Towards Video Streaming in IoT Environments: Vehicular Communication Perspective

Ahmed Aliyu[1], Abdul H. Abdullah[1], Omprakash Kaiwartya[2], Yue Cao[2], Jaime Lloret[3], Nauman Aslam[2], Usman Mohammed Joda[1]

[1]Faculty of Computing, Universiti Teknologi Malaysia, Johor Bahru 81310, Malaysia
[2]Department of Computer and Information Sciences, Northumbria University, Newcastle U.K.
[3]Department of Communications, Polytechnic University of Valencia, Camino de Vera 46022, Valencia, Spain
aahmed2@live.utm.my, hanan@utm.my, omprakash.kaiwartya@northumbria.ac.uk, yue.cao@northumbria.ac.uk, jlloret@dcom.upv.es, nauman.aslam@northumbria.ac.uk, umjoda@gmail.com

Abstract

Multimedia oriented Internet of Things (IoT) enables pervasive and real-time communication of video, audio and image data among devices in immediate surroundings. Today's vehicles have the capability of supporting real time multimedia acquisition. Vehicles with high illuminating infrared cameras and customized sensors can communicate with other on-road devices using dedicated short-range communication (DSRC) and 5G enabled communication technologies. Real time incidence of both urban and highway vehicular traffic environment can be captured and transmitted using vehicle-to-vehicle and vehicle-to-infrastructure communication modes. Video streaming in vehicular IoT (VSV-IoT) environments is in growing stage with several challenges that need to be addressed ranging from limited resources in IoT devices, intermittent connection in vehicular networks, heterogeneous devices, dynamism and scalability in video encoding, bandwidth underutilization in video delivery, and attaining application-precise quality of service in video streaming. In this context, this paper presents a comprehensive review on video streaming in IoT environments focusing on vehicular communication perspective. Specifically, the significance of video streaming in vehicular IoT environments is highlighted focusing on the integration of vehicular communication with 5G enabled IoT technologies, and smart city oriented application areas for VSV-IoT. A taxonomy is presented for the classification of related literature on video streaming in vehicular network environments. Following the taxonomy, critical review of literature is performed focusing on major functional model, strengths and weaknesses. Metrics for video streaming in vehicular IoT environments are derived and comparatively analyzed in terms of their usage and evaluation capabilities. Open research challenges in VSV-IoT are identified as future directions of research in the area. The survey would benefit both IoT and vehicle industry practitioners and researchers, in terms of augmenting understanding of vehicular video streaming and its IoT related trends and issues.

Keywords: Internet of things, Internet of vehicles, Video streaming, Vehicular Communication, Intelligent transportation system, traffic safety

1. Introduction

Recently, a steep growth has been witnessed in the production of smart electronic devices including wearables sensor devices, smart phones, network-based house appliances and even mobility machines such as vehicles. A communication enabling connectivity among any kind of networked electronic gadgets, at anywhere and any time in order to achieve some purposeful goals is referred as IoT network environments [1]. Sensor enabled intelligent electronic devices are capable of monitoring, cooperating and responding to their immediate physical surroundings. Due to the enabling computing capabilities in smaller devices, IoT has the capacity to influence human lives positively through interconnection and automation including home appliances, environmental monitoring, surveillance and security automated devices, health monitoring and managing day-to-day task. As the existing claim has shown that there will be more than 50 billion interconnected devices by the year 2020 [2]. The interconnected devices of which more than 90% will be of distinctive IoT devices including small embedded computers, wearable devices, vehicles and application-specific wireless sensors. It is considered that the highest data traffic generated from the IoT devices would be multimedia data including images, audio and video. The multimedia traffic will be about 80% of the overall Internet data traffic by the year 2019 [3]. Alvi, *et al.* [4], suggested a new paradigm named as "the Internet of Multimedia Things (IoMT)" and claimed that multimedia is an indispensable part of IoT. However, in the multimedia data, we focus on video data and for the IoT communication devices and emphasize on vehicles to vehicle and vehicles to IoT devices.

Mobile network has introduced a new paradigm called Vehicular Ad-hoc Networks (VANETs) with the focus on inter-vehicle communication for safety and efficiency in travelling and transportation [5, 6]. In VANETs, vehicles act as higher mobility aided network nodes, and facilitates traffic oriented communication. It comprises of Roadside Units (RSUs), On-board Unit (OBU), and in-built sensors with vehicles. RSUs are installed beside roads in urban and highway environments. RSUs enable smooth vehicular communication in two modes including Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I). The OBUs are often fitted inside vehicles such as DSRC devices which supports short distance and high speed communication via V2V and V2I [7]. The vehicular communication paradigm is based on co-operative communication and networking for realizing Intelligent Transportation Systems (ITS) [8, 9]. It defines various applications including emergency brake cautioning, cooperative navigation control, security distance cautioning, driver support, collision cautioning and supportive driving [10-12]. Vehicles as network nodes do not have the battery power issue, because of its high capacity automatic rechargeable battery via engine. This facilitates intensive data communication and processing capability in vehicular cyber physical system network environments [13, 14]. Due to the recent advancements in intelligent communication gadgets for vehicles including smart antenna, Global Positioning System (GPS), and smart onboard buffer, video streaming forwarding and cooperative downloading over V2V and V2I have been realized [15].

In order to explore video communication among vehicles, the text message and beacon signal based communication among vehicle have to be discussed as existing literature. As in vehicular communication, the vehicles entails wireless OBUs, which facilitates communication among vehicles and RSUs with DSRC standard [16]. Each vehicle periodically broadcast its current information including location, speed, direction etc. By using the periodical information, the neighboring vehicles can take early decision in case of traffic incidence for example traffic jam, accident and emergency braking [17]. In addition, advertisement, downloading and uploading data via native information acquisition for example, road maps, groceries, restaurants, hotel, fuel stations [18]. However, all the aforementioned applications are text or beacon signal based, which do not provide realistic traffic information or on-road traffic situations for example, level of traffic jam, severity of accident and actual position of incidence. Meanwhile, in video streaming of on-road situation, the vehicle displays actual position of other vehicles, level of traffic jams and severity of an on-road accident in order to take appropriate responsive actions. The OBUs display device is used for streaming video using the DSRC network connections among vehicle and the RSUs. Hence, video streaming is considered as one among the treasured VANETs applications [19]. The video streaming for communication is applicable for user-to-vehicle and user-to-office video conferencing [20]. Infotainment in vehicles can be made more realistic by video streaming for notice and advertisement of on road shopping malls, clinics, and nearby gas stations [21]. Consequently, video streaming applications can meaningfully improve the vehicle user experience during navigation.

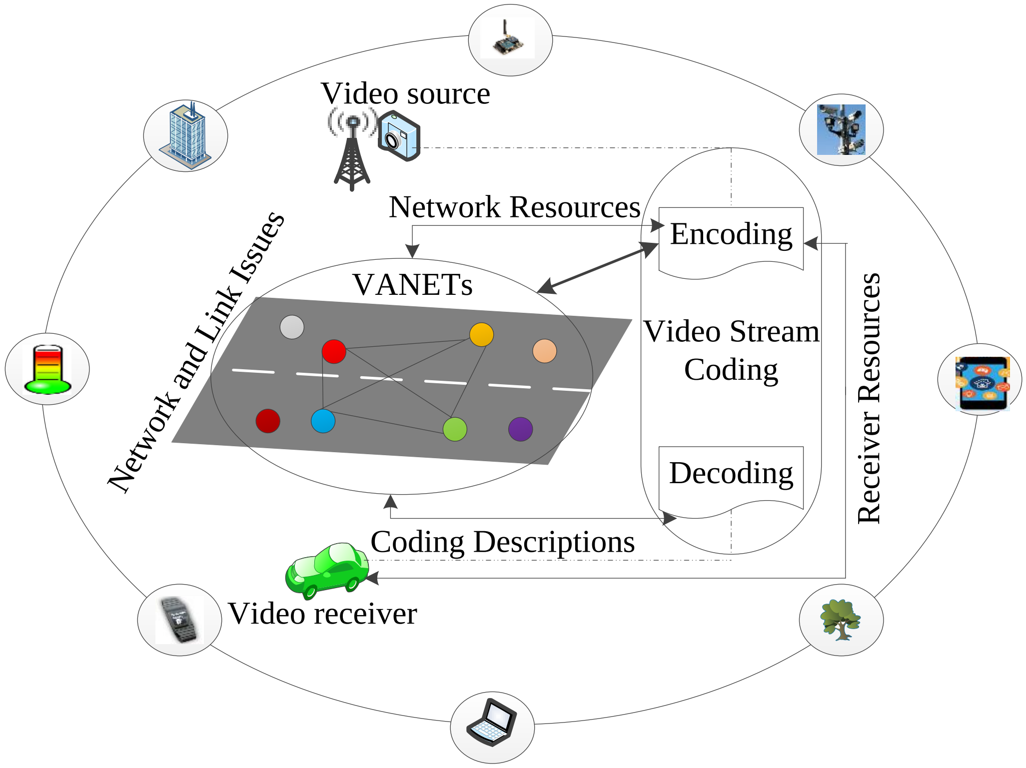


Fig. 1. System view of video streaming in vehicular traffic environments

In vehicular video streaming, video content is streamed in an encoded form over the network, and displays the content to end users in a pre-recorded or recorded manner [22]. A system view of video streaming in vehicular IoT environments is presented in Fig. 1 focusing on encoding-decoding layers. The benefit of efficient streaming is that, the user does not need to waste time in downloading a video content for playing the video. Instead, the media performs the task of sending continuous streams of data in pre-recoded video playing [23]. In current approaches, video streams are usually compressed and partitioned into sub-streams, to reduce video size and achieve efficient load balancing in video communication [24]. Most commonly used compression standard includes MPEG-1-2-4, H.264/AVC and H.263/SVC [25, 26]. The compression standard are used to reduce redundant and irrelevant video data [27, 28]. The redundancy could be color space, temporal or spatial, while the irrelevant information in video data is considered unimportant information [26]. The encoding process is carried out at source node before sending as video stream, while decoding is performed at the destination after delivery, i.e., before viewing the video content [29]. The video partitioning leverages encoding methods where video streams are coded frames including I-frames, P-frames and B-frames [30]. Different coded frames as sub-streams can be transmitted using single or multipath routing approach [31]. In this context, this paper presents a comprehensive survey on video streaming in IoT environments focusing on vehicular communication perspective. Specifically, the contributions of this paper can be majorly divided into following four folds:

- Firstly, a discussion on significance of video streaming in vehicular IoT environment is presented focusing on supporting technologies, and major application areas. This is followed by a critical discussion on related literature reviews on video steaming to differentiate and highlight the vehicular IoT environments focused contributions of this paper.

- Secondly, a taxonomy is presented for the classification of literature on video streaming over vehicular ad-hoc networks. Following the taxonomy, model-based qualitative review is carried out on video streaming literature focusing on major functional component, strengths and weaknesses.
- Thirdly, performance metrics are derived for video streaming in vehicular IoT environments. These metrics and simulation tools are analyzed in terms of their performance evaluation capabilities and usage.
- Finally, open research issues and challenges are identified in vehicular video streaming under IoT environments as future research directions in the area.

The remaining sections of the paper are structured as follows. In section 2, significance of video streaming based vehicular communication under IoT environments is highlighted. In section 3, literature surveys on video streaming over wireless network and mobile ad-hoc networks have been revisited. Section 4 presents comprehensive review on video streaming over vehicular ad-hoc networks focusing on taxonomy, model-based discussion and comparative analysis of recent developments. In section 5, performance metrics for vehicular video streaming are derived with a comprehensive analysis of simulation tools. In section 6, open research issues and challenges are identified in vehicular video streaming under IoT environments, followed by conclusions made in section 7.

2. Significance of Video based Vehicular Communication in IoT Environments

Internet of Things (IoT) has been an evolving technology that facilitates communication between every computing devices anywhere and anytime [1]. The everywhere computing devices includes miniaturized sensor devices, smart embedded computers in home appliances [33], customized special purpose sensors in transportation vehicles [34], and more. Thus, vehicles with the customized special purpose sensors and multimedia camera can supports communication with other IoT devices and the surrounding environment. In fact, vehicles are suitable communication enablers in IoT communications. Because vehicles are everywhere and does not have energy problem. Vehicles can facilitate communication and data gathering on IoT devices that are at its surroundings i.e. road side. In other hand, despite the great capabilities of vehicles, it has underlying challenges of on road accidents due to drivers' error, pedestrians crossing road, vehicle break down and malfunction. Vehicle malfunctioning could be due to tire burst, break failure and or engine breakdown. Embedded vehicle sensors can be used to monitor health of driver during driving, condition of vehicle tires, condition of break system and engine system, which are automatically synchronized with the driver phone or vehicle dash-board, it is also path of IoT. However, there are several research works in IoT related to vehicle communication named Internet of Vehicle (IoV). IoV is the incorporation of vehicle mobile Internet, vehicle intelligence with vehicle mode of communication including V2V and V2I [34]. The major difference of IoV and VANETs is the intelligence, the vehicle and it parts need to react intelligently and communicate with computing devices in their immediate surroundings [35]. Thus, IoV is centered on intelligent interaction of vehicles, things, humans, immediate environment, cities or even a country [36]. The communication in vehicular IoT settings are either inform of beacon signal-based or text message-based or multimedia-based. We focus more on the multimedia based that is, video communication in vehicular IoT settings.

2.1 Supporting Technologies for Video Streaming

The constituent of IoT includes hardware, bridging-software and presentation tool. The hardware include embedded communication devices, sensors and actuators. Bridging software which is also called middleware are software's for analytics computing tools and on-request storage device. The presentation tools are the functionalities of interpretation and visualization tools for varied platforms and applications [37-40]. Hence, there is need to explore and elaborate on different enabling technologies for the aforementioned basic constituent of IoT. The enabling technologies would include sensors, addressing scheme, Radio Frequency Identification (RFID), data analytics and on-request storage and presentation tools (see Fig. 2).

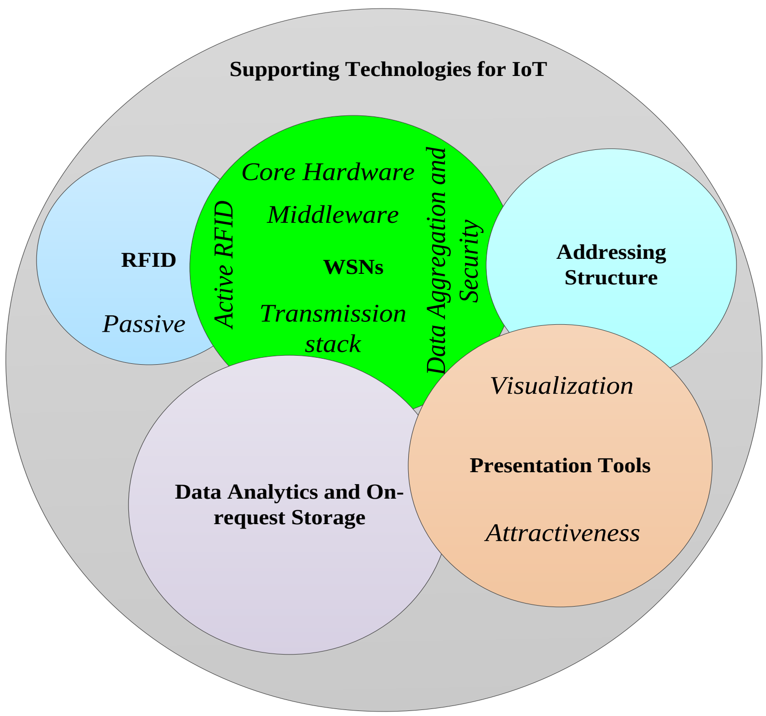


Fig. 2. Supporting technologies for vehicular video streaming in IoT environments

- **Automotive Sensors**

wireless sensor networks (WSNs) is termed as integration of miniaturized sensing device with wireless radio device for communication [41]. Sensed data are forwarded to either distributed or non-distributed systems for data analytics [42]. The constituent of WSNs includes core hardware, middleware, transmission protocol and, data aggregation and security. Core hardware comprises of analog/digital transformers for sensor interaction, transceiver units for communication, processing units for sensing activities, sensor display unit which serve as an interface and power supply unit for powering sensors e.g. batteries [43]. The ability of sensors to communicate efficiently makes it more versatile, which has also made it more feasible for IoTs paradigm. The middleware serves as a bridging software for various sensors applications. It also serve as a tool that integrates service-based architecture with cyber space infrastructure and sensor networks in order to offer access to heterogeneous sensor resources in an independent installation method [44]. In transmission protocol, network communication stack is considered, since the sensor nodes communicate in an infrastructure-less environment. Therefore, tuning of MAC layer and design of routing techniques that considers nature of topology and resource limitations of WSNs is paramount for durable period and scalability of deployed network. Considering IoTs, the sink node of a WSNs must be made in such a way that it transmission stack has the ability to interact with other external networks for effective IoTs system. Data aggregation and security are essential components of WSNs since major function of sensors is to sense data for analytics purpose. Meanwhile, sensors are faced with energy power problem thus, an effective data aggregation and security procedure are required in order to elongate the lifetime of the WSNs as well as ensuring untampered and reliable data from sensors [45]. Hence, WSNs are undoubtedly the most essential enabling factors for IoTs communication system.

- **Addressing Technologies**

The addressing is a challenging issue, because it is a concept of connecting anything to everything using network. Thus, the ability to discretely and distinctively recognize “Things” is critical for the realization of IoT. The addressing structure will not only uniquely recognize thousand millions of “Things” but will also supports in remotely controlling “Things” via the Internet. With the demand for unique identification of devices in IoT, IPv6 has been suggested in some research works [46-48]. However, addressing structure must possess quality features including uniqueness, scalability, reliability and continuity [49, 50].

- **Traffic Data Analysis**

Big traffic data is one of the constituent of IoT. Analysis of big traffic data is an emerging domain that would certainly generates exceptionally large quantity of data. Data storage management would be a severe issue in resource usage management. The adoption of video/voice data would certainly pose a critical challenges in terms of resource availability, since IoT devices are small and might suffer from resource limitations [40]. Hence, data center storage in cloud computing [51] is the concept proposed for data analysis and storage of IoT data. The data requires to be used intelligently and stored for actuation and smart monitoring. The aforementioned will go a long way in solving resource limitation and energy consumption issues in IoT.

