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IMPROVING QUALITY OF SERVICE THROUGH ROAD SIDE BACK-BONE NETWORK IN VANET

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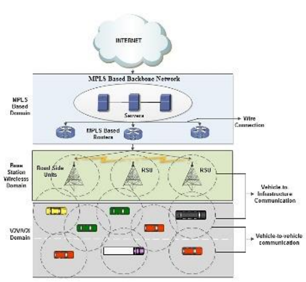
Graphical abstract



Abstract

The vehicular ad hoc Networks (VANETs) are expected to support a large spectrum of traffic alert, dynamic route planning, file sharing, safety and infotainment applications to improve traffic management. User satisfaction plus in time delivery of real-time messages is the most significant quality evaluation criterion for vehicular applications. High mobility and rapidly changing topologies always lead to intermittent quality of services, higher delay and packet dropping issues in network. To improve the quality of services for multi-hop and dynamic environment, different types of solutions have been proposed. The article introduces multi-protocol label switching based on roadside backbone network to provide widespread, scalable, high-speed, robust quality of services and improve network efficiency. The simulation results showed that proposed model improves data transmission and routing performance in terms of data delivery, throughput, end-to-end delay and achieve adequate utilization of resources.

Keywords: Quality of service (QoS), Vehicular ad hoc Networks, Mobility, Multiprotocol Label Switching MPLS

1.0 INTRODUCTION

The vehicular ad hoc networks (VANETs) have emerged as persuasive technology for providing safety and infotainment services to the passengers in the vehicles. Different projects and applications have gained a lot of popularity in this area in order to achieve productivity and traffic management. Different types of wireless and communication technologies have been implemented to support data communication in vehicular networks such as Wi-Fi, WiMAX, 3/4/5 G, cellular, and satellite systems. The VANETs have different communication modes such as vehicle-to-road side (V2R), vehicle-to-vehicle (V2V), and hybrid communication. In vehicle to roadside communication, IEEE 802.11(Wi-Fi) [1], dedicated short range communication (DSRC) [2] and IEEE 802.16 worldwide interoperability for microwave access (WiMAX) [3] technologies are working with the help of nearest Road Side Units (RSUs) or base stations that control the vehicles activities through wireless communication. Onboard units (OBUs) are installed in vehicles that enable to send and receive the information through DSRC standard from the roadside units. OBUs have global positioning services (GPS) [4] to obtain vehicles real-time position information and record the events in case of emergency or accident. However, if the RSUs are not available then vehicles switch to V2V or pure ad hoc mode. RSUs are connected with application servers or with traffic management centers for further data analysis. There are several well-known applications are working under vehicle-to-roadside communication such as infotainment, electronic toll collection, safety and web browsing. On the other hand, V2V communication is used for safety applications including collision avoidance, lane changing assistance with low transfer latency. However, some applications in VANETs require high bandwidth for data delivery that need high quality of services (QoSs) such as voice over IP (VoIP)[5], video conferencing (VC) [6], multimedia services and video Security. In time delivery of messages is always considered as a main objective in safety applications. Vehicular networks have been suffered from infrastructure, applications, security, and services challenges. High-speed and dynamically changing topologies always lead to inadequate end-to-end delivery, path loss and dis-connectivity issues in network. The QoSs over VANETs remain a challenge due to these characteristics and presence of different obstacles in the network. Therefore, there is a need to develop an adaptive QoS model that can easily be adoptable and efficiently tackle the performance parameters. Different types of solutions have been proposed to deal with the challenges related to routing, frameworks, and new infrastructure models. Most of the solutions belong to vehicle–to-vehicle communication and enhance the routing and MAC protocols performance. On the other hand, some infrastructure solutions have been proposed to add sensor network technologies to improve the network performance [7]. However, these solutions need more investment on infrastructure that suffered from maintenance plus energy consumption issues. To take these factors into account, we focus on existing infrastructure and proposed a solution which is multi-protocol label switching (MPLS) based backbone network in order to improve network performance in terms of QoSs.

