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VANETs Multipath Video Data Streaming Considering Road Features

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Abstract: Multipath video streaming in Vehicular Ad-hoc Networks (VANETs) is an evolving research topic. The adoption of video transmission in VANETs communication has become essential due to the comprehensiveness and applicability of video data for on-road advertisement and infotainment. Meanwhile, several research studies have considered how to apply and improve the transmission of the video quality. Due to this, the concurrent multipath transmission has been employed in order to achieve load balancing and path diversity, because of the high data rate of the video data. However, the main nature of the road, which is the pathway for VANET nodes has not been considered explicitly. In this paper, the road features are considered for VANETs multipath video streaming based on the greedy geographical routing protocol. Thus, VANETs Multipath Video Streaming based on Road Features (VMVS-RF) protocol has been proposed. The protocol was compared with an ordinary Multipath Video Streaming (MVS). The result demonstrates that the proposed VMVS-RF protocol outperforms the MVS in terms of Data Receiving Rate (DRR), Structural Similarity (SSIM) index and Packet Loss Ratio (PLR).

Keywords: Multipath, road features, VANETs, video streaming, high data rate.

1. Introduction

In recent times, there has been rapid growth in Vehicular Ad hoc Network (VANETs) research work. The VANETs communication paradigm that emanated from the Mobile Ad hoc Networks (MANETs) [1-3]. It is apparent that VANETs is very different from MANETs due to the nature of topology and resource capability. In MANETs, nodes are more scattered in a randomized manner, while VANETs has a defined pathway, which is the road. In addition, MANETs is constrained with limited resources such as battery, memory, and process, which is not the same for VANETs. The VANETs has two major communication type namely, Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) [4-6]. The V2V is a complete ad hoc based network, which signifies communication only between vehicles. While the V2I involves the use of Road Side Units (RSUs) to aid communication among vehicles on the road. The Video streaming in VANETs has also been related to cloud computing and Internet of Things (IoT) [7-10]. Some of the application domain of VANETs include safety, infotainment, monitoring. Looking at the application areas, video streaming can be applied in these areas. In the aspect of safety, the incidence of a scenario can be captured by another vehicle or an on-road RSU and transmit to vehicles moving towards the direction of the incidence. This would enable drivers navigating towards the direction to take a swift decision on whether to change route or not. The infotainment is more related to the video streaming services. Video streams can be forwarded to drivers on highways to notify them of good services, which is nearby their navigation location. This good and services include grocery shops, highway filling stations, nearby emergency clinics, restrooms, restaurants, lodging hotels. This will go a long way improving businesses and provide firsthand information to the road users. In addition, video streaming can be used to monitor the surroundings, because vehicles are used

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everywhere hence it can assist with monitoring the surroundings.

Video streaming in VANETs has been worked on by several researchers. The major issue in video streaming VANET is the high rate of video data and the high dynamicity of the VANETs nodes. The high data rate has led to numerous video compression standards including H.263/SVC, MPEG-1-2-4, and H.264/AVC. These standards are employed to minimize non-useful and redundant video data. Thus, there is encoding and decoding of video frames. The encoding of video data is at the sending vehicle before transmission, while the decoding is at the destination vehicle after delivery. One of the related ideas for the compression is the video splitting, where video frames are grouped into I-frame, P-frame, and B-frames. These split frames are transmitted through multiple paths in order to achieve path diversity and load balancing (See Fig.1). The I-frames are the most important frames called reference frames. The P and B-frames are less important compared to the I-frame. Due to this, the I-frames are given higher priority over the other frame types. The concept of video transmission via more than one path achieves lower delay and higher packet delivery and improved video quality compared to a single path video transmission.

