Evaluation and comparison study of video streaming routing protocols in vehicular ad-hoc networks

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Abstract

Video streaming is a challenging issue in Vehicular Ad-Hoc Networks (VANETs), due to the strict video streaming Quality of Service (QoS) requirements, such as throughput, delivery ratio, and transmission delay. Moreover, video streaming is influenced by VANET characteristics, such as the high dynamic topology, fluctuation of vehicle density, and environmental obstacles. In VANET, video streaming can be achieved through different VANET communication types, such as Vehicle to Vehicle (V2V), Vehicle to Infrastructure (V2I), and Vehicle to Broadband cloud (V2B). Based on these communications, the vehicles can exchange between them the video stream over single or multi-hop link. When the video content is delivered over a multi-hop link, the vehicles have to use a routing protocol to disseminate the video stream through a path (s) between the sender (s) end the receiver (s) vehicles. In this paper, we have presented an overview of popular existing routing protocols for video streaming in VANET, such as AODV, AOMDV, DSR, and DSDV. Furthermore, we have evaluated and compared these protocols in terms of some QoS evaluation metrics, such as throughput, packet delivery ratio, and end-to-end delay in function with vehicles density in order to judge which one is outperforming for video streaming in VANET. The simulation results show that the reactive routing protocols (AODV, AOMDV, DSR) provide higher throughput and packet delivery ratio than DSDV proactive routing protocol. However, DSDV achieves lower end-to-end delay than AODV, AOMDV, DSR routing protocols.

Keywords

Vehicular ad-hoc network, video streaming, routing protocol, AODV, AOMDV, DSR, DSDV

1. Introduction

Vehicular Ad-hoc NETwork (VANET) is a self-organized network that consisted of moving vehicles and fixed Road Side Units (RSUs) [1]. The vehicles exchange the messages between them or with the RSUs in a single or multi-hop communication using wireless communication support [2]. VANET can provide three types of communications: Vehicle to Vehicle (V2V), Vehicle to Infrastructure (V2I), and Vehicle to Broadband cloud (V2B) [3]. VANET aims to reduce the number of road accidents by integrating intelligence techniques into vehicles. The World Health Organization (WHO) estimated that the road traffic deaths number has reached 1.35 million per year [4]. Figure 1 shows the architecture of VANET.

VANET can serve several applications that are classified into three categories: transportation safety, transportation efficiency, and transportation comfort [5]. The first category aims to decrease the road accident number by disseminating the warning messages in the case of accidents. The second one

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manages and controls the traffic road to avoid the traffic congestion problem. The last one provides comfort and infotainment services to both drivers and passengers.

Video streaming in VANET provides more information than a simple text. However, VANET is characterized by high vehicle mobility, fluctuation of vehicle density, and the presence of environmental obstacles. Therefore, video transmission in VANET faces several challenges, such as packet loss and the high transmission delay due to the rupture of the communication path between the sender and the receiver. Video streaming in VANET is an important topic addressed by current research because many VANET applications focus on video transmission to improve road safety, traffic efficiency, driver assistance, infotainment, and urban sensing.

Routing protocols for video streaming in VANET have to select the appropriate set of relay vehicles between the source (s) and destination (s) to establish a reliable path for video streaming dissemination. In VANET literature, several works use routing protocols for video streaming at the network layer level. However, few of these works propose a comparison between these protocols in VANETs. Our work evaluates and compares AODV, DSDV, DSR, and AMODV routing protocols for video streaming in VANET to choose the most adequate routing protocol for video streaming in VANET. We have used many evaluation metrics in this work, such as throughput, packet delivery ratio, and end-to-end delay.

The rest of the paper is organized as follows. In section 2, we present the related work about the routing protocols for video streaming in VANET. Section 3 presents an overview of some routing protocols that will be compared and evaluated by our network simulation. Section 4 shows and investigates the simulation results. Finally, in section 5 we conclude the paper.

