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Vehicular ad hoc networks: From simulations to real-life scenarios

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ABSTRACT

The automotive industries have considerably grown in recent years. Indeed, the introduction of new technologies and communication devices make driving more convenient and safer. Recently , vehicle manufacturers have begun to integrate the D2D communication technology to allow cars to communicate with each other, as well as with road side units. Moreover, researchers are constantly working to develop efficient routing protocols to overcome the frequent and the fast topology changes in vehicular network. Indeed, to check the protocol effectiveness, it is very costly to make a test bed containing multiple vehicles. Therefore, we have to use network simulators to accomplish this task with minimum time and losses.
However, simulators remain unable to prove the effectiveness of routing protocols in real scenarios for many reasons such as human factors, unbounded network size and unexpected events. In this paper, we have surveyed the global initiatives made to develop VANETs routing protocols, including the challenges encountered in moving from simulations to real life scenarios.
To the best of our knowledge, this paper is the first that aims to highlightingthe various factors that impact the development of Intelligent Transportation System (ITS)in order to help researchers for further developments and implementations.

Key words: Vehicular network, Sensor, communication, smart car, simulation.

1. INTRODUCTION

VANET contains a set of moving objects travelling with high speed and communicating with each other using IEEE802.11p [1].Indeed, vehicles are Dedicated Short-Range Communication (DSRC) devices that work in 5.9 GHz band with bandwidth of 75 MHz and approximate range of 1000 m [2]. Despite the development of communication technologies, this type of network has a great challenge in size and speed that have to be considered to develop routing protocols.[3]. In this context, many leading companies such as BMW, Volkswagen and Hyundai have begun the implementation of their own projects. By conducting real experiments and identifying the most important shortcomings, the current trend seeks to provide a typical routing protocol able to achieve an intelligent inter-vehicle communications. Indeed, VANET protocols can be classified in different ways according to several criteria. Depending on the manner of the creation and the maintenance of routes, five classes of routing protocols are cited below.[4][5].

- *Topology-based routing:* In this type of protocol, the node have no information that indicates its geographic location or that of their neighbors. The discovery and the maintenance of roads are carried out through periodic exchanges of messages between neighbors.
- *Position-based routing:* In this type of protocol, each node has to know its geographical position and that of the destination. The coordinates of each node can be obtained using a geolocation system such as GPS.
- *Cluster-based routing:* In this type of protocol, the network is divided into various sets of nodes geographically close to each other (Cluster). In each cluster, one node is elected to assume essential features in routing (cluster head). It summarizes its cluster's information and sends it to neighboring cluster-heads by means of gateway. Subsequently, in each cluster there are three types of nodes "cluster-head", "gateway" and "internal node ".
- *Broadcast-based Routing:* In this type of protocol, the looking for a path between two nodes is done by broadcasting a message around the whole network. Thereby, each message received for the first time by any node will be repeated to all neighbors, and these neighbors will do the same later.
- *Geocast-based Routing:* In this type of protocol, the source delivers a message only to other nodes located in a specific geographical area which contains the destination. [6].

The various protocols developed so far do not provide an optimal solution in polynomial time because of the high mobility of nodes and the diversity of routing environments (city, urban, residential, highway)[4]. Therefore, significant efforts have been done to find a reliable intelligent system that ensures efficient routing of messages from source to destination with less transmission problems.

Although several researches have been launched recently in vehicular network , it is very difficult to provide a typical protocol effective in real life scenario.

To clarify the gap between theory and practice, this paper provides to researchers an understanding of the challenges that have to be considered before designing any routing protocol. It also provides precious information on existing simulators and global flagship projects that tackle routing within vehicular networks.

The rest of this paper is divided into the following sections: An overview of the common used simulators, their pros and consis presented in section II. Section III summarizes the global initiatives related to VANET and ITS research. Section IV highlights issues encountered in protocol implementation in real scenarios. Then section V concludes the paper with prospects of new directions for future researches.

