Vehicular Adhoc Network (VANET) - An Introduction

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ABSTRACT

With the rapid advancement in the automotive industry, vehicles are now coming with equipped sensors, on board units and other processing as well communication capabilities. VANET have come into existence because of this advancement and has offered various research dimensions to the industry. VANET considered as a distinct type of Mobile Ad Hoc Networks, holds the opportunity to make people's life and death decisions by predicting and helping the drivers and other people about the road safety and other critical conditions. This paper outlines the VANET definition, its architecture and protocols from a research point of view. Although, VANET are a subset of MANET but they are also the future of Intelligent Transport Systems. Such varied applications areas of VANET and future research directions of VANET are provided in the end of paper.

Keywords: Ad-hoc networks, sensors, things, vehicular ad hoc networks, traffic information system.

SECTION 1: INTRODUCTION

From the last decade, mobile communication techniques have transformed the automotive industry by providing anytime anywhere communication between different devices. This ease of communication allows exchange of valuable information between devices just on the go. The seamless exchange of information on real time bases has turned out to become a new paradigm in the industry. Correspondingly, the advances in the information technology and communication have easily supported the idea of communication between mobile devices [5]. Among these advancements, the concept of Vehicular Ad-hoc NETworks (VANET) came into limelight which has opened new possibilities to avail the use of safety applications. VANET refers to a network created in an ad-hoc manner where different moving vehicles and other connecting devices come in contact over a wireless medium and exchange useful information to one another. A small network is created at the same moment with the vehicles and other devices behaving as nodes in the network. Whatever information the nodes possess is transferred to all other nodes. Similarly all the nodes after transferring their set of data receive the data being transmitted by other nodes. After accumulating all of such data, nodes then work to generate useful information out of the data and then again transmit the information to other devices [2][4]. The communication between devices expands in such as way where nodes are free to join and leave the network i.e. it is an open network. The new vehicles being launched in the market are now coming with equipped on board sensors which make it easy for the vehicle to easily join and merge in the network and leverage the benefits of VANET.

VANET is a variation of MANET (Mobile Ad-hoc NETwork). MANET comprises of nodes which communicate without central network and where nodes are equipped with networking capabilities. VANET on the other side has emerged as a challenging and more liable class or variation of MANET. The freedom of nodes to enter or leave the network in VANET calls for different routing protocols than MANET [3].

This inter vehicle communication leads to passing and receiving of information so as to increase traffic efficiency, detect road conditions, decrease collisions, detect emergency situations and overall increase the

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efficiency of the network. VANET transfers the information to distant devices as well with the help of multi hops [6].

VANET can be characterized by following factors:

- Dynamic topology- The speed and direction of vehicles changes constantly thereby resulting in high dynamic topology
- Intermittent connectivity- Connectivity between devices changes very frequently like connection between two devices exchanging information can disconnect anytime. The reason behind frequent disconnection is high dynamic topology.
- Mobility Patters: A large section of vehicles follow a certain patterns to move which is generally a function of traffic signals, speed limits, highways, streets, road conditions etc. These patterns when observed help in the creation of routing protocols for VANET.
- Unlimited power and storage: It is assumed that the nodes in VANET are capable of possessing an unlimited amount of power as well as storage capacity. Therefore the nodes are free to exchange the data without the foundations of power consumption or storage wastage.
- On board sensors: VANET assumes that the nodes are seldom equipped with on board sensors which are capable of transmission of information to other devices or nodes.

VANET also forms a very important part in Intelligent Transport Systems as insights are produced from the information being exchanged by the vehicles and other devices in the VANET.

The rest of the paper is organized as: Section 2 explains the system and communication architecture for a VANET. Section 3 explains the transmission or broadcasting protocols being used by VANET for communication among various nodes. Section 4 explains the real world applications of VANET. Section 5 outlines the future research directions for VANET and Section 6 concludes the paper.