In this paper, we propose a MPLS based backbone network for improving and increasing the QOSs in VANET. The proposed model will solve the end-to-end delay and jitter issues in VANET.

The rest of this paper is organized as follows: Section 2 discusses the QOSs challenges in the vehicular network. Section 3 presents related literature. Section 4 illustrates the proposed model in detail. In last section 5, the performance evaluation of proposed model is elaborated and check the performance of proposed model with state of the art models in terms of packet delivery ratio (PDR), throughput and end-to-end delay.

2.0 QUALITY OF SERVICES CHALLENGES IN VANET

In VANET the applications are categorized into three main classes: safety, traffic management, and comfort or entertainment applications. The safety applications are notifying about any dangerous situation on roads such as warning about weather conditions, accident warning and collision warnings. The main concern of these applications is to finding low latency and efficient methods for data broadcasting between vehicles. To deal with high mobility and dynamically changing topologies, various data dissemination approaches have been proposed [8]. Some solutions are suggested that infrastructure less and independent pure ad hoc communication is feasible for vehicular communication [9]. However, in time delivery of messages is still under consideration. The second class traffic applications are working with traffic information systems in order to provide road information to vehicles in urban areas about road density plus street or junctions capacity such as self-organizing traffic information system [10] and traffic view [11]. The third class belongs to comfort applications, where the real time or non-real time multimedia streaming communication services are working such as gaming, video conferencing, data transfer, web browsing, weather information, advertisements about hotels and presence of gas stations. Multimedia applications are utilizing high bandwidth and need more strong backbone network, which is attached with roadside units. It provides high compression and user-friendly services to the network. Multimedia applications have been suffered with various QoSs challenges in network such as video coding (quantization, frame dropping, bitrates, decoding) and adjust these parameters by transmit multiple compressed programs over wireless network. Limited bandwidth and co-channel interference disturbed the network quality in terms delay. There is a need to design an efficient network model in order to provide satisfactory resources with maximum bandwidth, real-time streaming and improve QoSs requirements in network.

3.0 RELATED WORK

In order to improve QoSs in VANET applications, different types of models have been proposed. The two-tier model namely Mobile infrastructure based model for VANET (MI-VANET) was proposed in [12], with aims to improve data delivery and throughput in the network. In addition, this model uses buses as a mobile backbone network for data communication and delivery. The model is somehow like a mesh network with mobility features. The author divided buses and cars into low or high tiers. High tier bus nodes have wireless interfaces to communicate with low-tier car nodes. The model uses mobile infrastructure registering and mobile infrastructure routing protocols, which are belongs to location reactive routing protocols. The protocols select the optimal route with the help of road segments with transmission quality then forward the packets hop by hop. The performance of proposed model is evaluated with traditional GPRS [13] protocol. The results showed that MI-VANET is superior in terms of throughput and data delivery. However, the model is always looking for buses in routes, where VANET environment is dynamic in nature.

Another Multi-layer model with wireless backbone infrastructure was proposed in [14], for VANET with multi-layer functions. The wireless backbone model is based on wide local area network (WLAN) and WiMAX enable vehicle nodes in order to provide seamless services on highways. In addition, the model addressed the gap between the bandwidth of WWAN (Wi-MAX 802.16e) and WLAN technologies. The main idea in this model is using mesh network as a backbone infrastructure with the multi-layer functionalities. Additionally, this model has capabilities to work as an independent solution and adaptable for further development. It supports real-time data streaming for efficient backbone structure. However, the wireless based backbone network suffered due to different obstacles in network and cause of interference issues for radio transmission.

To deal with high mobility and dynamic changing topologies in VANET, network needs a feasible, cost-effective and scalable solution as a backbone network in order to improve the QoSs with better data delivery in the network.

4.0 PROPOSED SOLUTION FOR ROADSIDE BACKBONE NETWORK

The proposed integrated backbone network is based on IP and MPLS network connected with cables to enhance security with quality services. The model has three sub domains: MPLS based domain, Base station wireless domain and V2V/V2R domain. The VANET applications requirements are using maximum bandwidth e.g. 1.5 Mb/s to 6 Mb/s per user for video streaming services with low packet loss and jitter rate [15]. Figure 1 shows the proposed backbone model including three subdomains.