- **RFID aided Positing Technologies**

RFID is applicable for embedded communication concept. It aids in identifying any object or item automatically, once it is attached to the object [52]. It serves as an electronic barcode [53]. Considering RFID tags that are passive in nature, they do not require battery power, they only depend on power of scan reader’s signal to transmit Identification details (ID) to the RFID scanner. These advantages have led to its wide applications in almost every aspect of supply management and retail stock auditing. It application also covers access control and vehicle management, for instance registration sticker identification and ticket management. The passive RFID tags are also used in on-road toll gate tags and bank debit and credit cards. Meanwhile, the RFID tags that are active, usually requires battery for their powering and it can trigger communication [43]. It is applicable for monitoring containers in cargo ships [53]. In addition, they can also act as a sensor due to their functionalities. Although, they have limited resources when compared to main sensors in terms of storage and processing capabilities. Hence, RFID is one of the major enabling technologies for IoTs considering its applicability on everything.

- **Visualization Technologies**

It is all about visualization and interaction, which is very crucial for the realization of effective IoT system. It enables interaction of users with the IoT settings. The smart device touch screen can be applied on IoT devices for easier usage by non-computer expert. Visualizer need to have good resolution, easy to understand and very attractive. 2D and 3D concept could be leveraged for information to be displayed in a more expressive manner for IoT users [40]. Consequently, this will enables transformation of raw data to knowledgeable information for prompt decision making. It incorporates visualization and event detection of related raw data, with knowledge illustration based on requirements of users of the IoT. In conclusion, sensors with wireless network, robust addressing structure, data analytics and on-request storage, RFID and presentation are the essential enabling technologies for IoT. These can be effectively integrated into vehicular IoT, while considering video as the IoT data for information acquisition.

2.2 Application Area for Vehicular Video Streaming in IoT Environments

Video streaming in vehicular IoT paradigm that is, integration of video streaming VANETs with IoT. It considers stringent video streaming requirement, high position changing of vehicle and constrained resources of IoT devices in communication using 5G network connection [54]. The IoT devices have several limitations including power capacity, memory, central processing unit resources and even networking capability [55]. By considering aforementioned limitations, we highlight the following application areas of video streaming in vehicular IoT. The application areas include smart home, smart city surveillance, smart pedestrian and smart forest monitoring. With adoption of 5G and IEEE 802.11p/WAVE network technologies, powerful surveillance camera and customized embedded sensors, vehicle can support video streaming and interaction with IoTs' immediate environment, by considering application areas. The highlights are as follows;

- **Vehicle-to-Home Communication:** In smart home and smart vehicle interactions, the vehicle can connect to smart home devices in order to video stream the surroundings for surveillance purpose [56, 57]. Connectivity are carried out using 5G or IEEE 802.11p/WAVE network technologies in order to access information and to offload the information to a data centers of cloud using asynchronous or synchronous mode [32, 58, 59]. Further, customized and embedded sensors in vehicles can be used for sensing home building when parked in parking lot.
- **Vehicle-for-Surveillance**: It can be carried-out by installing high infrared illuminance camera on police patrolling vehicles [60, 61]. Cameras are mounted on top of patrolling vehicles for greater visibility, it is used to stream video of all areas patrolled by the police vehicle. Video streamed can be automatically synchronized to the cloud or the police headquarters' video database via 5G and IEEE 802.11p network for investigation in case of crime occurrence.
- **Vehicle-to-Pedestrian Communication:** It is the interaction with smart vehicle, an another application of video streaming in vehicular IoT, where powerful infrared cameras can visualize pedestrians crossing the road even in the dark [61, 62]. Pedestrians with phone sensor and wristwatches sensors can communicate with an incoming vehicle using customized sensors [63, 64]. It will enable the driver to be aware and at alert, then react to situations in order to avoid hitting

pedestrian (accident). The sensors can also sense the durability and conditions of the roads and bridges passed through every day.

- **Vehicle-to-Green Communication:** Another application is the smart forest [65, 66], it is true that vehicles move on highway for a long time journey, and the forest trees are normally concentrated at the side of highway roads [67]. Government transportation systems e.g. buses and trains can be used for monitoring forest environment by installing special sensors that gather information which are transmitted to cloud or environmental agency system using 5G and IEEE 802.11p network. The information gathered from forest and it environment might be used to forecast wild fire out-break due to bush burning and even tendency of high rainfall which could lead to erosion and flooding [68, 69]. The reason for using vehicle for data gathering is due to the fact that vehicles does not have energy challenges, since the vehicles have high capacity rechargeable batteries. The data gathering and acquisition is required. Although, many challenges might surfaced due to integration of video streaming, IoT and vehicle. However, video streaming had happen to be one of the most significant requirements of existing networks, due to its significance in vehicular IoT settings. The video streaming have some unique features, and hence unique network requirements are needed. This means that video streaming should take into consideration the dynamism of vehicle and IoT devices and constraints of existing network architecture. Furthermore, we presents challenges of vehicular IoT device communication in section 6. Considering Fig. 3, we depicts various applications areas of video streaming in vehicular IoT. Next section is related survey on related literatures.

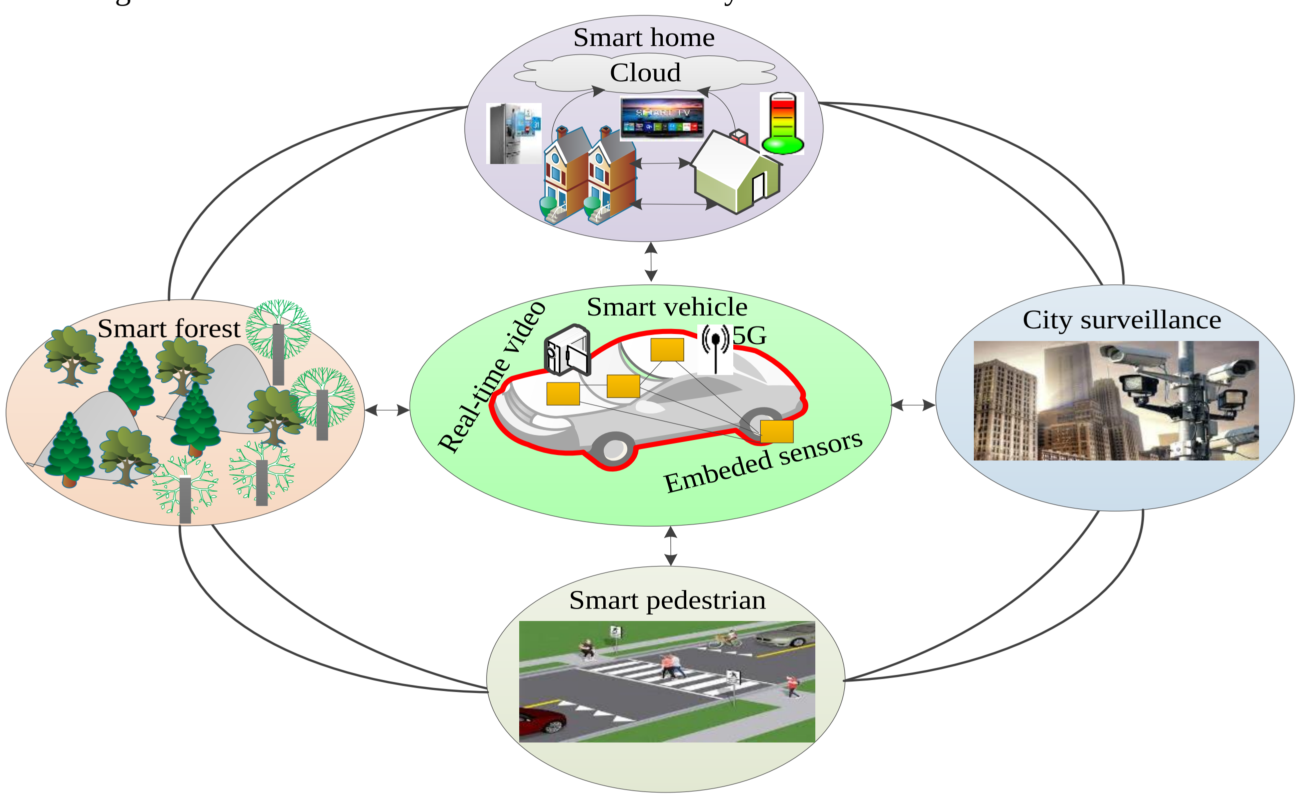


Fig. 3. Major application areas for vehicular video streaming in IoT environments

Cite As:
ALIYU, A., ABDULLAH, ABDUL H., KAIWARTYA, O., CAO, Y., LLORET, J., ASLAM, N., JODA, U., 2018.
Towards video streaming in IoT Environments: Vehicular communication perspective.
Computer Communications, 118, pp. 93-119. [pii: S0140366417305121]

3. Related Literature Reviews

In this section, survey papers on video streaming have been revisited focusing on wireless sensor networks and mobile ad-hoc networks, due to unavailability of extensive survey on video streaming in vehicular networks. A generic peer to peer (P2P) video streaming systems have been reviewed focusing on real time and on-demand video streaming in wireless network [70]. Another similar survey has been performed based on resilient techniques for P2P video streaming considering cross-layer and core layer techniques in wireless network [71]. A review on application layer approaches for adaptive multimedia streaming has been presented considering video compression scheme in wireless network [72]. Considering the advent of miniaturized devices having sensing capabilities, wireless sensor network has been developed. Several surveys on video streaming have performed, for example, a survey based on video encoding in wireless sensor network [73]. A similar review on Wireless Multimedia Sensor Networks (WMSNs) considering hardware constraints of WMSNs, algorithms and protocols have been presented [74]. Meanwhile, a survey based on QoS assurance routing techniques with focus on energy consumption in WMSNs has been suggested [75]. However, a video streaming review over WMSNs has been performed focusing on application and testbed environments [76]. It presents research work on different models of WMSNs with their incorporation into testbeds for experimental assessment of protocols and algorithms. Another extensive review that focuses on cross-layer design issues including security, QoS and mobility has been suggested for wireless sensor network [77]. These survey works do not consider mobility of nodes into account as wireless sensor networks environment is generally static in nature.

Mobility has been one of the unique features of MANETs network, which has also given rise to several and unique challenges in video streaming over mobile devices with network. An appraisal of QoS provisioning in MANETs multimedia has been presented [78]. The appraisal is based on different technologies of network protocol stack and cross-layer design. The techniques and challenges for video streaming under MANETs environments have been revisited focusing on mobility challenges [79]. The survey focused on cross-layer optimization approaches based on multipath routing and multi-description coding approaches. However, an appraisal based on energy efficiency in multimedia streaming over mobile devices has been suggested [80]. Further, a cross-layer review for video streaming over MANETs has been proposed [81]. The study demonstrates that several research papers have employed cross-layer approaches more than other approaches in MANETs video streaming. However, there is need to explore the current techniques employed for video streaming over VANETs. Thus, the summary of the aforementioned reviews on video streaming is highlighted in Table 2, focusing on major parameters and network type. It can be clearly observed that the investigations on video streaming over vehicular communication with IoT have not been revisited particularly considering the recent advancements in the area. Moreover, most of the parameters of video streaming investigation are considered in this review article. Table 1 represents major abbreviations particularly used in comparison tables.

Table 1. Abbreviations used in comparison tables

Abbreviation	Description	Abbreviation	Description
CL	Cross-layer	PBF	Playback Freezes
CMR	Coding-centric multipath routing	PLR	Packet Loss Ratio
DL	Delay	MM	Mobility Model
E2ED	End-to-End Delay	SL	Seeking Latency
ESR	Energy scheduling-aware routing	BU	Bandwidth Usage
FEC	forward error correction	NT	Number of Transmission

HC	Hierarchical coding	MOS	Mean Opinion Score
JTR	Jitter	FL	Frame Loss
MAC	Medium access control	SR	Success Rate
MANET	Mobile ad-hoc networks	LUR	Load utilization Ratio
MDC	Multi-description coding	SSIM	Structural Similarity index
MR	Multipath routing	THP	Throughput
OL	Overlay in video streaming	PSNR	Peak Signal to Noise Ratio
QoE	Quality of experience	CO	Control Overhead
QoS	Quality of service	DR	Data Received
VANET	Vehicular ad-hoc networks	STD	Start-up Delay
WSN	Wireless sensor network	QCR	Query to Connectivity Ratio

Table 2. Comparison of related literature review

Reference	**Parameters for Review**									**Type of Network**				**Range of Exploration Year**
	QoS/QoE-R	MR	CMR	MDC	HC	OL	CL	MAC/FEC	ESR	WSN	MANET	VANET	IoT	
[70]		✓								✓				1995-2007
[71]		✓		✓	✓		✓	✓	✓	✓				1998-2011
[72]	✓				✓			✓		✓				1992-1999
[74]	✓				✓		✓	✓		✓				1993-2006
[73]	✓			✓	✓		✓	✓		✓				1994-2006
[75]	✓	✓							✓	✓				1990-2011
[76]	✓									✓				2000-2007
[77]	✓				✓		✓	✓		✓				1998-2013
[78]	✓						✓	✓	✓		✓			2000-2011
[79]	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓			1994-2009
[80]					✓		✓	✓	✓		✓			1996-2012
[81]							✓	✓			✓			1992-2011
Our review	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	2010-2016

4. Video Streaming over Vehicular Ad-hoc Networks

In this section, Video Streaming over VANETs is qualitatively reviewed on the basis of taxonomy shown in Fig. 4. Video streaming is an evolving research theme in VANETs. It is emerging because of the growing need for ITS in order to enhance safety and infotainment in vehicular environments [82]. However, video streaming over VANETs is categorized considering different video streaming solution approaches. These include MAC and FEC, coding-centric routing and overlay techniques. These techniques have been investigated in several directions, which are qualitatively and critically reviewed in the following sections [83]. The issues introduced by strict requirements of video streaming transmission, lossy wireless channels, dynamicity of nodes and insufficient node resources present a number of challenges that cut across layers of network protocol stack [79]. In some of the previous work, cross-layer approach has been considered but, most of them have key focus on a specific layer [79]. Thus, the categorization of the techniques relied on major issues in video streaming and related contributions in literature considering network protocol stack [79, 84, 85]. Fig. 5, demonstrates two different scenarios of video streaming over VANETs.

Cite As:
ALIYU, A., ABDULLAH, ABDUL H., KAIWARTYA, O., CAO, Y., LLORET, J., ASLAM, N., JODA, U., 2018.
Towards video streaming in IoT Environments: Vehicular communication perspective.
Computer Communications, 118, pp. 93-119. [pii: S0140366417305121]