2. POPULAR SIMULATORS FOR VEHICULAR NETWORKS

Due to risk and high cost of real experiments in vehicular networks, routing protocols are evaluated through simulators [7]. Therefore, as shown in table 1, several platforms have been developed to simulate the behavior of the proposed models [8]. Some of these platforms are used for a wide range of problems and others are intended for specific applications [9][10].

Table 1: Summary criteria of most popular simulators

Criteria	NS2 / NS3	OMnet++	GloMoSim
Simulation Code	C++ OTCL	C++	C
Network scalability	High	Poor	High
Available help	Excellent	Meduim	Meduim
OS platform	Linux/Unix Windows	Linux/Unix Windows	Linux Windows
Graphical interface	×	√	√
Trace file	√	√	√
Mobile network simulation	√	√	√
Open source	√	√	√

Indeed, any typical VANET simulator is based on network simulator and traffic simulator as shown in figure 1 [11]. The traffic simulator called simulation of transportation systems is used to employ accurate models of transportation including roundabouts, freeway junctions, obstacles,….However, the network simulator is a package of tools used to analyze and understand the behavior of proposed networks.

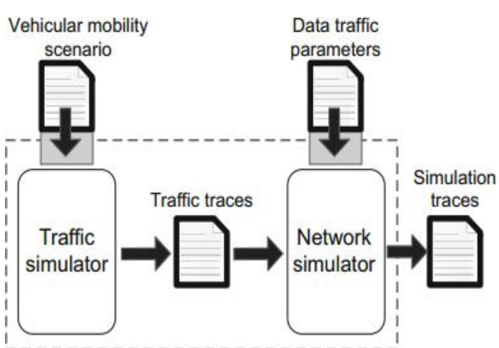

Figure 1: Simulation architecture

It has been shown in the literature that more than 80 % of papers used network simulators (NS2 and NS3),OMNet++, and GlomoSimto evaluate the performance of new protocols and algorithms.

Despite the widespread use and the total reliance on these protocols, there are several comments that make us doubt the correctness of evaluations provided in many research papers.

1. Tools are selected according to their available helps, their popularity and their active maintenance and not according to their suitability [12].
2. Complexity of existing hardware platforms[13].
3. Needed simulation time can be high.
4. You cannot choose the appropriate tool until you have seen all the others available and their pros and cons.
5. Always, the judgment of the effectiveness of a protocol is made based on two or three metrics, that weaken the credibility of the given results.
6. Most researchers avoid the comparison of their protocol with a competitive one designed for the same objective.
7. Until now, to make a comparison, there are no specific rules determining the competitive protocols and the expressive metrics to use.
8. Results obtained from simulation, emulation and testbeds were significantly different for the same scenarios [12]
9. The mobility models can affect the accuracy of the simulation results [9].

3. GLOBAL INITIATIVES IN VANET

The manufacture of intelligent cars has started at the beginning of the last century. Indeed, the first smart car emerged in 1984 through the projects of the Carnegie Mellon University and the Auto Life company [14].Then, in 1995, the "Mercedes Benz" company was able to manufacture the first one called "W140 S". This car was able to cross a distance of 1678 kilometers from Munich to Copenhagen [15].

Since then, many companies and research organizations have begun developing different models of self-driving vehicles that react individually to make the appropriate decisions related to unexpected incidents. It should be noted that the driver assistance systems currently used rely heavily on sensors to detect obstacles and vehicles on roads.
Car makers are trying to increase the safety and security of drivers by integrating devices that can warn or even avoid the accident before it happens.
For example, Honda announced that it has focused on the creation of a new research council in artificial intelligence in order to join other worldwide car makers in robotic research such as Ford and Volkswagen [16].

Also, Toyotahas announced a partnership with Microsoft to collect and analyze the important data provided by its cars. This new project will focus on linking cars and their owners' homes to identify road conditions and traffic congestion [17].

As shown in figure 2, there are many devices within smart cars that allow the self-driving [18].