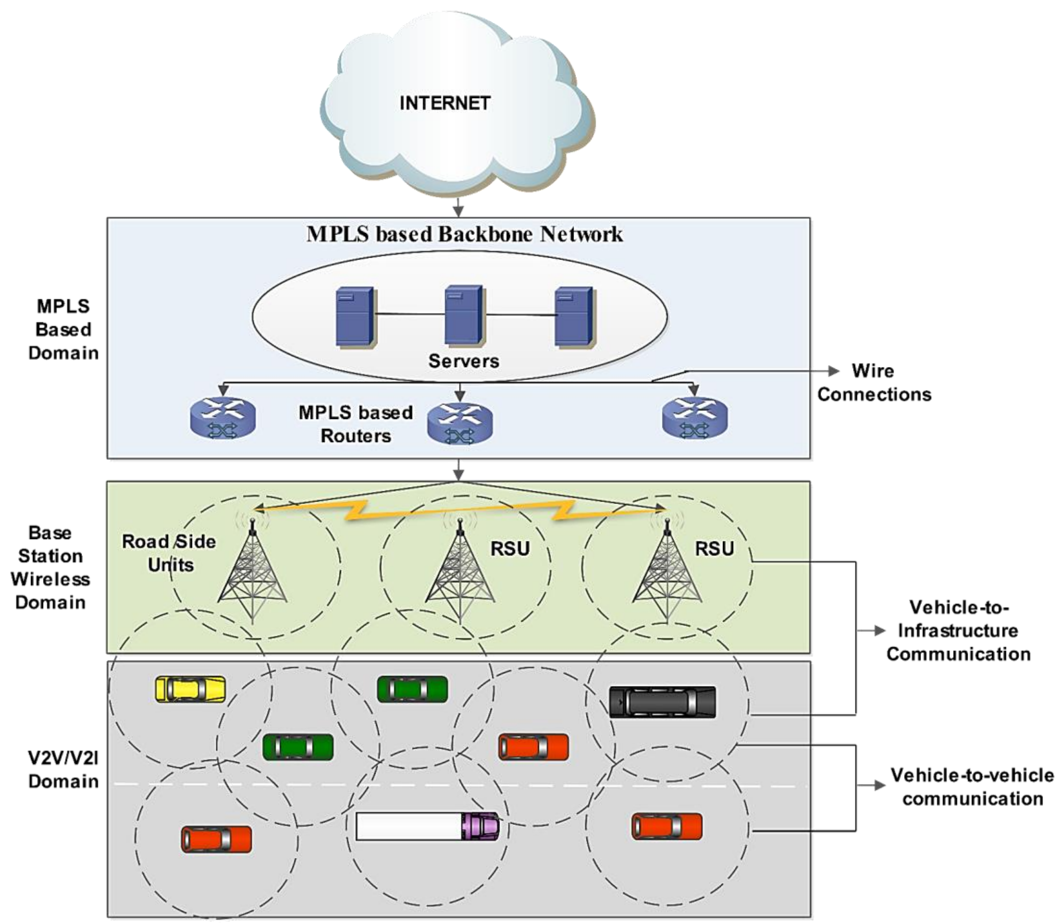


Figure 1 MPLS based backbone model of VANE

The MPLS-based domain refers to make a connection between roadside units and internet domain. The servers in this domain plays a central role to establish the connection between the both. MPLS-based servers are responsible for dynamic addressing, mobility management, intelligent routing and load balancing. The base station wireless domain equipped with WLAN and WiMAX technologies to access the network and mobile vehicles. The third domain provides communication by RSUs or V2V communication. In next section, we discusses these three domains in detail.