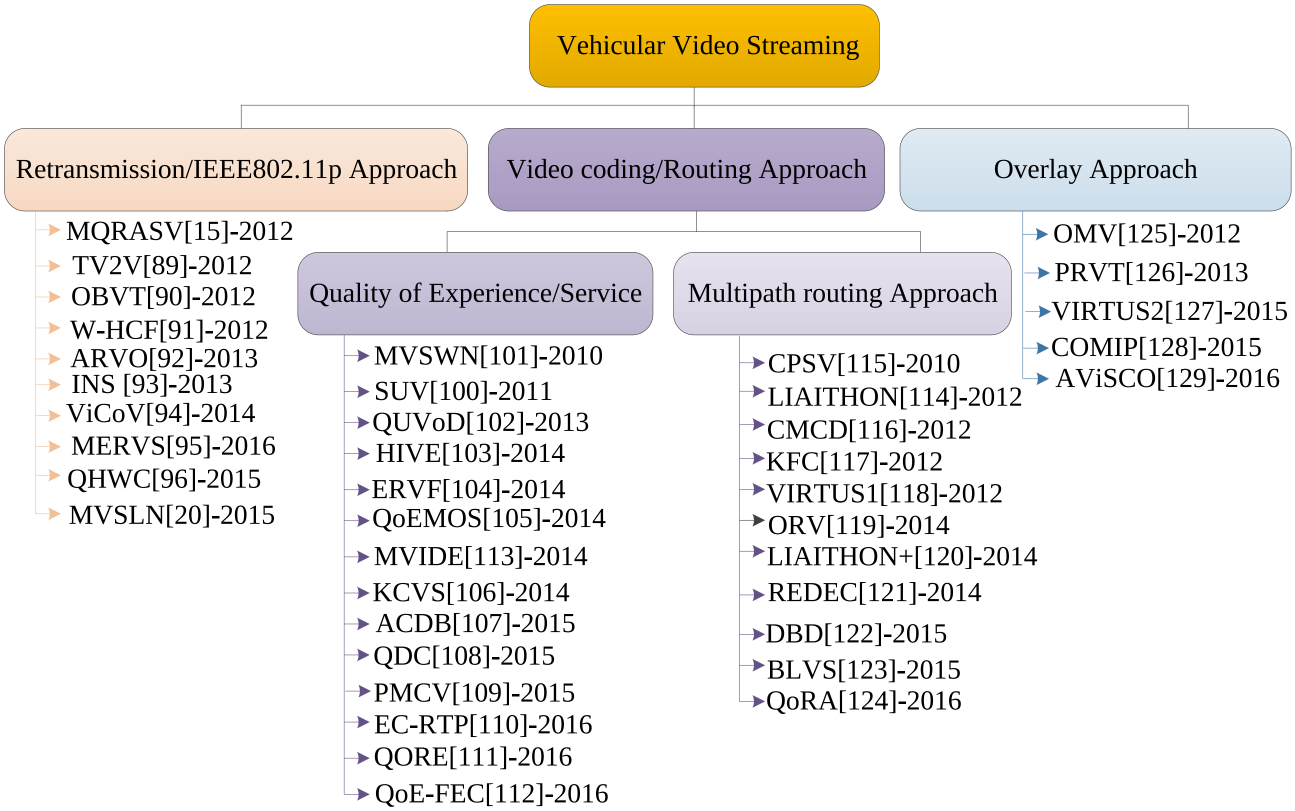


Fig. 4. Taxonomy of video streaming over vehicular ad-hoc networks

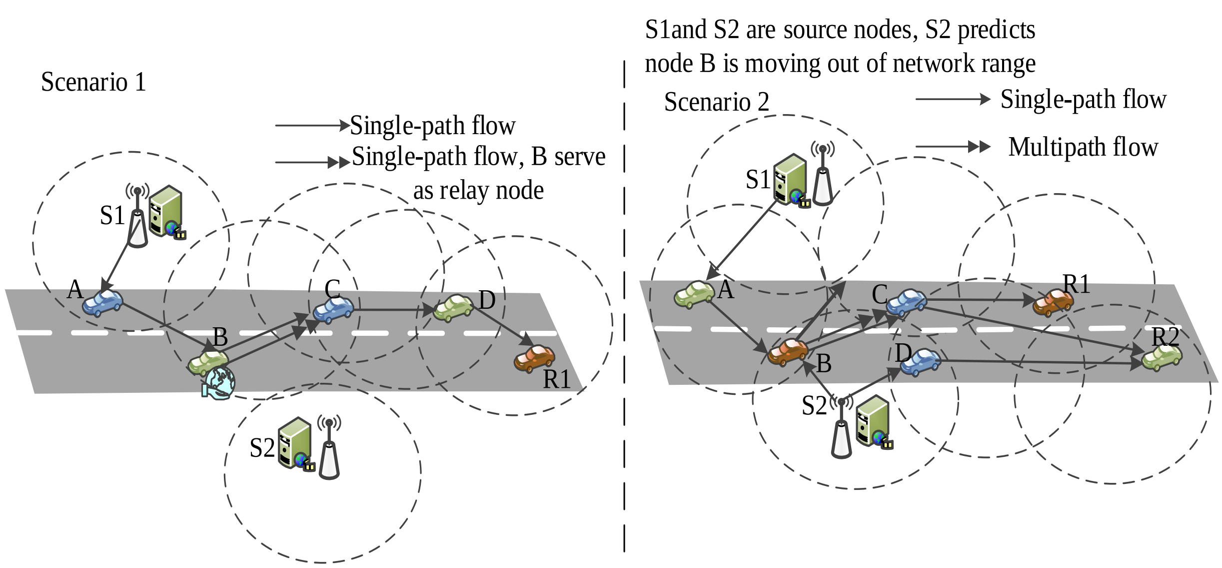


Fig. 5. Video streaming scenario over vehicular ad-hoc networks

4.1 IEEE 802.11p based Vehicular Video Streaming

One of the essential constituent 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 researches in link layer technology [86]. The use of MAC layer during network optimization provides significant benefits. The MAC layer is often manipulated to modify 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 [87]. At the MAC layer so many parameters can be manipulated including retransmission limit in order to achieve robust adaptation of the video transmission. FEC is an approach taken in recovering and correcting video stream loss or damage during transmission [88]. Although, FEC add some redundancy in order to compensate the packet loss, it ends up increasing the bandwidth utilization of the network, thereby creating another challenge [15]. MAC scheme that improves video quality through monitoring and frame size changing based on network scenario. The scheme uses adaption and dynamic parameters for enhancing video quality and experience at the destination. Considering MAC protocol, to improve performance of IEEE 802.11p standard for video streaming, a Mobility-aware and Quality-driven Retransmission limit Adaptation Scheme for Video streaming over VANETs (MQRASV) has been presented [15]. The adaptation scheme employs multi-objective optimization structure that concurrently reduces likelihood of start-up delay and playback freeze of a streamed video at the destination vehicle. These are reduced by tweaking the MAC retransmission limit in relation to channels' delay result and packet communication rate. In addition, intervallic channel state approximation is carried-out at the RSU considering the information obtained from the Doppler shift effect and Received Signal Strength (RSS). Furthermore, two hop transmission approach has been employed in zone where the destination vehicle is found within transmission range of any of the RSU. In particular, the average number of transmissions considering a vehicle (node) at a distance y from a dedicated roadside unit (RSU), $n(Q_{ij}, p_{ij}(y))$, for one packet until it is effectively delivered to vehicle node j or it reaches the retry limit, which is mathematically expressed in Eq. (1):

$$n\left(Q_{ij}, p_{ij}(y)\right) = \frac{1-p_{ij}(y)^{Qij+1}}{1-p_{ij}(y)} \tag{1}$$

Such that $p_{ij}(y)$ is the most current updated link loss probability of the channel between node at distance y and the RSU. Further, video packet quality are calculated on it arrival at the destination buffer, then we have Eq. (2):

$$\rho'_{ij} = P_a(y)\rho_{ij}(1 - P_{ij}^{T}(Q_{ij}, p_{ij}(y))) \tag{2}$$

Where ρ'_{ij} is the successful packet arrival rate at the destination buffer and ρ_{ij} is the packet input rate by RSU transmission before the signal arrives to the channel. However, despite its strength in terms of playback freeze, contention window, link breakage have not been considered in their model. Transparent Vehicle to Vehicle (TV2V) driver assistance system has been explored in order to enhance on-road safety for vehicles [89]. TV2V takes advantage of V2V communication and inbuilt sensors, and cameras. The windshield inbuilt cameras transform vision-blocking vehicles into see-through tabular object. The collaborative system has the ability to increase visibility of vehicle users aiming to overtake, hence making such dangerous maneuvers safer. Specifically, the augmented reality (transparent view) can be calculated considering the following mathematics relations in Eq. (3).

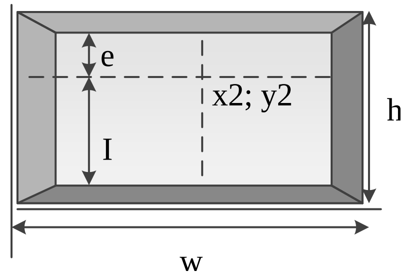


Fig. 6. Augmented reality for transparent vehicle which video streaming is applied on

Where $c = \frac{h}{h_o}$, and $d \times r = v$

$$Augmented\ reality = \begin{cases} r = \frac{c}{d_o} \\ h_o = \frac{h}{v} \\ w_o = \frac{h}{v+(l+e)\times r} \\ h_i = \frac{h}{v+(l+e)\times r} \\ w_i = \frac{w_f}{v+(l+e)\times r} \end{cases} \quad (3)$$

Where w, h (see Fig. 6) represents the actual computed width, height of the preceding vehicle respectively. The image ground ratio r between the calculated virtual width $w_o$and virtual height h_o, are proportional to the image dimension, which are also the same. The $v + (l + e)$, where $v = v = d \times r$, so we have $(d + l + e)$ which is used to compute camera ground capturing point, while d is the distance of the actual preceding vehicle. However, the system might not be cost feasible and might fail due to external factors.

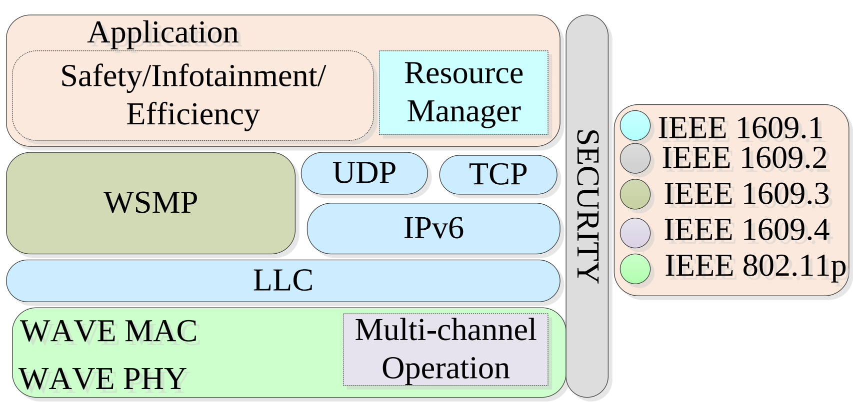


Fig. 7. The WAVE protocol stack for vehicular communication

Vinel, *et al.* [90], presents an Overtaking assistance system based on Beaconing and pre-recoded Video Transmission (OBVT). The system designed is to enhance performance of video-based overtaking assistant application. Nevertheless, structural similarity index for ascertaining quality of video is not considered. The WAVE/IEEE 802.11p has been enhanced in order to offer infotainment applications in VANETs due to the lack of infotainment applications standard protocols [91]. Most of the researches have focused majorly on safety application. The improvement is carried-out such that it complies with the multi-channel operations of WAVE design structure (see Fig. 7). Thus, it targets the support of non-safety applications, while maintaining the provision of safety services. The scheme is named as WAVE-based Hybrid Co-ordination Function (W-HCF), it takes the advantage of controlled access capabilities above of the basic contention-based access of the IEEE 802.11p. Further, it leverages vehicles' location information and coordination among WAVE providers in order to enhance performance of delay constrained and loss-aware infotainment applications. In their paper, the aim is to model the W-HCF protocol in order to enhance the 802.11p/WAVE protocol, the enhancement is represented mathematically in Eq. (4) as follows:

$$R_{W-HCF,HP} = \frac{E[P]N_{HP}}{L_{CAP}} \quad (4)$$

Where $E[P]$ is the information delivered in a controlled access period (CAP), N_{HP} is the frequency of QoS-aware flows functioned in CAP, which is belonging to High Priority (HP) classes. Even though, the performance of the scheme is not adequately assessed, because the PSNR and SSIM index of the video and voice frames are not measured. Belyaev, et al. [92] have proposed an Assistance on Road Video Overtaking (ARVO) system in order to reduce end to end latency in video communication, while improving quality of the video graphics. The system employs automotive radars for location region estimation. However, interference in the IEEE 802.11p channel when vehicle is approaching, is not considered. An Intelligent Network Selection (INS) scheme for vertical handover of audio and video streams considering different kinds of vehicular network has been suggested [93]. The study is motivated because of challenges encountered in vertical handover in a heterogeneous network. The INS focused on maximization grading function in order to effectively grade the available wireless network contenders. Three parameters including connection life time, fading signal to noise ratio and residual channel capacity are used to develop the maximization grading functions. However, standard VANETs communication protocol IEEE 802.11p is not considered. Video streaming for Cognitive radio VANET (ViCoV) is proposed for ensuring efficient video streaming and to handles intermittent disconnection issues [94]. ViCoV solution has the ability of transmitting infotainment and safety video messages in intermittent and full connection network under varied traffic conditions. ViCoV chooses optimal available cognitive radio channel to transmit video messages. Then, it wisely select a minimum sub-set of re-transmitter nodes to minimize interferences and to attain better video quality. The cognitive radio channel are chosen by considering their stability for a period of time. While the re-transmitter node is choose considering it new centrality metrics. The centrality metrics is stimulated considering Social Network Analysis (SNA), which is dubbed as dissemination capacity. Although, the SSIM index is among the most reliable metrics for video quality evaluation but not considered in this study.

A novel Multichannel Error Recovery Video Streaming (MERVS) protocol is proposed to address issue of high packet loss in VANETs [95]. MERVS uses an error recovery process for high quality and real time video streaming. It sends video through two channels: reliable and un-reliable channel. It transmits I-frames through reliable channel, while inter-frames are transmitted through unreliable channel. In order to reduce delay, scalable reliable channel, quick start and priority queue were incorporated. However, MERVS lacks routing and relay selection algorithm hence, further study is required. Further, QoS-aware Hierarchical Web Caching (QHWC) scheme for online video streaming applications in Internet-based VANETs has been presented to address bandwidth and delay challenges. The scheme consider mobile video streaming in order to attain qualitative video delivery at the receiver node [96]. In this proposal, new metrics including Query to Connectivity Ratio (QCR) and Load Utilization Ratio (LUR) are employed to maintain QoS for different video streaming applications. The hierarchical web catching scheme computes the effective transmission rate through channel, considering availability of resources. It is arithmetically expressed in Eq. (5) as follows:

$$T^{Effective} = (T_{flow} \times Q^T) - T_{loss} = \left(\frac{BW}{Nbyte \times W\_Size}\right) \times \left(\frac{S^T \times \theta \times BW^T}{\varphi^T}\right) \quad (5)$$

Where $T^{Effective}$ is the level of transmission effectiveness, Q^T is the rate of query transmission, BW is the bandwidth, S^T is storage capacity, φ^T is the video streaming rate and θ *ranges from* $0 \leq \theta \leq 1$. However, in a hierarchical web caching approach, a link breakage or dead node at one level of the hierarchy might cause failure of video message delivery. A Multipath Video Streaming solution for vehicular networks with Link disjoint and Node-disjoint (MVSLN) has been suggested to address FEC issues of video transmission in VANETs [20]. MVSLN ensures retransmission, rather than FEC. Also, a multipath solution centered on disjoint algorithm is also suggested to decrease the interference and contention, leading to an acceptable delay and higher transmission rate. In this, inter-frames are transmitted through the UDP protocol while only I-frames are transmitted through the TCP protocol. In order to enhance delay of TCP transmissions, an ETX-TCP algorithm are integrated to select the best and suitable path for TCP transmissions. However, despite its strength in retransmission of video streams, routing relay selection algorithms is not explored. Due to large number of metrics and approaches studied in this paper, we have abbreviated them as shown in Table 1. Meanwhile, Table 3 shows summary of related literatures on MAC/FEC techniques for video streaming over VANETs. The table heading entails protocols, issues, contributions, techniques, simulation tools used, metrics and research limitations of each paper reviewed.

Table 3 Summary of retransmission/IEEE 802.11p-based approaches

Characteristics → **↓ Protocols**	**Issues**	**Contributions**	**Techniques**	**Simulators**	**Metrics**	**Limitation**
MQRASV [15]	Optimization od start-up delay and playback freeze during video streaming	Adaptive scheme for tuning MAC with retransmission channel	Multi-objectives optimization and Two-hop transmission	Matlab and Monte-Carlo simulations	-STD - PBF	-Contention window size not considered -Complex distribution model
TV2V [89]	Design of on-road safety application for overtaking and manoeuvring	Cooperative driver-assistance system	MAC adaptation with inbuilt sensors	NS-3	-DL	System might not be cost feasible and might fail due to external factors.
OBVT [90]	Enhancement of safety applications	Codec channel adaptation	MAC Adaptation	Mathematica l model	-PSNR -THP	Practical implementation and SSIM index are not considered
W-HCF [91]	Lack of Infotainment applications in IEEE 802.11p	IEEE 802.11p enhanced MAC scheme	MAC layer augmentation	NS-2 with VanetMobiS im	-THP -E2ED	PSNR and SSIM index of both image and voice data are not considered.
ARVO [92]	Reducing end-to-end latency and improving good visual quality in safety applications	Overtaking system	IEEE 802.11p MAC adaptation	Mathematica l model	-PSNR -THP	Interference in IEEE 802.11p channel for approaching vehicles is not considered
INS [93]	In-efficient vertical handover	Network selection scheme for vertical handover	Vertical handover between WAVE and Base station	OMNET++	-E2ED -MOS -THP	IEEE 802.11p is not considered

ViCoV [94]	Intermittent disconnection	Efficient video streaming for cognitive radio VANETs	Cognitive Radio Channel selection	NS-2 SUMO and EvalVid	-PSNR -FD -FL	SSIM index is not measured
MERVS [95]	High data packet loss in VANETs video streaming	Video stream partitioning based on priority queue.	Multipath FEC and ARQ	NS-2 with EvalVid and SUMO	-PSNR -NT -DR -SSIM	Coordination between TCP and UDP protocol is challenging
QHWC [96]	How to maintain QoS	Hierarchical web catching scheme	QoS-aware web catching scheme	VanetMobiSim and NS-2 with SUMO	-LUR -QCR	Link breakage/ dead node at level of the hierarchy may cause failure in video delivery.
MVSLN [20]	-Redundancy in bandwidth usage	Retransmission scheme using TCP and UDP	-Retransmission mechanism - ETX-TCP algorithms	NS-2 with SUMO EvalVid	- PSNR -DR -SSIM -DL -JTR	Routing and relay selection algorithm are not considered.

Table 4 Comparison assessment of retransmission/IEEE 802.11p-based approaches and metrics

Protocol/Author	Approaches				Objective approaches		Metrics										
	MAC	FEC	CcR	QoS	SO	MO	DL	DR	THP	SSIM	MOS	PSNR	NT	QCR	LUR	STD	FL
MQRASV [15]	✓					✓										✓	
TV2V [89]	✓				✓		✓										
OBVT [90]	✓		✓		✓				✓			✓					
W-HCF [91]	✓				✓		✓		✓								
ARVO [92]	✓		✓		✓				✓			✓					
INS [93]	✓				✓		✓		✓		✓						
ViCoV [94]	✓				✓		✓					✓					✓
MERVS [95]	✓	✓			✓			✓		✓		✓	✓				
QHWC [96]	✓			✓	✓									✓	✓		
MVSLN [20]	✓	✓			✓		✓	✓		✓		✓					

In Table 4, characteristics of each paper reviewed are categorized into four including protocol/author, approach, type of objective approach and metrics. The protocol/author column comprises abbreviation of techniques and reference. The approach column is categorized into four namely, MAC, FEC, CcR, QoS. The type of objective approach is divided into two including Single Objective (SO) and Multi-Objectives (MO). Last column represents metrics including DL, DR, THP, SSIM index, MOS, PSNR, NT, QCR, LUR, STD and FL. Considering Table 4, the approaches in column two demonstrates that more contributions have been made on link layer based on MAC technique, followed by coding-centric routing and FEC techniques. Meanwhile, very few contributions have been made towards QoS-aware techniques. In relation to objective approaches, single objective approaches have been mostly employed when compared with multi-objective approaches. Further, metrics column shows that PSNR is the most considered metric, followed by delay and then throughput for measuring performance of MAC/FEC approaches. The next is Table 5 and 6 which shows analysis of QoS/QoE coding-centric routing techniques.

4.2 Video Coding based Vehicular Video Streaming

The integration of video compression techniques with the best route estimation and selection techniques are the fundamental issues in coding-centric routing [97]. These techniques have to be designed to guarantee optimal video stream quality [98]. Both the video compression and route selection for video stream need to consider the issues including wireless lossy channels, interference and severity of dynamic nature of VANETs [97, 99]. In general, both stringent requirement of video stream and VANETs constraint need to be considered in order to have qualitative video stream delivery [100]. The coding-centric multipath routing is further classified into QoS/QoE and cross layer solutions, and Multipath coding-centric routing.

