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## Improving QoS in VANET Using MPLS

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### Abstract

Vehicular Ad hoc Networks (VANET) as a sub class of Mobile Ad hoc Networks (MANET) provides a wireless communication among vehicles and vehicle to road side equipment [1]. Important applications of VANET are providing safety for passengers in one hand, and also resource efficiency including traffic as well as environmental efficiency on the other hand. As a result, providing Quality of Service (QoS) has a great role in Intelligent Transportation System (ITS). Different methods over network layers, especially over layer 2 and layer 3 were recently proposed to support QoS in VANET [2]. But in this paper, MPLS [11] as a forwarding method which can be compatible with any layer 2 technology is used in road side backbone network, to improve QoS in terms of end-to-end delay, packet loss and throughput in urban areas, where lots of roadside unit exist

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*Keywords:* VANET; MPLS; QoS; AODV

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### 1. Introduction

QoS is defined as a set of service requirements that needs to be met by the network while transporting a packet stream from a source to its destination [3]. Some protocols such as Intserv(Integrated services), Diffserv(Differentiated services) and MPLS are defined to support QoS in wired networks. MPLS is considered as layer 2.5 protocol [8], because integrates fast switching of layer 2, and also powerful routing of layer 3.

Vehicular communication promises many improvements in terms of accident avoidance, better utilization of roads and resources such as time and fuel, and new opportunities for entertainment applications [4]. Consequently, sending and receiving correct data in a fixed duration of time is critical in

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this type of network. There are two types of communications in VANET: vehicle-to-vehicle (V2V), in which vehicles transport data between each other without any fixed infrastructure, and vehicle-to-infrastructure (V2I), in which vehicles send and receive data to/from Road Side Unit (RSU) that is a fixed wired network with access points [2]. This paper investigates using MPLS in a road side network to improve overall QoS of VANET. One of the main benefits of this infrastructure is for sound and video transportation in VANET, which will be to most important applications of VANET in near future.

So, the rest of paper is organized as follows. Section 2 gives some characteristics of MPLS. Section 3 explains different parts of VANET, then in section 4 mobility models especially Manhattan mobility, which is used in the simulation are studied. In section 5 Ad hoc On demand Distance Vector (AODV)[9] routing protocol is described. Proposed method, simulation setup and supposed scenario are presented in sections 6. Obtained results and the discussions are given in section 7. Finally section 8 concludes the paper.

## 2. Multiprotocol Label Switching

### 2.1 Adventure of MPLS

MPLS birth started when several companies had begun to experiment with what is now generally referred to as label switching. The main goal of label switching networks was to bring those connection oriented benefits into a non connection oriented network; mainly IP. Original idea of MPLS was based on IP over ATM. Fast switching and virtual circuit mechanism of ATM for guaranteeing QoS, alongside popularity and scalability of IP led to advent of protocol named MPLS.

### 2.2 Independence of MPLS from layer2

Using MPLS, routers forward packets by looking at the label of a packet, instead of search in the routing table to find the next hop for packets that is a very time consuming job. Attached labels causes the layer 3 functions like routing and forwarding perform separately from layer 2 functions like switching. This is one of the most noticeable points about MPLS that runs over any layer 2 technologies like Frame Relay, ATM or Ethernet.

**2.3 Traffic Engineering** Another important characteristic of MPLS is Traffic Engineering (TE). Traditional routing protocols like Open Shortest Path First(OSPF) or Routing Information Protocol(RIP) are usually routes packets based on algorithms designed to obtain the shortest path, the acceptable bandwidth or other metrics in the network packet traversal, but metrics such as delay, packet loss, throughput, jitter and traffic congestion are not take into account. Using TE, MPLS can determine the best route which can prepare service requirements of packets that is not necessarily the shortest path. Fig. 1 shows an example of MPLS domain.

