VANET Parameters and Applications: A Review

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***Abstract*-Vehicular Ad-hoc Network (VANET) represents a challenging class of mobile ad-hoc networks that enables vehicles to intelligently communicate with each other and with roadside infrastructure. VANET poses number of challenges in terms of Quality of Service (QoS) and its performance. Quality of Service depends on numerous parameters such as bandwidth, packet delivery ratio, data latency, delay variance etc. In this paper we have discussed various issues associated with data latency, efficient bandwidth utilization and packet delivery ratio in VANETs. Moreover, challenges in providing security, reliability and confidentiality of the disseminated data are elaborated. Finally, various applications of VANETs in current computing scenario are also presented.**

Keywords-Quality of Service (QoS), VANETs, Packet Delivery Ratio (PDR), DSRC (Dedicated Short Range Communication), Orthogonal Frequency Division Multiplexing (OFDM), Direct Sequence Spread Spectrum (DSSS).

I. Introduction

Work on the ad hoc network begins from 1970s when network were originally called packet radio networks. Inter-Vehicle Communications (IVC) and Roadside-to-Vehicle Communication (RVC) are becoming one of the most popular research topics in wireless communications. Capability of VANET has to provide safety and traffic management: vehicles can notify other vehicles of hazardous road conditions, traffic jamming, or rapid stops.

In 1999, the Federal Communication Commission allocated a frequency spectrum for IVC and RVC. Studies in [1, 3] have demonstrated that communications among vehicles can exploit the short-range IEEE 802.11 based radio interface technology. IEEE, 802.11p group specifying the new physical layer and MAC (Medium access control) layer for inter- vehicular communication [2, 3]. Table 1. shows the comparisons between IEEE standards 802.11a, 802.11b and 802.11p.

In 2003, the commission then established the service and license rules for Dedicated Short Range Communications (DSRC) service, which uses the 5.850 to 5.925 GHz bandwidth (75 MHz) for the use of public safety and private applications. Vehicles and roadside base station use the allocated frequency and service to communicate with each other without central access point.

One of the most challenging tasks in VANET is quality of service (QoS) parameters. In wired networks, the QoS parameters are generally described in delay and throughput. The quality-of-service (QoS) parameter in vehicular ad-hoc network is difficult because the network topology changes with high mobility and the available state information for routing is inherently imprecise. In this paper we have discussed the packet delivery ratio, data latency, efficient bandwidth utilization in data dissemination. The main objective of VANET is to provide safety to vehicles. Applications like collision alert, road surroundings warning, etc. will be classified under safety associated applications where the main accent is on timely broadcasting of safety critical alerts to nearby vehicles. Some challenges of VANET are security, reliability, confidentiality in data transmission that also affects the QoS. Security is provided by different ways like by authentication, encryption etc.

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Table 1. Comparison of IEEE 802.11p with 802.11a, 802.11b.

Standard	IEEE 802.11 a	IEEE 802.11 b	IEEE 802.11p (DSRC)
Modulation	OFD M	DSSS	OFDM
Frequency [GHz]	5.725-5.850	2.400-2.485	5.850-5.925
Bandwidth [MHz]	20	22	10/(20)
No. of Channels/ non-overlapping	12/8	14/3	7/7
Max Rate [M Bit/s]	54	11	27/(54)

Rest of the paper is organized as follows: In section 2 we discuss QoS parameters such as data latency, packet delivery ratio, and bandwidth utilization. Section 3 presents the applications of VANET. Section 4 summarizes the challenges of VANET. And finally conclusion is made in Section 5.

II. QoS Parameters for VANETs

Dedicated Short Range Communications (DSRC), specified under IEEE standard 802.11p. The IEEE 802.11 standard places the specifications for both the Physical layer (PHY) and for the Medium Access Control layer (MAC) [4]. The MAC extensions are mainly attention to get better security and QoS. The physical layer extensions mostly redefine the way in which the physical layer works. PHY and MAC layers of the VANET planned communication, Wirelesses Access in Vehicular Environment (WAVE) [5], defined in IEEE 1609.x family of standards. The transmission technology for Intelligent Transportation System (ITS) can be typically classified into two categories, i.e. Vehicle-to-Infrastructure communications (V2I) and Vehicle-to-Vehicle communications (V2V). V2V are achieved by using effective routing protocol that considers the specific characteristic of the road information, relative car movements and application restriction. Qi's can use to collect the most accurate information, to route the packet from sender to receiver. Qi's is usually defined as a set of service requirements in terms of data latency, bandwidth utilization, and probability of packet delivery ratio.

