JACET Journal of Advances in Computer Engineering and Technology, 3(3) 2017

# Improving QoS in VANETs: A Survey

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Received (2017-04-05)
Accepted (2017-08-26)

*Abstract* — **The systems in which information and communication technologies and systems engineering concepts are utilized to develop and improve transportation systems of all kinds are called "The Intelligent Transportation Systems (ITS)". ITS integrates information, communications, computers and other technologies and uses them in the field of transportation to build an integrated system of people, roads and vehicles by utilizing advanced data communication technologies. Vehicular Ad-hoc Networks which is a subset of Mobile Ad-hoc Networks, provide Vehicle to Vehicle (V2V), Vehicle to Roadside (V2R) and Vehicle to Infrastructure (V2I) communications and plays an important role in Intelligent Transportation System. Due to special characteristics of VANETs, QoS (Quality of Service) provisioning in these networks is a challenging task. QoS is the capability of a network for providing superior service to a selected network traffic over various heterogeneous technologies. In this paper we present an overview of Vehicular Networks, QoS Concepts, QoS challenges in VANETs and approaches which aim to enhance the Quality of Service in Vehicular Networks.**

*Index Terms* —**VANET, Vehicular Networks, Quality of Service (QoS), Delay, Packet loss, Throughput**

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## I. INTRODUCTION

### *A. Vehicular Networks*

Traffic safety is a major challenge recognized by the major players in the automotive industry and by many governments. According to [2] each year thousands of road accidents are reported in any country. Traffic accidents are most of the times a result of the driver's failure to access quickly and correctly the driving conditions. Normally drivers have imperfect information about road situations, speed and position of vehicles around them and usually are compelled to make decisions like breaking and lane changing without the benefit of whole data. "The need for communication when the deployment of any fixed infrastructure is impossible and the advancement of computer and wireless communication technologies, led to the development of Mobile Ad-hoc Networks (MANETs)" [3]. MANETs are kinds of wireless networks which are self-configuring and infrastructure-less. Nodes are connected together without any fixed topology and each device in MANET is free to move independently in any direction, and will therefore change its links to other devices repeatedly. All nodes that take part in such a networks must forward the traffic unrelated to its own use, and play the role of a router. During the last years, researchers awarded a great interest to the deployment of MANETs to improve road safety, then, and as a result, Vehicular Ad-hoc Networks emerged [3]. Vehicular Ad-hoc Networks as a subset of Mobile Ad-hoc Networks which provide data exchange via Vehicle-to-Vehicle (V2V), Vehicle to Roadsides (V2R) and Vehicle to Infrastructure

(V2I) communications and a car which takes part in such a network is equipped with a WLAN and cellular communication device [6]. VANETs is also defined as a wireless communication technology which is also able to enhance driving safety and velocity by exchanging real-time transportation information, and "it should upon implementation, collect and distribute safety information to massively reduce the number of accidents by warning drivers about the danger before they actually face it" [5]. In addition, VANETs are also able to minimize incidents and improve traffic conditions by providing vehicles, drivers and passengers with information about the road condition. VANET has its own unique characteristics when compared with other types of MANETs, the unique characteristics of VANET include: predictable mobility, lack of powers constraints, variable network density, Rapid changes in network topology, High computational ability and large scale networking [7].

### *B. VANET Architecture*

The architecture of VANET consists of mobile nodes (vehicles), Base Stations (which could be a BTS, access point, or a Road Side Unit) and a core network [8]. Fig. 1, shows the main components of VANET architecture.

As it is described by authors in [7], the main system units are Application Unit (AU), On Board Unit (OBU) and Road Side Unit (RSU). An OBU is a device that is mounted on-board a vehicle and is used for exchanging information with other RSUs or OBUs. "The AU is the device equipped within the vehicle that uses the application provided by the provider using the communication capabilities of the OBU" [7], and the RSU is another component which is usually fixed along the road side or in dedicated locations such as at junctions or near parking spaces and is used for several purposes.

