Chapter 1
Introduction to QoS issues in vehicular Ad hoc networks

1.1 INTRODUCTION

Vehicular Ad hoc networks (VANETs) are self organizing networks and self manageable where the data or information can be organized in a distributed fashion without any centralized authority (a predefined infrastructure) using 802.11-based WLAN technology. VANET can be assumed as an integration of multiple wireless / mobile networking technologies such as Wi-Fi IEEE 802.11, WiMAX 802.16, Bluetooth, IRA, and ZigBee for providing an effective communication between vehicles on dynamic mobility.

VANET helps to incorporate safety measures in vehicles as well supports streaming services such as infotainment and telematics between vehicles. Dedicated Short Range Communication standard (Abdalla, Abu-Rgheff, & Senouci, 2007) defines gateways as fixed or minimal in mobility on the road sides to provide interim connectivity to vehicles. Hence the vehicles and Road side Units (RSU) form a vehicular Ad hoc network (VANET). VANET have recently received considerable attention in the field of automotive sector (Festag et al., 2008; Reichardt, Miglietta, Moretti, Morsink, & Schulz, 2002) and different industry groups (Consortium & others, 2007).

High speed vehicles with varying mobility constraints on a highway and drivers behavior are few factors due to which VANET’s possess different characteristics from the typical Ad hoc network models. Major characteristics include varying rapid topology, consistent updates in network links, minimal effective network diameter, unlimited battery power, storage maintenance and functional redundancy (Std, 2003).

Extensive researches had been carried out to implement QoS support for an on demand multi service routing algorithms over VANET. Reliability and on time delivery of information are considered to be the most important concern in VANET. The challenge faced by the researchers in VANET is to provide QoS for a specific time period which should be achieved with dynamically changing number of nodes.
Particularly this research work addresses on the necessity and importance of providing optimal QoS in VANET precisely on multimedia applications.

1.2 SYSTEM BACKGROUND

1.2.1 AD HOC NETWORK

An Ad hoc network by (Abdalla et al., 2007) is a collection of wireless mobile hosts or terminals forming a distributed reconfigurable network topology. They can operate without the help of any fixed infrastructure or centralized control and can be rapidly deployed and reconfigured.

Ad hoc networking (Futernik, Haimovich, & Papavassiliou, 2003) is a networking paradigm for mobile, self-organizing networks. In these networks, every node functions as a router as well as an application node and forwards packets on behalf of other nodes. Ad hoc networks have the ability to form “on the fly” and dynamically handle joining or leaving of nodes in the network.

General characteristics

[a] Dynamic network topology

The network nodes are mobile and hence the topology of the network may change frequently. Nodes may move around within the network but the network can also be partitioned into multiple smaller networks or be merged with other networks.

[b] Limited Bandwidth

The use of wireless communication typically implies a lower bandwidth than that of a traditional network. This may limit the number and size of the messages sent during protocol execution.

[c] Energy constrained nodes

Nodes in Ad hoc networks will often rely on batteries as their power source.

[d] Limited physical security

The use of wireless communication and the exposure of the network nodes increase the possibility of attacks against the network. Due to the mobility of the
nodes, the risk of them being physically compromised by theft, loss or other means will probably be bigger than traditional network nodes.

1.2.2 MANET

Mobile Ad hoc Networks (MANET) (Artimy, Robertson, & Phillips, 2005) are formed dynamically by an autonomous system of mobile nodes that are connected via wireless links without using an existing infrastructure or centralized administration as shown in Figure 1.1. (Kang, Kaur, & Singh, 2013) describes mobile nodes are free to move randomly and organize themselves arbitrarily; thus the network’s wireless topology may change rapidly and unpredictably.

A MANET is expected to be in larger size than the radio range of the wireless antennas. Because of this fact, it is mandatory to route the traffic through a multi-hop path and to give two nodes the ability to communicate. There are neither fixed routers nor fixed locations for the routers as in cellular networks that is also known as infrastructure networks.

MANETs are infrastructure-less networks which do not require any fixed infrastructure such as a base station for their operation. In general, routes between nodes in an Ad hoc network may include multiple hops and, hence, it is appropriate to call such networks, as “multi-hop wireless Ad hoc networks”.