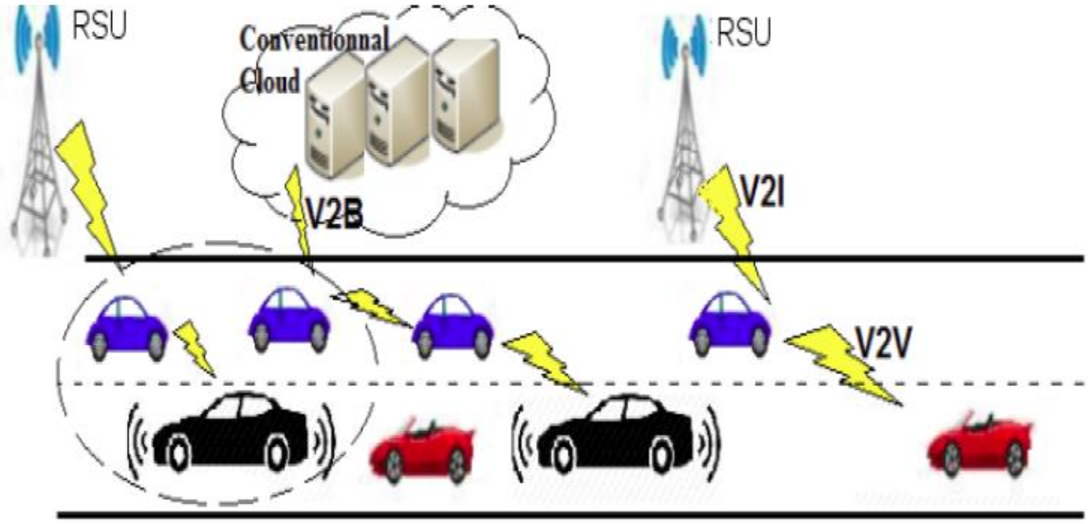

Figure 1: VANET communication patterns

2. Related work

This section presents some recent works that applied and analyzed the different routing protocols for video streaming in VANET.

Honda et al. evaluated in [6] the video transmission in urban VANET using Optimized Link State Routing (OLSR). The proposed work proved that throughput, delay, and jitter of OLSR is influenced by two factors: the video streams number and the environment buildings. This study demonstrates that OLSR outperforms AODV and DSDV protocols. Moreover, this work does not consider the evaluation metrics of video quality like PSNR and SSIM.

Pham et al. proposed in [8] an adaptation of OLSR for video streaming over VANETs named QOV. The proposed routing protocol forwards the video streams through fewer loss paths, in order to improve OLSR in terms of QoE metrics: MOS, USP, MDP, and packets loss rate. QOV has the same limit of OLSR of bandwidth overhead due to the periodic exchange of control messages in VANET, which is characterized by its high dynamic topology.

Rizwan et al. evaluated in [9] AODV and DSR for video streaming in VANET. The proposed work proved that DSR is better than AODV in terms of throughput and transmission delay in a simple scenario with only OBUs, or in a complex scenario that includes both OBUs and RSUs.

Benmir et al. proposed in [10] GeoQoE-Vanet routing protocol for video streaming over VANETs. In this proposed protocol, the selection of relay vehicles is based on a QoE parameters to provide video content with better quality. The selection decision of the next-hop vehicle is based on position, direction, speed, link expiration time, packet loss rate, transmission delay, and jitter. The simulation results showed that GeoQoE-Vanet provides better QoE to the end-user in terms of MOS, PSNR, and SSIM compared to GPSR and GPSR-2P protocols in an urban environment.

Most of these VANET video streaming works focus on video packet routing to guarantee efficient delivery of packets while decreasing packet loss rate and transmission delay. However, due that the data type transmitted between vehicles is the video, this transmission becomes complicated and challenging. The evaluation and comparison between the routing protocols for video streaming in VANET is an important task to choose the adequate routing protocol for this transmission.

3. Routing protocols for video streaming in VANET

The routing is the process that allows the forwarding of messages from one node to another based on some parameters, like the number of hops, the shortest path, and so on. In VANET, the dissemination of data is a challenging task due to the rapid movement of vehicles. Several routing protocols can be used to find optimal paths from the vehicle source to the destination but with some limitations, such as lack of scalability, self-organization, control, and routing complexity.

