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Study on QoS Management for Video Streaming in Vehicular Ad Hoc Network (VANET)

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Abstract

Vehicular Ad Hoc Network (VANET) is a particular type of MANET providing various wireless communications such as infrastructure communications and inter-vehicle communications. Recently, VANET networks are attracting ample attention from the scientific and business community. In VANET networks, the textual data is almost negligible compared to the multimedia data that is interactive and expressive. Quality management of video streaming over the VANET environment is a complex task, given the specific constraints of multimedia data in terms of Quality of Service (QoS), security, system performance, and a random number of vehicles. This article discusses existing video streaming techniques in VANET networks by highlighting different QoS and Quality of Experience (QoE) metrics related to video streaming. A comparative study of video streaming models of literature on VANET is presented, taking into consideration several QoS and QoE metrics. Finally, the trends in video broadcasting in VANET networks are identified as future research directions. We believe that our comprehensive survey will enhance the understanding of video streaming tasks in the VANET environment and provide useful knowledge about the research trends and directions. VANET environment and provide useful knowledge about the research trends and directions.

Keywords Vehicular ad hoc networks · QoS · QoE · Video streaming · Intelligent vehicles

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1 Introduction

Prospective authors are invited to submit papers that fit within the scope of the journal.

For improving road safety and traffic management services, the innovative paradigm of Intelligent Transport Systems (ITS) is an active research area [1]. In ITS, especially, the VANETs are attracting attention by user search queries, for example, information as a messages and multimedia contents and similar other search terms [2, 3 and 4]. Due to improved VANETs, the drivers can enjoy several video applications such as Video on Demand (VoD) and video conferencing. Over VANETs networks, video broadcasting focuses on areas related to the real-time video streaming, emergency video streaming, storage optimization, network coding utilization, bandwidth allocation, and video packets scheduling [5, 6]. Compared with traditional video streaming, VANETs services are challenging and require high bandwidth. Thus, the management of these resources becomes crucial for avoiding overload, delays, and downtimes. As per our knowledge, the management and control of the variation of the VANET channels and the bandwidth requirements have not been thoroughly investigated. For avoiding traffic jams and accidents on the road, video broadcasting plays a vital role in satisfying the needs of drivers. In particular, vehicles and local servers can broadcast video streams in real-time so that drivers change directions and course of actions according to observed information from live video streams.

Several other services may be exploited for drivers by applying real-time video transmission over VANET networks, such as video-on-demand, conference calls, games, and others. Video transmission in a VANET environment can experience several obstacles in terms of capacity, performance, and QoS, despite its significant beneficial aspects for drivers. The combination of precise characteristics of vehicular networks and strict requirements of the video in quality terms has contributed to the number of QoS challenges. Satisfying the end-users requirements by providing support for applications of video streaming and QoS satisfaction in VANETs will contribute to its exponential growth and success [7]. In various studies, the authors have addressed multiple aspects of VANETs, including routing protocols, cloud computing in VANETs, security, applications, etc. However, there are only scarce studies on video streaming that considers the strict requirements of videos QoS in VANETs.

This article discusses existing video streaming techniques in VANET networks by highlighting different QoS and Quality of Experience (QoE) metrics related to video streaming. A comparative study of video streaming models of literature on VANET is presented, taking into consideration several QoS and QoE metrics. Finally, the trends in video broadcasting in VANET networks are identified as future research directions.

The rest of the paper is organized as follows: Sect. 2 presents a related literature review, Sect. 3 summarizes perspectives applications of video streaming and discusses fundamentals issues of video streaming in VANET. In Sect. 4, we define QoS and QoE in a video streaming over VANET, and review QoS/QoE aware video streaming over VANET. Section 5 discusses some challenges, trends and future research directions. Finally, this paper is concluded in Sect. 6 with open research problems.

2 Video Streaming Applications in VANETs

This section examines the proposed solutions in the literature, which improve the robustness and efficiency of video streaming applications in VANETs. Figure 1 shows the number of publications from 2010 to 2018 for video streaming approaches and applications in

VANETs. In Fig. 1, we notice a remarkable growth of scientific papers in from 2010 to 2018 in relevant scientific sources of IEEE and Science Direct. This confirms the interest growth of video streaming techniques and applications in VANETs. Although, there is a considerable increase in the number of scientific publications, there are very few cumulative studies on QoS requirements of video streaming in VANET. Authors in [8] analyze the taxonomy of video streaming protocols, applications, requirements and challenges. In [9], protocols on multipath video streaming in vehicular communication are studied and analyzed. Authors in [10] present the supporting technologies and significant application areas of video streaming in vehicular IoT environments. In [11], the authors introduce definitions, concepts, and evaluation criteria used by video delivery routing protocols on the vehicular environment. The summary of the significant work on VANETs is highlighted in Table 1, focusing on several reviewed parameters.

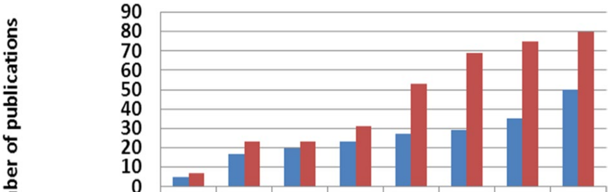
Real-time video broadcasting over VANETs is useful for many applications, including video streaming between vehicles, live emergency video transmission and many other related domains [12]. All of these applications and services face a number of challenges to specific characteristics of VANET environments and stringent video quality requirements. In the following, we present some of the difficulties involved in video streaming in the VANET framework.

2.1 Video Streaming as a Service in VANET

Video stream is the key aspect of the VANET paradigm, as it provides a clear and understandable view of traffic information for drivers compared to the textual data. For improving the travel experience of road users, video streaming offers useful applications ranging from comfort and leisure, such as video downloads, traffic security applications to security, and accident prevention. We present the potential applications and use cases of video streaming in VANET as follows:

2.1.1 Overtaking Maneuvers

A large number of accidents in highway or urban areas are due to wrong overtaking maneuvers [13]. An accident due to the wrong maneuvers and overtaking can lead to a series of the vehicle to vehicle crashes, generating traffic jams, especially, when there is no information about the accidents to the new users. These accidents and dangerous traffic flow situations can be avoided with the adoption of sensor technologies in vehicular networks [14],



	2010	2011	2012	2013	2014	2015	2016	2017 - 2018
IEEE	5	17	20	23	27	29	35	50
Direct sciences	7	23	23	31	53	69	75	80

Fig. 1 Number of publications related to the video streaming techniques and applications in VANET from 2010 to 2018

Table 1 Comparison of related literature reviews

References	Range of exploration year	Number of revisited publication	communication	Parameters for Review						
				QoS	QoE	Video coding app	Routing app	Error resiliency app	Overlay app	Adaptive app
[8]	2005–2014	11	V2V, V2I	✓	✓		✓		✓	
[9]	2008–2016	14	V2V,V2I	✓	✓		✓			
[10]	2010–2016	40	V2X	✓	✓		✓	✓	✓	✓
[11]	2007–2013	17	V2V, V2I	✓			✓			
Our review	2005–2018	50	V2V, V2I, V2X	✓	✓	✓	✓	✓	✓	✓

15. When there is a delay in driver alertness or the speed of the vehicle is above some limit, the situation often becomes dangerous [16].

