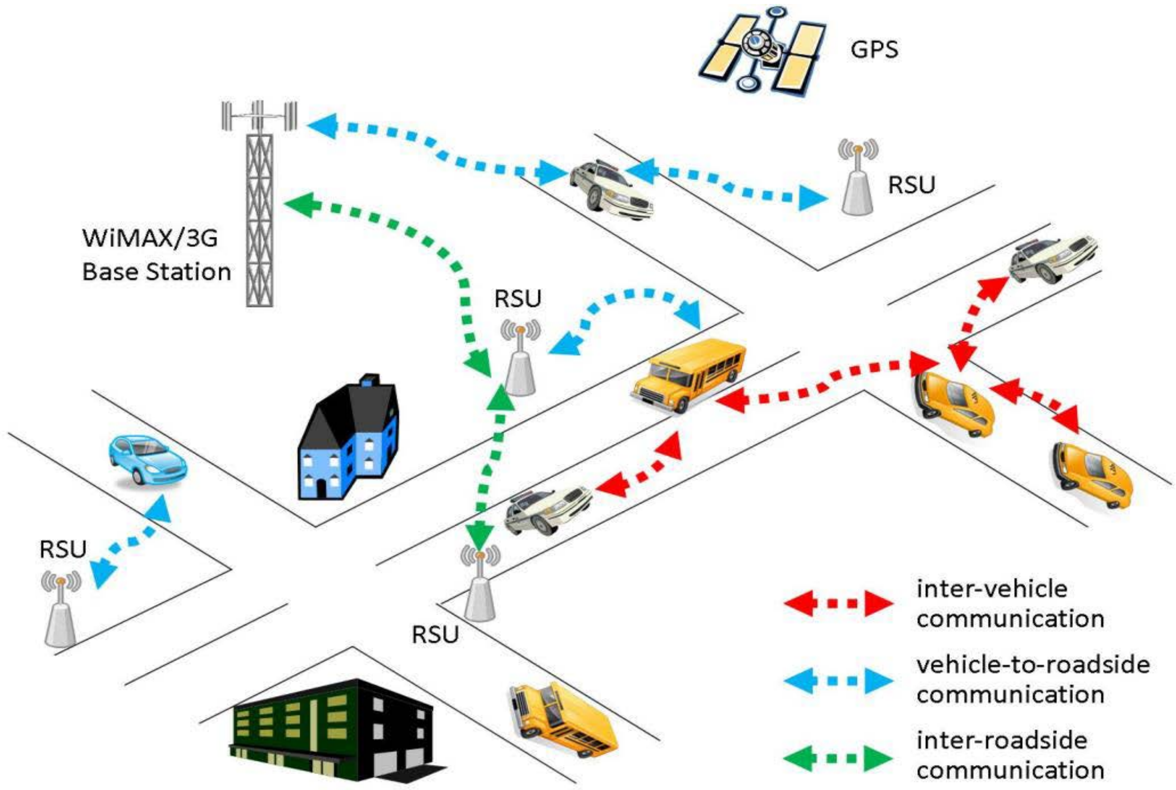


Figure 2.1 : Wireless Vehicular Networks

II.2.2 Services and applications for vehicular networks

Vehicular networks intersect two classes of applications [3], [4] i.e. applications to build an intelligent transportation system ITS (Intelligent Transport System) and those related to comfort and entertainment of the driver and any passengers.

Applications related to road safety (ITS applications) are an important part of the applications of vehicular networks. These applications include the dissemination of messages reflecting the state of the traffic, the weather, the road conditions, accidents, work or messages reminding speed limits and safety distances. ITS applications also include support systems and cooperative driving vehicles: Vehicle Assistance overruns, preventing output line or turning lanes, etc.

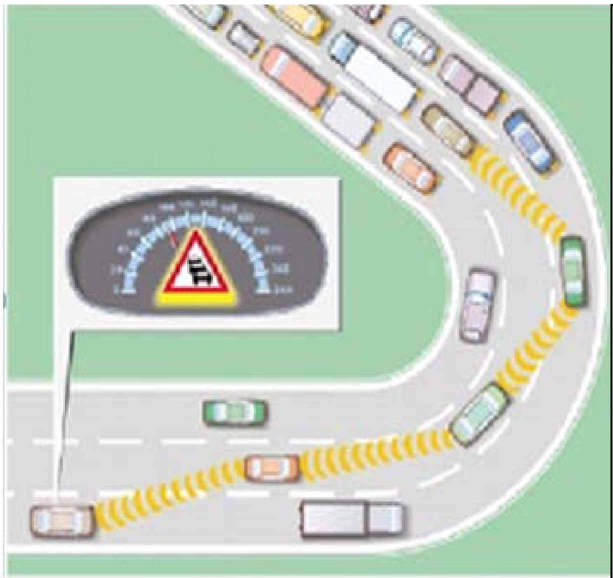
Examples of services are not only limited to road safety applications, but for other types of applications including dissemination of practical information to motorists by service providers (spot information provides useful services to drivers: gas station or presentation available parking spaces, Internet connection, helps communication between vehicles following, etc). These applications offer interesting opportunities for telecom operators seeking new service niches.

So we will describe in the following paragraphs some applications.

II.2.2.1 Road Safety Applications

a) Accident Alert

This service allows, in the case of an accident, to warn the vehicles heading to the scene of the accident that traffic conditions are modified and it is necessary to be vigilant (Figure 2.2). It is necessary also in case of reduced density of the vehicle can keep the information in to the relay if a vehicle enters the broadcast zone. Safety messages will be issued at regular periods. And the one or more nodes designated to relay messages at regular moments will issue alerts. Messages must be reduced in size to be sent as soon as possible. Messages should include the details of the accident and the parameters of the broadcast area.



→Information and Warning Function

A vehicle will transmit a warning message when it detects a high traffic density, a slowdown or information for other drivers on the road conditions, which can also prevent their sudden braking or even accident.

Figure 2.2 : Alert function between vehicles

b) Alert in case of abnormal deceleration (plug, jobs, weather,etc)

This service allows warning motorists of specific traffic situations (Figure 2.3). The information whatever the nature of the traffic congestion information motorists need to slow down. The warning message is issued by a vehicle detecting traffic problems (e.g. heavy braking, activation of hazard lights, rain). An unmarked vehicle performing work can also be the cause of the alert message. As the alert message informing of an accident, the alert message informing of a slowdown must be transmitted to other vehicles quickly and efficiently.

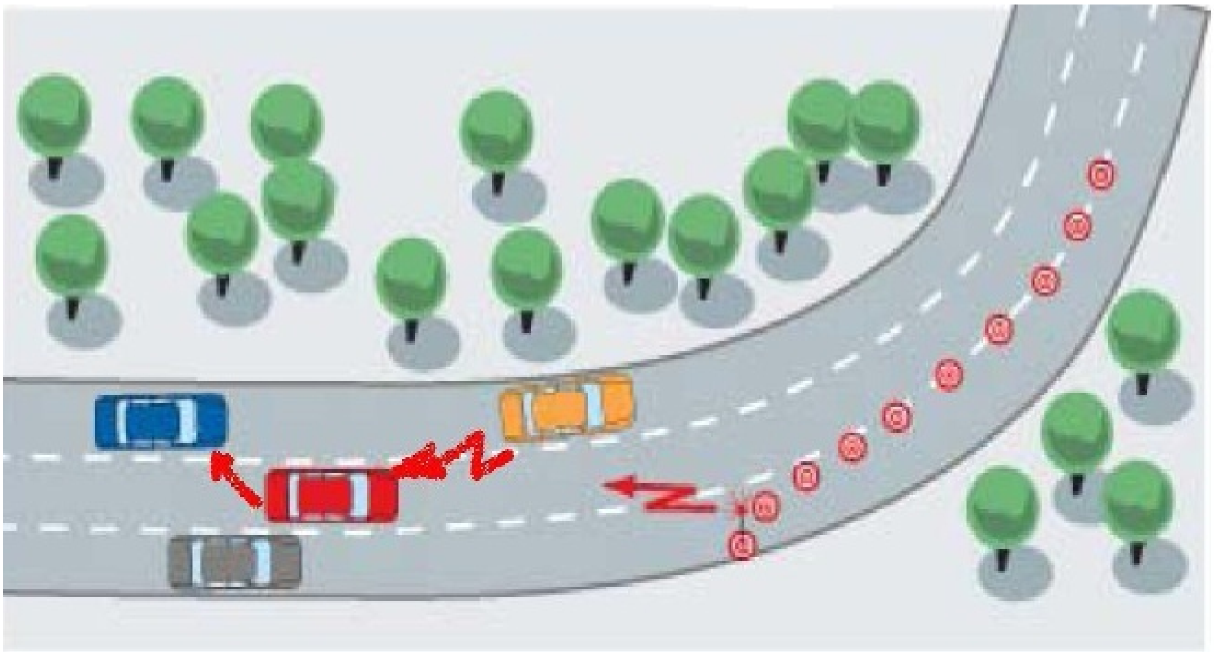


Figure 2.3 : Works on the roads

c) Collaborative driving

Collaborative driving is a concept that greatly improves the safety of road transport (reducing the number of victims), (Figure 2.4). This innovation is based on an exchange of information between vehicles equipped with instruments (e.g. sensors) enabling them to perceive their surroundings and work in groups. These groups of vehicles or ad-hoc networks can develop a collective driving strategy that would require little or no intervention from the driver. In recent years, different architectures of automated vehicles have been proposed, but most of them have little or no investment of inter vehicle communication problem. We can, also on the same principle, exchange traffic information and work to thin the road network including, for instance alternative routes. Automatic signaling is also possible with the caveat passing emergency vehicle, or the warning of a failure of a traffic light.

→Cooperation and Assistance System
A transparent traffic is one of the objectives of V2V – long demonstrated here on an intersection. The transfer of data between these three vehicles allows them to determine the order in which they all can pass safely through the intersection. The result is posted, in real-time, on screens, inside the vehicle.

Figure 2.4 : Cooperation between vehicles

II.2.2.2 Comfort Applications

a) Collaborative networks

Collaborative networks are being developed especially peer to peer networks. One can imagine a radio station or "distributed television" where each vehicle will share the music and videos that he has in his possession to build a streaming program. Collaborative cards (wiki) and classifieds services can be distributed based collaborative networks. A relay server (called "proxy-cache") may allow web browsing even in areas without internet connection. An advertising distribution system and practical informations (concerts, restaurants, ...) can be set up at the entrances to cities.

Figure 2.5 : the comfort car

b) Internet in transport

Today hot spots (Wi-Fi Internet access area) are more developed in the cities, especially with community initiatives ([5]) and telecommunications operators. By car, it is conceivable to buy music and video, at a gas station, a train station or even in full highway (moving from one car to another until the access point closer). The passengers in the car will be able to play networks, or even surf the web (Figure 2.6).

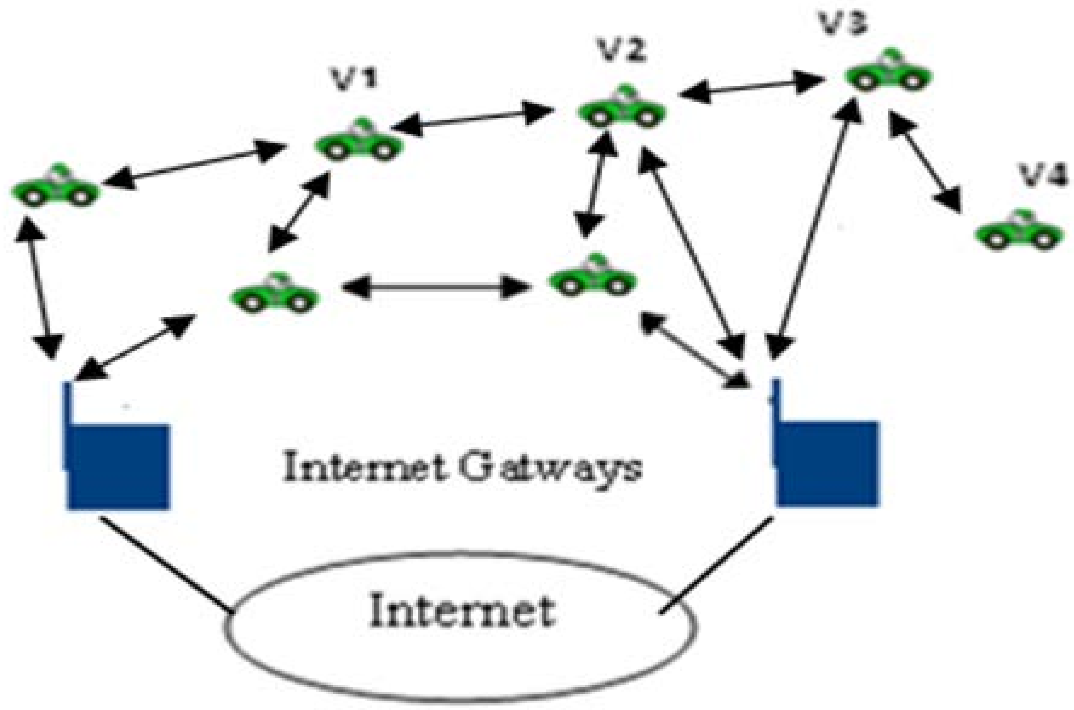


Figure 2.6 : Internet access in transport

c) Management of open spaces in parkings

This service allows gathering information on the availability of parking space in the car parks and coordination between motorists to guide them to free spaces (Figure 2.7).

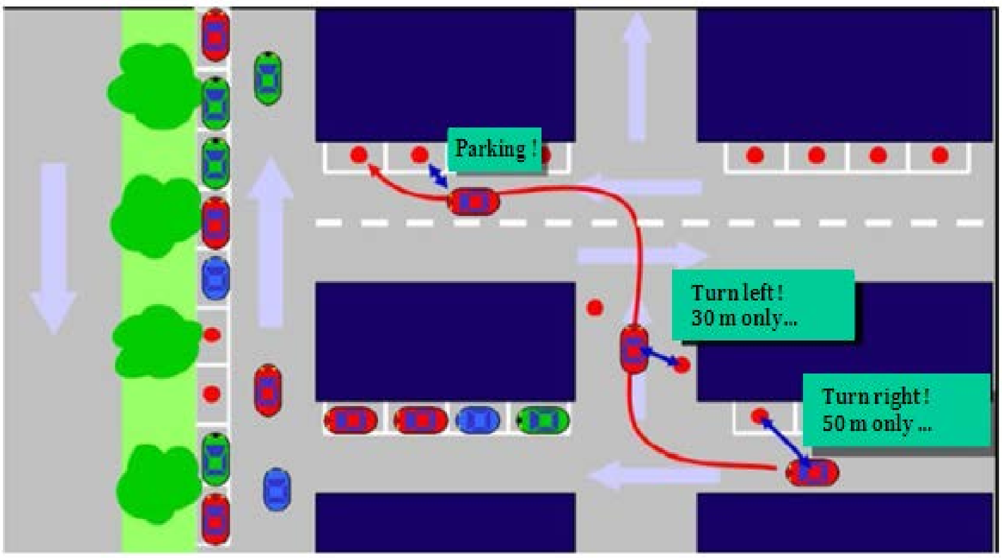
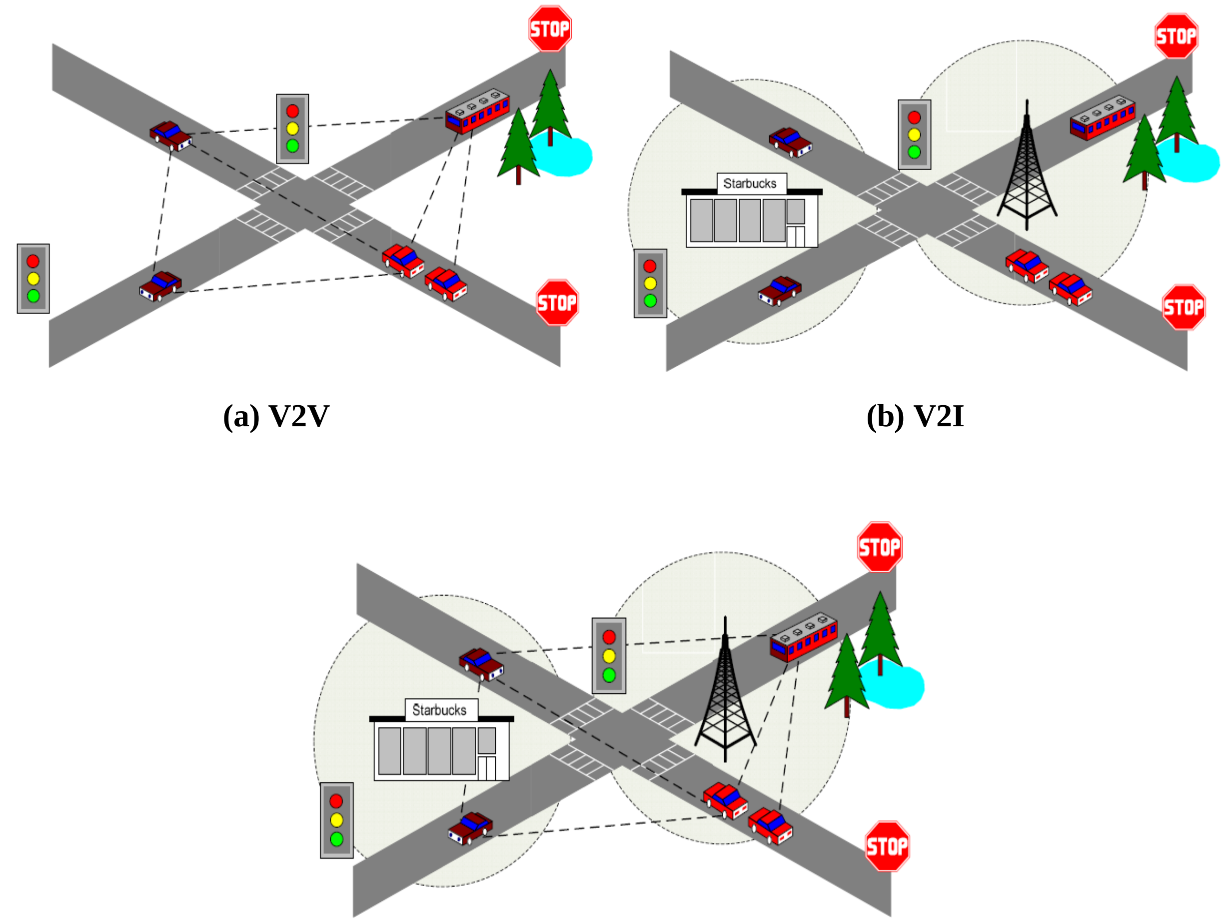


Figure 2.7 : Intelligent Parking

Given this potential, vehicular networks represent a new and promising growth market in terms of network infrastructure deployment and provision of related services.

II.2.3 Vehicular Networks Architectures

In the vehicular networks, offered services permit to distinguish several possible communications (Figure 2.8):



(a) V2V **(b) V2I**

(c) Hybrid

Figure 2.8 : VANET communication architectures [6]

The vehicular networks can be deployed by networks and/or services operators according to the configurations or the combination of the following configurations:

II.2.3.1 Vehicle to Vehicle (V2V) Communications

In this approach (Figure 2.8(a)), a vehicular network is seen as a special case of mobile ad-hoc networks MANET (Mobile Ad-hoc Network) or the constraints of energy, memory and capacity of calculation are released, and/or mobility model is not random, but predictable (sub-layer of the road network) with a very high mobility. This architecture can be used in alert broadcast scenarios (emergency braking, collision, slowdown, etc) or for the cooperative behavior. Indeed, in the context of these road safety applications, infrastructure networks have their limits, especially in terms of time. And it is clear that a multi-hop ad-hoc communication is more efficient than a communication passing through an operator network.

II.2.3.2 Vehicle to Infrastructure (V2I) Communications

We focus not just on simple inter vehicle communication systems, but also take into account the applications that use infrastructure points RSU (*Road Side Units*) (Figure 2.8(b)). These multiply services through common internet portals. Infrastructure-based services (Internet access, car-to-domestic data exchange, car-to-garage communications for remote diagnostics, etc) can benefit customers and motivate drivers to invest in additional wireless equipment for their vehicles.

II.2.3.3 Hybrid communications

The combination of these two types of communications makes it possible to obtain a very interesting hybrid communication (Figure 2.8(c)). Indeed, the ranges of the infrastructures being limited, the use of vehicles as relay makes it possible to extend this distance. With an economic aim and while avoiding multiplying the terminals each corner of street has, the use of jumps by intermediate vehicles takes all its importance.

A particular case of hybrid architecture is the VSNs Networks (*Vehicular Sensor Networks*) [7]. Indeed, The VSNs emerge as new network architecture of vehicles, which has for objective the collection and the proactive diffusion and in real-time of the relative data to the environment in which the vehicles evolve/move, more particularly in urban areas.

Indeed, the cars are provided more and more with sensors of all categories (cameras, sensors of pollution, sensors of rains, sensors of the state of the tires, GPS, etc). Those can be useful for obtaining information on the road traffic (congestions, decelerations, mean velocity of the traffic, etc), or on the parking spaces available or even for more general information such as the average fuel consumption and the rate of pollution or for applications of monitoring, via the cameras embarked on cars. We will be interested on this subject in the following chapter.

II.2.4 Potential Wireless Technologies for Vehicular Networks

The wireless networks can potentially bring a solution for the deployment of vehicular networks. It is thus advisable to make a state of the art of these technologies and various means of implementing them.

II.2.4.1 Main Wireless Technologies

There exist many solutions to exchange information by radio contact and, classically in the literature [8] [9], the various techniques are classified according to their flow and their range.

II.2.4.1.1 Global Positioning System

The GPS (Global Positioning System) is a satellite-based navigation positioning system. It was developed in 1973 by the U.S. Department of Defense for military aims. Considering its utility, the GSP has been used for determining 3D positioning for other non military applications. Especially, since the beginning of this century, it has been usually used in the vehicular context to permit the localization of the vehicle and then the computing of the itinerary.

As shown in figure 2.9, GPS uses the principle of multilateration to compute the receiver's position relative to a set of satellites orbiting the earth at a 20-km-altitude (MEO: *Medium Earth Orbit*). The satellites, using atomic clock, broadcast their positions on the 1.575-GHz-frequency. The receiver, not supplied with atomic clock, can exploit the arrival time of each signal to estimate the position of each satellite. At least, four satellites' signals are needed simultaneously to permit the computing of the three coordinates of receiver and correct the inaccuracy of the receiver clock comparing to the atomic clock using multilateration. If more than four satellites' signals are received, the accuracy of the estimated position is improved. The resulting coordinates are usually located on a preloaded map that should respect the cartography standard WGS 84 (*World Geodetic System 84*). The satellites also broadcast a secure coded signal on a second frequency (1.227 GHz) to improve the accuracy for military uses [16].

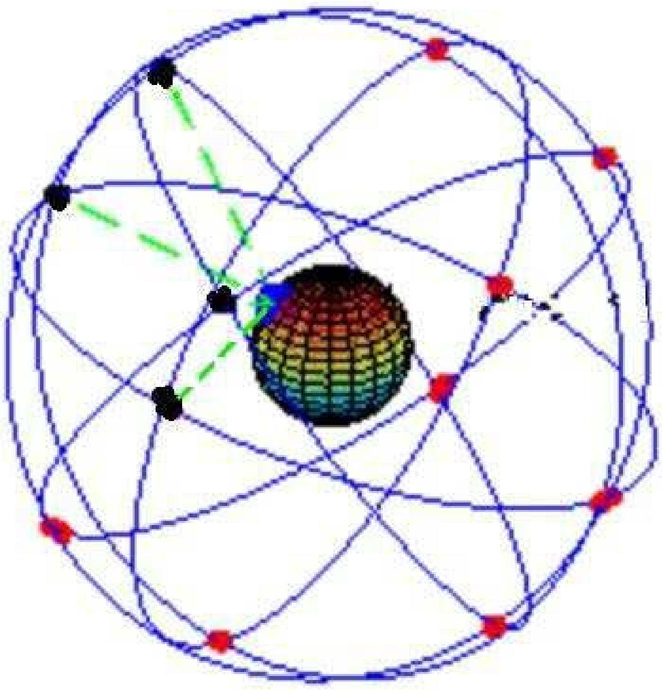


Figure 2.9 : Satellites' constellation for GPS [10]

Since GPS is controlled by the U.S. government, the ESA (European Space Agency) is currently developing a new GNSS (Global Navigation Satellite System) called Galileo. Galileo is an alternative to the GPS.

More technical details about GPS can be found in [10].

II.2.4.1.2 WPAN (Wireless Personal Area Network)

The WPAN are very low-range wireless networks (about ten meters). They are generally used within the framework of the vestimentary data processing (or Wearable Computing) which consists to communicate materials present on a person (for example an earpiece and a mobile phone). They are also used to connect computer equipments between them: for example to connect a printer or a personal assistant PDA (*Personal Digital Assistant*) to a desktop computer.

The IEEE 802.15 Working Groups is the organization to define the WPAN technologies.