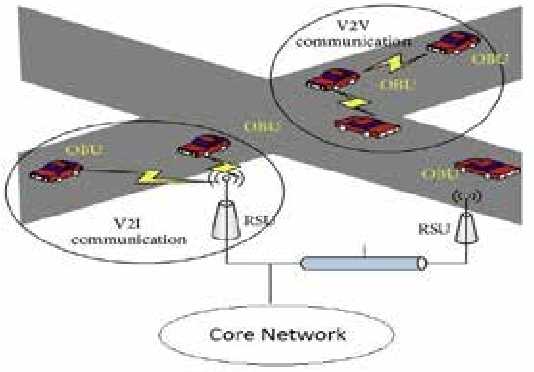


**Fig. 1. Architecture of Vehicular Networks**

For instance, RSUs extend the range of networking, work as an information source and provide internet connectivity for OBUs. Typically the RSU hosts an application that provides services and the OBU is a peer device that uses the services provided. The application could be installed in the RSU or in the OBU. The provider is a device that hosts the application and the user is another device which uses the application. "Each vehicle is equipped with an OBU and a set of sensors to collect and process the information, then send it on as a message to other vehicles or RSUs through the wireless medium" [7].

### *C. Communication Technologies and Handover in VANETs*

Nodes in VANETs need to be connected to each other in order to communicate together and send and receive data, so wireless communication technologies play an important role in this network. A suitable wireless technology for VANET should support high data rate, network access charge, Quality of Service and security. The technologies that are used for vehicular communications are: Dedicated Short Range Communication (DSRC) [36], Wi-Fi [35], Worldwide Interoperability for Microwave Access (WiMAX) [37], and cellular communications like GSM [17], GPRS [19], EDGE [22], UMTS [32], 3G [33], and LTE [34]. Fig. 2. Presents the types of communication used in VANETs. At this time, there are multiple ways for supporting vehicular communications, therefore making a seamless handover decision to guarantee the QoS of wireless communications for a vehicle moving in the regions covered by more than one access network is essential. QoS provisioning for the communications of a vehicle moving in the regions covered by more than one access networks is a challenging task. How to make handover decision is a challenging problem and the demands of vehicles should be satisfied while the overall network performance is optimized [40]. Several internetworking mechanism for combining WLANs and cellular networks into integrated wireless environments have been proposed [38, 39]. In addition, in [40] a controller to operate an algorithm is proposed which guarantees the performance of optimized handover decision. The controller collects real time traffic information, then it informs the vehicle of an appropriate access point. The optimization is a well-defined objective function which includes consideration of the data rate of overall network and load balancing across access points and each vehicle's demand should be satisfied to ensure their fairness to a certain extent.

*D. VANET Applications*

Applications of Vehicular Networks are divided into safety and non-safety services. The applications regarding safety are strictly tied to the main purpose of transportation; moving from a point till to destination, like avoiding emergencies and collision prevention. For example, if a vehicle was required to slow down due to an accident ahead, it would broadcast warning messages to adjacent vehicles. The vehicles behind it will thus be warned before they actually see the accident, helping the drivers react faster, thereby preventing rear ending of vehicles [1]. Other examples of safety applications are emergency brake light, accident annunciation, providing information about road conditions, etc. Non-safety applications include commercial and entertainment applications and they include a wide range of future multimedia and data applications such as e-maps, internet surfing, parking space locator, online gaming, etc. The requirement of these applications is the availability of high bandwidth and scalable internet connectivity [9]. Vehicular Networks are also considered to be a green technology. In order to reduce the amount of CO2, vehicles may collaborate with each other and road infrastructures. Recent research [10] has shown that vehicular communications can be used to advise drivers in order to optimize their driving and prevent unnecessary stops to reduce fuel consumption and CO2 diffusion.

The rest of this paper is structured as follows: In section II we present an overview of QoS concepts and QoS challenges in vehicular communications. In section III previous works and proposed ideas which aim to improve QoS in Vehicular Networks are discussed, before the conclusion in section IV.

