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VANET: Technical and Future Challenges with a Real Time Vehicular Traffic Simulation

Hayder Khzaali
Department of Electrical and Computer Engineering Florida Institute of Technology, Florida, USA

ABSTRACT
VANET or Vehicular Ad-Hoc Network is a special type of MANET or Mobile Ad-Hoc Network that is designed specifically for communications between vehicles or V2V and vehicles to infrastructure or V2I. There is a lot of studies and research that has been dedicated to study this technology due to its importance and necessity in our life. The fact that each and every module presented must be tested thoroughly before putting it into action, as there will be severe consequences in case of a system malfunction especially if it's a vehicular design problem. However, seeing VANETS coming into reality becomes very close with the advancement of IEEE 802.11p standard that is being dedicated to the DSRC or dedicated short range communication [1]. This paper will discuss this technology emphasizing some of its applications, current limitations and future challenges plus simulating a real traffic using SUMO and OpenStreetMap.
***Keywords*:** Ad-Hoc Networks, DSRC, MANET, OpenStreetMap, SUMO, VANET, V2I, V2V.

I. INTRODUCTION

VANT as stated is one application of mobile ad-hoc networking which provides vehicle to vehicle and vehicle to infrastructure interactions that will facilitate safe and secure transportation during hazard situations, or unexpected events from other vehicles, that might happen in the road. V2V communications mechanism is done through efficient routing techniques. The motive that derived scientists and engineers to study and develop this technology for many years was because of its potential significance that will take the driving experience to a whole new level, plus the economical implications of this technology. To make the picture more clearly in regarding to the economical benefits, let's put some numbers to it. According to the statistics taken from the United States Department Of Transportation or DOT, this technology will theoretically save about 1.3 trillion dollars every year in US alone, that's 8% of US GDB (Gross Domestic Product) or nearly 115 % of the defense budget. About half a trillion dollars comes from accidents avoidance, almost 32000 thousand people being killed on the US roads every year and millions injured. The savings from not killing those people estimated by the EPA (Environmental Protection Agency) and DOT have come up with to reach half a trillion dollars. Additional half a trillion dollars comes from productivity gains and about three billion dollars comes from fuel efficiency gains that falls down to gas plus congestion savings. The statistics shows that the global numbers can easily reaches up to five trillion dollars a year, hence, the dollar-cost savings alone makes it necessary to apply V2V and V2I in the roads as soon as possible.

II. OBJECTIVE

The main objective of this paper is to provide a brief overview of VANT technology and its applications, emphasizing its advantages and some of the technical implementation impairments. Additionally, a simulation will also be presented using SUMO and OpenStreetmap applications illustrating a nice module for providing a clear picture of how V2V based on ad-hoc wireless networking technology works in real time situation.

III. HOW VANET WORKS

The number of Vehicles that exists in a VANET system in the world today approximately exceed 750 million vehicle [2]. Each vehicle or node is able to communicate with other vehicles within its vicinity using a protocol called dedicated short range communication or DSRC for short. The frequency spectrum allocated for this wireless type of communication must be in the 75 MHz licensed spectrum or around 5.9 GHz, in compression to the IEEE 802.11a that only operates in the unlicensed portions of the frequency band. The theoretical maximum range for wireless communication is 300 feet or 1000 meter and the max allowable speed for each vehicle is 120 mph for efficient communication to happen according to DOT. The Ad-Hoc terminology used in V2V means that all nodes can communicate with each other without any kind of central management or in another words it can be called infrastructure less type of network. However, there is what is called RSUs (road side units) which act like access points that can store a variety of information for other cars that passes by the coverage area of these APs. This information will be valuable for other cars that will go through the same route in the future, especially if there is no direct communication between cars passing through the same route in different timings. Each vehicle has an on board unit (OBU) that stores all non-private information about the car, like speed, GPS position, acceleration and heading.