A. Data Latency

Data Latency means time duration between issuing a message from sender until it is received by receiver vehicles. An important parameter to be considered in sending and receiving a data packet is transmission time delay, through which the throughput rate can be calculated. In order to calculate transmission time delay, the following steps are utilized.
Bit-Rate = Data Size/ Transmission Time Delay
Transmission Time Delay=Data Size/Bit-Rate
Data size = User Data + Header
Authors [6] stress on finding the routing path that has maximum link reliability and a link delay less than an embarrassed bound. For the Qi's features of Deer, link reliability is of higher priority than link delay. This algorithm finds a path with maximum reliability and minimum data latency by NP -complete problem. This algorithm may be most useful in choosing a route for delivering multimedia content or other real-time data that depends on a reliable and minimal delay link.
In [7], they proposed an algorithm that minimizes the number of transmissions while forwarding a message to an access point within the message-specific delay threshold. They compare multi hop data forwarding strategy with Data Mulling strategy to achieve a good tradeoff between communication cost and delay. Data mulling strategy uses message buffer in local memory moving them at the vehicle's speed. Here *dittoing*be the remaining length,until the next intersection, of the current street segment. *Distain*denotes the currentshortest-path distance from the closest access point and *u* the averagespeed of the vehicle. Algorithm calculates the available delay budget *Del* for data broadcasting from current point to next intersection point as follows:

$$Del = TTL * distToInt / distToAp$$

It also calculates the expected delay by using Data Muling strategy for message dissemination to the next access point as follows:

$$Del_{Dm} = distToInt / u$$

Moreover, the high-speed moving vehicles rapidly change the topology of network, and this might result in the potential link breakage of the delivering routes. So as probability of link breakage is high, the value of data latency is also high.

B. Efficient Bandwidth Utilization

The utilization of bandwidth estimation has a tremendous impact on system performance. If the bandwidth estimation is lower than that of network capacity, then the available bandwidth is under-estimated and if the estimation bandwidth is higher than that of network capacity, then the available bandwidth is more-estimated. In both, systems performance decreases due to inaccurate estimation. In VANET, bandwidth utilization is more as compare to other wireless network due to high mobility in nodes.
One important factor in designing a VANET would be the ability to accommodate vehicles with equipment's of different network characteristics. Range and bandwidth of vehicle equipment may vary. There are number of protocols that assume homogeneous nodes may suffer due to the different properties of each protocol. Also vehicles that have velocity and GPS information will consume less bandwidth than others.
In [8], author estimated the bandwidth consumption from the interference range of the nodes. If the nodes are in their interference range they can easily communicate without any congestion. For sending information, sender checks its neighbor's bandwidth with its own bandwidth with in an interference range. If neighbor node has less bandwidth, then sender shares its own. Estimation of sender local bandwidth by, a node listens to transmission channel and the ratio of idle time and busy time for a predefined interval.

$$b_{local} = b_{channel} * t_{idl} / t_{channel}$$

Where b_{local} is sender's bandwidth, $b_{channel}$iscapacity of channel, t_{idle} denotes the idle time in a predefined interval $t_{channel}$.
In [9], in AODV [10] routing protocol to assisted with the roadside base station. AODV exactly matches the proposal for bandwidth calculation and check bandwidth is apposite for routing. Bandwidth utilization is precisely dependent on the traffic transmitted. They classified traffic as either real-time traffic or non-real-time traffic. The free bandwidth at base station for the request of real-time traffic can be expressed by

$$b_f = b_{unused} + \sum_i (b_{i,curr} - b_{i,\min}) - b_e.$$

where unused is the unused bandwidth at the base station, incur is the bandwidth currently allocated for the non-real-time traffic with index i, brimming is the minimum bandwidth required for the non-real-time traffic with index i, and be is the bandwidth reserved for transmission of emergency events.
In VANET, roadside base station consumes more bandwidth, because each base station has more overhead and all time associated to every vehicle. So, if a base station has scarce bandwidth that base station informs to other base stations that it is unable to receive routing information.

