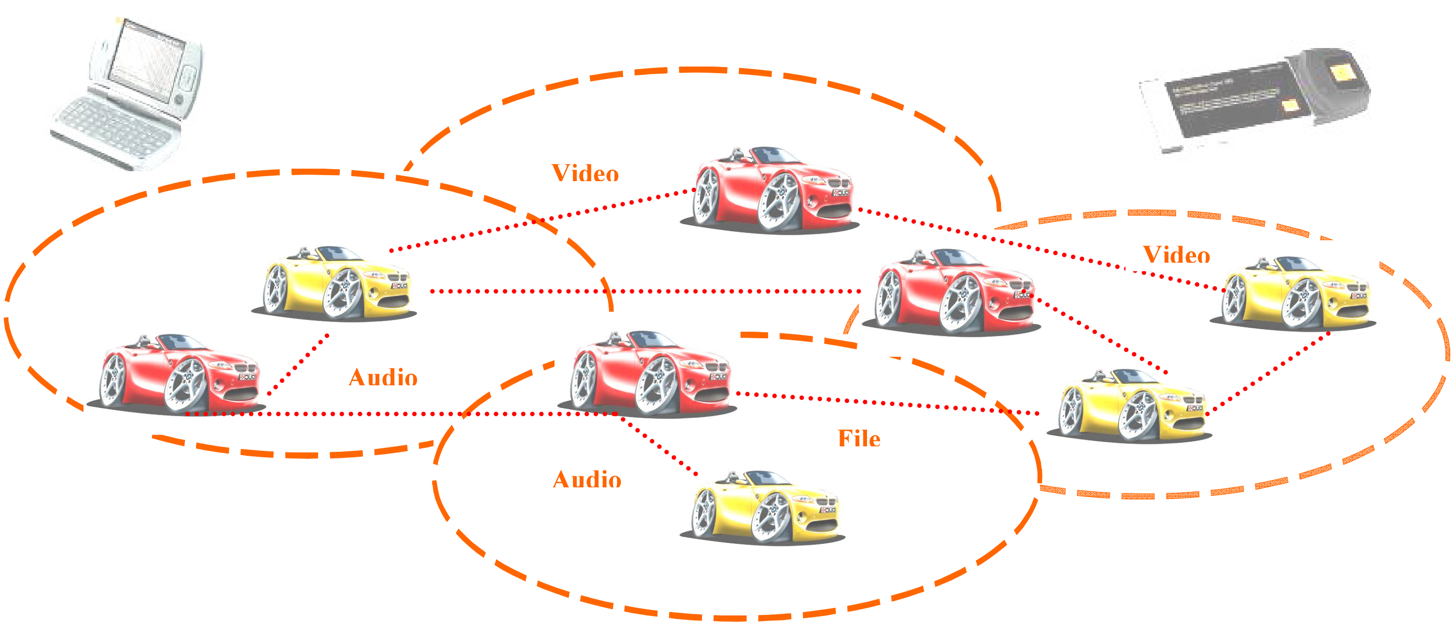
Performance Measurements in Multi hop Vehicular Ad Hoc Networks



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Internship

1/3/2005-31/8/2006

Internship Report
International Master of Science
in
Mobile Communication
Telecom Paris – Institute Eurécom

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Due Date: Friday, Sep 18, 2006

Acknowledgments:

First, I'd like to thank France Telecom R&D for this useful and interesting internship since I will always regard this experience as very memorable and remarkable event in my life. Then, I'd like to thank all the members of the CORE/M2I laboratory. Surely, a special thanks for my supervisor Dr. Sidi Mohammed SENOUCI for his help, support and for believing in me, I can say he was more than a but a supervisor, but a real friend and big brother.

Finally, and most important, I'd like to thank my Parents for their support and all kind of scarifications they granted. And the Mobile Communication staff at Institute Eurécom.

Table of Contents:

1. France Telecom R&D:

France Telecom, listed on the stock markets in Paris and New York, serves **125 million customers** on five continents in 220 countries.

Commentaire [AM1] : Regarding to the stock market records in Paris and New York ,France Telecom is considered as on of the Giant Operator with over than 125 million subscriber over all the five continents in 220 different countries.

In 2004, the Group recorded an increase of 7.7 million mobile subscribers (+13.9%) and 469,000 fixed telephony subscribers, mainly in Spain and Poland. Broadband access, as a percentage of total Internet access provided, is growing strongly, at 45.9% for Europe on 31 December 2004 compared with 25.2% a year earlier. France Telecom Group's consolidated turnover was **47.2 billion euros** on 31 December 2004, i.e., growth of 4.1% on the basis of pro forma data (2.2% on the basis of historical data). The trend in terms of historical data is affected by the negative impact of exchange rates and variations in scope, particularly due to the sale of CTE Salvador in October 2003 and Orange Denmark in October 2004.

Commentaire [AM2] : raise

Commentaire [AM3] : fixed line phone

Commentaire [AM4] : no need for that

Commentaire [AM5] : You can say higher gross rate than before

Commentaire [AM6] : What is this ??

1.1 About France Telecom R&D:

France Telecom has placed innovation at the core of the Group's strategy in order to speed up its growth and positioning as an integrated operator.

Commentaire [AM7] : Push forward

The contribution of the R&D Division to the development of the Group's commercial offerings takes multiple forms in order to enable the Group to remain the leader on its markets:

- improvement of existing offerings
- development of innovative technology and services
- integration of network architectures and infrastructures
- optimisation of take-to-market processes
- industrial dynamics
- expertise for its foreign subsidiaries
- close co-operation with major industrial groups and the scientific community worldwide

As a result, this contribution provides an ideal boost for co-operation to produce integrated, high added-value convergence services. France Telecom is the only French telecom operator with an integrated R&D.

Some Key figures about France Telecom R&D:

- **1.5%** of the annual sales of the Group (+19.9% compared to 2004).
- **17** sites, including 9 established abroad: Boston, London, Beijing, San Francisco, Tokyo, Warsaw, New Delhi, Seoul, Guangzhou (Canton).
- **3,900** engineers, scientists and researchers in the Research and Development division.
- More than **300** PhD and post-doctoral students.
- A portfolio of nearly **7,800** patents at the end of 2005.
- **530** new patents and **365** software applications filed during the year.

The France Telecom R&D Division is present in the world's major areas of innovation. With 16 sites, including 8 abroad, it assists the Group's international development by making its expertise available to foreign subsidiaries, Equant, Orange and Wanadoo in particular.

1.2 The RDC "Heart of Network":

The RDC "Heart of Network" of Division Research & Development, under the responsibility of Roberto Kung, joins together more than 500 people out of 3 different sites and is composed of:

• 6 laboratories of R & D structured and turned mainly towards the supply of architectures network and the associated equipment for the integrated operator,

• 4 functions fields for the Business projects management

• 3 poles of research,

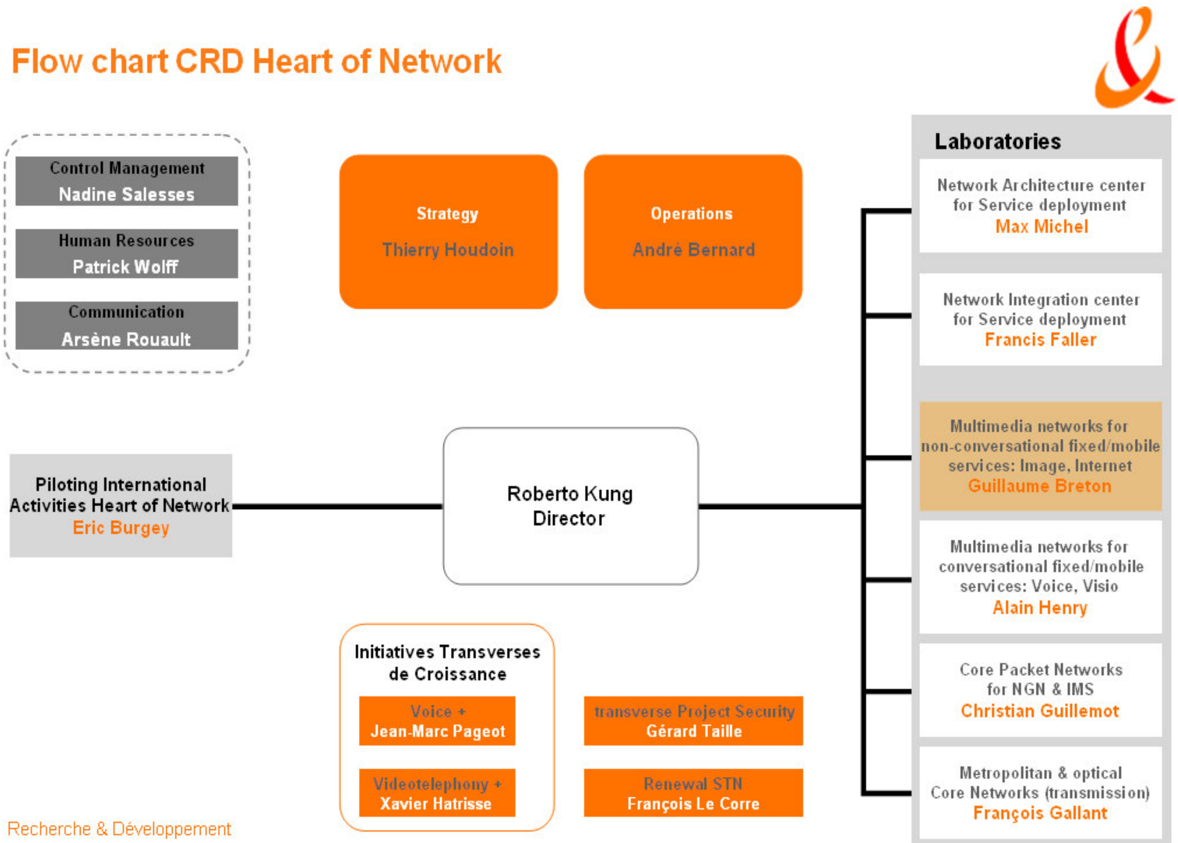
• 3 functions of piloting on the strategy, the operations and the international one,

• The technical responsibility for 2 Transverse Initiatives of Development (TID) and 2 building sites.

The figure below summarizes the general organization of RDC ..

The figure below summarizes the general organization of RDC "Heart of Network".

Commentaire [AM8] : The figure below summarizes the general organization of RDC ..



Figure(1) – CRD heart network

I took my internship in M2I (**Multimedia networks for non-conversational fixed/mobile services**: Image, Internet») laboratory directed by Xavier Hatrisse. This laboratory is in charge of studying the engineering of the non conversational services for both fixed and mobile networks: access to Internet and multimedia diffusion services. Like defining, selecting, evaluating, validating and participating in the integration of the equipment networks necessary for those services. The laboratory implements competences on the equipment and network architectures of fixed and mobile collection (LOW, NAS, SGSN, GGSN, node of video service, ad hoc networks), and of authentification and counting (chain RADIUS and its extensions, treatment of the nomadism in the network). It brings an expertise to the entities of the France Telecom Group in order to enable them to carry out the

Commentaire [AM9] : Taking within the M2I evolutions of the networks and services of collection in a preoccupation with a quality, safety and of optimization of the investments, loads and sales turnover.

1.3 The PRP SPONTEX Project

In my internship, I participated in a M2I project: PRP SPONTEX (Pluri-disciplinary Research Project dealing with Spontaneous Networks). Spontaneous networks are networks of which growth, behaviour and structure result from the individual and co-operative behaviours of the elements (nodes) constituting them. They are independent of infrastructure and more closely follow the human peer to peer communication model. They enable a more natural form of wireless computing when people physically meet in the real world. The independence from infrastructure makes spontaneous networking possible anywhere and anytime and without being dependent on any third party.

The objective of the PRP SPONTEX is study the following fields which will enrich the concept of spontaneous networks: ad hoc networks, vehicular ad hoc networks, sensor networks, p2p networks, social networks, etc. It is a 3 years France Telecom internal project (06/2004-06/2007). There are also a set of academic collaborations (Stanford university, GET, INRIA, Technion Israel, etc.).

Vehicular Ad hoc Networks are spontaneous networks since they have no fixed infrastructure and instead rely on ordinary nodes to perform routing/broadcasting of messages and network management functions. However, they have unique characteristics which have important implications for designing decisions in these networks. Thus, numerous research challenges need to be addressed for inter-vehicular communications to be widely deployed. In the PRP SPONTEX, we intend to study some issues of these networks (routing, broadcasting, security, mobility model, testbed, etc.)

2. Introduction:

?????????? what is the content of this section???????

A real introduction is needed here (like in the paper+)… The rest of the document is organized as follows. ????

3. Introduction to Mobile Ad Hoc Networks (MANET)

The acronym MANET stands for (Mobile Ad hoc Network), which could be defined as a ***set of devices connected to each other via wireless technology could be (Bluetooth, 802.11 a/b/g, UWB, etc..) and not restricted to a certain architecture which gives the users the ability to move freely with no constrains with an embedded routing operations between the devices with no need for any external devices.*** **This technology gives the opportunity for the devices to keep connected to each other and exchange all kind of data while moving randomly with no constrains. The most interesting feature about MANET that it could be easily deployed with no any needs for prior planning or architecture; it's a plug and play network.**

In MANET, devices can connect directly to any other which appears within the radio range of this device, also known as IBSS (Independent Basic Service Set) as in figure 2, independently without having the need to use a Central Connecting point (AP or BTS) as the case in figure 1, or, to some other devices which are out of the radio range through an intermediate node or a set of intermediate nodes, since the routing operation is being done within the devices themselves (embedded) with no need for any special router to do this process.

Just like any other communication system MANET has it's draw backs, this free mobility and independency of certain architecture is not for free, there is a price to pay as constrains in other resources like limited coverage area for each device, limited battery life (energy source), limited number of physical channels (frequency) to be transmitted on which leads to higher contention on resources in MAC layer , random mobility of the users which leads to complexity in routing and waste of resources.