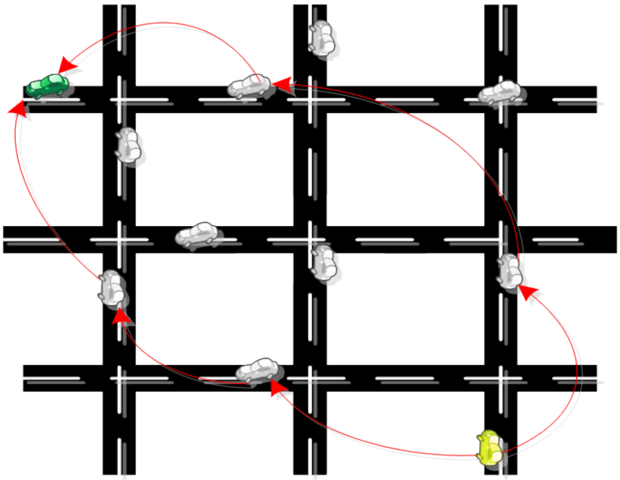

Fig. 1: The Illustration of Multipath Transmission

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Some routing protocols have been considered for video streaming. However, one of the most suitable routing protocol for VANETs video streaming is the geographic routing protocol due to the expedient consideration of vehicle location and minimal communication overhead due to the use of only neighbor vehicle information. Most of the routing protocol considered for video streaming in VANETs have not considered the road features including “U” Turn and junction when considering vehicle selection in the multipath video transmission. Although, the road features have been considered in some VANETs multipath routing. However, the impact on video transmission has not been explored. Therefore, there is need to consider the road features in multipath video streaming.

In this paper, an extensive review has been conducted based on related literature in VANETs multipath video streaming. A video streaming in VANETs considering road features has been proposed. Finally, experimental implementation is carried out and the results are validated. The rest of the paper is planned as follows. Section II involves the detailed review of related literature. Section III comprises of the design and discussion of the proposed protocol. Section IV presents the experimental implementation and result discussions. Section V concludes the research paper.

2. Related Literature in Multipath Video Streaming

In this section, an extensive review of related work in multipath video streaming VANETs are discussed. The related works have been divided into three (3) including coding-aware video streaming, adaptive video streaming and normal geographical routing protocols.

2.1 Coding-aware Video Streaming over VANETs

In this subsection, the coding-aware multipath video streaming related works are discussed. The integration of video compression techniques with the best route estimation and selection techniques. These are the fundamental issues in coding-centric routing. This technique must be designed to guarantee optimal video stream quality. Both the video compression and route selection for video stream need to consider the issues including wireless lossy channels, interference, and severity of the dynamic nature of VANETs. In general, both the stringent requirements of the video stream and VANETs constraint need to be considered to have qualitative video stream delivery. Symbol-level network coding for live multimedia video streaming over VANETs

(CodePlay) is suggested to provide stable video streaming and high streaming rate for willing vehicles [11]. CodePlay adopts the Symbol Level Network Coding (SLNC) strategy to organize local push scheme. The streaming video is fully transmitted from a dedicated source to willing vehicles through local coordination of non-centralized designated relay. Which ensures smooth playback for vehicles in the surrounding. Meanwhile, Playback freezes are not sufficient for evaluating qualitative video streaming. Razzaq and Mehaoua [12] proposed a Multi-Stream Coding that includes Network Coding (MCNC) for multi-path video transport in VANETs. It employs scalable video coding, which has path variation and network coding. Gonzalez, Ghafoor [13] suggest an approach, which is based on Fuzzy redundant adaptation and Joint source and Network Coding (FJNC) for VANETs video streaming. The aim is to accomplish flexible and robust video streaming over VANETs

An Evaluation analysis of High Efficient Video Coding (E-HEVC) video transmission in VANETs based on packet loss scenarios is proposed [14]. The E-HEVC analysis is motivated due to error-prone, high mobility networks and nature of the wireless channel of VANETs. The evaluation demonstrates that HEVC is very sensitive to packet loss. Further, creating a different number of slices from a single frame can either worsen or improve the situation. Therefore, a simple procedure for error concealment is introduced in the HEVC software. However, there is a need for incorporation of error resilient technique at the application layer and packet protection at the network layer in order to attain the minimum the video quality needed.

2.2 Adaptive Video Streaming over VANETs

This subsection discusses video streaming schemes that are adaptive in their design approach. One of the essential constituents of virtually all network solution is the link layer. The implementation of any of the current class of IEEE 802.11 protocol is the effort of most existing studies in link layer technology. The use of MAC layer during network optimization provides significant benefits. The MAC layer is often manipulated to modify the frame size based on the physical rules to achieve the best balance between the higher delay of smaller frames and the potential distortion of losing larger video frames [15]. At the MAC layer, so many parameters can be manipulated including retransmission limit in order to achieve robust adaptation of the video transmission [16]. MAC scheme that improves video quality through monitoring and frame size changing based on network event. The scheme uses adaptation and dynamic parameters for enhancing the quality of video and experience of the end-user. A Measurement-based analysis of Multi-hop pre-recorded video streaming Transmission (MTRM) using dedicated short-range communication devices is presented [17]. The performance of multi-hop transmission is measured to overcome the problem of high packet loss rate. High packet loss causes video quality degradation. The measurement also considers interference of the communication channel. Further, startup catching and retransmission strategies are introduced to enhance the video application. In addition, performance measurement of the retransmission strategy and analysis of the strategy are conducted. Although, the retransmission strategy adopted might lead to delay in the video transmission.