4.2.1 Quality of Experience/Quality of Service Oriented Streaming

The shortest routes for video streaming and other location-centric algorithms might not be sufficient to achieve qualitative video stream over VANETs. The major QoS factors including delay, packet loss, jitter and bandwidth need to be articulated in the coding-centric routing. In QoS/E approach, the target is often to derive peak result that will be acceptable to users of the streamed video [93]. Hence, QoS approach has been employed in one type of video streaming applications i.e. Video on Demand (VoD) service. A multi-source Video Streaming in a Wireless VANETs Network (MVSWN) investigates feasible conditions for multi-source video streaming across VANETs [101]. It employs VANET overlay, MVSWN uses spatial partition of a video stream based on Flexible Macroblock Ordering (FMO). The investigation shows that, it can achieve gain of over 5dB in video quality (PSNR) depending on packet loss rates and video content. Nevertheless, routing of streamed videos over multiple path might lead to noticeable packet losses, resulting in intolerable QoS. The study further investigates influence of different traffic densities and road topologies upon an overlay network's performance. The investigation demonstrates that driver's behavior and vehicles' mobility patterns need to be modelled to achieve and determine signal reception. Also, MVSWN considers the influence of wireless channel, and shows that, the channel need to be more realistically modelled. For the VANET default radio environment and mobility are modelled in Eq. (6) and (7) as follows:

$$D_c = \frac{4\pi y_t y_r}{\gamma} \tag{6}$$

Where D_C is the two-ray propagation crossover distance, γ is the transmission wavelength, y_t and y_r are the transmitter and receiver antenna respectively. For mobility, it is represented as follows:

$$D_S = S_{min} + (vel \times T) + \frac{vel\Delta vel}{\sqrt[2]{ac \times dc}} \tag{7}$$

Where D_S is the preferred dynamic distance, S_{min} is the minimum preferred distance, T is the least safe time between two vehicles. The velocity vel and it changes is Δvel, by considering acceleration ac and De-acceleration dc. However, bandwidth issues are not considered in the IEEE 802.11p wireless VANETs investigation. Video distribution streaming in VANETs has been suggested for transmitting video streaming data packets from one source to all existing nodes in an urban VANETs settings [100]. Streaming Urban Video (SUV) solution based on inter-vehicular communication has been presented in order to handle the problems associated with large video traffic. SUV solution adopt cooperative relaying techniques for forwarding video data packets. A QoE-driven User-centric VoD (QUVoD) services in urban multi-homed P2P-based (M-HH-P2P) vehicular networks has been suggested to provide a new service to achieve better QoE. It can be achieved by considering bandwidth issues [102]. It rely on M-HH-P2P and VANETs architecture (see Fig. 8). In QUVoD, vehicles generates a low layer VANETs through wireless access in vehicular environment interfaces. It generates an upper layer

Cite As:
ALIYU, A., ABDULLAH, ABDUL H., KAIWARTYA, O., CAO, Y., LLORET, J., ASLAM, N., JODA, U., 2018.
Towards video streaming in IoT Environments: Vehicular communication perspective.
Computer Communications, 118, pp. 93-119. [pii: S0140366417305121]

P2P chord overlay on top of the cellular network. Also, a new grouping-based storage strategy that uniformly distributes video segments along the chord overlay has been suggested. Specifically, speculation-based prefetching mechanism has been used to achieve smooth playback, which is mathematically modelled in Eq. (8) as follows:

$$P'_{ij} = \{c_j | c_i\} = \frac{f_{ij}+INC_{ij}}{\sum c_i+INC_{ij}} \tag{8}$$

Where INC_{ij} represents the frequency increment from association of c_i to c_j, and f_{ij} is the association between segment c_i and any other segment c_j and P'_{ij} is the probability of association between node i and j. However, the strategy does not consider delay and link issues. A HybrId VidEo (HIVE) transmission protocol is proposed to minimize high packet collision and transmission latency in VANETs video streaming [103]. HIVE employs receiver-based relay nodes selection techniques. Further, a MAC congestion control procedure for avoiding excessive packet collision and reducing latency with regards to vehicle traffic situation. However, the delay sensitive 3D video applications are not considered. Meanwhile, Torres, et al. [104] presents an Evaluation of Real-time Video Flooding (ERVF) quality in highway V2V communication. The evaluation strategies incorporates different flooding and coding techniques, it also measures the effectiveness of large area coverage of real-time video streaming. Nevertheless, an algorithm that considers both packet loss and frame loss need to be explored. In another approach, a QoE-centric coding and routing are employed to achieve better path selection by considering Mean Opinion Score (MOS) for QoE (QoEMOS) [105]. The QoE-centric approach is handled in four different categories including choosing of path and control packet, followed by event activation topology control packets and banned links, and then estimation of packet loss and mean loss burst size. In this, the MOS considered to estimate QoE of the video streaming is shown in Eq. (9), which is as follows:

$$MOS\left(LR^{e2e}_{Pi(s,d)}(k), \infty\right) \geq MOS\left(LR^{e2e}_{pi(s,d)}(k), MLBS^{e2e}_{pi(s,d)}(k)\right) \tag{9}$$

The MOS of loss rate (LR) of end-to-end ($e2e$) paths of $P_{I(s,d)}$, while Mean Loss Burst Size is represented as $MLBS$.

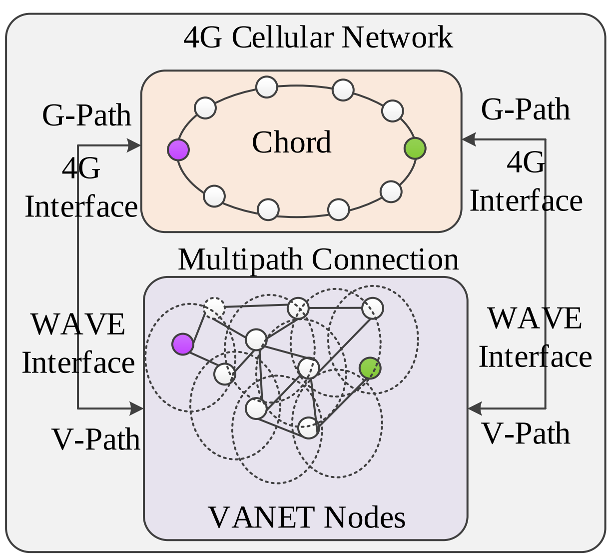


Fig. 8. QUVoD multi-homed hierarchical architecture

Lee, et al. [106] suggested a K-hop Cooperative Video Streaming (KCVS) that employs H.264/SVC in a hybrid VANETs. KCVS is proposed in order to achieve higher bandwidth usage. KCVS protocol is based on two main contributions including scheduling of streaming task assignment and strategies for forwarding packets. Nevertheless, SVC selection scheduling policy is not adequately explored. Furthermore, Torres, et al. [107] presents evaluation analysis on flooding for real-time video dissemination over VANETs. The aim is to investigate performance of video in flooding scenario. Further, an Automatic Copies Distance Based (ACDB) scheme is proposed as an enhanced flooding scheme that has the ability to handle varied vehicle density conditions. However, SSIM index not measured. In Sun, et al. [108], a strategy that consider QoE Distributed Catching method (QDC) for relieving network access pressure while also, improving video content delivery in VANETs cellular network has been suggested. The method considers constrained catching space of cellular base stations and fundamental user experience assurance for video streaming. The idea to attain maximum QoE is as presented in Eq. (10) as follows:

$$Max\ QoE(r_{ukn}) \ni \sum_{K=1}^{|U|}(\mu_a^n\, a \times r_{ukn} + b) \leq v \leq r_{uk}^{l} \leq r_{ukn} \leq r_{uk}^{u} \qquad (10)$$

The user bit rate is denoted as r_{ukn}, $\mu_a^n$is the video length, Meta data of the file is represented as b. r_{uk}^{l} and r_{uk}^{u} are the lower and upper bound of the user bit rate respectively. Meanwhile, there is need to consider geo-location data for the vehicular multimedia content distribution in cellular networks.

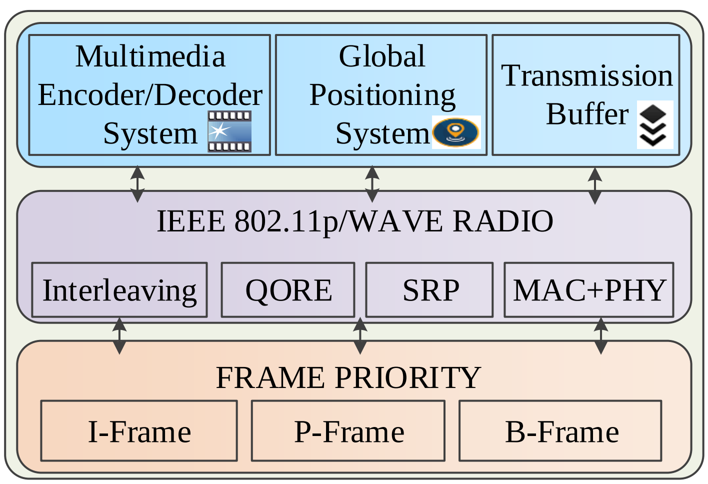


Fig. 9. Vehicle node architecture with interleaving QORE and SRP considering priority frames

Xu, *et al.* [109], presents a Performance-aware Mobile Community-based VoD (PMCV) streaming over VANETs. It supports high quality VoD by dealing with delay issues in mobile wireless networks. A video streaming method based on Erasure Coding and Real-time Transport Protocol (EC-RTP) has been suggested to resolve compatibility issues in using RTP for solving packet delay and packet loss [110]. The proposal is based on converter model; that manipulates the RTP by employing erasure coding strategy to reduce delay and deal with high packet loss. Although, the scheme does not consider 802.11p protocol hence, actual applicability in VANET environment cannot be ascertained. Quadros, *et al.* [111] improved MVIDE mechanism by employing cross-layer QOe-centric Receiver-based (QORE) scheme (see Fig. 9). Further proposed geographic Static Routing Protocols (SRP) for relay node selection and backbone maintenance. This is for minimizing frame loss by spreading out busty losses. Average video distortion has been ranked based on priority level of the frame and modeled in Eq. (11):

$$\delta_x^2\alpha = \begin{cases} if\ x \in I - frame\ then, \frac{\alpha_1(K_M - K_I)}{K_M} \\ if\ x \in P - frame\ then, \frac{\alpha_2 \sum_{i=1}^{T-1} 2^{T-1-i}(K_M - K_{Pi})}{(2^{T-1}-1)K_M} \\ if\ x \in B - frame\ then, \frac{\alpha_3(K_M - K_B)}{K_M} \end{cases} \quad (11)$$

Where $\delta_x^2\alpha$ is the impact on average video distortion rate, and K_M is the average data rate allowed by radio transceiver of each vehicle. K_I, K_{Pi} and K_B are the data rate of frame I, P and B respectively. Meanwhile, $T-1$ is the number of P-frames per Group of Picture (GoP). However, packetization size is not varied, which might have not given an adequate result of the schemes' performance.
However, another QoE-driven mechanism for enhancing H.265 video dissemination is proposed. it tackles challenges of time-changing channel conditions, scarce network resources and high-error rates [112]. The scheme merges both FEC techniques and adaptive QoE-driven mechanism (QoE-FEC). The FEC is manipulated to supports video dissemination with QoE guarantee in highly dynamic and error-prone networks. While, the adaptive QoE mechanism enhances the resilience of pre-recoded video dissemination in relation to packet loss. The adaptive QoE-driven depends on the merging of both High Efficiency Video Coding (HEVC) and characteristics of VANETs. However, more mobility scenarios and video parameters are not considered. Table 5 shows summary of related literatures on QoE coding-centric routing techniques with cross layer approach. The Table heading include protocol, issues, contributions, techniques, simulation tools, metrics and research limitations of each paper reviewed.

Table 5. Summary of Quality of Experience/Quality of Service-based approach

Characteristics → **↓ Protocols**	**Issues**	**Contributions**	**Techniques**	**Simulator**	**Metrics**	**Limitation**
MVSWN [101]	Lack of full modelled VANETs wireless channels	Multi-sources video streaming	Spatial (MDC) and Modelling of IEEE 802.11p	GloMoSim and VanetMobiSim	-PLR -E2ED -CO -PSNR	Bandwidth congestion is not considered
SUV [100]	In-efficiency in centralised video streaming traffic	Distributed video streaming traffic in urban settings	QoS/ Cross layer optimization	Mathematical model	Not mentioned	Unwilling vehicle participation in grouped vehicle communication
QUVoD [102]	How to attain QoE on home VoD	QoE driven user-centric solution	Multi-homed hierarchical P2P architecture	NS-2	-SL -CO -LSR	Delay and link stability are not considered
HIVE [103]	High packet collision and latency	An hybridized video transmission solution	Relay node and MAC congestion control with erasure coding	NS-2, Freeway and EvalVid	-PSNR -DL -FL -CO	Delay sensitive video application such as 3D video application is not considered.
ERVF [104]	Limited bandwidth, high packet loss and attenuation	Higher QoE and evaluation of user perceived quality of real time video	Performance evaluation of H.265 real-time video	OMNET++, SUMO	-PSNR -PLR -FL.	Algorithm for packet loss/frame loss is not explored
QoEMOS [105]	Measuring end-user perception of video quality	MOS-aware for path selection	QoE-centric routing approach	NS-2	-MOS -PLR.	PSNR is not measured

MVIDE [113]	Strict video quality requirement in VANET	QoE-aware path selection for pre recoded video	Multi-flow and Multi-driven approach	NS-2, SUMO with EvalVid	-PLR -E2ED -SSIM	Robustness of the mechanism is not explored.
KCVS [106]	Limited bandwidth problem	K-hop cooperative solution	K-hop cooperative approach with H.264/SVC	NS-2	-PSNR -THP	SVC selection/scheduling policy is not considered
ACDB [107]	Conflicting objective of high bandwidth and lower delay requirement	Comparison of performance video flood solution	Evaluation and analysis of video flooding schemes	OMNET++, SUMO VACAmobil	-PSNR -DR	SSIM index is not measured.
QDC [108]	Network access pressure and lack of distributed catching	QoE distributed catching solution	QoE distributed catching approach	-SR -MOS	Matlab	Geo-location data for the vehicular multimedia content distribution is not considered.
PMCV [109]	Balancing efficiency in content sharing and maintenance cost	Performance – aware streaming solution	Mobile community detection and community member management	NS-2	-SL -PLR -THP -PSNR -SR	There might be a partition level problem.
EC-RTP [110]	Compatibility issue in RTP for VANET packet loss	Adaptable converter model	Erasure coding for RTP approach	User designed Test-bed	-PSNR -SSIM -Delay -BU -PLR	802.11p is not used hence, actual applicability in VANET cannot be guaranteed.
QORE [111]	Broadcast storm problem in VANETs	Error correction and QoE driven Backbone solution	QoE driven coding centric approach	NS-2, SUMO with EvalVid	-SSIM -MOS -DL -PLR	Group of Pictures (GoP) and packetization sizes are not varied.
QoE-FEC [112]	Time varying channels and scarce network resources	Adaptive QoE driven solution	Coding centric QoE-driven approach	NS-3, SUMO with EvalVid	-SSIM -CO	Different mobility scenarios and video parameters are not considered

Table 6. Comparative assessment of Quality of Experience/Quality of Service-based approach and metrics

Protocol/Author	Approaches								Metrics											
	MAC	FEC	MP	CcR	RcC	QoE	OL	C-L	DL	DR	THP	PLR	SSIM	MOS	PSNR	CO	BU	SR	SL	FL
MVSWN [101]	✓		✓	✓			✓		✓			✓			✓	✓				
SUV [100]			✓	✓					✓			✓			✓	✓				
QUVoD [102]				✓		✓										✓		✓	✓	
HIVE [103]	✓			✓				✓	✓						✓	✓				
ERVF [104]				✓		✓				✓					✓					✓
QoEMOS [105]			✓		✓	✓						✓		✓						
MVIDE [113]			✓		✓	✓			✓	✓			✓							
KCVS [106]					✓						✓				✓					
ACDB [107]	✓			✓						✓					✓					

QDC [108]	✓			✓		✓								✓				✓		
PMCV [109]				✓		✓		✓			✓	✓			✓			✓	✓	
EC-RTP[110]				✓					✓			✓	✓		✓		✓			
QORE [111]		✓		✓		✓			✓	✓			✓	✓						
QoE-FEC [112]	✓	✓		✓		✓						✓				✓				

In Table 6, characteristics of each paper reviewed are categorized into three including protocol/author, approaches and metrics. The protocol/author column comprises abbreviation of techniques and reference. The approach column is divided into eight namely, MAC, FEC, MP, CcR, RcC, QoE, OL and CL. Last column represents metrics which includes DL, DR, THP, PLR, SSIM, MOS, PSNR, CO, BU, SR, SL and FL. Based on Table 6, the techniques demonstrates that more research works have been conducted in coding-centric routing techniques, followed by multipath approach, and then QoE approach. Meanwhile, few research contributions have been made towards MAC, overlay and cross-layer techniques. Metrics column shows that PSNR is the most considered metric, followed by PLR and DL for measuring performance of QoE/QoS coding-centric routing techniques. Next is Table 7 and 8 which shows analysis of multipath routing-centric coding techniques.

4.2.2 Multipath Routing Oriented Streaming

The sub-streams are forwarded through different paths from sender to receiver vehicle. Multipath coding-centric routing (see Fig. 10) considers compression of video while at the same time choosing most suitable and reliable paths for video stream forwarding. In multipath video scheme, video streaming flow is partitioned into distinct paths during transmission [114]. It reduces the high video data rate, by achieving load balancing during video transmission. Multipath video streaming mainly focus on path selection algorithm. It usually employs link/node disjoint approaches for efficient routing in video streaming. The multipath support the attainment of QoS in the following ways including fault tolerance, load balancing and, bandwidth and delay aggregation [20]. Another of its kind is multisource video transmission (see Fig. 11.) which it work in such a way that, if one source fails during video transmission another source can takeover. It may also require multi-source [101] when the video stream is split into different streams in order to take advantage of path diversity.

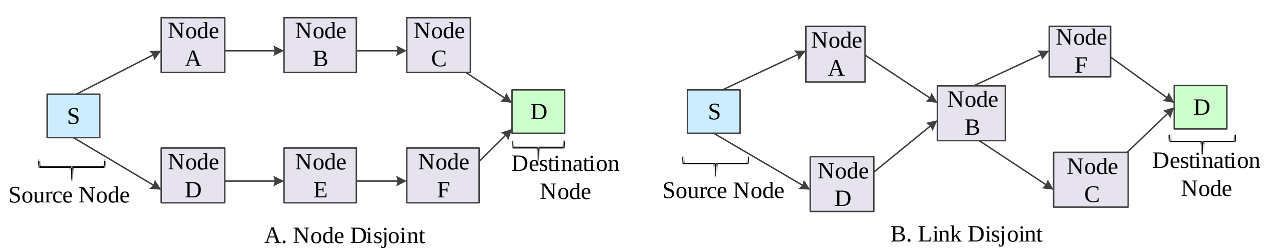


Fig. 10. Multipath node disjoint and link disjoint scenario

In Asefi, et al. [115], an approach that is based on cross-layer has been presented to reduce video distortion in order to attain quality video delivery. It considers path selection techniques (CPSV). The cross-layer-based approach maps application layer requirement by using routing layer to achieve its objectives. The approach considers coding rate allocation, it works in such a way that transmission rate must not surpass the encoding rate of the network. Further, the cross-layer takes into consideration of

Cite As:
ALIYU, A., ABDULLAH, ABDUL H., KAIWARTYA, O., CAO, Y., LLORET, J., ASLAM, N., JODA, U., 2018.
Towards video streaming in IoT Environments: Vehicular communication perspective.
Computer Communications, 118, pp. 93-119. [pii: S0140366417305121]

the spatial traffic distribution, queuing mobility model and possibility of connectivity between few and large traffic in VANETs. Location-centric multipath approach for streaming video over VANETs (LIAITHON) is proposed to avoid route coupling effect [114]. The approach is centered on consideration of location parameters to select the best multiple paths for video stream forwarding. Further, it uses forwarding zone scheme for reducing collision and congestion problem. In addition, a Cluster-based solution for Multimedia Content Delivery (CMCD) has been suggested to handle socio-economic issues in infotainment deployment over VANETs [116]. The suggested user-centric cluster based solution has the ability to handle vehicle passenger preferences and transmit multimedia content of either drivers' or passengers' interest. The CMCD includes cluster based scheme and cluster head selection algorithm. In generating the cluster-based solution, average interest of each vehicle is computed as denoted in Eq. (12):

$$AC_k = \frac{\sum_j IC_j}{NCL_k} \tag{12}$$

Where AC_k is the average interest of compatibility of vehicle node, k, j is the value of vehicle identification from 5-turples. The interest compatibility is IC_j and NCL_k is number of cluster. Notwithstanding, analysis of the clustering performance based on pre-recoded video is not measured.