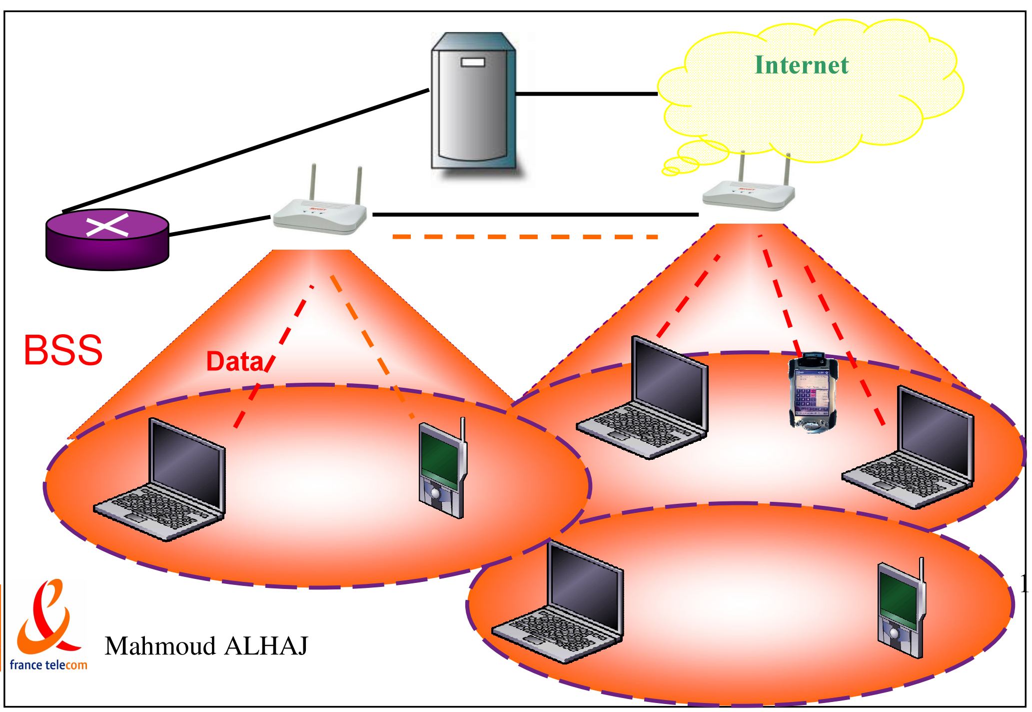


Figure 2 (System with infra structure)

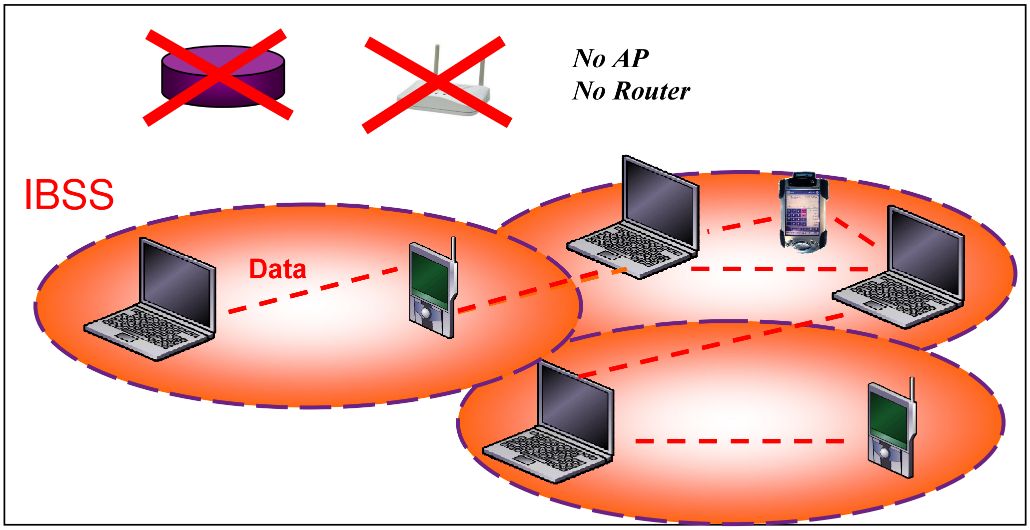


Figure 3 (Ad Hoc System)

The main reason behind pushing the MANET to the Market is the vast application that could be done by applying this technology in different commercial and military fields like:

- **Sensor Network [1]**
- **Patient Network [2]**
- **Vehicular Ad Hoc Network [3]**
- **Home Network [2]**

In this report I will show different details about Vehicular Ad Hoc Networks especially performance measurements. Also so many details and so about this application and the other applications could be found on the internet.

4. Introduction to Vehicular Ad Hoc Networks (VANET)

Inter-vehicle communication (IVC) is an important component of the Intelligent Transportation System (ITS) architecture. The traditional ITS traffic monitoring

systems are based on a centralized structure in which sensors and cameras along the roadside monitor traffic density and transmit the result to a central unit for further processing. Such systems are characterized by a long reaction time and an expensive cost for the deployment and the periodic maintenance of the required infrastructure in terms of sensors and communication systems. An efficient alternative is the use of vehicle to vehicle communications. IVC represents a distributed and flexible system composed of vehicles, equipped with short range wireless communication technology, that collaborate to form a temporary network between them. It enables a vehicle to communicate with other vehicles that locate out of the range of line of sight (or even out of the radio range if a multi hop network is built among several vehicles). As a result, information gathered through IVC can help to improve the road traffic safety and efficiency.

Commentaire [AM10] : Could be limited ?

Moving vehicles equipped with communication devices represent exactly a specific and direct application of conventional mobile ad hoc networks (MANETs). VANET shares numerous MANET proprieties, where communication is possible between vehicles themselves within the same radio range without the need of a central infrastructure. However, there are significant differences related to the specific vehicular context. Thus, the existing solutions designed for MANET (routing, security and QoS for example) can not be directly applied and must be adapted. The specific properties of VANET are:

- **Communication, energy and processing capability,**
- **Displacement environment and mobility model,**
- **Type of transported information and diffusion,**
- **Network topology and connectivity.**

The vehicular ad hoc network (VANET) topology can be standalone or interconnected to a fixed road infrastructure. Benefiting from the large capacities (in terms of both space and power) of vehicles, the nodes of these networks can have long transmission ranges and virtually unlimited lifetime. Current advances in MANETs show that vehicular ad hoc networks are a feasible approach with respect to several aspects: low data transport times, robustness due to the network's mesh structure, and low costs for usage.

There are numerous emerging applications that are uniquely attached to the vehicular setting. For example, safety applications would grant us more safely driving; driver information services could intelligently inform drivers about traffic congestion, businesses and services in the vicinity of the vehicle. Mobile commerce could extend to the realm of vehicles. Existing forms of entertainment may penetrate the vehicular domain, and new forms of entertainment may emerge, all supported by the inter-vehicular communications capabilities. These emerging services are currently not supported.

VANET is one direct application of MANET, but, with a few differences in terms of mobility due to the higher speed of the vehicles comparing to the pedestrian speed. Though, that creates new challenges in this filed. But, not only new challenges will be created, but also , it has some advantages over the ordinary MANET since Battery life is not a problem any more since we have energy long term energy resources due to the fact of being supplied by the car battery, Extra room is available for building more complex devices with high receiving and transmission capabilities, ability to reach higher ranges by using more transmission power. On the other hand, a routing problem could appear due to the aggressive mobility which is related to the high speeds since joining and leaving the network will be very fast, and though, a need for new routing protocols will come to adapt with this situation, since if the routing protocol are not reliable enough to deal with that kind of mobility, then more losses will be experienced and more wasting of resources.

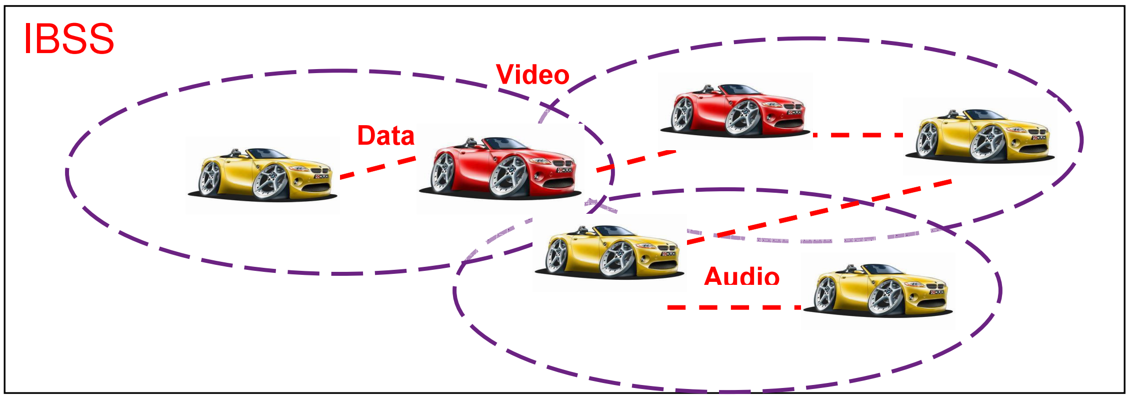


Figure 3 (Vehicular ad hoc Network)

During these years, a big interest on applications for inter-vehicle communications increased in the EU, the US and Japan, resulting in many vehicle safety projects and communication consortiums such as Car2Car [19] in the EU and VSCC (Vehicle Safety Communication Consortium) in the US. In the US, the dedicated short-range communication (DSRC) [21] technology operating on the 5,9 GHz band was recently granted by the FCC (Federal Communications Commission) for roadside safety applications including vehicle-vehicle and vehicle-roadside wireless communication. Moreover, the IEEE 802 committee [20] started recently the development of a new standard, the IEEE 802.11p, targeting wireless communications in the vehicular environment.

[19] Car2Car Communication Consortium, www.car-to-car.org
[20] IEEE 802.11 Wireless Local Area Networks, grouper.ieee.org/groups/802/11/

[21] Standard Specification for Telecommunications and Information Exchange Between Roadside and Vehicle Systems - 5GHz Band Dedicated Short Range Communications (DSRC) Medium Access Control (MAC) and Physical Layer (PHY) Specifications, ASTM E2213-03, September 2003.

5. Characterization and challenges in VANET

?????????? what is the content of this section???????

4.1 Mobility and Network Characteristics

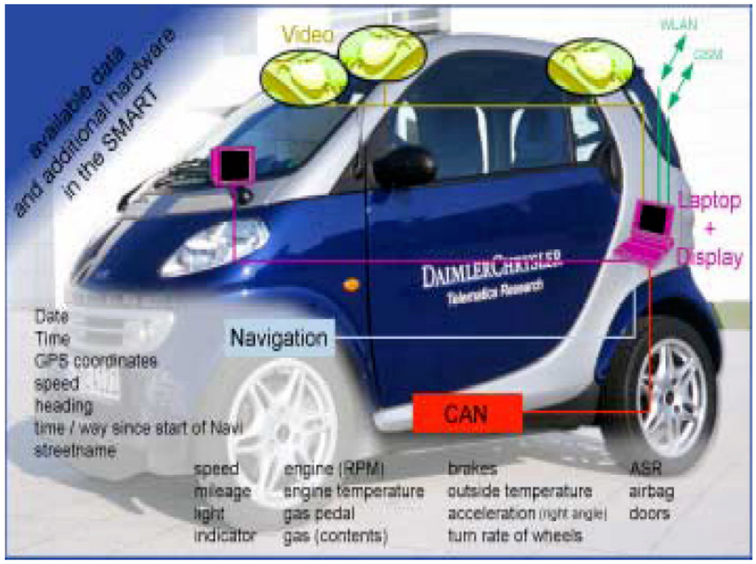
In this section we will discuss the mobility and network characteristics such as the speed, the connection life time, and multi hop organization of VANET. Normally such kind of characterization studies could be carried out either by using simulation model or by field measurements and experiments. With no contrast, the simulation has many advantages over the field experiments in terms of the ability to test the behavior of large scale networks and observe the continuous changes in topology. On the other hand, simulations are not sufficient to give the real behavior of the system, where, field experiments are limited to some nodes and could not be extended to be a larger scale.

In this report we have done our experiments in the streets and took measurements from a real system to have an understanding of the VANET system behavior which could be found in chapter 5 of this report. As we mentioned before, real experiments could not be made in large scales, and though, our experiments are limited to a few number of nodes 2, 3 and 4 at most as well as small scale routes and need to be coordinated. We should denote that the results of the real effect of topology changing due to the limited size network. However, our experiments could provide data on signal to noise ratio, speed, distance and losses.

4.2 Enabling Technologies

The pervious section discussion was about the characteristic of VANET and had comparison between some researched that has been done in this field. This section introduces the available technologies that are used in VANET, the main advantages of VANET and how it differs from MANET. Power resources are scarce in MANET than in VANET due to the type of resource we use; also in MANET we have a lack of visualization of the nodes since the devices are not equipped with navigation equipments. In VANET, as in *figure (4)* cars and vans are equipped with onboard GPS receiver. Also passengers are equipped with other devices of different technologies like laptops, handheld and cellular phones. Most of the researches assume that we could take an advantage of using GPS for routing issues. Despite of the fact that not all vehicles are equipped with GPS receivers, the assumption is still acceptable due the ability and possibility of being applied. One

example of making use of the available vehicle technology is the concept of integrating technologies together for resource sharing. In [10], the author explore the feasibility if a scenario, in which vehicles with WLAN cards can use other vehicles with WLAN cards and cellular network as a mobile gateway to the internet. The study has shown that the majority of vehicles can connect to at least one gateway long enough for a traditional application like FTP or HTTP.