General Characteristics

a) Dynamic Topology
b) Bandwidth and Energy Constraints
c) Minimal Infrastructure
d) Uncontrolled Mobility
e) Limited processing and storage capacity

Figure 1.1 MANET
1.2.3 VANET

Vehicular Ad hoc Networks (VANETs) (Gnanamurthy, Thangavelu, Kandasamy, & Sankaranarayanan, 2006), an outgrowth of traditional Mobile Ad hoc Networks (MANETs), provides the basic network communication framework for application to an Intelligent Transportation System (ITS). A vehicular Ad hoc network (VANET) (Kalivaradhan & Thangavelu, 2010) is a phenomenon of mobile Ad hoc networks, where vehicles and road infrastructures are equipped with wireless devices. Accordingly, the vehicles are able to communicate with each other as well as interacting with the road infrastructure as shown in Figure 1.2. One straightforward application of VANETs is safety, where communications are exchanged in order to improve the driver's responsiveness and safety in case of road incidents.

General Characteristics

- Highly dynamic mobility
- Vehicle density
- Driver behavior
- Mobility on controlled paths

1.3 VANET STANDARDS

1.3.1 DEDICATED SHORT RANGE COMMUNICATION (DSRC)

5.9 GHz (Std, 2003) is a short to medium range communication service that supports both Public Safety and Private operations in roadside to vehicle and vehicle to vehicle communication environments. DSRC is meant to be a complement to cellular communications by providing very high data transfer rates in circumstances where minimizing latency in the communication link and isolating relatively small communication zones are important.

The 5.9 GHz DSRC link uses digital radio techniques (Karagiannis et al., 2011) to transfer data over short distances between roadside and vehicles, vehicles themselves and between portable devices and vehicles. This link enables operations related to the improvement of traffic flow, highway safety, and other ITS applications.
in a variety of application environments called DSRC/WAVE (Wireless Access in a Vehicular Environment).

The aim of this standard is to provide wireless communications capabilities for transportation applications within a 1000m range at typical highway speeds. It provides seven channels at the 5.9 GHz licensed band for ITS applications, with different channels designated for different applications, including one specifically reserved for vehicle-to-vehicle communications. The ITS safety applications that could leverage the new DSRC standard include any system that can be enhanced by allowing information to flow between vehicles and between vehicles and roadside infrastructure. Examples of such applications include en-route driver information propagation, collision warning and avoidance systems, and adaptive cruise control systems. By the year 2003, American Society for Testing and Materials (ASTM) and Institute of Electrical and Electronics Engineers (IEEE) adopted the DSRC and it was further standardized by the IEEE 802.11p Task Group (TGp).

1.3.2 IEEE 802.11 p

The Federal Communications Commission (FCC) petition for 5.9 GHz was launched in 1999 and the standardization work started in the ASTM group E17.51 based on IEEE 802.11a as shown in Fig. 1.3. In year 2002, the ASTM E2213-02 standard was approved and accepted as the basis for 5.9 GHz American Intelligent transport systems) ITS. The standard was reissued as ASTM 2213-03 in September 2003. The further standardization was transferred to the IEEE 802.11 working group. In September 2003 the Study Group (SG) for Wireless Access in Vehicular Environment (WAVE) met for the first time. In September 2004 the Research work authorization request (RAR) was approved and the WAVE SG became Task Group (TG) “p”. The TG completed the initial draft 1.0 in February 2006.
1.4 MANET vs VANET

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Property</th>
<th>MANET</th>
<th>VANET</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IEEE Standard</td>
<td>IEEE 802.11 a / b / g</td>
<td>IEEE 802.11 p</td>
</tr>
<tr>
<td>2</td>
<td>Speed of Nodes</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>3</td>
<td>Mobility</td>
<td>Random</td>
<td>Structured</td>
</tr>
<tr>
<td>4</td>
<td>Power Constrain</td>
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<td>No</td>
</tr>
<tr>
<td>5</td>
<td>Tracking facility</td>
<td>Possible – static</td>
<td>Possible – dynamic</td>
</tr>
<tr>
<td>6</td>
<td>Node Density</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>7</td>
<td>Route Disconnectivity</td>
<td>Less</td>
<td>Frequent</td>
</tr>
<tr>
<td>8</td>
<td>Transmission range</td>
<td>Short</td>
<td>Long (1000 m)</td>
</tr>
<tr>
<td>9</td>
<td>Storage capacity</td>
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<td>Not an issue</td>
</tr>
<tr>
<td>10</td>
<td>Processing capability</td>
<td>Moderate</td>
<td>Not an issue</td>
</tr>
</tbody>
</table>