In this section, we present some routing protocols for video streaming in VANET (AODV, AOMDV, DSR, and DSDV) that will be evaluated and compared through our network simulation. Each routing protocol is designed by a flowchart that explains briefly the different steps of the process followed by this protocol.

3.1. Ad-hoc On-Demand Distance Vector (AODV)

AODV routing protocol could be classified as a unicast/multicast routing protocol. The process adopted by this routing is that each path is produced only on request. In fact, when a vehicle desires to transmit a packet, via the route discovery mechanism, the used routes are kept [7].

As shown in figure 2, AODV establishes the Route Discovery (RD) by means of Route REQuest (RREQ) and Route REPly (RREP) control messages. In AODV, routes are set up by flooding the network with RREQ packets. When an RREQ traverses a node, it stores the information about the source, the destination, and the node from which they received the RREQ. The later information is used to set up the reverse path back to the source. When the RREQ reaches a node, which knows a route to the destination or it is the destination itself, the node responds to the source with an RREP packet. To avoid overburdening the nodes with information about routes that are no longer used, nodes discard this information after a timeout. When either destination or intermediate node moves, a Route ERRor (RERR) message will be sent to the affected source nodes. When the source node received the RERR, it can re-initiate the RD process if the route is still needed. Neighborhood information is obtained by periodically broadcasting ‘Hello’ packets [11].

AODV is also known for its capacity to diminish broadcasts, transmission latency, and routing overhead. However, AODV suffers from the high end-to-end delay resulted from the route discovery process before every data transmission. Hence, high E2ED is not suitable for vehicular networks in case of crucial or dangerous information [7].

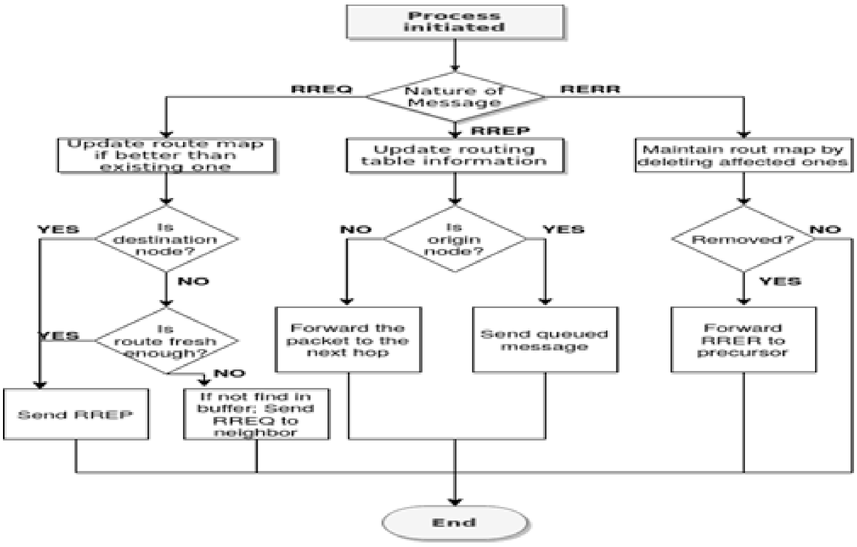

Figure 2: Flowchart of AODV routing protocol

3.2. Destination Sequenced Distance Vector (DSDV)

DSDV routing protocol is an adapted version of the conventional Routing Information Protocol (RIP) to the ad-hoc network routing. It adds a new attribute which is the sequence number, to each route table entry of the conventional RIP [12].

DSDV is a proactive table-driven protocol based on the Bellman-Ford routing algorithm to calculate the paths. The cost metric used is counting the number of hops that takes a packet to reach its destination. The changes are propagated through periodic and trigger update mechanisms. Due to these updates, there is a chance of having routing loops within the network. To eliminate routing loops, each update from the node is tagged with a sequence number. The sequence number from each node is independently chosen but it must be incremented each time a periodic update is made by a node [13]. The update of routing tables of each node is done periodically to make available information about paths to each destination in the network at any time, even if the paths are at this time unused. Despite the benefits of DSDV, such as simplicity, loop-free, and no added transmission delay caused by the discovery of the road technique [6]. Figure 3 depicts the flowchart of DSDV routing protocol.