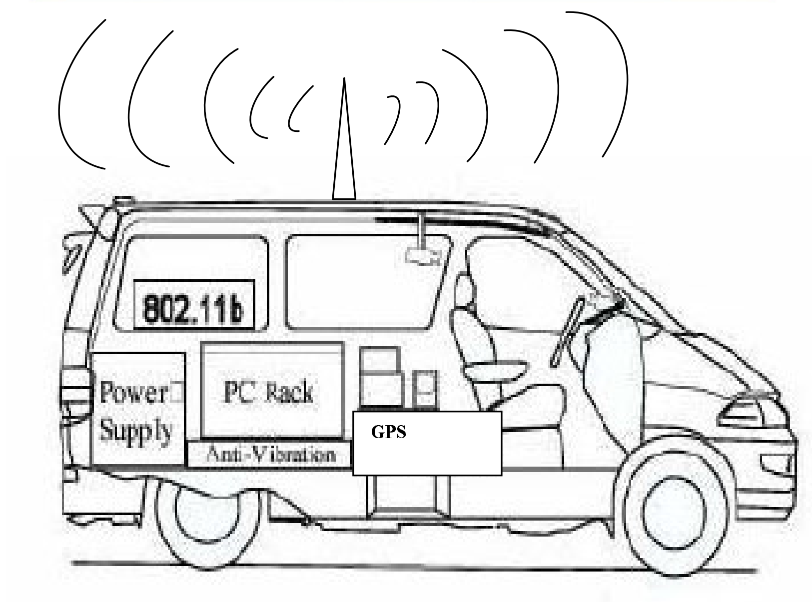


Figure 4 – Vehicle equipped to be a VANET node

The biggest candidate to be used in VANET is 802.11 WiFi technology, since the Bluetooth is limited in terms of power and number of client that could be connected to one node since in Bluetooth one device cant have more than 8 clients at a time, also using GSM / GPRS / UMTS is not possible since by then the service won't be free of charge in addition to some other problems like capacity issue.

4.3 Operating Environment:

Since the vehicles move on the road and pass through different environments city, deserts, weather conditions and planted roads...etc. It could interfere with other communication systems, for example in the city indoor WLAN in different building, also it can interfere with another ad hoc systems. For example, city environment has certain and unique characteristic due to the following reasons :(1) Building and other objects obstructing and possibly contain other communication systems that interfere with the transmission signal (2) Vehicles are closer together than in highway scenarios, though, they could interfere with each other if the transmission range is large (3) Topology is usually two dimensional.

4.4 Application Requirement:

One of the they point to design reliable and efficient VANET and find out the most suitable technologies and techniques in all layers ,like the modulation techniques in (1)Physical layer (OFDM, QPSK, QAM ,etc) bit rate , BER , coding techniques etc.., (2)MAC transmission protocol and error correction protocols (go back n , ALOHA , CSMA/CD , MACA , MACAW , …etc) (3) Routing protocols like (AODV , OLSR , DSRC) (4) Security policies, is to have an overview about the type of applications that could be used in VANET. In fact, many proposals were made for different applications were made ranging from safety applications to Internet e-commerce services. VANET applications can be categorized into two groups :(1) Message and file Delivery (2) Internet Connectivity.

4.4.1 Message Delivery

Many researches focused on enabling the delivery of the messages and file in a vehicular network to the target receiver with acceptable performance. A set of applications such as emergency and alert and warning applications, requires a certain type of protocols that deals with forwarding messages form the sender to the receiver only based on location and direction. Also safety applications have a

very special importance due to their sensitivity to time, thus, they should be given a priority over the non safety ones.

For example, in [11] the authors studied the feasibility if delay-critical safety application over VANET based on emerging dedicated short range communications (DSRC) standard. They quantified the BER, throughput, and latency associated with the vehicle collision avoidance applications employing the physical and MAC layers if DSRC. They have simulated a road topology with CORSIM and mobility model with a maximum speed of 75 miles/hour with omni-directional antenna. They found immunity in PHY layer for large delay spread, and significant degradation in performance under high mobility scenarios and concluded that the throughput needs to be improved since less than 60ù of the vehicles usefully receives the message successfully. They found out that the DSRC achieves a favorable latency performance compared to the application requirement. Also in [12] the authors the author suggested that the protocol determines the destination of the message based on the sending vehicle's location, speed, driving direction, and time instead of broadcasting a message to the vehicles in all direction. In [optimized dissemination of alarm message in vanet] the authors present ODAM scheme to perform and optimized dissemination of alarm messages, this scheme is based on GPS geographical location, node ID and message ID. In this scheme they abundant the usage of destination address to allow reducing the overhead introduced by the packet header. In this protocol, in case of a crash occurred, the damaged vehicle or any other vehicle which detects the problems broadcast an alarm message to inform all the other vehicles about it after determining it's location with GPS in report with the crashed vehicle. Vehicle in the risk zone constitutes a dynamic multicast group. One vehicle within that zone, selected in a distributed way, behaves as a relay in order to assure the rebroadcast of the message. This protocol has a double advantage .First; it enables us to avoid operations of the maintenance of the multicast tree (routing and calculating neighbors) since these operations degrades the performance and are very expensive in a strongly mobile environment like the road transport. Second; it allows providing information on the geographical location that is very significant in intelligent transport systems. *Figure (5) and figure (6)* **show the difference between using and not using a relay agent for message devilry.**

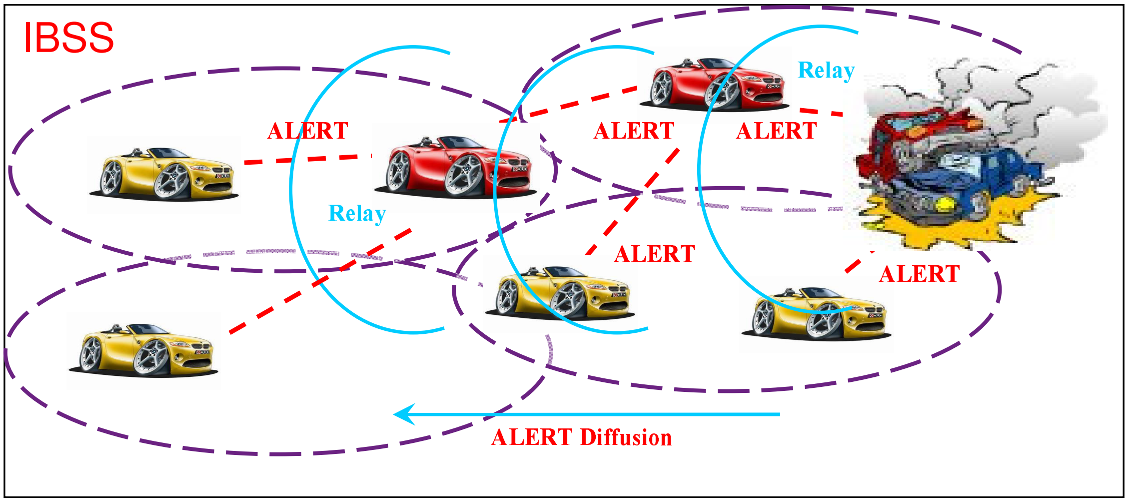


Figure 5 – ALARM Message Diffusion
using relay agents

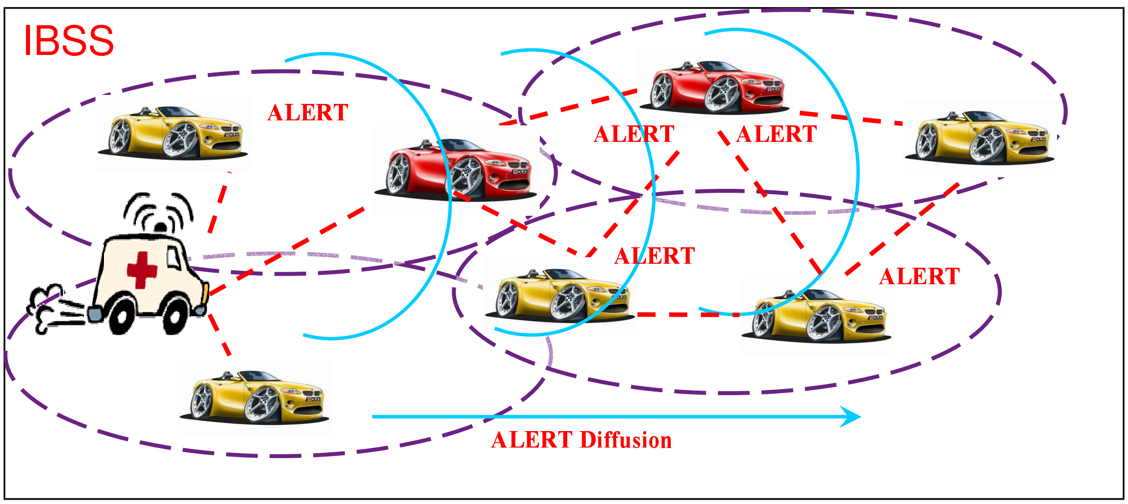


Figure 6 – ALARM Message Diffusion without
using relay agents

4.4.2 Internet Connectivity

Another type of application is concerned with connecting the vehicles to the internet using a road side beacons and inter-vehicle communications. In [] the author envision a future vehicular communication, in which the vehicles can communicate to roadside Internet gateway via the ad hoc networks as shown in the figure below. The author mentioned some difficulties such as the inter probability of communication protocols, mobility support, communication efficiency , the discovery of the Internet Gateway, and the handover pf the connection from one gateway to the next needed to be addressed for such a scenario. It focuses on providing a framework for discovering the roadside Internet gateway and applying QoS principles in selecting the best gateway for the underlying applications.

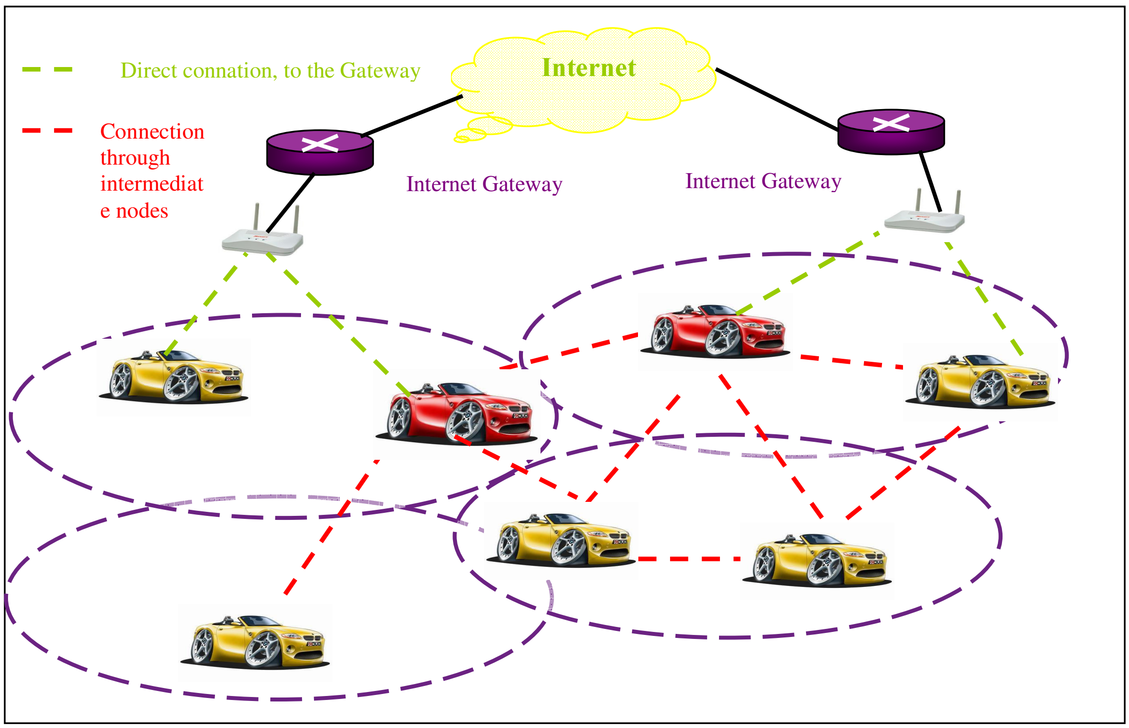


Figure 7 – internet connectivity in VANET

4.5 Security and Privacy

Security and privacy is main issue in VANET because the networks are publicly available in any roads at anytime. On good detailed study was done by [13]. He provided a detailed survey potential security issues in wireless and ad hoc routing. Privacy is also an issue. For example, in many positions-based routing protocols, the location and persistent ID of a vehicle are constantly broadcasted to neighboring vehicles [14].

Another example of the most proposed ad hoc routing protocols assume an implicit [15] trust-your-neighbor relationship in which all the neighboring nodes behaves properly. The propose a location service for position-based ad hoc routing to prevent message tampering, dropping, and location table tempering attacks by malicious or compromised users.

4.6 Physical Layer VANET

This section shortly discusses from a practical point of view the major modulation techniques (DSSS, OFDM) which are mostly used in practice in the physical layer in VANET using WiFi technology, the challenges and problems that affect the performance of the physical layer due to the operating environment and some hints about how to calculate certain major parameters in the system. But for more details about the Physical layer I strongly recommend to refer to [[19]

4.6.1 Modulation Techniques

The most famous modulation techniques that are used in WiFi technology are OFDM (Orthogonal Frequency Division Multiple) and DSSS (Direct Sequence Spread Spectrum) which is implemented in ORINOCO PCMCIA Wireless CARD that we used in our experiments.