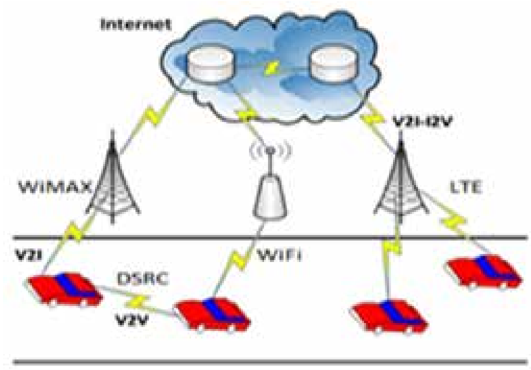


**Fig.2. Communication types in Vehicular Networks**

## II. QUALITY OF SERVICE

Quality of Service (QoS) is the ability of a network to provide improved service to selected network traffic over various underlying technologies, including frame relay, ATM, Ethernet, SONET, and IP-routed networks and offers flexibility, scalability, efficiency, adaptability, software reusability, and maintainability. "QoS is also 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" [4], in fact it is the measure of how satisfying a service is as presented to the end-user. QoS provisioning often needs negotiation between host and network, call admission control, resource reservation, and priority scheduling of packets [12]. QoS can be rendered in network thorough several ways: per flow, per link, or per node. In particular, QoS features provide improved and more predictable network service by supporting dedicated bandwidth, improving loss characteristics, avoiding and managing network congestion, network traffic shaping, and Setting traffic priorities across the network [13].

As it is mentioned, QoS is quantitatively defined in terms of guarantees or bounds on certain network performance parameters. The most important performance parameters are the bandwidth, delay, jitter, and packet loss. The term bandwidth describes the size of the pipe that an application program needs in order to communicate over the network. The channel bandwidth determines the channel capacity, which is the maximum information rate that can be transmitted [14]. The delay of a network specifies how long it takes for a bit of data to travel across the network from source to destination. It is typically calculated in multiples or fractions of seconds. Jitter is defined as a variation in delay of received packets. The sending side transmits packets in continues stream and spaces them evenly apart. "Because of network congestion, improper queuing, or configuration errors, the delay between packets can vary instead of remaining constant" [15]. Packet loss is one of the other important QoS parameters. Actually there are some applications which may not function perfectly, or may not work at all, when the packet loss rate is high. For instance, when streaming video frames, after certain number of lost frames, the video streaming may become useless, this number may be zero in certain cases, therefore, certain guarantees on the number of rate of lost packets may be required by certain applications for QoS to be considered. Packet loss can occur because of packet drops at congestion points when the number of packets arriving significantly exceeds the size of the queue. Corrupt packets on the transmission wire can also cause packet loss [14].

Providing QoS support in ad-hoc networks is a dynamic research area. VANETs have certain unique characteristics that facade several intricacy in QoS provisioning. The characteristics that affect QoS provisioning in these kinds of networks are: dynamic varying network topology, inaccurate state information, lack of central coordination, error prone shared radio channel, hidden terminal problem, limited resource availability and insecure medium [12]. There are several approaches in literature specially designed for providing QoS in MANETs but could not be used in VANETs, because they do not consider the high mobility constraints, large scale node population and large scale networking in urban areas [16]. QoS parameters such as packet loss, throughput, jitter and latency are the main requirements in vehicular communications. Each application in VANETs has its own requirements, 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 factors that are very important in active safety applications [11].

## III. QOS PROVISIONING IN VEHICULAR NETWORKS

### *A. Improving QoS in VANET Using MPLS*

Authors in [11] investigated using Multiprotocol Label Switching (MPLS) in a roadside network to improve overall QoS of VANET. This approach is useful for sound and video transportation in VANETs, which will be the most important applications of VANETs in near future. MPLS is a forwarding method which can assign packets to different forwarding equivalent class (FEC) for receiving the required service from the network to support QoS. MPLS is considered as layer 2.5 protocol [18] and it is compatible with any layer 2 technology, like Ethernet and ATM. Moreover, MPLS directs data from one network node to the next, based on short path labels rather than long network addresses, avoiding complex lookups in a routing table. Using MPLS in communication networks provides many advantages such as faster routing (due to the labeling technology, the speed of performing lookups for destinations and routing in MPLS-based routers is much faster than the standard IP-based routers), providing better QoS and traffic engineering. However, MPLS is a suitable technology for communication networks with fixed nodes and infrastructure, therefore MPLS has its overhead for the wireless nodes in VANETs that move with fast speed more than 100 Km/h. 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.

Therefore, in [11] vehicular communications are divided into two categories; Vehicular Ad-hoc Networks which includes V2V communications and a Roadside Network which consists of

Roadside Access Network (RAN) and Roadside Backbone Network (RBN). RAN enables the V2I communications and RBN represents the backbone network of RSUs, in which RSUs communicate with each other [18]. In this paper it is assumed 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 MPLS is enabled in the wired backbone network (Fig. 3. shows the proposed architecture in [11]). As we mentioned, there are two types of communications in this work: V2V and cell-based communications.

