Recent Multicast Routing Protocols in VANET: Classification and Comparison

[1]Ahmed Jawad Kadhim **[2]Seyed Amin Hosseini Seno**

[1,2]Faculty of Engineering, Ferdowsi University of Mashhad, Mashhad, IRAN

ahmed.kadhim@mail.um.ac.ir hosseini@um.ac.ir

Abstract

Vehicular Ad Hoc Network (VANET) classified as one of the most important classes of next generation networks that developed in recent years rapidly for vehicles and road transmissions. It can help in implementing a large set of applications related to vehicles, traffic light, traffic jam, drivers, passengers, ambulance, police, fire trucks and even pedestrians. Routing is the most prominent problem in the transmission of information in VANETs and there are many modes of dissemination: unicast, broadcast, multicast and geocast. In this paper, we will focus only on the multicast that is referring to a process of sending information from one node (called source vehicle) to a group of nodes that found in different locations (called destination vehicles). The purpose of this paper is to study the existing multicast routing protocols in VANET and produce good survey about them and determine the advantages and disadvantages of each one as well as classify them into different categories based on some effected parameters such as quality of service, vehicle trajectory and etc. After analyzing these routing protocols we concluded that there is persistent need to produce efficient multicast routing protocol in this network to decrease the resource consumption and improve the overall performance.

Keywords: VANET, Multicast, Routing Protocols, QoS, Vehicle Trajectory.

الخلاصة

الشبكة المخصصة للسيارات (VANET) صنفت باعتبارها واحدة من أهم فئات شبكات الجيل التالي التي طورت في السنوات الأخيرة بسرعة بالنسبة للمركبات وعمليات نقل الطرق. هذه الشبكه يمكن أن تساعد في تنفيذ مجموعة كبيرة من التطبيقات المتعلقة بالمركبات، اشارة المرور، ازدحام المرور، السائقين، الركاب، الإسعاف، الشرطة، سيارات الإطفاء وحتى المشاة. التوجيه هو المشكلة الأبرز في نقل المعلومات في الـــ VANET وهناك العديد من وسائط النشر: البث الاحادي، البث المتعدد و البحث في منطقه جغرافيه معينه (geocast). في هذه المقاله سوف نركز فقط على الإرسال المتعدد الذي يشير إلى عملية إرسال معلومات من عقدة واحدة (تسمى المركبة المصدر) إلى مجموعة من العقد الموجودة في مواقع مختلفة (تسمى المركبات الهدف). والغرض من هذه المقالة هو دراسة بروتوكولات توجيه الإرسال المتعدد الموجودة في الـــ VANET وإنتاج دراسه جيد عنها وتحديد مزايا وعيوب كل منها وكذلك تصنيفها إلى فئات مختلفة استنادا إلى بعض العوامل المؤثرة مثل نوعية الخدمة، مسار المركبة وما إلى ذلك. وبعد تحليل بروتوكولات التوجيه هذه وجدنا أن هناك حاجة ملحة لإنتاج بروتوكول توجيه متعدد الإرسال فعال لهذه الشبكة لتقليل استهلاك الموارد وتحسين الأداء العام.

الكلمات المفتاحية: الشبكه المخصصة للسيارات، البث المتعدد، بروتوكولات التوجيه، جودة الخدمة، مسار المركبة.

1. Introduction

Vehicular network or as it is called VANET is witnessing increasing attention from a large number of the vehicle manufacturers, the academic community and governments, which want to exchange information efficiently among vehicles or between vehicles and roadside unit (RSU) that distribute along the road to help the drivers to access to information anytime and anywhere quickly (Guanglin *et.al.*, 2012; Georgios *et.al.*, 2011). This type networks composed of a set of heterogeneous nodes as shown in figure 1, which could be divided into two kinds: first one are mobile nodes (vehicles) that move according to a realistic and predefined mobility model and the other one represents the fixed nodes called road side units (Haojin *et.al.*, 2009). However, there are many challenges related to vehicles due to their frequent mobility as well as limited degrees of freedom in their mobility patterns that lead to many links failures (Salim *et.al.*, 2013). This high mobility decreases the link stability and makes the routing process of data from source to the destination one of the large problems in the VANET which is accompanied with overhead incurred in path discovery and path maintenance, wasting in bandwidth and transmission/receiving energy and may not meet the delay constraint in addition to decrease the throughput and increase the packet lost (Tong-Ying *et.al.*, 2016).