4.6.1.1 DSSS (Direct Sequence Spread Spectrum)

This technique is used and standardized in 802.11 a/b WLAN technology and implemented in WLAN card that of this version. In simple words apart from complexity, the concept of DSSS is to use a certain chipping code called Barker Code to spread the transmitted signal on a wider bandwidth and lower power (which helps to lower down the interference effect). In other words each bit in the original signal is represented by multiple bits in the transmitted signal by using the spreading code as shown in ***figure-8,9,10*****.**

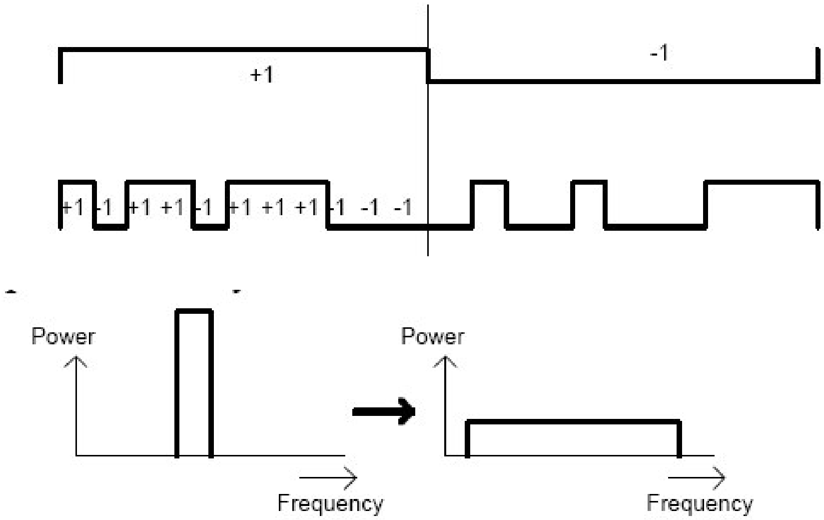


Figure 8 – Spreading Technique

- Example: DSSS with BPSK
  - $T / T_c = 3 \Rightarrow$ processing gain = 3

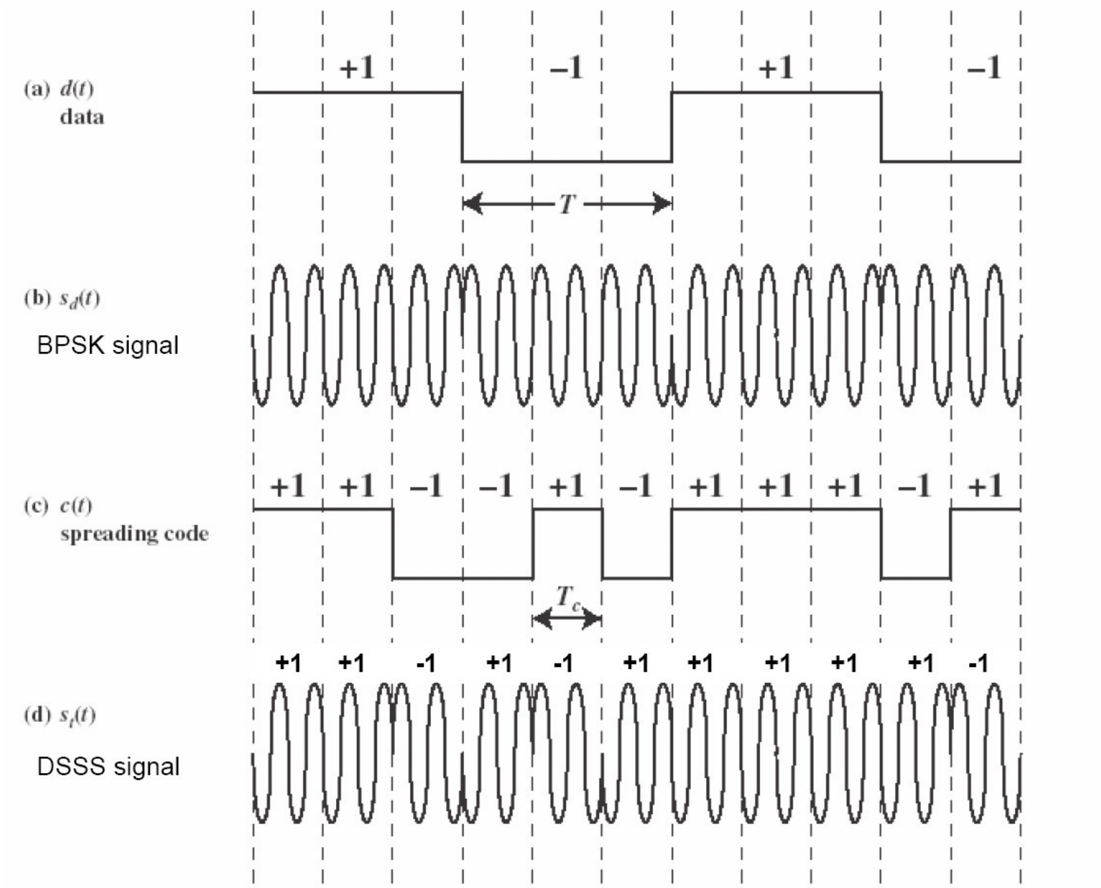


Figure 9 – Spreading Technique with BPSK

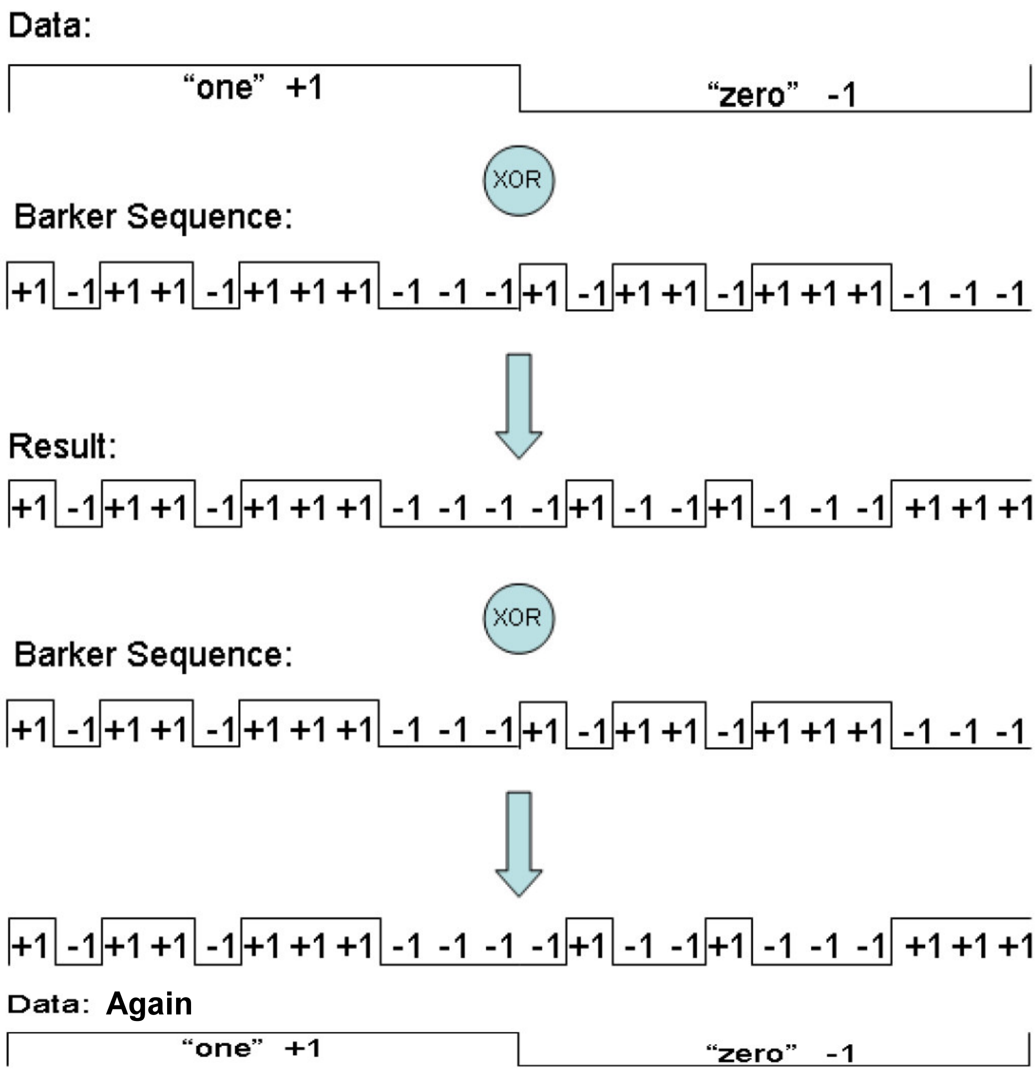


Figure 10– Spreading Technique
and recovering data

The spreading operation is done by performing XOR of the signal to be transmitted with the spreading code (Barker Code) on transmitter side and decoding on the receiver side by performing the received signal with the Barker Code (Spreading code) again.

DSSS Advantages

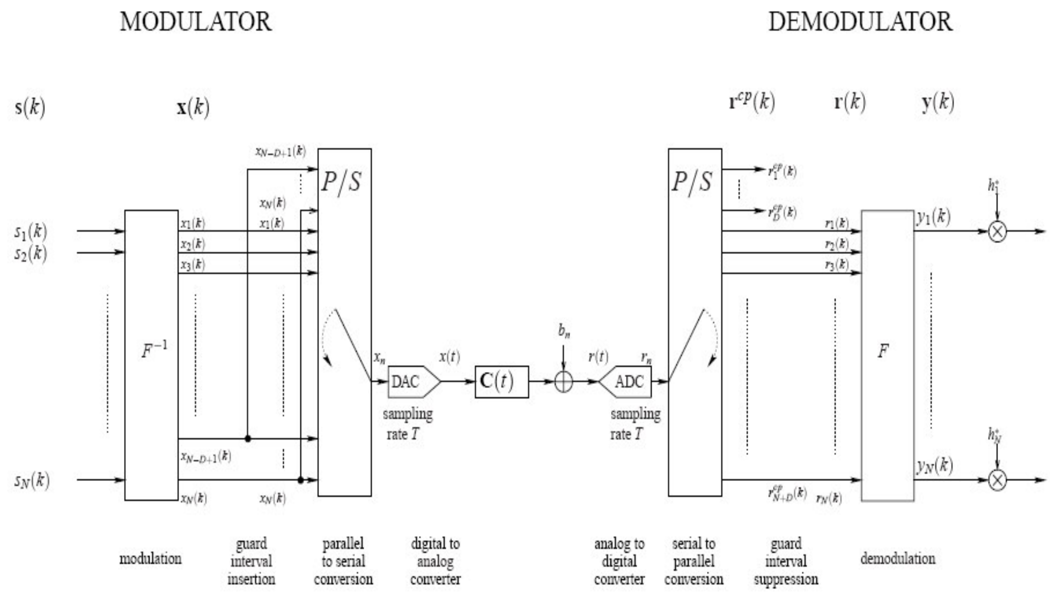
DSSS has two main advantages (1) It provides spreading gain against narrow band interference and signals (2) It spreads the transmitted signals into a wide range, though it appears like noise to the narrow band receivers.

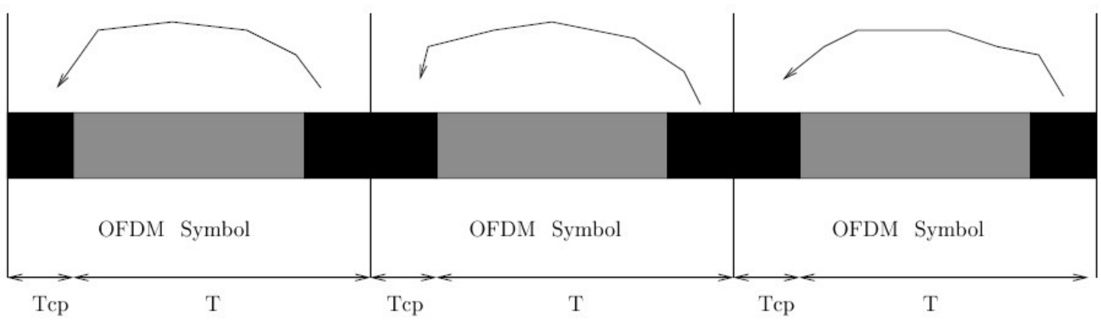
4.6.1.1 OFDM (Orthogonal Frequency Division Multiplexing)

OFDM is an emerging technology for hight data rates, this technique's been standardized for the 5GHz WLAN systems the 802.11 g with a data rate of 54 Mbit/s. [Méraune debbah] OFDM is a multi carrier transmission and suited for frequency selective channels and high data rates. This technique transforms a frequency selective wide band channels into a group of non selective narrow band channels, which makes it robust against larger delay spreads by preserving orthogonality in the frequency domain. It uses IFFT (Inverse Fast Fourier Transform) on the Tx side and FFT (Fast Fourier Transform) on the Rx side.

Input data bits are split into N symbols of duration Ts, and transmitted on all subcarries which implies to a flat fading. The main goal is not to have ISI. The sub carries are spaced by 1/Ts.

Ts = N.D.Tb where N is the number of sub carries , D is the number of bits carried over each N subcarrier and Tb is the bit duration. A cyclic prefix is added before each OFDM symbol as a guard period.


MODULATOR
DEMODULATOR
s(k)
x(k)
r^cp(k)
r(k)
y(k)
P/S
P/S
F^-1
F
DAC
ADC
C(t)
sampling rate T
sampling rate T
modulation
guard interval insertion
parallel to serial conversion
digital to analog converter
analog to digital converter
serial to parallel conversion
guard interval suppression
demodulation


OFDM Symbol
OFDM Symbol
OFDM Symbol
Tcp
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4.6.3 Physical Layer Performance Calculations in VANET

Generally, in any communication system path loss is one of the main factors to indicate the magnitude of loss in the our signals, the path loss can be expressed from by the formula below

$$Path\ Loss = \frac{P_R}{P_T} = K\frac{h_{Rx}h_{Tx}^2}{r^4 f_c^2}$$

In fact it's the ratio between the received signal power on the receiver side and the transmitted P_R signal power P_T that's been initiated from the transmitter's side. r is the Distance between the Tx and Rx , f_c is the carrier frequency , K is a contestant of proportionality. The path loss mainly depends on the environment (urban, rural, etc), at higher frequencies the range for a given path loss is reduced.

The received signal level is strongly joined to the environment, due to the different effects of reflection, scattering, attenuation, diffraction …etc. All these effects differ with the different environment for example, in an indoor environment; we can have less path loss and more reflections and rich scattering, thus , in an indoor you it a good signal level could be obtained but with high losses. Unlike out door, also in an outdoor environment the same effect could be found, but it happened less likely than in an indoor one. So the signal will be received with replicas of the same signal, thus, the summation of the signal could be constructive or destructive.