Consequently, any information that gives a hint to the drivers about the road situation and the decision to overtaking maneuvers is vital for the safety of vehicles and drivers. Other applications impose strict requirements in terms of end-to-end delay between the blocking of a vehicle and the overtaking of a vehicle. As mentioned in [13], the required time for video dealy must not exceed 200 ms. Otherwise, frames in the streaming video will not provide the necessary useful information. Besides, acceptable perceived video quality must be guaranteed for taking advantage of the real-time scenarios. The operation of the overtaking scenario and system is illustrated in Fig. 2.

2.1.2 Pedestrian Crossing Assistance

Pedestrian is the ordinary person who uses the roads and experiences risk due to the carelessness and erroneousness of drivers or pedestrians themselves [8]. The use of V2I communication support systems is an optimal option for enhancing pedestrian safety [17]. When a vehicle approaches a pedestrian crossing, it will be able to exchange video in real-time with neighboring cars. Mobile or static obstacles are considered a big challenge for this type of application that requires strict low latency with the acceptable video quality. Figure 3 shows the pedestrian crossing model.

One of the works that allow the removal of strict boundaries between layers, where data is strictly kept in a given layer, is multilayer optimization [18]. In particular, this approach allows communication between layers by allowing one layer to access data from another layer to exchange information and allow interaction. In [19], the authors showed that knowing the current physical state would help a channel allocation scheme or an automatic repeat request (ARQ) strategy at the MAC layer to achieve throughput maximization and optimize compromises. Based on QoS requirements, TCP can manipulate receiver windows for various applications to improve throughput [20]. In [21], part of the cross-layer solution uses Unequal Error Protection (UEP) codes, which is an efficient method to protect video data generated by the application layer by exploiting its fundamental properties. In [22], the authors proposed a design approach based on stand-alone components to optimize system performance. In this approach, cross-layer monitoring and control are also presented. This approach provides work roaming on the Internet by managing mobility at the application layer. A dynamic multilayer multi-attribute design framework (DMA-CLD)

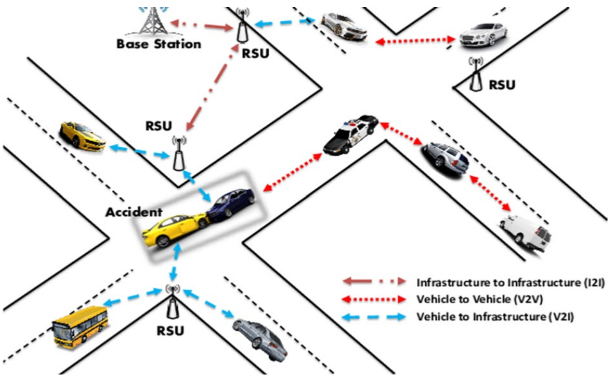


Fig. 2 Overtaking scenario

Fig. 3 Pedestrian crossing assistance

is proposed in [23], which allows interactions between the network layer and the upper and lower layers of the OSI model.

2.1.3 Video Surveillance

Anti-social behaviors and acts such as crimes, vandalism, robbery, and irritating people on moving public transport are exponentially increasing. As the safety and security of passengers is a top priority for the authorities, live video surveillance is very useful to prevent such behaviors [24]. The live video can be captured and forwarded to the traffic management or emergency services to avoid any crime. Through the V2I communication, a vehicle can transmit live video about a traffic accident or health conditions of the passengers of crashed cars to the hospital or the nearest ambulance. Video streaming provides realistic traffic information about road traffic situations, the level of traffic jams, and the severity of the accident. The driver thus, can take appropriate responsive actions [10]. Another purpose is also to warn drivers about any crashes, obstacles or animals crossing the roadways. The video stream provides more precious information than the simple textual message or an alert which normally are neglected by drivers. According to [8], the delay of video surveillance should not exceed 6 s, and the visual quality should not be less than 25 dB.

2.1.4 Video Communication for Entertainment

VANET provides comfort, infotainment, and entertainment using video streaming services like games, video conferencing, the nearest restaurant information, parking availability, tourist places, and similar others. Infotainment applications of video communication among vehicles contribute to the success of the vehicular network and its adoption and penetration in the market. Such video application needs low delay and acceptable video quality of 29 dB. However, the delay and video quality for infotainment applications do not require high priority in terms of delay and channel access as that of the traffic safety services.

Machine Learning, Deep Learning, and Artificial intelligence approach in VANET

Machine Learning (ML) can imitate human intelligence that can be used for several applications. In VANETS, ML can be used for QoS guarantee, traffic optimization, and secure data transmission and reception. Many machine learning (ML) techniques have been exploited by researchers to improve the QoS for Vehicular Ad Hoc Networks (VANETs). ML techniques assist the parametric network decision making to guarantee the QoS in VANETs. A Q-Learning based algorithm is proposed in [25] to tackle the traditional issues with IEEE 802.11p MAC protocol in VANETs, such as a high end to end delay, poor scalability, and poor packet delivery. A learning capability is induced through the proposed Q-Learning algorithm via interaction between vehicles that reduces the end to end delay and collision among packets with the optimal continuous wavelength. The proposed method does not require any prior environment information and behaves with a cumulative reward that corresponds to act accordingly. A context-based packet forwarding method is proposed in [26] in which the last communication hops utilize reinforcement to optimize the network. The Q-Learning algorithm is used for the next-hop selection with rewarding parameters that correspond to the status of the link. The Q-Value is designed so that every next hop is selected based on the performance evaluation to choose the most optimal next hop. The work presented in [27] propose an algorithm that enables the network to reduce end to end delay by selecting paths that are higher in vehicular density to avoid the forward and carry issues. The vehicles are assumed to have GPS deployed on them, and the road and location information is available on the Road Side Units (RSUs). If in case the vehicle is not in the range of RSU, then the location of the vehicle is predicted by the ML algorithm along with the direction and transmission range. A clustering-based routing algorithm is proposed in [28] that selects the cluster head considering the buffer size and velocity of the node, with the aid of Radial Basis Function (RBF) Neural Network (NN). A cost function is calculated for each cluster that is taken as an input to the RBF, which then makes the decision of selecting the best-suited cluster head for a given cluster. A method for training a classifier for a decision tree to classify data for predicting the most suited nodes for performing the role of an intermediate node is presented in [29]. Each node is provided with the decision tree, and hence the nodes for the job are selected based on the region where the nodes are deployed. A centralized congestion control strategy [30] for data that use RSUs at different intersections deploys the most famous unsupervised learning algorithm, K-means clustering. The vehicles are provided with preliminary information at the red lights so that the communication collisions are reduced.