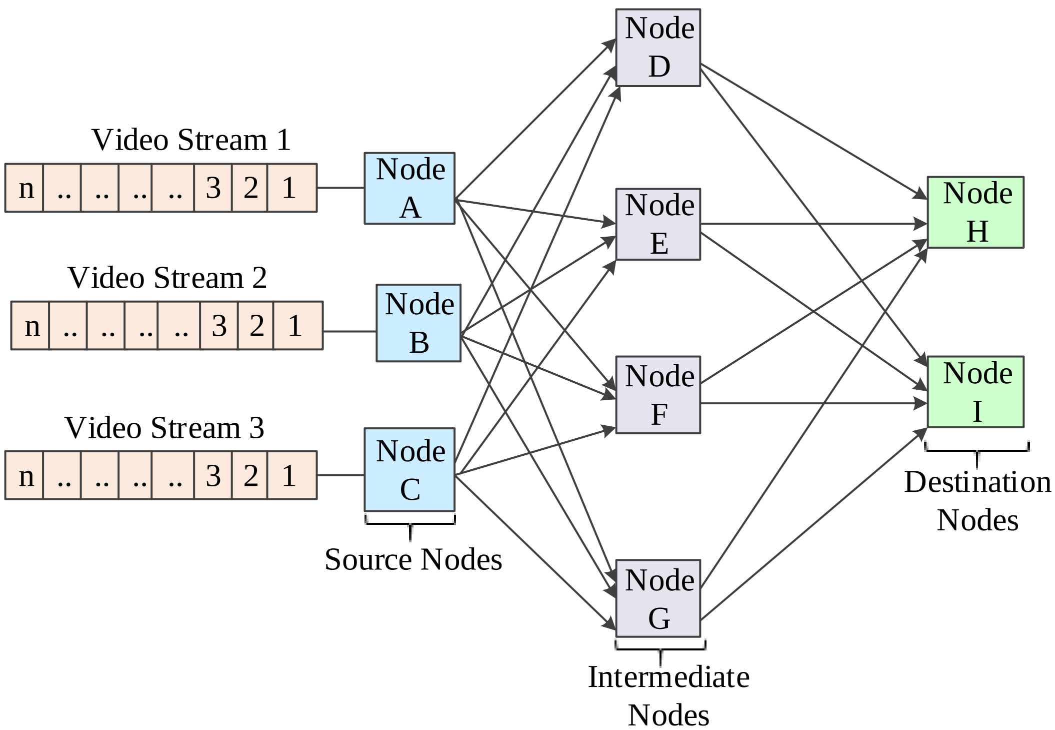


Fig. 11. Multisource video streaming scenario

A K-hop video stream Forwarding scheme for Cooperative (KFC) vehicular network has been suggested for alleviating bandwidth constraints [117]. The cooperative scheme works in such a way that vehicle can request for assistance from other vehicles which are in the same fleet to help in downloading video content. Each and every node in the forwarding area must take decision on how to transport buffered video stream via the limited bandwidth 802.11p network. Meanwhile, this approach may contribute to high delay. A resilient location-oriented video unicast scheme for VANETs video streaming is proposed to handle VANETs dispersion and mobility issues [118]. The scheme employs

VIdeo Reactive Tracking-based Unicast protocol (VIRTUS1). VIRTUS1 is a delivery-based solution that employs vehicles' existing and prospective position for selection strategy of relaying nodes. Meanwhile, density-based mechanism for preventing collision at high data rates is not considered.
An Opportunistic Routing solution for pre-recorded Video (ORV) streaming is proposed for handling interference in wireless fading channels [119]. The scheme takes into consideration of interference between vehicles from the surroundings during relay selection procedures. Specifically, distortion in video packet is estimated using Eq. (13):

$$\Delta D_{carry} = kP_{expi}(TTL_{cur} - \Delta T) - kP_{expi}(TTL_{cur}) = k\int_{TTL_{cur-\Delta T}}^{TTL_{cur}} f(t)dt \tag{13}$$

Where ΔD_{carry} is the distortion incurred in packet carrying, $TTL_{cur}$is the residual lifetime of a packet, $\Delta T$is the increment of delay, $kP_{expi}$is the distortion packet expire and t is the distortion time. Nevertheless, the SSIM index of the video streams is not considered to measure quality of the video. A multiple path solution with error correction for video streaming over VANETs (LIAITHON$^+$) has been presented. The aim is to reduce collision and packet loss in high data rate networks [120]. LIAITHON$^+$ employs multipath approach to distribute high data rate traffic into a set of paths. However, quality of the streamed video is not measured based on PSNR and SSIM index metrics. Rezende, et al. [121] proposed a receiver-based video transmission solution for VANETs which has network with content transmission decoupled from relay node selection (REDEC). However, it does not consider redundancy in handling packets loss while, at the same time sustaining a very low end-to-end delay. De Felice, et al. [122] suggested a non-centralized beaconless routing protocol for pre-recorded video transmission (DBD) over VANETs. It is an integrated framework that handles QoE of video services and routing protocol. DBD, further advances the performance of IEEE 802.11p/WAVE MAC layer, by resolving the spurious forwarding problem. The forwarding strategy is based on delay logic. The delay logic is shown as in Eq. (14):

$$D_L = D_{Tmax}\left(1 - \frac{d(V_s,V_r)}{TR_{max}}\right) \tag{14}$$

Where $D_L$is the shortest delay time, D_{Tmax} is the maximum delay time from sender. Sending vehicle and transmitting vehicles are represented as V_s, V_r respectively. TR_{max} is maximum transmission range and d is the distance. However, an adaptive backbone mechanism is not considered for DBD.
A Learning Automata (LA) with Bayesian Coalition Game Theory (BCGT) is used to design an intelligent Mobile Video Surveillance System (MVSS) [123]. The LA is considered to be the players in the game and they also form coalition among themselves by using BCGT. It works in such a way that if the coalition is formulated, then mutual decision about frame dissemination is taken by LA. For every action executed by LA, their actions are either penalized or rewarded. Al-Ani and Seitz [124], presents a video stream routing QoS for multi-rate mechanism, in order to achieve congestion control and avoidance. The mechanism employs Ant Colony Optimization (ACO) algorithm and Simple Network Management Protocol (SNMP) monitoring features. The mechanism is called QoRA, it decides on paths by considering application QoS needs and prevent transmission flow from entering congested nodes. Nevertheless, the mechanism is not adequately benchmarked. Table 7 and 8 shows summary of related literatures on multipath routing techniques and comparison table for the techniques and metrics respectively. Summary table entails protocols, issues, contributions, techniques, simulation tools, metrics and research limitations of each paper reviewed.

Table 7 Summary of multipath routing-based approach

Characteristics → Protocols ↓	**Issues**	**Contributions**	**Techniques**	**Simulators**	**Metrics**	**Limitations**
CPSV [115]	Video distortion problem	Path selection routing solution	Path selection and Cross-layer optimization	Mathematical model	-PSNR	Channels and external interference are not considered.
LIAITHON [114]	Route coupling effects	Location-centric multipath routing	Multipath approach	NS-2 Urban mobility model and EvalVid	-DL -FL -COST	Compression techniques not critically aligned with the route coupling effects.
CMCD [116]	Socio-economic constraints for infotainment deployment.	User-based cluster multimedia delivery solution.	Cluster-based multimedia content delivery approach	NS-3 and SUMO	-THP -FL	Analysis of the clustering performance is not performed and pre-recoded video is not implemented.
KFC [117]	VANETs bandwidth constraint	Cooperative K-hop packet forwarding scheme	K-hop forwarding routing technique	NS-2 and EvalVid	THP	Delay and SSIM index are not measured.
VIRTUS1 [118]	Challenges on dispersion and movement of vehicles	Point to point video streaming solution	Unicast protocol	NS-2, Freeway mobility model and EvalVid.	-DL -FL -Cost	Density based mechanism for preventing collision at high data rates is not considered
ORV [119]	Interference in wireless fading channels	Opportunistic routing protocol	Opportunistic routing protocol approach	NS-2	-PSNR -DL	SSIM index is not measured
LIAITHON+ [120]	Single paths are prone to collision at high data rates transmission	Minimized packet loss and collision in video streaming solution.	Multipath and error correction approach	NS-2 Urban mobility model and EvalVid.	-FL -DL -Cost	PSNR and SSIM index are not measured.
REDEC [121]	Dynamic topology problem and video streaming requirements	Decoupling of transmission content from relay node in VANETs settings	Routing relay node selection	NS-2 SUMO and EvalVid	-NT -E2ED -DR -JTR -PSNR	Conflicting objectives such as PLR and DR against end to end delay are not considered.
DBD [122]	Challenges on how to achieve QoE for end user in safety applications	Distributed beaconless dissemination	Multipath QoE routing approach	NS-2 SUMO and EvalVid	-SSIM -MOS -PSNR -PDR	Adaptive backbone mechanism is not considered
BLVS [123]	Effect of high velocity vehicles on video content delivery	Intelligent mobile video surveillance system.	Bayesian coalition game theory with LA for routing	NS-2	-CO -E2ED -THP -FL -PSNR	The scheme may not be suitable for delay-centric video
QoRA [124]	Congestion avoidance and control issue	Multi-rate ACO and SNMP solution	QoS routing scheme	NS-3 and SUMO	-JTR -CO -E2ED -THP -PLR	The scheme is not adequately benchmarked

Table 8 Comparative assessment of multipath routing-based approach and metrics

Protocol/Author	**Approaches**							**Metrics**										
	MAC	FEC	MP	RcC	QoS	QoE	C-L	DL	DR	THP	SSIM	MOS	PSNR	JTR	NT	CO	FL	COST
CPSV [115]		✓	✓	✓			✓						✓					
LIAITHON [114]			✓	✓				✓									✓	
CMCD [116]			✓	✓			✓			✓							✓	
KFC [117]			✓	✓						✓								
VIRTUS1 [118]			✓	✓				✓									✓	✓
ORV [119]	✓			✓				✓					✓					
LIAITHON+[120]		✓	✓	✓				✓									✓	✓
REDEC [121]			✓	✓				✓	✓				✓	✓	✓			
DBD [122]			✓	✓		✓		✓			✓	✓	✓					
BLVS [123]			✓	✓				✓	✓	✓						✓	✓	
QoRA [124]			✓	✓	✓			✓	✓	✓				✓		✓		

In Table 8, the characteristics of each paper reviewed are categorized into three including protocol/author, approaches and metrics. Protocol/author column comprises of protocol/abbreviation of technique and reference of each paper reviewed. Approach column is categorized into seven namely, MAC, FEC, MP, RcC, QoS, QoE and CL. Last column represents metrics which include DL, DR, THP, SSIM, MOS, PSNR, JTR, NT, CO, FL and Cost. Table 8 demonstrates that in approaches, multipath and routing-centric coding techniques have been mostly considered, followed by QoS, QoE and cross-layer approaches. Meanwhile, few research contributions have been made towards MAC and FEC techniques. Further, metric column shows that DL, FL and PSNR have been the most considered metrics, followed by JTR, CO and cost for measuring performance of multipath routing-centric coding techniques. The next is Table 9 and 10 which shows analysis of overlay techniques for vehicular video streaming.

4.3 Overlay based Vehicular Video Streaming

This type of technique depends on creating replication of the real network for faster video packet forwarding and routing from source to designated destination. Forwarding nodes are often called relay nodes. The relay nodes are usually along the path and direction of destination node. Meanwhile, a non-static and robust Overlay Multicast for multimedia streaming over VANETs (OMV) has been presented [125]. The approach tackles challenges of unwillingness for collaboration of non-group nodes. OMV improves stability of overlay considering two procedures including mesh structure overlay and QoS satisfied non-static overlay (see Fig. 12). Mesh structure overlay enables a node child to have multiple node parent. While, the QoS satisfied non-static procedure is used to manipulate overlay selection for possible new parents considering their overall delay and video stream packet loss rate.

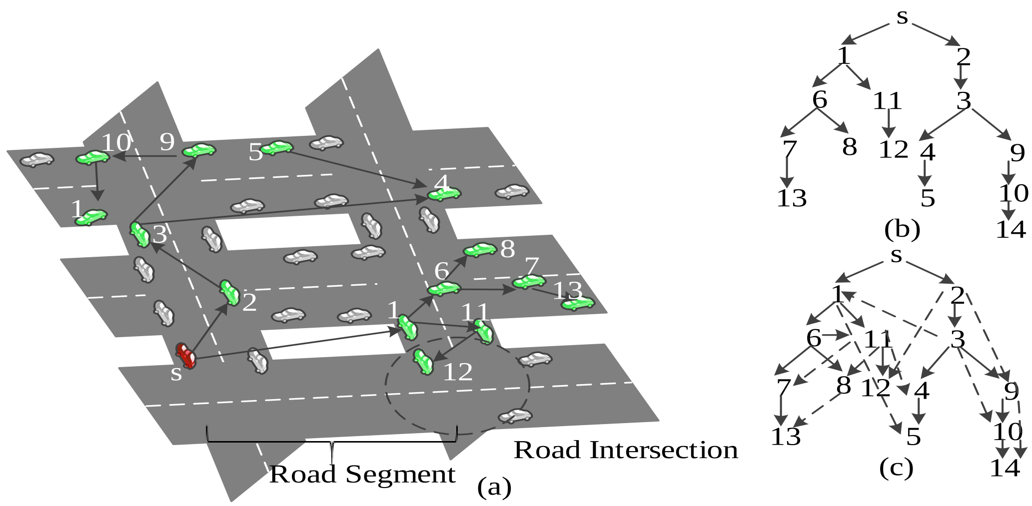


Fig. 12. Multicast overlay in urban VANETs, (a) an overlay in urban roads, (b) the corresponding overlay tree, (c) expansion of the tree

A Probabilistic Replica placement strategy for network Video streaming in vehicular delay Tolerant network (PRVT) has been suggested [126]. The strategy is based on data replication tree that depicts all nodes and their interconnection spanning from source to destination node. The depiction shows real time increase and decrease of node sizes as nodes leaves and join the network. A replica cost function is defined for handling data replica. It merges important factors including data update cost, data communication cost and data storage cost. Further, a Trust Estimation Metrics (TEM) is introduced based on the aforementioned cost factors between nodes for placement of a data replica. TEM has been mathematically represented in Eq. (15) as follows:

$$TEM = \propto \sum_{i=1}^{n} \left(\frac{S_C^f}{T_L^f}\right) \Delta T_M - \mu \sum_{i=1}^{n} \left(\frac{S_C^f}{T_L^f}\right) \Delta T_M \quad (15)$$

The representation of parameters $\propto, \mu \in [0, 1]$. S_C^f, T_L^f and ΔT_M are the successful total transmission frame and time interval respectively. The probability of activating a replica has been mathematically depicted in Eq. (16) as follows:

$$P(S_1, S_2, \dots, S_{i-1}; S_i) = \frac{LSV[T_{Mi}, T_{Mj}]}{LSV[T_M]} \quad (16)$$

Where LVS is the prediction value of node leaving the network. The state of vehicles represented in a specific area are depicted as $(S_1, S_2, \dots, S_{i-1}; S_i)$ and T_M is the total time for the vehicle node in a region. However, the PRVT has not been implemented with an adequate network simulation tool.