SECTION 2: ARCHITECTURE

VANET aims to provide communication between different neighboring vehicles. As per the guidelines of IEEE 1471-2000 [10,11] and ISO/IEC 42010 [12], the entities in a VANET can be divided into three domains

1) Mobile domain: Mobile domain comprises of two parts. First is vehicle domain which encompasses all the vehicles which are moving constantly such as buses, cars, trucks etc. Second part is mobile device domain which comprises of all the portable handy devices such as PDAs, laptop, GPS, smartphones etc.
2) Infrastructure domain: It also comprises of two parts. Roadside infrastructure domain comprises of stationary roadside entities such as traffic lights, poles etc. Whereas, central infrastructure domain encompasses the central managing centre such as vehicle management centre, traffic management centre etc.
3) Generic domain: It comprises of Internet infrastructure and Private infrastructure. For instance, different nodes and servers and other computing resources working directly or indirectly for a VANET come under generic domain.

The mobile domain exchanges information and communicates to Infrastructure domain which processes data and does its own modulation. Then in the second step, infrastructure domain in turn communicates to generic domain and exchanges information with it. This data flow among the stationary and mobile resources result in efficient and effective utilization of road by the users.

Another form of VANET architecture is communication architecture where communication types are characterized into 4 sections which are briefed as:

1) In vehicle communication: It detects the inner system data or performance of the vehicle and determines factors such as driver exhaustion or drowsiness etc. Determination of such factors and their extent is crucial for public safety as well as driver safety [1].
2) Vehicle to Vehicle communication (V2V): The data exchange between different vehicles so as to assist the driver by informing them about warnings and other critical information to one another. V2V communication does not rely on fixed infrastructure for data exchange to happen and it helps in dissemination, safety and security applications.
3) Vehicle-to-road infrastructure (V2I) communication: This communication taking place between mobile vehicles and roadside fixed infrastructure in order to gather data. It provides updates related to environmental sensing and monitoring such as real time traffic update or weather update.
4) Vehicle-to-broadband cloud (V2B) communication: This allows communication of vehicles over broadband connections such as 3G/4G. This enhances the driver assistance and vehicle tracking as the broadband cloud may contain more of traffic information and other data.

All the above listed communication types take place in a single or multiple VANETs. The type of communication doesn't matter until and unless performance of VANET doesn't suffers. When vehicles move and an ad-hoc network is established, then information exchange begins. This transmission of information to other vehicles and nodes happen in one of the above listed ways. The vehicle works and leverages the VANET as long as it stays in that particular network.

VANET primarily supports two types of applications one is driver assistance and other is information dissemination. Driver assistance requires exchange of such information which assists the driver to maintain a more secure and efficient environment. Information dissemination focuses on delivering information to everyone such as drivers, nodes, passengers etc. Information dissemination applications range from critical safety applications to entertainment applications [7] [8].

SECTION 3: PROTOCOLS FOR TRANSMISSION

The life of VANET lies in the communication that takes place between different vehicles. The data being gathered and exchanged by the vehicles requires some protocols or rules through which transmission can take place in a systematic and organized way. The data exchange between nodes in a VANET happens via routing protocols. These protocols define how a packet of data will be distributed among different nodes. On the basis of senders and receivers involved, three types of protocols are defined for VANET communication which are briefed as:

1) Unicast: Such protocols aim to deliver or transmit data from one source to one destination over a wireless medium. There are two ways to transmit packets; one is via multi-hop transmission where an information of packet in transmitted further and further via hopping of packet to neighboring vehicle. Second one is carry and forward technique where a packet is carried by the vehicle as long as possible and then transmitted to reduce congestion or rebroadcast of packet. Third is trajectory based where nodes calculate various paths of data transmission and then transmit data by keeping in notice that minimum rebroadcast of packet happen [12].
2) Broadcast: Broadcasting protocols aim to deliver and communicate to as many nodes as possible. In situations like, road blocks, traffic jams, places with high traffic density or emergency situations, broadcasting protocols are a must. They transmit data packet to more than one node at a time. On the counter side, broadcasting protocols also increase the chances of packet rebroadcast or storm problem. Figure 1 shows a list of broadcasting protocols.