In fact the path, many path loss models could be found in the literature and [16] has provided many of them, but the most used models are Okurama Model and Hata Model, etc...

- **Okumura Model: It is one of the most widely used models for signal prediction in urban areas.It is an empirical model in the frequency range of 150 MHz to 1920 MHz & distances from 1 to 100 Km. It can be extrapolated up to 3 GHz.**
- **Hata Model: It is an empirical formulation of the path loss data provided by Okumura, & is valid from 150 Mhz to 1500 MHz for urban area.**
- **PCS Extension to Hata Model: This is an extension of Hata model up to 2 GHz for Personal Communication Systems which have cells of the order of 1 Km to 20 Km radius.**

For more accuracy, we will use Okumura Model for Urban and Suburban areas.

<u>Okumura Model</u>

Path Loss = FPL + A(f,d) - G(hte) - G(hre) - G(Area)
Where:

$$FPL = Free\ Space\ Path\ Loss = 20 \log \frac{4\pi df}{ç}$$

$$ç = \text{Speed of Light}$$

$$d = \text{distance}$$

$$f = \text{Frequency}$$

$$G(hte) = 20\log(hte/200) \qquad : 1000m > hte > 30\ m$$

$$G(hre) = \begin{cases} 10\log(hre/3) & : hre < 3 \\ 20\log(hre/3) & : 10\ m > hre > 3\ m \end{cases}$$

$$for\ VANET\ we\ assume\ G(h_{te}) = G(h_{te}) = 10\log(\frac{hre}{3})$$

$$G(Area)\ \text{at 2.4 GHz from the Curves}$$

$$\begin{cases} 33\ (\text{Open Area}) \\ 27\ (\text{Quasi Open Area}) \\ 13\ (\text{Suburban Area}) \end{cases}$$

$$A(f, d) = \text{Median Attenuation : function of frequency \& distance}$$

$$= 13\ dB \text{ from curve at 2.4 GHz \& distance up to 1 Km.}$$

This model can be applied to a scenario as in *figure 11.*

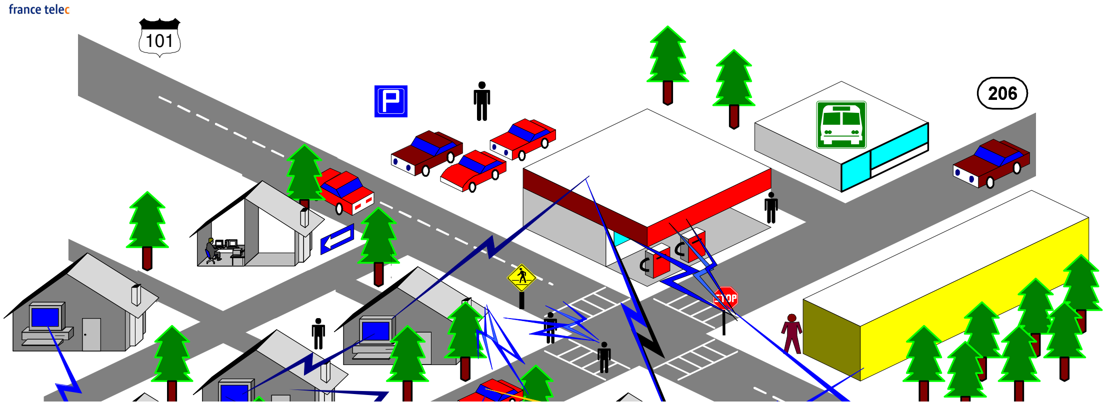


Figure 11 – path loss and fading effect

The Doppler Effect

Doppler Effect is a shift in f_c (center frequency), on the receiver side, on which the transmitted signal were meant to be sent at due to the velocity (speed) of the mobile receiver. The Doppler Effect was named after Christian Doppler, who first came up with the idea in 1842 [17]

Since VANET is a system with an aggressive mobility with high speeds, then as a consequence the Doppler Effect will have an important role to play due to the mobility of both the transmitter and receiver since that change of the apparent frequency will be observed by the receiver which makes it non trivial effect. If the mobile is moving towards the source of the wave, then the apparent frequency will be increased; moving

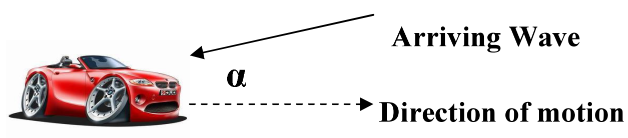
away from the source causes a decrement in the apparent frequency. This occurs because the mobile crosses the wave front of the incoming wave at a different rate from when it is stationary. More precisely, the apparent change in frequency, the Doppler Shift f_d, is given by the rate at which the mobile crosses the wave front of the arriving signal.[16]

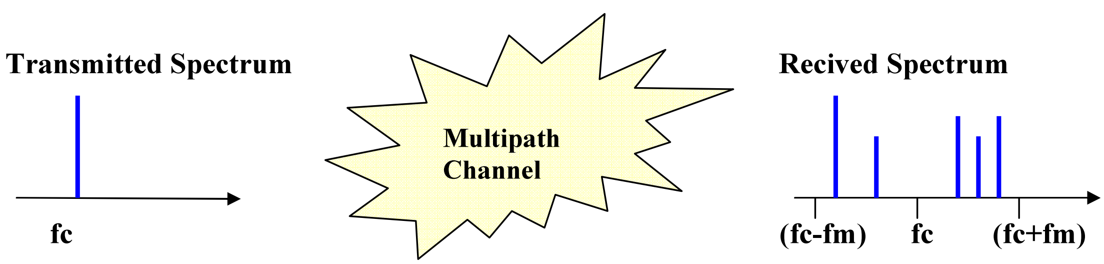
$$f_d = f_c \left(\frac{v}{\varsigma}\right) \cos\alpha = f_m \cos\alpha$$

$$f_d = \frac{v}{\lambda}\cos\alpha = f_c \frac{v}{\varsigma}\cos\alpha = f_m \cos\alpha$$

$$f_m = f_c \frac{v}{\varsigma}$$

Where fm is the maximum Doppler Shift which occurs at alfa = 0. Thus the Doppler shift can have any apparent frequency within the range $(f_c - f_m) <= f <= (f_c + f_m)$

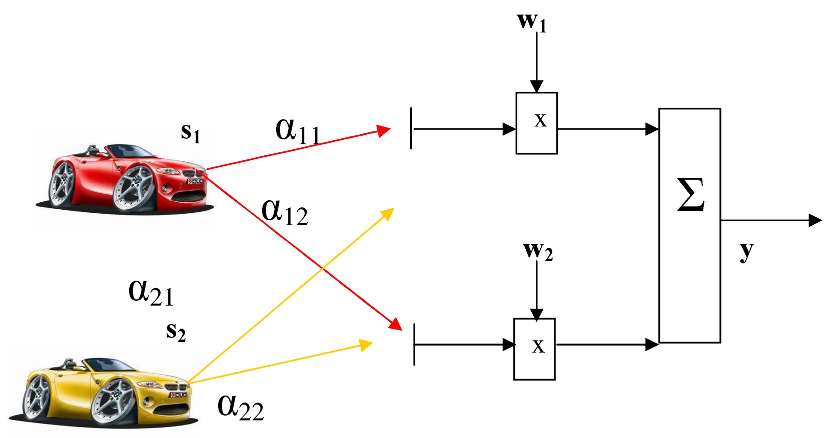




In case of having both the transmitter and receiver are mobile then the maximum Doppler frequency may be even greater if both are moving in the same direction.

Interference Effect

As in all wireless systems, interference plays an important role in VANET, since an interfering mobile affects the signal of a desired mobile due to a simultaneous transmission on co-channel signals. The interferer could be far apart from the transmitter not necessarily to be in the same spot. The following example will explain how the interference happens. The attenuation factor which represents all the different effects including fading, path loss and shadowing is represented by α_{ij}. And then at the receiver side the signal will be multiplied by complex weights and summed yielding the output y which represents the received signal.



$$x_1 = s_1\alpha_{11} + s_2\alpha_{21}$$
$$x_2 = s_1\alpha_{12} + s_2\alpha_{22}$$

The output of the combiner is

$$y = x_1 w_1 + x_2 w_2$$

Substituting x_2 and x_1 then solving both equations leads to

$$\alpha_{11} w_1 + \alpha_{21} w_2 = 1$$
$$\alpha_{21} w_1 + \alpha_{22} w_2 = 0$$

And the solving them simultaneously to get

$$w_1 = \frac{\alpha_{22}}{\alpha_{11}\alpha_{22} - \alpha_{12}\alpha_{21}}$$
$$w_1 = \frac{-\alpha_{21}}{\alpha_{11}\alpha_{22} - \alpha_{12}\alpha_{21}}$$

That was a small example about how interference and interference reduction in order to create a robustness in VANET system against interference.

4.7 MAC Layer VANET

The main purpose of developing and designing the IVC is to enhance the safe driving on the road, minimizing the road accidents, decreasing the traffic jams as well as granting the driver to reach its destination comfortably and easily with the shortest time. And due to the special feature and characteristics of VANET over the other kind of networks in terms of the continuous dynamic changing in the network topology, short terms connection life and changing in the number of terminals. Due to all that, the existing WLAN MAC protocols do not seem to be suit these new challenges, due to the Physical and MAC layer limitations. Thus, many researches are done in this field in order to improve the MAC layer to be well suited with the new challenges.

Many protocol were suggested for MAC layer [18] like Reservation ALOHA (R-ALOHA) for distributed channel assignment. R-ALOHA [20] has higher throughput than slotted ALOHA, since a node which catches a slot can use it in subsequent frames as long as it has packets to send. As in all protocols R-ALOHA has its drawbacks and though [21] has suggested improvements to the protocol as well as [22] have also studied that under node high mobility. RR-ALOHA [23] (Reliable Reservation ALOHA) is studying this protocol in order to solve the hidden terminal and destructive interference that causes losses in the signaling

transmission outcome problems. Also [24] [25] has proposed ADHOC-MAC which uses Dynamic TDMA as an access mechanism and multihop broadcast over the whole network using the reservation mechanism in RR-ALHA, this protocol offers high performance access scheme and simplicity in implementing MAC multihop broadcasting service as shown in [26] which deals in performance analysis and feasibility of this protocol. Some other studies combined CDMA with random channel access as in [27] that start their transmission immediate regardless of the channel's state by using code assignment and spreading code schemes, with an appropriate code assignment collisions ,which happens when 2 nodes with have the same code try to access the channel at the same time, can be avoided. This idea was adapted by RA-CAMA (Random Access CDMA) [28] which suffers form MAI (Multi Access Interference) resulting secondary collision and near- far effect problems at the receiver side, CA-CDMA [28] which uses RTS/CTS reservation mechanism [] which alleviates the near – far problem.

4.8 Routing in VANET

As we mentioned before IVC networks are an instantiation of a mobile ad hoc network (MANET). MANETs have no fixed infrastructure and instead they rely on ordinary nodes to perform routing of messages and network management functions. However, vehicular ad hoc networks behave in different ways than MANET research models. Driver behavior, mobility constraints, and high speeds create unique characteristics in IVC networks. These characteristics have important implications for design decisions in these networks. Thus, numerous research challenges should be directed towards inter-vehicular communications before it becomes possible to be widely deployed. For example, routing in conventional mobile ad hoc networks is a challenging task because of the network's dynamic topology changes. Numerous studies and proposals of routing protocols have been conducted to relay data in such a context; however these solutions can not be applied to the vehicular environment due to the specific VANET constraints and characteristics. Recently, some routing protocols specially oriented to vehicular networks have been proposed because as shown in the curves below the ordinary ad hoc protocols AODV , DSR , OLSR are not so efficient in VANET, thus, we need more effective and reliable routing protocols that is able to deal with the aggressive mobility in VANET.