The network security aims at securing the communication of data against any malicious activity whereas the transportation optimization aims at data storage, collision prediction, infrastructure, vehicle analysis etc. Deep learning algorithms are proposed in [31] for safe driving utilizing Back Propagation (BP) NN that evaluates the possible risk of collision and passes the information to the VANETs communications. Image sensing mechanisms are exploited in [32] to capture and analyze the situation of the vehicle. The vehicles are tracked for human attention mechanisms based on deep features explored for Convolutional Neural Network (CNN). The data storage issue of VANETs is targeted in [33] that aids in transferring the essential data to a new node within range when the carrier node is on the verge of getting away from the range. For selecting a new carrier, the fuzzy logic and reinforcement methods are used based on the throughput and bandwidth parameters. A deep learning method [34] is used for generating an integrated self-diagnosis system that deploys a module for creating the training dataset compiled from on-vehicle sensors. This data is further utilized to diagnose any issue in any part of the vehicle, henceforth predicting the condition of the vehicle. A method is proposed in [35] that utilize the parameters such as cluster head load, gateway candidates' load, duration of vehicle to vehicle connectivity and signal strength as criteria for the fuzzy logic to choose the gateway communication between the LTE infrastructure and the source vehicle. The source node takes the decision based on the data collected during the data collection process. The fuzzifier converts the input data into degrees using predefined functions and the fuzzy gateway decision is taken based on this input data. An adaptive approach [36] serves as beacon for vehicles to regulate vehicular beaconing. The fuzzy logic system takes as an input the parameters such as packet time, traffic condition, single hops neighbors and speed of nodes. Similar beaconing algorithm [37] based on beacon rate adaption utilizes the fuzzy logic model that takes traffic density, vehicle location and vehicle condition as input criteria. The criteria of fuzzy logic for the rate of beaconing is adjusted based on statuses such as hazard, non hazard and emergency, non emergency. Fuzzy logic in deployed for devising a routing protocol [38] that determines the trust value for choosing the link validity. The input parameters for the fuzzy logic are taken as connectivity, congestion and bandwidth.

2.2 Challenges/ Fundamental Issues

Some significant issues and challenges need to be tackled to enjoy all the services provided by video streaming and providing high-quality video. Video streaming over VANET is a challenging task, and this challenge is due to the combination of video's strict QoS requirements and VANET peculiarities. There are a certain number of fundamental issues affecting video streaming [39]. Video is comprised of a large number of images that should be transmitted /exchanged, which requires the use of considerable network resources. These requirements thus create overhead, consuming a lot of bandwidth [40]. Moreover, video streaming has stringent requirements in terms of delay and packet loss. Packet delay poses an issue given that with video streaming, the receiver must perform three steps simultaneously: receive, decode and display images at a constant speed. Every delay in an image can generate perturbations in video reconstruction [41]. For delay effect reduction, a buffer can be used by the receiver. It will avoid extra delays caused by the reception and the storage of all packets of a full block. A memory cache is also used to copy the receiving packets and then forwarding them to the target source. Cisco, which is the worldwide leader in networking has defined delay requirements for the exchange of video content, which should not exceed more than 4 to 5 s [42]. Overall, the effect of delay on video quality is related to the type of video application. Generally, the stored videos and video streaming are less demanding in terms of delay as compared to interactive and safety-related video applications.

The packet loss also poses an issue given that the loss of some packets often has a negative effect on the quality of the reconstituted video [43]. Several reasons can lead to the corruption of packets and data loss such as network congestion, route disconnection, and or transmission errors. Another cause of packet loss can be packets collision. In particular, collisions among hidden terminals are quite frequent in a broadcast which attenuates the packet loss effect. A controller and error correction approach can be designed in the video streaming system. According to Cisco, packet loss should not exceed 5 percent. Therefore, video streaming systems over VANET have to fulfill all of these basic requirements while being constraint by the VANET specifications. In VANET, with the number and speed of vehicles and the limited communication range, vehicles are frequently changing from one network to the other, which leads to a highly dynamic and unpredictable topology. These irregular patterns can adversely affect the communication path between the sender and the receiver when the video is forwarded. Thus, this leads to the intermittent of video streaming continuity. Also, the limited shared bandwidth of wireless medium is another reason for packet loss.

There are several applications that augmented in VANET through streaming video data in order to optimize drivers' and passengers' experiences. Due to the variety of applications involved, it is not simple to define a unique model of requirements. Each one of the applications must be handled according to their specific requirements in order to deliver an expected QoS. Whatever the video streaming service provides, the necessary resources to fulfill the requirements must be provided, and a minimal level of QoS/QoE satisfying users has to be guaranteed.

3 QoS/QoE Performance of Video Streaming in VANET

QoS represents the degree of satisfaction of a service requested by the user [3],4. The primary purpose of providing QoS is to deterministically manage the network resources. From the customer viewpoint in the streaming video, a satisfactory video distribution also requires the subjective acceptability of the content. QoE is the estimation of a service provider's quality from a user's perspective. Video streaming applications over VANET usually require different levels of QoS/QoE. In this section, we focus on the question of QoS/QoE as an issue for providing a satisfaction perceived video quality to the user/driver's needs.

3.1 Structure of Video Streaming Over Vehicular Ad-Hoc Networks

Video streaming in VANET is a process encompassing several steps. Firstly, the video content which is stored video (e.g. movie, TV shows) or live content (e.g. traffic conditions, imminent events) is encoded at the source node side. Then it is transmitted in compressed form over the network. Finally, the video content is decoded and displayed on the receiver side. The main advantage of streaming is that it avoids the downloading of the full video content for playing the video. Instead, a continuous stream of data is sent and is played as it arrives. Using a compression standard, Video streams are compressed and partitioned into sub-streams, to achieve efficient load balancing in video streaming and to reduce video size by reducing redundant and irrelevant video data [44]. The redundancy could be color space, temporal or spatial, while the irrelevant information in video data is considered unnecessary data. The most known and used compression standards are MPEG-2,-4,-7,-21 [45], H.264/AVC [46], and H.265/HEVC [47]. The differently encoded sub-streams can be transmitted using cooperative relaying techniques to one or multiple receivers through single or multipath communication. However, during transmission, video packets and due to several reasons such as network congestion, transmission errors, and connection failures, packets may be corrupted and lost. Therefore, error resiliency technique as redundancy, retransmission, or concealment technique can be used to overcome the erroneous packets. Also, for optimizing video quality, many video transmission parameters can be adapted. Figure 4 shows the taxonomy of vehicular video streaming.

3.2 Resource Allocation in VANET for Video Streaming Scalability

In VANET, the driving experience can be improved by delivering video streaming services. Consequently, strict delay and large bandwidth are needed to achieve videos transmission inside VANET. In reality, VANET constraints like interference linked to wireless channel and highly topology variation of the network can affect the network throughput. For that reason, many research works have been proposed to deal with these challenges.

In [48], the authors propose to use the scalable video coding (SVC) to enhance the quality of service linked to transmitting video inside VANET. The proposed work is focused

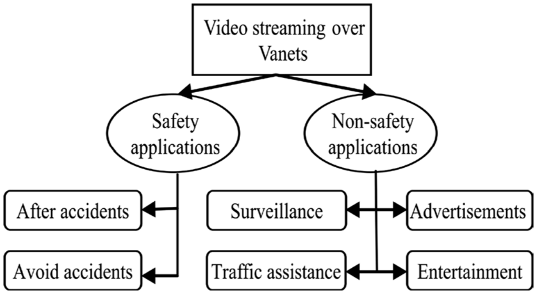


Fig. 4 Structure of Vehicular Video Streaming

on V2I video transmission in highway scenario. SVC is used to encode a group of pictures (GOP). The authors used also signal-to-interference-and-noise ratio (SINR) to deal with the challenge of mobility. The goal of the paper is to optimize the resource allocation by using an algorithm based on dynamic programming. According to the simulation results show that higher-quality videos are delivered. In addition, the proposed technique outperforms existing algorithm in term of PSNR. Despite good results presented in the paper, the proposed technique needs more simulation on difference scenario to get realistic evaluation. As example, the noise can be varied. The number of vehicles also can be discussed and defined according to the position in highway. In realty, the density of vehicles in the start and the finish of highway is always more elevated than in the middle of highway, and something for the vehicle speed.