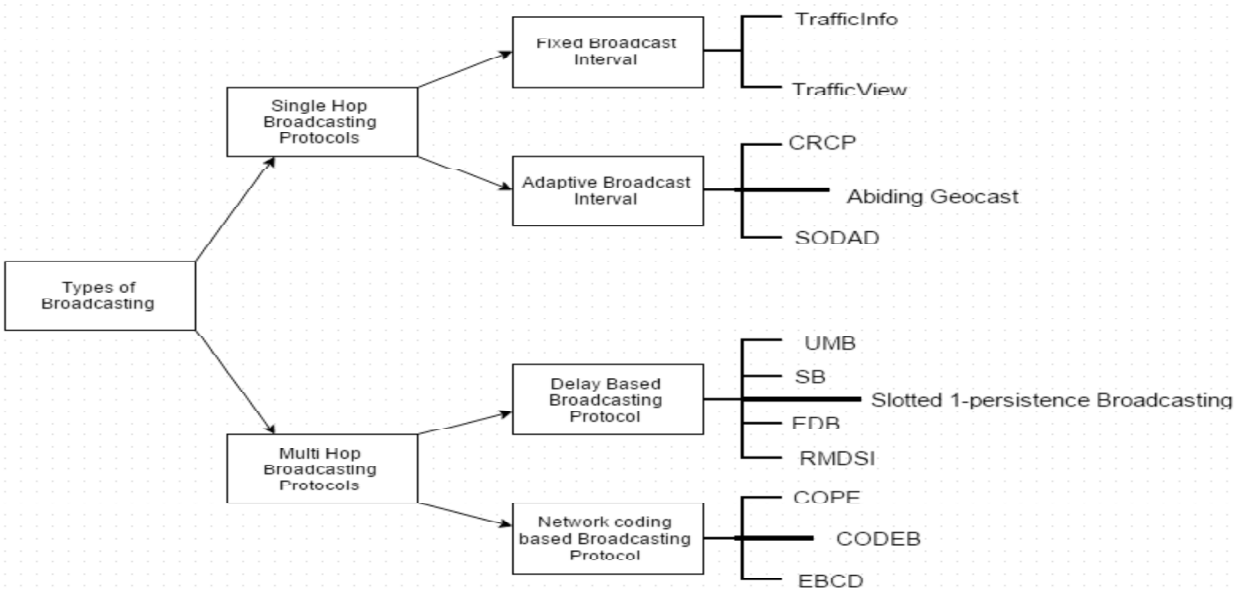

Figure 1: Classification of broadcasting protocols

SECTION 4: APPLICATIONS

The concept of VANET when deployed in real world scenarios provide numerous advantageous applications. As per Vehicle Safety Communications Project [VSCP], 2005, around about 75 applications areas were found out where use of VANET resulted in greater benefit. Some of these application areas are discussed as:

1) Safety Oriented Applications: These applications are developed to increase the safety of road and other users. This area plays a crucial role in saving lives of human beings as majority of accidents and loss of lives takes place because of collisions or lack of safety while driving. Three major applications are explained as:

   - Collision avoidance: in case an accident occurs, a signal is generated and is transmitted to other vehicles via multi hop so that other vehicles stay away from that place and does not create chaos in the emergency area. This information can be in form of vehicle speed, direction, route etc.
   - Cooperative driving: Information such as speed hike or limit, sharp turn, road conditions etc. when shared among various users can result in an optimized journey of vehicles without the fear of any critical situations. Most of the critical situations occur when drivers fail to coordinate among themselves. VANET solves this problem by providing a way of communication to drivers and other users.
   - Traffic optimization: In VANET, data gathering is done by the vehicles. In cases when some critical situations arises, a signal warning the other drivers can be propagated to drivers in distant locations so that they don't arrive at the same place and cause more congestion. By warning vehicles about such situations can result in optimization of traffic and other congestions.