To implement of such networks, principal technology is IEEE 802.15.1[11] or Bluetooth [12]. She was proposed by Ericsson in 1994 and provides a theoretical radio transmission rate of 1 Mbps for a maximum range of about thirty meters.

IEEE 802.15 proposed two additional categories of WPAN: the low rate 802.15.4 (known as ZigBee [13]) and the high rate 802.15.3 (known as Ultra-wideband or UWB [14]). The most WPAN devices use either Bluetooth or ZigBee. A small comparison between these two technologies is illustrated in the table 2.1.

Table 2.1 : ZigBee vs. Bluetooth [16]

Protocol	**ZigBee**	**Bluetooth**
IEEE	802.15.4	802.15.1
Memory	4 – 32 Kb	250 Kb +
Power Autonomy	Years	Days
Nodes number	65 000 +	7
Data rate	250 Kbps	1 Mbps
Transmission range	100 m	10 – 100 m

II.2.4.1.3 WLAN (Wireless Local Area Network)

These networks are mainly based on the IEEE 802.11 [15] supported by the WECA (*Wireless Ethernet Compatibility Alliance*) in 1999. The purpose of this alliance was to ensure interoperability among the IEEE 802.11 products of various vendors. So, WECA developed a WiFi (*Wireless-Fidelity)* test that has become a synonym of IEEE 802.11. Table 2.2 summarizes the main IEEE 802.11 standards.

Table 2.2 : IEEE 802.11 standards [16]

Standard	description
IEEE 802.11 a	It works at 6, 9, 12, 18, 24, 36, 48, 54 Mbps in 5 GHz band
IEEE 802.11 b	It works at 5.5 and 11 Mbps in 2.4 GHz band
IEEE 802.11 e	MAC enhancements for QoS (*Quality of Service*).
IEEE 802.11 g	It works at the same data rates as IEEE 802.11a but in 2.4 GHz band.
IEEE 802.11 i	MAC enhancements for security.
IEEE 802.11 n	High throughput (100 Mbps+).
IEEE 802.11 p	Enhancement required supporting Intelligent Transport Systems (5.9 GHz ITS band).

As shown in Table 2.2, a working group of the IEEE has defined a new wireless communication standard for vehicular communication called IEEE 802.11 p or WAVE (*Wireless Access in Vehicular Environment*). The aim of this group is, on the one hand, to define rules for fast network recognition and setup, and on the other hand, to allow differentiation between emergency use and normal use. Distance coverage up to 1000 m and devices speed of almost 200 km/h are in the scope of the task group. Higher transmitted power will be defined for special use cases (e.g. connection among firemen vehicles or ambulances).

The WLANs are generally used inside companies, universities but also among individuals since the development of high debit offers.

They bridge the gap between telephony and computing and have many advantages: (i) mobility: they allow a real mobility of computing equipment. (ii) throughput: they provide data rates compatible with the existing computer applications. (iii) frequency band: they use free frequency bands, and (iv) speed of deployment: they require little infrastructure with easy implementation that permit quick connectivity to the network.

You should always weigh these advantages by the fact that radio communications are less reliable than wired due to radio interference, multipath problems of waves, electromagnetic irregularities, etc. In addition, WLANs are less secure than wired networks: the medium to transit information being air, it is open to potential intruders.

II.2.4.1.4 WMAN (Wireless Metropolitan Area Network)

WMAN is also called WLL (*Wireless Local Loop)*, were originally designed to inter-connect geographical areas difficult to access using a wireless network. Currently these networks are used in certain cities in the world to provide an Internet access to the inhabitants. The networks based on IEEE 802.16 technology have a range about a few tens of kilometers (50 kms of announced theoretical range) and a theoretical radio transmission rate can reach 74 Mbps for IEEE 802.16-2004 [17] (or IEEE 802.16 d), more known under the trade name of WiMAX. IEEE 802.16 e-2005 [18] (or IEEE 802.16 e), is known under the name of "Mobile WiMAX" and contrary to IEEE 802.16-2004 (Fixed WiMAX,), it has a support for mobility.

Table 2.3 shows a small comparison between IEEE 802.16-2004 and IEEE 802.16 e-2005

Table 2.3 : IEEE 802.16-2004 vs. IEEE 802.16e-2005 [16]

Standard	Frequency band	Data rate	Mean range
IEEE 802.16-2004	2-11 GHz	75 Mbps	10 Km
IEEE 802.16 e-2005	2-6 GHz	30 Mbps	3.5 km

II.2.4.1.5 WWAN (Wireless Wide Area Network)

WWAN gather in particular the various cellular networks of first and second generation but also the satellite networks. The mobile cellular networks based on technologies like GSM (*Global System for Mobile Communication*) and GPRS (*General Packet Radio Service*) [19]. The satellite networks are based on the DVB-S (*Digital Video Broadcasting-Satellite*) standards to transmit information and propose high data rates (about 40 Mbps for DVB-S standard).

It is also in this category that the third-generation telephone networks using UMTS (*Universal Mobile System Telecommunication*) [20] standard can be classified for the transmission of voice and data. This UMTS standard proposes theoretical radio transmission rates can reach up to 2 Mbps on distances of several kilometers.

The UMTS technology upgrade has been baptized LTE (Long Term Evolution or 4G) [21]. The 4G LTE technology enables higher communication speeds to be reached with lower packet latency (a requirement for many actual services), and then, 3GPP LTE will enable cellular communications to move forward to meet the needs of vehicular networks based services for a reliable cellular technology.

The figure 2.10 presents the various categories of wireless networks described above.

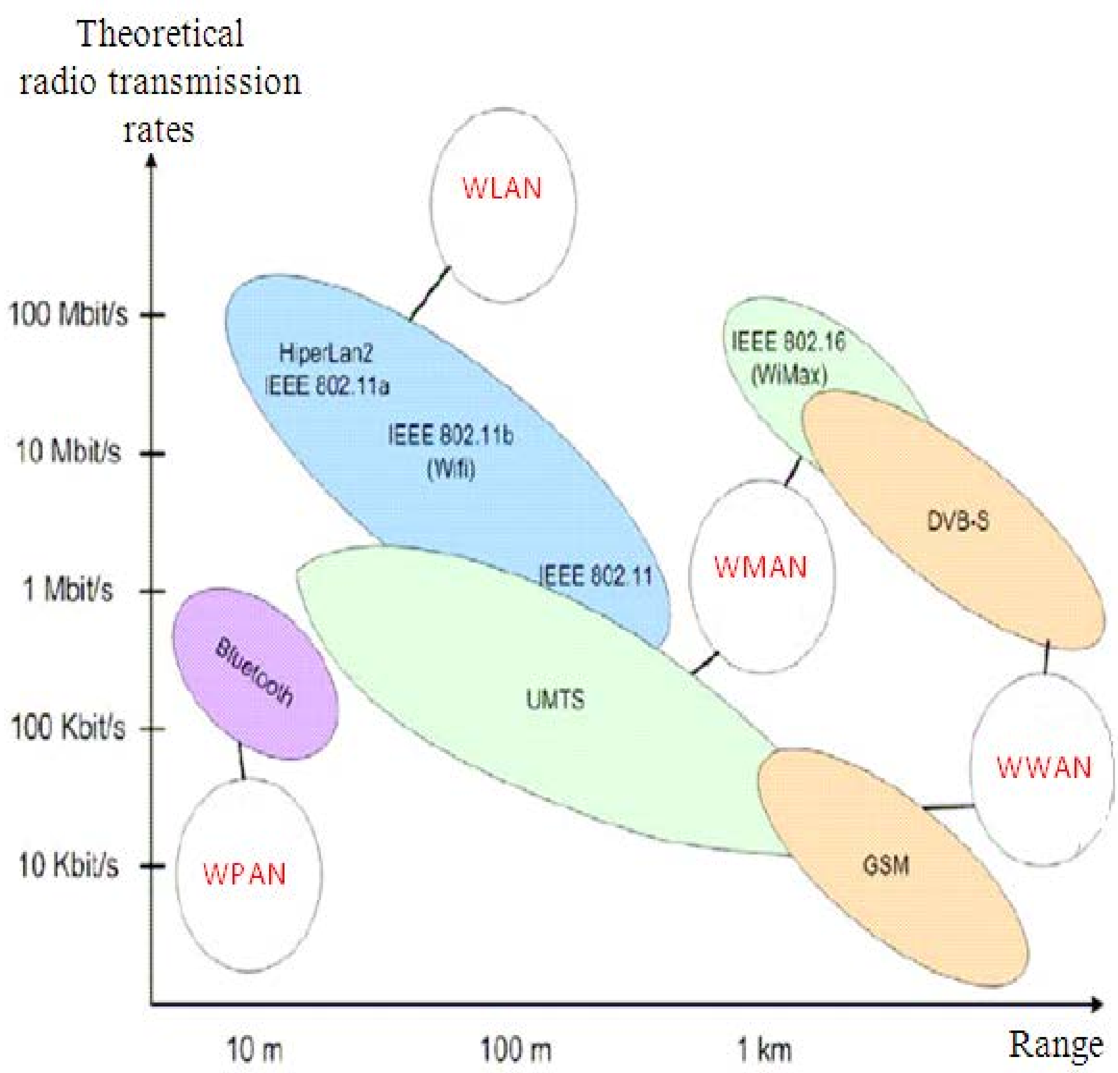


Figure 2.10 : Various categories of wireless networks [8]

II.2.4.2 Technologies used for Vehicular Networks deployment

With the rapid development of information technologies, there are several candidates that can be potentially used in wireless Inter-Vehicle (InV), Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communications.

Tables 2.4 and 2.5 summarize the main technologies available for, respectively, InV, V2V & V2I communications.

Table 2.4 : Wireless technologies for InV communications [22]

	ZigBee	**UWB (ultra-wide band)**	**Bluetooth**	**Wireless USB (Universal Serial Port**	**Wireless CAN**
Standard / Technology	Ratified in December 2004	Transmitting information spread over a large bandwidth (>500 MHz)	First launched (1998)	Short-range, high bandwidth based on the WiMedia Alliance's UWB	CANRF (CAN over RF) / CAN Bridge
Coverage	10 and 75 meters	< 60 cm for a 500 MHz wide pulse, < 23 cm for a 1.3 GHz bandwidth pulse	1 meter, 10 meters, 100 meters	3 meters up to 10 Meters	500 feet (152.4 m)
Bit rate	20-250 kbps per channel	Extremely high data rates 1 Gbps+	3 Mbps (Version 2.0 + EDR), 53-480 Mbps (WiMedia Alliance (proposed)	480 Mbps at distances up to 3 meters and 110 Mbps at up to 10 Meters	20kbps / 52.8 kbps – 164.4 kbps
Applications	Entertainment, smart Lighting control, advanced temperature control, safety & security, sensors, etc	Used at very low energy levels for short-range high-bandwidth communications by using a larger portion of the radio Spectrum	Connect and exchange information between devices	Game controllers, digital cameras, MP3 players, hard disks and flash drives. Also suitable for transferring parallel video streams	Communication among sensors and ECUs

Table 2.5 : Wireless Technologies for V2V & V2I communications [22]

	UMTS (3G)	**WiFi (Wi-Fi Alliance version of 802.11n)**	**WiMax**	**WAVE**
Standard / Technology	Third generation cellular technology (UMTS) in 2001	New Wi-Fi technology with MIMO standard in 2009, 802.11n standard in 2009	Broadband technology in 2007	A short to medium Range communications
Coverage	kilometers	500 m	5 km	1000m
Bit rate	2-3 Mbps	600 Mbps using MIMO	75 Mbps	6 to 27 Mbps
Applications	Between vehicle and mobile phone communication	Roadside to vehicle and vehicle to vehicle communication	Internet access, Email, VoIP (Voice over IP)	Roadside to vehicle and vehicle to vehicle communication

As shown in Table 2.6, no specific technology can come up to the entire vehicular network's requirements. Always, all or some of the proposed technologies are needed simultaneously in heterogeneous communication networks to allow the deployment of the different vehicular services envisaged nowadays.

Table 2.6 : Comparison between Wireless Technologies for Vehicular Networks [16]

	802.11p	LAN 802.11a/b/g	UMTS
Latency	Excellent	Good	Good
Coverage	Weak	Very wreak	Medium
Bandwidth	Medium	Good	Good
security	Good	Weak	Good
Reability (in vehicle's vicinity)	Excellent	Excellent	Medium
Reability (beyond vehicle's vicinity)	Weak	Weak	Excellent

In fact, the combination of the different technologies introduced above (3G, IEEE 802.11 p, WLAN, etc.) permits to obtain an attractive heterogeneous communication. The complementarity of these technologies permits to increase the service coverage area, to minimize the inter-vehicle communication delays, to guarantee more connectivity and to offer both V2V communication and communication between vehicle and centralized servers. In addition, a heterogeneous communication permits to share the communication load between the different networks. Then, WLAN technologies could be used, for example, to off-load the operator network.

II.3 Vehicular Networks: Actors, Projects, and Standardization

II.3.1 Main actors in the field of VANET

The many applications that introduce vehicle networks have attracted the interest of several entities, whether governmental organizations, standardization companies or research centers. As shown in Figure 2.11, there are many national / international projects dedicated to them. We can quote Consortium VSC (Vehicle Safety Consortium, US) [23], CAMP (Collision Avoidance metrics Partnership, US) [24], C2C-CC (Car-2-Car Communication Consortium, Europe) [25], ASV Program (Advanced Safety Vehicle, Japan) [26], many standardization efforts as we will see below and actual experiments such as made by the program VII (Vehicle Infrastructure Integration, US) [27].

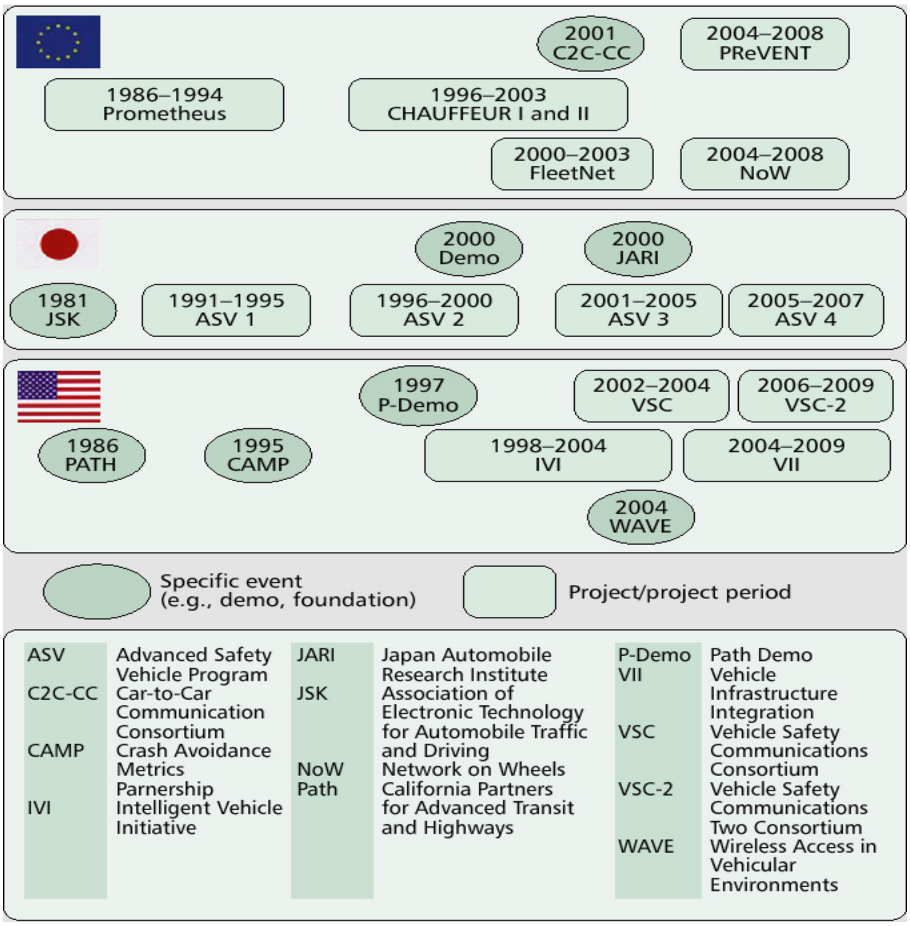


Figure 2.11: Actors for VANET Networks [28]

II.3.2 Related Projects

Many research, development and standardization on the inter communications vehicles are currently in progress. In Europe and around the world, major R&D project was initiated to form the basis of a transmission system European intelligent. Below are described some major projects addressing vehicle communications:

- **DRiVE**: the project DRiVE (Dynamic Radio for IP Services in Vehicular Environments) [29] aims to work on convergence between different cell technologies and high-speed networks (GSM [19], UMTS, DAB and DVB-T) to bring up the substrate necessary for the development innovative IP services for vehicles.

- **FleetNet (2000-2003):** For the purpose of communicating vehicle to vehicle within a group, the project FleetNet (Internet on the road) [30] was launched by six German car manufacturers and three universities, it was opened to the suppliers, the research organizations and to other partners. The main purpose of this major project is the development of communications platform for vehicular networks, to implement an intelligent system, and to standardize the proposed solutions in aim to improve drivers' and passengers' safety and comfort. The FleetNet routing architecture is based on a location and navigation system. For providing the Internet access service, FleetNet considers vehicles to infrastructure communications.

- **NoW (2004-2008)**: The project NoW (*Network-on-Wheels*) [31], the successor of Fleetnet project [30], is working on implementation of communication protocols and data security algorithm in vehicular networks. Based on the IEEE 802.11 wireless technology and a routing based on the position in the context of communication vehicle to vehicle or vehicle to infrastructure, the aim is to establish a reference communication system and contribute to standardization of such solution in Europe.

PReVENT (2004-2008): the European Integrated Project PReVENT [32] aims to develop related applications road safety by using advanced detection devices and communication integrated in embedded systems driving aid. These systems analyze the nature and the significance of any potential danger, while taking into account the situation of the driver.

- **Carlink (2006 to 2008) [33]**: This project developed by the University of Malaga and funded by the Spanish government and the European commission has main objective the development of an intelligent wireless traffic service platform between cars and supported by wireless transceivers beside the road. The first objective of this project wasn't the car-to-car communication to avoid unexpected events, but real-time local weather data, urban transport traffic management, etc, through the wireless communication between cars and local data base station. In order to transmit this kind of information cars could communicate to each other as members of an ad-hoc network. The radio communications systems being tested on this project were evolutionary extensions of WLANS, WiMAX or mobile communications such as GPRS and the systems were tested on different weather conditions with different topologies.

- **SeVeCom (2006-2008)**: SeVeCom project (*Secure Vehicular Communication*) [34] is interested in the security of future vehicular networks, including the safety and anonymity of V2V and V2I communications.

- **Watch-Over (2006-2008)**: The purpose of WATCH-OVER [35] is to design and develop a Cooperative system for the prevention of accidents in accident-prone areas. The innovative concept is represented by a vehicle platform and a user module. The system is based on short distance communication and vision sensors.

- **COMeSAFETY** [36] (2006/2009) is a support activity, which coordinates the European research and standardization efforts for vehicle-to-vehicle and vehicle-to infrastructure communication as the basis for cooperative intelligent road transport systems. In close cooperation with all stakeholders, the project is defining a common European architecture that harmonizes current activities and represents a framework for future deployment of the systems. A common European ITS architecture will fasten the technical developments and consequently the future deployment of the systems.

- **VICS** (*Vehicle Information and Communication System*) [37] (1990/2010) is a Japanese national project in ITS field, in cooperation with Japanese National Police Agency, Ministry of internal affairs and communications, and Ministry of Land, Infrastructure and Transport. By meeting the demand of each user for avoiding traffic congestion, VICS aims at solving problem of traffic congestion, and achieving comfortable motorized society.

- **CVIS (2004-2010)**: CVIS project (*Cooperative Vehicle-Infrastructure Systems*) [38] aims to devise, implement and test new technologies needed to allow to vehicles communicate with each other and with the road infrastructure nearby. Its ambition is to start a revolution in mobility for travelers and goods designing entirely new modes of interaction between drivers, their vehicles, goods carried and road infrastructure. Thus, the CVIS project aims to improve the safety and efficiency of road transport and reduce its impact on the environment.

- **SafeSpot (2006-2010)**: the main objective of this European project SafeSpot [39] is to improve safety road. Studies have shown that the driver is 90% responsible for the accident, mainly for causes of inattention or errors of judgment. Also, the project SafeSpot proposes to develop a set of support providing the driver indication of its margin of safety. This is performed sufficiently in advance to an approaching difficulty.

- **GST (2006-2010)**: the overall objective of GST project (*Global System for Telematics*) [40] is to create an environment in which innovative automobile telematics services can be cost-effectively created and provided. It is expected to expand the range of economic telematics services that are available to manufacturers and consumers.

- **COOPERS** (*Co-operative Systems for Intelligent Road Safety*) [41] (2006/2010) focuses on the development of innovative telematics applications on the road infrastructure with the long term goal of a "co-operative traffic management" between vehicle and infrastructure. COOPERS attempts to improve road sensor infrastructure and traffic control applications, develops a communication concept and applications able to cope with the requirements for infrastructure-to-vehicle communication, and demonstrates results at major European motorways with high-density traffic.

- The **EU** project **GeoNet** [42] (2008/2010) implements a reference system for vehicular ad-hoc networking using concepts for geographical addressing and routing. Particular focus lies on integration of GeoNetworking with IPv6 and solutions for IP mobility support. In GeoNet, a vehicle is regarded as a mobile network, where the NEMO [43] [44] protocol handles Internet connectivity of the nodes in the mobile network with intermittent access to roadside units. For wide deployment of the project results, it is planned to provide the GeoNet implementations to other R&D projects.

- The **InteliDrive** project [45] (2005/2013) (old name: The *Vehicle Infrastructure Integration* VII) [27]: This initiative is a cooperative effort between Federal and State departments of transportation (USDoT) and automobile manufacturers. Together they are evaluating the technical, economic, and social/political feasibility of deploying a communication system that will be used primarily for improving the safety and efficiency of the road transportation system. Additionally, VII will enable the deployment of a variety of applications that support private interests, including those of vehicle manufacturers.

II.3.3 Standardization and normalization Activities

II.3.3.1 DSRC ,WAVE and IEEE 802.11p

In the 1999, the U.S.FCC (*Federal Communication Commission*) reserved 75 MHz in the 5.9 GHz band (5,850 –5,925 GHz) to DSRC [46] spectrum to be used exclusively for V2V and V2I communications. This standard is adopted in 2002 by the ASTM (*American Society for Testing and Materials*). In 2003, the IEEE working group resumed the work to define a new standard dedicated for inter-Vehicles communications, named WAVE (Wireless in Ability Vehicular Environments) and also known as IEEE 802.11p [47]. This new standard is designed to support longer ranges of operation (up to 1000m), high-speed vehicles (up to 500 km/h), extreme multipath environments with many reflections with long delays (up to 5 us), overlapped ad-hoc networks that need to operate with high quality of service and nature of the automotive applications to be supported (e.g. reliable broadcast).

- **Assigned spectrum**

The DSRC spectrum is structured into seven 10 MHz channels (Figure 2.12). The central one (5.885–5.895 GHz) is the Control Channel (CCH) and is restricted to safety communications only. The first and the last channel are reserved for future advanced accident avoidance applications and high powered public safety usages. The rest are Service Channels (SCH) available for both safety and non-safety usage and a 5MHz guard band.

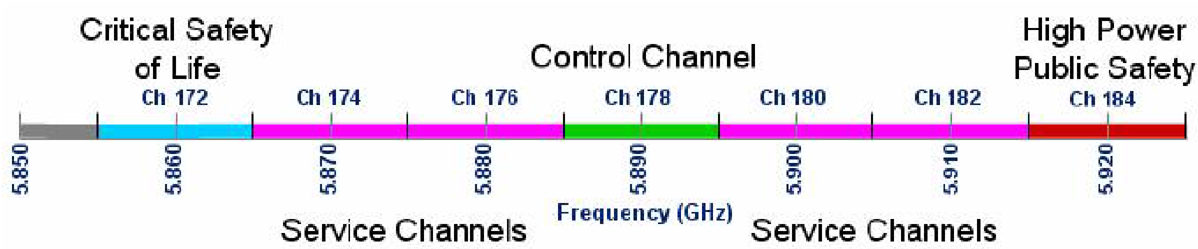


Figure 2.12 : Distribution of DSRC spectrum [22]

The allocation of dedicated spectrum in Europe has been more difficult, due to the multiple parts involved. The Electronic Communications Committee (ECC) reserved in August 2008 [48], [49] five channels of 10 MHz. These channels are placed in the frequency band between 5,875 and 5,925 GHz for road safety, this band is not exactly the same as in the US , however ECC recommends to use the spectrum between 5.855 - 5.875 for non- safety ITS applications. Transmission power in this band is limited to 33 dBm.

On the other hand, in Japan, the frequency bands for DSRC is allocated in the 5.8 GHz band (5.770 –5.850GHz).

- **WAVE System Architecture Overview**

The WAVE standards cover multiple layers of the open systems interconnection (OSI) model (Figure 2.13). The specification of the physical (PHY) layer and the Media Access Control (MAC) sublayer for DSRC are addressed in the IEEE 802.11p.