C. Packet Delivery Ratio (PDR)

Packet delivery ratio is the ratio of the number of packet received by the destination to the number of packet sent by the sender. It is most significant metric that we should consider in packet forwarding. It may affect by different crucial factor such as packet size, group size, action range and mobility of nodes. The robust message transmission is defined as the 100% packet delivery. Here 100% delivery

means receiver receive all the packets send by sender node before time period expires. The time of the packet delivery for various VANET applications is defined in [11].
The basic idea for PDR is that choose reliable routes. Reliable route need longer predictable lifetime and less number of hops. If the sender have prior information about routes should be chosen instead of the shortest paths which may probably break soon and introduce high maintenance overhead. How to define Routing Overhead? The number of packet transmitted on a route, no matter broadcast or uncast per node. There are some options

i. The total number of routing packets receives at per node.
ii. The total number of routing bytes receives, at per node.
iii. The number of routing packets, count with sequence number, this means end-to-end, not calculated by per node basis.

The link availability prediction [12] requires two nodes maintain their movement patterns during the prediction time. Normally the availability of route depends on the routing overhead. Also each forwarded packet is counted as one transmission. This metric is also highly correlated with the number of route changes occurred in the simulation. A realistic mobility model is not only very important for getting accurate results in routing performance evaluation but also a necessary component to predict the next positions of vehicles and make smarter route decisions in many VANET routing protocols. In [13] authors balances hop minimization with the ability to provide robust routes. From the global perspective of connectivity a new metric called the "expected disconnection degree" (EDD), is introduced to estimate the quality of a route based on factors such as speed, vehicle position and trajectory. It is an estimation of the probability that a given path would be broken during a given time interval. Thus, low EDD route is chosen. Prior the knowledge of vehicle positions, speeds, and trajectories, make some guesses about the stability of a route along a sequence of nodes. Intuitively, route along nodes moving in similar directions at similar speeds are more likely to be more stable.
In [14] solves the problem of path detachment by providing the safe guard which mechanically adjust the connectivity route when sender and receiver nodes change their direction and/or speed.
With a highly dynamic nature of nodes [15, 16], it is not possible to sustain multicast/unicast connections. And packet delivery is dependent on the connection between two nodes. So by using different intelligent techniques such as clustering [17], location aware broadcasting and aggregation [18] performance of packet delivery ratio can be increased

III. Application of VANET

VANET communications (IVC and RVC) can be used for number of potential applications with highly diverse requirements. The three major classes of applications possible in VANET are safety oriented, convenience oriented and commercial oriented. Safety applications will monitor the surrounding road, approaching vehicles, surface and curves of the road. Convenience application will be mainly of traffic management type. Commercial applications will provide the driver with the entertainment and services as web access, streaming audio and video. Below we identify the most representative VANET applications and analyze their requirements through use-cases.

A. Traffic Signal

Communication from the traffic light can be created with the technologies of VANET. Safety applications would be Slow/Stop Vehicle Advisor (SVA) in which a slow or motionless vehicle will broadcast alert message to its neighborhood. Congested Road Notification (CRN) detects and notifies about road congestions which can be used for route and journey planning. The toll collection [19] is yet another application for vehicle toll collection at the toll booths without stopping the vehicles. Vehicular networks have been shown to particularly useful for traffic management. For instance, Vehicle to infrastructure solution for road tolling is widely deployed.

B. Vision Enhancement

In vision enhancement, drivers are given a clear view of vehicles and obstacles in heavy fog conditions and can learn about the existence of vehicles hidden by obstacles, buildings, and by other vehicles.

C. Weather Conditions

Either vehicle sensors (wipers movement, grip control, outside thermometer, etc.); if not available/reliable, weather information can be updated/requested by an application via DSRC. In post-crash notification, a vehicle involved in an accident would broadcast warning messages about its position to trailing vehicles so that it can take decision with time in hand as well as pass information to the highway patrol for support. Parking Availability Notification (PAN) helps to find the availability of space in parking lot in a certain geographical area as per the weather conditions. For the convenience of the vehicle, highway and urban area maps are available which avoid the traffic jam and accident conditions and also provide shortest path in critical situation which saves the time

D. Driver Assistance

Vehicular networks can also be used to support driving military exercises, by providing drivers with information that they might have missed or might not yet be able to see. By [20] having vehicles exhibiting abnormal driving patterns, such as a dramatic change of direction, send messages to inform cars in their locality, drivers can be warned earlier of potential hazards, and therefore get more time to react and avoid accidents. Other applications of vehicular networks to driver assistance include supporting decision making.

E. Automatic Parking

Automatic Parking is an application through which a vehicle can park itself without the need for driver intervention. In order to be able to perform an automatic parking, a vehicle needs accurate distance estimators and/or a localization system with sub-meter precision.