2.3 Multipath Geographical Routing over VANETS

The Geographical DIstance Routing (GEDIR) is a protocol that considers the distance of a vehicle according to it region for packet forwarding [18]. Another of its kind is the packet forwarding using the Voronoi diagram for GEographic DIstance Routing (V-GEDIR) which is an extension of GEDIR [19]. A loop-aware position-based routing protocol has been proposed. The protocol selects next hop vehicle considering the Voronoi region of the vehicle, which either covers or cut the assumed destination vehicles' sector. However, the dynamic nature of vehicle node is considered during formation Voronoi diagram. Hence, might not be suitable for vehicular communication. In Raw and Das [20], a packet forwarding techniques based on Peripheral vehicles GEographical DIstance Routing (P-GEDIR) has been suggested. It is based on all vehicles available inside the circular strip coverage area of width *R/2* where *R* is the transmission range of a vehicle, which is in the direction of destination vehicle. The vehicles in the circular strip coverage area are called the peripheral vehicle. In junction-based multipath data forwarding, more than one routes from source to destination are employed with logics of characteristics of the road junction in order to deliver data packet successfully. The junction is a point where vehicles are likely to change direction during data communication. This made the selection of next forwarding vehicle to be very challenging due to direction changing. Some few research studies on multipath data forwarding have been suggested in [21-24]. Thus, in Sermpezis, Koltsidas [21], an analytical Junction-centric Multipath Source Routing mechanism (JMSR) has been suggested. JMSR features include the junction-aware logics, the multipath route from source to destination and the source routing scheme. The JMSR employs the geographic routing protocols, such that the location of vehicles and junctions of a street are leveraged through the street's digital maps for data forwarding purpose. In the next section, the proposed video streaming protocol over VANETs is discussed.

3. VANETs Multipath Video Streaming Considering Road Features

In this section, the proposed VMVS-RF is presented and discussed. The VMVS-RS algorithm has three modules when transmitting video streams. The first module is the neighbor information acquisition. The second part is the selection of next forwarding vehicle node considering junction and U-turn roads. The third is route path direction by estimating the Azimuth angle. Because we are considering video frames, the I-frames are transmitted via a path, while the P and B frames are forwarded through a different path, which is the same. Thus, in the study, only two paths are considered for the multipath video transmission. In the proposed protocol, it is assumed that each vehicle node has information pertaining it neighbors and the source vehicle knows the location of the destination vehicle, this information(s) are used to select the next forwarding vehicles in the multipath transmission. The detailed discussion of each module is as follows.

3.1 Neighbor Information Acquisition

At this stage, each vehicle sends a *Hello Packet* to its neighbor vehicles, which are within the range of its network coverage. Since the source vehicle is already aware of the location of the destination vehicle. Therefore, each vehicle forwards information including speed, direction, and current position to its neighboring vehicle. Most current information(s) are utilized to select the forwarding vehicle based on the aforementioned information.