WAVE physical (PHY) and MAC layers are based on 802.11a. However, some modifications are needed to improve the performance in VANET environments. This physical layer is able to offer a flow rate between 6 and 27 Mbps (for distances up to 1000 meters) with OFDM modulation (Orthogonal Frequency Division Multiplexing) and 10 MHz channel (half of the 802.11a) in order to have longer guard intervals and therefore, support higher delays, and best performance against multipath errors. Also, the MAC layer of 802.11p uses the principle of CSMA / CA (Carrier Sense Multiple Access with Collision Avoidance) developed in the MAC protocol of IEEE 802.11, with a complement bringing the management of the quality of service and the protocol support of priority marking. Indeed, the MAC layer of the WAVE is managed using priorities access as the IEEE 802.11e standard. Thus, the contention window is calculated according to the four priorities available.

The rest of the protocolar stack of DSRC being located between the link layer and the application layer is being standardized by the work group IEEE 1609 [50] working group that tackles layers 1, 2, 3 and 4 issues. Hence, IEEE 1609 is a standard for the high layers on which IEEE 802.11p is based. Indeed, the IEEE 1609 Family of Standards for WAVE consists of four standards: (i) IEEE P1609.1-WAVE Resource Manager- defines the basic application platform and includes application data read/write protocol between RSU and OBU (On-Board Unit), (ii)

IEEE P1609.2 - WAVE Security Services for Applications and Management Messages- defines the 5.9 GHz DSRC Security, anonymity, authenticity, and confidentiality, , (iii) IEEE P1609.3 - WAVE Networking Services- defines network and transport layer services, including addressing and routing, in support of secure WAVE data exchange , and (iv) IEEE P1609.4 - WAVE Multi- Channel Operations - provides DSRC frequency band coordination and management, where it manages lower layer usage of the seven DSRC channels, and integrates tightly with IEEE 802.11p standard.

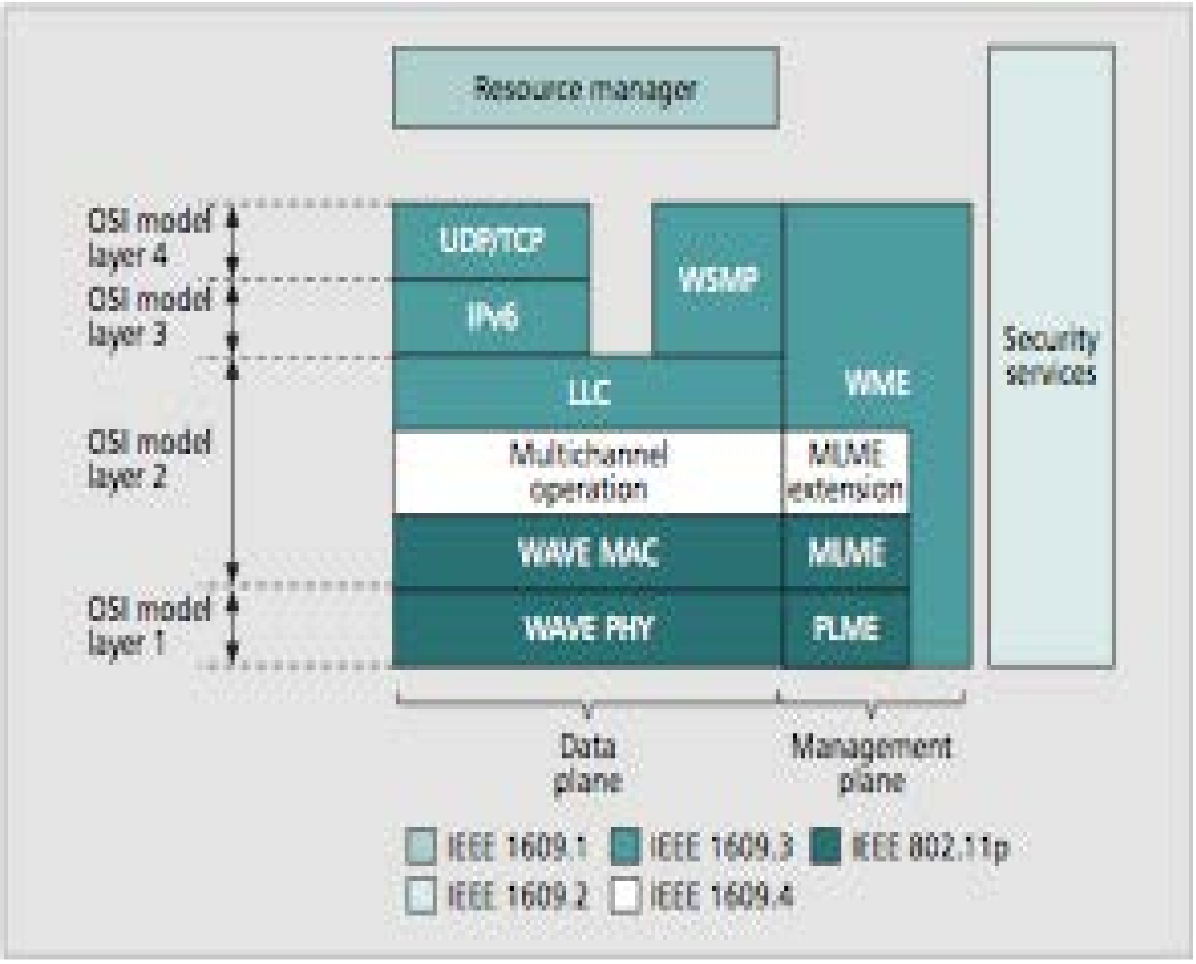


Figure 2.13 : OSI model architecture of WAVE [22]

 IEEE 802.11p

The philosophy of IEEE 802.11p design is to make the minimum necessary changes to IEEE 802.11 PHY layer so that WAVE devices can communicate effectively among fast moving vehicles in the roadway environment. The physical layer changes between Wi-Fi and IEEE 802.11p are displayed in Table 2.6.

Table 2.7 : Comparison between Wi-Fi standards and 802.11p [22]

	802.11p WAVE	Wi-Fi
Bit rate	3-27 Mb/s	6-54 Mb/s
Communication range	< 1000 m	< 100 m
Transmission power for mobile (maximum	760 mW (US) 2 W EIRP (EU)	100 mW
Channel bandwith	10 MHz 20 MHz	1-40 MHz
Allocated spectrum	75 MHz (US) 30 MHz (EU)	50 MHz @ 2.5 GHz 300 MHz @ 5 GHz
Suitability for mobility	High	Low
Frequency band(s)	5.86-5.92 GHz	2.4 GHz, 5.2 GHz
Standards	IEEE, ISO, ETSI	IEEE

II.3.3.2 ISO: TC204 / WG16 – CALM

The worldwide ISO TC204 / WG16 has produced a series of drafts ITS relating to the radioelectric interface necessary in short or long range known as CALM (Continuous Air-interface, Long and Medium Range) [51]. CALM's goal is to develop an embedded software platform in vehicles that provide the interface between several communication technologies

(2G, 3G, 5 GHz, 802.16e) and handover between technologies enabling seamless mobility. It will be able to choose automatically to pass through Wi-Fi, GSM or WAVE depending on the availability of networks and the message to be transmitted. CALM also may include new communication technologies. Thus the targeted applications ranging from security Road to commercial applications, for the multitude of technologies considered.

The CALM concept, that ETSI is also helps to develop, is at the center of several European projects such as the above mentioned projects (CVIS [38] and Safespot [39]) that test CALM solutions. In the US, the initiative VII [27] uses standard IEEE 802.11p / 1609 at 5.9 GHz expected to be aligned with CALM 5.9 GHz Standards, although the IEEE standards do not include the vertical handover between different access technologies.

II.3.3.3 ETSI: TC ITS

At European level, the ETSI [52] (European Telecommunications Standards Institute) has created a Technical Committee TC ITS in order to develop standards and specifications for ITS. The TC ITS is organized into five Working Groups: WG1- User & Application requirements, WG2- Architecture and cross layer issues, WG3 - Transport and Network, WG4- Media and related issues, and WG5- Security. In the WG3 for example, they are interested in an addressing and geographic routing.

The committee has set up a road map in order to produce a set of standards from the communication architecture to the specification of protocols with a set of tests. The ETSI ERM TG37 (Electromagnetic compatibility and Radio spectrum Matters) working group is at the head of this committee. ERM TG37 also cooperates with other ETSI committees and with other SDOs (Standards Development Organizations), particularly ISO TC204 (CALM). Indeed, it contributes to the development of ISO TC204 group standards and also assumes the access heterogeneity.

II.3.3.4 The consortium Car-to-Car (C2C-CC)

The communication consortium Car2Car [25] was launched by six European car manufacturers and open to suppliers, research organizations and other partners. The Car2Car consortium has set the objective of improving road safety, to effectively manage traffic through the use of IVC. The main tasks of communication consortium Car2Car are :(i) the creation of an open European standard for V2V communications based on wireless LAN components, (ii) development of prototypes and systems V2V demonstrators for the traffic safety applications, (iii) promoting the attribution of a free exclusive frequency band for the Car2Car applications in Europe, and (iv) development of deployment strategies and economical models for market penetration.

The consortium aims to allowing interoperability among cars from different car manufacturers and suppliers of OBUs and RSUs. In this context, the C2C-CC is concerned with real-live demonstrations of safety applications for tangible ad-hoc networks.

II.4 Vehicular Networks : Characteristics, Constraints and Challenges

II.4.1 Characteristics of Vehicular Networks

Vehicular networks have specific characteristics that distinguish them from other types of mobile networks (ad-hoc networks, sensor networks):

- **Displacement environment and mobility model**

The environments considered in mobile ad-hoc networks are often limited to open spaces or indoors (as the case of a conference or within a building). Vehicle movements in turn are related to road infrastructures in highways or within a metropolitan area. The trajectories can be predictable and the environment can be urban, rural or motorway. The constraints imposed by this type of environment, namely the radio obstacles (e.g. due to buildings) and the effects of multipath and fading, significantly affect the mobility model and the quality of radio transmissions to be considered in protocols and proposed solutions. In addition, mobility is directly related to driver behavior.

Processing capabilities, energy and communication

Unlike the context of ad hoc networks or sensor networks or the energy constraint, for example, represents one of the issues addressed in the literature, the network elements VANET have no limit in terms of energy and have a high processing capacity and may have multiple communication interfaces (Wi-Fi, Bluetooth, and others).

High mobility, network topology and connectivity

Unlike ad hoc networks and sensor networks, the VANET networks are characterized by a high mobility, related to the cars speed which is more important on the motorways. Therefore, an element can quickly join or leave the network in a very short time, making topology changes very frequently (Figure 2.14).

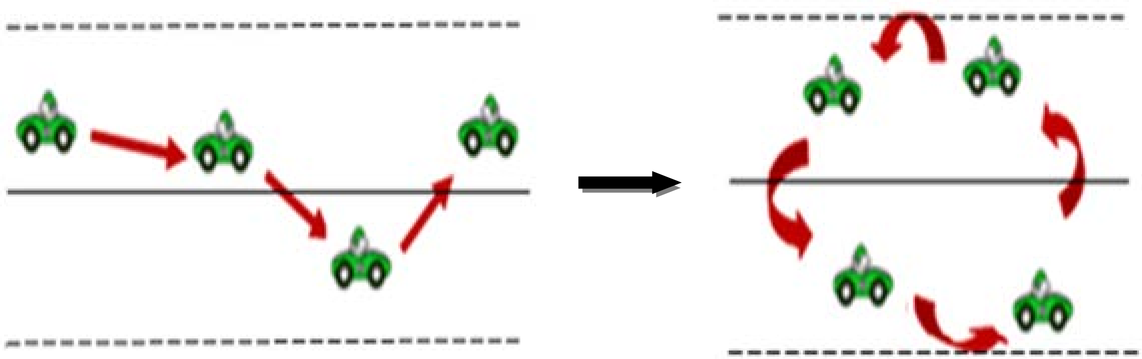


Figure 2.14 : Topology change of Vehicular Networks

In addition, problems such as network partitioning can frequently appear, mainly when the IVC system is not widespread and equipped in the majority with vehicles. One of the constraints and the parameters to study closely is the fragmentation problem of the VANET network according to the spatiotemporal conditions. This implies a low connectivity and very limited lifetimes of roads. Moreover, the inherent properties to VANET networks notably in terms of size open scalability problematic and require a complete revision of existing solutions.

II.4.2 Constraints and challenges

The vehicular networks properties engender significant technical challenges that need to be solved in order to deploy vehicular communications. In this section we cite a number of these challenges [53]:

- ***Access to the channel*** [54]: The vehicular networks use radio communications. Therefore, it is important to design specific MAC solutions for vehicular networks that help to provide quality of service and manage priorities in solving problems of radio interference, multipath problems of waves, electromagnetic irregularities, distributed resource allocation in a dynamic topology, etc.

- ***Self-organization:*** Self-organization facilitates the vehicular network's management task and permits the deployment of wide panoply of services in large scale. A self-organizing architecture takes advantage of node properties to issue a global virtual structure enabling the network self-organization. This structure must be sufficiently autonomous and dynamic to deal with any local change of the network topology in order to optimize the vehicle-to-vehicle and vehicle-to-infrastructure communication with regard to nodes' high mobility.

Self-organization is a critical issue for vehicular networks. Most researches suggest virtual backbone [55] and clustering [56] as most efficient structures to self-organize the vehicular network and to achieve scalability and effectiveness in many operations like routing, data collection and data dissemination, etc.

The last issue of this PhD thesis is to define a reliable self-organizing architecture based on clustering permitting the deployment of many services.

- ***Routing:*** In order to establish V2V or V2I communications, vehicles must define a routing protocol. Indeed, when the terminals are not in a direct radio transmission range, the unicast routing is required to establish communication between two vehicles or between a vehicle and a fixed relay. Each vehicle can thus take the role of a transmitter, receiver or router.

In the literature many routing protocols have been designed for vehicular networks [57] [58]. These routing protocols must consider the VANET's specific characteristics such as the disconnected network problem which is a crucial research challenge for developing a reliable and efficient routing protocol in vehicular networks that can support highly dynamic network topologies.

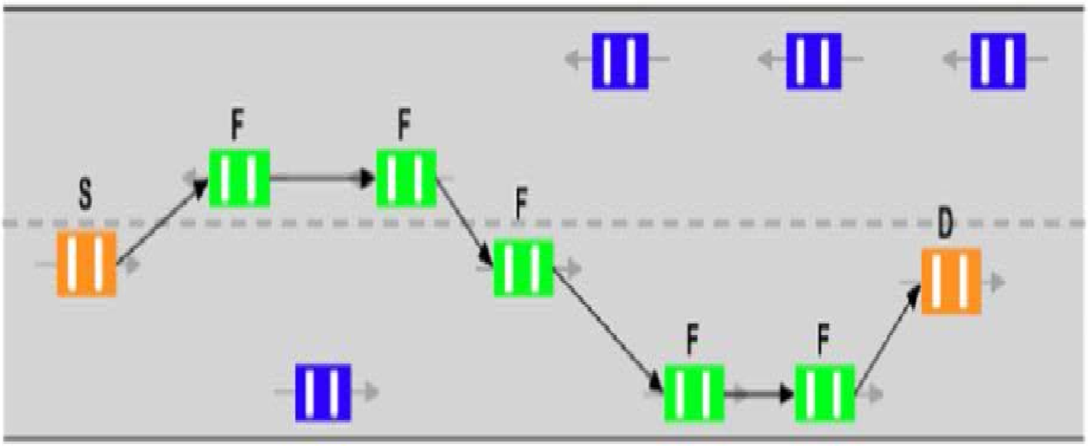


Figure 2.15 : Communication with single destination (unicast)

- ***Data collection*** [59]: is an essential paradigm in vehicular networks. It permits to bring together data collected from all vehicles' sensors and aggregate them. The processing of the data collected from all vehicles permits to provide interesting global information like info-traffic and parking availabilities for drivers. An efficient data collection solution should optimize the use of resources and be adapted with the different environments (urban environment, highways, etc.).

- ***Data Dissemination:*** the dissemination algorithms [60] consist in forwarding informations from one source to one or more destinations. The dissemination of information should be mostly broadcast like in the safety applications, in a way to assure the messages propagation to the required cluster of vehicles in the appropriate delays with a great reliability and a better use of resources.

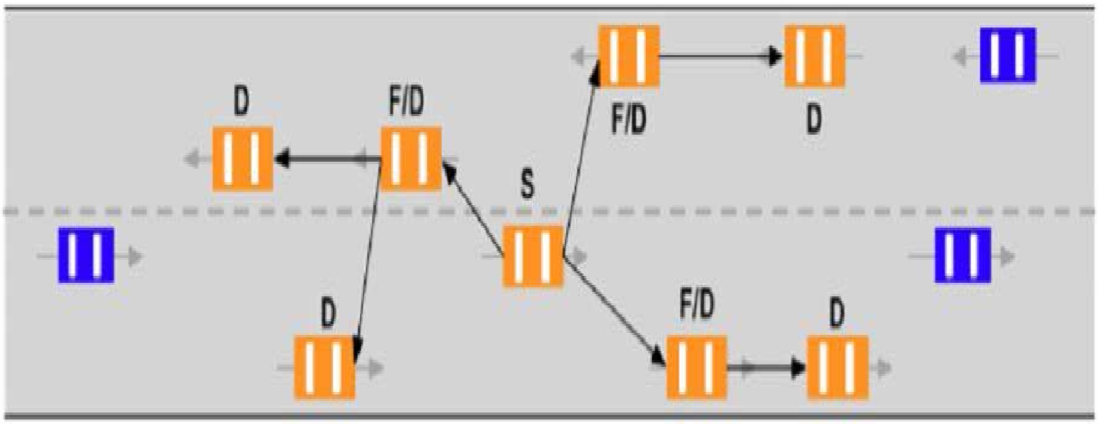
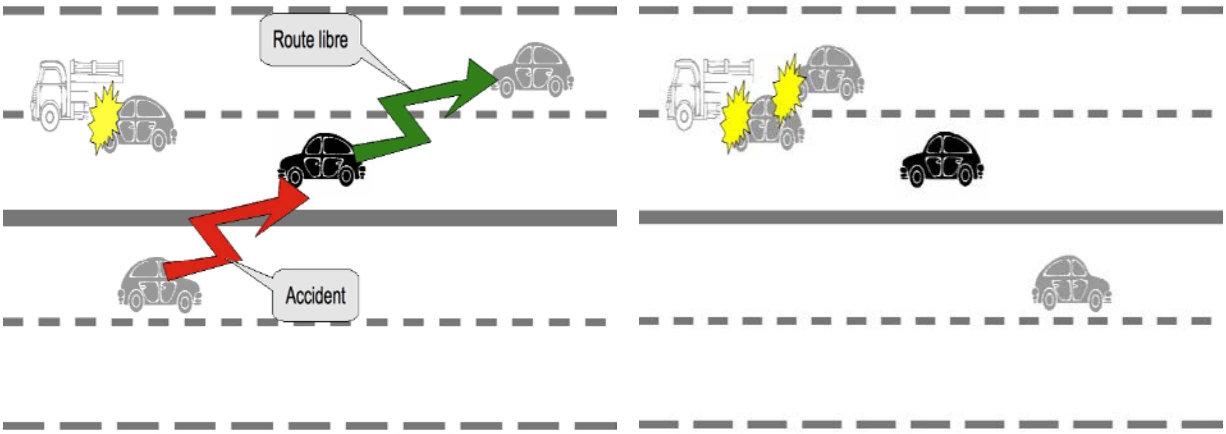


Figure 2.16 : Limited diffusion to vehicles with two hops (multicast)

- ***Security:*** security [61] is a major challenge having a great impact on the future deployment of vehicular networks and their applications. In this context, the development of security mechanisms instituting confidence relationships between communicating entities and guaranteeing the access control to services as well as the security of data transfers that includes authenticity, message integrity and source authentication, privacy, and robustness, proves of paramount importance. A model of possible attacks on inter-vehicle communication systems is presented in [62] and defines a set of guidelines which have been used for the proposal of a novel security framework called VaneSe [63].



(a) Interception, injection **(b) Collision**

Figure 2.17 : Example of attack per injection in VANET

II.5 Conclusion

We have presented in this chapter generalities on vehicular networks by exposing the VANET network concept with its different services and applications, communication architectures and potential wireless technologies for this type of network, the main actors in the field as well a project overview and standardization work. Then we presented the different characteristics, constraints and challenges associated with vehicular networks.

New themes have been opened and new challenges have emerged to meet the needs of individuals and the requirements of several applications in the vehicular areas. Research today is much focused on vehicular sensor networks (VSN); considerable efforts have emerged to introduce intelligence into transport systems whose aim is to improve safety, efficiency and usability in road transport. These networks will play an important role in building the Future Internet, where they will serve as a support for various communication applications and integrated into our daily lives.

In the next chapter, we will describe the characteristics and applications of the sensor networks (WSN and VSN), and then we give a table of comparative study for the both networks.

CHAPTER 3

THE SENSOR NETWORKS WSN AND VSN

III.1 Introduction

Progress in recent decades in the fields of microelectronics, micromechanics, and wireless communication technologies; have produced a reasonable cost component of a few cubic millimeters in volume. The latter, known as micro-sensors, embedded systems are real where the deployment of several of them, to collect and transmit environmental data to one or more collection points, in an autonomous manner, form a network wireless sensors (WSN; Wireless Sensor Network). The wireless sensor networks are likely to be widely deployed in the future because they greatly expand our ability to monitor and control the physical environment to remote locations. Recently the research group and the car companies were equipped vehicles with regular sensors, thus practically creating a sensor network based mobile vehicles (VSN).

The introduction of intelligent transport systems requires the existence of networks of interconnected sensors. In the vehicle, these sensors are scattered throughout the cabin (chips), below or on the sides of the vehicle (sensors or transmitters) or above (antennas). On roadsides, at crossroads, near bridges or tunnels, larger infrastructure can be arranged: cameras, gates, infrared radar. Everything is connected to a central station that provides collection, processing, circulation and storage of data: the "back office". All these facilities make up the system. But, in the same way that a computer cannot function without software, this system must be programmed to produce results. These programs, called "applications" are exploiting the system and make it "smart": they tell it in real time how to mediate complex situations based on multiple parameters.

The objective of this chapter is to make a comparative study between the two sensor networks (traditional static sensors network and vehicular sensor network).

The remainder of the chapter is organized as follows. In the following section, we describe the characteristics and applications of the sensor networks (WSN and VSN), then we give a table of comparison study for the both network. Finally, section IV concludes this paper.

III.2 The Sensor Networks

III.2.1 The Ad-Hoc Network

An ad-hoc network [64] [65] is a collection of hosts equipped with antennas that can communicate without any centralized administration, using a wireless communication technology such as Wi-Fi, Bluetooth [12], etc. In contrast to wired networks where only certain nodes called "routers" are responsible for routing data, in an ad-hoc network all nodes are both routers and terminals. The choice of nodes that will provide a communication session in an ad-hoc network is dynamically according to network connectivity, hence the term "ad-hoc"[2].

In an ad-hoc network, a node can communicate directly (point-to-point) with any node if it is located in its zone of transmission, while the communication with a node, located outside from its area of transmission ,is carried out via several intermediate nodes (multi-hops).

[2] The term "ad hoc" is a phrase of Latin origin which means « appropriate to the subject, to the situation ...»

Formally [11], an ad hoc network can be represented by an unoriented graph $G = (V, E)$ where V denotes the set of nodes and $E \subseteq V^2$ indicates the set of arcs corresponding to the possible direct communications. Let *i* and *j* be two nodes of V, the arc (i, j) exists, if and only if, i can directly send a message to j, then j is neighbor to i. The couples belonging to E depend on the nodes position and their communication range. If we assume that all the nodes have an identical range R and if $d\ (i, j)$ designates the distance between nodes *i* and *j*, then the set E can be defined as follows:

$$E = \left\{(i,j) \epsilon\, V^2 \mid d(i,j) \leq R\right\} \tag{3.1}$$

III.2.2 Advantages of Ad-Hoc Networks

The ad-hoc networks have several advantages; the most important are [66]:

- ***Easy deployment, fast and inexpensive:***

In ad-hoc networks, the tedious task of deploying base stations (wiring, installation, etc.) is no longer necessary. Consequently, the deployment is faster and is done with a low cost.

- ***Fault tolerance:***

An ad-hoc network continues to function even if some nodes fail, this is because it has no central nodes.

III.2.3 Types of Sensor Networks

In this section, we describe two types of ad-hoc networks, i.e. Wireless sensor networks (WSNs) and Vehicular Sensor Networks (VSNs). We will also present their applications.

Although WSNs and VSNs have several common features, however, they have several differences involving naturally different communication solutions. We end this section by comparison table.