4.1 MPLS Domain

The MPLS-based backbone network provides high bandwidth facilities and services to vehicles. It is wire based domain with enhanced reliability and protection mechanisms. The domain uses IEEE 802.11 standard [16], where roadside units are connected with backbone network through digital subscriber line and local area network connections [17]. These types of IP-based wired infrastructures are usually deployed in urban areas, towns and on highways for traffic management [18]. In traditional systems, the central devices plus terminals are used to connect with dedicated interfaces. Afterward, IP-based systems are replaced with integrated interfaces, which are used for advanced composite services. Some researchers suggested the fiber optical cables for dedicated interfaces due to its fastest data flow with at least 1 Gb/s bandwidth [18]. However, these solutions are most expensive and do not suitable for complex infrastructure environment. Furthermore, these solutions are still suffered with weather conditions especially with humidity and moisture [19].

A. Multiprotocol Label Switching

The MPLS technology was introduced in late 90's for improving QoSs and designed for high-speed backbone networks [20]. Almost all IT companies are looking for an effective and appropriate solution for their wide area networks. Most of the companies are adopted frame relay or asynchronous transfer mode leased lines [21]. The virtual private network [22] is another layer 2 tunnel based technology for data routing over the Internet with maximum security. Although, VPN is not scalable to deal with new IT technologies and security challenges in network [23, 24]. The MPLS provides scalability plus efficient security due to its layer 2 (data link) and layer 3 (network) capabilities and known as 2.5 technology [25]. Furthermore, MPLS offers an efficient and effective packet forwarding services across the network with contents of labels, which are attached with IP packets [26]. The MPLS technology looks like a virtual circuit concepts, where ATM (Asynchronous Transfer Mode) is used to find the next hop in the routing tables. The ATM based systems suffer with time consumption issues. On the other hand, MPLS uses label packets for data forwarding in the network, where the attached labels are routing like layer 3 and perform separately like layer 2 switching. The MPLS does not determine the best route and shortest path in the network in order to prepare service requirements. Recently, MPLS provides a better high processing power and considered as an essential ingredient for the wireless domain. The MPLS technology particularly takes extraordinary measures for quick processing at layer 2, TCP/IP protocol stack header in order to improve end-to-end delay. Figure 2 shows the MPLS model.

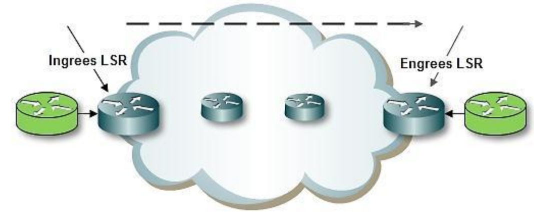


Figure 2 MPLS based model

In MPLS-based domain, various QoSs metrics use to improve the vehicular network performance such as it reduce round trip delay, decrease packet loss with fault tolerant paths, and provide structural management services. To deal with high mobility, MPLS implementation on V2V communication may not have a positive effect on the network, so we adopted MPLS in backbone network. The vehicles send their data to the base stations and then data move to MPLS based infrastructure for further analysis. The MPLS based backbone domain better in QoSs metrics and gain higher results compared with traditional systems [27].

B. Road Side Units Domain

In this domain, the RSUs are based on different communication technologies in order to communicate with vehicle nodes such as IEEE 802.11p (WAVE) [28], 802.20 and 802.16e WiMAX [29]. The basic function of these RSUs is providing preloaded contents requested by the vehicles with load balancing and content transmission scheduling. Further, it also provides in time important information to the upper domain for further analysis.

C. Vehicle-to-vehicle and Vehicle-to-infrastructure domains

In this domain, vehicles are communicating with each other and disseminate the information in ad hoc manner through roadside units. Vehicles are equipped with on-board units for wireless communication with RSUs via IEEE 802.11p also known as WAVE. The 802.11p/1609 standard family aims to provide a set of specifications to allow interoperability between OBUs and RSUs.

After the brief discussion about proposed MPLS backbone model, we analyze the performance of model through simulation.

5.0 SIMULATION SETUP

First we set the mobility model, to test proposed backbone network. In VANET, the mobility models are divided into two types: microscopic and macroscopic. The vehicle movements and behavior belong to microscopic whereas, roads, street, crossroads, traffic lights, distribution of vehicles, generation of vehicular traffic density and flow fall in the macroscopic model. The various types of mobility models are proposed to generate the mobility, some of them are shown in Table 1.