This network supports the communications among vehicles via inter-vehicle communication (V2V) mode and between vehicles and roadside units via vehicle to infrastructure (V2I) communication mode in order to simplify the exchanging of information in unicast, broadcast, geocast or multicast dissemination fashion (Georgios *et.al.*, 2011; Salim *et.al.*, 2013). In some cases like the accidents, it is better to send some of safety messages with a certain level of quality of service from a source vehicle that found in the accident location for a set of endangered vehicles in different locations. This transmission mode is known as multicast mode (Esraa *et.al.*, 2016). As a result the endangered vehicles must perform some actions quickly before a certain critical time such as stopping or changing the moving direction to avoid a road accident or collision. So it is necessary the average end-to-end delay to be low and bandwidth to be highly significantly in order to deliver such QoS safety messages correctly (Salim *et.al.*, 2013).

The multicast routing problem in VANET with respect to QoS considered NP-complete problem that depends on end-to-end delay and link bandwidth constraints along the paths from the source to each destination, and minimum cost of the multicast tree (Forsati *et.al.*, 2008). The authors in (Garey *et.al.*, 1977; Guoliang Xue, 2003) proved that the QoS based multicast routing is NP-complete problem.

There are other authors presented surveys about the multicast routing protocols in VANET (Waqar *et.al.*, 2015; Navis *et.al.*, 2016) but they did not study what are the parameters that took into account in each one. So in this paper, we determine these parameters and present different categories of the multicast routing protocol with QoS, vehicle trajectory, scheduling algorithm and emergency applications.

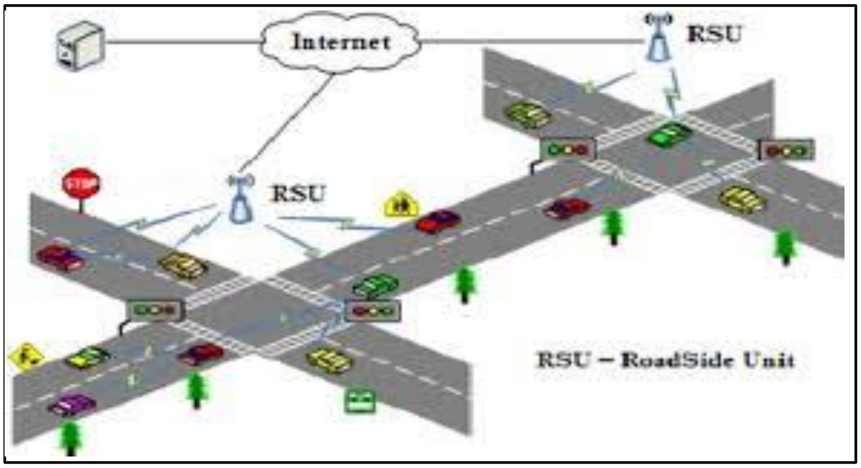

Figure 1: The vehicle ad hoc network (Haojin *et.al.*, 2009)

2. Multicast Routing Protocols in VANET

There are many protocols have been proposed to solve the multicast problem in VANET that can be classified as follows:

2.1. QoS based Protocols with Least Cost

Forsati et al. presented centralized approaches based on the harmony search algorithm to solve the multicast routing problem with respect to bandwidth and delay constraints and with minimum cost. They first algorithm modified the Prüfer number as a Steiner tree representation, but it is not suitable due to the weak locality and heritability in evolutionary search, so they described a new representative called node parent index (NPI) representation, for representing the trees and explain the harmony operations according to this representation. Then they proposed other algorithm depending on NPI representation. Generally the drawback of the central approach is that the complete network topology information must be available at the source node that is responsible for build the entire routing table. This will increase the overhead and decrease the scalability. Also, the author did not provide any solution for the link failure due to the mobility of vehicles (Forsati *et.al.,* 2008).