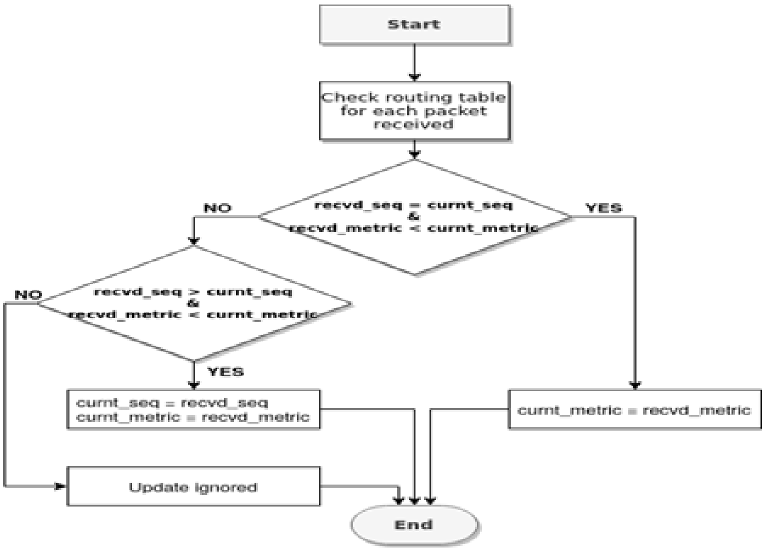

Figure 3: Flowchart of DSDV routing protocol

3.3. Ad-hoc On-Demand Multipath Distance Vector (AOMDV)

The basic idea behind multi-path routing is of finding multiple paths between the source and the destination. On-demand routing protocols for wireless Ad-hoc networks discover a route when a source needs to communicate with a destination. The multi-path routing protocol discovers multiple paths during the single route discovery process. These multiple paths can be used for load spreading or as backup routes when the primary route fails [14].

AOMDV is a multi-path extension of AODV. AOMDV is based on the distance vector concept and uses hop by hop routing approach. Moreover, AOMDV also finds routes on demand using an RD procedure. Unlike AODV, AOMDV finds multiple routes in a single route discovery procedure. In AODV all duplicate RREQs are discarded whereas AOMDV looks for an opportunity of getting an alternate route with each duplicate RREQ. In AOMDV, RREQ propagation from the source towards the destination establishes multiple reverse paths both at intermediate nodes as well as the destination. Multiple RREPs traverse these reverse paths back, to form multiple forward paths to the destination at the source and intermediate nodes. AOMDV also provides intermediate nodes with alternate paths as they are found to be useful in reducing route discovery frequency. The core of the AOMDV protocol lies in ensuring that multiple paths discovered are loop-free and disjoint and inefficiently finding such paths using a flood-based route discovery. AOMDV route update rules, applied locally at each node, plays a key role in maintaining loop-freedom and disjoint-ness properties [15]. Figure 4 shows the flowchart of AOMDV routing protocol.

