Thoughts on Vehicular Ad Hoc Networks (VANETs) in the Real World Traffic Scenarios

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Abstract: The real world scenario has changed from the wired network to wireless network. Latest enhancements in wireless technologies are enabling the design and implementation of different types of wireless networks that are being deployed in various environments. The Vehicular Ad hoc Network (VANET) is an emerging new wireless networking concept. It is a promising approach for the Intelligent Transportation System (ITS). VANETs play an important role in providing a high level of safety and convenience to drivers on the road. The rapid growth of vehicles on the roads calls for effective means to improve road safety, efficient transportation, and passengers’ comfort. In the real world, the research community, the vehicles industries and the governments all over the world are investing much of their efforts and money in the development of VANETs. In this paper, we present a significant role of VANET in real world traffic scenarios to secure communication platforms, reasonable coverage of wireless network among vehicles as well as cooperation from drivers themselves.

Keywords: MANET, VANET, DSRC, WAVE, V2V, V2R, Protocols, IEEE 802.11p.

I. INTRODUCTION

With the rapid growth of vehicles on the roads in the recent years, driving becomes more dangerous and challenging. These rapid growth of vehicles in the city with limited road space, careless driving and violation of traffic rules caused large number of traffic accidents. Thousands of people around the any major city die every year because of traffic accidents and many more are injured. Increasing parking demand with limited parking space and unfamiliar with travel related information is an obstruction to the smooth flow of vehicular traffic, especially in crowded and major commercial areas.

To facilitate the safe, secure, clean, efficient, and comfortable mobility of people and goods, advanced communication technologies are required. Road safety is a major factor of vehicular traffic management. To reduce large number of vehicular traffic accidents, improve safety, and manage traffic control system with high and reliable efficiency, computer networking researchers proposed a new wireless networking concept called Vehicular Ad hoc Network (VANET) [1]. Why the academician and researchers are interested in VANETs? The answer is the large set of communication based automotive applications provided by VANET. Our objective in this paper is to explore the basics and deployment of VANET in the real world.

The rest of this paper is organized as follows. In section II, we describe the basics of VANET. Section III presents the specific characteristics of VANET. In section IV, VANET applications are described. Section V describes the standard and protocols used for VANET. Section VI and VII presents the communications between vehicles and road side units and traffic monitoring. In section VIII, need of VANET in the real world introduced. Section IX describes the challenges of VANETs. Finally in section X we conclude this paper.

II. VEHICULAR AD HOC NETWORK (VANET)

Mobile Ad-hoc Networks (MANETs) [2] refer to self-organizing wireless networks consisting of mobile nodes capable to establish communication among them without any fixed infrastructure. Every node in this network acts as router and forwards the message hop by hop. Due to its nature i.e. infrastructure-free environments, MANETs can be deployed in emergency rescue, military, airports, sports stadiums, campus, and disaster management. Due to this broad applications
area of MANETs researchers paying more attentions in the development of such networks.

VANET is a form of MANET, to provide communications among nearby vehicles and between vehicles and nearby fixed roadside equipment. VANETs have the following properties:

- Communication can be Vehicle to Vehicle (V2V) or Vehicle to Roadside unit (V2R).
- Special electronic devices are mounted on each vehicle known as On-Board Unit (OBU).
- Road-Side Unit (RSU) has short range communication capacity by which it communicates with nearby vehicles.
- Both OBU and RSU have computational as well as storage capacity.

VANET [3] is one kind of vehicular communication based on wireless network technology to establish the wireless ad hoc network between vehicles and between vehicles and road side unit (see figure 1).

VANETs are the special class of MANETs that are currently attracting the extensive attention of research in the field of wireless networking as well as automotive industries. VANETs have some similar characteristics to MANETs, e.g. short radio transmission range, low bandwidth, omni-directional broadcast etc. The mobility of nodes in VANETs is very high than MANETs. To establish communication in this network exhibits stronger challenges than MANETs. The topology of these networks dynamically changes over time. It causes frequent network partition and makes communication more difficult. The governments, standardization bodies and automobile industries come forward around the world to focus on the improvement of existing Intelligent Transportation Systems (ITS). The VANETs is an essential part of ITS, its research on the development of vehicular communication system.