Another scheme to deal with resource allocation for video streaming scalability: RALS (Resource Allocation and Layer Selection) was proposed in [49]. The proposed technique is dealing with resource allocation in the context of highway. RALS is based on using multi-user video streaming. RALS is resolved by decomposing it into two phases. Phase 1 is regarding resource allocation challenge where greedy based resource allocation based was used face to this problem. In phase 2 which including scalable video coding layer selection where the author used dynamic programming to deal with this problem. Multiple scenarios were used in simulation study showing that RALS outperforms other techniques. However, there is a lack of realistic scenario as explained in the previous paper discussion. In addition, the authors did not consider the quality of service.

In [50], the authors propose to use SVC streaming for resource allocation in VANET. The main problem is split into two sub-issues. The first issue is regarding the layer selection. While the second sub-issue is linked to resource allocation based on quality of service. The system architecture is based on using cooperative VANET. PSNR ratio is used to measure the quality of received video. Two kinds of video communication are considered V2I and V2V. Tabu search algorithm is used to optimize the results provided by greedy algorithm. The performance of the proposed scheme is measured through a simulation study. Even the fact that the proposed technique outperforms greedy algorithm but there is a lack of explaining and discussing the threshold of the channel condition for complexity and system performance.

The problem of resource allocation in VANET is deeply treated and surveyed in [51]. Three kinds of VANET type were treated which are: (1) Cellular Vehicular Network, (2) Dedicated Short Range Communications Vehicular Network, and (3) heterogenous Vehicular Network. Many allocation techniques have been discussed and compared. The future directions of this challenging problem will be concentrated essentially on using deep and machine learning, and on adopting blockchain technology for securing the communication and to guaranty the integrity and availability of data. The resource allocation strategies for video streaming in VANET is still attracting the research community as a challenging problem that open new direction in ITS.

3.3 QoS/QoE compatibility in VANET

Video streaming in VANETs is a complicated task, which leads to the strict parameters of QoS and QoE and the optimal QoS/QoE satisfaction from the user viewpoint.

3.4 Video Coding Category

The primary trend of research directions within this category is to use, evaluate and compare video coding standards and techniques mainly at the application layer level.

In [52], the authors compare the H.264 and H.265 video coding standards under the highway scenario. As the two schemes have different traffic demands, two flooding algorithms; the Counter-Based strategy, and the Distance-Based strategy are compared for selecting and employing the best configurations. In [53], the authors evaluate the HEVC video coding standard's behavior for video streaming in the VANET environment. It is concluded that actors like packet size, slices number per frame, packet rate which is a number of transmitted packets per second, and a number of transmitted I-frames per second should be taken into consideration to guarantee a certain video quality.

In [54], the authors analyze the jitter and transmission delay of video streaming over VANET using Network Coding (NC). The transmission of video encoded based on NC uses several steps. The sender encodes packets, then considers for dissemination, and finally, transmitted to the destination. However, [54] does not consider other QoS parameters of the video, for example, transmission delay like packet delivery ratio. In [55], the authors in the form of the Network Coding based Data Dissemination (NCDD) suggest the use of network coding broadcasting video content. This mechanism forces the relay nodes to wait for the reception of a whole block of decodable frames. It thus makes it possible to increase the bandwidth consumption because different packets are sent to the nodes. However, that causes additional delays after a few hops of communication. In [56], the authors propose a video streaming solution on a VANET overlay. The overlay approach is based on the replication of the real network to have faster transmission to the destination nodes [57].

Others standards are proposed to support routing protocols to manage the resource and information into VANET network and reduce complexity such as:

3.4.1 IEEE 1609.1 (Ressource Manager)

This standard describes the resource management service called RM (Resource Manager) designed to allow remote applications to communicate with OBUs via RSUs. The RM aims to meet the requirements of remote applications by providing them with timely access to OBU resources such as memory and user interface in a consistent manner and ensuring interoperability.

3.4.2 IEEE 1609.4 (Multi-Channel Operation)

DSRC-based (Dedicated Short Range Communication), WAVE devices must provide multi-channel access and allow communications over the control channel and service channels. It's the role of the 1609.4 standard which defines all the mechanisms necessary for priority access to the channels, the coordination and routing of data to the channels, and the transmission of data Being DSRC-based, WAVE devices must provide multi-channel access and allow communications over the control channel and service channels. It's the role of the 1609.4 standard which defines all the mechanisms necessary for priority access to the channels, the coordination and routing of data to the channels, and the transmission of data.

3.5 Informations Management in VANET Networks

To minimize the different resource in VANET we need some techniques to reduce the traffic and the quantity of information convey through the network. For this reasons several approaches are proposed in the literature we can cite as example:

In [58], the authors discussed energy consumption and the quality of service in the routing of packets in vehicular networks. They proposed an improvement of the OLSR (Optimized Link State Routing Protocol) to reduce power consumption. They named their DE-OLSR version. The results obtained that their version clearly surpasses the standard version (OLSR) in terms of energy consumption, while offering comparable quality of service.

The authors of [59] studied the performance of networks vehicles for energy saving and have proposed a model for optimizing RSU transmission radius according to road traffic. The performance is studied considering a realistic vehicular traffic scenario. The results show that their model saves more energy compared to other models scheduling. The authors of [60] studied an ordering model of RSUs to reduce energy consumption. Given a set of RSUs already deployed, the objective is to seek an optimal scheduling which allows activate or put the RSUs on standby for a specified period of time, so that the overall energy consumption of the RSUs is minimized and the connectivity in the network is not degraded. The problem is divided into two sub-problems. The first aims to determine the minimum number of RSUs to activate in a particular instance of the vehicular network, while the second sub-problem decides when to sample the course of the network scenario. The authors have shown that their model manages to make a number work reduced RSUs to meet vehicle communication requirements and thus to reduce the consumption of energy in the network (Table 2).

3.5.1 Error Tackling

As the loss of video packets can severely degrade the QoS of perceived video, integrating a controller and error correction technique in the video streaming system is very useful. In state of the art, several error recovery mechanisms and techniques are proposed to overcome the erroneous packets. The state of the art under this category is divided into three sub-classes according to recovery techniques. These are techniques based on retransmission, methods based on concealment, and techniques based on redundancy. Table 3 shows the advantages and weaknesses of different error resiliency mechanisms in VANET networks.