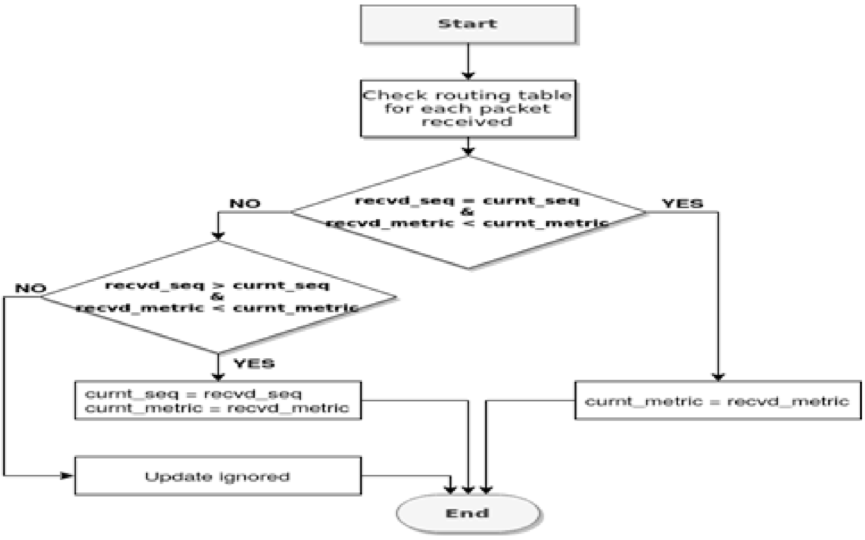

Figure 4: Flowchart of AOMDV routing protocol

3.4. Dynamic Source Routing (DSR)

DSR is a reactive protocol for network routing. It is basically made for multi-hop communication. It is a self-organizing and self-configuring protocol that does not require any monitoring. The two main functions of DSR are route discovery and route maintenance [14] as illustrated in figure 5.

3.4.1. Route Discovery (RD)

Let a source S wants to send the data to the destination D. S will broadcast an RREQ packet. If the receiver node is not D then it will append its address in the packet and rebroadcast it again. If the node is D then he sends an RREP to S, using the reversed path address that copied from the received packet.

3.4.2. Route Maintenance (RM)

During the sending of the data from S to D. If S did not receive an acknowledgment from D for the successful delivery, S will wait for some predefined amount of time and if it does not receives the acknowledgment it will send the RERR packet to all the nodes in the path from which it received the packets. All the nodes which will receive the packet will update their corresponding route tables for that path and remove the old path. Also, the source S has to initiate the RD to find a valid path again.

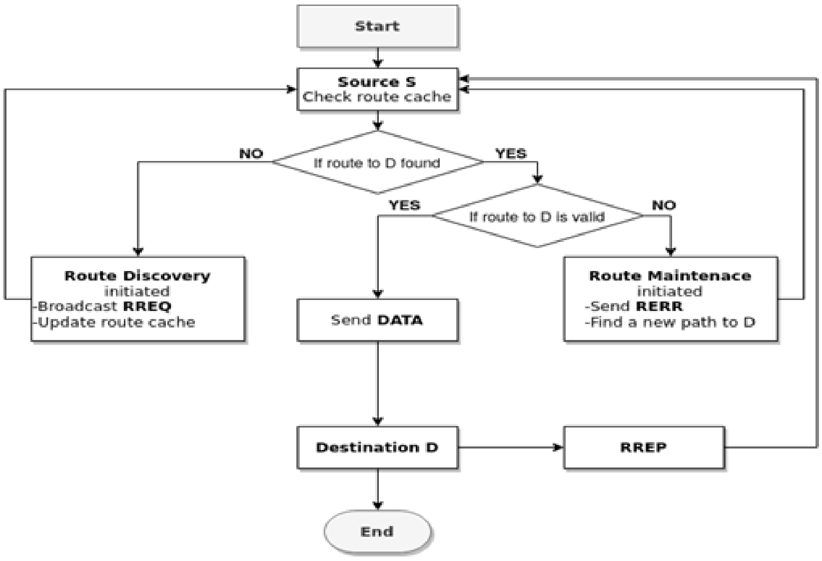

Figure 5: Flowchart of DSR routing protocol

4. Simulation

In this section, we have evaluated and compared some routing protocols for video streaming in VANET, such as AODV, AOMDV, DSR, and DSDV in function of vehicle density and in terms of throughput, packet delivery ratio, and end-to-end delay.

We have performed our simulation using network simulator 2 (ns-2) [17]. The network topology is extracted from Oum El Bouaghi city (Algeria) using OpenStreetMap [18], and the traffic mobility is generated using SUMO [16].