Table 1 Different types of mobility models and their usage

S/No	Mobility Models	Usage
1	Manhattan Mobility Model (MHM)	For vehicle node movement
2	Freeway Mobility Model (FWM)	For freeway motion behavior
3	Random Waypoint Model (RWM)	For research Community

The second and important step in VANET environment is mobility generation, different tools are available for mobility generation such as VISIM, MOVE, SUMO, and VanetMobiSim [30]. These tools are designed to provide simulation scenarios at the micro and macro scale levels. Afterward, the NS-2 selects [31] to test the proposed model performance. NS2 is an event-driven tool and compatible with MOVE to generate realistic mobility and built on top of an open source micro-traffic simulator (SUMO) [32]. Vehicles allow to move along the grid of vertical and horizontal streets in the map. We set a map in the simulation with multiple roads, traffic lights, and intersections. Vehicles are divided into four groups and each group has four vehicles. The simulation parameters are listed in Table 2 and Figure 3 shows the simulation model and parameters.

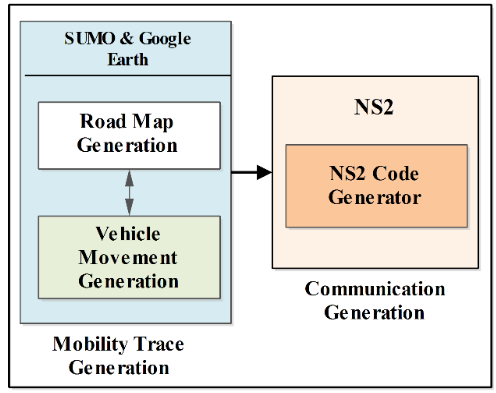


Figure 3 Simulation model

Table 2 Simulation Parameters

Parameters	Values
Network Area	500 * 600 M
Radio Range	150 m
Channel	Wireless
Traffic type	CBR
Routing Protocol	AODV
Number of Vehicles	16
Base stations	10
Speed of vehicles node	30 km/h
Packet size	800 byte
Transport protocol	UDP

5.1 Data Communication

Different types of routing protocols have been implemented in vehicular environment such as topology based, position based and cluster based [33, 34]. We set topology based protocol to test the performance due to its shortest path finding mechanism [35]. Topology based protocols are divided into reactive and proactive types, in proactive type, every node keeps information of all connected nodes in the routing table and cause high network overhead. On the other hand, in reactive protocols, the routes are discovered and maintained on demand. The ad-hoc on demand distance (AODV) protocol is an example of reactive routing protocol [36]. AODV addresses various issues of proactive protocols by supporting a large networks with various nodes and reduces the message flooding issues in the network.

With MPLS technology, the network performance is greater in terms of QoSs, where the vehicle nodes connect with RSUs and further connect with MPLS domain through wire network. The vehicle nodes communicate with RSUs and with each other in order to forward the data to MPLS backbone network. Each RSU has its own 3 level addressing domain. The proposed model will improve the QoSs with fast and reliable communication compared to previous traditional mechanisms.

6.0 RESULTS

After the simulation setting, we compared MPLS-based network with two previous models: MI-VANET [12] and Multi-layer model model based on wireless backbone infrastructure [14].

The simulation is running for several times to check the network performance. After determined the results the Figure 3 shows the throughput of all technologies. It is noted from the graph that total 7500 packets are passed through MPLS-based model which results in the average throughput of 25 packets/sec while the total number of packets are 8000. On the other hand, the total packets passes through MI-VANET are around 6500 out of 8000, which results 39 packets /sec. The Multi-Layer model performance is less with 6200 packets as compared to the state of the art models. The throughput of three technologies show the correct choice for network for data traffic and that is MPLS-based model. The results show the better performance of proposed MPLS-based backbone model