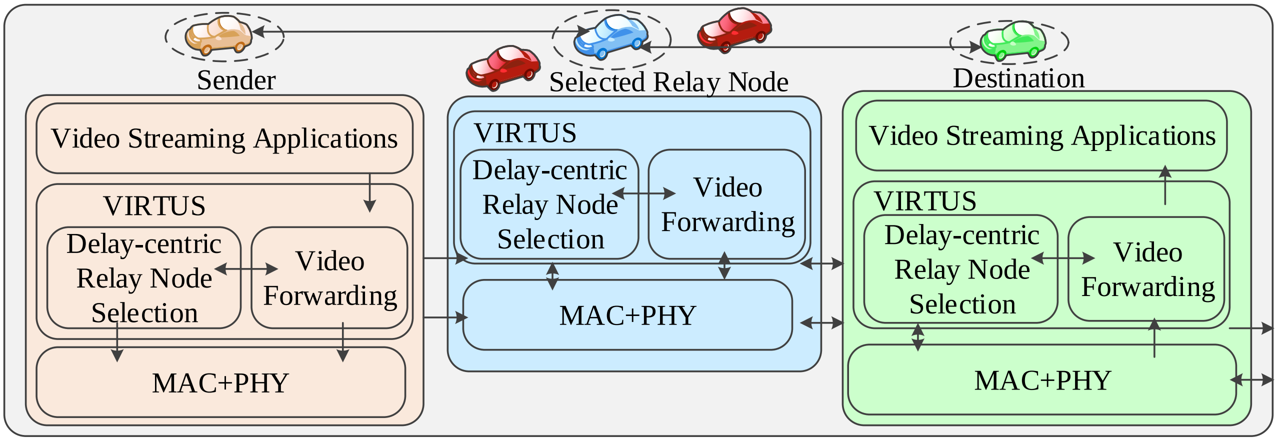


Fig. 13. The representation of VIRTUS architecture

A reactive and scalable unicast solution for video streaming over VANETs, named VIRTUS has been proposed [127]. It is aimed to address strict necessities for video streaming in VANETs (see Fig. 13). VIRTUS takes into consideration of numerous data packet disseminated sequentially in a short duration of time. Hence, it extends the period of decision of nodes to send packet from a single dissemination to a certain time window. Additionally, it computes the appropriateness of a node in order to serve as a relay node for data packet dispatching considering stability between geographical advancement and link steadiness. Further, an additional scheme that detach procedure of relay node selection and dissemination of video content has been developed. It also employ a density-aware process, which adapt its actions and manners according to local density. The concept is formulated in Eq. (17) as follows:

$$P_r\left(y_k; r_j, j \leq k\right) \approx \sum_{i=1}^{n} \vartheta_k^i \times \delta_{y_k^i} \tag{17}$$

Where $P_r\left(y_k; r_j, j \leq k\right)$ is the probability of different weight and $\vartheta_k^i \times \delta_{y_k^i}$ particles for location prediction. Issues on video error correction has not been considered. Therefore, further investigations is required. Cluster-based Overlay for Mobile IP (COMIP) system has been suggested to address frequent interruption and dissemination of invalid video fragments [128]. The clustering scheme is based on grouping of nodes that have the same moving characteristics and video supply/requirements. These grouped nodes have the ability of learning and taking decision based on deploy-ability of a recorded video. Further, an analysis of packet loss that occurred during handoff and its impact on the streamed video quality are conducted. Further, the use of mobile IP with and without fast handoffs has been studied to look at effects of mobility over video transmission. However, parameters and metrics for measuring visual quality of transmitted video have not been considered. An Adaptive Video Streaming System over a Cooperative (AViSCo) fleet of vehicles using the mobile bandwidth aggregation approach has been suggested. It addresses challenges in K-hop cooperative streaming in fleet based vehicular network, by considering bandwidth issues [129]. Precisely, a k-hop adaptive video transmission protocol has been proposed in order to attain better throughput by performing the following: i) choosing suitable vehicles among k-hop coverage members to download data packet in video streaming and ii) then retransmitting lost data packets from server to increase quality of the video. Through simulation, authors assured that priority first assignment scheme with the retransmission scheme is suitable to be adopted in cooperative video streaming settings in VANETs. Hence, the idea is mathematically formulated as in Eq. (18).

$$MAC_i = \begin{cases} MAC_{i-1}^{R} + VD_{i+1}, if\ QT_{ALL}^{i} > \sum_{m=1}^{NUM_{EL}^{FQV}} \sum_{n=1}^{M_i} size(EL_m^n) \\ VD_{i+1}, if\ QT_{ALL}^{i} \leq \sum_{m=1}^{NUM_{EL}^{FQV}} \sum_{n=1}^{M_i} size(EL_m^n) \end{cases} \quad (18)$$

The MAC transmission is denoted as MAC_i, MAC retransmission is represented as MAC_{i-1}^{R}, VD_{i+1} is the volume of video data at a node $i+1$, and QT_{ALL}^{i} is the estimated quantum of video data that can be downloaded by a helper. The EL_S is the Enhancement Layer, NUM_{EL}^{FQV} is number (NUM) of EL_S that can attain full video quality (FQV). Thus, in VANETs overlay there are challenges of frequent and swift update of nodes because of high mobility. Summary of related literatures on overlay techniques is given in Table 9 and 10, which comprises characteristics/protocol, issues, contributions, techniques, simulation tools used, metrics and research limitations of each paper reviewed.

Table 9. Summary of overlay-based approaches

Characteristics → / Protocols ↓	Issues	Contributions	Techniques	Simulators	Metrics	Limitations
OMV [125]	Non-cooperation of non-group nodes	Dynamic and flexible overlay solution	Overlay with multicast approach	Qualnet and VanetMobiSim	-PLR -E2ED -CO	Recorded video streaming has not been evaluated
PRVT [126]	Problem of shorter contact time between forwarding and receiving node.	Probabilistic reliable solution	Overlay replication for store and forward strategy	VanetMobiSim	-SR -E2ED -DR	Network simulation tool has not been considered.
VIRTUS2 [127]	Challenges in stringent video requirement	Reactive and scalable unicast solution.	Density awareness cooperative mechanism	NS-2 and SUMO EvalVid	-DL -PSNR -DR -NT	Error correction has not been considered.
COMIP [128]	Invalid video fragments and frequent interruption	Reduced video frame damage.	Cluster-based Overlay approach	NS-2 and SUMO	-E2ED -PLR -STD	Vital parameters such as PSNR has not been considered.
AViSCO [129]	K-hop cooperative streaming problem	QoS video streaming in fleet of vehicles	QoS-aware bandwidth aggregation scheme	EstiNet (NCTUns)	-PSNR -NT	overload and link quality have not been considered

Table 10. Comparative assessment of overlay-based approach and metrics

Protocol/Author	Approaches			Metrics								
	RcC	QoS	OL	DL	DR	PLR	PSNR	NT	CO	SR	STD	FL
OMV [125]	✓		✓	✓		✓			✓			
PRVT [126]	✓		✓	✓	✓					✓		
VIRTUS2 [127]	✓		✓	✓	✓		✓	✓				
COMIP [128]	✓		✓	✓		✓					✓	
AViSCO [129]	✓	✓	✓				✓					✓

In Table 10, approaches of each paper reviewed are categorized into three including protocol/author, approaches and metrics. The protocol/author column comprises abbreviation of techniques and reference. The approach column is divided into three namely, RcC, QoS and OL. Last column represents metrics including DL, DR, PLR, PSNR, NT, CO, SR, STD and FL. Considering Table 10, the approach column demonstrates that more contributions have been made towards overlay and routing-centric coding techniques, followed by QoS-aware approach. Further, metrics column shows that DL is the most considered metric, followed by PLR, and PSNR for measuring performance of overlay techniques.

5. Metrics and Simulation Tools for Vehicular Video Streaming

In this section, evaluation metrics that are used in assessing recent research works in Tables 3-10 are put forth, while theoretical explanations are presented in subsection 5.1. Metrics might differ depending on aim and objective of research work. The tables, pie chat, histogram and theoretical explanations shows that video streaming over VANETs is evaluated by using the following metrics; peak signal noise ratio, delay, delivery ratio, packet loss ratio, number of transmission, start-up delay, playback freezes, load utilization ratio, query to connectivity ratio, seeking latency, throughput, control overhead, frame ratio and structural similarity index. Various metrics are shown in subsection 5.1.

5.1 Metrics Derivation

In this subsection, various metrics considered in video streaming over vehicular communication are defined and mathematically formulated.

- **Peak Signal-to-Noise Ratio (PSNR)**

The Peak Signal-to-Noise Ratio (PSNR) is an expression for the ratio between maximum probable value of a signal and the power of distorting noise that affects the quality of its representation. Because, many signals have a very wide dynamic range, (ratio between the largest and smallest probable values of a variable quantity) [20, 95, 129]. The PSNR is generally expressed in terms of the logarithmic decibel scale, see Eq. (19) and (20).

$$PSNR = 10\log_{10}\left(\frac{MAX_f^2}{MSE}\right) \tag{19}$$

The Mean Square Error (MSE) can be expressed as:

$$MSE = \frac{1}{mn}\sum_0^{m-1}\sum_0^{n-1}\|f(i,j) - g(i,j)\| \tag{20}$$

Where f denotes the matrix data of original image, g represents matrix data of degraded image in question, m represents numbers of rows of pixels of the images and i represents index of that row n represents number of columns of pixels of the image and j represents index of that column, MAX_f is the maximum signal value that exists in the original "known to be good" image.

- **Delivery Ratio**

The Delivery Ratio (DR) is the ratio between number of data packets in video streaming generated at source vehicle and number of data packet in video streaming delivered to vehicles at destination [95]. The statistical formula used to calculate Delivery Ratio (DR) in terms of percentage can be expressed in Eq. (21) as follows:

$$DR\% = \left\{ \left(\sum_{i=1}^{n} \frac{PS}{PR} \right) \Big/ N \right\} \times 100 \quad (21)$$

Where PS denotes the number of data packet in video streaming sent in i^{th}simulation run and PR represents number of data packet in video streaming received in i^{th}simulation run.

- **Packet Loss Ratio**

The Packet Loss Ratio (PLR) is the failure of one or more transmitted data packet in video streaming to arrive at their destination. It is mainly because of network partitions, congestion and buffer overflows [101]. The statistical formula used to calculate packet loss (PL) in terms of percentage can be expressed in Eq. (22).

$$PLR\% = \left\{ \left(\sum_{i=1}^{n} \frac{PS-PR}{PS} \right) \Big/ N \right\} \times 100 \quad (22)$$

- **Structural Similarity**

The Structural Similarity (SSIM) index is an approach used to calculate the perceived similarity between the transmitted video images and the original video images. The calculation of the SSIM index are grouped into three including contrast, luminance and structural assessment. Contrast assessment [130] $Ct(a,b)$ is the difference of σ_a *and* σ_b then, we have $Ct(a,b) = \frac{2\sigma_a\sigma_b+K_2}{\sigma_a^2+\sigma_b^2+K_2}$ while the Luminance assessment is denoted as $Ln(a,b) = \frac{2\mu_a\mu_b+K_1}{\mu_a^2+\mu_b^2+K_1}$ where K_1 and K_2 are constant. The structural assessment is carried out as $St(a,b)$ on the normalized signals $(a-\mu_a)/\sigma_a and\ (b-\mu_b)/\sigma_b$ Thus, $S(a,b) = f(Ct(a,b), Ln(a,b), St(a,b))$ then finally, Eq. (23) and (24) are depicted as follows:

$$SSIM(a,b) = \frac{(2\mu_a\mu_b+K_1)(2\sigma_{ab}+K_2)}{(\mu_a^2+\mu_b^2+K_1)(\sigma_a^2+\sigma_b^2+K_2)}. \quad (23)$$

$$MSSIM(a,b) = \frac{1}{M} \sum_{j=1}^{M} SSIM(a_j, b_j) \quad (24)$$

Where μ_a, μ_b represents the local means, σ_a and σ_b is the standard deviations, while σ_{ab} is the cross-covariance for video images a, b.

- **Loss Frames**

The Loss Frame (LF) is the difference between the total number of sent frame and the total number of the delivered frames at the receiver end [129]. See Eq. (25) as follows:

$$LF = \sum FR_s - \sum FR_d \quad (25)$$

Where FR_s is the number of frames sent and FR_d is the number frame delivered to the end user.

- **Load Utilization Ratio**

The Load Utilization Ratio (LUR) is the number of frames transmitted from the frame service rate within a service time compared with the frame arrival rate [131]. It can be mathematically denoted in Eq. (26) as follows:

$$LUR = \frac{N_{fr}(S_t \times \delta)}{\varphi} \tag{26}$$

The N_{fr} represents the number of frames, S_t is the mean service time, δ is the rate of frame service, and φ is the rate of frame arrival.

- **Query to Connectivity Ratio**

The Query to Connectivity Ratio (QCR) is the whole ratio of successful queries in relation to the number of re-connection of a vehicle to the video streaming server [132]. It is mathematically represented in Eq. (27).

$$QCR = \frac{(Q_S \times S_t)}{N_{cs}} \tag{27}$$

Where Q_s represents the successful queries, S_t is the time taken for the connection and N_{cs} is the number of re-connection with the server.

- **Delay**

The delay (DL) is the total time taken for a video stream to be transmitted from source to a specified destination [20]. The total delay time encompasses five major steps in video stream transmission including startup delay, propagation delay, transmission delay, queuing delay and processing delay. It can be represented mathematical in Eq. (28) as follows.

$$DL = N \sum D_{St}, D_{Pr}, D_{Tr}, D_{Qu}, D_{Prs} \tag{28}$$

Where N is the number of links (hops) in the network, D_{St} is the startup delay of the video stream, D_{Pr} is the propagation delay for transmitting a single bit from source to destination, D_{Tr} is the transmission delay of a video stream packet transmitted from source to destination, D_{Qu} D D_{Qu} is the queuing delay for video stream before transmission and D_{Prs} is the processing delay encountered during video streaming from source to destination.

- **Startup Delay**

The Startup Delay (STD) is the total time used by video stream applications in order to delay its first bits contents (buffer) to attain optimized and fast stream video transmission from source to destination [15]. Eq. (29) has been presented as follows:

$$STD = T_{db} \tag{29}$$

Where T_{db} is the time within the period of initial transmission of first bit of the video stream.

- **Playback Freezes**

The Playback Freezes (PBF) is the number of video stoppage and play again scenarios during video stream from source to a destination [15]. It is represented in Eq. (30) as follows:

$$PBF = \sum N_{fr} \tag{30}$$

Where N_{fr} is the number of occurrence of freezes and playback during video streaming.

- **Seeking Latency**

The Seeking Latency (SL) is the average time at which a vehicular node request a video stream segment to the time it received the video stream segment into its playback buffer [133]. It can be represented as shown in Eq. (31).

$$SL = RQ_t/RC_t \tag{31}$$

Where RQ_t is the total duration taken for requesting a video stream segment and RC_t is time taking during receiving period of the video stream segment.

- **Success Rate**

The Success Rate (SR) is the scale of relation between number of lookup success occurrence obtained and the over-all number of lookup attempts [133]. Mathematically, it is represented in Eq. (32) as follows:

$$SR = N_{Ls}: N_{La} \tag{32}$$

Where N_{Ls} represents the number of lookup success, while N_{La} depicts total number of lookup attempts.

- **Control Overhead**

The Control Overhead (CO) is the average total number of traffic control messages in relation to the occupied bandwidth size per seconds [133]. It can be represented as in Eq. (33) shown below.

$$CO = \frac{A_{VR}(T_{cm})}{B_t} \tag{33}$$

Where $A_{VR}(T)_{cm}$ is the average time taken for traffic control messages', while B_t is the bandwidth size occupied by the traffic control messages per seconds.

- **Throughput**

The throughput (THP) is the total performance of the system when transmitting video streams from source to the destination. In another word, it is the sum of video data rate delivered to all nodes of the network [109]. Mathematically, it is formulated as in Eq. (34).

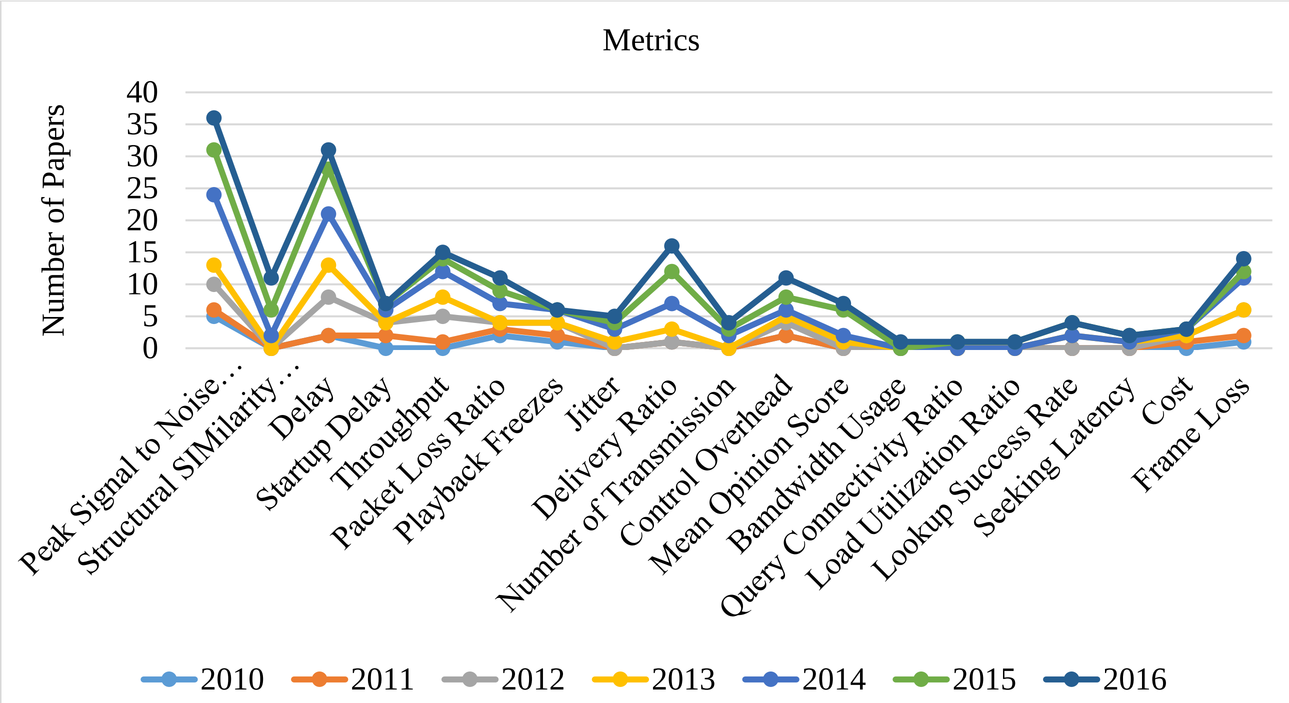
$$THP = \sum \left(\frac{Dt}{Ti}\right) \times Nd \tag{34}$$

Where $\frac{Dt}{Ti}$ represents the data rate and Nd is the number of nodes in the network.

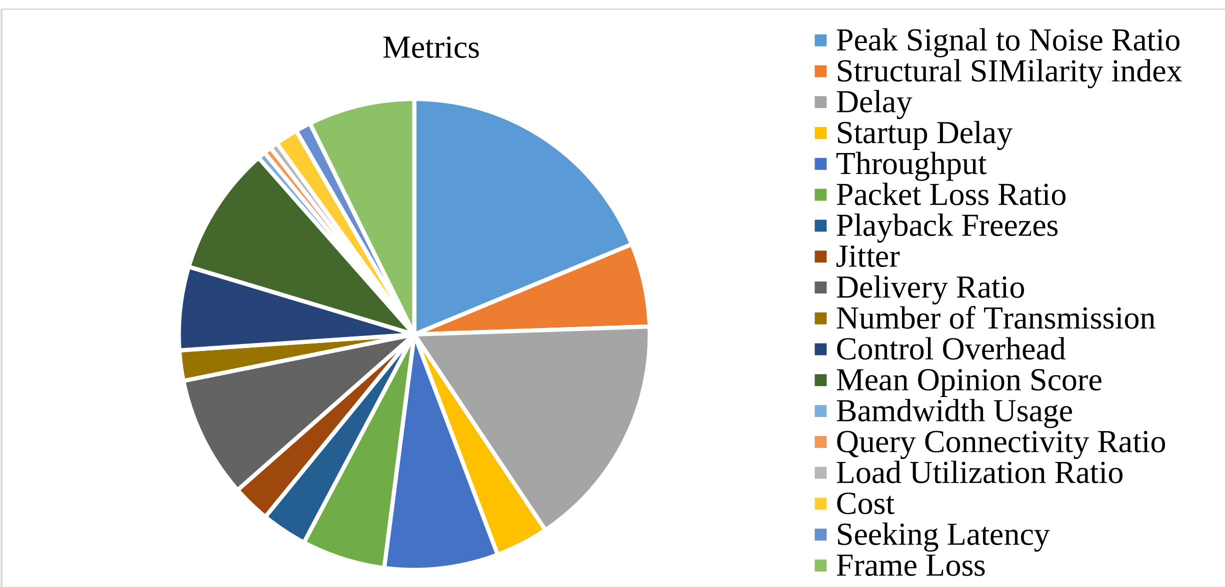
5.2 Analysis of Metrics

In Fig. 14(a), the histogram shows representation of metrics based on their usage from year 2010 to 2016 research papers. The graph demonstrates that peak signal to noise ratio (PSNR) is the most used metric throughout the years for measuring overall video quality at receiver end. Specifically, PSNR is more used in 2014, these depicts that it is generally accepted for measuring overall video quality. Delay is the second most used metric for measuring video streaming quality, it is used to measure single frame delay and end to end delay. It has the highest usage in year 2014, this also shows that reducing delay would positively impact on quality of video streamed. Delivery ratio and frame loss are the third most considered metrics for measuring video quality. The ratio of video frames received by end user determines the quality of the video. Also, the number of frame loss can determine the level of video quality. However, other metrics that have been less considered as shown in Fig. 14(a), which are also used but not often. Thus, those metrics have less acceptability by the researchers. Fig. 14(b), is the representation of the metrics in pie-chart, to show percentage of acceptability of each metrics.