4.1. Simulation setup

We have mainly three parts that cover our simulation procedure for this study. Firstly, road maps are obtained using Open Street Map (OSM), which is a map editor tool that allows the extraction of real-world locations into the OSM file. This is followed by importing the road map into SUMO, a microscopic traffic simulator for generating the required TCL script and mobility trace files. In the last step, NS-2, a network simulator is used to simulate the VANET scenario for analyzing the performance of the aforementioned routing protocols for video streaming in VANET. In order to execute the traffic simulation in this partially used area, three procedures are followed:

4.1.1. Studied area

The Oum El Bouaghi city (Algeria) map was extracted from the open-source 'OpenStreetMap' represented as an OSM File. Figure 6 demonstrates the selected city sector that was simulated.

Figure 6: Studied area of OUM EL BOUAGHI city

4.1.2. Vehicles mobility

The movement of the vehicles within the simulated urban scenario is randomly generated using SUMO to emulate real-world traffic as shown in figure 7. Then, the SUMO mobility traces are adopted for the simulation. The distribution of vehicles on the starting locations (source) in each scenario is made randomly according to the binomial distribution. This means each vehicle has a random departure rate (starting time) and a random arrival rate (ending time). The initial placement of vehicles is also randomly assigned by SUMO. It is assumed that each vehicle in the simulation is equipped with an OBU that facilitates onboard computation and communication with other neighboring vehicles based on IEEE 802.11p. As a result, SUMO generates a TCL script for the mobility of vehicles traffic.

Figure 7: Mobility simulation of vehicles traffic in OUM EL BOUAGHI city using SUMO tool

4.1.3. Network simulation

To simulate our chosen routing protocols and their impact on the video streaming transmission over VANET, we have used a Network Simulator 2 (Version 2.35) integrated with Evalvid (Version 2.7). In our simulation, we have used a video sequence called 'hall-cif' having 300 frames with a frame size 352-288 pixels (YUV format). The frame rate of this sequence is 30 frames/second. We have encoded the video sequences with H.264/ffmpeg standard. During our simulation, the channel bandwidth is fixed at 10 MHz and the vehicle speeds are limited to 20 m/s and 30 m/s.

Figure 8 describes an overview of our simulation process which used the three tools: OpenStreetMap, SUMO, and NS-2. In order to test the effect of the network vehicle density, we test our network sparsity model with several network vehicle density ranging from 50 to 120 vehicles. Table 1 shows our simulation configuration.

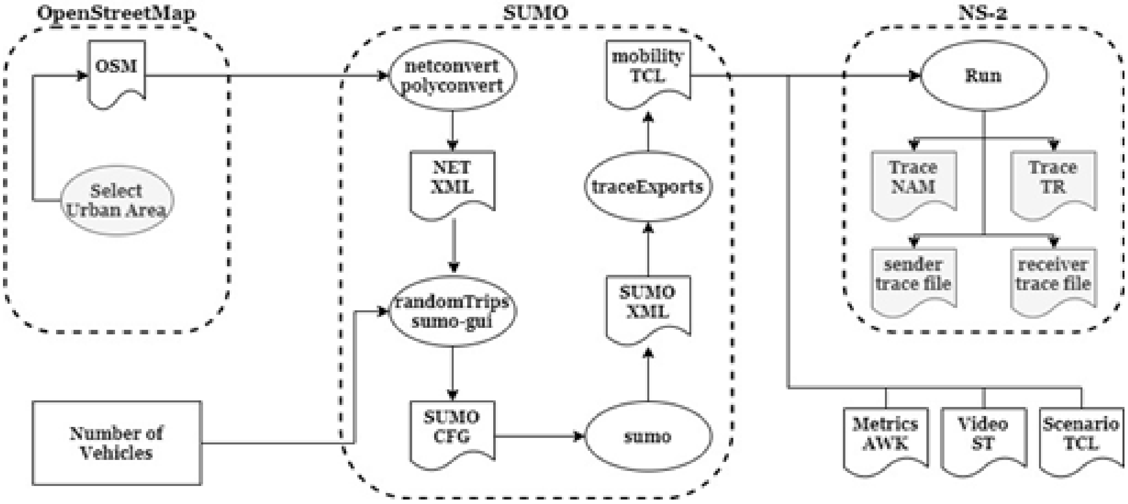

Figure 8: Workflow of our simulation

Table 1
Simulation Parameters

Parameter	Value
Simulator	NS-2.35
Routing Protocols	AODV, DSDV, AOMDV, DSR
Transport protocol	UDP
Number of vehicles	50, 60, 70, 80, 90, 100, 110, 120
Simulation time	500 s
Simulation area	Oum El Bouaghi city (2492 m X 2381m)
Packet size	1024 Bytes
Channel	Channel/WirelessChannel
Radio propagation	TwoRayGround
Network interface	802.11p

4.2. Simulation results

The metrics that we have used to evaluate the routing protocols are throughput, End-To-End Delay (E2ED), and Packet Delivery Ratio (PDR).