To achieve the multimedia streaming in VANET, Yi-Ling Hsieh et al. proposed dynamic overlay multicast scheme and to improve an overlay's stability they present two techniques: QoS-satisfied dynamic overlay and mesh-structure overlay. The first one of these techniques used streams' packet loss rates and end-to-end delay parameters to select potential new parents. While the next one allows a child to have two parents. They proposed that the selection procedure of parents is done by the source node and each parent node has limitation about the number of the children. The problem of this paper occurs in the parent selection procedure where if the number of children of potential parents reaches to the threshold, then the selection procedure will repeat for many times that leads to high delay and high packet loss rate. Another problem occurs when there are no two potential parents then the stability will degrade again. Final problem occurs when the distance between the source node and the new node that wants to join to the multicast tree is long then the delay of parent selection procedure will be high (Yi-Ling *et.al.,* 2012).

In an attempt to solve the QoS based multicast routing problem, Salim Bitam et al. proposed bee colony optimization algorithm called bee life algorithm (BLA). The two famous behaviors in the nature of bees that are the reproduction and the food foraging have been used in this algorithm. This algorithm has four objectives and three constraints. The objectives are cost, delay, jitter, and bandwidth while the constraints are maximum allowed delay, maximum allowed jitter and minimum requested bandwidth. This algorithm suffers from the low stability of a link that leads to depletion of bandwidth for the route discovery and route maintenance processes in addition to high overhead and packet loss rate (Salim *et.al.*, 2012).

Depending on the concept of swarm bee Salim Bitam et al. proposed QoS based multicast and multipath routing protocol. They proposed that each multicast group has head node represents the first node in the multicast group and proposed technique for the route discovery: if the source node knows the route to the head node, it will send the message to it using the unicast mode which will forward the message to the other multicast members. Else it will send the message to the neighbors. This work will repeat until reach to the one member of multicast group. Also, they proposed approach to construct the multicast tree. It starts by one node that wants to join to multicast group. If there is previous multicast group, its head will add the new node to the group; else the new node will be the head. Multicast group publication starts by sending message from the head to the source node. To maintenance the multicast tree, the nodes exchange hello messages. The disadvantages of this paper are high overhead, bandwidth wasting, not link stability, delay in constructing the multicast tree, and high energy consumption (Salim *et.al.*, 2013).

Amilcare Francesco Santamaria et al. proposed multicast protocol based on partitioning concept for providing large number of services, increasing the network reliability and giving the possibility to a higher group of users to access to those services. This protocol uses several clusters: each cluster is composed of a multicast subtree. The cluster head (CH) represents the root of the subtree, which is commonly associated with local RSU. The CH has the main role of managing the whole subtree, managing their destinations, and allowing or denying multicast joining. Each group of CHs connect to border router that connect to certain server called Multimedia Content Server assumed to be the static source of the multicast services. This protocol did not take into account bandwidth constraint and the transmission cost. The position update of vehicles and determining the link status is done by periodically sending of messages that can increase the overhead and consume the resources (Amilcare *et.al.*, 2015).

Xiu Zhang et al. abstracted the QoS based constraints multicast routing problem to continuous optimization problem. Then they used micro artificial bee colony algorithm and the binary representation as a solution to this problem. The minimum delay cost and maximum network lifetime considered as QoS parameters in this paper. In this proposed work if one node wants to send data, it will broadcast it to all neighbor nodes. This will consume the energy by increase the transmission energy consumption and unnecessary receiving energy consumption. Also, because there no any infrastructure the mobility of vehicles will effect on the link stability and leads to unnecessary transmission of control packets to maintenance the link that will increase the energy consumption, delay and overhead as well as wasting in the bandwidth (Xiu *et.al.*, 2016).

2.2. Multicast Protocols with Delay Constraint

Guanglin Zhang et al. studied the multicast problem for hybrid VANET with throughput capacity and directional antenna on each vehicle. It is also taking into consideration the delay constraint (D). In this proposed network, there are *n* vehicles and *m* base stations connected using wire links with high bandwidth. There are many multicast sessions and each one has one source and set of destinations. They investigated the multicast throughput capacity for two vehicle mobility models with two mobility scales, respectively. The source vehicle transmits the data to its destination vehicles by using normal nodes only (using ad hoc mode) within *D* time periods or the transmission will be performed in the infrastructure mode. The limitations of this paper are: it is not taking into consideration the bandwidth. There is no strategy to construct the multicast tree or discovery the paths to the destinations. Also, there is no any approach to join some new vehicle to the existed sessions (Guanglin *et.al.,* 2012).