III.2.3.1 Wireless Sensor networks (WSNs)

III.2.3.1.1 Definition

The WSNs (Wireless Sensor Networks) [67] are ad-hoc networks consist of intelligent sensors nodes powered by batteries, and equipped with processing capabilities and limited storage. Indeed, the sensor nodes are able to perform three additional tasks: i) the statement of a physical or environmental size (e.g. temperature, pressure, pollution, etc.); ii) the possible treatment of this information; iii) the routing of this information. The network may contain a large number of nodes (thousands) generally static and deployed randomly (e.g. by dropping from a helicopter) in environments that can be dangerous. In addition to the sensor nodes, a WSN includes energy-rich base stations (sink nodes) characterized by greater processing and storage capacity. These nodes act as gateways between sensor nodes and the final user (Figure 3.1).

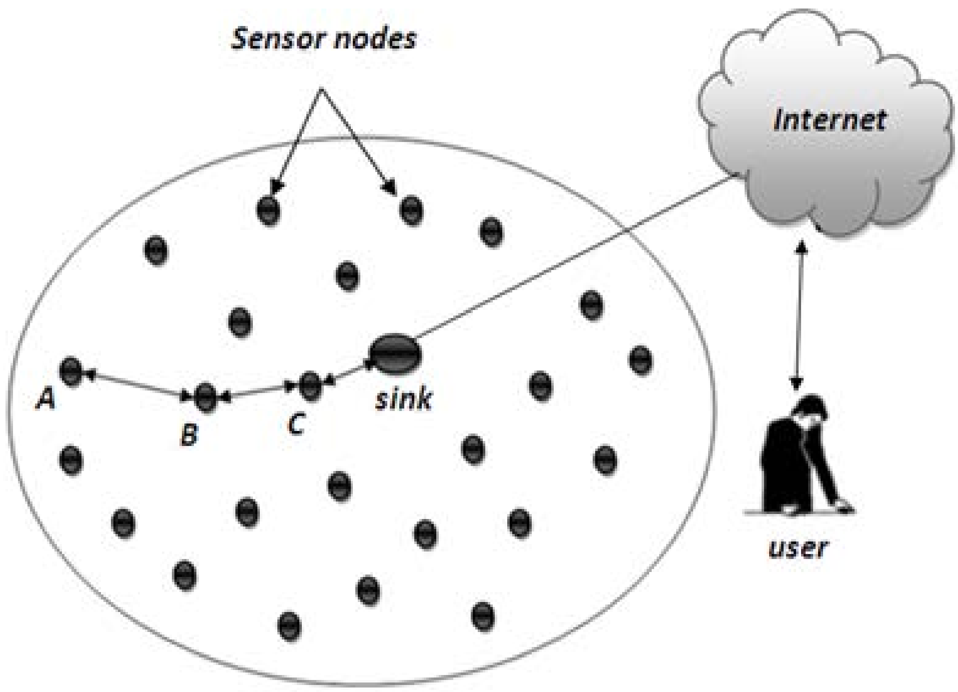


Figure 3.1 : Sensor network architecture [67]

III.2.3.1.2 Components of a sensor node: (Figure 3.2)

A sensor node consists of the following key which pulls:

- **Sensing unit**: this allows the sensor and the phenomenon observed converter from an analog signal into a digital signal. It will be then supplied to the calculation unit.
- **Processing unit:** it is responsible to execute communication protocols that enable sensor nodes to work with other nodes to perform the query in question.
- **Transceiver unit**: it is charged to effect all emissions and data reception.
- **Power Unit**: it performs control of the remaining energy operations and measuring the lifetime of the sensor node.
- **Location Finding System**: provides information on the location required by routing techniques.
- **Mobilizer**: it is called if the sensor node must be moved to complete the query to treat.

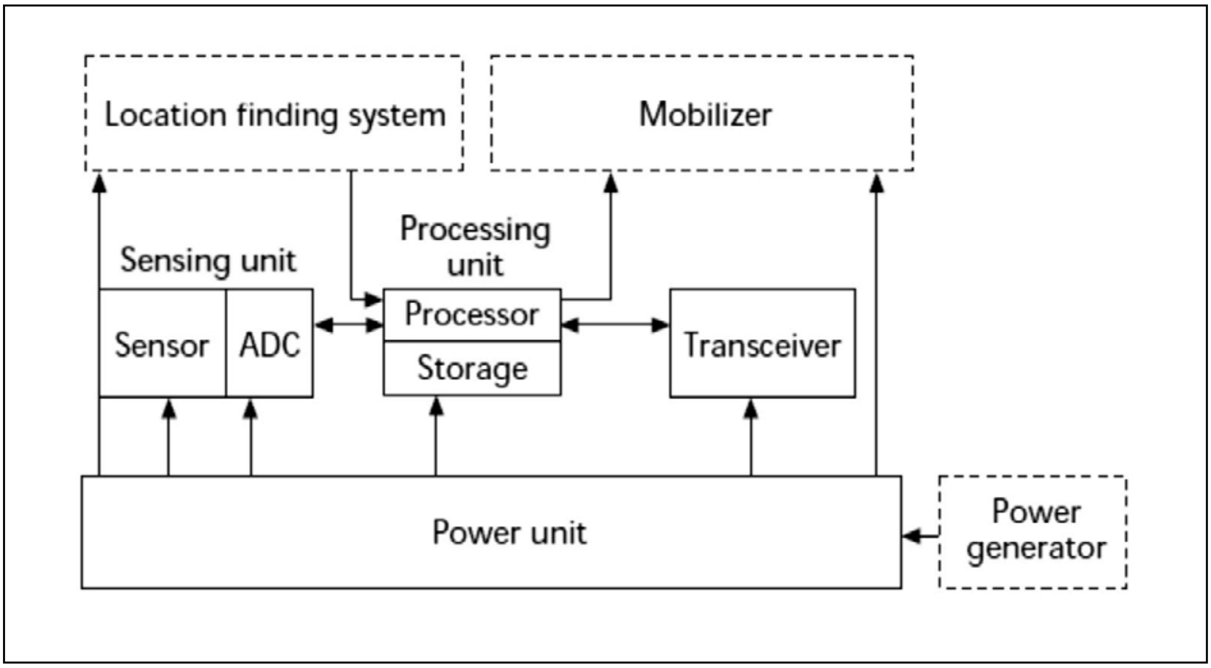


Figure 3.2 : Sensor node components

III.2.3.1.3 Applications of WSN

The miniaturization, the adaptability, the low costs and the wireless communication allow the sensors networks to invade several scopes of application. They allow extending the field of the existing applications. Among these fields where these networks appear very useful and can offer better contributions, we can note the military, health, the environmental one, and smart homes [68]:

- ***Military applications***

Low costs, fast deployment, the car-organization and the fault-tolerance are characteristics which made the networks of sensors effective for the applications soldiers.

Several projects were launched to help the military units in a field of battle and to protect the cities against attacks, such as the terrorist threats. Project DSN (Distributed Sensor Network) or DARPA (Defense Advanced Research Project Agency) was one of the first projects in the Eighties which have used sensors networks to gather distributed data. Researchers of the national laboratory Lawrence Livermore set up the network WATS (Wide Area Tracking System). This network is composed of detectors of the gamma rays and the neutrons to detect and detect nuclear devices.

It is able to carry out the constant monitoring of a zone of interest. It uses techniques of aggregation of data to bring them back to an intelligent center. These researchers set up then another network called JBREWS (Joint Biological Remote Early Warning System) [69] to inform the troops in the battle field of the attacks biological possible. A network of sensors can be deployed in a strategic or hostile place, in order to supervise the movements of the enemy forces, or to analyze the front ground to send troops to it (detection of the chemical weapons, biological or radiations). The American army carried out tests in the desert of California.

- ***Applications to security***

The application of the sensors networks in the field of safety can decrease considerably the financial expenditure devoted to the security of the places and the beings human.

Thus, the integration of the sensors in great structures such as the bridges or the buildings will help to detect the cracks and deteriorations in the structure following to a seism or aging of the structure. The deployment of a movement sensors network can constitute a distributed warning system to be used for detecting the intrusions in a wide sector.

- ***Environmental applications***

Environmental issues: the control of the environmental parameters by the sensors networks can give rise to several applications. For example, the deployment of the thermo-sensors in a forest can help to detect a possible beginning of fire and consequently to facilitate the fight against forest fires before their propagation. The deployment of the chemical sensors in urban environments can help to detect pollution and to analyze the quality of air. In the same way their deployment in the industrial sites prevents the industrial risks such as the escape of toxic products (gases, chemicals, elements radioactive, oil, etc).

Agriculture: the sensors can be used to suitably react to the climate changes for example the process of irrigation at the time of detection of dry zones in an agricultural field. This experimentation was carried out by Intel Research Laboratory and Agriculture and Agri-Food Canada on a vine with British Columbia.

- ***Medical applications***

In the field of medicine, the networks of sensors can be used to ensure a permanent monitoring of the vital bodies of the human being thanks to micro-sensors. They can also facilitate the diagnosis of some diseases by taking physiological measurements such as the blood-pressure, beats of the heart… using the sensors having each one a quite particular task. The physiological data collected by the sensors can be stored during one long life for the follow-up of a patient [70]. In addition, these networks can detect abnormal behaviors (falls of a bed, shock, cry…) at the dependant people (handicapped person or elderly).

- ***Home automation***

With technological development, the sensors can be embarked in apparatuses, such as the vacuum cleaners, the microwave ovens, the refrigerators, the video tape recorders… [71]. These embarked sensors can interact with each other and with an external network via Internet to allow a user to control locally or remotely the domestic devices.

The deployment of the sensors of movement and temperature in the future houses known as intelligent makes it possible to automate several domestic operations such as: light dies out and the music is put in stopped state when the room is empty, air-conditioning and the heating is adjusted according to the multiple points of measurement, the release of an alarm by the sensor anti-intrusion when an intruder wants to reach the house.

- ***Automobile traffic***

Sensors are integrated in the vehicles and road side for congestion control and monitoring. We will be interested on this subject in the next part.

The Figure 3.3 illustrates the applications of the WSN.

Figure 3.3 : Applications of WSN [68]

III.2.3.2 Vehicular Sensor Networks (VSN)

III.2.3.2.1 Definition

VSN is a new network paradigm that is essential for the collection of valuable information in urban environments. In a vehicular sensor network, each vehicle is responsible for detecting one or more events; routing messages to other vehicles or infrastructure and treatment of detected data.

The VSN have been extensively studied and proven to be very useful to support the safety of car and the road, the analysis of the flow profile, road surface diagnosis, monitoring the urban environment, street level air pollution monitoring, and many other application of transport systems. Their growing popularity highlights the need for a thorough analysis of their most relevant features to pave the way for VSNs' full practice deployment.

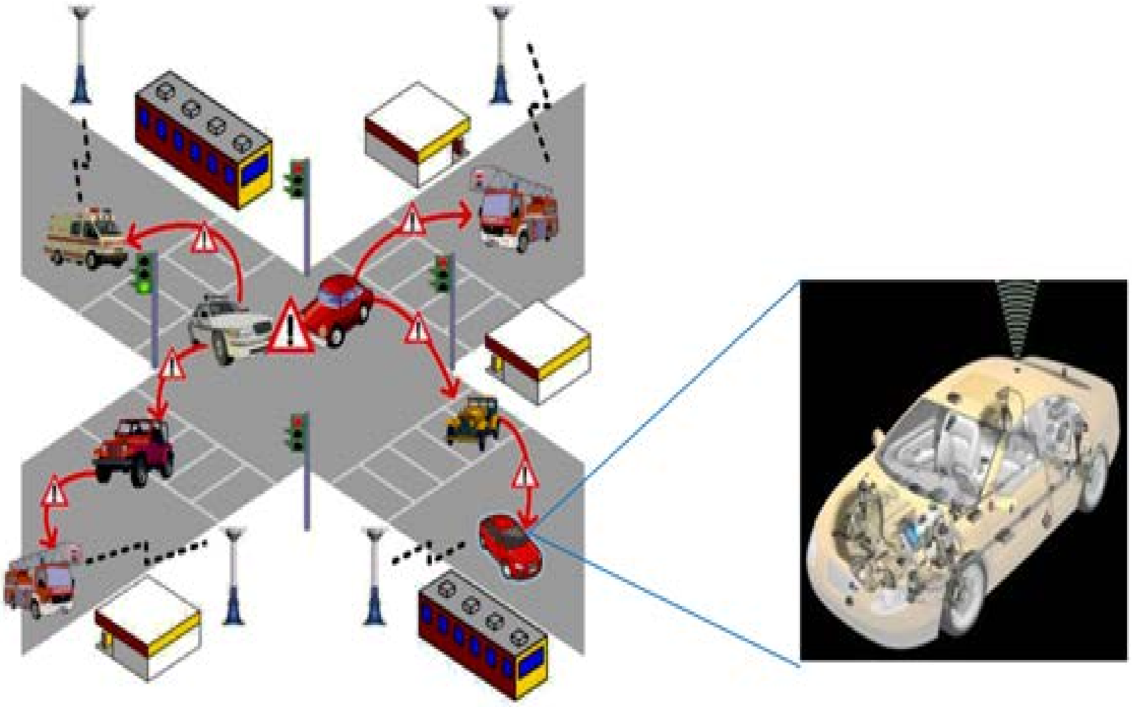


Figure 3.4 : VSN architecture

III.2.3.2.2 VSNs Classifications

In literature, The VSNs can be broadly classified into two groups:

- Intra-vehicle VSNs (a “single vehicle” VSN used for giving diagnostics to the driver)
- Inter-vehicle VSNs (used for sharing the sensor data with other vehicles or Infrastructure components)

VSN inside the vehicle are introduced for monitoring, control and communication between the components and sub-systems within a vehicle. They are motivated by the growing complexity, weight and cost of wiring, as well as versatility of wireless networks, the opening of space for new programmable architectures and features. Connectivity in a VSN intra-vehicle is usually enabled by wireless standards for ad hoc communications such as Bluetooth [12], ZigBee [13] and UWB [14].

Inter-vehicle VSNs, either V2I/I2V or V2V, are based on different DSRC (Dedicated Short Range Communication) standards at physical and data link layers [46] [72]. They can either be fully distributed or centralized. In V2V communication, a vehicle can communicate with its neighboring vehicles even in the absence of a central entity (e.g., a Base Station). The concept of this direct communication is to send vehicle safety messages one-to-one or one-to-many via a wireless connection. Such messages are usually short in length and have very short lifetime in which they must reach the destination. The inter-vehicle communication system contributes to the increase in safety and the more intelligent traffic management on roads [73].

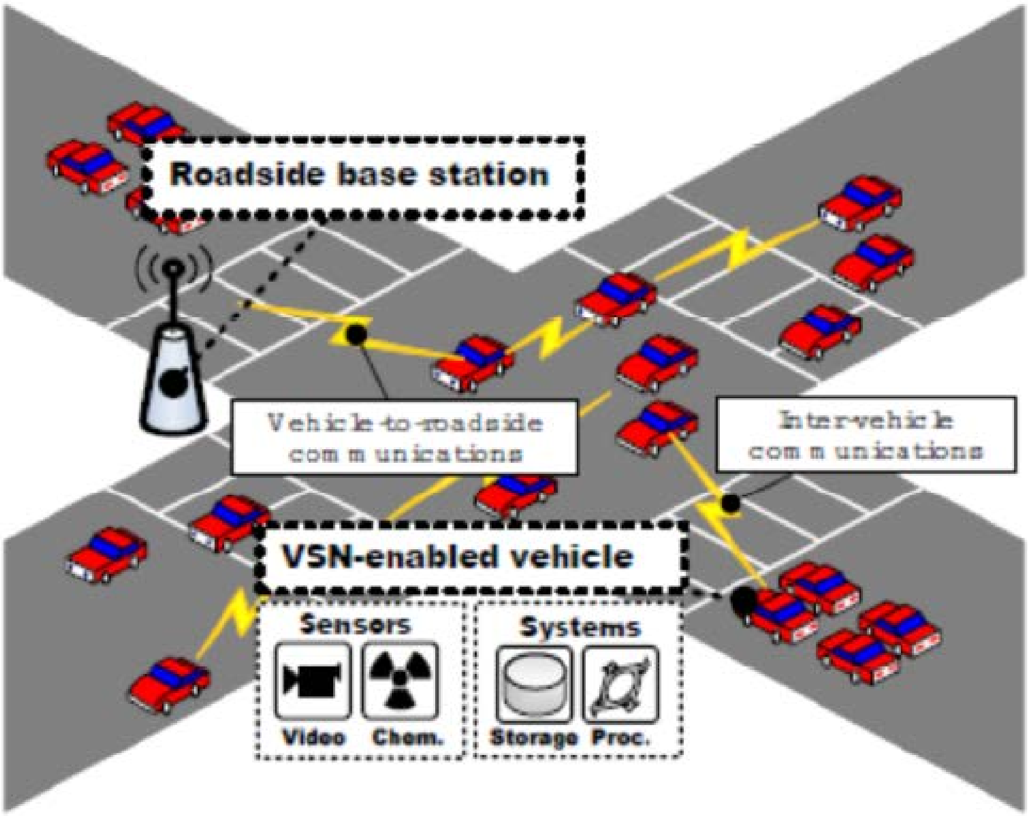


Figure 3.5 : VSNs Classification

III.2.3.2.3 Operation Principles of the Connected Vehicle

1) The Vehicle and Embedded Systems

Embedded systems consist of tangible and intangible resources integrated into the vehicle. It is the most visible face of the system. It includes systems for the collection, processing and dissemination of information within the scope of the vehicle.

As part of ITS, information gathering takes place at two distinct levels. The first data collection performed by the vehicle. The second concerns the data collected outside the vehicle (weather, traffic monitoring, pollution level ...). Automobiles in use today are already equipped with multiple sensors. Among the most common are found, for example, water temperature sensor, fuel gauge, speedometer, tachometer, the radio.

Since a few years, more specific features have been added such as wheel rotation sensors, rain sensors, radar sensors, GPS. We can add to this list another sensor, which is still rarely secured to the vehicle: the mobile phone. This device tends increasingly to be connected to the vehicle, including through Bluetooth. Other detection systems more or less sophisticated (internal and external cameras, sensors for positioning on the floor, radar obstacle detection) are already available in several ranges of vehicles (Audi, BMW, Ford, Infiniti, Lexus, Mercedes, Opel, Volkswagen, Volvo ...) [74].

Table 3.1 : Sensors in vehicles

Vehicle Sensor	**Data Inference**
GPS Data	Localisation
Traction Control	Snow, Ice, Wet Pavement
ABS Breaking	Abrupt Stop, Skidding
Speed	Approach Speed to Signal, Congestion Levels, Speed Limits
Airbag	Accident
Wipers	Moisture
Headlights	Darkness
Fog Lights	Fog
Ambient Air Temperature	Freezing

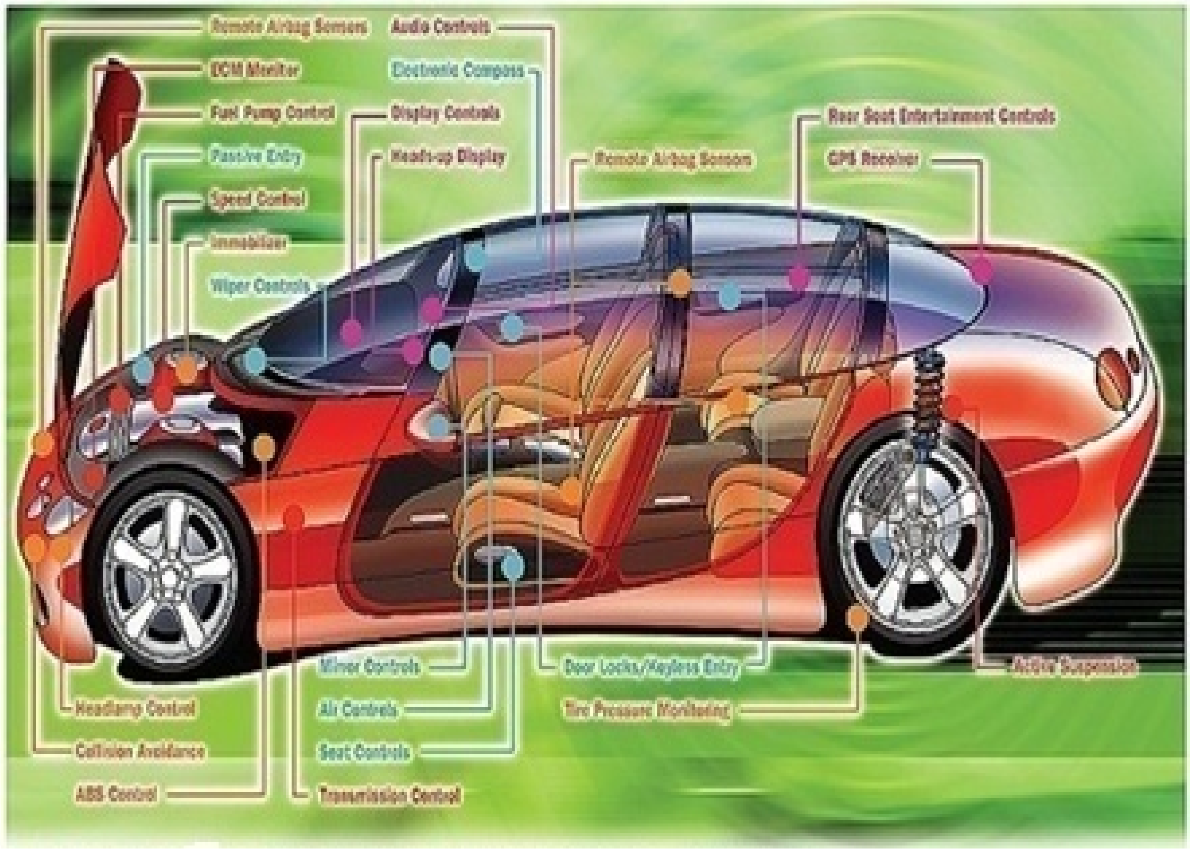


Figure 3.6 : Sensor technologies in the vehicle

The data are currently processed by multiple systems and in an independent way. One of the principal contributions of the STI is precisely to centralize this information and to treat them in their globality. Among the embarked processing centers, one can quote calculator of the vehicle, the GPS, the cellphone. With those are added the processing centers of edge of road (tele tolls, radars speed) and they centers of traffic control. In the future, one will attend with the regrouping of the systems of treatment or, at least, an interconnection between them in order to allow them “to dialog” and to grow rich mutually. Thus, in the car, the central calculator will communicate with the apparatus of géo localization, the equipment of mobile telephony, or with any other shipborne equipment [74].

After treatment, information collected must be repeated with the multiple embarked users, so that the latter can adjust their choices starting from the data collected.

2) A telecommunication network

The role of the infrastructure of telecommunication is extremely important. This one makes it possible to establish the bonds necessary to the transfer of information between the vehicles and the platforms of service. It is an essential link in the chain of communication. One distinguishes the communication between vehicles (V2V, Vehicle to Vehicle), the communication of the vehicle with the structure edge of road (V2I, Vehicle to Infrastructure), the communication of the structure with the car (I2V, Infrastructure to Vehicle) and the communication of infrastructure to infrastructure (I2I, Infrastructure to Infrastructure). The infrastructure is composed, on the one hand, of the physical part (the material) and, on the other hand, of an immaterial component (communication protocols).

The information exchange enters the various elements constituting the infrastructure of communication is done on the short ones and long distances. The connections between infrastructures can be realized with wire. But, for obvious reasons, the other connections are based exclusively on the transmission without wire. One distinguishes several categories of wireless networks according to the coverage area, transmission speed and necessary reliability. The principal modes of transmission without wire currently used are the infra-red transmission (for the very short distances, lower than 30 meters), the transmission by GSM, the transmission by radio waves (for the short ones and long distances), and the satellite communication (for very the long distances). These various modes of transmission require material structures specific to each one of them. But each time, one needs a transmitter and a receiver, and, in certain cases, it is also necessary to add points relay.

Thus, the satellite transmissions require, as their name suggests it, the support of one or several satellites geostationary. The transmissions on averages and long distances require the presence of antennas positioned on high points. For this reason, they are placed on pylons, towers water, or other high constructions. It is in particular the case of the antennas for mobile telephony. The transmissions of weak range require transmitters and receivers of much more small sizes. The Bluetooth systems or Wifi terminals are the perfect illustration [74].

Because of the various modes of transmission and variety of technologies used to convey the data, it is necessary to define a common protocol of communication so that each interface can exchange with the others. To this end, the International Organization Standard (ISO) developed a family of international standards around the telegraphic connections and without wire applicable to the sector of the STI. It is about the standard ISO TC 204 WG 16, which is based on concept CALM [51] (Communications Mobile Accesses for Land). This standard integrates a multitude of technologies such as the cellular communication of 2nd and 3rd generations, the satellites, the infra-reds, the microwaves…

3) Information system and “back-office”

Information circulates through several modes of transmission built around networks. The management of these networks is entrusted to public operators or deprived. It is the case for example for the mobile telephone operators.