4.2.1. Throughput

Throughput is the rate of successful packet delivery through a network connection per unit of time. Figure 9 depicts the achieved throughput of different simulated routing protocols for video streaming in VANET in function of the number of vehicles. As shown in this figure, AODV, DSR, and AOMDV provides higher throughput than DSDV routing protocol. The main reason of this result is that contrary to DSDV proactive routing protocol, in the reactive routing protocols (AODV, DSR, and AOMDV), the sender vehicle updates its routing table only when it wants to send the video packets. Therefore, the network overload will be highly reduced which avoids the congestion problem and increases the throughput.

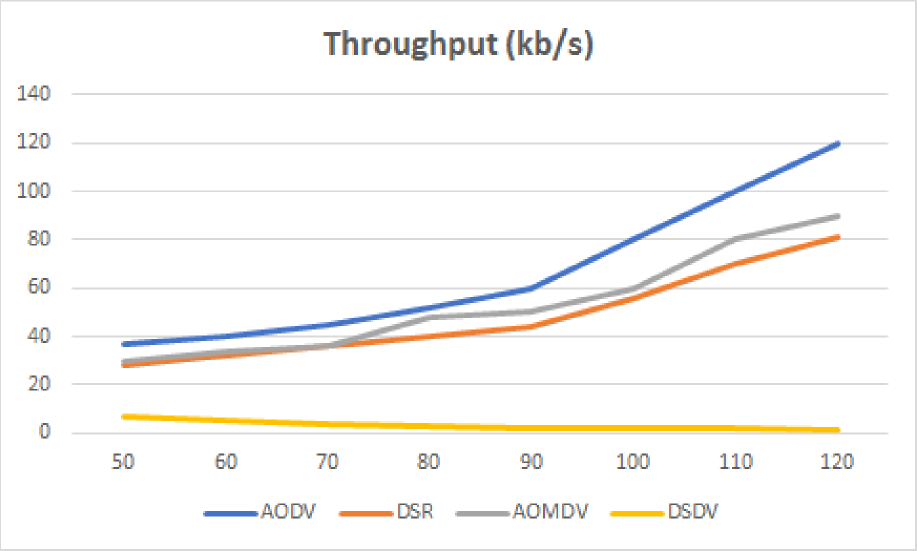

Figure 9: Throughput of simulated routing protocols for video streaming in VANET

4.2.2. End-To-End Delay (E2ED)

E2E delay is the average time needed for a packet to reach its destination. Figure 10 shows the E2E delay achieved by the simulated routing protocols for video streaming in VANET in function of the vehicle density. An illustrated in this figure, DSDV provides lower E2E delay than the other routing protocols. This result is due to the periodic updating of DSDV routing tables which allows the vehicles to find quickly the path for the transmission of video packets.