- **DSR (Dynamic Source Routing Protocol)**
  - **Reference IETF Draft : draft-ietf-manet-dsr-09.txt**
  - **DSR tutorial , [29]**
- **AODV (On – Demand Distance Victor)**
  - **AODV: IETF Experimental RFC Number 3561, July 2003**
  - **AODV tutorial [29]**

- **OLSR (Optimized Link State Routing)**
  - **Reference IETF Experimental RFC 3626 October 2003**
  - **OLSR tutorial [29]**

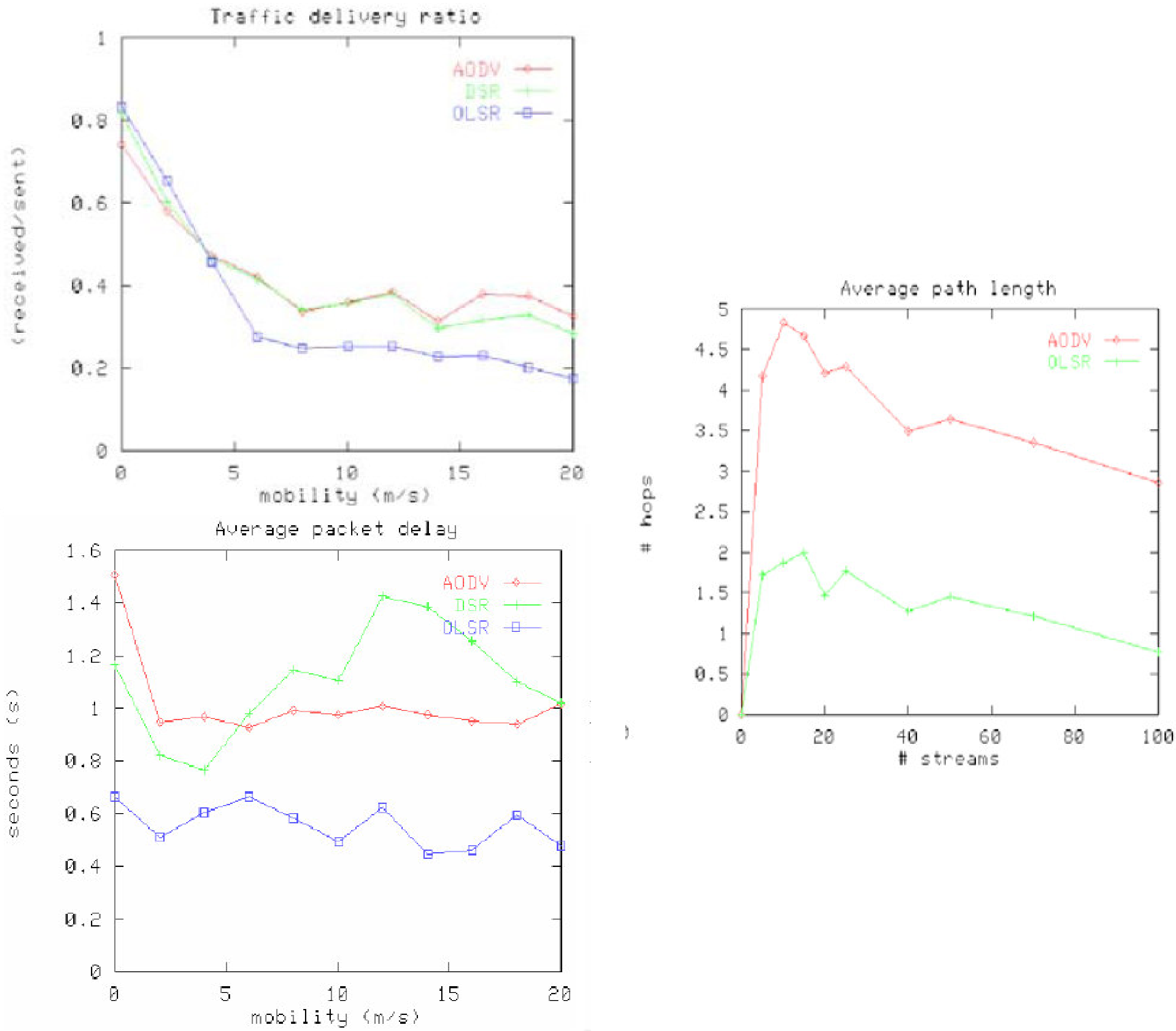


Figure 12- comparison between the performances of Mobile ad hoc routing protocol [29]

Some VANET protocols

GPCR [30] (Greedy Perimeter Coordinator Routing) is one of them since it is able to deal with the challenges of city scenarios. It does not require any global or external information such as a static street map the main idea of GPCR is to forward data packets using a restricted greedy forwarding procedure. That means when choosing the next hope, coordinator node (a node on a junction) is preferred to a non-coordinator node, even if it is not the closest node to destination.

'GSR'[30] (Geographic Source Routing) has been recently proposed as a promising routing strategy for vehicular ad hoc networks in city environments. It combines position-based routing with topological knowledge. The simulation results, with the use of realistic vehicular traffic in a city environment, show that GSR outperforms topology-based approaches (DSR and AODV) with respect to delivery rate and latency. In another study Erreur ! Source du renvoi introuvable.**, the same authors have shown, for highway scenarios, that routing approaches using position information, e.g., obtained from on-board GPS receivers, can very well deal with the mobility of the vehicles.**

'A-STAR'[32] (Anchor-based Street and Traffic Aware Routing) is a new position-based routing scheme designed specifically for IVC in a city environment. It features the novel use of city bus route information to identify anchor paths of higher connectivity so that more packets can be delivered to their destinations successfully. A new recovery strategy for packets routed to a local maximum1 was also proposed, consisting on the computation of a new anchor path from the local maximum to which the packet is routed.

GYTAR [33] is a novel routing protocol for vehicular networks in urban environment called GYTAR: improved GreedY Traffic Aware Routing protocol. Based on a localization system like GPS (Global Positioning System), this solution aims to efficiently relay data in the network using city maps. It also considers information about vehicles speed and direction since we suppose real city configuration with multi lanes and double direction roads. GYTAR aims to (i) efficiently use the network resources (wireless bandwidth) by limiting the control message overhead, (ii) and to route data packets from sources to destinations in the vehicular network with a reduced end-to-end delay and low packet loss. This solution is conceived for both user information and road safety application. This protocol is a geographic routing using the map topology to efficiently select the adequate junctions that data packets across to reach the destination. In addition, an intelligent greedy forwarding strategy was used between two successive junctions.

Commentaire [MR11] : C'est ce qu'on veut réaliser avec (notre objectif), mais vu qu'il y a pas de résultats pour l'instant on se contente de mentionner ce que notre proposition voudrait réaliser

Commentaire [SS12] : A refaire à la fin…

[1] Situation where there is no neighbour of sending node s, which is closer to destination than s itself.

The above mentioned protocol is simulation based with no any existing implementations, but, some instable implementations could be found for AODV and OLSR. And so, we used tried to use those implementations in our experiments.

6. VANET Experiments

5.0 Related work

In [34] they discussed some experimental results using multimedia application (video streaming) in inter-vehicular ad hoc network using two vehicles equipped with IEEE 802.11b devices in 'only' two typical driving scenarios in urban areas and highway. Various video bitrates and packetization policies have been tested, in other words they changed the transmission rate and the packet size while measuring the link availability (number of received beacons over the number of transmitted beacons within a certain temporal window), SNR, Packet loss rate, Goodput and PSNR. The results show that the two scenarios differ in terms of link availability and SNR. Moreover, the video quality measured at the receiver by means of the PSNR value shows that the best packetization policy depends on the scenario. The authors came out with the following results:

- **(i) The link is more available in a Urban than in a Highway while the SNR in highway is higher than Urban area , he refereed that to the higher average distance in highway than in urban areas, while SNR is higher due to the less separation between the vehicles and less likely availability of interfering devices.**
- **(ii) Despite the fact of low link availability in highway, the through put is high and transmission is error free due to the high SNR value, thus, the channel should be exploited while the link is available. Since low link availability causes packet dropping due to the MAC- Level timeout expiration.**
- **(iii) The optimal transmission policy varies depending on the scenario, since it is better to use large packets with a low bit rate in highways rather than urban areas, and to use small packets with a high bit rate in urban areas.**

Scenario	Link availability	Average SNR while the link is available
Highway	33.98%	22.49 dB
Urban	97.78%	19.14 dB

Optimal Transmission policy

Scenario	Packet size	Rate
Highway	Large	Low
Urban	small	High

The results were obtained in [35] regarding to the SNR and noise level differs from those whom were obtained in [34].The results in [35] has shown that the overall SNR in suburban areas is slightly higher than in highway and the same noise level in both environments. Moreover, the authors give some other results related to RTT (Round Trip Time), TCP throughput, UDP throughput, jitter, and percentage of datagram losses in case of UDP connection in two scenarios: suburban and highway. The authors come out with the following results:

Commentaire [SS13] : g rajouté ça ...

(i) **The average RTT is higher in highway than suburban areas in case of two vehicles, But, lower in case of using three vehicles than that when using two vehicles.**

(ii) **The average TCP and UDP throughput is higher in suburban than in highway, and in case of 3 vehicles is the highest but the figures are ambiguous and show continuous disconnection in the link. But, in TCP case the overall throughput is higher in TCP case than in UDP in case of two vehicles, but in case of 3 vehicles it's shown better value.**

(iii) **The average jitter is higher in suburban than in highway but higher in case of 3 vehicles than the case of two vehicles.**

(iv) **The average datagram loss is higher in suburban than in highway. This is because of the frequent loss of line of sight and distance changes at stop signs. In case of using 3 vehicles and static routing losses were 0%.**

The discontinuity in highway graphs shows disconnection in the link in highway scenario which proves the validity of what was mention in [1] from their point of view, the deployment of multi-media applications is difficult. They found out that the signal quality and the network performance greatly depend on both the distance and line of sight communication.

Scenario		**RTT**	**Throughput**	**Jitter**	**Loss**	**SNR**
Highway	**TCP**	**Higher**	**Lower**	/	/	/
	UDP		**Higher**	**Lower**	**Lower**	**Higher**
Suburban	**TCP**	**Lower**	**Lower**	/	/	/
	UDP		**Higher**	**Higher**	**higher**	**lower**

Note that their graphs were not that obvious to be able to come out with clear conclusions, since there was a continuous cutting in the connection.

[36] Agreed with what came in [34] concerning the impact of changing the packet size according to the environment. The study has the link quality (SNR), throughput, number of packet losses, etc… in relative to distance and velocity in different environment urban, suburban, freeway. The study provided the following results:

- **(i) Degradation in the link quality as it intuitively should in suburban and urban areas while in freeway the link quality lies between suburban and urban link quality.**
- **(ii) Link quality is independent of the packet size for a given scenario.**
- **(iii) Suburban environments are the most favorable and urban driving is the most hostile for IVC.**
- **(iv) Throughput decreases with increasing the distance. In freeway the throughput increases with the distance initially, and then starts falling with increasing the distance.**
- **(v) Increasing the packet size increases the throughput in urban area as well as in a freeway crossing but at smaller distance between the communicating terminals. Where large packets degrade the throughput at large distance, so it is favorable to adapt the packet size according to the separation between the vehicles.**
- **(vi) Freeway and suburban scenarios the connectivity enhances by decreasing the packet size.**

The results obtained by [34] recommended large packets highway we should use large packets while in [36] they recommended a small ones. As well as in urban scenarios, it shows the opposite.

I [34] the study was very good but with some gaps which make the obtained results could be tricky and not giving the right indication:

- **The scenarios where totally arbitrary driving in an urban area and highway not a predefined scenarios (certain speed and distance), which definitely had an impact on the behavior of the system.**
- **The average link availability and link quality was measured in the same way.**
- **The last flows using Paris CIF format different in both packet size and rate than the other formats. This makes it not so right to be compared to the other flows.**

The same thing in [35] , the were no predefined scenarios, the speed was not fixed, and in case of 3 vehicles even the distance was not measured so the impact of hops and intermediate nodes can't be compared to the two vehicles under the same condition even though it has shown some improvement in terms of losses.

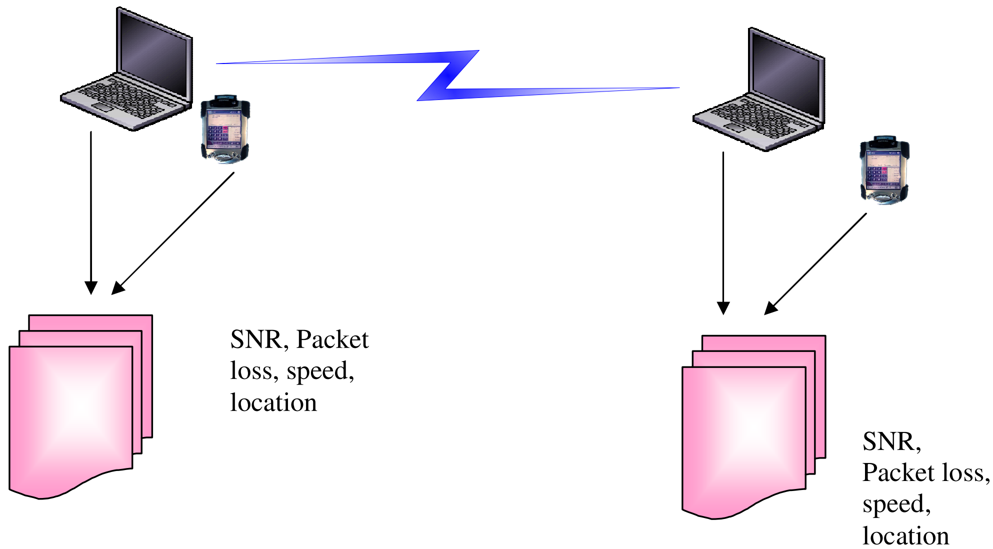
In [] the study has not shown graphically the effect of changing the packet size in freeway scenario. Also he wanted to study the influence of the environment on the system behavior, but unfortunately, he should have fixed the speed while conducting his experiments see the real impact of the environment , since he used different speed , and different testing durations.

5.1 VANET Tested

VANET Tested is a tool that is used to perform filed experiments and real-time measurements, the tested consist of PC's with PCMCIA WLAN card connected to external antennas and running traffic generator to exchange data and logs all the details of the communication process with all parameters in order to be perform a post analysis for the saved long to have an understanding of the system behavior and use this understanding to optimize the system efficiency .

Different VANET testbed has been used we can see a number of testbeds which have been created in [34][35][36], as well as different surveys and proposals could be found in concerning this topic in [37][38][39][40].

In order to perform our experiments we have created our own testbed in order to collect the data we need from both the WLAN card (SNR, Number of Packets, Losses, etc) and the location and speed from the GPS and save them to logs.



5.2 Experiment setup

This section presents our testbed and the experiment setup process. To setup our experiments we use laptops running Linux operating system (Redhat) and equipped with an Atheros PCMCIA 802.11b/g Orinoco cards with external antenna (Lucent Technology Antenna, 2.5dB gain)2, and Holux GPSlim236 Bluetooth based3. We use a modified version of Multi-band Atheros Driver for WiFi, also known as MADWIFI [5] which gives the ability to monitor the entire transmitted and received packets that reach the network card. The modified tool is developed at the University of Stanford. We use also Iperf [6] as a traffic generator.

We performed experiments between two vehicles in different environments, at various speeds and intervehicle distances. Figure 1 shows our experimental testbed. The first car acts as the traffic receiver while the second is the traffic transmitter. Both vehicles operate using the 802.11 ad hoc modes, i.e. without relaying on any access point. The monitoring tool (MADWIFI) is installed on the two cars.