VANETs enable suitable, stable and economical distribution of data to benefit the safety and comfort “on the road”. The applications supported by VANETs are congestion detection, road conditions warning, collision alert, stop light assistant, emergency vehicle warning, deceleration warning, toll collection, border clearance, merge assistant etc. Several research projects [6] namely FleetNet–Internet on the Road, NoW (Network on Wheel), SOTIS-Self-Organizing Traffic Information System, PATH, CarTalk, CITranS, DynaMIT, Cartel, Drive-In, Safespot, SeVeCom (Secure Vehicular Communication), VISTA etc. are going on across the globe to provide better driving assistance, resolve difficulties in communications, security, privacy and safety issues of VANETs.

Several major automobile manufacturers have already begun to invest real inter-vehicle networks. Audi, BMW, DaimlerChrysler, Fiat, Renault, and Volkswagen have united to create a non-profit organization called Car2Car Communication Consortium (C2CCC) [7] which is dedicated to the objective of further increasing road traffic safety and efficiency by means of inter-vehicle communications.

III. VANET CHARACTERISTICS

We are discussing some unique characteristics [8] that differentiate VANETs from other networks.

A. Self-Organization

VANET is self-organizing and adaptive network. Thus a network in VANET may formed or deformed...
automatically anywhere at any time. The nodes in the network transmit packets with or without the need of a fixed infrastructure.

B. Highly Dynamic Network Topology
The speed and selection of route defines the dynamic topology of VANET. Roads limit the vehicular network topology to actually one dimension; the road direction. If we assume two vehicles moving away from each other with a speed of 50 km/h (13.88 m/s) and if the packet transmission range is about 200m, then the link between these two vehicles will last for only 7.20 seconds \(\frac{200m}{27.77 \text{ ms}^{-1}}\). This defines the VANET has highly dynamic network topology.

C. Unpredictability
Due to highly node movement and dynamic topology, there is high degree of change in the number and distribution of the nodes in the network at any time instant. Vehicular nodes are usually controlled by pre-built highway, roads and streets. Therefore for the given street map and speed, the future position of the vehicle can be predicted.

D. Infinite Energy Supply
In VANETs vehicular nodes have plenty of energy and computing power, since nodes are vehicles instead of small handheld devices. Thus vehicular nodes can provide continuous power to their computing and communication devices. As a result, routing protocols do not have to account for methodologies that try to prolog the battery life.

E. Vehicle Mobility
The vehicular networks environment is extremely dynamic. On highway relative speed may be more than 250 km/h, while node density may be 1-2 vehicles per km. On the other hand, in the city, relative speed can reach up to 50 km/h and node density can be very high, particularly during rush hour. Since the nodes are highly mobile, the network topology may change rapidly and unpredictably. The vehicles in the network dynamically establish routing among themselves during movement and form their own network on the fly.

IV. VANET APPLICATIONS
VANET has a variety of applications such as life safety, roadside service finder, electronic toll collection, control of traffic flows, nearby information services, etc. Some specific applications \([9, 10]\) of VANETs allow the deployment of VANET is the necessity of human beings.

A. Safety Applications
Safety is the major objective of VANETs. This type of application increases the safety of passengers and drivers by exchanging safety relevant information via V2V communications. In VANET, each vehicle equipped with digital map and electronic sensors through which they can detect sudden changes in path or speed and send appropriate information such as emergency warning, road condition warning, lane changing warning, etc to neighboring vehicles. In advance vehicular communication systems, at intersections the system can decide which vehicle has the right to pass first and alert all the drivers.

