

Research Issues on Vehicular Ad hoc Network

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Abstract— Vehicular Ad Hoc Network (VANET) is a kind of special wireless ad hoc network, which has the characteristics of high node mobility and fast topology changes. VANET has become an active area of research, standardization, and development because it has tremendous potential to improve vehicle and road safety, traffic efficiency and convenience as well as comfort to both drivers and passengers. Vehicular networks will not only provide safety and lifesaving applications, but they will become a powerful communication tool for their users. This paper presents the aspects related to this field to help researchers and developers to understand and distinguish the main features surrounding VANET.

Keywords— ad hoc network, broadcasting, FCC, mobility, QoS, topology.

I. INTRODUCTION

The growth of the increased number of vehicles are equipped with wireless transceivers to communicate with other vehicles to form a special class of wireless networks, known as vehicular ad hoc networks or VANETs [1]. VANET is a special class of Mobile Ad hoc Network (MANET) to provide communication among nearby vehicles and between vehicles and nearby roadside equipment [2]. As mobile wireless devices and networks become increasingly important, the demand for Vehicle-to-Vehicle (V2V) and Vehicle to-Roadside (V2R) or Vehicle-to-Infrastructure (V2I) communication will continue to grow [3]. It is supposed that each vehicle has a wireless communication equipment to provide ad hoc network connectivity [4]. Such networks comprise of sensors and On Board Units (OBU) installed in the car as well as Road Side Units (RSU) [5]. The data collected from the sensors on the vehicles can be displayed to the driver, sent to the RSU or even broadcasted to other vehicles depending on its nature and importance. VANETs offer the potential for fast and accurate driving information (e.g. traffic, accidents and emissions) that would otherwise be more difficult to disseminate. Possible applications for such networks can be generally classified as safety and non-safety applications [6]. Safety applications include accident avoidance and cooperative driving. Non-safety applications include traffic information, toll service, Internet access, cooperative entertainment, etc.

Different frequencies for VANET were allocated in different parts of the world. In 1999, the Federal Communication Commission (FCC) allocated 75 MHz of spectrum at 5.850-5.925 GHz for Dedicated Short Range

Communication (DSRC) for intelligent transport system (ITS) in North America [5]. It provided short range communications (<30m) and low data rates (500kbps). In Europe, car to car (C2C) communication is located in the band between 5.885-5.905 GHz [7]. It can provide a maximum data rate of 2 Mbps for still nodes and 384 kbps for mobile nodes for the range of 15-20m. In Japan, the bands 5835-5840 and 5845-5850 MHz were allocated for uplink and 5790-5795 and 5800-5805 MHz for downlink for the Association of Radio Industries and Businesses Standard ARIB STD-T55 [5]. It uses ASK modulation for a data rate of 1 Mbps for a maximum of 8 cars within a range of 30m.

VANETs have several properties that distinguish them from other MANETs. Nodes (vehicles) in VANETs are highly mobile, the probability of network partitions is higher, and end-to-end connectivity is not guaranteed [8]. However, although VANETs do have dynamic topologies, they are not completely random. The movement of nodes in a VANET is relatively predictable because it is restricted to the roads on which the vehicles travel. Most of the vehicles provide sufficient computational and power resources, thus eliminating the need for introducing complicated energy-aware algorithms. Vehicles will not be affected by the addition of extra weight for antennas and additional hardware [9]. The advantages and disadvantages of these properties make VANETs a hot research area all over the world, and attract great academic attention.

In this paper, an overview of the technologies and ongoing research areas is provided related to VANETs. The remainder of this article is organized as follows. Section II provides the distinguishing characteristics of VANET. Section III focuses on network layers and architectural model of VANET. In section IV different applications of VANET are discussed. In Section V, open research issues are proposed. Finally, concludes the paper in section VI.

II. VANET CHARACTERISTICS

VANETs have turned into an important research area over the last few years. VANET has its own unique characteristics when compared with other types of MANETs, the unique characteristics of VANET include:

A. Predictable mobility

Unlike MANETs, the network nodes (here vehicles) of VANET move in a predefined way because roads layout are fixed and vehicles have to obey and follow road signs, traffic signals, as well as respond to other moving vehicles [10].