Same manner that a computer cannot be used without software, the infrastructure previously described is not useful which if it is supplied with an ad hoc application. They are them service providers who develop these applications. Some are paying, others are free. They are addressed to the various recipients described above: public authorities, car manufacturers, drivers, managers of fleets, hirers out of cars, managers of infrastructures, insurance companies… It is the case for example GPS (Total Positionning System). The driver which has a receiver GPS can know its exact position and profit from a géo free guidance. But it can also subscribe to a paying additional service which calculates its route while holding count conditions of traffic [74].

III.2.3.2.4 Features and Benefits associated with VSN

A. Prevention of accidents

The VSN allows the driver to better control his vehicle, but also to assess its own capacity to lead. Numerous technological applications have already come in for a long time usage. Without even thinking, with a simple glance at the dashboard, the driver checks the multiple indicators critical to safety or operation from the vehicle: fuel level and oil, engine temperature, speed, mileage, Headlamp ... the high-end vehicles offer more precise indicators and more specialized tire pressure, belts hanging safety, collision avoidance radar, outside temperature, audio signal of a risk of freezing rain or fog ... All of these technologies in place during the past two decades reinforce the safety and comfort of travel. But they are based on an assumption: the driver will be able to understand the information that may put to flight instruments and he will interpret it and make the right decisions to adjust his conduct. But the statistics prove this assumption is wrong: 90% of accidents result from human error.

ITS is an answer to this paradox. This is just to increase the number, nature or accuracy indicators edge, but offset the limitations or human failures.

An example: the driver's ability to control his vehicle. For reasons of culture and habit, the driver tends to overestimate their abilities and minimize the risks it is exposed. Nervousness, stress, depression, or conversely an overly excited or euphoric joy disturb the judgment and can cause accidents. Like alcohol abuse, as is proved alcohol testing: drivers systematically underestimate the amount of alcohol consumed and difficulty in admitting their inability to respond quickly and appropriately to unexpected situations. The VSN of new generations of embedded devices will detect this weakness by measuring different parameters and can alert the driver before he takes the road, or possibly block the vehicle in case of inconsistent behavior.

It’s the same with regard to lack of sleep. Drowsy driving is the cause of many accidents. Sensors located on the dashboard or in equipment (steering wheel, seat, outside edge of the vehicle) will detect its most characteristic symptoms (frequent and prolonged blinking of the eyelids; stiff neck, repetitive yawning; deviant trajectory of the vehicle against the benchmarks of the roadway, inappropriate speed, inconsistent or incoherent) and will give warning.

VSN can not only trigger an alarm (an audio message, a bell in the car for the driver), but still be able to prevent the danger to other road users. For example, the system can warn a driver come from the opposite direction; it faces a frontal impact due to the abnormal trajectory of the first vehicle. In case of deep sleep, resulting in an off line, using the tracking of the trajectory (Lane Keeping Support, LKS) can also be activated (the system "takes over" on the vehicle and keeps him in the middle of the carriageway in order to avoid collisions longitudinal or lateral). It can even help coordinate with the path of other vehicles identified in the immediate environment. The "platooning" is to drive a vehicles group together according to established parameters in order to prevent any risk of collision. The "Cybernetic Transport Systems" can even manage fleets of vehicles fully automated.

Another example: the view. An estimated one third of accidents are related in one way or another, lack of visibility. The VSN can compensate for the weaknesses of the human eye. It's not science fiction. Engineers do not plan to equip drivers with electronic eyes. But almost, thanks to the satellite geolocation (GPS, Galileo), we know the exact position of a vehicle on a highway; we know what direction it is progressing and we can accurately assess its speed.
Through this same process we can identify in the same way another vehicle, for example located one hundred meters behind the first vehicle. Suppose that the second vehicle is traveling at a speed much higher than the first, in heavy fog. There is a risk of collision because the driver of the second vehicle cannot see the vehicle in front and toward which he directs. In this hypothesis, the VSN can establish a link between the two situations: real-time information system identifies each vehicle, reports the positions and issues a warning because of the risk of accident. The system can suggest to the first vehicle speed to maintain a safe distance from longitudinal or in adhering to the side of the road, and recommend to the second vehicle to slow or anticipation. Thanks to the mediation system, and complement systems of autonomous driving assistance on the vehicle board, the drivers of both vehicles see themselves, despite the distance and fog [74].

But risk reduction is not limited to "dialogue" between vehicles (V2V called for "Vehicle to Vehicle"), it also concerns the relationship between vehicles and infrastructure (V2I, for "Vehicle to Infrastructure"). When approaching a crossroads with, motorists will be informed of the danger of crossing the state possibly faulty installation, or even the presence of other risk vehicles or pedestrians.

B. Damage reduction in collision

The connected car will benefit from several advantages over the autonomous vehicle. The information system that could be detected just before the collision imminence thereof, he may undertake immediate measures to reduce its impact. For example, it can accurately measure the weight, shape and position of each occupant of the vehicle to determine the exact timing and triggering of airbags inflation level required to reduce the impact of inflation. It can also "take control" of the vehicle and provide the best brake system based on multiple parameters, impossible to comprehend as efficiently by the driver in a very short time, the order of a fraction of a second .

The VSN then instantly calculates vehicle speed, its position on the floor, the existence of specific barriers on it (other vehicles, pedestrians), specific weather (rain, ice) and acts on the parameters of the collision.

C. Emergency management

The triggering of emergency is a very important step in the management of traffic accidents and determines some of the balance disorder. In a very short time, we must take steps to avoid complications of an accident (an accident caused by the additional first accident), assess the extent of damage (human, material) and trigger the alarm (to call the police, the firefighters, and other motorists).

The VSN can precisely react immediately regardless of the status of the passenger. The detection of the shock is immediate (GPS instantly identifies the crash and abnormal vehicle, the shock is detected by onboard sensors programmed to trigger activation of airbags). The analysis of the environment (other vehicles on the approach) is used to trigger automatic and on-the-field bounds warning (flashing lights), to reduce the risk of an accident. The VSN are then used to accurately assess the damage: using sensors and the radio communication networks, we can quantify the number of people aboard the vehicle, determine whether they are conscious or not, estimate the risk of fire or explosion, indicate the exact position of the vehicle etc.

Many of these applications in the near future will have an effect on the rate and severity of accidents will become mandatory in vehicles, as will soon be systems of "Emergency Call" (automatic communication with the relief collision). The emergency call is already on the market for many years in Europe (BMW, Mercedes, PSA, Volvo ...) [74].

III.3 Comparison between VSN and WSN

To our knowledge, at this time, the mobility of sensor networks is not widely traded. The majority of existing research considers static networks. In this section we will briefly illustrate the differences between static sensor networks and mobile. A sensor array consists of a set of nodes deployed in an area of interest for the purpose of the monitor, and to transmit information to the end user (the observer).

A static sensor network WSN does not consider any node mobility, or the observer, or the area of interest. In this case, the sensors are combined to capture for example the temperature in a given region. This requires an initial installation of communications infrastructure to create the path between the observer and the sensors.

On the other hand, in a mobile sensor network VSN, the nodes, the area of interest, and the observer are moving. If the nodes are moving, that implies a change of interest zone which becomes “mobile”. As the zone changes, the observer will be obliged to rebuild the access path and to break the old one. In this case, the observer's interest is to build more paths between itself and the nodes, and choose the most beneficial.

How a node can be mobile? It can be attached to a robot with a human being, vehicle, etc. For example in military applications, nodes can be attached to soldiers or trucks, or in other cases attached to animals to track their movements.

The goal of mobile sensor networks is to gather more information about an environment by using less of sensor nodes, and allow the network to organize its own nodes. In addition, it becomes able to move its sensors dynamically according to environmental changes, making it adaptable to the changing environment [75].

Although the VSN and WSN have several common characteristics, but they differ in several aspects [76]:

- The main characteristic of a constituent node VSN is the mobility, while the sensor nodes in a WSN are static.
- In the VSN, communication can occur between any network nodes, while in a WSN communication is always initiated from wells nodes.

- The VSN are characterized by a lower density compared to the WSN.
- In a VSN all nodes are equal, thus the failure of any node has the same importance, while a WSN is more sensitive to the failure of nodes as well that of the sensors.

The main differences between VSN and WSN are summarized in the following table 3.1.

Table 3.2 : Comparison between WSN and VSN [77]

	WSN	VSN
Objective	Target goal	General /Communication
Collaboration	Nodes working together for the same purpose	Each node has its own target
Data flow	Many-to-one	Any-to-Any, One-to-All, One-to-Many
Identity	Very large number of nodes without ID	Presence of the concept of ID
Main factor	Energy resource	Throughput, QoS
Type of communication	Broadcast	Poin to Point (Unicast), Multicast, Broadcast
Mobility	Nodes are static	The nodes are mobile
Computing capacity	Low power computing	High calculation capacity
Storage space	Low storage capacity	Great capacity of storage
Communication capacity	Low capacity of communication	Reliable communication
Energy	Nodes have a constrained battery life	There is no battery life constraint
Data volume	A small volume of data generated on the types of applications	A large volume of data generated

III.4 Conclusion

In this chapter, we have investigated the main characteristic and applications of two type of Ad hoc networks WSN and VSN.

Unlike other networks, WSNs are designed for specific applications. Applications include, but are not limited to, environmental monitoring, industrial machine monitoring, surveillance systems, and military target tracking. On the other hand VSN will play an important role in the coming years, whether to communicate with another vehicle or with existing infrastructures. Indeed, today's cars no longer be satisfied to detect hazards through radar or cameras, they will be able to receive alert messages sent by other drivers or infrastructure (panels, gantries, etc.. ...) and to transmit this information to other vehicles. Each application differs in features and requirements.

A critical aspect, when studying VSN or VANETs, is the need for a mobility model which reflects, as close as possible, the real behavior of vehicular traffic under a realistic conditions including, representative data traffic models, and realistic movements of the mobile nodes which are the vehicles. In the chapter four, we will investigate the concept of mobility model and we will present a comparative simulation between two mobility models for VANET.

CHAPTER 4

MOBILITY MODELS FOR VANET SIMULATION

IV.1 Introduction

The mobility is the principal constraint met in the vehicular networks, therefore the performance investigation of VANET routing requires the exact prediction of mobility of nodes forming the network, and this is realized by the good choice of the mobility model.

Generally, the traces and the synthetic models [78] are two kinds of mobility patterns used for the networks simulation. For simulating the complex and large scale networks that require more real world scenarios for a real modeling, the traces are used. But in several situations, these traces are created with difficulty, particularly for the networks of high mobility like the vehicular networks. In this case, the mobility of nodes (i.e., the vehicles nodes) are modeled with the synthetic patterns, these models try to really present the behavior of these environments of vehicles.

A variety of synthetic mobility models for vehicular networks are discussed in Literature, some of them are presented in Section 2. Section 3 illustrate that a mobility model has a large effect on the performance evaluation in simulation of VANET network. Finally, Section 4 presents some concluding remarks.

IV.2 Mobility model for Vehicular Network

IV.2.1 Mobility model features

The study of the performance of routing protocols in VANETs in the presence of mobility is an essential step in their design. As real implementations of VANET are rare, it is difficult to collect evidence of actual movements. Approach common is the use of synthetic models in the simulations. According to reference [79], Mobility patterns used must:

- ***Reflect the actual movement of users***: given the variety of possible applications of VANETs, mobility scenarios to consider are many. They vary from the movement of vehicles on the urban environment to the movement on highway and roadside. Obviously, it is impossible to design a model of mobility for all these scenarios, but a model must at least be representative of one of these.

- ***Be simple to simulate and analyze***: a model of mobility should be simple enough that the simulation time is reasonable and to facilitate analysis of the results.

However, for the model to be realistic, it must include as much detail, increasing its complexity. Therefore, a synthetic model must find a compromise between these two criteria omitting some details.

IV.2.2 Importance of Choosing a Mobility Model

Many models of mobility can be used to generate the movement of the vehicles instead of the traces which are difficult to create in the VANET environments.

However, the behavior of these networks is very complex; the drivers must react to the high change of the road conditions like the congestion, traffic jam, and works in the roads.

The state of the roads in turn depends on the behaviors of the drivers. Thus, the choice of the mobility model affects the relevance and viability of the obtained results.

IV.2.3 Mobility models Classifications

In general, vehicular traffic simulators or mobility models can be classified in two great kinds, the microscopic and macroscopic simulators.

- **The microscopic simulator** is interested in the movement of each vehicle taking part in the road traffic like car-to-car interactions, car-to-road interactions, acceleration and deceleration, overtaking, etc.

- **The macroscopic simulator** (road topology, street characterization, car class dependent constraints, traffic signs**)** is interested in all the vehicles forming the network; it compute road capacity and the distribution of the traffic in the road net, by determining a certain parameters like traffic density (number of vehicles per km per lane) or traffic flow (number of vehicles per hour crossing some points of interest, usually an areas with a great density of nodes).

IV.2.4 Entity Mobility Models for VANET in the literature

The literature present a large variety of mobility models for VANET.

TIGER

The work of Saha and Johnson [80] models vehicular traffic in real road topologies of the maps of USA, available from TIGER (Topologically Integrated Geographic Encoding) [81] database. The mobility of nodes is random. Vehicles compute the shortest path to get their destination; over the graph by weighting the cost of displacement on each road on its speed limit and the traffic jam.

Manhattan Grid

Huang et al. [82] studied taxi behavior. In this work, a Manhattan style grid with an uniform block size is modeled. The streets of simulation area are two-way, with one lane in each direction. These lanes constrain vehicle movements. A set of parameters characterize the vehicle behavior which are preferred velocity, maximum acceleration and deceleration, a velocity variation associated with the preferred speed at steady state and a list of preferred destinations, i.e. the taxis stands. The taxis assign randomly one of three preferred speeds.

STRAW Model

In the work of Choffnes et al. [83], an integrated mobility and traffic model are conceived; named STRAW. For modeling real traffic conditions, this model incorporates a simple car-following model with traffic control. The road map of this pattern is constructed by street plans with one lane in each direction .The vehicles move in these lanes according to a random street placement model. Each vehicle enters the map is placed behind the existing one.

VanetMobiSim

In [84] Haerri et al. proposed a vehicular mobility simulator for VANET, called VanetMobiSim [85] .The speed of vehicles for this model is determined by the use of the Intelligent Driver Model (IDM) (see appendix).

SSM; TLM; PTSM

Three different models were presented in the work of Mahajan et al. [86]: Stop Sign Model (SSM), Traffic Light Model (TLM) and Probabilistic Traffic Sign Model (PTSM). In these models all roads are two-way, with one lane in each direction for the SSM and PTSM, whereas TLM model streets with multiple lanes. An algorithm is employed to reproduce stop signs for each model.

CityMob

Martinez et al [87] present Citymob [88]. This mobility model generates different mobility patterns in VANETs, Simple Model (SM), Manhattan Model (MM) and Downtown Model (DM). Each model has its own characteristics, for the SM, the plan of the road is very simple, neither semaphores nor direction changes. In constract, MM and DM simulate semaphores at crossing and random positions in zones with different vehicle density. CityMob allows simulating damaged cars and tries to prevent congestions. Figure 4.1 present the interface of this model.

MOVE

Karnadi et al. [89, 90, 91] develop a tool MOVE (MObility model generator for Vehicular networks) [92]. This model provides facility for the users to generate real world scenarios in VANET environments. This model contains two editors; one for road map and the second for vehicle movement. The user can manually and automatically create the road topology or import it from existing real world maps such as Google maps. For vehicle movement, the pattern can be manually created, generated automatically or specified based on a bus time table to simulate the movements of public transportations. Figure 4.2 shows the interface of this model. MOVE tool is built on top of an open source micro-traffic simulator SUMO [93, 94, 95]. The output of MOVE is a mobility trace file that contains information of real-world vehicle movements which can be used by NS-2[96] or Qualnet [97].

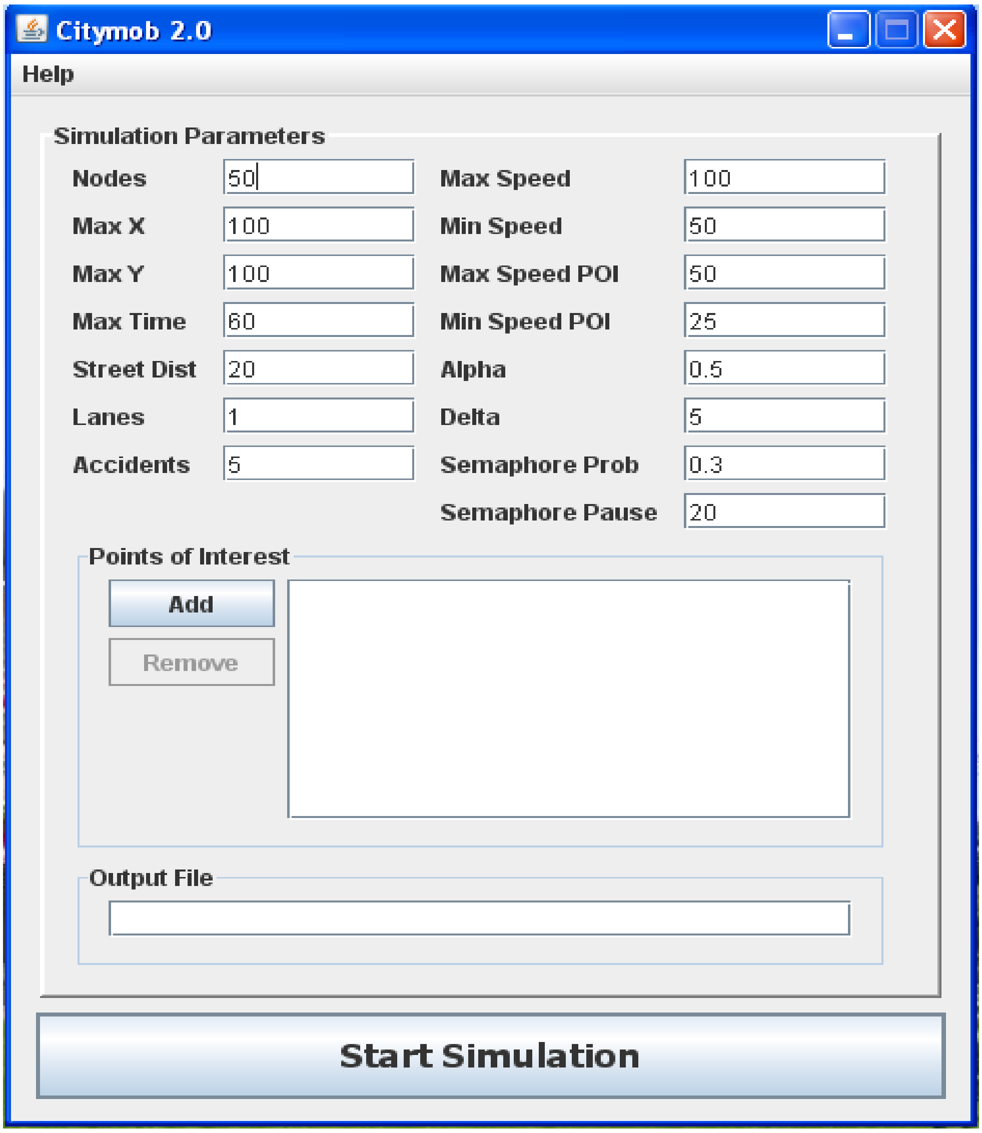


Figure 4.1: CityMob Interface

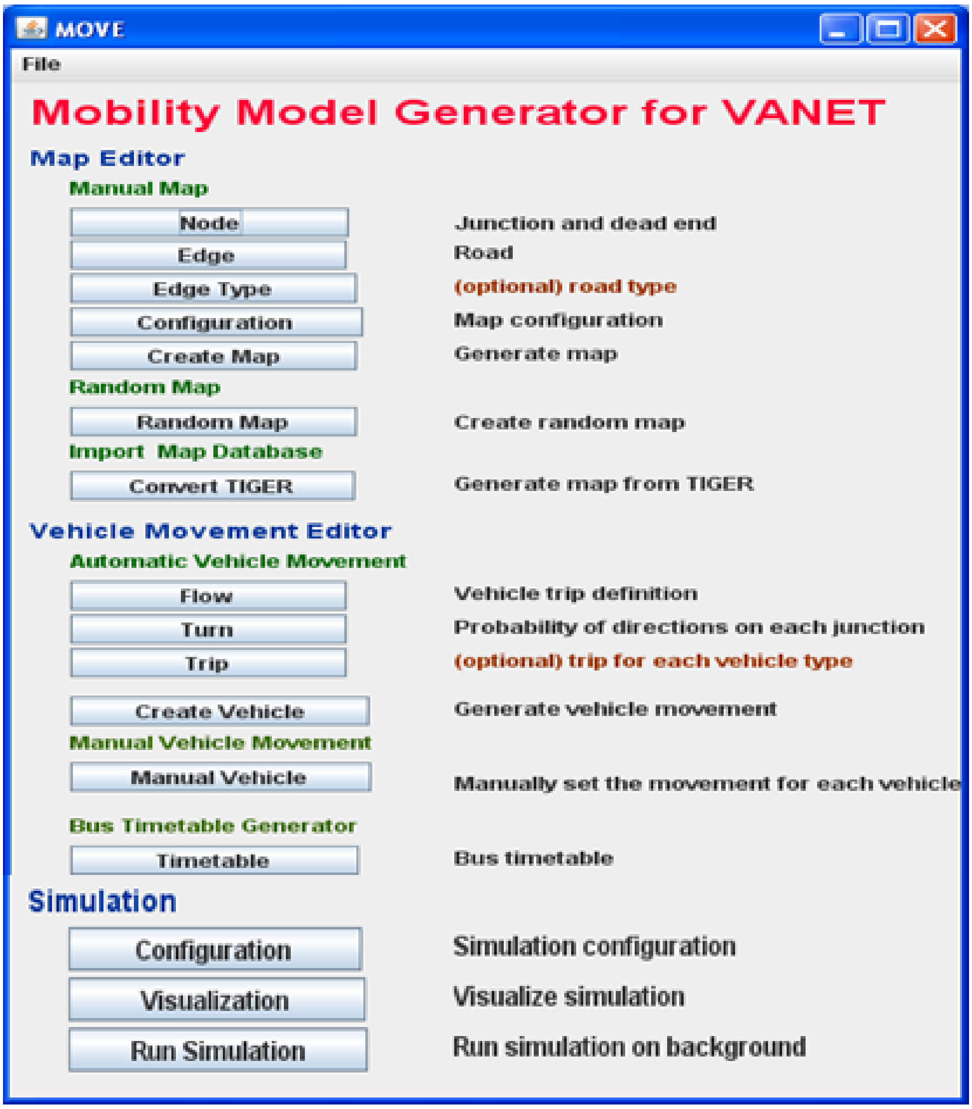


Figure 4.2 : Move Interface

IV.3 Influence of mobility model in VANET simulations

IV.3.1 Simulation Setup

Simulation can be defined like the process of model design for a real system, and the realization of experiments with this model. Simulation is the most used approach in the evaluation of the communication protocols in the ad hoc networks. That is justified:

- The limitation of the analytical approach: even if the analytical study of the communication protocols in the ad hoc networks gives an outline on the properties of the latter, but the results obtained remain limited because the studies are based on strict assumptions (no mobility, mechanisms perfect MAC, etc).

- The high cost of experiments with real implementations: it is very expensive to deploy networks only for objectives of research. Moreover, it is easier and less expensive to carry out a great number of tests by simulations.

IV.3.2 Simulation Parameters

We use NS-2 version 2.34 [96] to compare the performance of the CityMob Model and the MOVE tool via a simulation.

The routing of packets is accomplished with the Ad-hoc On Demand Distance Vector (AODV) [98].

AODV is a reactive protocol that does route discovery when needed by a node. The route discovery process is initiated only when a source node has data traffic to send to a destination node, that makes AODV a truly On- Demand routing protocol.

We chose AODV since it behaves well in several of the performance evaluations of the routing protocols (e.g. [99, 100, 101]).

The NS-2 code used in our simulations of AODV was obtained from [102].

We have chosen the parameters for both mobility models in a manner to simulate the same path as possible.

Each simulation run lasted for 300 seconds with an uniform block size of 500 x 500 m^2; the maximum speed of vehicles is of 40 Km/s.

The number of vehicles nodes varies from 15 to 100. We chose the traffic sources at a constant rate CBR (Constant Bit Rate). The traffic between nodes is generated using a traffic generator characterized by the following parameters: Data packets size is 512 bytes, Interval between packets is 0.25 s, maximum of packets transmitted 1000. All nodes use IEEE 802.11

MAC operating at 2Mbps. The propagation model employed in the simulation is Two Ray Ground reflection [96,132].

Table 4.1 : Simulation parameters

Simulation time	300s	Data packets size	512 bytes
Simulation area	500x500 m^2	Channel Capacity	2Mbps
Mobility model	CityMob,MOVE	Packets Interval	0.25s
Vehicle velocity	30 Km/h-50 Km/h	Nbr of packets	1000
Nbr of vehicles	20-100	Propagation Model	Two-Ray ground

IV.3.3 Simulation Scenarios

In our simulation, we propose two different scenarios with two mobility models under urban environments. We model in both scenarios a city with an uniform block of size 500 x 500 m^2 through the sector of simulation. All the streets are one-way. The vehicles move according to the CityMob and MOVE models with speed ranges varies from 30 to 50 km/h.