We have developed a data analysis toolkit to analyze connectivity, signal-to-noise ratio, error rates, and data rates over different distances, and speeds. Iperf and MADWIFI log

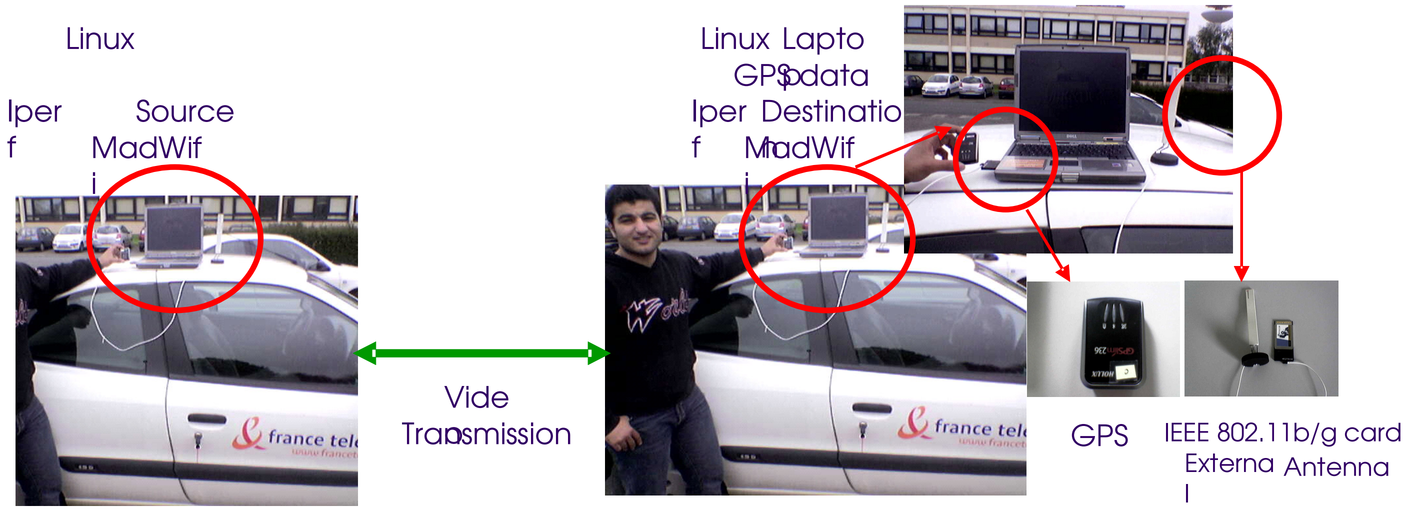
[2] Section 4.6 deals with the effect of external antenna in our experiments.

[3] We use the features of a localization system like GPS in order to measure both speed and position of vehicles.

files combined with the GPS [38] data allow a detailed statistical analysis. In order to measure the distance between the two vehicles (V1 and V2) based on the vehicles position we use the following formula [39]:

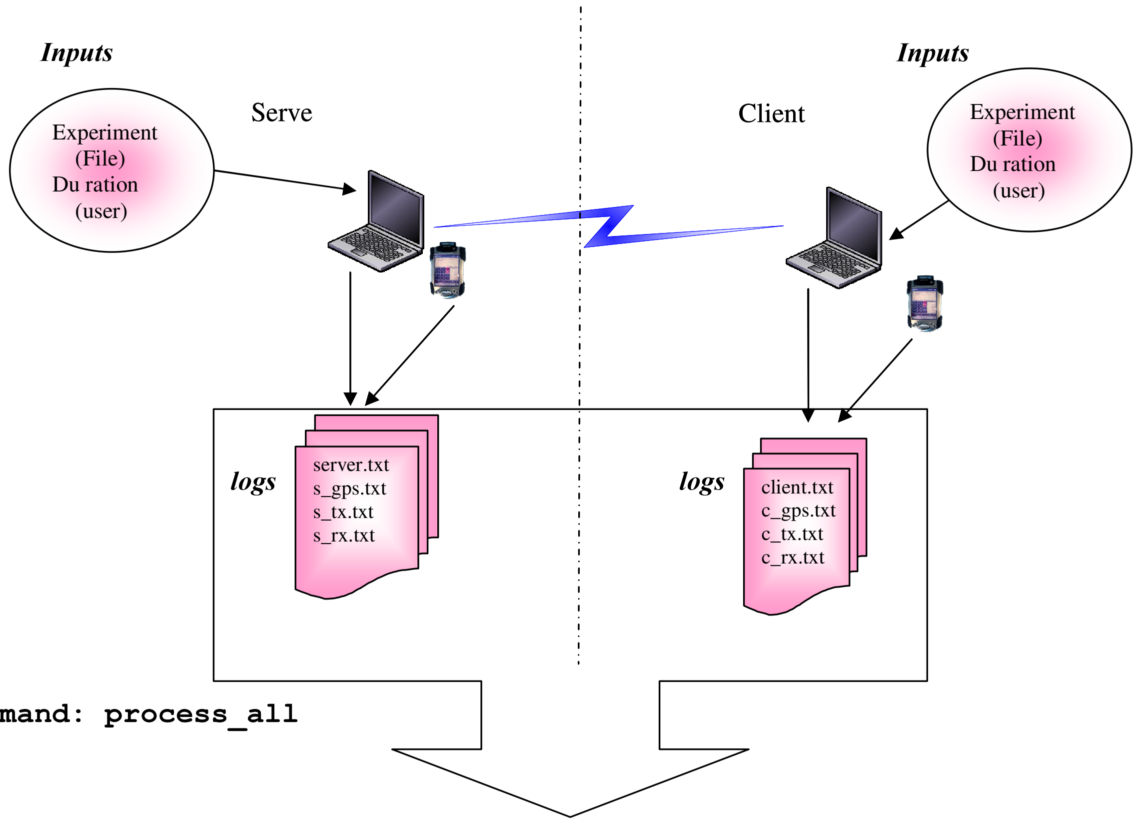
$$\text{Dist}(V1, V2) = r \times \text{acos}(\sin(lat1) \times \sin(lat2) + \cos(lat1) \times \cos(lat2) \times \cos(lon2 - lon1)) \qquad (1)$$

Where r is the earth radius (6378.7 Km).



Our testbed is user friendly tool and easy to be used , it's automatic , efficient and reliable, all what one should do is to define the experiments he needs to do , add them to the experiments file, then run the testbed, giving the test bed the experiment number and the duration of the experiment then start driving while all the data is automatically saved to the log files. The tool also will perform and automatic checking to the connectivity of the system before it starts running as well as informing the user if an error occurred in the system.

`Command: run_VANET`



`Command: process_all`

`Command: plot_all`

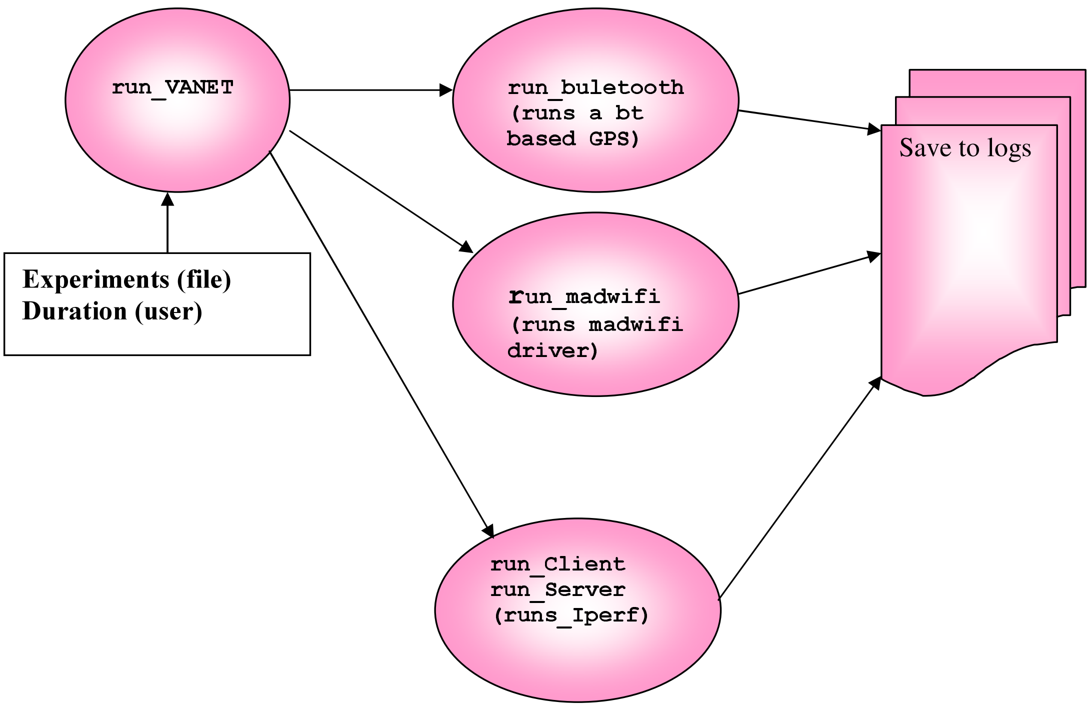
After running the `run_VANET` command, all the data will be saved to the logs as shown below

Logs:

- **GPS logs**
  - **s_gsp.txt , c_gps.txt**
- **Iperf logs**
  - **server.txt , client.txt**
- **MADWIFI logs**
  - **c_tx.txt , c_rx.txt , s_tx.txt , s_rx.txt**

Running the `process_all` command afterwards will process and save the data to another set of files to be ready for plotting. Finally, `plot_all command` will plot the graphs of the different parameters.

The testbed was implemented using SHELL SCRIPTS, C programming, GNUPLOT, AWK, SED. The testbed consists of modules which are launched in sequence as follows



`run_VANET` is the module that runs the whole system (all other modules), after this command is being launched, it will perform an automatically check wither the node is connected to the network or not then alert the user if not and move forward to the run the other modules (`run_bluetooth`, `run_madwifi` , `run_client` & `run_server`).

`run_bluetooth` is a module which connects though the Bluetooth to the GPS receiver to obtain the location on the earth and save them in logs in order to calculate the distance between the nodes at a later stage.

`run_madwifi` is a module which runs the capture process , it captures the incoming and outgoing packets directly from the PCMCIA card in addition to the signal and noise levels and save them to logs.

`run_client`, `run_server` is a module which runs the traffic generator IPERF client and server then save the results to logs.

Setting up a VANET experiment is not as easy as it looks , since while one is driving on the road he should pay attention to the road and not perform any kind of operating the system , so the system should be fully automated as well as some points should be taken into account before perfuming the experiments:

- **The machines timing should be synchronized and set the hardware clock to UTC on both machines in order to match the GPS timing and avoid any mistakes in the processing the files not to loose any data.**
- **Some scenarios are very short terms ones like crossing and passing , so in such a type of scenarios we should not start the system a few seconds (5 second for example) before then start moving , and for sure cut out those five seconds while processing the files.**
- **GPS accuracy, errors between 5 up to 25 meter could appear in the GPS readings and distance calculations.**
- **Good testing scenarios should be defined in order to study the effect of the deferent parameters on the system.**
- **VANET is unlike the other mobile networks, due to the difference in power and other parameters, the heights of the antennas, even the reflection and other effects.**

5.3 Test Environment and Testing Scenarios

In our work we have tried to apply many real scenarios like those which we face in our daily lives while we are driving on the road:

Scenario 1: A vehicle passes beside another static vehicle rapidly and exchange data with that vehicle (cf. Figure 2 (a)),

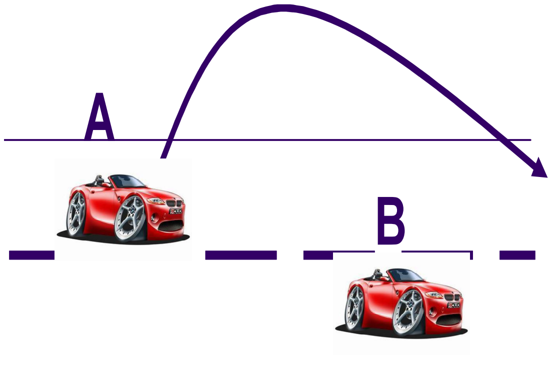
Scenario 2: Two vehicles are crossing each other on different side of the road, like two way road (cf. Figure 2 (b)),

Scenario 3: Round About, (cf. Figure 2 (c)),

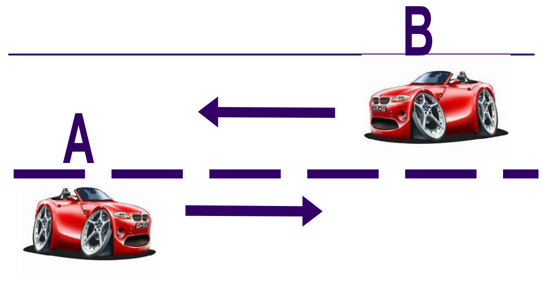
Scenario 4: Vehicles in city exchanging data, (cf. Figure 2 (d)),

Scenario 5: Vehicles in highway exchanging data,

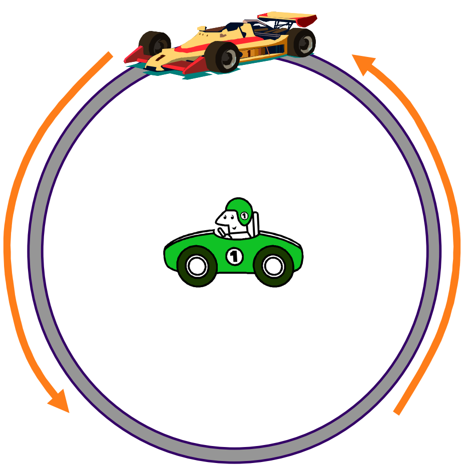
Scenario 6: External antenna impact.