Table 1.1 Comparisons of MANET and VANET

Data exchange on the roads become more and more interesting, as the number of vehicles equipped with computing technologies and wireless communication devices is poised to increase dramatically. Communications between vehicles and within the same vehicle (inter-vehicle) is becoming a promising field of research and we are moving closer to the vision of intelligent transportation systems (ITS), which can enable a wide range of applications, such as collision avoidance, emergency message dissemination, dynamic route scheduling, real-time traffic condition monitoring and any kind of "infotainment" information spreading (i.e. movies, gaming and advertisement). However, it is extremely important to consider several aspects when approaching any kind of data transfer in a VANET because, nodes can move unlike it is not fixed. Furthermore, in this scenario, other complications can easily arise because, in a mobile Ad hoc network (MANET) the node can freely move...
in a certain area, where as in VANET’s, vehicles movements are constrained by streets, traffic and specific rules. The comparison of MANET and VANET is shown in Table 1.1.

In the recent decade, control systems for the automotive industry have moved from analog to digital domain. Networked Electronic Control Units (ECUs) are increasingly being deployed in automobiles (H. Guo & Global, 2009) to realize diverse functions such as engine management, air-bag deployment, and even in intelligent brake systems and at the same time, emerging vehicular networks in the forms of Intra-Vehicle (in-vehicular networking), Vehicle-to-Vehicle (V2V), and Vehicle-to-Infrastructure (V2I) communications are fast becoming a reality and will enable a variety of applications for safety, traffic efficiency, driver assistance, as well as infotainment to be incorporated into modern automobile designs.

With the increase in vehicular networks in commonplace, critical data is being exchanged with inside and outside vehicle through vehicular networks, and new technologies have been developed for vehicular networks. This chapter is meant to introduce the basic concepts behind the unindustrialized areas of vehicular networks and data exchange such as, Ad-Hoc networks, mobility issues and Mobile Ad-Hoc Networks (MANETs). At the same time, to provide an overview of the new technologies and standards for car communication systems.

Following are few issues by which VANET are affected

[a] High mobility

The environment in which vehicular networks operate is extremely dynamic, and includes extreme configurations. In highways, a relative speed of 300 km/h may occur, while density of nodes may be 1-2 vehicles per kilometer in less busy roads. Because of the relative movement of the vehicles, the connectivity among nodes could last only few seconds, and fail in unpredictable ways.

[b] Partitioned networks

Vehicular Ad hoc networks are being frequently partitioned due to the dynamic nature of traffic which may result in large inter-vehicle gaps in sparsely populated scenarios, and in several isolated clusters of nodes. The degree to which the
network is connected depends highly on two factors, such as the range of wireless links and the fraction of participant vehicles, as only a fraction of vehicles on the road could be equipped with wireless interfaces. Maintaining end-to-end connectivity, packet routing, and reliable multi-hop information dissemination will become extremely challenging in such networks. There are several additional issues to take into account as it concerns specifically with the data transmission in VANETs: They are

[i] Signal fading, this becomes really fast due to the surrounding buildings.

[ii] Strong interference and collision related to the high number of mobile transmitters (vehicles).

[iii] Interference caused by fading effect and vehicles' speed.

The traditional vehicular networks rely on specific infrastructures, such as road-side traffic sensors reporting data to a central database, or cellular wireless communication between vehicles and a monitoring center. Hence the focus will be completely on decentralized data dissemination solutions, in order to avoid expensive infrastructures and increase the overall scalability of the system. In fact solution to the exchange traffic information among vehicles in a scalable fashion is to be solved in VANETs

1.5 QUALITY OF SERVICE (QOS) IN VANET

The United Nations Consultative Committee for International Telephony and Telegraphy (CCITT) Recommendation E.800, (Demetrios, 2001) has defined QoS as:

"The collective effect of service performance which determines the degree of satisfaction of a user of the service".