Fig. 14(b) depicts percentage of acceptability of each metrics in video streaming over VANETs. The analysis demonstrates that peak signal to noise ratio has the highest usage with 19% of the overall metrics considered, followed by delay with 16%. Mean opinion score has 9%, followed by throughput and delivery ration with 8% usage each, and then frame loss with 7% usage. Structural similarity index, packet loss ratio and control overhead have 6% usage each. Start-up delay covers 4%, while, playback freezes and jitter have 3% usage each. Number of transmission and cost have 2% each although, query to connectivity ratio, load utilization ratio, bandwidth utilization and seeking latency have the least usage with 1% each. However, these have shown that PSNR is more generally used for evaluating video quality. While, metrics with 1% are rarely considered for determining video quality.



(a)

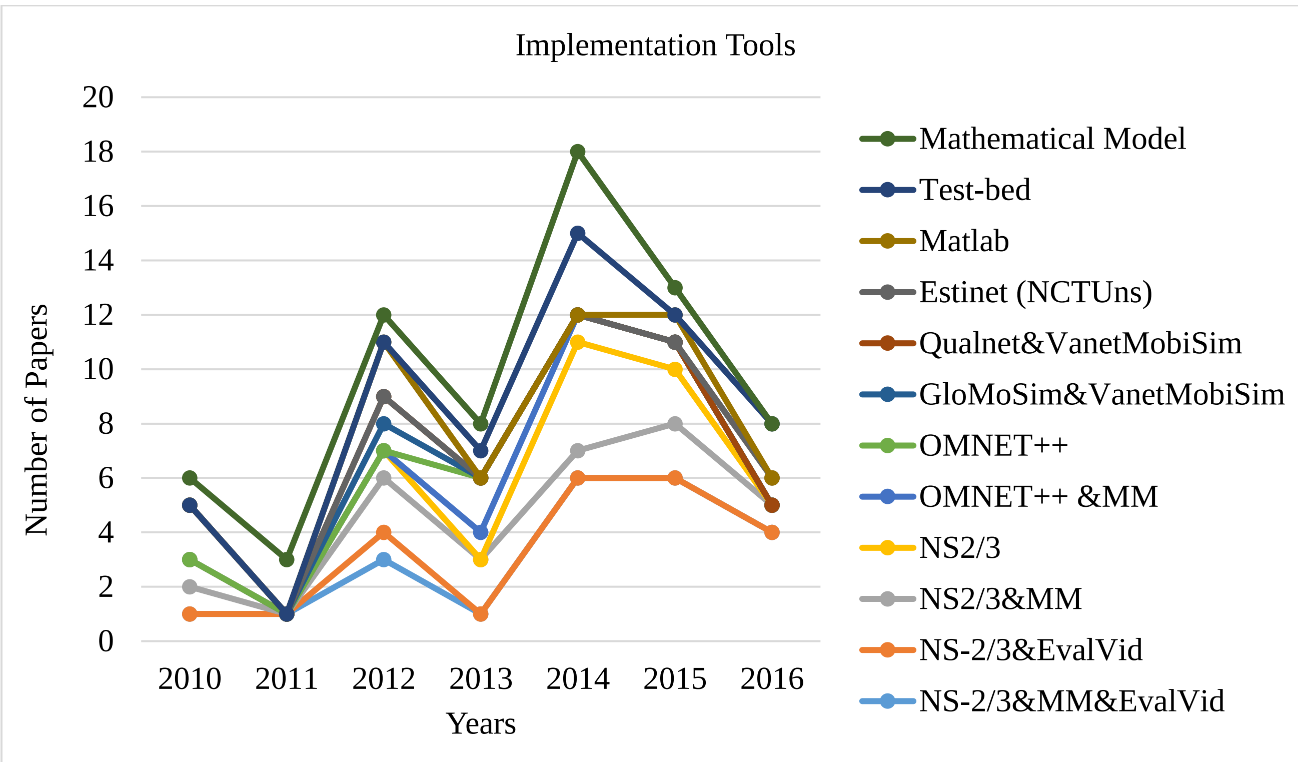


(b)

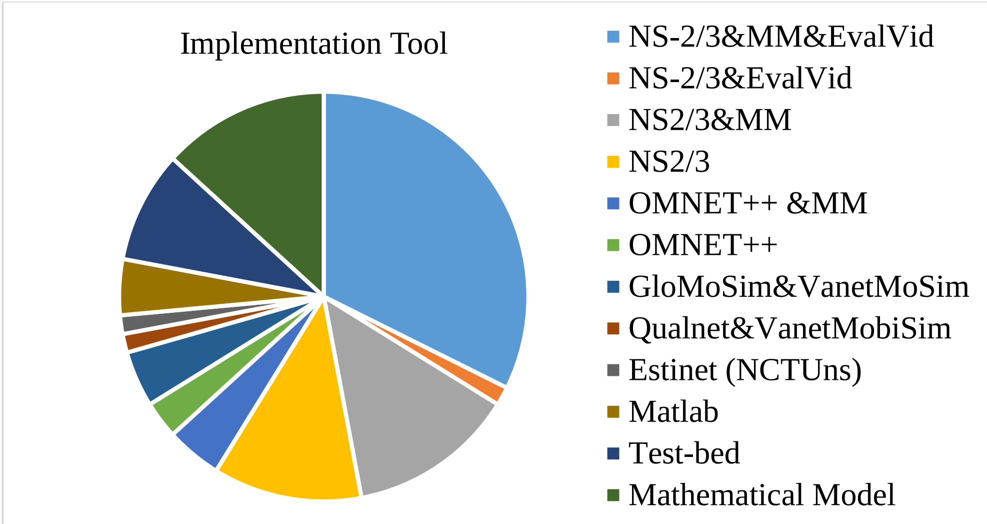
Fig. 14. Analysis of metrics for video streaming in vehicular communication between 2010-2016

5.3 Analysis of Simulation Tools

In this section, we have analyzed several tools used in implementing research concepts including algorithms, protocols, models and so forth. As shown in Fig. 15(a) and 15(b), several research works have employed the use of related tools including network simulation, mobility configuration and video quality evaluation tools. The network simulation tools including NS2/NS3 [134, 135], OMNET++ [136], Qualnet [137], GloMoSim [138], Estinet (NCTUns) [139], Matlab [140], user designed test-bed and mathematical modelling which are used for implementing network communication. The mobility simulation tools which include Vehicular ad hoc network Mobility Simulator (VanetMobiSim) [141], realistic and joint Traffic and Network Simulator for VANETs (TraNS) [142], Simulation of Urban Mobility (SUMO) [143], Urban Mobility Model (UMM) [144], Freeway Mobility Model (FMM) [145] and Vehicular ad hoc network Car Mobility Manager for OMNET++ (VACAmobil) [146] which are used for the micro and macro mobility setup and design. Meanwhile, the EvalVid is a video quality evaluation tool that provides a tool-sets of video files and framework for appraisal on video transmission [147].



(a)



(b)

Fig. 15. Analysis of implementation tools for video streaming in vehicular communication

Fig. 15(a) and 15(b) shows analysis of various tools that are used in implementing video streaming techniques over VANETs. In Fig. 15(a), the histogram depicts representation of all implementation tools based on their usage from year 2010 to 2016 research papers. The graph demonstrates that NS2/3 with mobility model and EvalVid are the most considered tools for implementing video streaming techniques. Furthermore, NS2/3 with mobility model and EvalVid have the highest usage in year 2014 and 2015. It mean that, they are generally accepted for implementing video streaming technique in vehicular communication. NS2/3 with mobility model and mathematical modelling are the second most used tools. In NS2/3 with mobility model, the EvalVid video framework tool is not considered, therefore, their result might not be realistic. The mathematical model is also widely accepted for modelling the numerical assumption of the video streaming solution. The third most considered implementation tools are NS2/3 and user designed test-bed. In this case, only NS2/3 is used without considering mobility model and video tools. Hence, the implementation might not be realistic. For the user designed test-bed implementation, a realistic result might be achieved, but it is not economically feasible. However, other implementation tools have been less considered as shown in Fig. 15(a), which are also used but not frequently. Thus, the less used implementation tools might be connected to their lack of suitability for video streaming in vehicular communication. Fig. 15(b), represents percentage acceptability of various implementation tools.

Fig. 15(b), demonstrates that, incorporation of NS2/NS3 with mobility models and EvalVid are the highest most used tools for video streaming over VANETs with 32% of the overall simulation tools used. EvalVid integrated with NS2/NS3 without mobility models has the lowest usage with 2% while, mobility model incorporated with NS2/NS3 without EvalVid has 13% of the overall tools. NS2/NS3 and EvalVid without mobility model have 12% of the overall tools employed. For OMNET++ integrated with mobility models has 4% while, OMNET++ without mobility models has 3% of the total tools used. GloMoSim integrated with VanetMobiSim has 4% of the overall tools used. Qualnet integrated with VanetMobiSim has the lowest usage like in the case NS2/NS3 with 2%. Estinet (NCTUns) is also among the lowest used tools with only 2%. Matlab has 4% while, user designed test-bed has 9%. Mathematical modelling has 13% usage. However, the analysis demonstrates that NS2/NS3 with mobility models and EvalVid video quality evaluation tools are widely accepted for simulation from year 2010 till date. Meanwhile, NS2/NS3 and EvalVid without mobility, Estinet (NCTUns) and Qualnet with VanetMobiSim have very low usage, perhaps due to complexity or lack of suitability.

6. Open Research Challenges in Vehicular Video Streaming

The dynamic and vigorous nature, restricted movement pattern of vehicles are critical issues in IoT communication. In addition, there are stringent requirements for video sensing including fewer packet loss, lower error rate and minimum delay. The requirements are to attain qualitative video sensing. Further, there are challenges confronting IoT devices based on the aforementioned resource limitation. The challenges are highlighted as follows.

- **Robust Traffic Video Encoding**

Considering miniaturized IoT devices for video streaming task, which has resources limitations. The act of estimating motion vectors in the predictive encoding is a tedious and intensive task. Also, Compression techniques which adequately considers VANETs features are not critically considered for better video streaming such as in H.264/AVC [90, 148].

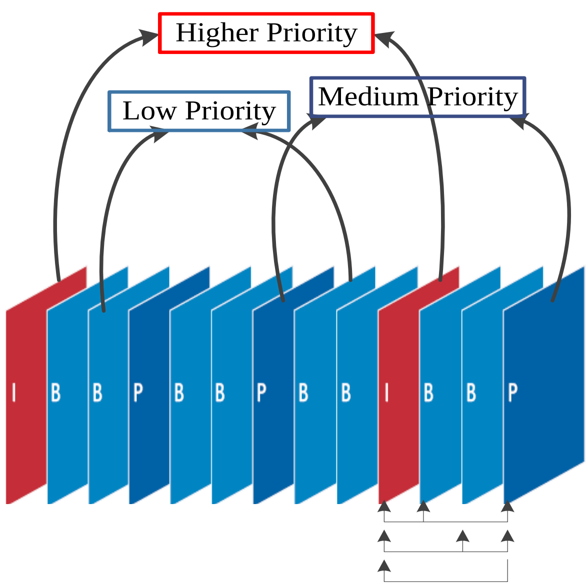


Fig. 16. Video frame priority for robust traffic video encoding

In Fig. 16, video frame coding standards has been presented. Multiple description coding including intra-frame (I-frame) and inter-frames (P-frame and B-frame) are depicted. I-frame consist of the major information of the entire video frame, while the P-frame and B-frame are dependent based on reference frames that is, I-frame. Thus, whenever an I-frame is lost or damaged, the entire video Group of Picture

Cite As:
ALIYU, A., ABDULLAH, ABDUL H., KAIWARTYA, O., CAO, Y., LLORET, J., ASLAM, N., JODA, U., 2018.
Towards video streaming in IoT Environments: Vehicular communication perspective.
Computer Communications, 118, pp. 93-119. [pii: S0140366417305121]

(GOP) might be lost or damaged. But once transmission of I-frame is guaranteed, the quality of the entire video GOP can be enhanced. Therefore, priority-aware coding for intra-frames and inter-frames that put into consideration features including memory size, power and processing capabilities of IoT device and dynamicity of vehicle are required. However, more tedious and resource consuming task should be offloaded to the cloud and also there is need to develop robust and flexible video encoding solutions in order to attain QoS in the video data transmission.

- **Transmission Range Oriented Traffic Video Delivery**

The pattern of vehicle movement considering IoT communication is a challenging task, because vehicle have restricted topology for movement [86]. Mobility pattern might affect video streaming transmission between smart home devices with vehicular IoT devices. The movement is stated under numerous varied mobility models [149]. However, several research study are being carried-out in order to bring mobility models to correspond with mobility that is in nearness to real world situation. Because, movement of vehicles and IoT devices directly impacts on total performance of the communication.

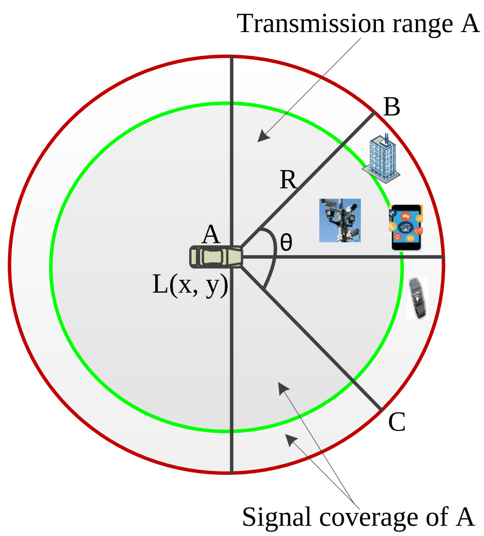
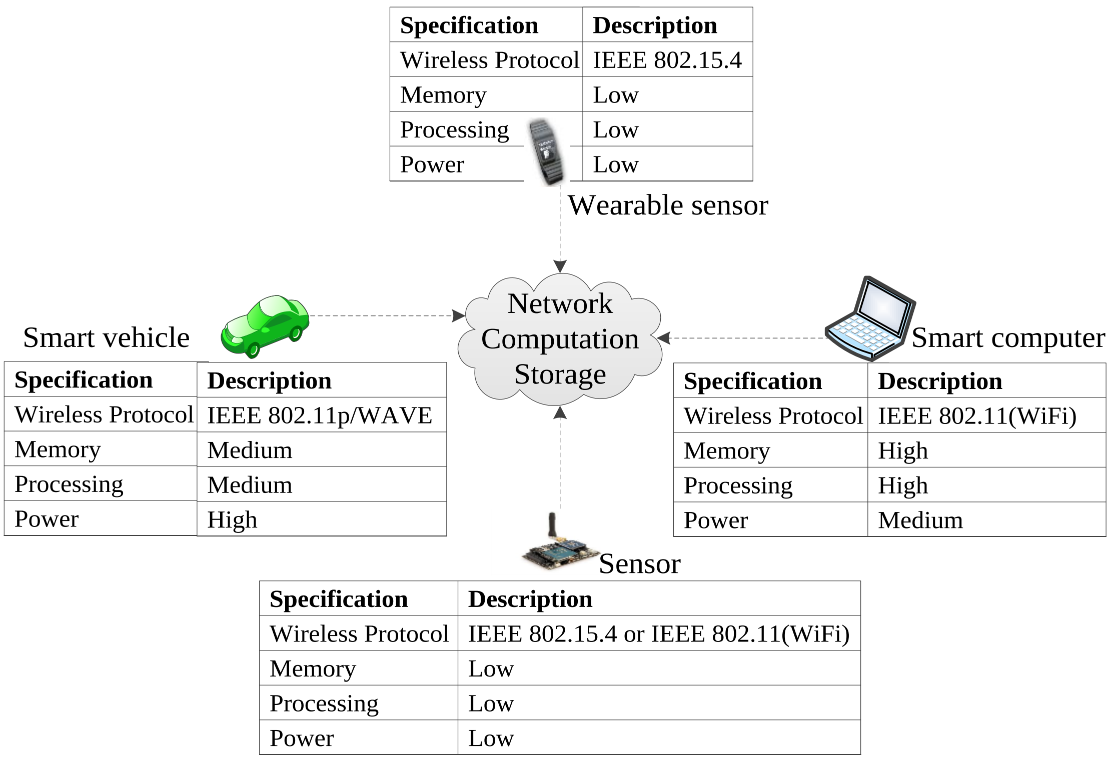


Fig. 17. Transmission range related issue due to vehicle position change in video delivery

Video sensing in vehicular IoT might encounter video packet loss due to frequent network disconnection during video sensing between vehicle and the smart home or core organization server. For example in Fig. 17, vehicle A with position $L(x, y)$ is sensing and transmitting video packets while at the same time changing position. The rapid change in position could lead to network disconnection because radio signal coverage. Also, distributed distance between vehicles and IoT devices would affect efficient video streaming. Thus, there is need to employ fog network [150]. In this case, other vehicles could serve as a fog network for the successful transmission of the video stream. In addition, highly scalable video streaming solutions are required.

- **Traffic Video Streaming over Heterogeneous Communication Devices**

Communication devices in vehicular IoT are varied in terms of network connections technology, memory size, processing and power capabilities. For example, communication devices such as pedestrian wristwatch and mobile phone and other sophisticated gadget need to be harmonized for efficient communication by considering various device limitations [151, 152]. In addition, vehicles use IEEE 802.11p, while other IoT devices could be using other network technology such as 3G, 4G, 5G, and ZigBee etc.