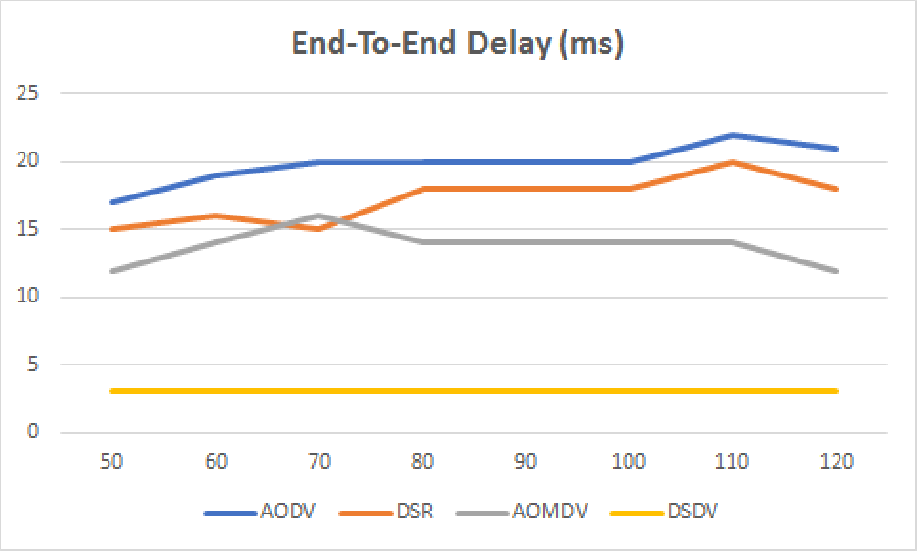

Figure 20: End-To-End Delay of simulated routing protocols for video streaming in VANET

4.2.3. Packet Delivery Ratio (PDR)

PDR is the number of packets successfully received divided by the number of sent packets. According to the figure 11, AODV, AOMDV, and DSR have shown a similar result of the Packet Delivery Ratio while the DSDV protocol started with 90\% and decreased to 25\% of PDR when the number of vehicles reached 120. This result is due to the on demand updating of routing tables of reactive routing protocols (AODV, AOMDV, and DSR) which increases the successful packet delivery, contrary to DSDV proactive routing protocol.

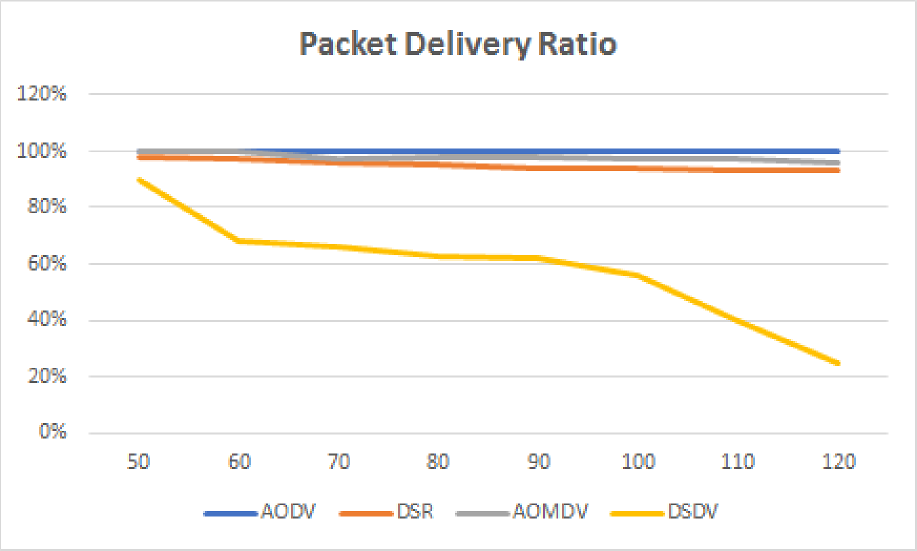

Figure 31: Packet Delivery Ratio of simulated routing protocols for video streaming in VANET

5. Conclusion

In this paper, we have presented our network simulation of four routing protocols for video streaming in VANET (AODV, AOMDV, DSR, and DSDV). Moreover, we have performed an evaluation and comparison of these routing protocols in terms of QoS metrics, such as throughput, E2ED, and PDR. The experiments were achieved by sending a video file from one source to one destination in an urban area over VANET.

The results generated have showed that the reactive routing protocols (AODV, AOMDV, DSR) provides higher throughput and PDR than DSDV proactive routing protocol. However, DSDV achieves lower E2E delay than AODV, AOMDV, DSR routing protocols.

Our future work is to perform the same study with several routing protocols in VANET as well as apply more QoS parameters to extend the scope of the analysis of the results using different simulation tools, such as NS2, NS3, and so on.

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