QoS refers to different notions at different networking layers. At the physical layer, QoS refers to the data rate and packet loss on the wireless links, which is a function of the channel quality. At the MAC layer, QoS is related to the fraction of time a node is able to successfully access and transmit a packet. At the routing layer, end-to-end QoS metrics would depend on the metrics at each hop of a multi-hop route. The routing layer must try to compute and maintain routes that satisfy the QoS requirement for the lifetime of a connection. The transport and upper layers could include support for QoS if the routing layer is not able to meet the QoS requirements.
In Ad hoc networks, Quality of service (McNally, Recker, Jayakrishnan, & Marca, 2002) is becoming an inherent necessity rather than an “additional feature” of the network. Following are the three main reasons that make a strong case for designing QoS enabled Ad hoc networks rather than adding such features as an afterthought.

1. Wireless channel fluctuates rapidly and the fluctuations severely affect multi-hop flows.
2. Packets contend for the shared media on adjacent links of a flow.
3. Interference can affect transmissions at nodes beyond the neighbors.

Implementation of real time critical, QoS On-demand, bandwidth ‘hungry’ applications between high speed dynamic vehicles demand major research works to be carried out. Providing QoS for a definite time period is the most challenging problem among researchers. QoS refers to the capability of a network system to provide the required service quality metrics such that its existing quality improves or suggests an optimal service for application specific network traffic over any of the underlying technologies. QoS algorithms should focus on effective use of existing resources and applying the required level of service without responsively enlarging or establishing the networks.

Network parameters such as required bandwidth, latency, packet loss, jitter and throughput support QoS in VANET, which is challenging than in a fixed and wireless access networks. It is difficult to support diverse applications with appropriate QoS in VANET because it has highly dynamic network in varying topology and traffic load conditions, less communication bandwidth and smaller processing power capacity than fixed networks (B. Das & Bharghavan, 1997). Factors such as varying wireless link capacity, propagation path loss, fading multi-user interference, power expended and topological changes become very important issues in mobile ad hoc networks. In vehicular ad hoc networks QoS violation can happen due to excess delays during the handovers, packet losses or total denial of a service (Abdalla et al., 2007). The requirement to transfer real time multimedia traffic along with voice and data traffic with varying properties of transmission over Ad hoc networks led to the need for the optimal QoS for applications (Bachir & Benslimane, 2003).
The end applications requiring optimal QoS has to deal with complexity of directly dealing with underlying QoS provisioning services, environment to demand and manage the service (Std, 2003). There are two types of QoS models proposed by IETF (Kalivaradhan & Thangavelu, 2010), Integrated Service (IntServ) (Bachir & Benslimane, 2003) and Differentiated Services (DiffServ) (Bachir & Benslimane, 2003). The IntServ model integrates resource reservation and traffic control mechanisms to support special handling of individual traffic flows. The DiffServ model uses traffic control to support special handling of aggregated traffic flows. In DiffServ, priority based treatment without reserving the resources will be done. (Futernik et al., 2003) used DiffServ model for providing necessary QoS for the end users.

To support QoS on multi-hop paths, QoS must be designed for the end-to-end path as well as for each hop. The physical and MAC layers are responsible for QoS properties on a single-hop. The routing layer is responsible for QoS metrics on an end-to-end route. QoS support in MANET had been much discussed by researchers, however less attention has been paid to mechanisms to deliver end-to-end QoS and support in multi-hop VANET environments. Actually, it is a systematic work under a given QoS framework. QoS control and support need to be implemented at several sub-layers, which involve the following research issues:

1) QoS framework for overall system architecture to support QoS

2) QoS routing algorithm, that focus on routing layer issues to deal with route computation and maintenance that satisfy both routing and QoS constraints

3) QoS signaling for reserve and release network resources (Abdalla et al., 2007)

4) QoS algorithm, media access mechanism support QoS control.

1.5.1 QOS FOR MULTIMEDIA APPLICATIONS

A Quality of Service (QoS) (Momanyi, Oduol, & Musyoki, 2014) guarantee is essential for successful delivery of multimedia network traffic. QoS requirements typically refer to a wide set of metrics including throughput, packet loss, delay, jitter, error rate and so on. Wireless and mobile Ad hoc specific network characteristics and constraints such as dynamically changing network topologies, limited link bandwidth
and quality, variation in link and node capabilities, pose extra difficulty in achieving the required QoS guarantee in a vehicular Ad hoc network. Providing QoS for Multimedia applications in VANET is a challenging task because of its characteristic of highly dynamic mobility. Link breakage frequently happens because of the short lifetime of the connection.