B. Comfort Applications
As like safety applications, comfort applications are the most important class of applications in VANETs. This type of applications improves traffic efficiency and optimizes the route to a destination. Traffic information system, weather information, restaurant location, gas station, and price information are the some important comfort applications. Comfort applications may consists some interactive applications like Internet access or music download in the vehicles.

C. Emergency Event Verification
In the real vehicular traffic, roads can be blocked due to congestions and accidents. If we can warn the vehicles coming towards the blocked road, they can avoid that road. So, the vehicles can avoid going blocked road or intersection and any emergency events can be notified in this way.

D. Congestion Detection Verification
A vehicle can detect jamming in the following way. When its speed lowers below a certain level it sends beacon message to its direct neighbors. This beacon message is different from the beacon message generated by intersection devices. If its neighbors’ speeds are also below that level then they also generate beacon message. Each vehicle counts the number of neighbor vehicles around it by counting different
beacon messages. If number of its neighbor is higher than a threshold value, then the road is said to be congested and it will send congestion notification message to the first intersection of the road using vehicles going towards first intersection. After getting the congestion message the first intersection warns all the vehicles approaching to it about the congested road by broadcasting warning message.

<table>
<thead>
<tr>
<th>Applications</th>
<th>Priority</th>
<th>Network Traffic Type</th>
<th>Transmission Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life-Safety</td>
<td>Class 1</td>
<td>Event</td>
<td>300 – 500 m</td>
</tr>
<tr>
<td>Safety Warning</td>
<td>Class 2</td>
<td>Periodic</td>
<td>50 – 300 m</td>
</tr>
<tr>
<td>Traffic Control</td>
<td>Class 2</td>
<td>Event</td>
<td>300 m</td>
</tr>
<tr>
<td>Internet Access</td>
<td>Class 3</td>
<td>Event</td>
<td>300 m</td>
</tr>
<tr>
<td>Group Communication</td>
<td>Class 4</td>
<td>Event</td>
<td>300 m</td>
</tr>
<tr>
<td>Toll Collection</td>
<td>Class 4</td>
<td>Event</td>
<td>20 m</td>
</tr>
<tr>
<td>Weather Information</td>
<td>Class 4</td>
<td>Event</td>
<td>500 m</td>
</tr>
<tr>
<td>Roadside Service Finder</td>
<td>Class 4</td>
<td>Event</td>
<td>300 m</td>
</tr>
</tbody>
</table>

The application of VANET includes the traffic control and exchange of useful information about the road condition, such as traffic collisions and road congestion. VANET applications [11] can be discussed with the priorities of classes, network traffic types, and packet transmission ranges (see Table I).

V. RELATED STANDARD AND PROTOCOLS

In VANETs, the mobile nodes are vehicles, and because of their fast mobility, the main disadvantage of VANET is the network topology changes frequently and very fast. In VANET, there is no issue of resource limitations in terms of data storage and battery power. Global Positioning System (GPS) can be used to provide the exact position of the vehicle in a geographical region.

Medium Access Control (MAC) protocols can be introduced to take power constraints and time synchronization problems less into consideration. In VANET, MAC protocols reduce the medium access delay which is important for safety applications. IEEE 802.11 [12] wireless networking standard is used to provide communications between vehicle to vehicle (V2V) in ad hoc mode and vehicle to roadside unit (V2R) using access point (infrastructure mode). IEEE 802.11, Distributed Coordination Function (DCF) is responsible of the medium access based on Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA), i.e., the node listen to the medium before transmitting to avoid collisions. To access the medium in ad hoc mode for VANET, IEEE 802.11 uses an RTS/CTS/ACK packet exchanges.

![Figure 2: Wireless Access in Vehicular Environment (MAVE) Architecture](image)

Although American Society for Testing and Materials (ASTMs) E2213 standard [13, 14] is being developed, the IEEE P1609.1, P1609.2, P1609.3, and P1609.4 were developed for VANETs. VANET uses several IEEE 802.11 versions such as 802.11a, 802.11b, and 802.11g physical layer standards. These physical
layer standards use the 5 GHz frequency band with maximum throughput of 54 Mbps. IEEE P1609.1 is the standard for Wireless Access in Vehicular Environment (WAVE) based on DSRC. The WAVE uses a modified version of IEEE 802.11a for MAC known as IEEE 802.11p. The IEEE 802.11p MAC/PHY layer standard is specially meant for VANETs which operate in wireless access in vehicular environment (see figure 2).