3.6 Redundancy Based Approaches

Using the Redundancy technique, the original data sender duplicates the data before forwarding it to the recipient, which allows it to use that copy latter to recover lost data when needed. In state of the art, there are mechanisms based on the redundancy of error

Table 2 Comparison of QoS/QoE aware video-coding-based video vehicular streaming approaches

Work	Year	Motivation	Coding technique	Environment	Scenario	Simulator	QOS metrics									QOE metrics				
							JT	DL	PL	PSNR	CO	TH	PDR	PBF	FL	MOS	SSIM	SL	IR	APK
[52]	2014	The more robust video coding standard for VANET	H.264/AVC, H.265/ HEVC	Highway	V2V	OMNeT++				✓					✓					
[53]	2013	HEVC's suitability for VANET	H.265/HEVC	Urban	V2V	OMNeT++			✓	✓										
[54]	2015	Increasing PDR and reduce delay	Network coding	Urban	V2V	NS3	✓	✓												
[55]	2006	Improve bandwidth consumption	Network coding	Urban	V2V	QualNet					✓		✓							
[56]	2010	reduce the impact of packet loss	SVCMDC / FMO	Urban	V2V	NS2		✓	✓	✓	✓									

resiliency, such as interleaving [61], Erasure Coding (EC) [62], and Forward Error Correction (FEC) [63]. Nevertheless, techniques based on redundancy can lead to an overload of the VANET network, given the variable number of video packets crossing networks between source and destinations.

In [64], the authors represent a calculation mechanism to describe the optimal number of redundancies required for a video sequence, terming it as a SHIELD approach. It is based on an FEC technique for improving the transmission of video packets in the VANET network. By guaranteeing a more resilient transmission of video sequences, SHIELD is able to maintain an optimal QoE of video data. In [65], the authors present a ShiedHEVC as the extension of the SHIELD. ShiedHEVC is a self-adaptive mechanism that has been proposed for the improvement of the transmission of video sequences encoded according to the H.265 standard based on the blurred Hierarchical File System (HFS).

3.7 Packet Retransmission

When a video packet does not reach the recipient in a certain fixed time, retransmission of that lost packet becomes necessary. This error resiliency technique is thus based on sending a recipient error message (negative acknowledgment) to the source for retransmitting the lost packet again. Redundancy overloads the VANET network bandwidth due to retransmission. The Multichannel Video Error Broadcast (MERVS) [66] approach splits the frames of the MPEG stream via two channels, a low-reliability channel using UDP protocol for P and B frames, and reliable channel using TCP protocol to I-frames transmission. The authors thus propose to rely on (i) a fast start of frames to be able adjust and negotiate the bit rate transmission, (ii) a Scalable Reliable Channel (SRC) to balance communication between the two channels and schedule video messages, and (iii) a priority queue to give an exact order of video packets based on their ID. In [67], the author claims that when packet retransmission is needed, delays will be induced. To minimize these delays, the authors in [67] propose using the ARQ retransmission mechanism of TCP. This technique gives priority to I frames and uses TCP protocol for retransmission of this frame type. On the other hand, it uses the UDP protocol for retransmission of P or B frames type. The objective is to improve the video quality when a retransmission request is sent. The disadvantage of this technique is the extensive delays introduced. In [68], Hybrid Error Recovery Protocol (HERP) is a protocol based on (i) unequal protection of video images according to their type (I, P, B), (ii) a reporting technique and (iii) subpacket error correction (SPFEC) as in [69]. HERP offers a high rate of retransmission to I-frames type over P and B frames and to protect the I-frames that more critical. When a receiving vehicle does not receive packet burst errors, it sends the sender a retransmission request for lost packets and the state and

Table 3 Comparison Between Different Error Resiliency Mechanisms In Vanet

Error resiliency technique	Advantages	Disadvantages
Redundancy	High Packet Delivery ratio Low transmission delay	High network overload
Retransmission	Low network overload	High transmission delay
Concealment	Low network overload Low transmission delay	High artifacts in the displayed video

current load of the network. HERP has met the QoS and QoE requirements compared to other protocols such as UDP and UDP-SPFEC.

3.8 Concealment Approaches

Lost images can be recovered from other images in the same video using the concealment techniques. It is a technique that has no feedback video encoder and only applies to the decoder side. Several video streaming approaches in VANET based on the concealment technique have been proposed. In [70], the authors propose a method based on an approximation of decoded image slice. The decoder takes a copy of the missing slice and selects the gray area of lost data. Despite the improvement of the video quality during the playback of a sequence, this approach was not useful in case of significant losses of video packets. In [12], the authors propose the DQORE approach for dealing with the burst loss problem at the application layer. The authors propose to integrate the interleaving techniques to QoE-aware and driven REceiver-based QORE. When an emitter needs to stream video, it interleaves a predefined number of frames, then stores its own current geographic coordinates in the header of the packets, then floods them to all its neighbors. As a result, the effects of frame loss are mitigated by distributing burst losses. Once the frames have reached the recipients, the interlaced images are restored in their original order and read. The Interleaving method is based on the Frame-Copy error concealment technique, in which the last well-received image replaces the lost images. The detailed comparative study of the related techniques is presented in Table 4.

3.8.1 Cooperative Relays Strategy

The approaches within this category find the most reliable path for forwarding video streams. The proposed solutions can be classified into Unicast and Broadcast, based on the number of destination nodes.

3.9 Broadcast Forwarding

Broadcasting is considered a process of disseminating the data to all nodes within a certain distance to the source node. In the literature, we can discover several transmission schemes designed for video streaming. The work in [71] proposes the REDEC approach. It is a solution based on the receiver, which cuts the selection of the relay nodes of the transmission of video content before the transfer of video content begins. It always checks whether they are relay nodes or not. The control packet is periodically broadcasted by the source node to update the state of the node according to the current topology. The decision to determine if a node can relay the received packets depends on the waiting time. In [72], the authors propose QoE Driven and Link QualiTy Receiver (QOALITE) approach. Beacon-less receiver-based approaches have made a significant contribution by avoiding beacon transmissions and saving bandwidth and media access. In [73], the authors propose the Streaming Urban Video (SUV) approach to divide the neighbors into four classes/sectors and selecting one node in every sector as a candidate for rebroadcasting. One in each of the 90◦ sectors of the circle around the node and ideally within the ring formed by a distance far enough to facilitate the dissemination towards the whole network. SUV requires that neighboring nodes exchange beacons containing their positions, time for synchronization, and list of one-hop neighbors with their respective location and the signal power perceived by the reception

Table 4 Comparison of QoS / Q aware error resiliency-based vehicular video streaming approach

Work	Year	Error resiliency technique	Error type	Environment	Scenario	Simulator	QOS metrics									QOE metrics				
							JT	DL	PL	PSNR	CO	TH	PDR	PBF	FL	MOS	SSIM	SL	IR	APK
[64]	2015	FEC (redundancy)	Uniform errors	Urban / Highway	V2V	SUMO					✓						✓			
[65]	2016	FEC (redundancy)	Uniform errors	Urban	V2V	NS-3/ SUMO					✓						✓			
[103]	2016	SPFEC (redundancy)	Uniform errors	Urban	V2V	MATLAB														
[104]	2017	SPFEC (redundancy)	Uniform errors	Urban	V2V	NS-2 /SUMO				✓			✓			✓				
[105]	2009	FEC/Interleaving (redundancy)	burst errors / Uniform errors	highway	V2V				✓	✓	✓									
[106]	2016	Erasure coding (redundancy)	Uniform errors	Urban / Highway	V2V	BEM		✓	✓	✓							✓			
[12]	2016	Interleaving (concealment)	burst errors	urban / Highway	V2V	SUMO		✓					✓			✓	✓			
[107]	2013	Erasure coding: RLC/ XOR (redundancy)	Uniform errors	Highway	V2V/V2I	NS-2		✓	✓				✓							