B. High mobility and rapid changing topology

Vehicles move very fast especially on roads and highways. Thus, they remain within each other communication range for a very short time, and links are established and broken fast which results to rapid changes in network topology [7]. Moreover, driver behavior is affected by the necessity to react to the data received from the network, which causes changes in the network topology [10]. The rapid changes in network topology affect the network diameter to be small, while many paths may be disconnected before they can be used.

C. Geographic position available

Vehicles can be equipped with modern, accurate positioning systems integrated by electronic maps. For example, global positioning system (GPS) receivers are very popular in cars which help to provide location information for routing purposes [7].

D. Variable network density

The network density in VANET varies depending on the traffic load, which can be very high in the case of a traffic jam, or very low, as in suburban areas [10].

E. High computational ability

As vehicles are nodes in VANET, they can hold a sufficient number of sensors and enough communication equipment such as high speed processors, large memory size, advanced antenna technology and modern GPS. These resources increase the computational power of the node, which help to create reliable wireless communication and to collect accurate information of node's current position, speed and direction [10].

III. SYSTEM ARCHITECTURE

From the network point of view, the VANET system architecture is divided into five layers: physical layer, MAC layer, network layer, transport layer, and application layer.

A. Physical layer

This involves issues concerning antenna, modulation, spectrum allocation etc.

B. MAC layer

It concentrates on avoiding transmission collision on VANET and to achieve reliable and efficient medium access control (MAC) protocol.

C. Network layer

This relates to wireless multi-hop communication based on geographical addressing and routing. It performs function related to traffic congestion, vehicular movement, data dissemination etc.

D. Transport layer

It involves transportation of data to the intended recipients while satisfying certain requirements such as delay, reliability, and so on.

E. Application layer

This relates different types of safety applications as well as comfort/entertainment applications for vehicle drivers and passengers.

VANET architecture can be divided into different forms based on different perspective. According to [11], as shown in fig. 1, the architecture of VANET falls into three main categories:

A. Inter-vehicle communication

This is also known as vehicle-to-vehicle (V2V) communication or pure ad hoc networking. In this category, the vehicles communicate among each other without infrastructure support. Any valuable information collected from sensors on a vehicle, or communicated to a vehicle, can be directed to neighboring vehicles.

B. Vehicle-to-roadside communication

This is also known as vehicle-to-infrastructure (V2I) communication. In this category, the vehicles can use cellular gateways and wireless local area network access points to connect to the Internet and enable vehicular applications.

C. Inter-roadside communication

This is also known as hybrid vehicles-to-roadside communication (VRC). Vehicles can use infrastructure to communicate with each other and exchange information received from infrastructure or from other vehicles through ad hoc communication. Besides that, vehicles can communicate with infrastructure either in single-hop or multi-hop fashion depending on their location during moving or stationary. This architecture includes V2V communication and provides greater flexibility in content sharing and increases network reliability.

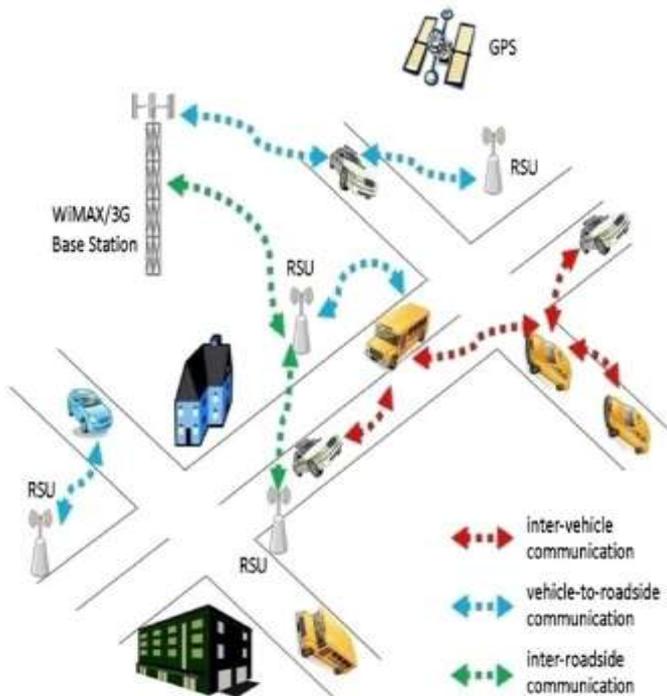


Fig. 1 VANET architecture [11]

According to [12] the communication between vehicles and the RSU and the infrastructure form three types of domains as shown in fig. 2.