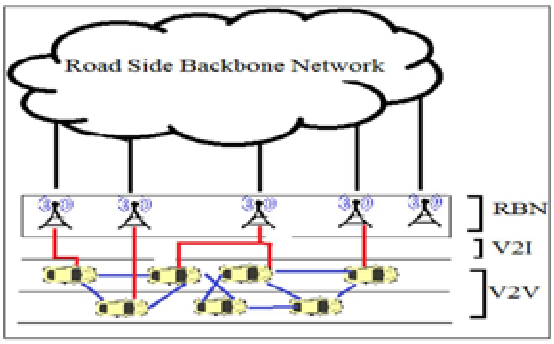


**Fig. 3. Vehicular Communication Pattern in [11]**

V2V ad-hoc communications is done by using AODV routing protocol internally in VANET [20] and the cell-based communications which transmits packets to other base stations and vehicles by using the MPLS enabled RBN. The hypothesis is that, if vehicles send their data through the base stations (the wired infrastructure-RBN), it is possible to gain higher QoS than V2V ad-hoc communication. Finally authors used SUMO [23] to design Manhattan mobility model and then they exported the output of SUMO to NS2.34 for the main test.

Results show that in comparison to AODV (for V2V ad-hoc communications), the MPLS enabled road side backbone network provides better QoS in terms of E2E delay, packet loss and throughput,. Table 7 provides more information in detail and table 1, discusses about the advantages and disadvantages of the proposed idea in [11.]

**Table 1. Advantages and disadvantages of the proposed idea in [11]**

| Main Idea | Advantage | Disadvantage |
|---|---|---|
| Using MPLS based backbone | Improves QoS impressively by using standard protocols | It is not cost effective because it need many new hardware and equipment.<br>It is only suitable for a few kinds of network traffics in VANETs |

*B. Utilizing Mobile IP and MPLS to Improve QoS in VANET*

Mobile IP is the running standard for supporting IP mobility of mobile nodes in the wireless networks with infrastructure. Moreover, Mobile IP enables the mobile node to access internet and changes its access point without losing the connection [43]. Mobile node (MN), Home Agent (HA), Foreign Agent (FA) and Care-of-Address (CoA) are the main components of Mobile IP. When the MN moves away from HA to the foreign network, a CoA is assigned to it in order to inform the HA of its current location. This operation enables MN to send and receive at any location without going through HA.

In the last section we discussed about using MPLS in a wired backbone network and the results showed that an MPLS based roadside backbone network improves QoS. In order to connect moving vehicles to the infrastructure, which can be an Internet router, packets must have address that is valid for both wired network and also Ad hoc network of vehicles. When a vehicle moves far from the coverage area of its access point or base station, to be able to send and receive packets of Internet server to/from it, packets should be addressed dynamically. The mobile node in VANET which is a vehicle should be in the coverage range of Mobile IP base station and must be connected to it directly. Therefore authors in [21] integrate VANET with QoS support using MPLS for forwarding (which is proposed in [11]) and Mobile IP for continuous connection between vehicles and base stations.

Simulating the proposed idea, 3 methods are compared in terms of throughput, packet loss and delay. In the first method, packets are sent by source nodes to the destination vehicles or base stations in a completely wireless mode through base stations and vehicles by using AODV routing protocol. The second method, which is proposed in [11], base stations are connected through an MPLS enabled wired backbone network and in the third method, the wired backbone network is used with MPLS, and Mobile IP is enabled on each node to have stable connection for mobile nodes. Although using Mobile IP instead of static addressing imposes overhead for network, but packet loss and throughput of network is improved.

The achieved results show that in comparison to MPLS enabled scenario in [11], using Mobile IP doesn't have positive effect on delay but improvement is seen in packet loss rate and throughput. Table 2, provides a comparison between the proposed idea in [21] and the MPLS based backbone architecture discussed in [11] and AODV.