Table 4 (continued)

Work	Year	Error resiliency technique	Error type	Environment	Scenario	Simulator	QOS metrics									QOE metrics				
							JT	DL	PL	PSNR	CO	TH	PDR	PBF	FL	MOS	SSIM	SL	IR	APK
[66]	2016	Retransmission	burst errors / Uniform errors	Urba	V2V/V2I	NS-2/ SUMO		✓		✓										
[67]	2015	Retransmission	burst errors / Uniform errors	Urban	V2V	NS-2/ SUMO	✓	✓		✓										
[68]	2018	Retransmission	burst errors / Uniform errors	Urban	V2V	NS-2		✓		✓			✓			✓				
[69]	2013	Concealement	Uniform errors	Urban	V2V	SUMO/ OMNeT++		✓						✓						

of their own beacons. [74] proposes the Automatic Copies Distance Based (ACDB). The ACDB uses data about the number of pending packets and vehicle density provided by the beacon system. The goal is to increase the waiting time when vehicle density is at a peak.

3.10 UNicast Forwarding

If the network is very dense, or the throughput is very high, several problems can occur, such as the interferences and packets collisions. In [75], the authors prove that receiver-based approaches are more appropriate than sender-based solutions as they optimally handle the high dynamic VANETs' topology. The analysis of intermediary nodes' buffers size impact on the delivery ratio proves that it is necessary to buffer a large amount of packets in order to achieve high delivery ratios but it does not need to be unlimited as after a certain point. In [76], the authors propose Video Reactive Tracking-based Unicast (VIRTUS), a receiver-based approach. VIRTUS adopts a transmission zone that limits the selection of relay nodes to a sector of the region reached by the communication range of the nodes. This scheme adopts a receiver-based strategy in which the choice of a relay node is extended to a time window rather than a single transmission. In [77], the authors propose the VDADVT approach, which extends the VIRTUS. In this approach, video transmission is decoupled from the relay node process. The authors augment a density-sensitive mechanism to the VIRTUS approach. This augmentation provides stable performance even with an increase in node density and transmission rates. In [78], the authors suggested selecting the best relay vehicles in an urban environment for the transmission of video packages based on the vehicle mobility forecast. The proposed protocol modifies greedy geographic routing protocols for selecting relay vehicles. This protocol takes into account other parameters, such as the transmission rate, the incentive factor and the management of the buffer memory. Table 5 summarizes the QoS/QoE aware cooperative relays-based vehicular video streaming schemes.

3.10.1 Adaptive Approaches (MAC Layer)

Several adaptation approaches for video transmission parameters have been proposed to ensure an acceptable quality of video streaming in VANETS networks. We focus on the number of video layers in the application layer, adapting the retransmission limitation at the MAC layer. In [79], to control the VANET network load and to improve the quality of video streaming, the authors of [68] proposed a technique for adjusting the frame rate and transcoding on IEEE 802.11 by integrating a frame jump. The transmitter decides a frame jump, which is dropped later when it detects a timeout allowed by this frame for optimizing the bandwidth use. In case the case where two consecutive frames are ignored, the sender of video may decide that it is a congestion of the network; thus, it reduces the frame rate. In [80], the authors present the MQRASV approach. It presents an IEEE 802.11p protocol enhancement scheme. Retransmission of frames will be necessary in case of a high frame error rate, which will lead to a buffer overload. Therefore, the transmitter must estimate the VANET network bandwidth and video packet error rate. The proposed adaptation scheme slightly increases the starting delay of sender video packets. However, it considerably minimizes the reading blocking frequency. In [81], the authors use the advanced Scalable Video Coding (SVC) to suggest an adaptive video streaming scheme in a highway environment. This technique takes into consideration the current download speed and the state of the buffer memory to adapt the necessary number of video enhancement layers. As a result,

Table 5 Comparison of QoS / QoE aware cooperative relays-based vehicular video streaming schemes

work	Year	Relay/hop selection	Communication scheme	Environ-ment	Sce-nario	Simulator	QOS metrics									QOE metrics				
							JT	DL	PL	PSNR	CO	TH	PDR	PBF	FL	MOS	SSIM	SL	IR	APK
[71]	2014	Waiting time	Broadcast	Urban	V2V	SUMO	✓	✓		✓			✓							
[72]	2015	Location information link quality Human perception	Broadcast	Highway	V2V	NS-2 /SUMO		✓					✓			✓	✓			
[73]	2011	Positions, time List of one-hop neighbors Respective location Signal power	Broadcast	Urban	V2V/ V2I	Mathematical model														
[74]	2015	Vehicles density minimum waiting time	Broadcast(Flooding)	highway	V2V/ V2I	SUMO/ OMNeT + +				✓			✓							
[99]	2013	Belonging to a high priority broadcast regions	Broadcast	Highway	V2V/ V2I	SUMO		✓		✓					✓					
[108]	2014	Node's waiting time	Broadcast	Highway	V2V	NS-2/ Freeway/ EvalVid		✓	✓	✓	✓									
[109]	2014	Node 's dissemination capacity	Broadcast	Urban	V2V/ V2I	NS-2 /SUMO				✓					✓					
[110]	2010	how many useful symbols can that node provides to its neighbors	Broadcast	High-way/ Urban	V2V/ V2I	NS-2														✓
[75]	2007	Location Velocity Driving direction	UnicastOne path	Highway	V22	NS-2				✓		✓								
[76]	2012	Node's current location Node's future position	UnicastOne path	Highway	V2I	EvalVid		✓	✓											
[77]	2015	Node's current location Node's future position	UnicastOne path	Highway	V2V	NS2/ EvalVid/ SUMO		✓					✓							

Table 5 (continued)

work	Year	Relay/hop selection	Communication scheme	Environment	Scenario	Simulator	QOS metrics									QOE metrics				
							JT	DL	PL	PSNR	CO	TH	PDR	PBF	FL	MOS	SSIM	SL	IR	APK
[111]	2015	Mobility prediction Stability Distance Buffer management Transmission rate	Unicastmultipath	Urban	V2V	NS2		✓							✓					
[112]	2012	Link stability The degree of closeness to the optimal path	UNicast multipath	Urban	V2V	NS-2 /UMM		✓							✓					
[100]	2014	The degree of closeness	UNicast multipath	Urban	V2V	NS-2 /UMM		✓							✓					
[102]	2010	Grey relational analysis	Unicastmultipath	Urban	V2V															
[113]	2016	Nearest neighbors of the destination	Unicastmultipath	Urban	V2V	myEvalvid		✓		✓			✓				✓			
[98]	2016	Connectivity probability	Unicastmultipath	Urban		EvalVid/ SUMO		✓	✓				✓							
[97]	2014	Centrality metric:dissemination capacity	broadcast	Highway	V2I/ V2I	NS-2 /SUMO/		✓	✓	✓										

