Vehicular Ad-Hoc Networks (VANET)

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Abstract— Vehicular ad-hoc networks (VANETs) technology has emerged as an important research area over the last few years. Being ad-hoc in nature, VA NET is a type of networks that is created from the concept of establishing a network of cars for a specific need or situation. Vehicular ad hoc networks (VANETs) are an important communication paradigm in modern-day mobile computing for exchanging live messages regarding traffic congestion, weather conditions, road conditions, and targeted location-based advertisements to improve the driving comfort. Along with the benefits, there arise a large number of challenges in VANET such as provisioning of QoS, high connectivity and bandwidth and security to vehicle and individual privacy. This article presents Network architecture, signal modeling and, routing protocols and network security and, a comparative test of various mobility scenarios of Vehicular Ad-hoc Network in three well-known Indian Metros. The AODV routing protocol have been used for the simulation.

Keywords: VANETS, Modeling, Routing, Security, NCTUns6.0 network simulator, Performance, Throughput

I. Introduction

Although Vehicular Ad-hoc Network (VANET) is not a new topic, it continues to provide new research challenges and problems. The main objective of VANET is to help a group of vehicles to set up and maintain a communication network among them without using any central base station or any controller. The goal of VANET research is to develop a vehicular communication system to enable quick and cost efficient distribution of data for the benefit of passengers' safety and comfort. Vehicular ad-hoc networks are responsible for the communication between moving vehicles in a certain environment. A vehicle can communicate with another vehicle directly which is called Vehicle to Vehicle (V2V) communication, or a vehicle can communicate to an infrastructure such as a Road Side Unit (RSU), known as Vehicle-to-Infrastructure (V2I). Figure 1 shows a typical VANET scenario. A detailed study of network architecture with different topologies and network modeling is presented in this paper. A key design area in VA NET in order to properly form a communication network is routing the packets in effective manner. The paper discusses different routing algorithms for VANET and presents limitations of those algorithms. Security issues in VA NET environment are also addressed in the paper so that trustworthy network architecture can be modelled.

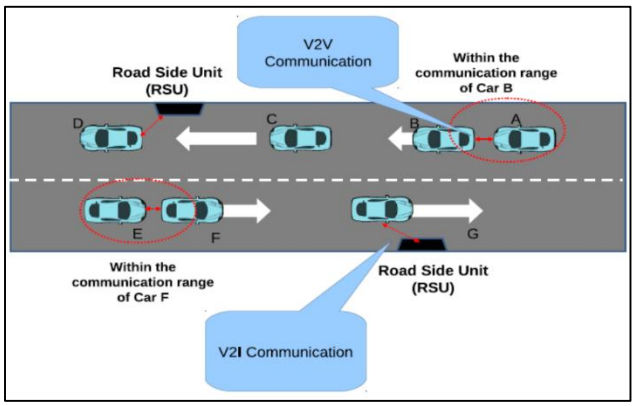

Fig. 1: An Illustrative Network Architecture of a VANET

II. Architecture and Network Modeling

In principal, there is no fixed architecture or topology that a VA NET must follow. However, a general VANET consists of moving vehicles communicating with each other as well as with some nearby RSU. A VA NET is different than a MANET in the sense that vehicles do not move randomly as nodes do in MANETs, rather moving vehicles follow some fixed paths such as urban roads and highways. While it is easy to consider VANETs as a part of MANETs, it is also important to think of VA NETs as an individual research field, especially when it comes to designing of network architecture. In VANET architecture, an on board unit (OBU) in a vehicle consists of wireless transmitter and receiver.

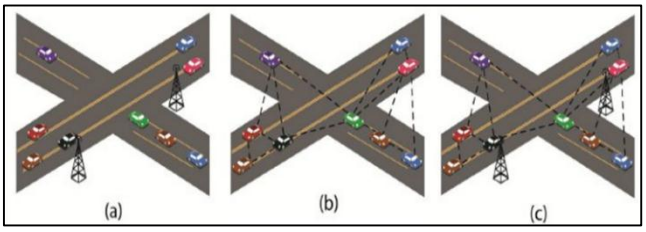

Fig. 2: Network Architecture in VANET

Understanding of network architecture is important in order to realize the full potential of vehicular communication. Most of the researchers[42, 43] have based their studies by dividing VANET scenarios in three categories namely Urban Rural and Freeway/Highway.

One of the reasons to investigate in such a manner is to make sure that it will eventually cover the need of inter-networking for entire vehicular environment. Each environment has its own specific challenges to overcome. For example, in a sparse network like highways, the low den- sity of vehicles remains the prime issue. Even in some urban environments, low penetration ratio and low traffic at night times can cause long network delays.