Moreover, this model simulates semaphores with different delays (in our case, we use 20 s). When a vehicle meets a semaphore, it will remain stopped until the semaphore turn to green, whereas damaged vehicles will remain stopped during the entire simulation time (in our work, this parameter is null: the number of accidents = 0).

IV.3.4 Simulation Results

In our comparison of the two mobility models [103], [104], we consider the following performance metrics obtained from the AODV protocol: throughput, end-to-end delay and protocol overhead.

IV.3.4.1 Throughput

Figure 4.3 illustrates the throughput of AODV for the two mobility models (CityMob and Move) as a function of vehicles number. During all the simulation, the throughput of AODV when using CityMob is lower and unstable than when using MOVE model; this is due to high change topology and unstable network connectivity imposed by constrained node movements by roads and traffic control mechanisms.

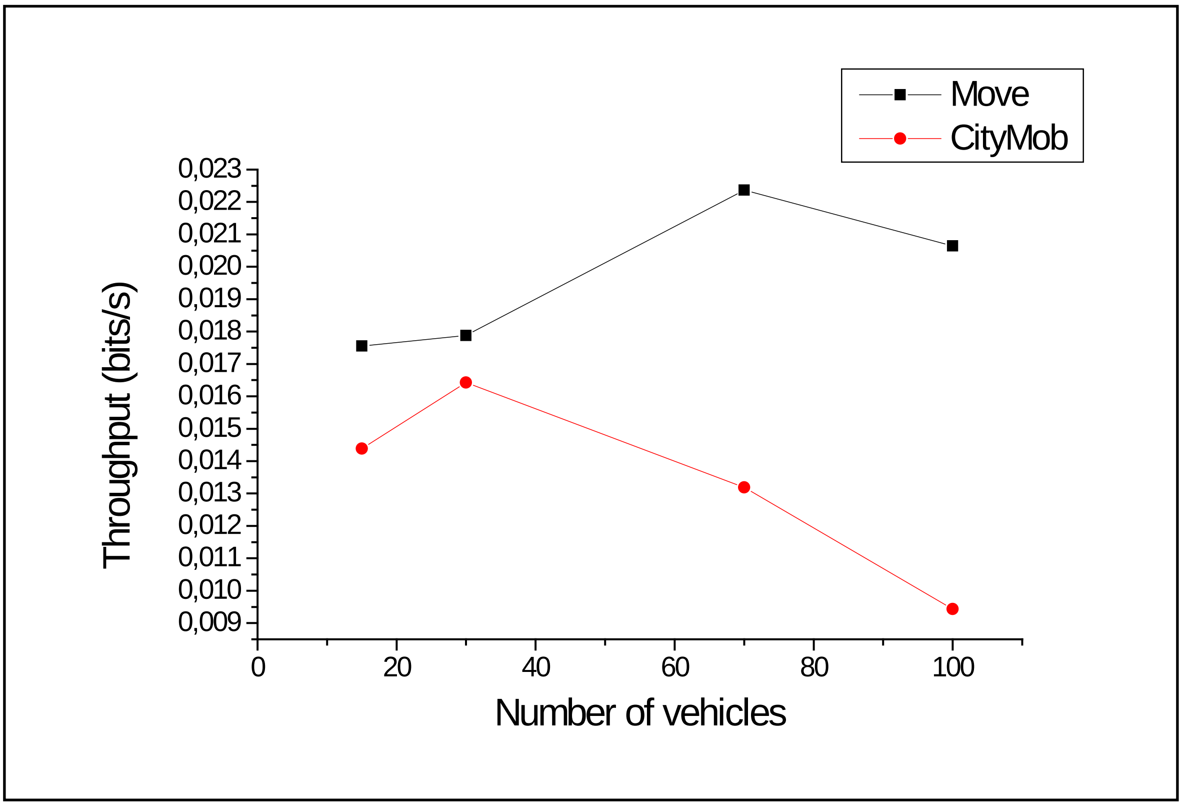


Figure 4.3 : Throughput vs. number of vehicles

IV.3.4.2 End-to-end delay

The trace 4.4 shows the end-to-end delay changes of AODV for MOVE and CityMob as a function of vehicles number. We remark that AODV causes a low stable delay with MOVE; it means that AODV route packets to destination faster when using MOVE because the roads are more defined compared to CityMob.

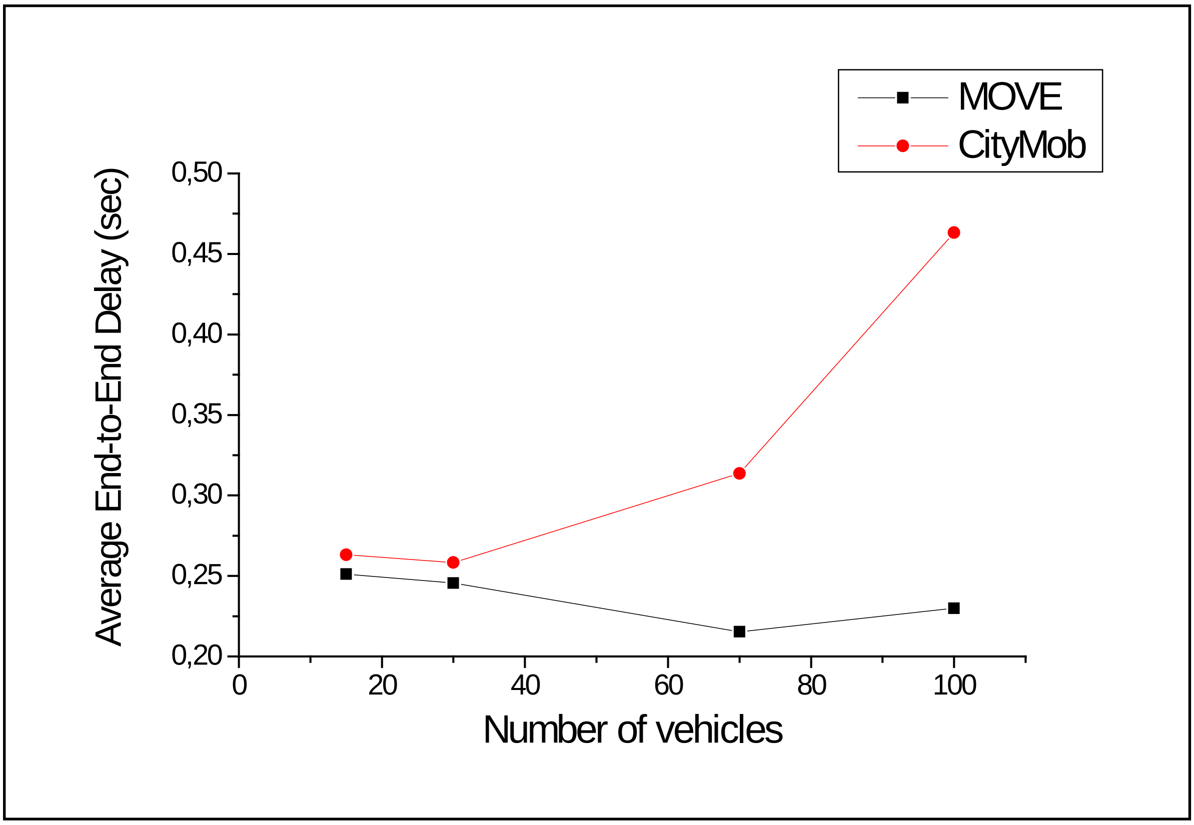


Figure 4.4 : End-to-end delay vs. number of vehicles

IV.3.4.3 Overhead

Figure 4.5 illustrates the overhead AODV required with each of the two chosen mobility models for different numbers of vehicles. The vehicles moving with CityMob generate a higher overhead; this is due to instability of the ways establishment caused by the frequent change of topology.

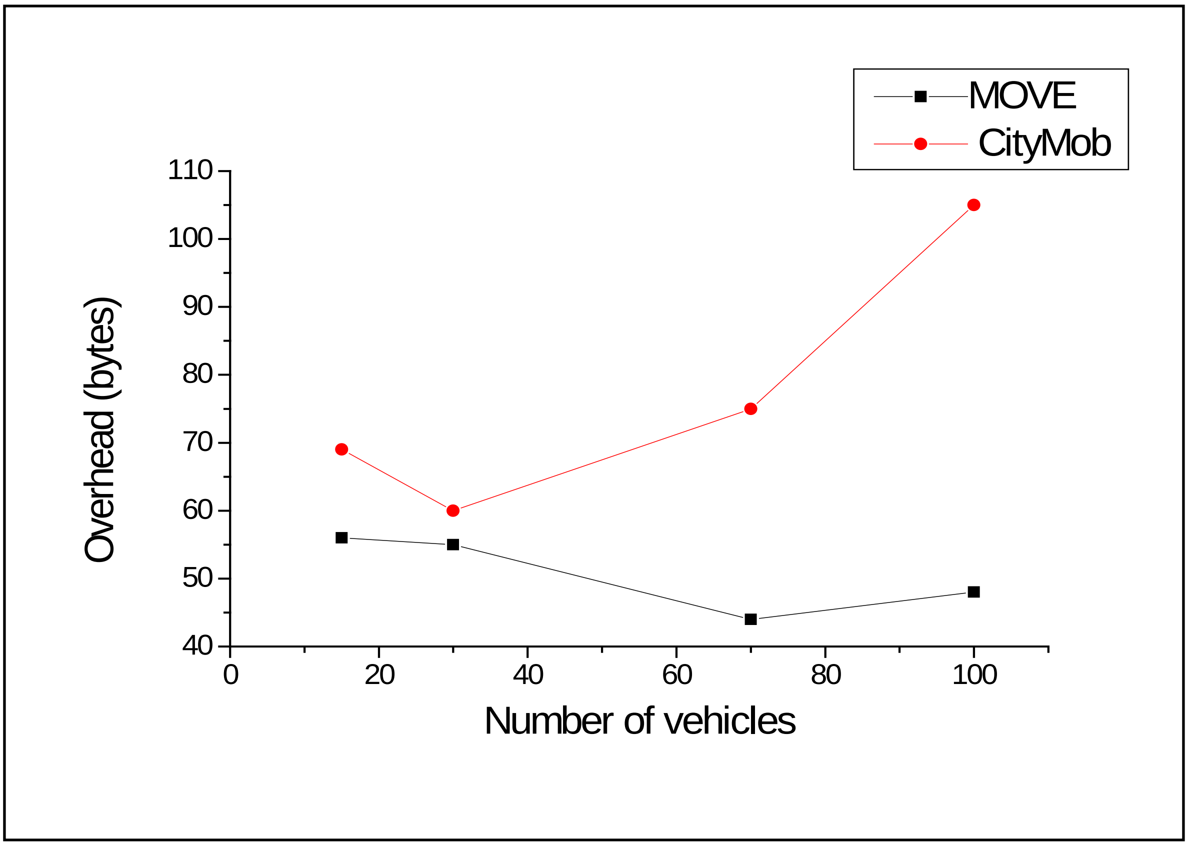


Figure 4.5 : Overhead vs. number of vehicles

IV.3.5 Discussion

The three figures combine to illustrate that the MOVE Model stresses AODV less than the CityMob pattern. Specifically, the MOVE has the highest Throughput, the lowest end-to end delay, and requires the least amount of overhead.

These results confirm the suitability of MOVE tool for simulating VANET, since it provides facility for the users to generate real world scenarios in vehicular environments.

The simulation results are greatly affected by the selected mobility model.The results presented in this section illustrate the importance of choosing a suitable mobility model for performances evaluation of routing protocols in VANET.

IV.4 Conclusions

In this chapter, we compared the performance of two mobility models for VANET Simulation i.e. MOVE (MObility model generator for VEhicular networks) and CityMob (City Mobility).

Simulation analysis using realistic mobility model for VANET environment shows that the performance of the protocol is greatly affected by the mobility model.

The performance of an ad-hoc network protocol can vary significantly with different mobility models then, the choice of mobility model in simulating VANET is very important.

The mobility models for VANET should be most closely matching the expected real-world scenario. In fact, the realistic scenarios can improve significantly the development of the routing protocols.

In the next chapter, we present and discuss a self-organization algorithm based on clustering, which are our main contribution in this thesis.

CHAPTER 5

CLUSTERING ALGORITHM UNDER POLICY BASED TECHNIQUES IN VEHICULAR AD-HOC NETWORKS

V.1 Introduction

As described in previous chapter, Vehicular networks are a kind of wireless ad hoc networks spontaneous, mobiles and totally autonomous. Moreover, these networks are characterized by their high mobility (topology change, variable distance between vehicles, frequent loss of connectivity, unreliability of the communications, delay, etc). The management of such networks and the deployment of advanced services such as driver-vehicle safety applications, infotainment, and mobile internet services for passengers present considerable challenges.

On the other hand, network management by policies [105] is a promising technique that has several benefits. This solution, widely adopted in fixed wired networks, can simplify and automate the management and configuration mechanisms of the Quality of Service (QoS), enabling the node configuration according to the network constraints and application needs without the intervention of an administrator; this would be particularly appropriate to the context of vehicular ad-hoc networks. In such architecture, management and control are centralized. It has a policy server PDP that manages and administers a set of fixed PEP owned a stable area. An adaptation of this architecture is needed to expand its use to VANETs.

Several studies [106], [107], [108] have focused on this aspect. The commonly used method is to divide the network to groups (clusters). In each group, a leader is elected to assume the role of PDP (cluster-head). The other members perform the role of PEP (members). We are particularly interesting to the solution described in [109], which represents an extension of the management by policies in ad-hoc network. The same algorithm was adopted by VANET clustering techniques, but without considering the battery power factor as it is not a crucial problem in vehicular network.

We think that the performance of the grouping mechanism used for the selection of cluster-head and the dynamic domains formation greatly affects the quality and the global performances of management system. Hence proposition of an effective clustering mechanism adequate for vehicular ad hoc networks is very interesting. In this chapter, we present a new Clustering Algorithm based on Mobility and Connectivity in Vehicular networks (MCAV). It allows forming dynamically clusters of varying radius. Cluster heads are selected among the most powerful vehicles in the network. The stability of clusters formed is achieved through the introduction of constraints on re-affiliations.

This chapter is organized as follows. In the next section, we expose briefly the inventory of clustering mechanisms presented in the literature both for MANET and VANET networks. In the third section, we describe our clustering algorithm MCAV, its principle and its properties. The final section presents the results of the conducted simulations.

V.2 Backgrounds and Related Works

V.2.1 Clustering-based self-organization

Clustering-based self-organization is to partition the network into homogeneous groups called clusters. Each cluster has at least one cluster head, and many members. Typically, cluster members have certain common characteristics that speeds or contiguous contact information, etc. Solutions based on clusters represent a viable approach in spreading messages between vehicles. Thus, clustering architecture typically allows the creation and update of a virtual backbone. The idea of defining a virtual backbone is brought from the wired networks. The principle of this solution is to constitute a backbone of best interconnected nodes (usually cluster heads are members of the backbone). The other nodes will be associated with the dorsal nodes. The subset of nodes must be defined to form a stable and persistent backbone. This means taking into account a number of conditions in terms of mobility, power level and security in the process of backbone formation. Every other node, not chosen as dominant, must be a neighbor of at least one dominant node [58,59].

V.2.2 Clustering in MANETs

The clustering or grouping was used for different objectives such as scaling of ad-hoc networks [110], the topology abstraction for flood control in networks [111], collecting informations in the sensors networks [112] and the sharing of bandwidth [113]. Figure 5.1 shows an example of the organization of MANET networks in clusters.

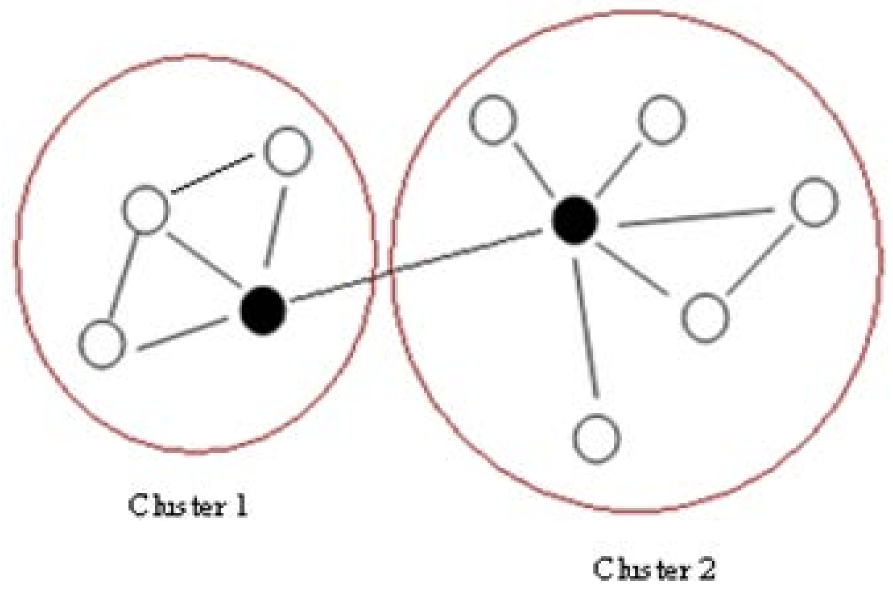


Figure 5.1 : Clustering in MANET Environment

The clustering algorithms Lowest-ID [114], [113] and Mobic [115] have fairly similar mechanisms. They are based on a particular criterion for the selection of clusterheads or group chiefs, respectively, the identifiers of nodes, the number of neighbors and the degree of mobility. These algorithms allow forming clusters in one hop, where each member is direct neighbor to its cluster head. They consider a formation phase of clusters or «clustering set up». During this phase, the nodes proceed to the knowledge of their neighbors and unroll between them the algorithm of fields' formation. However, the nodes are supposed fixed during this step and a synchronization between them is necessary for the good progress of the algorithm. Moreover, this phase of clusters formation is repeated periodically due to changes in topology that can occur. The periodic re-execution of this process of clustering degrades the stability of clusters.

The authors in [110] present a clustering mechanism that allows reducing the overhead of clustering. Each node diffuses only one message during the phase of formation of clusters. However, the assumption of absence of mobility during this phase must be checked. In addition, the clustering mechanism proposed overcomes the notion of cluster heads and does not treat the case where they leave the cluster.

The algorithm "Distributed and Mobility Adaptive Clustering» presented in [116] and [117] introduced the concept of generic weight for selecting cluster head. This is a mechanism of clustering that can respond to changes in topology. The algorithm requires no synchronization between nodes. For improve the stability of formed clusters, two new factors of performances have been defined. The first, K, allows the maximum K cluster-heads to be direct neighbors. The second, H, limits the re-affiliations between clusters. The nodes are re-affiliated with a new cluster head only when the weight of this last is higher of a certain factor H than the weight of their current cluster head. However, this solution enables the formation of clusters to one hop and the performance factor H is difficult to specify in a judicious way.

In other works [118] and [119], the authors tried to present adequate algorithms to the formation of clusters to k hops. However, [119] manages mobility by periodic re-execution of the all algorithm. [118] requires on the one hand information on the k neighborhood and on the other hand that the nodes check the hypothesis of no mobility during the clustering phase.

In [120], the authors presented a multi-criteria formula for the choices of cluster-head. It takes into account the mobility, the connectivity and available energy. This mechanism of clustering "Weighted Clustering Algorithm" requires, however, a global synchronization and an exchange of neighborhood between all the nodes of network.

The work [107] presents a clustering mechanism based firstly on the preliminary knowledge of the deployment area of the network and on the ability to position and secondly on the prediction of nodes movements by considering their history.

V.2.3 Clustering in VANETs

Clustering algorithms are applied in vehicular networks to organize all vehicles into groups and to obtain a hierarchical network organization. Figure 5.2 provides an example of the organization of thirteen vehicles into three clusters.

This section discusses a set of clustering algorithm conceived for vehicular network.

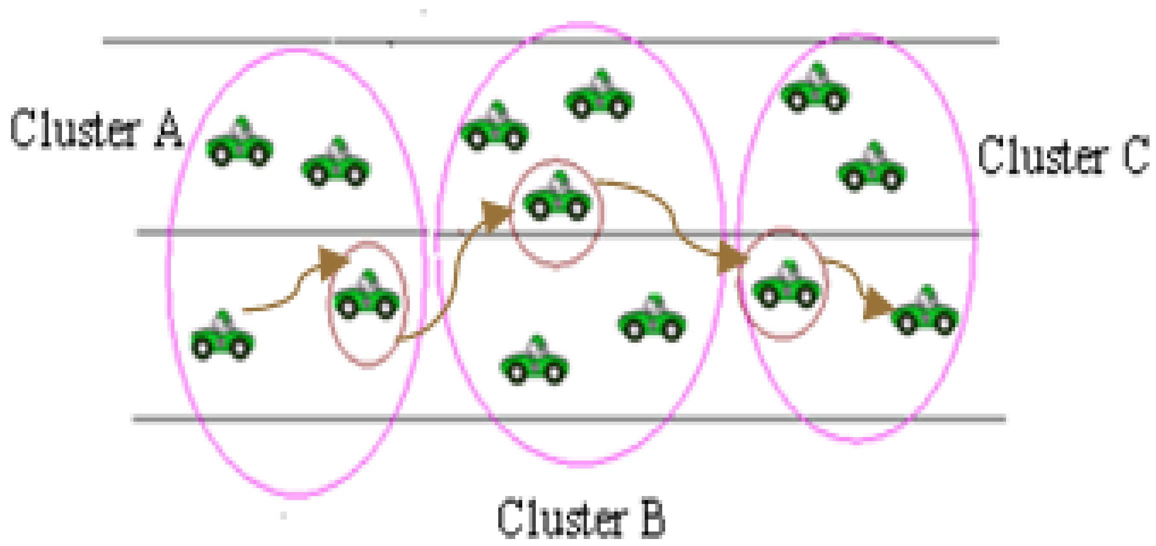


Figure 5.2 : VANET Architecture with Clusters

In [121], authors use a complex metric to propose clustering such as the Connection density, link quality and traffic conditions. The quality of link is determined from signal to noise ratio (SNR) and prediction of node mobility via GPS. To avoid unnecessary re-clustering and increase reliability of the algorithm, a method of member lifetime counter is used. This solution behaves more reliable in dense networks.

Robust Mobility Adaptive Clustering (RMAC) is proposed in [122]. In this algorithm, the clustering metric used is location, speed and traveling direction. The feature of this solution is cluster overlapping where a cluster head is a member node of one or more clusters. With this the communication between clusters is routed only through cluster heads. To extend the communication range, a zone of interest predefined by some radius is introduced.

In the aim to minimize the total number of created clusters and prolong the clusters lifetime, the authors in [123] proposes a new algorithm for grouping vehicles together, with similar mobility patterns, speed and direction of travel in the same cluster. In this algorithm, difference in transmission range for control channel and service is also taken in account.

The distributed mobility-based clustering algorithm is presented in [124]. The authors aim to minimize both distance between cluster head and nodes, and the relative mobility. The stability in this algorithm is defined by long cluster head lifetime, long cluster member lifetime; low rate of elections (declaration of a node as the cluster head). The direction of vehicles is taken in account for increasing the stability.

A weighted clustering algorithm for vehicular networks is proposed in [125]. The cluster stability and connectivity is increased by the use of a complex metric which is based on vehicle direction and dynamic transmission range to calculate the number of neighbors. For detecting abnormal vehicles in the network, the algorithm also proposes a monitor of vehicles behavior in the system. And for compensation of the variable node density, a transmission range allocation technique is adapted.

The paper [126] proposes a clustering based on movement direction, where the formation of cluster is achieved before road intersections and is based on the prediction of traveling path. The vehicle location, route and destination must be known in advance. Navigation system is necessary in this system for knowing routes. This algorithm is suitable for urban environment.

In [127] The Algorithm AMACAD takes into account for clustering, speed, location and both relative and final destination. As the solution described in [126], the knowing of the final destination in advance might be a problem since navigation system is not used by drivers in most cases.

The solution in [128] is conceived to form stable clusters on highways. It based on speed and vehicles direction. Clustering process is initiated from the fastest or slowest vehicle. This approach also depends on the location service. When the deviation of a vehicle speed is very important from other vehicles speed, the vehicle leaves alone the cluster and this is a drawback for this algorithm.

V.2.4 Management by policies in vehicular networks

In the context of management by policies, it is necessary for the reliability of deployed services, that all the nodes of network are constantly attached to a cluster (or cluster head). Thus, the clustering algorithms managing mobility by periodic re-execution of the clustering process are not adequate. Furthermore, the periodic re-execution of the clustering process leads to the destruction of clusters in place and the election of new cluster head. However, any change from one cluster to another generates a significant traffic synchronization of policies between the old and the new cluster-head. In addition, several algorithms of clustering presented in the literature allow the formation of clusters to a single hop. This may be advantageous in the case of negotiations within clusters (between cluster-head and members). But, this can increase the number of clusters generated in the network and consequently the period of inter-cluster negotiations (between cluster head).