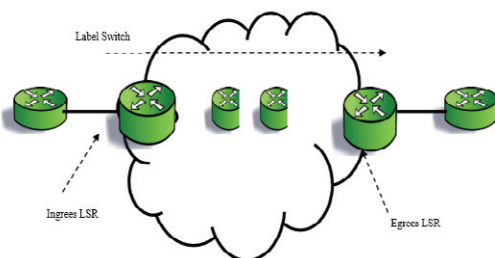


Fig. 1 Architecture of MPLS domain [1]

### 3. Vehicular Ad hoc Network

Vehicular communication networks (VCN) have emerged as a key technology for next-generation wireless networking [2]. Since VCNs form the basis for supporting not only the ITS services, especially public-safety related applications, but also a wide range of future multimedia and data applications, such as audio/video as well as e-maps and road/vehicle related services [7], Vehicles are envisaged to become a part of the Internet in the near future, either as mobile endpoints, as mobile backbone routers, or as mobile sensors [8].

Vehicular communications system specifies two levels of communications network in its infrastructure [8], as revealed in Fig. 2:

- 1- Vehicular Ad hoc network (VANET)
  - Including V2V and V2I communications
- 2- Roadside Network consists of twofold:
  - (a) Roadside Access Network (RAN), which comprises the RSUs and enables the V2I-communications through appropriate connections to the backbone;
  - (b) Roadside Backbone Network (RBN), which represents the backbone network of RSUs, and in which RSUs communicate with each other and with Internet [8].

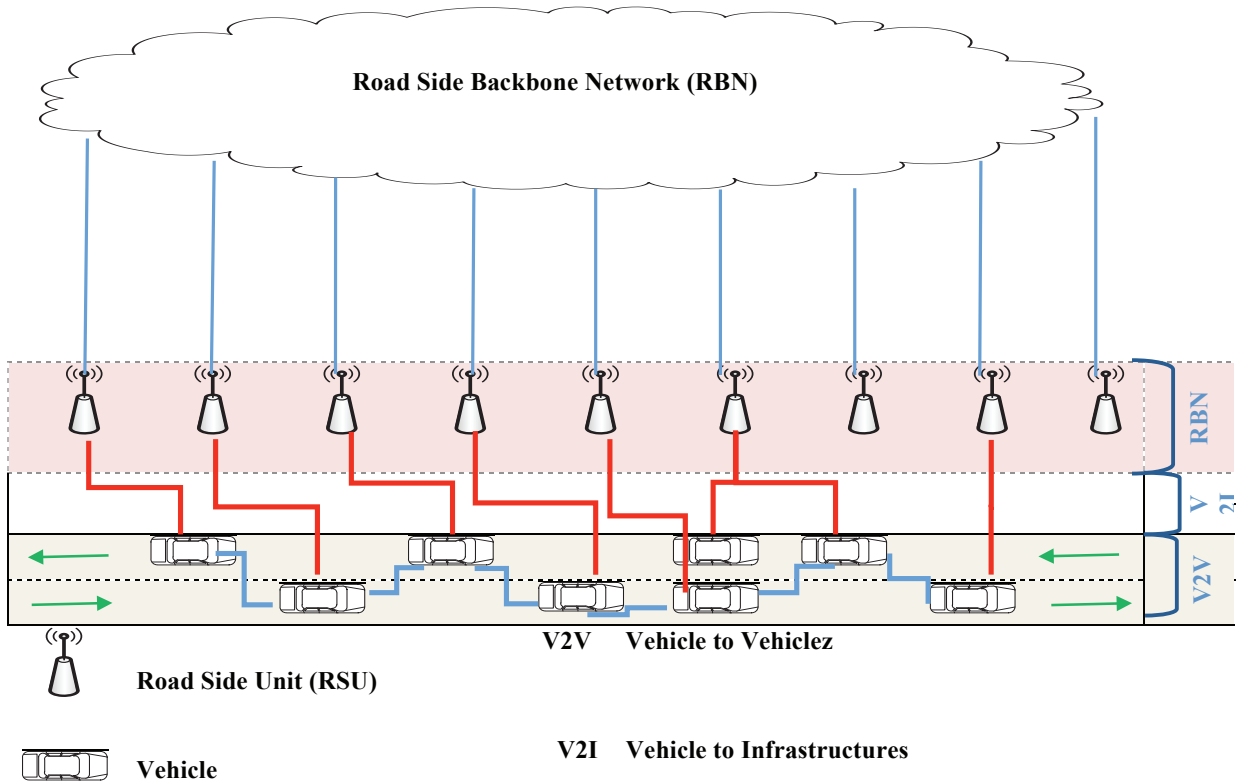


Fig. 2 VCN architecture [2]

VCN provides an environment for different applications in the field of ITS, and also internet related applications from active safety situations like danger of accident to business and entertainment applications like gas payment. Each application has its own QoS requirement. For example safety warning applications should have minimum End to End (E2E) delay, because if a warning message receives at destination with high delay, that message could not be helpful for preventing an accident. Accordingly, packet loss and throughput are two other QoS factors that are very important in active safety applications.