Generally, a mobility model can be classified at micro and macro levels depending on the nature of details required in modeling. The consideration for roads,

buildings and streets are classified as macroscopic whereas the behaviour of vehicles is treated as microscopic level[9]. In general, the mobility models in VANET can be categorised in three categories such as: a) Stochastic or Random Modeling, b) Traffic or Flow based Modeling, and c) Trace based Modeling[44].

III. Routing in VANET

One of the major challenges in the design of vehicular ad-hoc network is the development of a dynamic routing protocol that can help disseminate the information from one node (vehicle) to another. Routing in VA NET is different to the traditional MANET routing because of highly dynamic and ever changing topologies in the former. Few protocols that were earlier designed for MANET environment have been tested on VANET. The challenge however remains as how to reduce delay associated with passing the information from one node to another. Overcoming these hurdles in MANET protocols, can help implement real time appli- cations for VANET environment. Other implications such as reducing control overheads also need to be looked into carefully. Keeping an eye on the dynamic characteristics of VA NET (as highlighted previously), the routing protocol should be able to withstand the unpredicted and dynamic nature of vehicular network topology. Perhaps the most difficult task in VA NET routing is finding and maintaining the optimal paths of communication in desired environments. As highlighted in Figure 3, routing in VANET can be classified into five major categories namely as:

- Ad-hoc or Topology Driven Protocols
- Location Based Routing Protocols
- Cluster Based Protocol
- Broadcast Protocols
- Geocast Protocols

IV. Ad-hoc or Topology Driven Routing

Topology driven protocols are sub-classified into three categories such as proactive, reactive and hybrid. A number of such protocols were designed to cater the needs of VANET environment[18],[21],[19],[20],[21]. In a proactive protocol, nodes continuously update their routing table with information regarding new routes within the network. This information is passed around to all nodes by sending periodic HELLO packets. This approach, however, creates substantial This approach, creates substantial control overheads.

On the other hand, in reactive approaches, for example AODV[87], DSR[21], BRP[19] nodes will only send the control data when there is a need. This reduces overheads associated with establishing the link, and helps distribute the actual information faster. This approach however still puts undue resource overheads like maintenance of used/unused routes. These unused paths are created and broken, due to stringent network topology of VA NET. Overheads created in reactive protocols are associated with discovering the path to send the information. The path finding process is initiated by sending certain type of message called Route Request Message (RREQ).

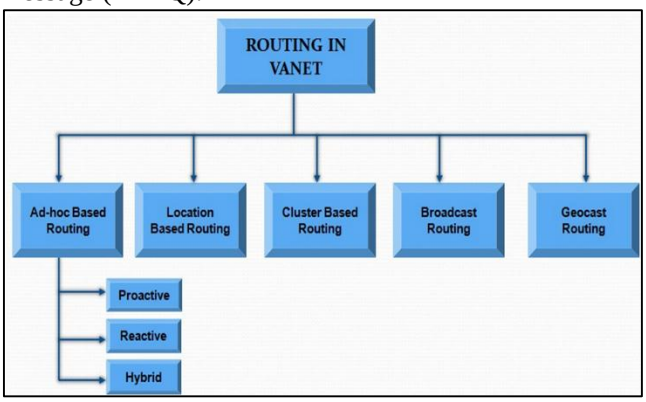

Fig. 3: Routing Types in VANET

V. Location Based Routing

Another category of protocols that have shown interest among the researchers are Location or Position Based Routing protocols. In this scheme of protocols information regarding geographic location of vehicles is obtained from different sources like maps, Global Positioning System (GPRS) or even traces of traffic models to help disseminate the information. Quite a few researches like[23] and[24] have presented a thorough comparison of well-known topology based protocols like AODV and DSR in con- junction with Position Based algorithm and the results have shown better and improved performance as compared to using plain topological approach. In applications where delay and Packet Delivery Ratio (PDR) have stringent requirements mostly in urban environment, GPSR in its original form cannot be used. To cater this problem,[39] presented a modified version of GPSR called Advanced Greedy Forwarding (GPSR-A GF). In this version, information about speed and direction of the destination node are included within the HELLO packets. This showed an improvement in relation to the above mentioned performance metrics.

Another important location based routing approach was presented in[12],[13] namely Location Assisted Routing (LAR). LAR is classified as a reactive protocol which uses location information of nodes to decrease the routing overheads that were underlined by other reactive protocols such as AODV and DSR. LAR mainly employs two methods to determine the next hop, one based on window size and other with distance variation.