the receiver will be able to decide an optimal quality of service. In [82], the approach is based on cooperation between vehicles. A vehicle requests a video via a 3G/3.5G network by searching for nearby vehicles to help it cooperatively obtain the requested video. The selected vehicles transmit the downloaded videos via IEEE 802.11p vehicle networks. The challenges for such an approach are the video packet recovery methods that are lost in streaming video, selecting the cooperative vehicles and aggregating the bandwidth, and finally, a proposed scheme for aperiodic re-planning of video data to the assistants. In [83], the authors evaluate the multi-hop video transmission for scalable video codecs of DWT 3D and H.264 SVC. Every RSU randomly eliminates the excess of incoming packets. Consequently, this work proposes a technique for selecting the adaptive target video bit rate. The authors calculate the probability of packet loss to determine the best target video bit rate, which provides the maximum possible visual quality. Accordingly, the maximum possible visual quality depends on the number of vehicles and their positions. In [84], the authors propose the Profit Oriented Resource Allocation (BPRA) approach for resolving the allocation problem of video streaming resources in VANET networks. H.264 SVC coded video is used to provide the optimum quality for each receiver vehicle. To ensure video playback, the proposed algorithm programs the base layer video stream transmissions for each request. To obtain maximum quality with limited resources, the algorithm requires planning for multicast communication of enhancement layers. In [85], to adjust the number of video layers requested by considering the vehicle's speed and position as well as drivers' activity, the authors proposed an algorithm based on a prediction window. For solving the channel competition problem among multiple vehicles, [86] proposes the auction-based channel allocation mechanism. In this approach, the vehicles can bid reasonably according to their utility values, which help the RSU to allocate channels to the vehicles with the most urgent need for and the vehicles with high transmission rates. Therefore, this scheme guarantees the vehicles' smooth playback and visual quality. The vehicles can make the tradeoff between visual quality and no-interruption playback by changing the required layers. Table 6 summarizes a comparison with different QoS/QoE parameters between adaptive-based video streaming schemes.

3.10.2 Optimization Problem in VANET

An optimization is an intelligent approach that solves problems with and without the evolutionary synthesis approaches. The most common and famous optimization technology used in VANETs is.

Ant Colony Optimization (ACO) technology, which is a self-organizing mechanism that is attained through direct communication. ACO is an efficient phenomenon that has the capability of solving complex tasks in a simple manner. ACO is majorly deployed for transportation optimization and QoS routing in VANETs. A position-based traffic-aware routing protocol is proposed in [87] for VANETs that utilize ACO technology to analyze the routes and allot them weights. The work in [88] proposes a Bus Trajectory-based Street Centric (BTSC) method for routing that utilizes the buses for relaying and delivering the messages. The optimal routes are chosen based on the as the density of buses, transmission probability, and deviation of direction from routes. An optimal route selection mechanism is proposed in [89] that is based on ACO that exploits the end to end latency, energy consumption, and throughput as input criteria. The traditional ACO is modified in [90] that decides for selecting the shortest path in congestion scenarios. A hybrid ACO is employed [91] for

Table 6 Comparison of QoS / QOE aware adaptive-based video streaming scheme

work	Year	Adapted parameter	Parameter in consideration	Environment	Scenario	simulator	QOS Metrics									QOE Metrics				
							JT	DL	PL	PSNR	CO	TH	PDR	PBF	FL	MOS	SSIM	SL	IR	APK
[68]	2007	Frame rate	network congestion	Highway	V2V	NS-2				✓										
[69]	2012	MAC retransmission limit	The channel characteristics	Highway	V2I	Matlab								✓				✓		
[102]	2012	number of video enhancement layers	Network throughput	Highway	V2V	Matlab												✓	✓	
[97]	2016	Numeber of helper/ volume of video data to each helpe	Helper's link quality	Highway	V2I	NCTUns			✓	✓										
[98]	2014	Target video bit rate	Number of vehicles Vehicles position Video encoding algorithm	Highway/ Urban	V2I	JSVM 9.8			✓	✓		✓								
[99]	2013	The number of enhancement video layers of each subscriber	Vehicle density The requirement of each subsubscriber	Highway/ Urban																

Table 6 (continued)

work	Year	Adapted parameter	Parameter in consideration	Environment	Scenario	simulator	QOS Metrics									QOE Metrics				
							JT	DL	PL	PSNR	CO	TH	PDR	PBF	FL	MOS	SSIM	SL	IR	APK
[100]	2014	The number of enhancement video layers	Prediction window length channel occupation The vehicle density	Highway	V2I	Matlab		✓		✓									✓	
[101]	2017	Number enhancement of video layers	Location and the velocity of vehicle The activity of the high-priority services The requirement of visual quality	Highway	V2I					✓									✓	

routing that attains higher PDR and lower delay. The reliability of VANETs is proved to be enhanced in [92] with ACO deployment to obtain different alternates.

In [93] the authors proposed a logarithmic QoE model formulated as a convex optimization problem for wireless networks. This model adopts a two-step process to solve the snapshot problem. To characterize the optimal solution analytically and obtain the numerical solution of the set of reading rates, the first process uses the Lagrange multiplier method. To find the optimal number of cached files, the authors developed three alternative search algorithms.

In [94], the authors defined a scheme based on a multivariate statistical approach for the prediction of QoS in a real-time multimedia environment. The authors have also combined their scheme with another scheme for regression analysis and estimate the perceived QoS as a function of the aggregate QoE influencing the weighted parameters. They based their work on a segmentation of the multimedia/VANET distribution network within a framework of three QoS optimization components, in order to structure the proposed QoE prediction model. QoE is estimated as a weighted sum of the parameters influencing QoE.

In [95], A QoE Index for Streaming Video (SQI) model has been proposed, which is ideal for optimizing streaming media systems, but it does not support the reporting function degradation of QoE and has limited monitoring parameters. To build their model, the authors first introduced a video database, and then they studied the interactions between playback blocking and video quality. To optimize the QoE by calculating the optimal starting threshold, which influences the number of starvations, a model was proposed in [96]. This model has allowed the content provider to meet its QoE requirements by choosing the right QoE metrics and to avoid starvation.

In [97], they proposed an optimization scheme for the dynamic rerouting of QoS flows to broadcast scalable encoded videos, consisting of a base and one or more layers of enhancement on OpenFlow networks. This scheme has given the best results for improving the quality of scalable video streaming while causing minimal disruption to traffic at best. A scheme has also been proposed in [98] to optimize the operation or improve the QoS of flows. This scheme aims to extend traditional approaches to multi-domain in order to better manage the scaling of services while managing end-to-end congestion. The authors considered the computation of optimal paths per domain and the sharing of this knowledge among distributed SDN controllers.

3.10.3 Comparative Analysis

Figure 5 shows the different QoS and QoE metrics, the approaches used, and the different scenarios. The first graph of Fig. 5 shows that the delay (which is an end to end delay and frame delay) and Peak Signal to Noise Ratio (PSNR) are the most important metrics for QoS measuring in video streaming systems. Delivery ratio and frame loss are the second most considered metrics for measuring the video quality. The ratio of video packets received by the end-user reflects the quality of the video. Also, the number of frames lost can determine the level of video quality given that the loss of some frames can have a deteriorating effect on video quality. However, other metrics like throughput, control overhead, SSIM, and MOS are less frequently analyzed.