As mentioned before we have two types of communication in VANET: point-to-point for V2V communications and cell-based or point-to-multipoint for V2I communications. So, by using MPLS in RBN, the QoS parameters in terms of E2E delay, packet loss and throughput is improved.

#### 4. Mobility Model

Vehicular mobility models are usually classified as either microscopic or macroscopic. When focusing on a macroscopic point of view, motion constraints such as roads, streets, crossroads, and traffic lights are considered. Also, the generation of vehicular traffic such as traffic density, traffic flows, and initial vehicle distributions are defined. The microscopic approach, instead, focuses on the movement of each individual vehicle and on the vehicle behaviour with respect to others [7].

To emulate movement pattern of mobile nodes or vehicles, different mobility models are defined. Each one corresponds to a specific situation as follow:

- A) Random Waypoint Model (RWM): This model is a commonly used mobility model in research community.
- B) Reference Point Group Mobility (RPGM) Model: This Group mobility model is usually used for military battlefield communications.
- C) Freeway Mobility Model (FWM): This model emulates the motion behavior of mobile nodes on a free way.
- D) Manhattan Mobility Model (MHM): is used to emulate the movement pattern of mobile nodes on streets defined by maps and usually used to simulate the movement of vehicles in rural areas in which lots of vertical and horizontal streets and intersections are exist[6]. Example of this mobility model is illustrated in Fig. 3, which is used in the simulation.

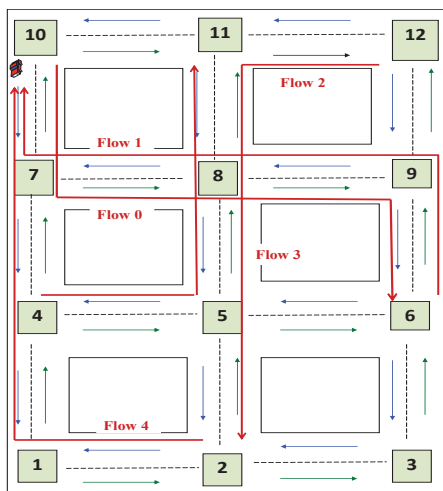


Fig. 3 Manhattan mobility model

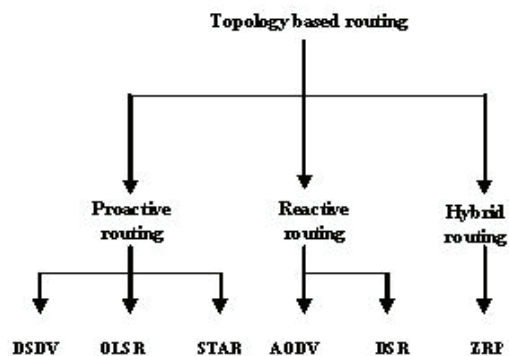


Fig. 4 Ad hoc routing protocols [5]

Several routing protocols have been proposed to compete with sudden changes that may arise due to the nature of VANET. Topology based routing protocols are grouped into three categories of proactive, reactive and hybrid routing as shown in Fig. 4.

Proactive routing protocols are mostly based on shortest path algorithm. Every node keep information of all connected node in a routing table and nodes exchange tables with each other. DSDV is a type of proactive algorithm which is used in VANET. These protocols create a high overhead for network [4].

In reactive routing protocol, routes are discovered and maintained for only those nodes that are currently being used to send packets from source to destination.

AODV is an example of reactive routing protocol which uses an efficient method of routing that reduces network load by broadcasting route discovery mechanism and by dynamically updating routing information at each intermediate router. AODV reduces several problems that occurred in proactive routing protocols. AODV provides support by reacting at on demand needs for communication of such ad hoc network that have large numbers of nodes. And this can help when the sudden change in topology happens. AODV reduces flooding of messages in the network as compared to proactive routing protocols, so AODV reduces the network overhead.