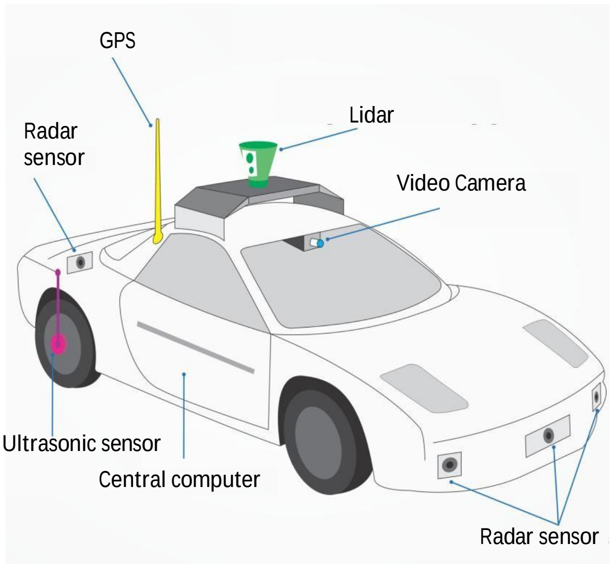

Figure 2: Self driving car components

1. Remote sensors: Allow to draw maps in three dimensions to indicate the potential risks.

2. Camera: To photograph the area around the car. Each camera provides an angle of view of 50 degrees, and a resolution of about 30 meters.

3. Ultrasonic sensors: Installed in vehicle wheels to detect other cars in the parking.

4. The central computer: Fixed inside the car. It analyzes all the available data coming from sensors to give orders, such as acceleration and braking.

5- GPS: Is a global navigation satellite system based on the use of radio signals emitted by dedicated satellites. The common use of the Global Positioning System (GPS) is to find the current position. [19].

As shown in figure 3, it has been estimated that the number of self-driving cars will reaches 10 million with the beginning of 2020. Also, the first fully autonomous vehicle without the need for driver intervention will be adopted in 2019 [20].

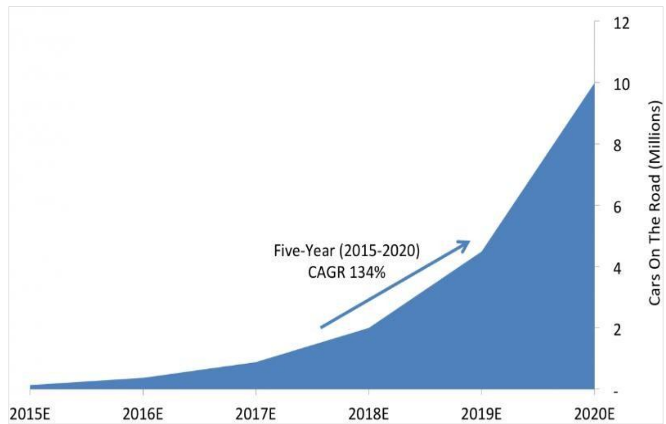

Figure 3: Estimated Self driving cars (2015-2020)

Indeed, we presented in table 2 a non-exhaustive list of the most important task forces and projects related to VANET and smart cars.

Table 2: Summary of important vanet projects

	Name	Description	Participant	Deadline	Reference
1	AdaptIVe (Automated Driving Applications & Technologies for Intelligent Vehicles)	Using advanced sensors and novel technologies to develop self-driving cars and trucks.	• European commission.	2017	
2	Amsterdam Group	Is a strategic alliance of the V2V Communication Consortium to develop and deploy co-operative ITS in Europe.	• CEDR • ASECAP • POLIS • C2C-CC.	2017	https://amsterdamgroup.mett.nl/default.aspx
3	COMPASS4D	Implementing cooperative services on roadside units and traffic lights and on vehicles.	• Bordeaux, • Copenhagen • Helmond • Newcastle • Thessaloniki • Verona	2016	http://www.compass4d.eu/