Tong-Ying Juang *et.al.,* presented multicast protocol based on linear regression delay constraint to transmit data to many destinations in different regions within user-defined delay of each region. This protocol used the hybrid of data mulling to deliver the messages to the destination regions and the vehicles can carry these messages when the available time is enough. They used two schemes: the greedy and centralized. But this protocol did not take into account the mobility of vehicles and not presented any solution to solve the link failure problem. Also, it is not considered other metrics such as bandwidth, overhead, packet loss ratio, jitter and packet delivery ratio (Tong-Ying *et.al.,* 2016).

2.3. Trajectory based Protocols

Jaehoon Jeong *et.al.,* proposed statistical forwarding scheme based on the vehicle trajectory (TSF), tailored for the multi-hop data delivery from infrastructures to vehicles using I2V connection. The authors investigated how to use the packet destination vehicle's trajectory for I2V data delivery. To transmit the data to some vehicles, a target point that is the best rendezvous point of the packet and the destination vehicle must be computed depending on the destination vehicle's trajectory. This target point must be selected optimally to decrease the packet delivery delay while met the required packet delivery probability. TSF scheme forwards packets to a selected target point where the vehicle is expected to pass by. The theoretical analysis and simulation illustrated that their design provides an efficient data forwarding under a variety of vehicular traffic conditions. The problem of TSF is that it transmits messages to a single destination vehicle with a minimum delay, and cannot be applied to efficiently deliver messages to a group of vehicles simultaneously (Jaehoon *et.al.,* 2012).

Jaehoon Jeong *et.al.,* proposed multicast protocol based on trajectory to deliver the data with least transmission cost. It depends on the trajectories of moving destination vehicles. This trajectory computes based on the initial and final points of trip that inputs by the driver at the beginning of his trip to the GPS that at least will be sent to a central server. At receiving a request of multicast data from a source, the central server knows how the data has to be delivered to the destination vehicles. For each one of the moving destination vehicles, many relay points are computed to temporarily hold the data. These relay nodes deliver the data to the destination vehicles when reach to their coverage area. The problems of this paper: the driver may not wish to input information about his trip so the trajectory cannot be computed and as a result the data will not deliver to the destination vehicles correctly. Also, the computed trajectory may be changed through the trip. Also, when there are many destination vehicles want to download some data from same relay node before passing its coverage area may be failing due to the congestion (Jaehoon *et.al.*, 2013).

Guann-Long Chiou *et.al.*, demonstrated that selecting of the rendezvous point and the multicast tree construction separately may effect on the overall performance of the network. So they designed trajectory-based I2V group message delivery protocol (eTGMD) for applications with delay sensitivity. This protocol selects a rendezvous point and extends the multicast tree to cover the selected point. During each iteration, from the remaining rendezvous points, eTGMD attempts to select the best one that is closest to the previous selected rendezvous points. Besides, exploiting the delay budget, eTGMD minimizes the total transmission cost under the premise that the delay constraint is guaranteed. The limitations of this paper are: The authors assumed that the navigation system on each vehicle, which contains a GPS receiver, a digital map and the statistical/historical information about the road network, provides the driver with a suggested route to his/her destination and assumed that drivers will complete their journeys by following their suggested routes and each vehicle will report its trajectory and position to the server periodically (Guann-Long *et.al.,* 2016).

2.4. Multicast Protocol with Scheduling Algorithm

Sana Sahebgharani *et.al.*, studied the vehicle–RSU communication mode and demonstrated that in most previous works, RSU serves one request at one time while some works to serve multiple requests used broadcasting, but without any difference between urgent and normal data i.e. without priority of data. So the authors proposed a scheduling algorithm to download data from RSU using multicast technique in order to serve multiple requests. In first step: requests are classified based on nature of the requested data into normal and emergency. Requests are placed in two queues and within each queue they are sorted with FCFS scheduling technique. In second step: selecting one of two queues is done through D*S/W scheduling technique. Heads of these two queues are compared with D*S/W technique and provide the service to the queue with less DSW-value. When some vehicles want to download the same data, the request is suspended and vehicles should wait for some time interval. Then, data is sent to all requesting vehicles at a specific time. The problems in this paper are: there is no method to construct the multicast tree and no strategy to address the link failure problem. Also, it used the GPS to collect information about the vehicles without using method to correct the inaccurate information (Sana *et.al.,* 2012).