**Table. 2. Advantages and disadvantages of the proposed idea in [21]**

| Main Idea | Advantage | Disadvantage |
|---|---|---|
| Using MPLS based backbone + Mobile IP | Uses standard, worldwide known protocols and provides improved throughput and packet loss rate in comparison to AODV routing protocol and the MPLS based backbone architecture proposed in [11] | Costly to implement. Increases delay, in comparison to MPLS based backbone architecture |

*C. Improving the Quality of Service in the VANET by Detecting and Removing Unused Messages*

Authors in [1] tried to improve the performance of the VANETs by removing the useless or unused packets. For this purpose they considered the following scenarios:

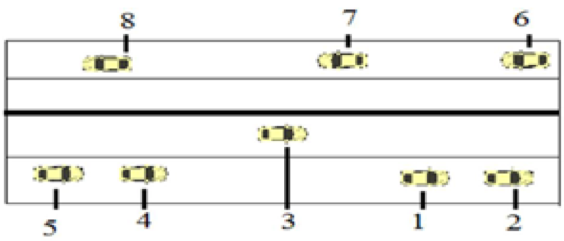


**Fig. 4. Impact of vehicles position [1].**

Scenario1: consider a highway that has at least two lines for car traffic (Fig. 4). Assume that car 1 brakes suddenly.

In this vehicle, Emergency Electronic Brake light Application sends a message in its area. In this way other vehicles that receive the message must have a proper response. Vehicles that are in the same line and are behind the car1 – such as 4 and 5 – after receiving and processing of the received message from car 1 they must reduce their speed. Although car 3, 6, 7, 8 and 2 receive these messages and after receiving the safety message they can remove it. In this special safety application, the position of vehicles has influential effect on their reactions [1]. According to this scenario if car 3 brakes and sends a safety message, car 1, 4 and other cars receive this message, but according to their position they do not have to do any reaction.

So all cars which receive this message do not need to process it and without any processing they can drop it. If we do not have this idea, each car which receives the safety message should process it and according to the type of that message, each car should do a reaction [1].

Scenario2: In this scenario as shown in Fig. 5, suppose that car 1 brakes abruptly and sends a safety message over its area.

Each car which receives the sent message will be forced to react and send a safety message according to its situation. If we review the scenario, we will see that the received safety message for vehicles far from the source vehicle such as 4 and 5 is less important that closer ones. In this scenario all of the cars in the same lane and according to the previous scenario all of them must process the message after receiving and then show a proper reaction according to the type of the received message. But we know that when car 1 braked, car 2 which is the nearest car behind to it must react quickly. Car 3 which is so far away from car 1 does not need to do any reaction because of its distance to car 1. In this proposed approach, each vehicles must be able to compute the distance between itself and another and also be able to detect and remove the unused messages.

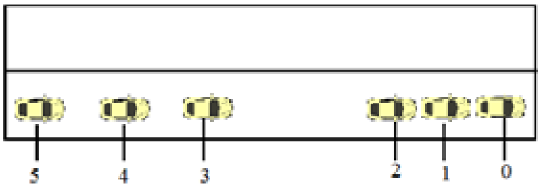


**Fig. 5. Impact of distance between vehicles [1].**

After simulation, authors concluded that with the help of the proposed algorithm in [1] the message expiration ratio will be reduced. More information about this research is presented in tables 3 and 7.

**Table. 3. Advantages and disadvantages of the proposed idea in [1]**

| Main Idea | Advantage | Disadvantage |
|---|---|---|
| Detecting and Removing Unused Messages | Reduces network message expiration ratio. Does not need additional hardware and equipment for implementation | The main QoS parameters such as throughput and delay are not discussed |

*D. Anchor bus based street and traffic aware routing (ABSTAR)*

The history of VANET routing protocols starts from traditional MANET protocols such as Ad-hoc On Demand Distance Vector (AODV) [24] and Dynamic Source Routing (DSR) [25]. There are also other proposed approaches like MDDV [27], VADD [28], and SADV [29]. In city environments there are buildings, towers, trees and other obstacles and they could rise several problems in direct communication between vehicles [26]. Most of the existing protocols face problems in data delivery in presence of obstacles in city environments. Therefore existing protocols may not perform good enough in metropolitan areas according to various reasons such as frequently network disconnection, multiple hops, routing loops, and incorrect route selection. Authors in [26] proposed a new routing protocol called ABSTAR which aims to overcome some of the mentioned limitations. ABSTAR is based on a localization system like the GPS (Global Positioning System). Moreover, by considering the real-time road traffic and urban environment characteristics, it aims to efficiently relay data in the network. In addition, in this protocol an actual city configuration with multi-lane and double direction road is considered, so ABSTAR is able to consider the information about the speed of cars and their directions. Furthermore, by reducing the control message overhead and routing data packets from sources to destinations in the vehicular communications with a reduced end to end delay and packet loss rate, ABSTAR uses the network resources (i.e. bandwidth) more efficiently. The main unique characteristic of ABSTAR is its ability to sense about the type of vehicles since each vehicle shows its own specific characteristics depending on its behavior [26]. In addition, ABSTAR is an intersection-based geographical routing protocol, which is able to find robust and efficient routes in the urban environments. In this routing protocol there are three main issues: Junction Selection, Forwarding packets between two junctions and sense about type of vehicle.