## 6. Proposed method

Although using MPLS may result in improvement of E2E delay due to the fast processing of layer 2 headers, but it has its overhead for the wireless nodes, that move with fast speed more than 100 Km/h. Therefore, utilizing MPLS in wireless nodes that are vehicles in VANET for V2V communication may not have positive effect on QoS parameters like E2E delay, because negative effects of MPLS overhead on QoS may be more than MPLS benefits for it. As a result, we assume that each vehicle is covered by a base station, which has its own domain of service, and base stations are connected with a wired network named RBN and then we create MPLS domain in a wired domain. If vehicles send their data through base stations and the wired infrastructure, we can gain higher QoS than V2V ad hoc communication between vehicles.

Moreover we use AODV as a wireless Ad hoc routing protocol, because AODV imposes less overhead to the network. In comparison with proactive routing protocols, AODV requires less space to store routing information, and also consumes less bandwidth to communicate among neighbors for the highly mobile ad hoc network like VANET. DSR as an another reactive routing protocol have lots of characteristics in common with AODV, but its route cache and also source routing may result in more overhead for the network in comparison with AODV. Consequently it is not suitable for our scenario, so in this paper we choose AODV as a wireless routing protocol.

## 7. Simulation

In the simulation, using SUMO [10], which is a Java based software for simulating different mobility models, we created Manhattan mobility model in which vehicles are allowed to move along the grid of horizontal and vertical streets on the map. In this model as shown in Fig. 3, we have created a city area with multiple roads and traffic light on each intersection. Moreover, crossing from each junction of four lines is done with a specific probability for each line that their sum is totally one. In our scenario, five flows of vehicles that each group consists of 5 vehicles are moving in streets that are shown in Fig. 3 with red line arrows. At each intersection there is a traffic light that is also a base station, whose frequency range covers part of a road. We assume that each base station have 200 meters frequency coverage. Simulation parameters are depicted in table 1.

Table1- Simulation parameters

|                         |                       |
|-------------------------|-----------------------|
| Network area            | 652 * 752 M           |
| Channel type            | Wireless              |
| Radio range             | 200 m                 |
| Traffic type            | CBR                   |
| Visualization           | Nam, Sumo             |
| Mac                     | IEEE 802.11p          |
| Routing protocol        | AODV                  |
| Mobility                | Manhattan Mobility    |
| Number of vehicles      | 25                    |
| Number of base stations | 12                    |
| Vehicles Speed          | 40 km/h               |
| Transmission rate       | 64 Kbps               |
| Packet size             | 1000 byte             |
| Transport protocol      | UDP                   |
| Duration                | 200 s                 |
| Radio propagation       | Two Ray Ground        |
| Queue type              | Drop tail             |
| Addressing type         | Hierarchical- 3 level |

After designing mobility model, the output of SUMO [10] is exported to NS2.34 for the main test. In NS2.34 we have 12 base stations which are situated on each junction and capable of communicating between wired and wireless nodes. Base stations are MPLS enabled nodes, which are connected through a wired network that is a MPLS domain. The Proposed design divides VANET into a number of domains, in which any node including vehicles and base stations has hierarchical address. In our Scenario each base station has its own domain for addressing in 3 levels of domain, sub domain and cluster. Also vehicles that are, wireless mobile nodes constitute a separate domain which is covered by base stations according to their physical position in moving toward destination. Base stations are responsible for communicating between vehicles and the wired domain that is the MPLS domain. Transport protocol of the simulation is UDP, because UDP can be faster than TCP for transporting critical alerts.

In our scenario we suppose that vehicles that are near node 6 of Fig. 3 see a heavy traffic, which is caused by an accident and one of them want to send a message to the first roadside unit that is node10 to warn other vehicles about this event. In VANET, by using AODV routing protocol which is a multi hop and reactive routing protocol, vehicles send data among each other and RSUs to receive at destination. But in the proposed method, each vehicle sends data to its nearest base station and the base station that is connected to the other base stations through a wired network we send data on the MPLS domain to the destination. Using this method, we achieve better QoS in terms of E2E delay, throughput and packet loss.