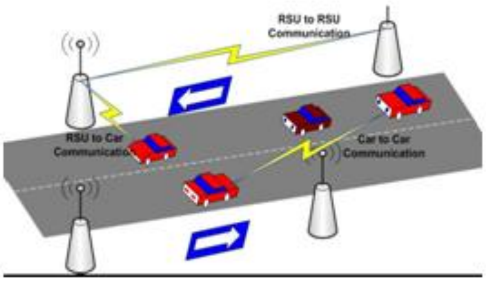

figure (1) VANET structure

IV. VANET APPLICATIONS

Both safety and efficiency should be considered in the design of VANET applications. For example, in the case of a car accident or road maintenance issue that might happen suddenly on the main road, that will lead to the temporary block or a stifling road congestion. Therefore, a message being sent reporting this event containing a warning sign to all nearby vehicles will be of a great importance. The drivers of those vehicles will now have the awareness of this road hazard and not only that, V2V communications will also provide suggestions (based on car's GPS information) for alternative route to choose from. Different types of data being monitored by VANET applications including weather conditions, nature of the road, approaching vehicles information and nearby roads. The relevant data will be exchanged between mobile nodes (vehicles) for different purposes using wireless communication and below are few types of VANET applications:

4.1 Safety Applications

The most significant goal of VANET applications is safety that involves two major factors, delay and reliability. If an accident or a collision occurs in the road, two issues need to be taken care of instantly: accident location and awareness of upcoming vehicles to this spot. All nearby nodes should be alerted and transmission delay is not prohibited whatsoever. Therefore, using efficient routing protocol is a critical for V2V communication. Simple type of applications that triggers a warning message to a call center that transfer this information to a rescue personal or emergency responders are already being used like GM's and OnStar system [3]. It has been hopped that for a future safety application it will take it a step further, for instance and depending on the location of the accident form approaching cars specially if they are coming fast within a certain speed limit that these applications may send several fast warning messages, automatically reducing the speed of the car or even triggering the emergency breaking system for these vehicles to avoid a possible collision. Of course, these applications should also be designed to prevent road disasters from happing in the first place by acting proactively to provide drivers with early alarm messages in time to prevent accidents from happening.

4.2 Efficiency Applications

Efficiency applications can be further subdivided into two sections according to the desired goals: intersections in cross roads applications and congestion management applications.

4.2.1 Intersections in Cross Roads

An important research area in VANET technology is traffic control management. For instance, vehicles passing through an intersection have a higher probability of collision where at least two or may be more traffic flows converge. In this scenario, V2V and V2I communications between vehicles is necessary (specially, if there is no traffic lights available) to maintain smooth flow of traffic by alarming vehicles drivers ahead of time to wait for another vehicle heading from different direction (oblivious to the diver) to take the proper decision.

4.2.2 Congestion Management Problem

The best scenario to illustrate this issue is when a traffic jam occurs in a road. The goal here is establishing V2V communications to provide an alternate route for upcoming vehicles that will pass through the same road after a short period of time, to insure a nice smooth flow of movement and reduce roads traffic jam.

4.3 Comfort Applications

It includes all applications that provide the driver with useful information during the desired trip. For instance close by restaurants and hotels, gas stations, parking locations, city leisure and tourist's information and other services that V2I communication provides from nearby RSUs.

4.4 Urban Sensing

VANET system can be considered as a network paradigm for urban sensing. A huge number of vehicles in an urban areas can be expected with an on board sensing unit installed in each one. This high concentration of Vehicles play a significant role in urban sensing [4][5].There are hopes to integrate smart-phones applications with VANET sensors to further provide a great potential future for urban monitoring[6][7]. Since vehicles are not restricted by energy consumptions and other constrains and can be equipped with intensive processing units, a variety of sensing equipments like chemical detectors, acoustic sensors and video cameras can be imbedded into these nodes. This will present a massive opportunity for a big-scale VANET applications, making it a promising area of research.

V. FUTURE PERSPECTIVE AND CHALLENGES

Realizing VANET future perspectives requires providing efficient solutions for the challenges that may face this technology. Below are some of these problems that should be addressed:

5.1 Information Management and Storage

It is expectable to have millions of vehicles in a big scale vehicular network. This huge number means more data must be stored and shared in an efficient and organized manner across VANETs as mentioned in [8][9]. This continual network expansion with the rise of the amount of data being produced besides VANET dynamic properties will pose a new challenge for data management in this technology.