In ABSTAR, the packet is passed through various junctions in order to reach its destination. This junction selection is a dynamic event and is selected one by one (in order) based on real time vehicular traffic variation. The sending vehicle or an intermediate vehicle in a junction will select its next destination junction by finding the position of the neighboring junctions with the help of a map. A score is calculated to each junction by considering the traffic density (the measure of the traffic density between the current intersection and potential intersection) and the curve metric distance (it is the measure of the distance to the destination in road length. Shorter distances to the destination is preferred) to the destination [26] and then the junction with the highest score is the best destination junction.

"After selection of destination junction, the data packets must be forwarded towards the selected destination junction by using improved greedy strategy" [30]. When the destination junction is determined, the improved greedy strategy is used to forward packets to the selected junctions. (Note: all these data packets are labeled by the location of this destination junction). Statically and dynamically rated maps are also used in ABSTAR, for finding the number of junctions. In statically rated maps, the schedule of buses is used for providing a good connectivity and in dynamically rated maps [41], ABSTAR collects the latest information of traffic in order to find the path. Here the entire vehicle maintains a separate neighbor table in which velocity, position and direction of each neighbor vehicle are recorded. Updating of this table is done through HELLO messages which are exchanged periodically by all vehicles. Thus, when a packet is received, the forwarding vehicle computes the next junction and also selects a route with lower number of buses.

Finally authors simulated their proposed protocol and compared it with Greedy Perimeter Coordinator Routing (GPCR) [31]. The simulation results show that ABSTAR provides better rates in terms of byte overhead, routing overhead and delivery ratio. As additional hardware and equipment is not needed for using ABSTAR, it could be called a cost-effective approach to implement, but before making any comment about this approach, ABSTAR must be compared to other standard protocols such as AODV and DSR and must be compared in terms of delay and bandwidth utilization too.

### *E. A Novel Protocol Stack for Improving QoS in Vehicular Networks*

In [42] authors proposed a novel protocol stack aiming to improve the QoS in vehicular networks. In this protocol stack, layer 3 and layer 4 of the well-known TCP/IP protocol stack are modified. In the proposed architecture, geographical regions are divided into 25 unique areas and in each area there are 9 WiMAX base stations which provide wireless access to the vehicles and they are connected together with a wired network. These WiMAX base stations operate as a wireless switch for in-cell communications and a gateway for out-of-cell communications. Moreover, Cars communications is also restricted, and each car could only communicate with other cars and base stations in the other 24 areas around it. VCNP (Vehicular Communication Network Protocol) is the proposed layer 3 protocol in [42] for vehicular communications. There are some differences between VCNP and Internet Protocol (IP). As we know, there are four octets for each of source and destination address fields in IP but in VCNP using 3 octets instead of four is proposed. The first octet represents the area, the second octet represents the base station and the third octet represents the vehicle, so any node will have a unique layer 3 address and according to the restricted communication domain, it will be possible to reuse layer 3 addresses several times in other areas.

In addition, a new transport is also proposed in [42] aiming to provide the high throughput of UDP, as well as the packet loss rate of the TCP. VCTP is similar to UDP in terms of source port, destination port and checksum fields but in contrast to UDP, there is a recovery option as well as a handshaking process. VCTP also guarantees that the sent packets will reach to destination.

Finally authors simulated their proposed protocol stack and compared it with a similar scenario in which TCP/IP protocol stack was used. The type of communication that was used in the simulation was Vehicle to Roadside to Vehicle (V2R2V). The results show that the proposed protocols provide better rates in terms of delay, packet loss and throughput. Table 4 and 7 discuss about the proposed protocol stack in [42] in details.