V.3 MCAV: A Clustering Algorithm under Policy based Techniques in Vehicular ad-hoc Networks

In the following, we present our new algorithm of clustering adapted to VANET, called « MCAV, Mobility and Connectivity based Clustering Algorithm for Vehicular networks » [129], [130] .It was designed to meet the needs for management by policies in vehicular networks.

Clusters are formed following the election of cluster head and re-affiliations of the vehicles to these cluster head.

The notations used in the algorithms are summarized in Table 5.1:

Table 5.1 : MCAV Parameters Abbreviations

Notation	Description
CH	Cluster-Head
PDP	Policy Decision Point
PEP	Policy Enforcement Point
Nv	The set of adjacent vehicles
Cv	degree of Connectivity of the vehicle v
Mv	the average Mobility (speed) of the vehicle v
w_1	clustering _connection_ weight
w_2	clustering _mobility _weight
$\mathrm{W}v$	Weight of the vehicle v
RA	Re-affiliation Rate
RE	Rate of Election
$A(t)$	The set of neighboring clusters
H	The cluster_max_hop (cluster radius)
$Wmin$	The cluster_ref_Weight (minimal Weight)
$Dmin$	The cluster_min_Density
$Dmax$	The cluster_max_Density
Chw	The Weight of the cluster- head
$clusterD$	The cluster Density
$Chid$	Cluster-Head identifier

V.3.1 MCAV structure

Our clustering algorithm is based on the following principles:

V.3.1.1 Cluster head election Process

The mechanism used to create cluster head, consists of selecting the vehicles with the best performance to perform the role of cluster head. We define bi-factor metric for calculating This metric takes into consideration mobility and connectivity degree.

If {Nv} represents the set of adjacent vehicles of a particular vehficle v, then the degree of connectivity of v is represented as

$$\mathrm{C}v = |\mathrm{N}v| \tag{5.1}$$

Where $|\mathrm{N}v|$ is the cardinality of $\{\mathrm{N}v\}$. Mv is the average speed of a vehicle v.

The combined weight of every vehicle v is calculated as

$$\mathrm{W}v \;=\; \mathrm{w}_1.\mathrm{C}v \;+\; \mathrm{w}_2.(1/\,Mv) \tag{5.2}$$

The values of w_1 and w_2 are the weighing factors that depend on the system needs and are chosen so that $w_1 + w_2 = 1$. A vehicle having higher weight among all its neighbors is selected as the cluster head. So we expect a cluster head with a higher connectivity and a lower mobility.

V.3.1.2 Clusters Formation Algorithms

The formation of the clusters is done by the election of the cluster-head and the re-affiliation of the vehicles to these cluster head. The mechanism of election of the cluster-head is not synchronized between all the vehicles of the network. It does not imply that all the nodes execute at the same time the election procedure. The principle of our solution is shown in the Figure 5.3. The decision to be cluster-head is carried out by each vehicle not detecting in the H-vicinity a cluster-head to which it affiliates. It then diffuses a CH message in its H-vicinity while indicating its weight as shown in the pseudo code of the Algorithm 1. Each vehicle that receives a CH Message compares the weight of its cluster-head with the weight received in this message. If the received weight is higher, it can join this new cluster head under certain conditions (Algorithm 2 in Figure 5.4).

Algorithm 1: *Starting clustering process*

1: ***if*** $A\ (t)$ *is empty // (no cluster finds in the* H *−vicinity)* ***then***
2: $CH \leftarrow vx.W$ *//* vx *sets its weight*
3: *Send* Ch *message* (CH)
4: ***end if***

Figure 5.3 : Clusters Formation Process

Algorithm 2: *CH designation*

1: ***if*** $vy \in A\ (t)$ ***then***
2: *On Receipt (CH)*
3: $vy\ .chooseCh()$ *// chooses the best Ch in the neighborhood under certain conditions.*
4: ***if*** $chooseCh\ \neq 0$ *//(there is a best Ch in the neighborhood)* ***then***
5: *Send* $JOIN()$ *// decision to affiliate to a neighboring cluster*
6: ***else***
7: vy*. Situation* $\leftarrow Ch$
8: CH *id* $\leftarrow vy.id$ *//* vy *declares itself as a Ch because impossible to affiliate to a nearby cluster*
9: $vy.CH \leftarrow Chid$ *//* vy *sets its cluster id*
10: $vy.CH\ \leftarrow Chw$ *//* vy *sets its weight*
11: *Send* $CH\ (Ch\ id)$ *// sends its cluster id to all vehicles*
12: ***end if***
13: ***end if***

Figure 5.4 : Cluster Head Election Algorithm

V.3.1.3 Re-affiliations and joining a cluster

To keep the stability of clusters, a set of conditions is defined for re-affiliations and joining others clusters.

The procedure is described as follows:

- *Re-affiliations*

The parameters which determine the re-affiliations are H, W_{min}, D_{min} and D_{max} (Table 5.1). H represents the maximum number of hops between a cluster head and its members. W_{min} is the minimal weight that can have a vehicle to assume properly the role of cluster-head. Dmin is the minimal number of vehicles per cluster below which the cluster is considered unstable and therefore subject to re-affiliations. Finally D_{max} designate the maximum number of vehicles per cluster, which, once reached, the cluster head refuses the new requests for affiliations to its cluster.

The re-affiliation can occur when:

- A member node moves from one cluster to another,
- Cluster-head becomes a member,
- A member node becomes a cluster head.

The re-affiliations can only occur following the reception of a CH message or following the loss of connection with the cluster head. Each vehicle holds the following informations: identifier and weight of its cluster head, density of its cluster (number of vehicles per cluster) and the number of hops to its cluster head.

- *Joining a cluster*

A node can join a neighboring cluster if:

- The cluster head is with more than H hops of it.
- The density of the neighbor cluster has not reached the maximal density Dmax.

A node, that receives a CH message sent by a cluster-head of weight better than its current cluster head, re-affiliates to a new cluster head only if (Algorithm 3 Figure 5.4):

- The density of the cluster is less than Dmin,
- The density of its cluster is greater than Dmin but its weight is less than Wmin.

The idea here is that it is not necessary for the vehicle to be always affiliated with the best cluster head as long as the performances of their current cluster-head are «suitable» and this, in order to improve the stability of the clusters and to reduce the movement of vehicles between clusters.

A new vehicle joining the network is ordered to:

- Wait for a certain period during which it listens to its neighborhood in search of a cluster that it can join.
- If it finds a neighbor cluster that satisfies the conditions cited above, it joins and notifies the cluster head concerned by a message JOIN.
- If it is impossible for him to join a neighbor cluster, it takes the decision to be cluster head and inform the vehicles located in its H-vicinity by a CH message.

Once the clusters formed, there is a regular exchange of Keep-Alive messages between cluster heads and their members. These messages allow one hand to ensure they are still part of the same cluster and the other to exchange information useful in the case where a node is required to change the cluster.

Algorithm 3: *Re-affiliations and joining a cluster*

```
if vz ϵ A(t) then
   On Receipt (Ch message) Ch ← vy.W
   vz.Compare Weight () // compares the weight of its cluster head with the weight
   received in the Ch message.
   while vy.W > vz.Chw do
      if vz.clusterD > Dmin then
         if vz.Chw < Wmin then
            Send Join message (JOIN) // decision to affiliate to this CH
         else
            aff_impossible // cannot affiliate to this CH
         end if
      else
         Send JOIN ()
      end if
   end while
end if
```

Figure 5.5 : Algorithm of Re-affiliations and Joining a Cluster

V.4 Performances Evaluation

V.4.1 Mobility Model and Simulation Setup

To evaluate the performance of our solution in VANET environment, we have implemented the MCAV algorithm in the NS-2 simulator [96,134].

The mobility model, used to generate the traffic, has a great impact on the accuracy of the obtained simulation results. In this work we used the realistic traffic generator called (VanetMobiSim) (see Appendix).

The output from VanetMobiSim simulation is a traffic generator trace file that corresponds to position coordinates of each vehicular node at every time steps. This traffic generator trace file is the mobility model that goes through network simulator (by NS-2 package in present study) and ultimately generates a communication trace file (Figure 5.6).

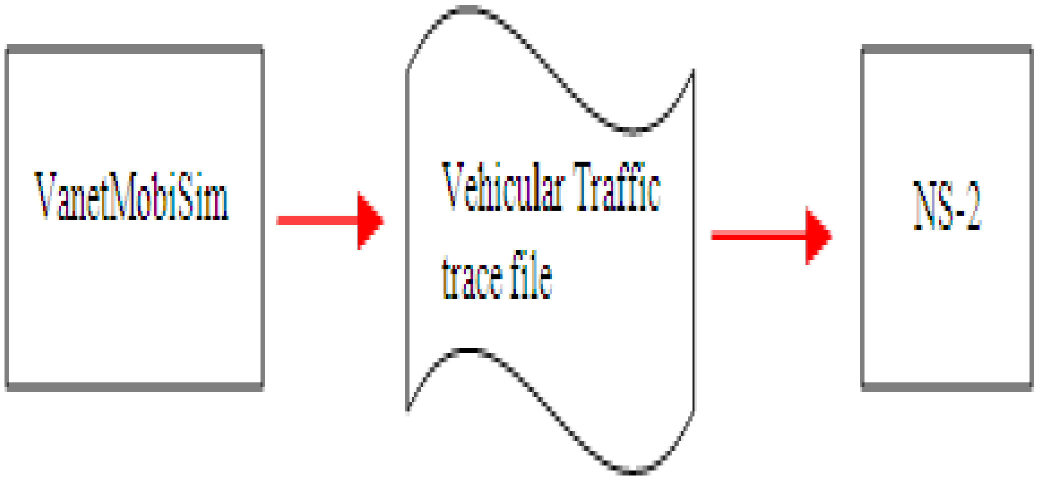


Figure 5.6 : Simulation architecture

V.4.2 Simulation Environment

We conducted a series of simulations to evaluate the performance of the proposed clustering mechanism. The data rate is 5 Mbps, the message size including the informations is 100 bytes and the periodic messages are sent every 200 ms.

Table 5.2 shows the simulation parameters used to evaluate the performance of MCAV.

Table 5.2 : Simulation Parameters

Simulation time	200s	Mobility model	VanetMobiSim
Transmission Range	250m	Antenna	OmniAntenna
MAC layer	IEEE 802.11	Radio propagation Model	Two Ray Ground reflextion
Simulation area	1000 x 1000 m²	Data Packets size	512 octets
Number of vehicles	70-100	Packets interval	200 ms
Velocity range	20 – 120 Km/h	Data rate	5 Mbps

In our simulation, we varied the speed of vehicles (20 Km/h to 120 Km/h).
The configuration of our Algorithm in this implementation is given in the following table 5.3.

Table 5.3 : Implementations parameters

Metric	Weighting factors		Radius	D_{min}	D_{max}	W_{min}
	w_1	w_2				
Speed, Connectivity	0.5	0.5	H=1(*1hop*) H=2(*2hops*) H=3(*3hops*)	30	35	2.08

V.4.3 Evaluation Criteria

During the simulations, we are interested in following metrics:

- The rate of re-affiliations: changing a node in a cluster
- The rate of elections: declaration of a node as the cluster-head.
- The average lifetime of cluster head
- The average number of clusters.

V.4.4 Simulation Results

In this section, we evaluate the performances of MCAV via simulation.

V.4.4.1 Re-affiliations Rate

Figure 5.7 presents the rates of re-affiliations as a function of velocity range. The velocity varies from 20 km/h to 120 km/h. we remark that the re-affiliations rate increases with the speed of vehicles. Indeed, more the speed is high, more the probability that a vehicle is out of its cluster following a movement is great. However, we note that for this configuration, the re-affiliations become almost constant from speed 50 Km/h to 80 Km / h (displacement velocity of vehicles in urban environment). This environment is characterized by the intersections that are usually equipped with traffic lights. Then the vehicles are more stable in the intersections, so the re-affiliations become constant. We also note that the variations between re-affiliations are not much large especially for the values of H (2 and 3 which let more flexibility to the user for the choice of clusters radius forming the network.

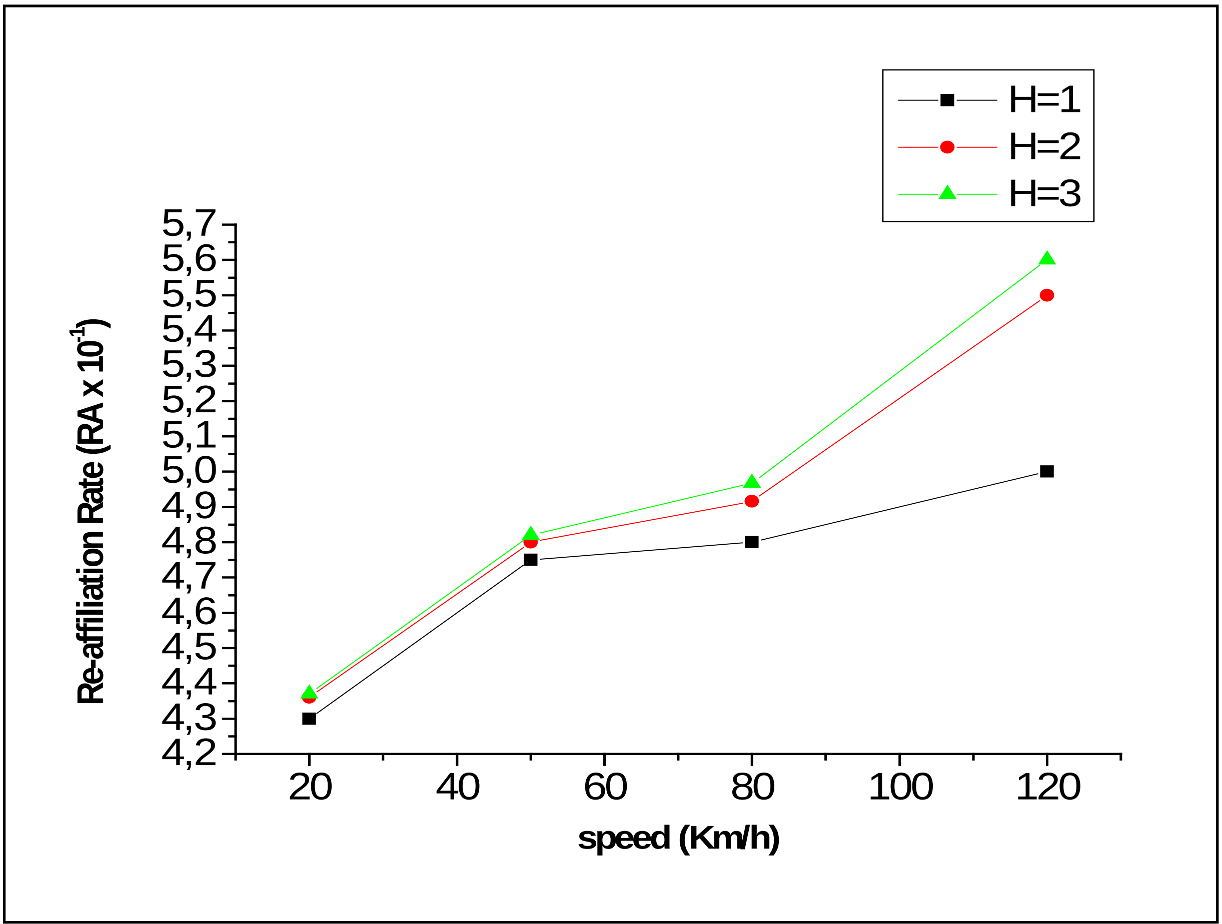


Figure 5.7 : Re-affiliations rate vs. vehicles speed

V.4.4.2 Elections Rate

Figure 5.8 illustrates the rates of elections according to the speed of vehicles. More the velocity is high, more the election rate becomes great, except the velocity ranges from 50 Km/h to 80 Km/h where the head election process for two and three hops clusters seems constant in the urban environment where the re-affiliations occur in the same time.

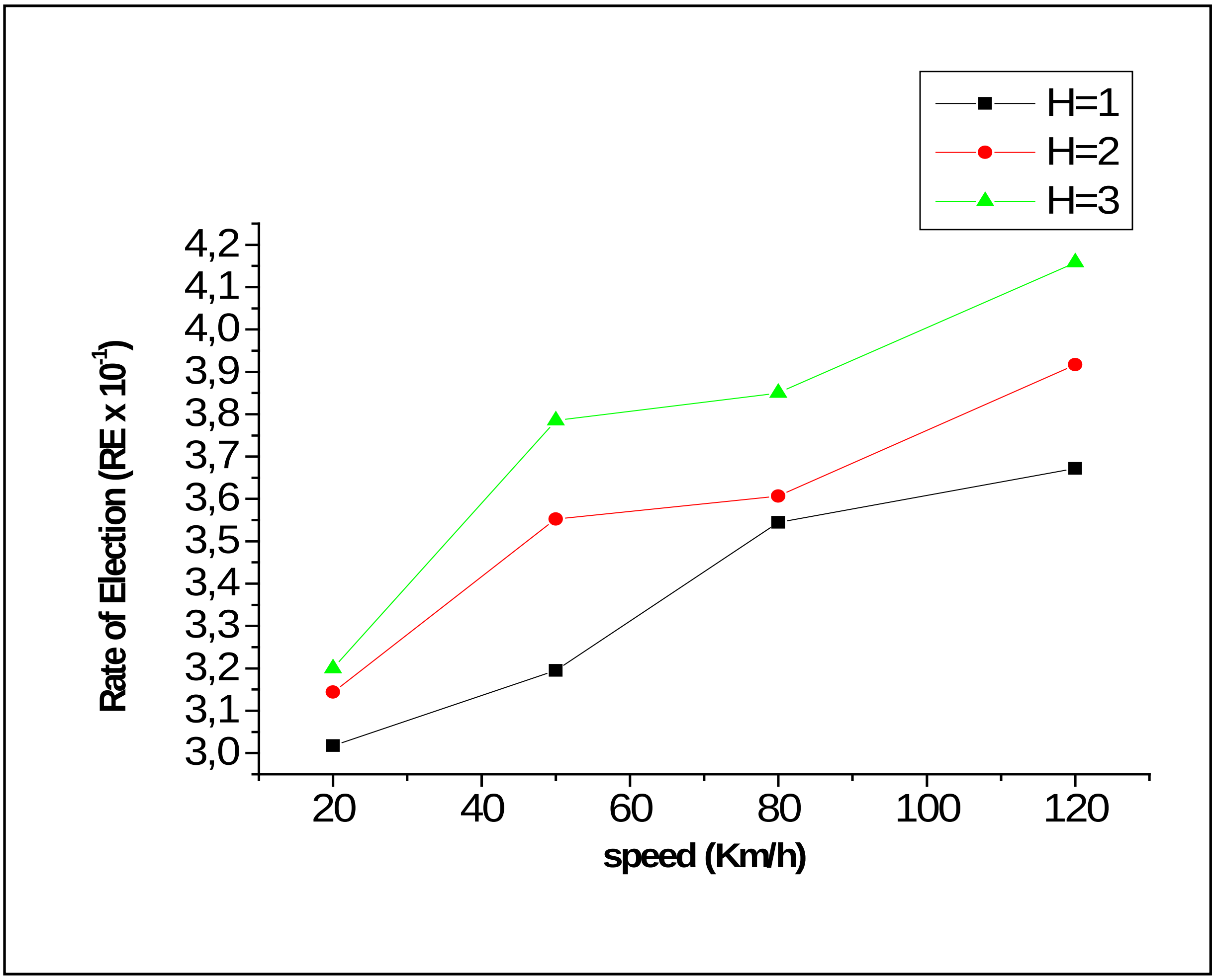


Figure 5.8 : Elections rate vs. vehicles speed

V.4.4.3 Cluster lifetime

The mean of the cluster life duration shown in Figure 5.9 decrease in function of velocity since vehicles mobility introduces more instability in the network. However, we note that the cluster lifetime for the values of H= 2 and H = 3 is more stable compared to H = 1 which is beneficial in the case of dense network like VANET.

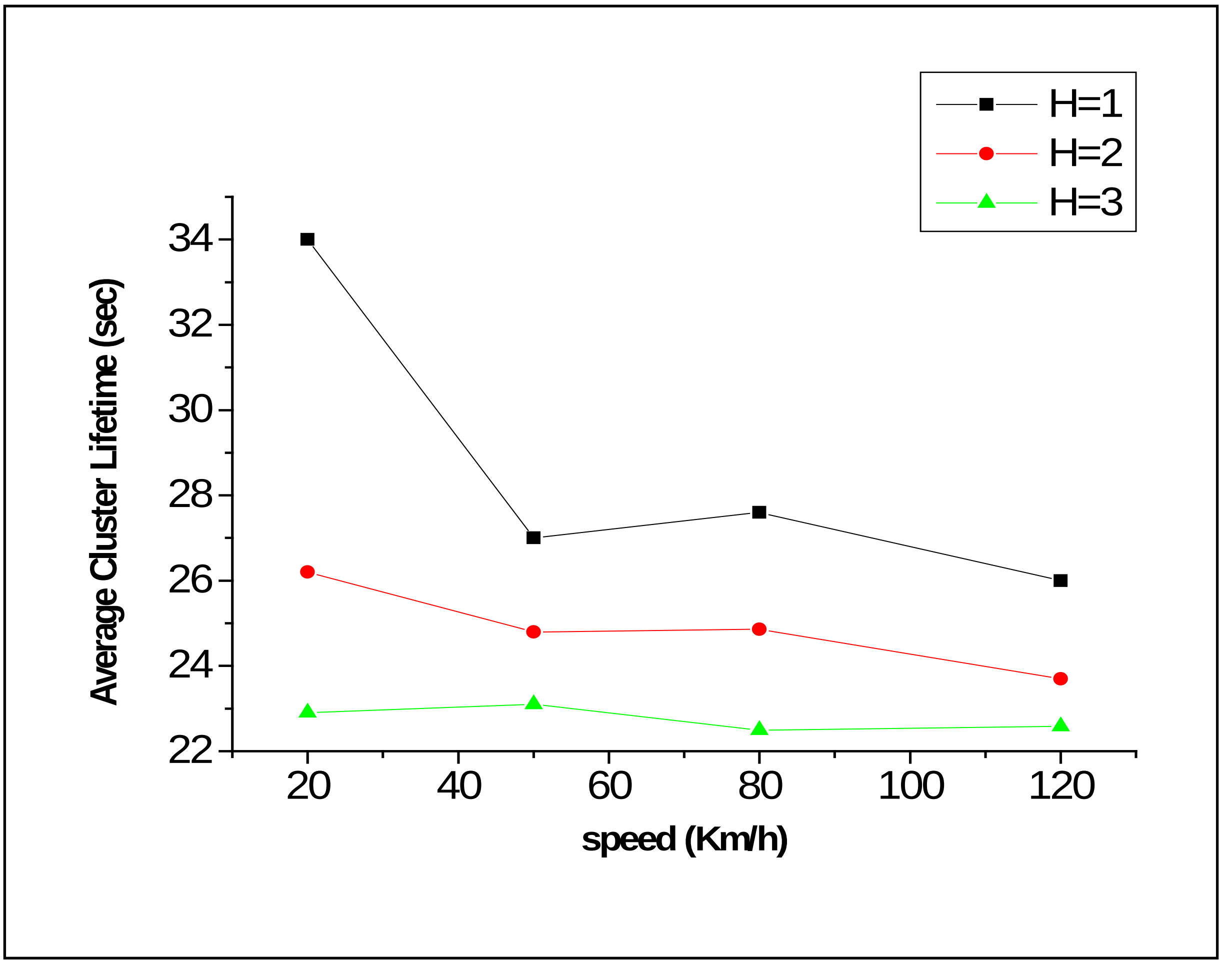


Figure 5.9 : Cluster-head lifetime vs. vehicles speed

V.4.4.4 Average Number of Clusters

Figure 5.10 shows the average number of formed clusters for different vehicles speeds. We remark that this number decreases slightly depending on the speed. So clusters number depends mainly on the mean velocity of vehicles. This behavior can be argued by the fact that in case of mobility, the vehicles are able to reorganize and join existing clusters which is beneficial in the case of VANET.