The second graph in Fig. 5 represents techniques based on their applications in state of the art discussed in previous corresponding sections. The graph demonstrates that the video coding technique is the less adopted one. As such, there is no compression technique, which takes into consideration the VANET directly. The literature only studies the features,

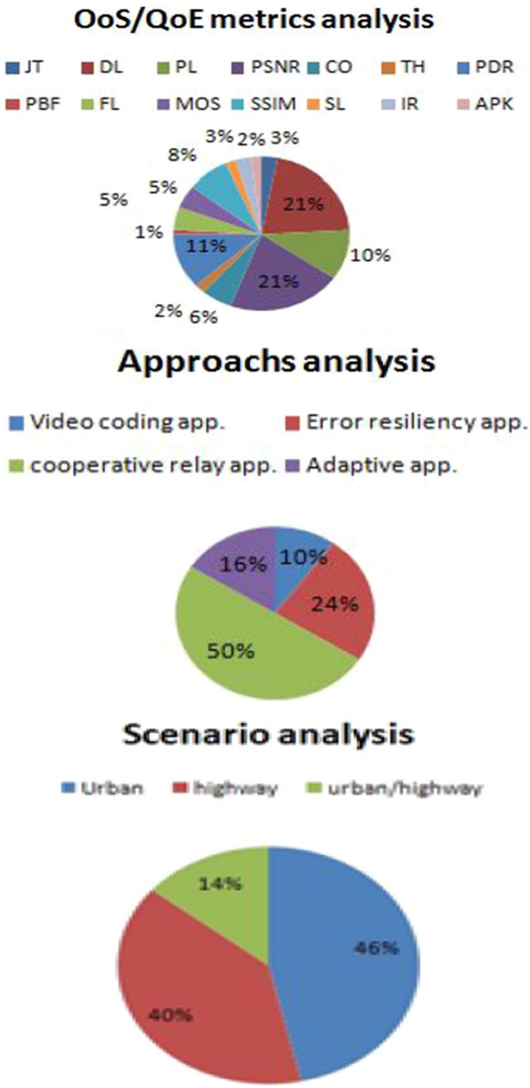


Fig. 5 QoS/QoE metrics, approaches, scenario

suitability and compares the traditional video coding standards. Generally, the cooperative relay approaches are the most adopted. As such, there is always room to apply a new routing algorithm and to optimize relay selection to enhance video quality.

4 Challenges and future works

In this article, the state of the art video streaming over VANET solutions is reviewed, compared and criticized. These schemes thus can be termed as the foundation for video transmission in vehicular environments. The approaches deal with the problems of delay, bandwidth, jitter, distortion, etc. However, many open issues have to be addressed. The following are some of the research directions for improving video streaming in VANET.

1. Video coding in VANET: For optimal video streaming, a compression strategy that takes into account the specific constraints of VANET is the top priority of the optimal VANET. A coding technique that takes into account the dynamic nature of the vehicles and speed is an open and clear research direction.
2. Standard improvement: Although all IEEE 1609.4 802.11p and multichannel standards have seen major enhancements for efficient data transmission over VANET networks, some problems still exist such as fair bandwidth allocation, the lack of necessary resources to streaming videos, and considerable end-to-end delays due to different VANET-specific criteria. As a result, these standards are currently not solving the problems of video broadcasting applications on VANET. Therefore, it is a higher priority to resort to many improvements in the functionality of IEEE 802.11p standards and MAC layer specifications.
3. Cooperation with other networks: VANET network subscribers need to interact with other users in different networks. This cooperation and collaboration can provide optimal services to drivers. Improving the deployment and management of video streaming applications in a context of collaboration between the vehicular cloud and ubiquitous external systems is an exciting research direction [64].
4. Wireless access and radio technologies: The number of vehicles transmitting and exchanging videos is exponentially increasing. This thus results in an increase in the number of video security and infotainment services. However, besides benefits, it can lead to an overload in terms of bandwidth, thus resulting in the degradation of QoS. The future research work should thus consider the more efficient algorithms for QoS guarantee in video streaming systems over VANET environment in heavy usage scenarios.
5. Cross-layer design: The design of the routing algorithms, regardless of the node capacity for forwarding the receiving packets, may inhibit the scalability. Persistent heavy traffic can lead to dropped packets using the 802.11p, which degrades the delivery ratio. The idea of cross-layer design is thus a widely accepted concept because it improves video streaming in the network protocol stack.
6. Video Streaming in Vehicular Internet of Things (VSVIoT): Several problems must be solved in VSVIoT infrastructure and needs further research, such as QoS depending on video streaming application types, IoT devices with limited resources, heterogeneous devices, video coding, and its dynamic and continuous growth.
7. Security and privacy: To provide relevant video data, intelligent systems can handle detailed information about drivers in VANET. As a result, researchers must incorporate new privacy and security mechanisms in the VANET infrastructure, as in the example of [114].
8. Inter-layer interactions: While QoS in the heart of the wireless network has been widely explored in recent years, mainly by the Internet Engineering Task Force (IETF), QoS in VANET networks remains an open field that is only just beginning to be invested in by the research community. QoS in this latter segment must be ensured not only at the IP level, but across all layers of the network architecture. For this, inter-layer interactions, known as cross-layer, are necessary to allow the layers to exchange performance metrics in order to adapt their operation accordingly. Thus, adaptation is the key word in the design and implementation of new protocols and new applications. The latter must be more and more flexible and they must interact with their environment, characterized by

growing heterogeneity. Preserving the quality of the video perceived by the user on the receiver side is the ultimate goal of cross-layer adaptations. The application loss rate is the performance metric considered in the majority of these adaptations. The degradation of video quality by packet loss depends mainly on the type of frames to which the lost packets belong. Indeed, if the transmission causes a loss rate, the video quality will not be identical if the lost packets belong to the I image, to the P images or to the B images. For this, it becomes necessary to have metrics that can inform on the video quality perceived by the receiver in real time and without using the reference video.

9. The progress state of this work also leaves several perspectives open. For the realization of a complete streaming system, the design and production of the encoding module must lead us to the complete implementation of a video CODEC, which can be integrated into existing players; The client of our system will have to integrate this CODEC on an operating system for light equipment like ANDROID. The encoding and streaming modules will need to be more tested in order to determine the optimal basic characteristics (resources required) for the deployment of our streaming server.

5 Conclusion

In this article, we have presented an in-depth study of the literature regarding video streaming in VANET. Numerous policy-based schemes used in video streaming are discussed and analyzed. We also evaluated each approach by presenting a comparative assessment table for the relevant approaches. We present future research directions into video streaming in VANET. According to our comprehensive study, to meet the new context of infotainment video applications, future research should be focused on improving the functionality of the IEEE 1609.4 and IEEE 802.11p standards. We believe that our comprehensive survey will enhance the understanding of video streaming tasks in the VANET environment and provide useful knowledge about the research trends and directions. Thus, new video streaming solutions will improve infotainment applications and road safety in VANET.

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