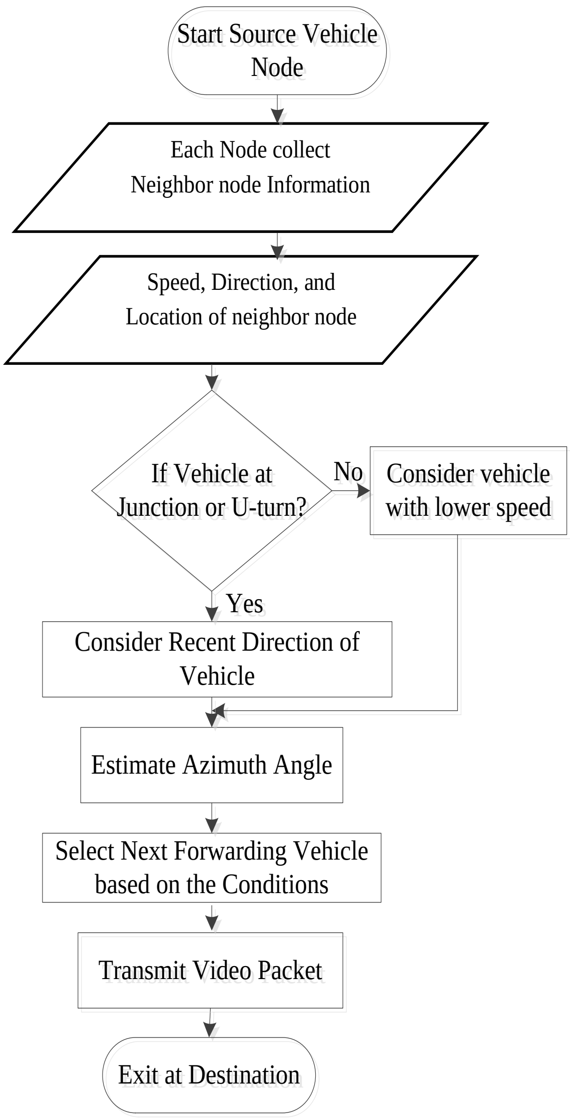

Fig. 2: The Flowchart of the VMVS-RF

3.2 Next Forwarding Vehicle Selection

In this part, when the forwarding vehicle is at the junction or a U-turn, it waits for some random time and request for neighbor vehicles information. At this point, priority is given to the direction of navigation. Only vehicles in the direction of the destination vehicle at the junction or U-turn are selected as next forwarding vehicle. The slowest vehicle is selected if there no vehicle in the direction of the destination vehicle. There two forms of vehicle location at the junction area, namely vehicle before the junction and the vehicle that has already exited the junction. The vehicle, which has already exited the junction in the direction of the destination vehicle is selected. This strategy guarantees video packet delivery since the vehicle is navigating in the direction of the destination vehicle.

3.3 Route Path Direction based on Azimuth Angle

In this subsection, the route path is maintained by estimating the azimuth angle of each intermediary vehicle in order to have a node-disjointed path. When selecting an intermediary vehicle to serve as next forwarding vehicle for the video transmission, the position, and azimuth angle of the vehicle are estimated. This will also minimize the interference between different vehicles in the multiple paths. The related flowchart is depicted in Fig. 2.
The flowchart in Fig. 2 demonstrate the steps and flow of the algorithm. This is employed in simulation experimentation to validate its performance of the proposed protocol.

4. Results and Discussion

In this section, the simulation experiment and the obtained results are discussed. The proposed VANETs Multipath Video Streaming based on Road Features (VMVS-RF) protocol is simulated using NS-2, SUMO and Evalvid video framework. The results obtained from the simulation are compared against the ordinary Multipath Video Streaming (MVS) protocol. The performance is evaluated in terms of Data Receiving Rate (DRR), Structural Similarity (SSIM) Index and video Packet Loss Ratio (PLR). Table 1 highlights the parameters considered during simulation implementation. The parameters are represented along with their corresponding values.

Table 1: Simulation Parameters

Parameters	Values
Simple lane area	$2{,}000 \times 1{,}200$ m^2
Urban simulation area	2500×1800 m^2
Simulation time	600 s
Vehicle speed	2.78 to 13.89 m/s (10 to 50 km/h)
Number of vehicles	50 to 150
MAC protocol	IEEE 802.11p
Video Name	*akiyo_cif*
Video resolution	352×288

Parameters	Values
Video play duration	9 seconds
Transmission range	200 m
Frequency	5.9 GHz
Propagation model	Shadowing
Antenna model	Omni-directional
Channel type	Wireless
Packet type	UDP
Hello packet timeout	1 second
Simple lane area	2,000 $\times$ 1,200 m^2
Urban simulation area	2500 $\times$ 1800 m^2
Simulation time	600 s

The table presents all parameters employed and their individual corresponding values. Further, the results obtained are discussed considering the two metrics including DRR and SSIM index.

4.1 Data Receiving Rate

The average video Data Receiving Rate (DRR) at the destination vehicle has been evaluated. The proposed VMVS-RF protocol supersedes the ordinary Multipath Video Streaming protocol. The relationship of the results is depicted in Fig. 3, which shows that VMVS-RF performs better because the vehicle nodes that move away from the direction of the destination vehicle. Thus, high delivery of video packet is achieved.