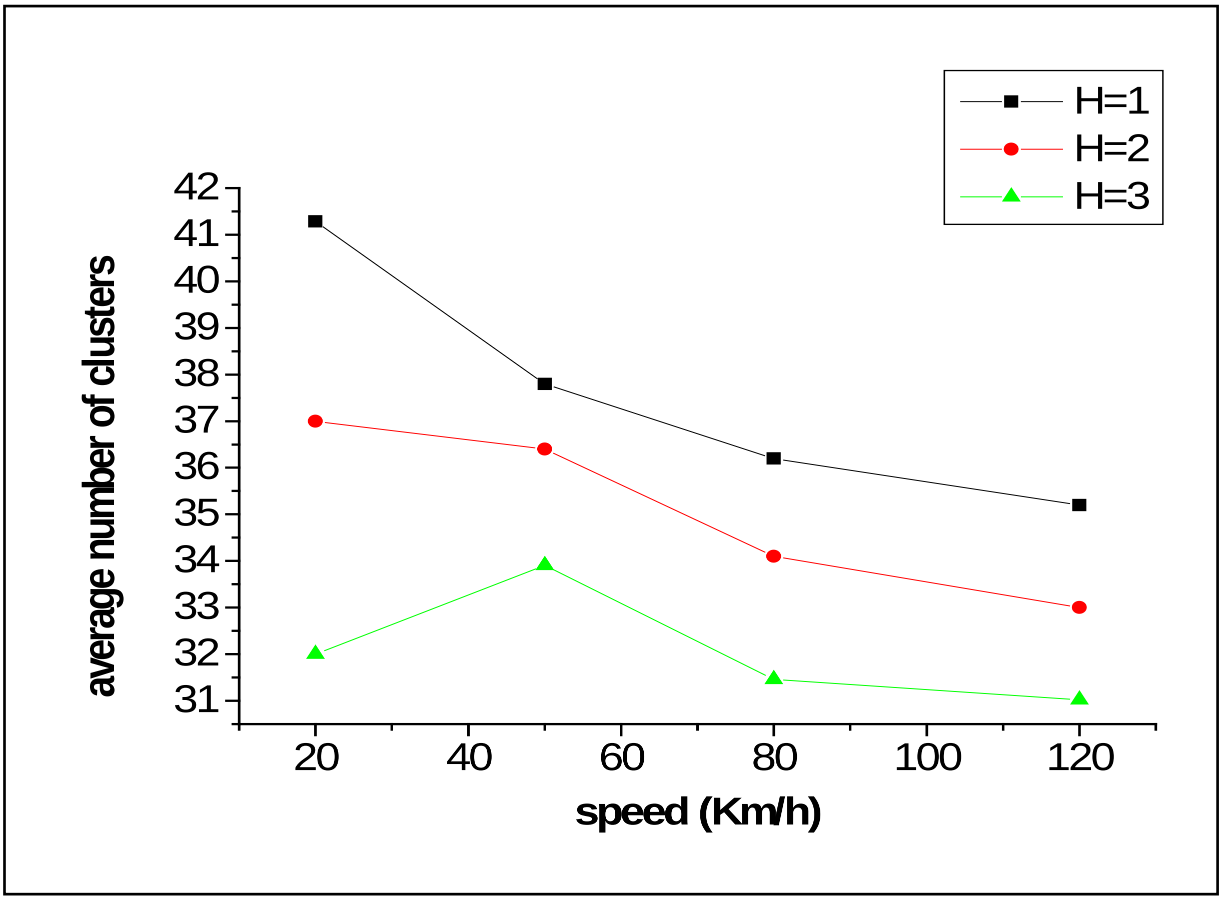


Figure 5.10 : Average number of clusters vs. vehicles speed

V.5 Discussion

MCAV is a mechanism based on dynamic clusters to self-organize the vehicular Network communications. These clusters were formed under certain conditions. For this, we have introduced a set of parameters to control the re-affiliations and the elections process of clusters heads.

The simulation studies results show that MCAV permits to form clusters of configurable size and radius according to the vehicles mobility. Indeed, MCAV ensure a stable clusters lifetime which allows permanent connection between heads. Then the vehicles are able to reorganize and join existing clusters which is beneficial in the case of VANET.

The idea of MCAV is that it is not necessary for the vehicle to be always affiliated with the best cluster head as long as the performances of their current cluster-head are «suitable» and this in order to improve the stability of the clusters and to reduce the movement of vehicles between clusters.

The mechanism of election of the cluster-head is not synchronized between all the vehicles of the network. It does not imply that all the nodes execute at the same time the election procedure

The principle of this solution is to reduce the re-affiliations and minimize the election rate to ensure the best stability of clusters as possible.

MCAV can self-organize the vehicular Network in both highways and urban environments. But the simulation results confirm the suitability of MCAV for the urban VANET environments.

V.6 Conclusion

In this chapter, we presented a new algorithm of clustering adequate for management by policies in VANET. It allows forming clusters of configurable size and radius according to topology changes induced by vehicle mobility.

The originality of the algorithm lies to the management of re-affiliations vehicles between clusters of clusters. For this, control factors were introduced to reduce the re-affiliations and improve the stability. Although it is proposed for management by policy, our algorithm is fairly generic and can be used for other purposes.

Since VANETs are dense and highly dynamic networks, in our future work we plan to study more detailed performance of our algorithm by studying the influence of various parameters (W_{min}, D_{min}, D_{max}) in different VANET environments according to the mobility of vehicles and compare it to existing solutions.

CHAPTER 6

CONCLUSION AND PERSPECTIVES

VI.1 General Conclusion

The communications between vehicles without any access points or base stations is a great field of research. The main aim of VANET offers a safety and comfort for passengers. For this purpose, a particular electronic device will be placed inside each vehicle which will provide Ad Hoc Network Connectivity.

This network tends to function without any infrastructure. Each vehicle equipped with a device VANET will be a node in the Ad Hoc network and can receive and transmit messages.

The applications related to the road safety represent a big part of the applications of the vehicular networks. These applications understand the diffusion of the messages giving an account of the state of the traffic, the weather, the state of the roadway, the accidents works or messages pointing out the speed limits or the security distances.

The examples of services are not limited only to the applications of safety but to other types of applications in particular the diffusion of practical informations by providers of services to the motorists (spot of information, offer of service useful for the drivers: service station or presentation of parking bays available), all this, is thanks to connection to Internet available in the vehicles via ad hoc network using both communications between vehicles and between the vehicles and the fixed equipments installed along the roadside.

In worldwide, major research, development and standardization on the inter-vehicle communications are underway. Moreover, many projects, in Europe were initiated to form the basis of an Intelligent Transportation System (ITS).

VI.2 Performed Works

This thesis is specifically interested in the issues of self-organization of VANET to optimize communications within the vehicles in ITS systems.

In this context, this thesis is specifically interested in the issues of self-organization of VANET to optimize communications with in the vehicles in ITS systems. Our objective was to propose a clustering mechanism tailored to the characteristics of these networks of vehicles and to targeted applications. Initially, we presented the main concepts, characteristics and challenges vehicle-related networks. We also presented the dynamics around this type of networks. This allowed us to gain insight and an overview on the current state of this new wireless network technology with a vision on future advances and especially assimilate the necessary basis for understanding operation and mechanisms of vehicular networks.

Then, we discussed another interesting topic about the emergence of sensor networks (Traditional (WSN) and vehicular (VSN)), new themes have been opened and new challenges have emerged to meet the needs of individuals and the requirements of several application areas. Research today is much focused on vehicular sensor networks (VSN); considerable efforts have emerged to introduce intelligence into transport systems to improve safety, efficiency and usability in road transport. These networks will play an important role in building the Future Internet, where they will serve as a support for various communication applications and integrated into our daily lives. In this part, we surveyed the main characteristic and applications of two type of Ad hoc networks WSN and VSN, and we make a comparison between them.

Another part of the thesis deals with the mobility which is the principal constraint met in the vehicular networks, therefore the performance investigation of VANET routing requires the exact prediction of mobility of nodes forming the network, and this is realized by the good choice of the mobility model. In this part we showed that the mobility models can significantly affect the simulation results in VANETs. We made a comparative between two mobility models for VANET, The results presented prove the importance of choosing a suitable real world scenario for performances evaluation in VANET environment.

In the last part of this PhD thesis, we proposed a new clustering algorithm called MCAV appropriate for management by policies in vehicular ad hoc networks. Our algorithm allows the formation of clusters of configurable size and radius. The stability of these clusters is enhanced by the introduction of control factors re-affiliations. In second step, we evaluated by simulation, its performances related to vehicles mobility.

VI.3 Perspectives

In the continuity of this work, it will be interesting to handle other aspects of communication in vehicular networks.

In the continuity of the presented work, we could deepen our study to improve results. Since VANETs are dense and highly dynamic networks, in our future work we plan to study more detailed performance of our algorithm (MCAV) by studying the influence of various parameters (W_{min}, D_{min}, D_{max}) in different VANET environments according to the mobility of vehicles and compare it to existing solutions.

Then, in case of MCAV, it will be interesting to take into account other parameters to improve the choice of the new head by including other parameters in the head electing formula. For example, parameters like velocity deviation, position, acceleration and vehicle brand can make the comparison between different head candidates more accurate.

Another aspect that could prolong the work of this thesis is the integration of this clustering mechanism with a routing protocol in the aim to optimize the communication in the vehicular network by studying the impact of different network parameters in the context of VANET.

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List of Publications

A. INTERNATIONAL JOURNALS

[A1] B. Boukenadil, M. Feham,"Importance of Realistic Mobility Models for VANET network simulation", *International Journal of Computer Networks & Communications (IJCNC)*, Vol.6, No.5, pp. 175-182, September 2014.
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[A2] B. Boukenadil, M. Feham,"The sensors networks WSN and VSN: a Theoretical Comparison", *International Journal of Wireless & Mobile Networks (IJWMN)*, Vol. 6, No. 5, pp. 59-66,October 2014.
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[A3] B. Boukenadil, M. Feham,"Clustering Algorithm under Policy Based Techniques in Vehicular Ad hoc Networks", ELECTROTEHNICĂ*, ELECTRONICĂ, AUTOMATICĂ (EEA Journal, ISSN 1582-5175)*, Vol.63, No.2, pp. 25-32, June 2015.

B. INTERNATIONAL CONFERENCES

[B1] B. Boukenadil, M. Feham, "Comparison between DSR, AODV and DSDV in VANET using CityMob", *in proceedings of the 1st International Conference on New Technologies & Communication (ICNTC-2012),* pp. 5-9, Chlef, Algeria,5-6 December 2012.

[B2] B. Boukenadil, M. Feham,"DRCV: Distributed Re-affiliation Controlled Clustering Algorithm for Vehicular Networks», *in proceedings of the 2nd International Conference on Electrical Engineering and Control Applications (ICEECA'2014),* pp. 126, Costantine, Algeria, November 18-20th, 2014.

[B3] B. Boukenadil, M. Feham, "Mobility Models for VANET simulation ", *in proceedings of the 2nd International Conference on New Technologies & Communication (ICNTC'15)*, pp. 62-65, Chlef, Algeria, 03-04 March 2015.

[B4] B. Boukenadil, M. Feham, "A New Clustering Algorithm for Vehicular Network ", *in proceedings of 1st International Conference on Telecommunications and ICT (ICTTelecom-2015)*, pp. 131-134, Oran, Algeria, 16-17 May 2015.

C. NATIONAL DAYS

[C1] B. Boukenadil, M. Feham, "Projet VSN :Vehicular Sensor Networks", *Days - Formations et Recherches à impacts -JSTIC'2011,*STIC Laboratory, University of Tlemcen,Algeria,12-13 December 2011.

[C2] B. Boukenadil, M. Feham, SM. Senouci, "Data Collection in vehicular Ad-hoc Networks (VANET) ", *Day -JSTIC'2014,*STIC Laboratory, Faculty of Technology, University of Tlemcen, Algeria, 18 March 2014.

Appendix

Vehicular mobility simulator: VanetMobiSim

A.1 Introduction

In the performance evaluation of a protocol for a vehicular ad hoc network, the protocol should be tested under a realistic conditions including, representative data traffic models, and realistic movements of the mobile nodes which are the vehicles (i.e., a mobility model). We will present a comparative simulation between two mobility models for VANET.
To perform our simulations, we have used a traffic generator, called VehicleMobiSim.

We introduce briefly the function of VehicleMobiSim in the next paragraph.

A.2 The Vehicular mobility model VanetMobiSim

VanetMobiSim [85,131,132,133] is based on CANU Mobility Simulation Environment (CanuMobiSim) [135]. Indeed, CanuMobiSim is a flexible platform for the modeling of mobility.

This platform is implemented like an autonomous JAVA application and can be used with almost any tool of simulation and emulation for mobile networks (format NS-2, GloMoSim, and QualNet). To simulate the movement, it provides several models of physics and automobile dynamics. Moreover, the structure contains several random models of mobility, like the Brownien movement or the movement “Random Waypoint”.

VanetMobiSim is an extension of CanuMobiSim, which is focused on automobile mobility and has new models of realistic automobile movements as well at the macroscopic level as microscopic.

- At the macroscopic level, VanetMobiSim can produce road maps by using the diagram of Voronoï as shown in the figure 3.6. He adds also the management of multilane roads of circulation, one-way flows, and constraints speed to the intersections and traffic lights.

- At the microscopic level, VanetMobiSim implements new models of mobility allowing the taking into account of the vehicles close (deceleration, distance from safety, etc…).

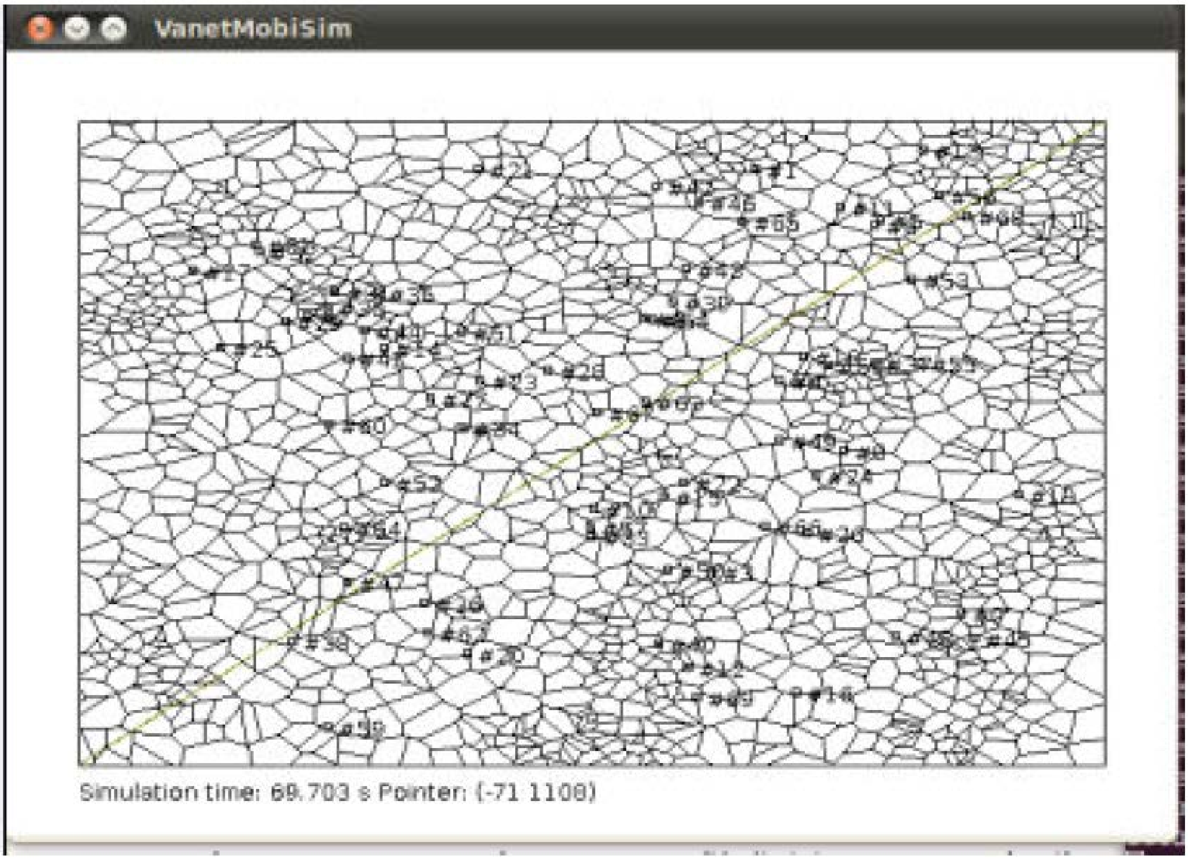

Figure A.1 : Screenshot of VanetMobiSim

```
<?xml version="1.0" encoding="UTF-8" ?>
<!-- Cars in a City Center using the SpaceGraph.   -->
- <universe>
    <dimx>2000.0</dimx>
    <dimy>2000.0</dimy>
    <!-- <seed>13</seed>   -->
    <extension class="de.uni_stuttgart.informatik.canu.mobisim.extensions.NSOutput" output="test_trace10n" />
    <extension class="de.uni_stuttgart.informatik.canu.mobisim.simulations.TimeSimulation" param="40.0" />
  - <extension name="SpatialModel" class="de.uni_stuttgart.informatik.canu.spatialmodel.core.SpatialModel" min_x="0" max_x="2000" min_y="0" max_y="2000">
      <max_traffic_lights>3</max_traffic_lights>
      <reflect_directions>false</reflect_directions>
      <number_lane full="false" max="2" dir="false">2</number_lane>
    </extension>
  - <extension class="eurecom.spacegraph.SpaceGraph" cluster="true">
    - <clusters density="0.000004">
      - <cluster id="downtown">
          <!-- <density>0.0025</density>   -->
          <density>0.0002</density>
          <ratio>0.1</ratio>
          <speed>13.89</speed>
        </cluster>
      - <cluster id="residential">
          <!--   <density>0.0009</density>  -->
          <density>0.00005</density>
          <ratio>0.4</ratio>
          <speed>13.89</speed>
        </cluster>
      - <cluster id="suburban">
          <!-- <density>0.0001</density>  -->
          <density>0.00001</density>
          <ratio>0.5</ratio>
          <speed>13.89</speed>
        </cluster>
      - <cluster id="suburban">
          <!-- <density>0.0001</density>  -->
          <density>0.00001</density>
          <ratio>0.5</ratio>
          <speed>13.89</speed>
        </cluster>
      </clusters>
    </extension>
    <extension name="PosGen" class="de.uni_stuttgart.informatik.canu.tripmodel.generators.RandomInitialPositionGenerator" />
  - <extension name="TripGen" class="de.uni_stuttgart.informatik.canu.tripmodel.generators.RandomTripGenerator">
      <reflect_directions>false</reflect_directions>
      <minstay>0.0</minstay>
      <maxstay>0.0</maxstay>
    </extension>
  - <nodegroup n="10">
    - <extension class="de.uni_stuttgart.informatik.canu.uomm.IntelligentDriverMotion" initposgenerator="PosGen" tripgenerator="TripGen">
        <minspeed>8.33</minspeed>
        <maxspeed>13.89</maxspeed>
        <step>0.5</step>
      </extension>
    </nodegroup>
  - <extension class="de.uni_stuttgart.informatik.canu.mobisimadd.extensions.GUI">
      <width>640</width>
      <height>480</height>
      <step>1</step>
    </extension>
    <!--   <extension class="de.uni_stuttgart.informatik.canu.spatialmodel.extensions.DumpSpatialModel" output="dumped_graph.fig"/>
         -->
</universe>
```


Figure A.2 : VanetMobiSim's scenario file

test_trace

```
#
# nodes: 70, pause: 3.4028235E38, max speed: 3.4028235E38  max x = 1000.0, max y: 1000.0
#
$node_(0) set X_ 865.000001
$node_(0) set Y_ 176.000001
$node_(0) set Z_ 0.0
$node_(1) set X_ 228.000001
$node_(1) set Y_ 24.000001
$node_(1) set Z_ 0.0
$node_(2) set X_ 1.0E-6
$node_(2) set Y_ 406.000001
$node_(2) set Z_ 0.0
$node_(3) set X_ 836.000001
$node_(3) set Y_ 670.000001
$node_(3) set Z_ 0.0
$node_(4) set X_ 1.0E-6
$node_(4) set Y_ 654.8108118108108
$node_(4) set Z_ 0.0
$node_(5) set X_ 915.000001
$node_(5) set Y_ 295.000001
$node_(5) set Z_ 0.0
$node_(6) set X_ 27.000001
$node_(6) set Y_ 887.000001
$node_(6) set Z_ 0.0
$node_(7) set X_ 476.000001
$node_(7) set Y_ 141.000001
$node_(7) set Z_ 0.0
$node_(8) set X_ 485.000001
$node_(8) set Y_ 624.000001
$node_(8) set Z_ 0.0
$node_(9) set X_ 947.000001
$node_(9) set Y_ 575.000001
$node_(9) set Z_ 0.0
$node_(10) set X_ 318.000001
```

Figure A.3 : VanetMobiSim's trace file.

Abstract

Currently, the Intelligent Transportation Systems (ITS) are increasingly studied as well in the community of research in industries (automobile, telecommunications, etc). Indeed, the implementation of ITS applications may in the short term to improve road safety, effectively increasing the use of roads, reduce congestion and traffic jams, reduce the impact of vehicles on the environment, etc.

However, several problems must be solved before being able to conceive such applications, among which the self-organization of inter-vehicles communications has a privileged place.

In this thesis, we focus on the optimization of VANET architecture. Initially, we are interested in two types of ad hoc networks WSN (Wireless Sensors Network) and VSN (Vehicular Sensors Network) where their main characteristics and applications are surveyed and a comparison between them is presented. Then, we tackle the principal constraint in the vehicular networks i.e. the mobility. In fact, the exact prediction of mobility of the nodes forming the network is very important in the simulation of VANET networks. Hence, a comparative study between two mobility models is made after a presentation of a set of related works dealing with mobility models in vehicular networks. Finally, we propose a self-organization mechanism called MCAV based on clustering, able to efficiently adapt to the vehicular network characteristics and applications. This advocated technique is evaluated by a combination of network simulator (NS-2) and a realistic mobility model VanetMobiSim.

Keywords: Vehicular Networks, VANET, self-organization, WSN, VSN, Mobility model, Clustering, VanetMobiSim.

Résumé

Actuellement, les systèmes de transport intelligent (STI) sont de plus en plus étudiés aussi bien dans la communauté de recherche que dans les industries (automobiles, télécommunications, etc.). En effet, la mise en place d'applications ITS peut à court terme améliorer la sécurité routière, augmenter efficacement l'utilisation des routes, réduire les congestions et les embouteillages, limiter l'impact des véhicules sur l'environnement, etc.

Cependant, plusieurs problématiques doivent être résolues avant de pouvoir concevoir de telles applications, parmi lesquelles les communications inter-véhicules ont une place privilégiée.

Dans cette thèse, nous nous concentrons sur l'optimisation de l'architecture des réseaux VANETs. Dans un premier temps, nous nous sommes intéressés à deux types de réseaux ad hoc WSN (réseau de capteur sans fil) et VSN (réseau de capteur véhiculaire). Leurs caractéristiques et leurs principales applications sont présentées et une comparaison entre eux est effectuée. Ensuite, nous abordons la principale contrainte dans les réseaux de véhicules à savoir la mobilité. En effet, la prédiction exacte de la mobilité des nœuds formant le réseau est très importante dans la simulation du réseau VANET. Ainsi, une étude comparative entre deux modèles de mobilité est faite après une présentation d'un ensemble de travaux portant sur les modèles de mobilité pour réseaux de véhicules. Enfin, nous proposons un mécanisme d'auto-organisation appelé MCAV basé sur le clustering capable de s'adapter efficacement aux caractéristiques et applications des réseaux véhiculaires. Cette technique préconisée est évaluée par une combinaison du simulateur de réseau (NS-2) et du modèle de mobilité réaliste VanetMobiSim.

Mots clés: Réseaux ad hoc de véhicules, auto-organisation, Réseau de capteur sans fil, Réseau de capteur véhiculaire, Clustering, modèle de mobilité, VanetMobiSim.

ملخص

حاليا، تدرس أنظمة النقل الذكية بشكل متزايد في البحوث العلمية والصناعية (السيارات, الاتصالات السلكية و اللاسلكية و غيرها). في الواقع، يمكن لتطبيقات هذه الأنظمة الذكية أن تحسن من أمن الطرقات، تزيد من استخدام الطرق بفعالية ، تحد من الازدحام والاختناقات المرورية، وتحد من تأثير السيارات على البيئة، الخ

و لكن، هناك العديد من الإشكاليات التي يجب حلها حتى نتمكن من تصميم مثل هذه التطبيقات، بما فيها التنظيم الذاتي للسيارات الذي يعتبر أكثر أهمية في شبكة المركبات.

في هذه الأطروحة، نحن نركز على تحسين بنية شبكة المركبات. في البداية ، نقدم دراسة مقارنة لنوعين من الشبكات اللاسلكية، (شبكة الحساسات التقليدية وشبكة الحساسات المدمجة في المركبات) بذكر مجموعة مفصلة من خصائصها وتطبيقاتها الرئيسية. ثم نتطرق إلى العائق الرئيسي في شبكات المركبات ألا وهو الحركة المستمرة للسيارات التي تحتاج إلى تنبؤ دقيق و نماذج خاصة لمسايرتها,و في هذا الصّدد, نقوم بالمقارنة بين نموذجين للتنقل بعد تقديم مجموعة من الأعمال التي تركز على هذه النماذج في شبكة السيارات.وفي الأخير نقترح خوارزمية التنظيم الذاتي(MCAV) التي تعتمد على التجميع و تتكيف بشكل فعال مع خصائص وتطبيقات شبكة المركبات، حيث يتم تقييم هذه التقنية باستعمال (NS-2) ونموذج لتنقل واقعي VanetMobiSim.

الكلمات المفتاحية: شبكات المركبات، أجهزة الاستشعار، شبكة الحساسات المدمجة في المركبات، خوارزمية التجميع، نموذج التنقل، VanetMobiSim.