A. *In-vehicle domain*

This domain consists of an OBU and one or multiple AUs. An OBU and an AU can reside in a single device. The OBU provides a communication link to the AU in order to execute a set of applications provided by the application provider.

B. *Ad hoc domain*

The ad hoc domain on VANET is composed of vehicles equipped with OBUs and a station along the road side, the RSU. Two types of communications are available in the ad hoc domain: vehicle to vehicle (V2V) communication and Vehicle to RSU communication.

C. *Infrastructural domain*

The RSU can connect to the infrastructural networks or to the Internet, allowing the OBU to access the infrastructure network.

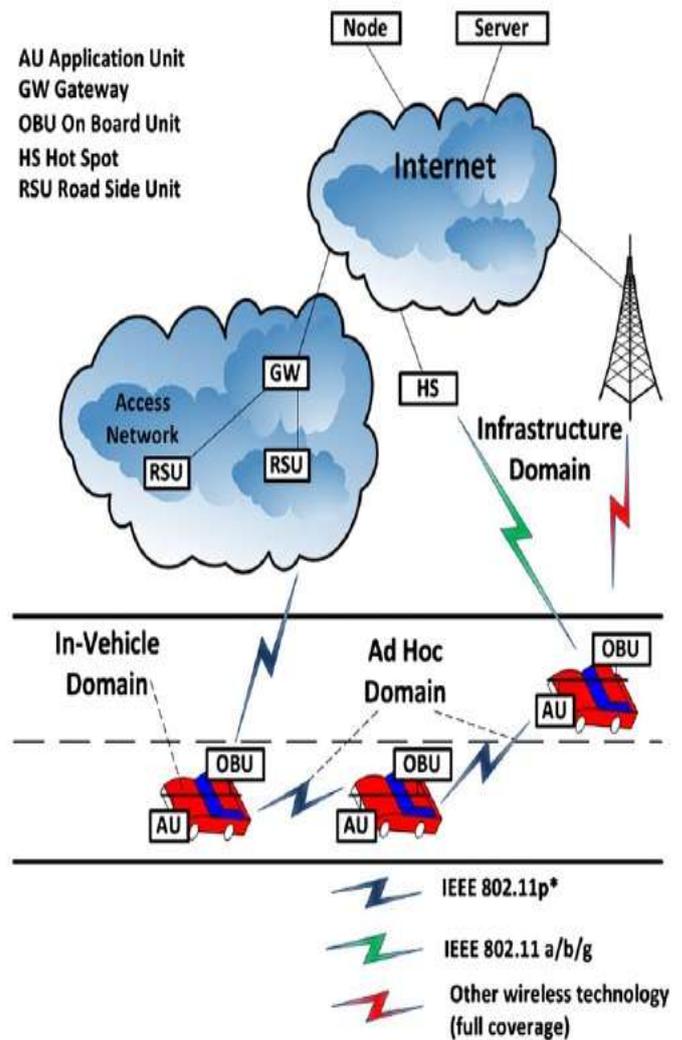


Fig. 2 Communication domains in VANET [12]

The authors in [13] categorized the communication types in VANET into four classes as shown in fig. 3: intra-vehicle communication which refers to the in-vehicle domain; vehicle to vehicle communication (V2V) and vehicle to roadside infrastructure communication (V2I) which are classified as the ad hoc domain and the last type of communications is the vehicle to broadband cloud communication where the vehicle communicate with a monitoring data center, this type conform the infrastructural domain as the classification shown in fig. 2.