**Table 4. Advantages and disadvantages of the proposed idea in [42].**

| Main Idea | Advantage | Disadvantage |
|---|---|---|
| Using a novel layer 3 and layer 4 protocol for vehicular communications | Improves QoS in comparison to a similar but TCP/IP based scenario.<br>Provides better security because of using unique protocols for vehicular communications | Does not use standard protocols and therefore it is a time-consuming task to implement it.<br>Additional hardware are needed, because nodes in VANETs need to be connected to other networks that use standard protocols. |

### *F. Improving QoS in VANETs by Using AOMDV Routing Protocol*

In [44], the performance of AODV and AOMDV routing protocols are compared in terms of packet loss, throughput and packet delivery ratio. Ad-hoc On Demand Distance Vector (AODV) is a routing protocol developed for wireless mobile ad-hoc networks. It is a reactive or on demand routing protocol which uses bi-directional links and provides unicast and multicast communications.

In AODV route discovery cycle is used for route finding and routes are maintained just as long as necessary. More information about AODV is available in [45]. Ad-hoc on demand multipath distance vector (AOMDV) is also a reactive routing protocol which is an extension of AODV. It is developed to overcome the drawback of single path routing protocols such as AODV. More information about AOMDV could be found in [46]. In [44], authors propose using AOMDV instead of using AODV for improving QoS in VANETs. In this work, nodes are randomly distributed and communicate among themselves over a wireless channel with the Wi-Fi network. NS.2 is the simulation tool in which the mentioned scenario is implemented. The achieved results show that in comparison to AODV routing protocol, AOMDV is able to increase the packet delivery ratio up to 91%, reduce the packet loss ratio up to 9% and increase the throughput up to 9 to 10 mbps. In table 5, the advantages and disadvantages of using AOMDV in VANETs is discussed.

**Table 5. Advantages and disadvantages of the proposed idea in [44].**

| Main Idea | Advantage | Disadvantage |
|---|---|---|
| Using AOMDV routing protocol instead of AODV in vehicular communications | Provides better QoS in comparison to AODV<br>Does not need additional hardware for implementation | Authors did not discuss about the bandwidth utilization and routing overhead.<br>In similar scenarios, using multipath routing protocols increase bandwidth utilization and routing overhead. |

*G. Bee Inspired QoS Routing for improving QoS in VANET*

Discussing about the bee inspired QoS routing algorithm for VANETs, we must explain about bee's foraging process.

The bee's foraging process begins with some scout bees leaving their hive to fly lengthy distances in many directions for finding food. When the scout finds a food source, it takes a sample of the food and transports it back to the hive. The scout bees then do a waggle dance to lead other bees in the hive to visit the food source. In [47], an agent-based clustered network is proposed for QoS routing in VANETs. This routing scheme is inspired by the natural bee communications paradigm and aims to reduce packet loss rate and increase throughput in vehicular ad-hoc networks. Three types of agents are used in the proposed routing scheme which are listed in table 6. The deployment of these agents is illustrated in a conceptual VANET scenario in Fig. 6.

Vehicles that are within the communication range to the nearest smart agent (SA) are connected together forming a cluster as shown in Fig. 6. The SA is situated along the street and at intersection are connected to the neighboring Routing Agent (RA).

**Table 6. The types of agent used in [47]**

| Agent | Description |
|---|---|
| Smart Agent (SA) | This is a portable agent placed at the strategic location along the street and at intersections. It maintains the routing information and the network traffic database for vehicles within its communication range. |
| Route Agent (RA) | Basically for route discovery and to establish the connection between the vehicles in the cluster. |
| Onboard Agent (OBA) | Agent equipped with transceiver fixed inside the vehicle for communication purposes. Responsible for collecting vehicle status and to linked up with GPS services to provide vehicle location. |

In a nutshell, the proposed routing algorithm starts with a mobile agent, a scout, leaving the base station (beehive) to search for a destination node (food source). Once the destination is found, the mobile agent sends the achieved information (the location of destination) to the source node. The mobile agent must also accumulate the QoS route information during the process of discovering the destination node.

The proposed scheme uses two agents, the scout (RA) and the forager agent (OBA) for QoS route discovery. The scout agent can be the forward scout or the backward scout. These scout agents are launched by the source vehicle to discover QoS route to the intended destination.