VI. Cluster Based Routing

In order to reduce the network traffic and routing overheads in VANET, a routing paradigm namely Cluster Based Routing (CBR) is introduced in[28],[29],[30],[31]. The main idea behind CBR is to create a network architecture based on small groups of vehicles called as clusters. In a cluster, one of the vehicles plays the role of a cluster-head as shown in Figure 4. The size of the cluster depends on the design of the routing algorithm which may be based on the number of vehicles in a cluster or the geographical position of the vehicles.

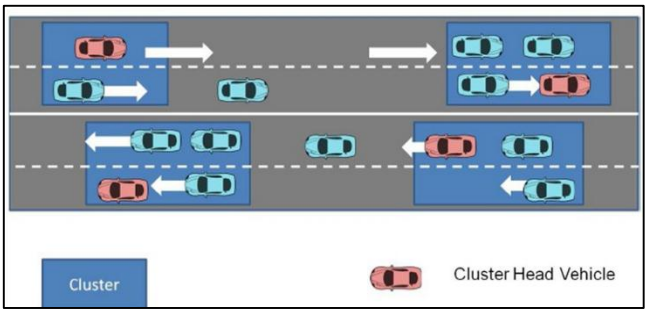

Fig. 4: Cluster Based Routing

In[31] authors have presented another cluster based routing scheme with the main objective of achieving better results for network topology stability as well as decreasing the dynamic nature of VANET. The routing algorithm considers the speed differences among the vehicles in addition to the geographical location and destination of the vehicles. The performance of proposed threshold based algorithm is compared with other position based and weight based algorithm in terms of the change of average number of clusters. It is shown that the average cluster change per vehicle with the proposed algorithm is much smaller compared to other routing protocols. This concludes the less dynamic nature of the algorithm.

VII. Broadcast Routing

Broadcast Routing was one of the traditional routing techniques used in VA NET. Primarily broadcast approach is used when the message is needed to be sent to the vehicle that is outside the range. Packets are transmitted using flooding techniques. This ensures delivery of information, but uses extensive resources of bandwidth. As briefed previously, this sort of technique is utilised in many well established routing protocols, especially in the stage of discovering of route to the destination. BROADCOMM[32] and the Nth-Powered P-persistent Broadcast protocol (NPPB) are such well known protocols designed using the broadcasting concept. In BROADCOMM, a hierarchical structure of highway is simulated and the whole region is divided into virtual cells. Cell members establish a hierarchy of Cell Reflector (CR), which acts like a base station to gather messages for particular call as well as from neighbouring cells. The performance of this protocol depends on a reasonable choice of the number of nodes in the environment.

VIII. Geocast Routing

Geocast routing is the classification of routing that deals with dissemination of information in specific area of relevance. Since the early induction of VANET, quite a few approaches of Geocast routing were presented [10], [11],[12],[13],[14],[15],[16]. Many VANET applications require position dependent multi casting e.g. disseminating hazardous traffic information to vehicles approaching in the same direction. The key idea behind the Geocast routing is to narrow down the search for next hop to a specific Zone of Relevance (ZOR). Imagine the possibility of having a mechanism in which if a car gets involved in an accident, it will automatically report the accident to the approaching vehicles within that zone.

In order to localize the search space by using node positions and map information, there are few techniques which are based on this idea. In[16], authors have presented a context based routing protocol, VCARP, which uses vehicles information such as destination, location and packet cache state to make optimal routing decision. The packet retransmissions are avoided by storing them temporarily in a cache. Simulations studies have shown that VCARP achieves better PDR and reduces the routing overheads in VA NET scenarios. Another vehicle assisted routing protocol for VANET is presented in[34] and is called Vehicle Assisted Data Delivery in Vehicu lar Ad-hoc Network (VADD). In this protocol authors adopted the concept of carry and forward. Four different variants of VA DD are presented and their performance is compared with each other. It is shown that the proposed VADD protocols have better performance in terms of PDR, Average End to End delay and routing overheads compared to other existing protocols. Among the different variants of VADD, the H-VADD out performs the other three.

IX. Security in VANET

Security in VA NET should be considered as important as securing other networks in computing. As per basic computer and network security definitions [37], attacks on a computer network can be classified in three main groups of threats; threats associated with Authenticity, Confidentiality and Availability of the resource. If one applies this model of security on vehicular network, the one threat that really stands out is the Confidentiality of the source.