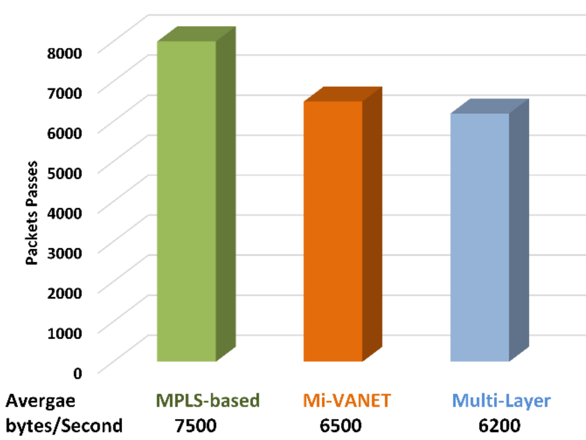


Figure 3 Throughput (MPLS, MI-VANET and Multi-Layer)

The vehicular environment has unique characteristics such as high mobility, dynamic nature of topologies and different obstacles. Because of these characteristics the network still suffered from data loss and dis-connectivity issues. Figure 4 shows the average packets loss of three models. The average number of packet loss in the MPLS-based environment is 1800, while in MI-VANET the packet loss ratio is 2200 and multi-layer model is 2500 packets. The overall performance of MPLS model is better compared to the state of the art models. The results clearly shows that MPLS-based model overcome the ratio of packet loss compared to other two models.

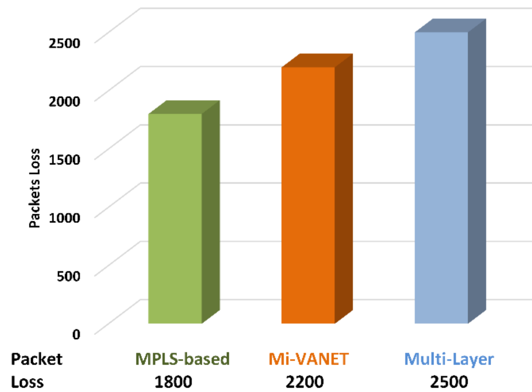


Figure 4 Packet Loss

Figure 5 shows the average delay of three models. The graph clearly shows the different pattern of delay that affect the performance of traffic in terms of end-to-end delay. The graph shows the MPLS-based model delay is small at the start of communication while that is increasing when the number of nodes are increasing in the network. This is because of broadcasting the packets in the network to inform other vehicles about each other positions. Still the average delay rate of MPLS model is better compared to MI-VANET and Multi-layer models.

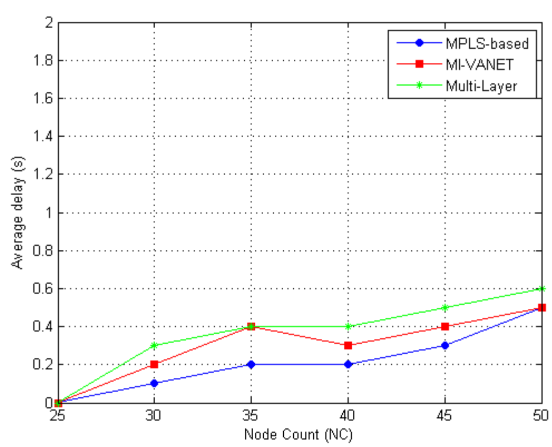


Figure 5 End-to-end Delay

The proposed MPLS-based backbone network model performance is better compared with MI-VANET and Multi-Layer in terms of throughput, packet loss, and end-to-end delay. The MPLS-based model is the best option for the vehicular network to improve the QoSs parameters and improve the services performance of transportation applications.

7.0 CONCLUSION

Due to high mobility and dynamic nature of topologies, the VANET suffered from packets loss and packet delay issues in the network. In this paper, we overcome these issues with the help of MPLS-based backbone model in order to improve network QoSs performance. In MPLS based proposed model, the vehicles are communicating via roadside units. RSUs are further connected with MPLS network and with the internet. Through simulation results, we proved that MPLS based model performance is superior in terms of PDR, network throughput and end-to-end delay. The proposed model is an efficient model considers as a low-cost solution for vehicular networks.

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