2) Infotainment applications: Such applications facilitate the drivers and other users by providing various messages that aim to offer entertainment related and other information to them such as information regarding nearest car repair station, coffee shop, parking lot etc. It is divided into types of applications:

   - Cooperative applications: Information provided but the local nearby nodes such as interest notification, media downloading etc.

- Global internet applications: Here the data is obtained globally via internet. For example, insurance/ finance services, parking management services etc.

SECTION 5: CHALLENGES AND FUTURE RESEARCH DIRECTIONS

Apart from the advantages one can take from adoption of VANET, there are numerous challenges as well which VANET has to face. These challenges can be viewed as a future research direction or open research issues where advancement and solutions are still required. Some of these challenges which user can take as research issues are:

- Mobility: Ad-hoc networks comprises of mobile devices, PDA, laptops and other devices as nodes which have limited mobility or less mobile nature whereas in VANET the mobility factor of nodes is very high. Vehicles come and lose contact in a matter of seconds as speed is measured in miles per hour. Exchanging information in such a small amount of time and with such highly heterogeneous nodes is an open research issue which calls for development of more advanced and rich network topology model which has to differ from traditional models which require a larger interaction level between sender and receiver [14].
- Data administration and storage: Any number of vehicles and other mobile as well as stationary devices can participate in a VANET. For large scale VANET's, number of nodes participating in a VANET can increase up to millions which will in turn generate a large amount of data. Monitoring, managing and storing such a large amount of data is still a challenge which researchers face. Technologies such as Big Data have scope to solve such problem but still merging of two concepts is a research topic [15].
- Security and privacy: VANET is an open network where any node is allowed to join the network. There is no certain mechanism which can ensure the trustworthy nature of the nodes. Therefore, security becomes a major concern for researchers as communication between nodes happen over a wireless medium where any node can transfer malicious data and may cause significant harm to other nodes. Moreover the identification of such a vehicle is also difficult and calls for better and robust security models to ensure security in VANET. Moreover, untrustworthy nodes can detect the activities, habits and patterns of other users by peeking the VANET and may cause serious threat to privacy of the individual.
- Quality service delivery: The nodes participating in a VANET are very mobile and have very dynamic nature. Factors such as node position, topology, distance between nodes, connectivity etc. vary significantly and thereby the routing strategies and protocols applied become incapable of delivering a good quality of service. Designing, modelling and developing mechanism which ensure a good quality of service throughout the VANET is also an open research issue as well as a challenge which seeks solution.
- Heterogeneity and standardization: The nodes participating in a VANET are highly heterogeneous in nature such as cars, buses, trucks, roadside units, and traffic lights and other nearby computing resources. Such diverse nature of nodes or vehicles have different modes of communications and every node follows its own set of communication mechanisms. Dealing with such high density networks and their varied modes of communication requires standardization of protocols via which nodes can communicate with any node on the go. Moreover, standardization should involve government, industry and their standards, academia and all other institutes as without their cooperation standardization won't help.
- Routing protocols: Traditional routing protocols are not appropriate for a VANET as the nodes participating in a VANET have very high mobility and thus they change the network topology in a

matter of seconds. Moreover establishing a connecting between nodes and exchanging information between source and destination nodes and further propagation of information to other nodes requires the development of robust algorithms and routing protocols so as to deliver higher throughput, better service and enhanced packet delivery ratio.

SECTION 6: CONCLUSION

Invention of vehicular ad-hoc networks constitutes of vehicles, here referred as nodes with the capability to establish wireless communication with other nodes thereby transforming the network into a self-organized shared mesh. This open network of vehicles is referred as VANET which gives numerous applications so as to make the road travel experience more efficient, safer, convincing, effective, easy and pleasant by decreasing traveling time, road congestion, increasing road capacity, avoiding congested areas and emergency situations etc. This paper outlines the basic overview of what a VANET is all about. Further sections elaborate the architecture of VANET from system and communication point of view followed by the types of protocols being used by VANET. Application areas of VANET such as safety, infotainment etc. are explained in the next section from the research point of view. Finally, open research issues as well as challenges which still need addressing are presented followed by conclusion of the paper.

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