WAVE uses CSMA/CA as the basic medium access scheme for link sharing. At the PHY layer; IEEE 802.11p should work in the 5.850 – 5.925 GHz spectrum. By using the OFDM system, IEEE 802.11p provides both vehicle to vehicle and vehicle to roadside unit or infrastructure communication over distances up to 1000 meter.

VI. VANET COMMUNICATIONS

Vehicles can communicate to each other on the road in two ways in VANETs.

A. Vehicle to Vehicle (V2V) Communication

V2V communication [10] is the pure ad hoc communication. This type of communication is mainly used in safety applications like safety warning, traffic information, road obstacle warning, intersection collision warning etc. V2V communication (see figure 3) uses both unicast and multi-cast packet forwarding techniques between source and destination vehicles. Unicast forwarding means that a vehicle can only send/receive packet to/from its direct neighbors. While multi-cast forwarding enables the exchange of packet with remote vehicles using the intermediate vehicles as relays.

B. Vehicle to Roadside (V2R) Communication

V2R communication [10] is the combination of both fixed infrastructure and ad hoc mode. Thus V2R communications involve vehicles and roadside base stations. The V2R communication (see figure 4) represents a single hop broadcast where the roadside unit sends a broadcast message to all vehicles in the neighborhood.

VII. VANET TRAFFIC MONITORING

In the near future, a modern vehicular traffic system needs to monitor overall traffic condition of the city, collects useful data and controls overall traffic system. Intersection communicate with central computer server either using direct wireless communication (Wi-Fi) or using its neighbor junctions or intersections as intermediate nodes.

We can monitor the entire traffic by dividing entire highway/ street into distinct road sectors. Therefore if we can determine the road sector a vehicle is currently running then the position of the vehicle in the highway can be easily determined. A vehicle runs on a road sector which is incident to the intersection it has most recently passed away. We can get the id of the intersection that a vehicle most recently crossed by comparing message history between intersection device
and vehicles for all intersections. Central computer server can do this comparison. Again we can approximate the position of a vehicle by analyzing message history of vehicles running towards or opposite direction to that running vehicle.

VIII. VANET IN THE REAL WORLD

The automotive industries are strongly deploying communication based public safety applications that save lives and improve traffic flow. According to World Health Organization (WHO), millions of people around the world die every year because of vehicular traffic accidents and one fourths of all deaths caused by injury. Also about 50 millions of people are injured in vehicular traffic accidents. When we consider different traffic scenarios, there are plenty of vehicles like car, truck, buses, motorcycles etc runs on the road at any given time. Take the metropolitan city Delhi in India for example; Delhi had a population of 9.40 million in 1991 and 12.79 million population in 2001 [15, 16]. It is projected that the population will increase to 19.0 million by 2011 and 23 million in 2021.

Vehicles population in Delhi is large among all metropolitan cities in India. The averages annual growth rates of vehicles in Delhi is about 19.7 and on an average about 500 new vehicles are added in Delhi every day. To analyze the vehicular traffic characteristics of Delhi, the traffic information produced for the Delhi city by the various studies conducted by Central Road Research Institute (CRRI) [17], New Delhi have been utilized. Over the years, there is a major shift from the share of cycles towards fast moving vehicles like two wheelers and cars in the city. According to the CRRI study the traffic loads on the road have been nearly doubled from 2001 to 2009 (see figure 5).

Annually more than one lakh lives are lost on Indian roads due to vehicular traffic accidents. With less than 1% of the world’s vehicle population, India accounts for 6% of world’s road accidents and 10% of world’s road fatalities. With rapid growth in vehicles demand, the road transport demand is increasing very fast and subsequent safety is becoming a major hazard.