The major concern of VANET routing is that whether the performance can satisfy the throughput and delay requirements of such media streaming applications. Unavailability of efficient routing algorithms for the VANET scenario forces the researchers to use the MANET routing algorithms. An analysis of MANET routing protocols (Subramaniam, Sivanandam, & Thangavelu, 2011) shows that its performance is not acceptable in VANETs due to VANETs feature of very high mobility in terms of speed. And also its adverse effect leads to broken links, with high packet drop and overhead due to missing route repairs or failure. This phenomenon leads to low throughput ratio and high delay in transmission.

In this research work three schemes are discussed namely AODV, FSR and DYMO approach which focuses on optimal and QoS aware routing schemes for variable “on demand” services. Providing QoS for Multimedia applications in VANET is a challenging task because of its characteristic of highly dynamic mobility. Link breakage frequently happens because of the short lifetime of the connections and the unpredictable driver’s behavior. In vehicular Ad hoc networks, the support for Quality of Service (Bachir & Benslimane, 2003) is becoming an inherent necessity rather than an “additional feature” of the network.

1.6 ADAPTIVE AND OPTIMAL QOS OVER VANET

The primary objective of research work carried out is:

[a] To study, identify and analyze the required optimal QoS for media streaming service over VANET and Provide optimal QoS in cases when the node density is less, or when nodes are out of range of communication.

[b] To develop a modeling approach for QoS aware routing scheme to support on demand variable services.
[c] To design an adaptive routing approach for VANET to support QoS in battlefield scenario.

[d] Major challenge in various approaches of design for VANET is to improve reliability of routing data as well to reduce delivery delay time and minimize the number of packet retransmission. Vehicles which require high quality service for service specific applications is a challenge in VANET, which had to be considered as ‘priority’ during routing.

[e] To simulate and implement optimized QoS aware routing scheme for media streaming services. Abstract vehicular mobility is one of the major issue (Bhatt & Srivastava, 2013) that leads to delay, hence designing of delay bounded routing protocols is also a challenge, since multicast carry and forward is an approach to deliver packets.

The proposed routing schemes are designed and implemented as per the DSRC specifications (Karp & Kung, 2000) and IEEE 802.11p MAC (Bachir & Benslimane, 2003) standards. This research work proposes a QoS aware adaptive routing algorithm, which focuses on identifying optimal paths for effective routing in highly dynamic mobile Ad hoc network such as VANET. The process of selection and utilizing the optimal QoS route gets updated on transmission.

The layout of thesis is organized as follows

[a] Chapter-1 discusses on introduction to VANET and QoS issues.

[b] Chapter-2 elaborates on literature review on QoS aware routing protocols, handoff, middleware and media streaming and its related issues.

[c] Chapter-3 discusses on an adaptive QoS approach, AQVA being simulated using ns2.

[d] Chapter-4 identifies adaptive service based QoS approach for battlefield, BAVAN being simulated using ns2.

[f] Chapter-5 works on a middleware based media streaming service adaptive QoS approach HOSA, over a real time scenario.
Chapter-6 summarizes on the result, performance analysis and discussion on the work carried out with future work to be done.

1.7 CHALLENGES AND NEED FOR RESEARCH

Communication in VANETs can be either done directly between vehicles as one-hop communication, or vehicles can retransmit messages, thereby enabling the so-called multi-hop communication. In order to increase coverage or robustness of communication, relays at the roadside can be deployed. Roadside infrastructure can also be used as a gateway to the Internet and, thus, data and context information can be collected, stored and processed somewhere (e.g. the upcoming Cloud Computing).

[a] since the nodes are highly on mobility, data transmission is less reliable and suboptimal. Few features of VANET add complexity to network, which creates routing, security, QoS and faulty management features more challengeable.

[b] VANET architecture comprises of both infrastructure networks and ad hoc networks, hence in any standard network phenomena, the concept of routing and its characteristics are highly linked with QoS. The foremost worry of VANET routing is that whether the performance can satisfy the throughput and delay requirements of media streaming applications.

[c] An analysis of MANET routing protocols shows that its performance is not acceptable in VANETS (Y. Wang & Li, 2009) due to MANET’s feature of limited mobility. Its contrary effect leads to broken links, with high packet drop and overhead due to missing route repairs or failure. This phenomenon leads to low throughput ratio and high delay in transmission.