5.2 Localization Systems

Accurate localization is required for highly sensitive applications in VANETs. One suggestion to achieve this task is to put a navigation device in each mobile node, a satellite GPS for instance. The problem with this system however is the undesired problems that comes with the satellite based positioning applications like loss of connection due to weather conditions and other factors. Several techniques has been suggested to address this issue [10]. For example, Cellular localization, matching of maps, Image and video processing, Dead Reckoning and distributed ad-hoc localization. However, none of these techniques mange to solve all the problems relative to node position computing. What makes this issue more challenging is that the nature of roads, speed of nodes and drivers behavior that make the network topology changes rapidly with time, which will lead to an outdated positioning information. One approach to handle this task is to apply a module that predict vehicles position in the future by studying its path history and there are many researches in this field.

5.3 Security and Privacy

Besides the common wireless security and privacy problems, security challenge is a major issue because of the large scale of vehicular network in VANETs, nodes mobility, rapid changing in network topology and the variety of applications being used. Another factor posing a threat here is the possibility of network attacks by intruders or hackers. VANETs must meet the security requirement by applying novel protocol solutions with certain characteristics [11]: minimum number of hopes required for communication between nodes, very little overhead due to the sensitivity of time and enhanced information dissemination solutions. Additionally, privacy limitations for exchanged information must be addressed as well. For example, the exchanged data between nodes should not include private information like the driver license number or name of the vehicle's driver. Despite the fact that many efforts and studies has been done to manage security and privacy problems, still there are needs for highly secure communication protocols due the unique nature of heterogeneous vehicular networks.

5.4 Tracking Targets

Tracking a targets is a fundamental functionally in VANET networks since vehicles physical locations defines wireless communications patterns. However, tracking targets are not trivial, there should be some kind of a mechanism that predicts vehicles future physical locations depending on the previous path that these mobile nodes had followed [12]. As mentioned earlier, Privacy problem should be considered in defining a proposed solution.

5.5 Standardization of Protocols

Different types of mobile nodes (cars, tracks, motorbikes, bicycles or others) from different venders are considered in VANETs. Therefore, they all must talk efficiently with each other (exchange wireless information) using a unified language or protocol and a standard effort by government, academia and industry is the only way to make this happen.

5.6 Interaction with Other Networks

Interaction with other nearby wireless networks within range present a whole new area of applications and services to the users. For instance, information about weather conditions, close by restaurants, gas stations, hospitals, police stations and others. This type of information can be provided through interactions with the Internet, other sensor networks or services.

5.7 Variable Density Networks

In rural areas or in a high ways scenario, not so many vehicles are present on the roads, this will lead to a sporadic connectivity. Therefore, there is a need for a protocol to be aware of this irregular connections. However, in urban areas, hundreds of mobile nodes are expected in a small area. The proposed protocol in this case should address this scheme to avoid transmission errors and data packets collisions. Additionally, mobile nodes that travels between the two scenarios stated above should have an adaptive protocol to adapt their behavior depending on the variation of network density to maintain a good data exchange.

5.8 Network Fragmentation

Another problem in rural or light traffic areas is the network fragmentation issue that will pose a challenging task for network designers. Network fragmentation makes some mobile nodes unreachable. This scenario is expected during the first implementation of VANET when only small percent of vehicles will be equipped with transceivers and this will lead to a frequent fragmentation in the network [13].Therefore, traditional protocols that depend on nodes topology information are not suitable for handling this problem in VANETs and new approaches should be studied and presented.

VI. VANET SIMULATION

Traffic simulations make the evaluation of any changes in infrastructure and policy more feasible before applying them in real life. For example, the performance of a traffic light control algorithms or V2I and V2V communications may be examined well before being implemented in streets.

VANET being implemented here using a simulation of urban mobility (SUMO) and Openstreetmap. SUMO is an open traffic simulation suite and free application that exist since 2011. Intermodal traffic systems are being modeled by SUMO like, pedestrians public transport and road vehicles. Many tools can be embedded with SUMO to handle various tasks, for example visualization, route findings and others. It also can be further enhanced with custom models to supply many APIs for managing the simulation remotely. The reason for choosing SUMO as a simulation tool here is because of its many features including online interaction, multimodal traffic simulation, no limitations in number of simulated vehicles or network size, support several formats like Openstreetmap, NavTeq and others. Also SUMO is implemented using C++ and portable libraries only. Openstreet map on the other hand is a web application that provides terrain details like roads, bridges, intersections and others for any area around the globe. This road map is than integrated with SUMO using specific command lines and other tools to help in building up the simulation.