2.5. Multicast Protocols with Emergency Applications

Alwin Sebastian et al. presented a Cooperative Collision Warning System for warning message dissemination to the moving vehicles using multicast scheme. This scheme is used to find the abnormal vehicles, the vehicles that might be affected by the abnormal vehicles and expected time of reception of warning message by the possible surrounding vehicles. The authors mapped a multicast routing problem into a delay constrained minimum Steiner tree problem. Also, they developed an analytical model for the delay constrained minimum Steiner tree problem (Alvin *et.al.,* 2010).

Alwin Sebastian *et.al.*, proposed multicast protocol based on a context aware for a highway in VANET to send the warning message only to the moving vehicles that are close to an accident location using V2V connection mode. The context information used in this protocol is: the network topology, end-to-end delay, sender vehicle, and receiver vehicles (multicast group). In this work the abnormal vehicle represents the sender node and the relevant vehicles are the receiver nodes. The sender needs to know the relevant or endangered vehicles that can be determined based on the current road traffic situation. To determine the endangered vehicles, an abnormal vehicle generates or updates a vehicle interaction graph. The execution time of this protocol is more because of the multicast tree generations and the exchanging of the location information among vehicles increases the overhead and bandwidth consumption (Alvin *et.al.,* 2012).

Niyoti Pathak *et.al.,* developed system for the emergency situations. This system attempts to find the relative position based on travel direction among moving vehicles using information delivered from GPS. This system is developed for multicast of alert messages in emergency situations such as accident. The concept of Multicast is used in this system to avoid traffic congestion during excess alert message transmission in highway scenario. This system is used for finding the relative position among moving vehicles (Niyoti *et.al.,* 2014).

To avoid the road accidents by disseminating Emergency Warning Message (EWM) P. Gokulakrishnan et al. presented Bandwidth Efficient Acknowledgement based Multicast protocol for Highway scenario called BEAM-HW. Also, it is aiming to reduce the overhead of the in-network messages by sending EWM only to vehicles that are near the accident location. The BEAM-HW works as the following: first step is the predication of the road accidents by the RSU based on the status report and traffic data send by the road sensors and the vehicles. The second step is upon this successful prediction, the RSU generates a EWM. In the third step, the RSU must form the multicast group. Finally, the RSU must multicast the EWM to the vehicles. Then vehicles need to respond with an acknowledgement. But the data that collects from the sensor based on the speed and the yaw-rate may be not accurate and leads to incorrect decisions. Also the RSU periodically broadcasts *join* packet to the vehicles. The Vehicle sends the *reply* packet with vehicle ID. If the ID of the vehicle is new then it is added to the Multicast Group (MG). The MG is updated periodically. This process repeats whether there is an accident or not that means wasting in the bandwidth and increasing in the overhead (Gokulakrishnan *et.al.,* 2015).

2.6. Other Multicast Protocols

In order to solve the temporal network fragmentation problem Smitha Shivshankar *et.al.,* presented a spatio-temporal multicast/geocast protocol. Here, messages are transmitted to all vehicles in a prescribed region of space at a particular time period. This protocol used group of nodes as a forwarding group between source and multicast destinations to disseminate the messages by using a hello control packet. Also, it collects content-based subscriptions in a compact data format using Binary Decision Diagram and applies Spatio-temporal Multicast Routing Protocol to extend this context from the middleware-tier to construct an optimized dynamic dissemination mesh. The problems of this paper are: first, each vehicle acquires location information via GPS that is not accurate and leads to many errors. Second, the information of location exchanges to the neighbors by hello messages that cause high overhead and increase the use of bandwidth. Third, the link stability is low because there is no infrastructure in the proposed architecture. Finally, the proposed approach did not take into account the delay and bandwidth constraints (Smitha *et.al.,* 2013).

Esraa Al-Ezaly *et.al.,* studied the multicast problem and proposed architecture consists of RSUs and vehicles. Vehicles send information to RSUs periodically such as speed, location, and direction. Each RSU saves this information and uses them to determine and estimate the current location of vehicles. If some source vehicle wants to transmit message to set of destination vehicles, it will send the message to the first RSU. If some of these destinations are not available, then RSU sends the message to the next RSU. Any RSU finds the destination, delivers the message to it and inform the first RSU using reply packet. The algorithm that used to form the multicast group uses some types of packet such as join queries, reply queries and group leave. Their proposed algorithm used the speed, length and densities of road to choose the minimum delivery delay path. But it did not take into account the bandwidth or energy consumption. Other problem occurs when the distance between the source and destinations is very high the path discovery time will increase which effects on the link stability and performance due to the source and destination mobility (Esraa *et.al.,* 2016).