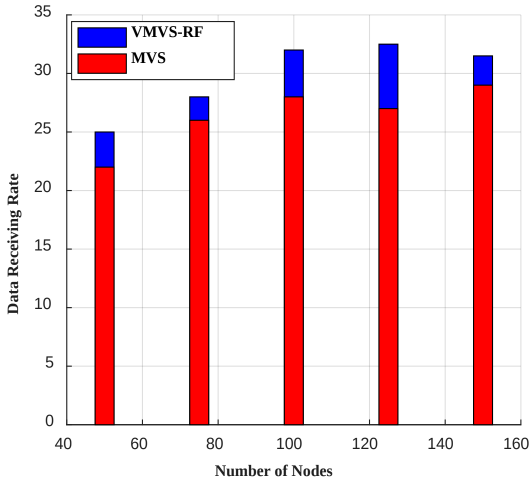

Fig. 3: Data Receiving Rate

4.2 Structural Similarity Index

The Structural Similarity (SSIM) index is employed to ascertain the quality of the video received at the destination vehicle. The SSIM index is evaluated and compared against MVS. The result depicted in Fig. 4, shows that VMVS-RF performs better than the MVS and its relationship is demonstrated. The improved output might be related to the reason that road features are considered in video packet forwarding process.

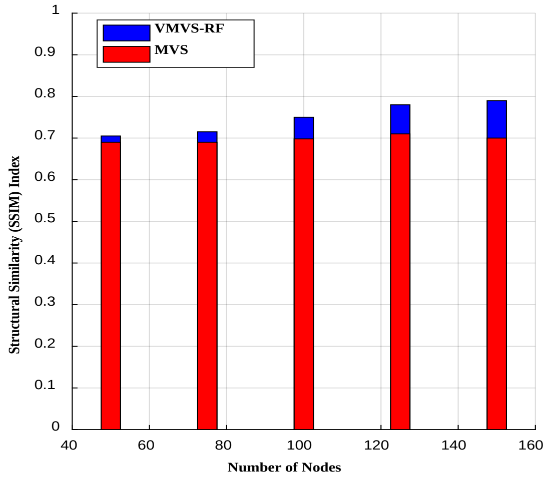

Fig. 4: Structural Similarity Index

4.3 Packet Loss Ratio

The video Packet Loss Ratio (PLR) is used to assess the performance improvement of the proposed VMVS-RF protocol against a normal multipath video packet transmission, which does not consider the junction or U-turn situated on the roads for video packet transmission. The result obtained in the simulation shows that the proposed protocol outperforms the ordinary video transmission scheme as demonstrated in Fig. 5. This improvement might be related to the strategies employed in the proposed protocol. Therefore, fewer video packet loss was experienced in the simulation.

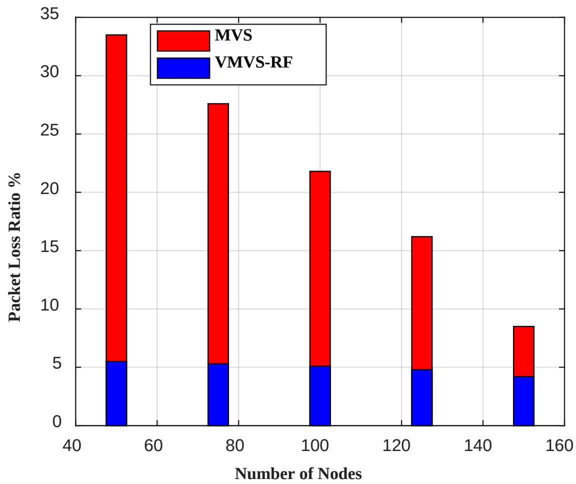

Fig. 5: Packet Loss Ratio

5. Conclusion

In this paper, the road features are considered in the multipath video streaming. The proposed VANETs Multipath Video Streaming, which is based on Road Features (VMVS-RF) protocol has considered U-turn and junctions on the road for video data forwarding. The VMVS-RF protocol provides higher data receiving rate and qualitative video streaming delivery. The proposed

VMVS-RF has been compared against an ordinary Multipath Video Streaming (MVS) protocol. The VMVS-RF protocol achieves higher video Data Receiving Rate with 7% increase and higher video quality in term of Structural Similarity (SSIM) index with 5% increase. The performance gain on the Packet Loss Ratio (PLR) is 19.5% compared to the MVS. Based on the aforementioned results, the proposed protocol has depicted it an improvement and its strengths in multipath video streaming over VANETs.

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