For this simulation the module chosen is of an area in my country IRAQ/Baghdad which illustrates few roads meeting up at an intersection and others converging into a public square to give an idea of V2V communications between vehicles. The Platform used is windows 7 Ultimate 2009 64-bit operating system.

After running the simulation, and focusing on areas when collisions might happen (for example a roundabout or circular intersection) to make sure that ad-hoc wireless communications work properly between mobile nodes. The following can be noticed:

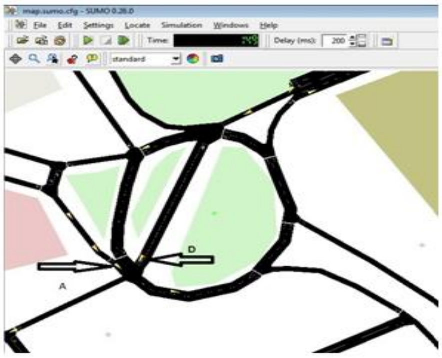

Figure (2) roundabout intersection - at 149 sec

According to "Fig. 2" it's clear that vehicle D is standing by without movement because vehicle A and two other vehicles are occupying the intersection. It can also be noticed that vehicle A had a prior knowledge of vehicle's D position and movement status. Therefore, it continued its movement. So even if there is no LOS between vehicles they still communicate through V2V communication and exchange status information.

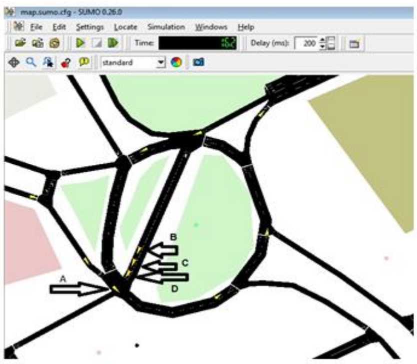

Figure (3) roundabout intersection - at 162 sec.

As shown above in "Fig. 3", vehicles B and C also entered the intersection and behave the same way that vehicle D did again with no line of sight between vehicles.

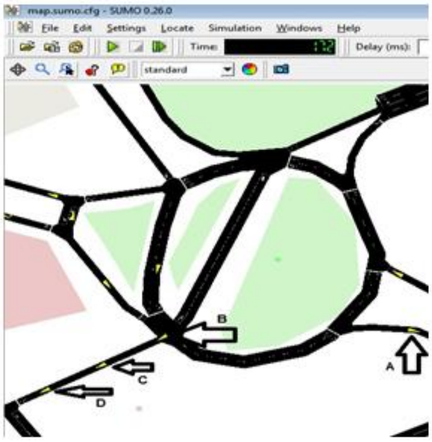

Figure (4) roundabout intersection - at 172 sec

In "Fig. 4", Its now noticeable that all standby vehicles (B, Cand D) moved though the intersection after it was cleared from incoming traffic. Although there was no traffic light in the intersection to control vehicles movement nor a clear line of sight between them, they still obtain each other position and mobility status through vehicle to vehicle communication or V2V. Thus, letting the vehicles drivers to make the right decision at the right time.

VII. CONCLUSION

Perhaps the most significant achievements of ad-hoc networking is VANET. Thousands of vehicles accidents has been recorded every year, around the world. Smart Intelligent Transportation system (SITS) has been an active area of research for many years, as it saves lives, money and time. In this paper, some brief history behind the motive that derived the interest in developing this technology has been discussed. Both V2V and V2I types of communication are used in VANET, specific routing protocols for each wireless network design architecture should be implemented to achieve security, reliability, data rate and maximum possible range. Several VANET applications had been debated in brief discussion along with some future perspectives and challenges that will face the implementation phase of this technology. Finally, a virtual VANET V2V infrastructure illustrating a real time traffic in an urban area had been presented through a simulator to give an idea of one example from the endless applications of this technology that will present a new era of intelligent vehicular traveling system.

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