To alleviate the broadcast storm problem of multicast tree discovery and minimizing the number of forwarding vehicles, Ali Tauseef Reza et al. proposed a position prediction based multicast routing protocol. This protocol gathers the information of vehicle’s position from digital map, Inertial Navigation System and GPS installed on vehicles. This information is available at the destination vehicles. When a route breaks then the destination vehicle uses this information and informs the source vehicle about other predicted routes. This eliminates the overhead and helps the source vehicle to transfer data without any route discovery. They used Kalman Filter and its modifications to remove the inaccuracies of data collected by GPS and Inertial Navigation System. There are many problems in this paper: first, the path with minimum hops is not always the best. Second the protocol do not considered the bandwidth. Third, it is not considered the mobility of source. Fourth, the position prediction based on the previous information introduced by the old RREQ may lead to many errors. Fifth, in the case of prediction failure, the source will again start the route discovery by flooding RRESs. This means that the source’s data incur the delay of path prediction and the delay of new route discovery (Ali *et.al.,* 2016).

Jeongcheol Lee *et.al.,* used the farthest destination selection and shortest path connection (FSSC) algorithm to create a multicast tree to support mobility of destinations and minimize the jitter and end-to-end connection delay. Every vehicle collects the locations of closest vehicles by exchanging periodic beacon packets. FSSC first selects the farthest one among destinations from the current multicast tree which has only the source vehicle in the beginning, and then connects the farthest one to the multicast tree via the shortest path. By connecting the shortest path for the farthest destination to an edge or a vertex, the multicast tree is separated into branches on the edge or the vertex. This process continues until FSSC connects all destinations to the multicast tree. The problems of this strategy are: first, it is depend on the location information collected by onboard navigation system that may be not accurate. Second, it is not considered the bandwidth in selecting the path. Third, the overhead of exchanging the location information among the vehicles is high. Fourth, there is no guarantee about the connection if the destination vehicle moved to the opposite direction of the source vehicle (Jeongcheol *et.al.,* 2016).

Table 1 contains comparison and classification of existing multicast routing protocols and provides view about the parameters that took into consideration in each one and whether the proposed architecture contains the road side unit (RSU) or not in addition to the using of scheduling algorithm to schedule the multicast requests and to download the data from the RSU.

Table 1: the comparison and classification of multicast routing protocols in VANET

Paper	Year	Protocol	Journal?	SDN based	Delay	Bandwidth	Energy	Jitter	Cost	Reliability	Used the RSU	Request Scheduling	Scheduling in RSU	Mathematical model?
[7]	2008	QoS based multicast protocols	Yes		+	+			+					Yes
[12]	2012				+				+					
[13]	2012				+	+		+	+					Yes
[4]	2013				+	+					+			
[14]	2015				+					+	+			Yes
[15]	2016				+		+		+					Yes
[1]	2012	Multicast protocols with only the delay constraint	Yes		+						+	+		Yes
[5]	2016				+									Yes
[16]	2012	Multicast protocols based on trajectory	Yes		+						+			Yes
[17]	2013				+				+		+			Yes
[18]	2016				+				+		+			Yes
[19]	2012	Multicast with scheduling algorithm	No		+	+					+		+	Yes
[20]	2010	Multicast protocols with emergency applications	Yes		+									
[21]	2012		Yes		+							+		
[22]	2014		No		+									
[23]	2015		Yes		+	+					+			
[6]	2016	Other multicast protocols	Yes		+						+			
[25]	2016		No		+									
[26]	2016		No		+			+	+					

3. Conclusion and Future Works

In this paper, we studied the multicast dissemination of information in VANET and classified the existing routing protocols that proposed in this field based on QoS, vehicle trajectory, using of scheduling algorithm, and emergency applications. Also, we compared these protocols depending on a set of parameters such as delay, bandwidth, energy, cost, reliability and supporting of scheduling algorithm whether inside the RSU or in constructing the multicast tree for each multicast request. At this point we found that all multicast routing protocols have been proposed for the traditional VANET and there is no any multicast routing protocol in software defined network (SDN) based VANET. So in the future work, we will produce routing protocol in SDN based VANET with respect to the QoS requirements.

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