Because of the faster forwarding of MPLS nodes in comparison with IP nodes and also wireless nodes which are mobile nodes with high speed more than 100 Km/h better E2E delay achieved. Fig. 5 shows a line graph which compares E2E delay in two states: Ad hoc V2V routing and V2I MPLS enabled routing. According to Fig. 5, in the proposed method the delay has a minimum fluctuation and has a constant rate near micro seconds. In V2V Ad hoc mode, due to the reactive nature of AODV, routing of first packets may take some milliseconds to establish route between sender and receiver. As a result, we see a significant drop in delay near first 3 packets. After route establishment, delay is fluctuating near

0.1 milliseconds. As shown in Fig. 5, in proposed method delay have constant rate with minimum fluctuation near microseconds, which is much lower in comparison with V2V ad hoc mode.

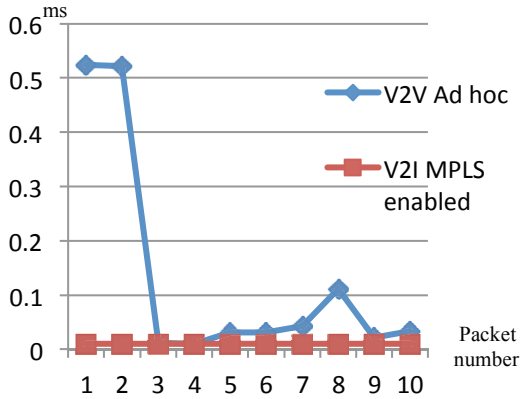


Fig. 5 End to end delay

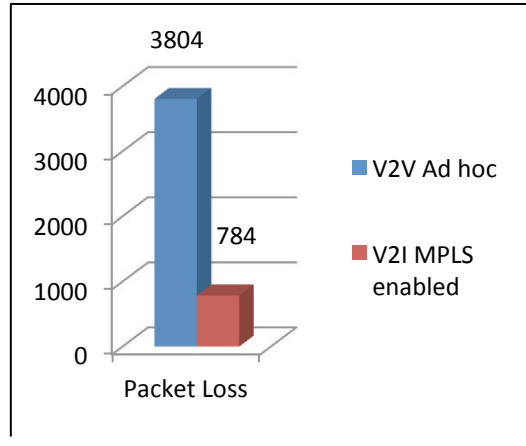


Fig. 6 Packet Loss

Due to the high mobility and also inconsistent nature of VANET during routing a packet with AODV, lots of packet drop may happen. As a result, sending critical data like quick warning alert should be sent through a reliable infrastructure to be useful for accident prevention. Using MPLS in a RBN, we have decreased the packet loss to the one-fifth of AODV Ad hoc routing in the V2V state. Fig. 6 indicates packet loss in two states.

Furthermore, throughput is also improved because of higher reception of data bytes at destination, and also minimum probability of link breakage in wired network. Fig. 7 is a bar chart which compares throughput between two states of V2V ad hoc and V2I MPLS enabled.

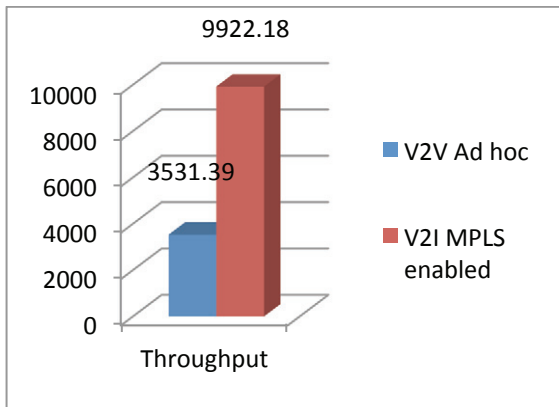


Fig. 7 Throughput

### 8. Conclusion

In this paper, the idea of using MPLS in VANET, specifically in the roadside backbone network to gain better QoS is introduced. Due to the unreliability of V2V communications, we propose a method for vehicles in urban areas to send data to the nearest base station and after that data is sent via wired RBN which is MPLS domain, and have higher reliability in terms of E2E delay, packet loss and throughput.

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