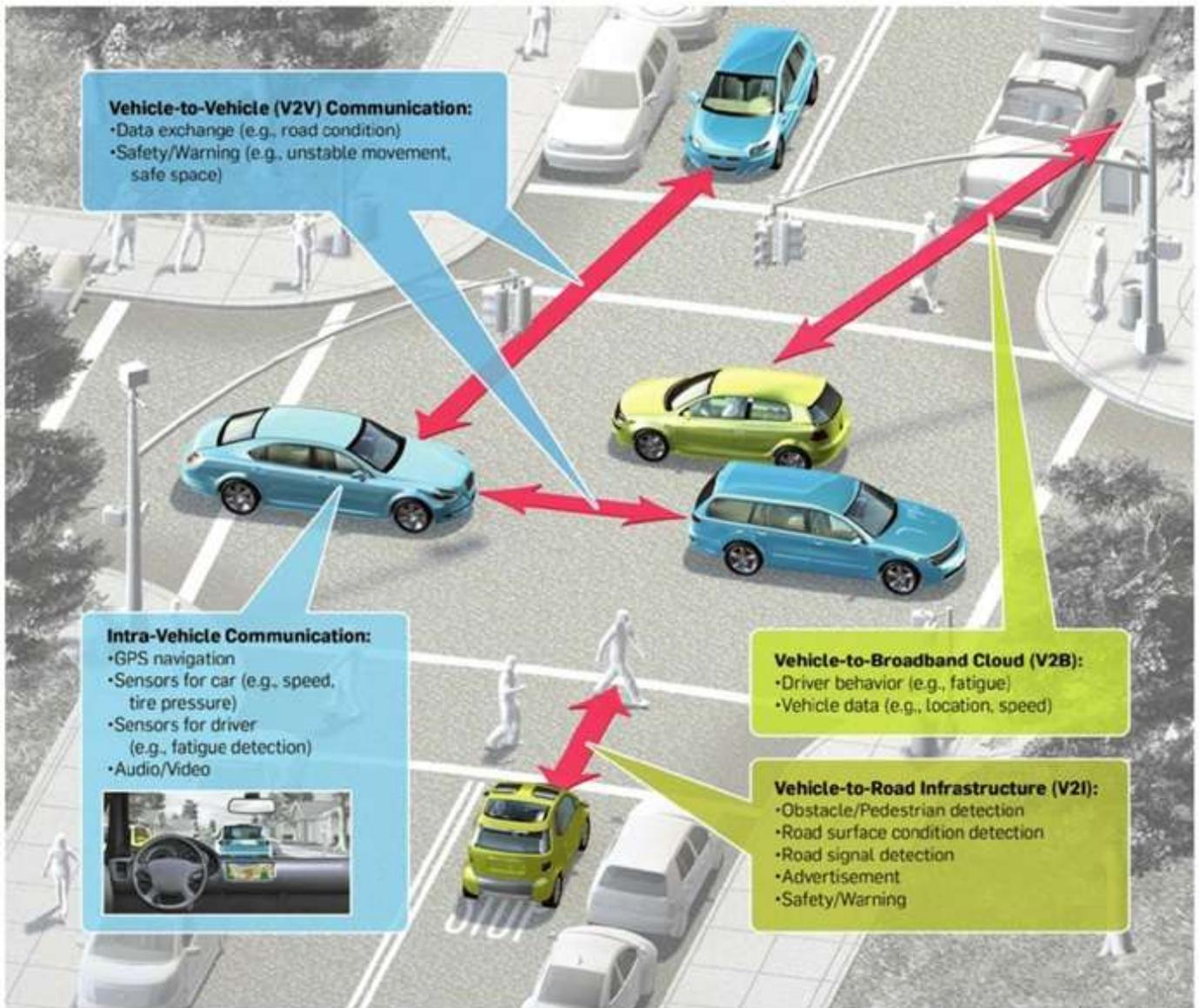


Fig. 3 Communication types in VANET [13]

IV. APPLICATIONS

VANET applications can be divided into two major categories [14]. Applications that increase vehicle safety on the roads are called safety applications. Applications that provide value added services, for example, entertainment, are called user applications.