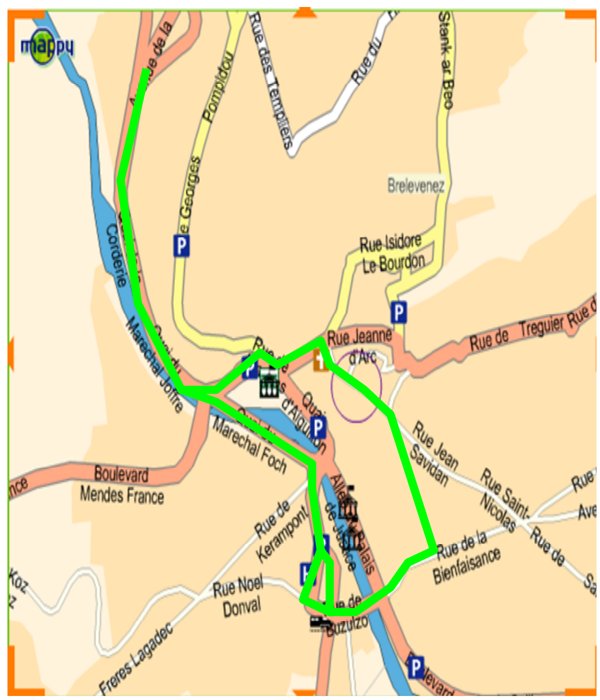
(a)



(b)



(c)



(d)

Figure 2. The experimental scenarios.

Scenario 1: Vehicle passes beside a static vehicle

This scenario corresponds to Figure 2 (a). It's a scenario that describes two vehicles: one of them is fixed and the other passes beside it. We have taken our measurement for two different speeds 30 Km/h and 60 Kms/h.

Results of this scenario are presented in Figure 3. We note that those figures correspond to the interval when the moving vehicle has approximately stable speed (around 30Km/h and around 60Km/h).

Scenario 2: Crossing

This scenario corresponds to Figure 2 (b) where two vehicles on a two-way road approach each other until they cross. We took our measurements at two different speeds (30 Km/h and 60 Kms/h).

Results of this scenario are presented in Figure 4. We note that those figures correspond to the interval when the two moving vehicles have approximately a stable and same speed (around 30Km/h and around 60Km/h).

Scenario 3: Round about

This scenario corresponds to Figure 2 (c). Here, we have a moving vehicle turning around a static one. We vary, the distance between the two vehicles (m, and m) and the mean speed of the moving vehicle (Km/h, and Km/h), also the same scenarios were performed with a person walking around the round about instead of a vehicles to see the impact of the speed due to the big difference between a pedestrian speed and a vehicles speed. Also the same experiment was performed with a variable speed instead of a constant speed.

Scenario 4: City

This scenario corresponds to Figure 2 (e): one vehicle tracks the other during 10 minutes. Depending on the road conditions, other vehicles could appear between the two cars occasionally and we would lose line-of-sight communication. In the city scenario the average speed is low, less than 50 km/h. Occasional stops are caused by traffic jams, traffic lights and roundabouts, while the distance between the two cars is on average smaller than in a highway. In this part of the experiment we drove downtown Lannion

city. City environments have also certain unique characteristics like buildings and objects obstructing the transmission signals.

Scenario 5: Highway

In the highway scenario, the speed is greater than the city scenario and limited to 90km/h. There are no stops, no traffic lights and no roundabouts. During this part of the experiment, we drove out of Lannion city, heading to Guingamp. One vehicle tracks the other also during 10 minutes. Results of this scenario are presented in Figure 8.

4.6. Scenario 6: External antenna impact

The goal of this experiment is to see the added value of external antennas on vehicle-to-vehicle communications. Therefore, we do the same experiment with 2 static vehicles once with external antenna and another one without (distance 95 meters). Results of this scenario are summarized in the following table.

	Packet Loss (%)	Jitter Delay (ms)
With antenna		
Without antenna		

Table 1. External antenna impact.

External antenna's advantages: adding an external antenna is profitable for VANET since it helps to extend the range by amplifying the signal and adding more power. Consequently, it decreases packet loss and the jitter delay.

External antenna's disadvantages: adding an external antenna has some drawbacks like: (i) extending the range leads to more interference with other nodes (ii) adding extra delays related to the contention.

5.4 Results and Analysis

7. Terminology
8. References
9. Appendices
9.1 Related work and Studies on VANET characteristics

As we mentioned before many different simulation and characteristics of VANET exist. The simulations are based on establishing a certain mobility model to simulate the node movement within the network and another model to represent the different layers of the network (Physical model related to the environment, MAC protocols and routing protocols). Vast mobility models could be found in literatures. However, a wave of new researches in VANET mobility appears recently for (1) the Movement the VANET is not completely random as in MANET since speed and dynamics are constrained to the road rules (2) The availability of traffic maps helps to study the model in a more realistic way. Here we are about to discuss the recent studies that focus on the network mobility characterization of vehicular ad hoc network.

Most of the simulations based studies are microscopic models that simulates the movement of an individual node no the behavior of the traffic flow as a whole. Below is a comparison between the different existing models.

Artimy et Al study [4] the authors have developed microscopic simulator to investigate the effects of the free flow traffic on connectivity in a VANET. There model has somehow a lack of reality since because of the imaginary roads they have assumed by dividing the road into a fixed length segments. Either none or only one vehicle in each segment is traveling at certain speed. All vehicles travel with at the same speed. At each simulation step, the output is used to draw the connectivity graph between the nodes which represent the cars and the paths that represent the communication link between them.

The main factors in this model that influence the connectivity are the number of vehicles in the system which is expressed as the vehicles density, the relative velocity, and the number of lanes.

Saha and Johnson study [5] was concerned of creating realistic models and avoid imaginary models in order to be able to correlate their models with the performance in a real development. Their model is based on using data of real street maps where the nodes move to simulate Dynamic Source Routing and compatible with ns-2 network simulator. They used the publicly available TIGER (Topologically Integrated Geographic Encoding and Referencing) database from the U.S. Census Bureau. Their mobile nodes are injected in the system to move

along the paths on the graph. Vehicles start and end at random points on the TIGER road map. They converted convert the starting and ending coordinates to x-y coordinates using a standard Mercator projection. Also they assumed that the drivers move through shortest path to the destination. Their study has shown in many ways that the Random Waypoint mobility model is a good approximation for simulating the motion of vehicles on a road, but there are situations in which their new model is better suited. They have shown that a transmission range less than 500 meters produces server network fragmentation. As in [] they have show that the vehicle density improves the connectivity. DSR delivers about 90% of the packets with acceptable latency in network of 150 nodes with wireless range on 500 meter.

Another microscopic study is Wang's study [6], he has used a commercial traffic simulator VISSIM, to simulate the node movement. a normal ordinary road has been used in this paper which is a 3 lane highway of 26 Km with no entry and exist to simulate the car while moving ordinarily on the road. The authors claims that a real behavior can be simulated like acceleration/ deceleration, car chasing and some other behaviors using well developed models fro literatures on transportation. The metrics on connection lifetime are collected for vehicles communicating with vehicles moving on the reverse direction only, the same direction only, and both directions. The results have shown that the unicast paths have a lifetime less than 50 seconds.

Blum [7] has also used a commercial microscopic simulator, CORSIM, to simulate the inter-vehicular communication network. The author simulates a 9.2 miles highway with 10 exits and 10 in ramps. They used a different assumption which is not all the vehicles on the road have the ability to transmit and receive data only 20% of them are equipped with wireless equipments, and the network model has been simulated using NS- simulator.

Their result led them to conclude that the network layers need to use the limited bandwidth effectively, and to function efficiently in the rabidly changing topology. Even for vehicles traveling the same direction with long transmission range, links are still very short term (about 1 minute on average). Also, sending even a relatively small message over 3 or 4 hops is likely to suffer a route error. At about 9 hops, the path disappears before the first packet can be acknowledged.

Traffic density can affect the delays experienced in VANET as came in [8], they have used the same simulator CORSIM that was used by Blum [7]. They aim to compare the delays experienced by different routing algorithm the optimistic and pessimistic ones, different highway directions one way and two ways ones with variable number of lanes from 1 – 5 taking into account the joining and disjoining

vehicles. In pessimistic forwarding, the message is dropped when the next hop does not exist. While in optimistic forwarding messages are kept by the intermediate nodes in case of the inexistence of the next hop. They found out that in optimistic forwarding that latency decreases in this case. The authors recommended that application can increase robustness in a less dense network by increasing their tolerance of the delay to at least 200 seconds and use optimistic forwarding. The study also finds that three or more lanes decreases delays indicating the liberty in movement is essential to prevent vehicle clustering due to a few slow moving vehicles.

For more realistic movement the authors in Jetcheva [9] have chosen their data to be several week long traces of the movement of Washington city buses in Seattle. This transport networks is composed of over 1200 vehicles covering 5100² Km area. The city has a location system for tracking each bus using a combination of odometer and signpost transmitters. The authors have fed this data into an NS-2 network simulator. They have assigned the busses different transmission ranges from 1-3 Km, based on the traveled distance, and the busses speeds vary between 10 miles/hour for 90% of the busses and 97 % were less than 20 mile/hour. At range of 1 km, the median node degree, which indicates the number if other nodes that this node is connected to, is 30. They found out that with a 1.5 Km range, the maximum wireless path length is 48 wireless hops. This number is quite large to expect that two nodes can communicate with each other without an access point since in [] the author has shown that the link expires even with only 5 hops before the 1st packet is acknowledged , thus , we expect that we need an access point to communicate two far apart points.

4.1.2 Comparison and analysis

All of the six studies above used microscopic simulator to simulate the motion of each vehicles in a vehicular ad hoc network. The entire do not have a detailed network model that accounts for network contention or transmission errors.

Study	Mobility Model	Topology	Speed limits	Network/transmission Range
[4]	Microscopic simulator	Multilane highway unidirectional and close	129 Km/h speed	Connectivity graph no delays or errors / 250 meter
[5]	Microscopic simulator	Real map tracing including highway and normal streets.	35, 37 mile / hour	NS-2 simulator with DSR routing / 500 meters
[6]	Microscopic	Multi lane highway,	80 – 110	Connectivity graph with

	simulator,	bidirectional , closed , constant vehicle , density (2000 vehicle)	km/hour.	no protocol layers / 1000 meters
[7]	Microscopic trace based	Traces on a portion of a highway, bidirectional.		NS-2 simulator / 25 – 500 feet
[8]	Microscopic	Topology multilane highway, bidirectional	50 MPH speed	Simulation with pessimistic and optimistic forwarding / 200 meters
[9]	Microscopic trace based ,	Topology: Based on city map.	1200 vehicle , covering 5100 square Km area, 20 miles/hour	NS-2 simulator / 1-3 Km

In this table summarizes the microscopic models and traffic type and network models that were used in these researches. In [6] the author has used 2000 assumed 2000 vehicles on the road which is far from being real, since no such a number of cars on a highway. In both [4] and [6] the roads were closed where no exist or entrance. So it simulates the partial of the network, since the number of nodes and network topology are not affected by the entering and existing vehicles. Jetcheva's study [9] is the only one that have used a real traffic trace. But, in this study the speed was less than 20 miles/hours, so mostly a low speed, with a very large transmission range which are considered as defects in this study.

The author in [5] used a different road types varying between highway and city roads while the study in [8] focuses on highway traffic, the study in [9] collects traces in the city roads only. Normally, all studies have chosen a random starting and ending points to their vehicles, where [5] has chosen the shortest path to the destination.

In the table below we will continue the compression of the microscopic simulation based studies, in Table two the comparison will be according to the physical characteristics of the traffic pattern and transmission area.

Study	Vehicle Density	Number of Lanes	Range
[4]	Connectivity increases as density increases but decreases after reaching a critical density level as	Multilane has greater connectivity and	Connectivity drops rapidly beyond transmission range.

	in traffic jam.	better than 1 lane	
[5]	At least 150 nodes to stay well connected , connectivity increases as density increases	Not considered	At least 500 meters of transmission range to stay well-connected
[6]	Not considered	Not considered	Not considered
[7]	• Low Deployment cause low density • Frequent fragmentation , rapid topology changes	Not considered	At least 500 ft range, a node can reach 37% of the other nodes.
[8]	Increment in density may increase delay if there is not enough number if lanes to avoid slowing down the moving vehicle	Multilane road has less delays than 1 lane road in general	Not considered
[9]	With 1km of transmission range , the median nodes degree is 30	Not considered	Not considered

Study	Route Redundancy	Connection Lifetime	Number of hops (Path Length)	Routing Latency
[4]	_	Probability distribution of the connection lifetime that resembles power low	Increasing the path length decreases the connectivity	_
[5]	_	_	Average of 3 hops in all simulated scenarios	DSR Delivers 90% of packets Average latency 18.2 ms
[6]	_	90% of all paths have less than 50 seconds of lifetime	Increasing the path length decreases the connectivity	_
[7]	Lifetime is shorten if more than one route is needed	Connection life time directly affected by driving direction and transmission range	Small messages over 3 to 4 hops likely suffer route error	_
[8]	_	_	_	Optimistic forwarding and bi directional traffic decrease delay
[9]	_	_	Maximum number of hops for 1.5 Km transmission range is 48 hops	_

10.Terminology:

11.References:

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12. Appendices:

Internship/Employment Report (continued)

INTRODUCTION

Describe the company with whom your internship/employment was carried out and the background to your involvement with this company, including the location of the facility at which the work was done. Describe your position and the basic engineering areas in which you worked for your internship.

PROJECT DESCRIPTION

Describe in detail the nature of the work or the nature of the project or projects, which you carried out, stressing as much as possible the engineering aspects of your work. Describe the goals for the project, the methods used to approach the project, and the accomplishments. Do not disclose any proprietary information. If you are or have been a full time employee, you need only describe your work of the last 3 months.

ANALYSIS

Describe the usefulness of your internship/employment work in advancing your understanding of the engineering profession. What did you learn from this experience? Include both the technical and non-technical learnings (for example, you might describe such things as how your organization was structured, how individuals worked together in your company, how technical employees interacted with customers, what company initiatives you observed, etc.)

Analyze your performance during the internship. What are your three primary strengths? Give examples of what you did well. What are three areas that you would like to improve? Give examples of what you would do differently. Ask your supervisor for input on this aspect of the report.

CONCLUSION

Summarize the usefulness of your internship/employment work in advancing your understanding of the engineering profession, both technically and organizationally. Summarize what you learned from the experience.