			• Vigo		
4	DRIVE C2X	Providing an overall, European-wide assessment of cooperative systems through operational field tests.	• Europe	2014	www.drive-c2x.eu/project
5	PRESERVE Preparing Secure Vehicle-to-X Communication Systems	Secure the V2X communication and protect the privacy of users.	• Netherlands • France • Sweden • Germany	2015	www.preserve-project.eu/
6	Project Titan	Developing an autonomous driving system.	• Apple's team	---	https://www.theguardian.com/technology/2015/aug/14/apple-self-driving-car-project-titan-sooner-than-expected
7	Self-driving research project	Replacing human control with artificial intelligence.	• Baidu • BMW	2019	https://www.theguardian.com/technology/2015/jun/10/baidu-could-beat-google-self-driving-car-bmw
8	BMW iNEXT	Creating an open standards-based platform for bringing self-driving cars.	• BMW • Intel • Mobileye	2021	https://arstechnica.com/cars/2016/01/bmw-uses-ces-to-show-its-autonomous-i8-concept-to-the-world/
9	Twin Self-Driving Teslas	Providing the automation of vehicles,connectivity and electric vehicles.	• BOSH • Google, • Tesla • Porsche	2020	http://www.forbes.com/sites/dougnewcomb/2015/06/12/forget-auto-pilot-bosch-builds-twin-self-driving-teslas/#1c4b93a53be5
10	Platooning trucks	Using smart technology, many trucks connected by wireless signals, one closely following the other.	• DAF • Daimler • Iveco • MAN • Scania • Volvo	2016	http://www.bbc.com/news/technology-33675934
11	Ford Smart Mobility LLC	Providing autonomous vehicles.	• Ford	2025	https://media.ford.com/content/fordmedia/fna/us/en/news/2016/03/11/ford-smart-mobility-llc-established--jim-hackett-named-chairman.html
12	V-Charge project	The car can find open parking spaces in a garage without human intervention.	• Volkswagen	2019	http://www.v-charge.eu/
13	Intellisafe	Self-Driving Car.	• Volvo	2021	http://www.volvocars.com/au/about/innovations/intellisafe/autopilot
For more details refer to : https://www.cbinsights.com/blog/autonomous-driverless-vehicles-corporations-list/					

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4. PRACTICE ISSUES IN VEHICULAR NETWORK

Although, there are several researches and extensive projects in vehicular network, the slow development of autonomous vehicles reveals the existence of many practice issues as shown in figure. 4.

Figure 4: Vanet practice issues

a- Signal fading: The large number of deployed obstacles along roads prevents the signal from reaching destination [21].

b- Bandwidth limitations: The mismanagement of bandwidth leads to rapid channel congestion which adversely affect the time delay for disseminating message [22].

c- Security and privacy: The exchange of information between cars poses major security and privacy challenges, including the inability to encrypt data transferred using the Internet and the lack of secure code practices [23].

d- Mac design : In VANET, the performance of the medium access protocol (MAC) affects the effectiveness of traffic safety applications . Thus, the proposed MAC protocol has to achieve confident delivery of messages within the time limit even in dense scenario [24].

e- Diversity of scenarios: It is very difficult to design a typical protocol suitable to all routing environments (city, urban, residential, highway) [4].

f- High cost experimentation: The real-world VANET systems including the deploying of RSU involves high cost and manpower [25].

g- Connectivity: The small network diameter in VANET and the short life time of link communication adversely affect the connectivity and decrease the packet delivery ratio [26].

h- Mobility model: Although there are several mobility models such as graph constrained and random pattern, providing a typical model that reflect the movement pattern of nodes on the road (trees, intersections, traffic light, buildings,...) remains a challenging area for researchers [27].

5. CONCLUSION AND OPEN RESEARCH ISSUES

The main aims of this survey are to help researchers and developers to understand and distinguish aspects related to vehicular network between reality and expectations.

Indeed, the increasing number of vehicles and accidents has prompted car makers to develop self-driving vehicles. Since the experiment evaluation is expensive, researchers have to test their solution based on simulators.

In this study, an overview on vehicular network is presented including available technologies and developed protocols. We discussed the pros and cons of used evaluation methodologies. We also presented a non-exhaustive list of the most important task forces and projects related to VANET and smart cars. We cited at the end, the main issues encountered in moving from simulations to real life scenarios.

Although the diversity of solutions, the future efforts have to be interested not only by effectiveness but also by minimizing the cost of proposed solutions and by providing general rule for choosing the suitable simulator and metrics for each scenario.

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