A. Safety applications

These can decrease significantly the number of road accidents. These applications use the wireless communication between vehicles or between vehicles and infrastructure, in order to improve road safety

and avoid accidents; the intention being to save people's lives and provide a clean environment.

B. User applications

These can provide vehicle users with various information, announcements, and entertainment during their journey. They can provide drivers or passengers with weather and traffic information as well as detail the location of the nearest restaurant, hotel, café, petrol station and their prices. Passengers can play online games, access the internet and send or receive emails, chat with friends and can perform office works while the vehicle is connected to the infrastructure network.

V. OPEN RESEARCH AREAS

VANETs introduce a new challenging environment for developers and communication engineers. There are many different hot topics to be studied by researchers as follows:

A. *Mobility modeling*

Traditional ad hoc networks typically assume limited node mobility, where nodes are usually handheld devices carried by users like laptops, PDAs, smart cellphones, etc. For VANETs, mobility is typical, and it is measured in miles, not meters, per hour [16]. Also, there is a strong relationship among vehicles mobility patterns on the same road as they travel by following the same traffic rules and regulations. Furthermore, since two vehicles remain within their communication range for a matter of seconds, it is an open research issue to develop rich topology model for VANET that will differ from traditional network topologies which require significant interaction between the sender and receiver.

B. *Routing protocols*

Routing plays an important role in VANET applications but the traditional network routing protocols are inappropriate with this unique vehicular environment as the vehicles move in high-speed resulting rapid change in network topology and not to establish end-to-end connectivity between source and destination nodes [15]. This has prompted researchers and developers to establish rich and robust routing algorithms to deal with the VANET environment that will be able to provide high throughput and better packet delivery ratio.

C. *Scalability issues*

One of the main challenges inherent to the deployment of VANETs is operability, both in very light and in highly overloaded networks [7]. It is always expected that VANET must work in very low density areas such as roads and highways, as well as in situations with very high traffic density areas, such as cities, urban areas where traffic jams are high and major intersections exist on road. The number of active nodes (vehicles) and scalable protocol design may be a great issue both for researchers and developers.

D. *Security frameworks*

Vehicular networks rely on distributed untrustworthy nodes which should cooperate with each other and with RSU [5]. Security issues are a major concern in the VANET environment as nodes communicate with each other through wireless communication. Any change in the network information by a fraud node

may cause the great harm for the vehicle drivers and passengers, as well as partition the network and decrease the performance of the whole network. So it can be an essential research issue to develop a robust security solution for the VANET network that will meet the diverse needs of the applications reliably with minimum involvement of untrusted nodes.

E. *Quality of Service (QoS)*

QoS support over VANETs remains a challenge when current routing paths become no longer available as a result of changes in node velocity, node positioning, network topology or distance between vehicular nodes [15]. It may be a challenging issue both for network engineers and researchers to utilize the available bandwidth allocated for VANET to improve delivery of messages as well as to develop adaptive QoS routing protocols that will establish new routes quickly and efficiently.

F. *Broadcasting*

Broadcasting continues to be a strong research area of focus by VANET researchers because a significant number of messages transmitted in VANETs are broadcast messages [15]. Effective and co-operative broadcasting algorithms are of concern for the researchers and developers to circulate safety and routing information both in the low density car areas and in the congested city areas where large number of private cars are plying on.

VI. CONCLUSION

As a result of the substantial advances in the wireless technology, vehicles are becoming a part of the global network. This paper provides an overview dealing with all the issues facing VANET, in particular, VANETs characteristics that distinguish them from other types of ad hoc networks, VANET system architecture focusing on different network layers with various architectural models proposed by different authors, VANET applications both for safety and entertainment purposes and finally some VANET open research areas are discussed that still need to be addressed in order to enable the deployment of VANET technologies, infrastructures, and services cost-effectively, securely, and reliably. There are a number of contributions that produced significant results, but the general feeling is that the subject is not still mature, and that a lot of work remains to be done. It is expected that this paper will help students, developers and researchers to address the challenges involved in VANET.

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