**Table 7. A comparison between all the reviewed papers**

| The Proposed Idea | Results are compared to | Delay | Packet loss | Throughput | Message Expiration Ratio | Packet Delivery Ratio | Routing Overhead |
|---|---|---|---|---|---|---|---|
| **Using MPLS Based Backbone [11]** | V2V AODV Routing Protocol | Decreased | 80 % decreased | Increased up to 180% | Not discussed | Not discussed | Not discussed |
| **Using MPLS and Mobile IP [21]** | V2V AODV Routing Protocol and MPLS enabled mode in [11] | No positive effect on delay | In comparison to AODV: Decreased by 72%<br><br>In comparison to MPLS enabled mode: Decreased By 40% | In comparison to AODV: Increased by 147%<br><br>In comparison to MPLS enabled mode: Increased by 30% | Not discussed | Not discussed | Not discussed |
| **Detecting and Removing Unused Messages [1]** | A similar scenario in which the unused messages are not detected and removed | Not discussed | Not discussed | Not discussed | Reduced by 64 % | Not discussed | Not discussed |
| **A new routing Protocol – ABSTAR [26]** | Greedy Perimeter Coordinator Routing Protocol | Not discussed | Not discussed | Not discussed | Not discussed | Increased by 133% | Reduced by 80% |
| **A Novel Transport and Network Protocol for VANETs [42]** | TCP/IP protocol stack | Decreased by 28% | Decreased by 1% | Increased by 133% | Not discussed | Not discussed | Not discussed |
| **Using AOMDV Routing Protocol in VANETs [44]** | AODV | Not discussed | Reduced by 9% | No impressive increase is seen | Not discussed | Increased up to 91% | Not discussed |
| **Bee inspired QoS Routing for Improving QoS in VANETs [47]** | AODV & DSR | Not discussed | In comparison to DSR: Reduced by 45%<br><br>In comparison to AODV: Reduced by 23% | In comparison to DSR: Increased up to 78%<br><br>In comparison to AODV: Increased by 35 % | Not discussed | Not discussed | Not discussed |

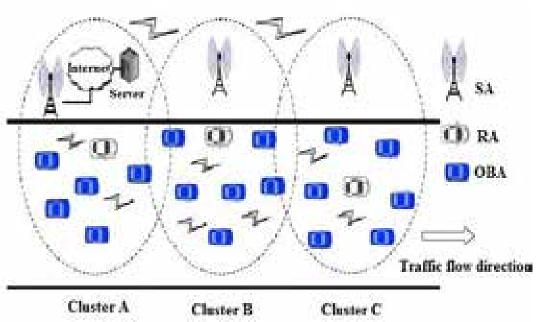


**Fig. 6. Deployment of agents in a conceptual VANET in [47]**

The discovered QoS route information shall then be conveyed back to the source vehicle via the route reply process. The forward scout agent guarantees to explore the whole network for discovering routes to the intended destination. It also gathers routing information during its route discovery process. The backward scout conveys the information about route to the source and the forager agent deals with data packets forwarding operation i.e. it determines the data packets used for broadcasting the data packets.

Finally authors simulated the bee inspired routing protocol by using NCTUns-6.0 simulation tool. Two urban-like VANET environment were setup for comparing the proposed scheme against the two widely used Ad hoc On-Demand Distance Vector (AODV) and Dynamic Source Routing (DSR) protocols. The CBR/UDP traffic were used in all three algorithms. All nodes were moving in the same direction and were made to stop for a specific time defined by the pause time duration. The simulation results show that the proposed algorithm in [47] increases throughput up to 78% in comparison to DSR and 35% in comparison to AODV routing protocol. The results were also compared in terms of packet loss rate. The bee inspired routing protocol reduces packet loss rate by 45% in comparison to DSR and by 23% comparing to AODV.

## IV. CONCLUSION

VANET is emerged to provide safety of transportation by providing V2V and V2I communications. Because of special characteristics of VANETs like, high mobility, bandwidth limitation, variable network density and large scale networking, QoS provisioning in these networks is a challenging task. In this paper, after reviewing the architecture, applications, characteristics and challenges of VANETs, we presented a survey on QoS concepts and approaches which enhance the level of QoS in vehicular communications. Many works have been reviewed in this paper, some of them focused on providing routing algorithms which do not require additional hardware and equipment for implementation. Some of the other works, discussed about using MPLS and wired technologies in VANETs. All in all, the available researches in the literature focus on different architectures and parameters and it does not let us to have a complete and great conclusion. In addition, many research attempts these days go into improving QoS a little bit. These attempts often work with simulation studies which rarely or never are really validated, lead to very marginal improvements and have near zero practical impacts. Therefore, for the future works we suggest VANET researchers to do more practical researches and consider at least, the main QoS parameters in their works, and compare the results with other similar protocols and algorithms in the state of the art.

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