Road safety problem in India, which has grown to disaster supports, has created a major public health issue. There is a need of implementing new vehicular technology and implementation of an effective traffic management system to make a breakthrough in such a huge problem.

A number of efforts are currently ongoing to investigate V2V communications for developing Internet facility on the road. However, so far, these efforts have focused more on the protocols and routing algorithms for message transmissions than on the application of the technology as the foundation for a decentralized, real-time transportation system. In today’s market, radio transmitters/receivers are becoming cheaper and smaller. Although they may not meet requirements of such safety-critical applications as collision avoidance and automated driving, they can be used in less critical applications falling under the domain of advanced traveler information systems (ATIS) and management systems (ATMS) [18].

To improve safety, traffic efficiency and provide Internet facility in vehicles, there has been a significant research effort by government, academia and industry to integrate computing and communication technologies into vehicles. It is predicted that VANETs will be deployed over the next decade, to achieve significant market penetration around 2014 [19, 20, 21].

IX. VANET CHALLENGES

Vehicular ad hoc networking refers to the procedures of maintaining a system of wireless communication which enable vehicle users to communicate with each other by transmission paths using exchange of messages. VANET has some major challenges [14] which will pay a major role in the ongoing process of VANET deployment and research.
A. Routing
Routing plays an important role in VANET applications but fast mobility of vehicles and their rapidly changing topology results in conventional ad hoc routing protocols being inadequate to efficiently and effectively deal with this unique characteristics as intermediate nodes cannot always be found between source and destination and end-to-end connectivity cannot always be established. This has encouraged researchers to find scalable routing algorithms that are robust enough for the frequent path distributions caused by vehicle mobility, novel approaches that can deliver improved throughput and better packet delivery ratio.

B. Security
Efficient security support is a main requirement of VANETs. It is important feature to protect communication in VANET from spam and fraud. Some significant VANET security challenges still need to be addressed in the areas of authenticity and driver assistance.

C. Speed and Information Flow
VANET technology should works smoothly without any interruption while driving at high speed. VANET technology enables a smooth flow of information between vehicles.

D. Privacy
Privacy is also a major challenge that will need to be addressed. Secrecy must be preserved - the VANET communications should not make the vehicle tracking. The lack of taking into account the privacy concerns at the early design stage could result in multiple rule suits after the network is deployed. Data protection and privacy are the keys to success of VANET.

E. Safety
The main motives behind VANET were safety on the road, many lives were lost and much more injuries have been incurred due to vehicle crashes. VANET makes driving safer and it will help to reduce accidents.

However, VANETs behave in different ways than conventional MANETs. Driver behaviors, vehicles mobility constraints, and high vehicles speeds create unique characteristics of VANETs. These characteristics have important suggestion for designing decisions in the VANETs. Thus, various challenges need to be addressed for vehicular communications to be widely deployed.

X. CONCLUSION AND FUTURE RESEARCH
The convergence of computing, mobile communications and various kinds of services are enabling the deployment of different kinds of VANET technologies. In the past decade, many VANET research projects around the world have been undertaken and several VANET standards and protocols have been developed to improve VANET communications in different traffic scenarios. VANETs will not only provide safety and life saving applications, but they will become a powerful communication tool for their users. In this paper, we presented a comprehensive analysis of VANET concept and its need in the real world. We hope this analysis will be useful to future VANET researchers for their VANET design goals. Finally, we discussed some of the VANET challenges that still need to be considered to enable the deployment of VANET technologies, infrastructures, and services cost-effectively.

VANETs introduce a new challenging networking environment for academician and researchers. VANET has some research areas of great importance include routing, localization, sensor design, antenna design, OBU specifications, RSU design, V2V and V2R communication network specifications and VANET servers’ requirements and software platform. These systems should cooperate in an efficient manner to reach the ultimate goal of faster, safer and information rich journeys on the road.

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