For example, an attacker who is busy in analysing which certificates are attached to each message distributed in the system, might also be able to track the exact location of the vehicle (compromise of privacy). Currently a broadcast authentication scheme is utilised in current standards of security for VA NET such as IEEE 1609.2. This scheme is based on the use of a public key signature. Broadcast authentication enables the receivers to verify that received information was really sent by the claimed sender. In order to protect the privacy of the node, few approaches have been adopted[38],395]. In VANET security, the attack threats can be classified into different categories. In[40], authors have described three key types of attacks:

- Bogus Information:- An inside attacker can make bogus safety messages to be distributed in the entire network. This can cause disastrous situations (a threat to Authenticity).
- ID Disclosure:- Location information in relation to vehicle's e xact position (privacy) needs to be protected (a threat to Confidentiality).
- Denial of Service:- Attackers can potentially flood the entire network so that no one will be able to use the applica- tions/services. Such circumstances can create catastrophic situations if triggered instantaneously (a threat to Availability).

X. NCTUNS-6.0 SIMULATOR

To complete out the experiment discussed in this paper NCTUns-6.0 simulation tool is used. The scenarios used for analysis, simulation setup, performance metrics used for making various comparisons are discussed in this section. The hybrid simulator used is NCTUns-6.0(National Chiao Tung University Network Simulator) whose core technology is based on the novel kernel re-entering methodology invented by Prof. S.Y. Wang [9]. The wide range of various features of VANET supported by NCTUns-6.0 makes it an obvious choice for this study. The first step for simulation setup is to create Vehicular Ad Hoc Network. We designed two different networks for evaluation of routing protocols. Network is created by using blank project workspace that is provided by NCTUns6.0 network simulator.

In Figure 5 the step we designed roads networks and select the total number of nodes. First we designed the roads by selecting the appropriate icons for road design that is provided by NCTUns6.0 network simulator. Roads are designed according to real situation for the movement of vehicular nodes.

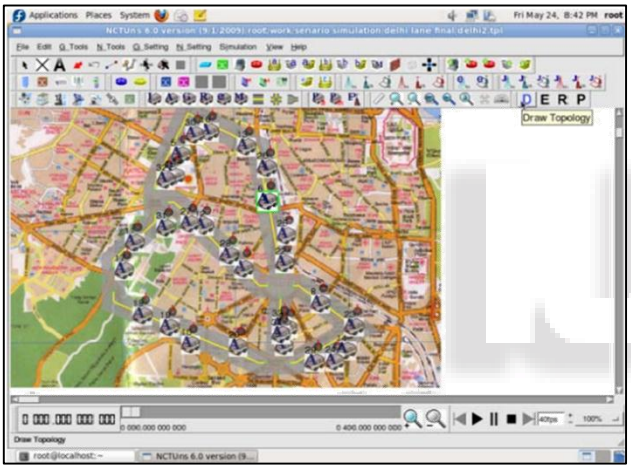

Fig. 5: Delhi scenario on simulator

XI. PERFORMANCE

Different performance metrics are used to check the performance of routing protocols in various network environments. In our study we have selected throughput and packet drop to check the performance of VANET routing protocols against each other. The reason for the selection of these performance metrics is to check the performance of routing protocols in highly mobile environment of VANET. Moreover, these performance metrics are used to check the effectiveness of VANET routing protocols i.e. how well the protocol deliver packets and how well the algorithm for a routing protocol performs in order to discover the route towards destination. The selected metrics for routing protocols evaluation are as follows[6][9].

XII. THROUGHPUT

Throughput is the average number of successfully delivered data packets on a communication network or network node. In other words throughput describes as the total number of received packets at the destination out of total transmitted packets [6]. Throughput is calculated in bytes/sec or data packets per second. The simulation result for throughput in NCTUns6.0 shows the total received packets at destination in KB/Sec, mathematically throughput is shown as follows:-

$$(\text{bytes/sec}) = \frac{\text{Total number of received packets at destination} * \text{packet size Throughput}}{\text{Total simulation time}} \text{kb/sec}$$

XIII. CONCLUSIONS

This paper presented an overview and tutorial of various issues in VANET. We try to simulate other routing protocols (ADV, DSR, ADV) to study the mobility VANET scenarios in various metros to have a comparative picture for them. A comparative analysis of different routing algorithms in the field of VANET has been presented. It also highlighted the main issues in routing algorithms. The performance metrics for routing algorithms, discussed in this paper, were PDR with respect to average velocity of vehicles, node density and system throughput. Finally, main research challenges and areas of interest in vehicular communication were discussed.

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