F. Safety

Safety applications include immediate collision warning, forward obstacle detection and avoidance, emergency message dissemination, highway/rail collision avoidance, left/right turn assistant, lane changing warning, stop sign movement assistant and road-condition warning, intersection decision support, cooperative driving (e.g. collision warning, lane merging, etc. [21,22]).

G. Searching Roadside Locations and vehicle's Direction

For unknown passenger help to find the shopping center, hotels, gas stations, etc., in the nearby area along the road. GPS, sensors and database from the nearest roadside base station are capable of calculating information

H. Entertainment

A number of applications aim to entertain passengers who spend a very long period in transit. FleetNet [27] that provides Internet access, as well as communication between passengers in cars in the same vicinity, allowing them to play games. A pure V2V based solutions cannot address these application domains and there is a definite need for V2I infrastructure and VANETs have this V2I support as well.
VANETs would support life-critical safety applications, Safety warning applications, electronic toll collection, internet access, automatic parking, roadside service finder, etc. Table 2. shows the comparisons between the above application on the bases of priority, latency, and network traffic and message range.
We believe that main applications of VANETs are divided into two categories. One is safety applications and another one is non-safety application. In safety applications communications are usually of broadcast type where as in non-safety applications communication is on demand only request response bases (e.g. gaming mobile commerce, multimedia, streaming).

IV. Challenges of VANET Communication

A. Security

esides the introduction and management of trust also the security of message content is a big issue for vehicle to vehicle communication. The content of a received message has to be verified within a short time to be able to use the information as soon as possible.

Table 2. Comparison of VANETs applications

Applications	Priority	Allowable Latency(ma)	Network Traffic	Message Range(m)
Life-Critical Safety	Class1	100	Event	300
Safety Warning	Class 2	100	Periodic	50-300
Electronic Toll Collection	Class 3	50	Event	15
Internet Access	Class 4	500	Event	300
Automatic parking	Class 4	500	Event	300
Roadside Service Finder	Class 4	500	Event	300

Fundamentally, in [23] VANET security should guarantee for the few main issues:-

B. Authentication

The authentication service is concerned with assuring that the communication is authentic in its entities. Vehicle should react to events only with disseminating messages generated by legal senders. Therefore we need to authenticate the senders of these messages.

C. Integrity

The integrity service deals with the stability of a stream of messages. It assures that messages are received as sent, without modification, insertion, reordering, or replays.

D. Confidentiality

This service provides the confidentiality to the communication content. It guarantees the privacy of drivers against unauthorized observers.

E. Accessibility

A kind of attacks can result in the loss or diminution in the accessibility. Even a robust communication channel can still suffer some attacks (such as deny of service) which can bring down the network. Therefore, availability should be also supported by alternative means.
An important feature of VANET security is the digital signature as a building block. Infrastructure communications or communications inter-vehicle through, authentication (using signatures) is a fundamental security requirement.

F. Scalability

The term scalability means that the number of users and/or the traffic volume can be increased with reasonably small performance degradation or even network outage and without changing the system components and protocols.

G. Reliability

Due to the brief communication time, it is difficult to assure the reliable message reception and acknowledgement between communication vehicles on opposite directions. In vehicular ad hoc networks a majority of the messages that are transmitted will be periodic broadcast messages that announce the state of a vehicle to it neighbors. So in case of broadcast messages it needs more reliability. In [24], authors proposed to use a group of vehicles carrying the messages to improve the reliability.

H. Confidentiality

Confidential issue is totally related with the security. Vehicles are very costly devices, so the user those who are accepting need to protect their personal data. So there are number of methods to protect user private data. One way to protect data, collect information for a long time from number of source nodes and evaluate that data [25].

I. Media Access Control

To create wide scale vehicular ad hoc networks, changes need to be made to the media access control (MAC) layer [26]. The aim of MAC layer is to access to shared medium, which is the wireless channel. If no method is used to coordinate the transmission of data, than a large number of collisions would occur and the data sent would be lost.

V. Conclusion

VANET is not a new research field in network communication. MANET and VANET both share some common features of network. In this paper, we have explained few QoS parameters such as data latency, efficient bandwidth utilization and packet delivery ratio of VANETs, which affects the performance of network communication. However, the performance of VANETs depends heavily on the mobility model, routing protocol, vehicular density, driving environment and many other factors. There are still quite a few parameters that have not been carefully investigated yet like network fragmentation, delay-constrained routing, efficient resource utilization, and delay-tolerant network. Focus of our future work would be on the above said parameters. Nevertheless, VANET shows its unique characteristics which impose both applications and challenges to the research communities.

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