Wearable sensor:

Specification	Description
Wireless Protocol	IEEE 802.15.4
Memory	Low
Processing	Low
Power	Low

Smart vehicle:

Specification	Description
Wireless Protocol	IEEE 802.11p/WAVE
Memory	Medium
Processing	Medium
Power	High

Smart computer:

Specification	Description
Wireless Protocol	IEEE 802.11(WiFi)
Memory	High
Processing	High
Power	Medium

Sensor:

Specification	Description
Wireless Protocol	IEEE 802.15.4 or IEEE 802.11(WiFi)
Memory	Low
Processing	Low
Power	Low

Fig. 18. Heterogeneous vehicular IoT devices related issue in traffic video delivery

Fig. 18 represents various heterogeneous IoT devices, which are varied in terms of wireless communication protocol, memory size, processing and power capabilities. However, video streaming in heterogeneous devices is challenging because, video are large in size and requires minimum delay in delivery. The network connection, computation and storage capabilities of various devices need to be integrated in such a way that every device has its own video compression standard considering sender and receiver devices capabilities. Further, for large video data, 5G network technology can be employed for automatic synchronization and offloading of the video data to cloud datacenter [153]. This would minimize the need for large memory space and high processor capability for resource storage and computations.

- **Real Time Traffic Video Relaying**

Based on the fact that some of the IoT devices might be static e.g. forest monitoring sensors might be in static position, while the vehicle sensors are in motion, there is need to consider a form of content data relaying mechanism between vehicles during data gathering. For example, considering a smart forest, where vehicles moving along the forest collect data for transmission to cloud or environmental management agency network for subsequent data analysis.

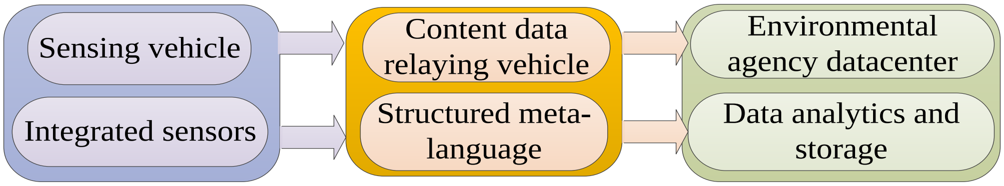


Fig. 19 The real time traffic video content relaying

In Fig. 19, illustrative representation of vehicle sensing, content data relaying and transmission to environmental management agency datacenter is presented. It shows functional requirements of 3 elements including 1) integrated sensors for sensing vehicle, 2) structured meta-language for content data relaying vehicle and 3) data analytics and storage for the environmental management agency datacenter. The major challenge is how to integrate content data relaying concept into vehicular sensors for effective data gathering in IoT.

- **Location Privacy in Location based Traffic Video Streaming**

Considering communication between two or more external devices, like in the case of communication between smart pedestrian and smart vehicle, issue of privacy might come into play. Such as revealing of vehicle location and identity information. These information can be used for intrusion and malicious activities [154, 155]. Thus, appropriate authentication is required at both pedestrian and vehicle end, in order to achieve assured privacy. Another challenge for supporting video/audio applications in the vehicular IoT is security variation of actuator network, wireless and wired sensors [156]. Hence, a generic solution for all kind of communication is required to be extensively explored.

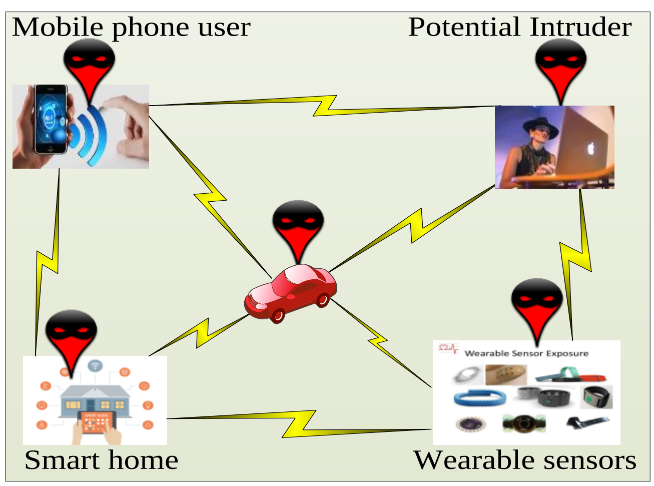


Fig. 20. The location privacy in location based traffic video delivery services

In Fig. 20, locations of vehicular IoT devices are revealed, due to vehicle movement while communicating using map route navigation. Since the concept is interconnection of everything, an intruder can penetrate to the most vulnerable device in order to attack other device with the communication network [157]. For example, a potential intruder could take advantage of either smart phone or wearable sensor devices to penetrate into smart home devices or vehicle information. However, location encryption and two-level authentication and verification are required for secured vehicular IoT communication.

7. Conclusion

In this study, a comprehensive classification structure and qualitatively of related literatures on video streaming for VANETs in relation to IoT perspective have been presented. Different issues and techniques employed in video streaming in vehicular IoT have been analyzed. Further, we have derived a number of performance metrics for evaluation of video streaming and have presented a comparative analysis of the metrics. We have also elaborated future research directions. In our analysis of video streaming metrics, we have observed that, PSNR is the most considered metrics for evaluating performance quality of video streaming. However, some authors have claimed that SSIM index is more accurate for evaluating video streaming performance. In the analysis of implementation tools, reasonable amount of video streaming research papers has considered incorporating network simulation tools with mobility model tool and video framework tool sets for simulating video streaming. The incorporation of the three tools tends to give a realistic result. Meanwhile, some handful video streaming research papers does not consider either mobility model or video tool sets or both. Thus, this implementation using two or single tool might not give a realistic result. Moreover, very few simulators are able to simulate all parameters studied in this work, so the research community should work on improving the simulators by adding more simulation parameters for video streaming communication in VANETs. This review work will improve the understanding of video streaming research trends and directions in both VANETs and IoT. Thus, this will stimulate research work in video streaming domain by making research gap finding easier. However, better video streaming solutions will improve IoT multimedia communication efficiency, on-road infotainment and enhance on-road safety applications in VANETs.

Acknowledgement

The research is supported by Ministry of Education Malaysia (MOE) and conducted in collaboration with Research Management Center (RMC) at University Teknologi Malaysia (UTM) under VOT NUMBER: RJ130000.7828.4F708.

References

[1] L. Atzori, A. Iera, and G. Morabito, "The internet of things: A survey," Computer networks, vol. 54, pp. 2787-2805, 2010.
[2] L. Ericsson, "More than 50 billion connected devices," White Paper, 2011.
[3] V. Cisco, "The zettabyte era: Trends and analysis," Updated (29/05/2013), http://www. cisco. com/c/en/us/solutions/collateral/serviceprovider/visualnetworking-index-vni/VNI_Hyperconnectivity_WP. html, 2014.
[4] S. A. Alvi, B. Afzal, G. A. Shah, L. Atzori, and W. Mahmood, "Internet of multimedia things: Vision and challenges," Ad Hoc Networks, vol. 33, pp. 87-111, 2015.
[5] H. Hartenstein and L. Laberteaux, "A tutorial survey on vehicular ad hoc networks," IEEE Communications magazine, vol. 46, pp. 164-171, 2008.
[6] J. Lloret, A. Canovas, A. Catalá, and M. Garcia, "Group-based protocol and mobility model for VANETs to offer internet access," Journal of Network and Computer Applications, vol. 36, pp. 1027-1038, 2013.
[7] J. Yin, T. ElBatt, G. Yeung, B. Ryu, S. Habermas, H. Krishnan, et al., "Performance evaluation of safety applications over DSRC vehicular ad hoc networks," in Proceedings of the 1st ACM international workshop on Vehicular ad hoc networks, 2004, pp. 1-9.

[8] V. Milanés, J. Villagra, J. Godoy, J. Simó, J. Pérez, and E. Onieva, "An intelligent V2I-based traffic management system," IEEE Transactions on Intelligent Transportation Systems, vol. 13, pp. 49-58, 2012.

[9] L. Zhang, A. Lakas, H. El-Sayed, and E. Barka, "Mobility analysis in vehicular ad hoc network (VANET)," Journal of Network and Computer Applications, vol. 36, pp. 1050-1056, 2013.

[10] A. Boukerche, H. A. Oliveira, E. F. Nakamura, and A. A. Loureiro, "Vehicular ad hoc networks: A new challenge for localization-based systems," Computer communications, vol. 31, pp. 2838-2849, 2008.

[11] M. Kakkasageri and S. Manvi, "Multiagent driven dynamic clustering of vehicles in VANETs," Journal of Network and Computer Applications, vol. 35, pp. 1771-1780, 2012.

[12] Y. Liu, J. Niu, J. Ma, L. Shu, T. Hara, and W. Wang, "The insights of message delivery delay in VANETs with a bidirectional traffic model," Journal of Network and Computer Applications, vol. 36, pp. 1287-1294, 2013.

[13] A. Fonseca and T. Vazão, "Applicability of position-based routing for VANET in highways and urban environment," Journal of Network and Computer Applications, vol. 36, pp. 961-973, 2013.

[14] D. B. Rawat and C. Bajracharya, Vehicular cyber physical systems: Adaptive connectivity and security: Springer, 2016.

[15] M. Asefi, J. W. Mark, and X. S. Shen, "A mobility-aware and quality-driven retransmission limit adaptation scheme for video streaming over VANETs," IEEE Transactions on Wireless Communications, vol. 11, pp. 1817-1827, 2012.

[16] P. Papadimitratos, A. Kung, J.-P. Hubaux, and F. Kargl, "Privacy and identity management for vehicular communication systems: a position paper," in Workshop on standards for privacy in user-centric identity management, 2006.

[17] S. Biswas, R. Tatchikou, and F. Dion, "Vehicle-to-vehicle wireless communication protocols for enhancing highway traffic safety," IEEE communications magazine, vol. 44, pp. 74-82, 2006.

[18] S.-B. Lee, G. Pan, J.-S. Park, M. Gerla, and S. Lu, "Secure incentives for commercial ad dissemination in vehicular networks," in Proceedings of the 8th ACM international symposium on Mobile ad hoc networking and computing, 2007, pp. 150-159.

[19] M. Guo, M. H. Ammar, and E. W. Zegura, "V3: A vehicle-to-vehicle live video streaming architecture," Pervasive and Mobile Computing, vol. 1, pp. 404-424, 2005.

[20] H. Xie, A. Boukerche, and A. A. Loureiro, "A multipath video streaming solution for vehicular networks with link disjoint and node-disjoint," IEEE Transactions on Parallel and Distributed Systems, vol. 26, pp. 3223-3235, 2015.

[21] C. Müller, S. Lederer, and C. Timmerer, "An evaluation of dynamic adaptive streaming over HTTP in vehicular environments," in Proceedings of the 4th Workshop on Mobile Video, 2012, pp. 37-42.

[22] T.-Y. Huang, R. Johari, N. McKeown, M. Trunnell, and M. Watson, "A buffer-based approach to rate adaptation: Evidence from a large video streaming service," ACM SIGCOMM Computer Communication Review, vol. 44, pp. 187-198, 2015.

[23] Y. Shan and S. Kalyanaraman, "Hybrid video downloading/streaming over peer-to-peer networks," in Multimedia and Expo, 2003. ICME'03. Proceedings. 2003 International Conference on, 2003, pp. II-665.

[24] I. E. Richardson, H. 264 and MPEG-4 video compression: video coding for next-generation multimedia: John Wiley & Sons, 2004.

[25] I. E. Richardson, The H. 264 advanced video compression standard: John Wiley & Sons, 2011.

[26] G. J. Sullivan and T. Wiegand, "Video compression-from concepts to the H. 264/AVC standard," Proceedings of the IEEE, vol. 93, pp. 18-31, 2005.

[27] C.-H. Ke, C.-Y. Yang, J.-L. Chen, K. Z. Ghafoor, and J. Lloret, "Frame-based mapping mechanism for energy-efficient MPEG-4 video transmission over IEEE 802.11 e networks with better quality of delivery," Journal of Network and Computer Applications, vol. 58, pp. 280-286, 2015.

[28] A. Canovas, M. Garcia, J. Lloret, M. Atenas, and R. Rizo, "Improving IPTV QoE taking the suitable MPEG-2/MPEG-4 Quantizer based on Jitter, Delay and lost packets measurements," International Journal on Advances in Telecommunications, vol. 3, pp. 129-139, 2010.

[29] W.-j. Han, "Video encoding and decoding methods and systems for video streaming service," ed: Google Patents, 2005.

[30] T. Chiang and Y.-Q. Zhang, "A new rate control scheme using quadratic rate distortion model," IEEE Transactions on circuits and systems for video technology, vol. 7, pp. 246-250, 1997.

[31] M. Ghareeb, A. Ksentini, and C. Viho, "Scalable video coding (SVC) for multipath video streaming over video distribution networks (VDN)," in Information Networking (ICOIN), 2011 International Conference on, 2011, pp. 206-211.

[32] Q. C. Li, H. Niu, A. T. Papathanassiou, and G. Wu, "5G network capacity: Key elements and technologies," IEEE Vehicular Technology Magazine, vol. 9, pp. 71-78, 2014.

[33] M. Soliman, T. Abiodun, T. Hamouda, J. Zhou, and C.-H. Lung, "Smart home: Integrating internet of things with web services and cloud computing," in Cloud Computing Technology and Science (CloudCom), 2013 IEEE 5th International Conference on, 2013, pp. 317-320.

[34] O. Kaiwartya, A. H. Abdullah, Y. Cao, A. Altameem, M. Prasad, C.-T. Lin, et al., "Internet of vehicles: Motivation, layered architecture, network model, challenges, and future aspects," IEEE Access, vol. 4, pp. 5356-5373, 2016.

[35] M. Gerla, E.-K. Lee, G. Pau, and U. Lee, "Internet of vehicles: From intelligent grid to autonomous cars and vehicular clouds," in Internet of Things (WF-IoT), 2014 IEEE World Forum on, 2014, pp. 241-246.

[36] Y. Fangchun, W. Shangguang, L. Jinglin, L. Zhihan, and S. Qibo, "An overview of internet of vehicles," China Communications, vol. 11, pp. 1-15, 2014.

[37] R. Buyya, C. S. Yeo, S. Venugopal, J. Broberg, and I. Brandic, "Cloud computing and emerging IT platforms: Vision, hype, and reality for delivering computing as the 5th utility," Future Generation computer systems, vol. 25, pp. 599-616, 2009.

[38] S. Tilak, N. B. Abu-Ghazaleh, and W. Heinzelman, "A taxonomy of wireless micro-sensor network models," ACM SIGMOBILE Mobile Computing and Communications Review, vol. 6, pp. 28-36, 2002.

[39] M. Tory and T. Moller, "Rethinking visualization: A high-level taxonomy," in Information Visualization, 2004. INFOVIS 2004. IEEE Symposium on, 2004, pp. 151-158.

[40] J. Gubbi, R. Buyya, S. Marusic, and M. Palaniswami, "Internet of Things (IoT): A vision, architectural elements, and future directions," Future generation computer systems, vol. 29, pp. 1645-1660, 2013.

[41] D. Puccinelli and M. Haenggi, "Wireless sensor networks: applications and challenges of ubiquitous sensing," IEEE Circuits and systems magazine, vol. 5, pp. 19-31, 2005.

[42] O. Younis and S. Fahmy, "HEED: a hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks," IEEE Transactions on mobile computing, vol. 3, pp. 366-379, 2004.

[43] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "Wireless sensor networks: a survey," Computer networks, vol. 38, pp. 393-422, 2002.

[44] A. Ghosh and S. K. Das, "Coverage and connectivity issues in wireless sensor networks: A survey," Pervasive and Mobile Computing, vol. 4, pp. 303-334, 2008.

[45] Y. Sang, H. Shen, Y. Inoguchi, Y. Tan, and N. Xiong, "Secure data aggregation in wireless sensor networks: A survey," in Parallel and Distributed Computing, Applications and Technologies, 2006. PDCAT'06. Seventh International Conference on, 2006, pp. 315-320.

[46] S. Ziegler, C. Crettaz, L. Ladid, S. Krco, B. Pokric, A. F. Skarmeta, et al., "Iot6–moving to an ipv6-based future iot," in The Future Internet Assembly, 2013, pp. 161-172.

[47] S. D. T. Kelly, N. K. Suryadevara, and S. C. Mukhopadhyay, "Towards the implementation of IoT for environmental condition monitoring in homes," IEEE Sensors Journal, vol. 13, pp. 3846-3853, 2013.

[48] T. Savolainen, J. Soininen, and B. Silverajan, "Ipv6 addressing strategies for iot," IEEE Sensors Journal, vol. 13, pp. 3511-3519, 2013.

[49] M. Zorzi, A. Gluhak, S. Lange, and A. Bassi, "From today's intranet of things to a future internet of things: a wireless-and mobility-related view," IEEE Wireless Communications, vol. 17, 2010.

[50] N. Honle, U.-P. Kappeler, D. Nicklas, T. Schwarz, and M. Grossmann, "Benefits of integrating meta data into a context model," in Pervasive Computing and Communications Workshops, 2005. PerCom 2005 Workshops. Third IEEE International Conference on, 2005, pp. 25-29.

[51] M. Usman, A. Ismail, H. Chizari, A. Gital, and A. Aliyu, "A Conceptual Framework for Realizing Energy Efficient Resource Allocation in Cloud Data Centre," Indian Journal of Science and Technology, vol. 9, 2016.

[52] E. Welbourne, L. Battle, G. Cole, K. Gould, K. Rector, S. Raymer, et al., "Building the internet of things using RFID: the RFID ecosystem experience," IEEE Internet computing, vol. 13, 2009.

[53] A. Juels, "RFID security and privacy: A research survey," IEEE journal on selected areas in communications, vol. 24, pp. 381-394, 2006.

[54] A. Gupta and R. K. Jha, "A survey of 5G network: Architecture and emerging technologies," IEEE access, vol. 3, pp. 1206-1232, 2015.

[55] A. Sehgal, V. Perelman, S. Kuryla, and J. Schonwalder, "Management of resource constrained devices in the internet of things," IEEE Communications Magazine, vol. 50, 2012.

[56] B. Bellalta, E. Belyaev, M. Jonsson, and A. Vinel, "Performance evaluation of IEEE 802.11 p-enabled vehicular video surveillance system," IEEE Communications Letters, vol. 18, pp. 708-711, 2014.

[57] T. Perumal, M. N. Sulaiman, N. Mustapha, A. Shahi, and R. Thinaharan, "Proactive architecture for Internet of Things (IoTs) management in smart homes," in Consumer Electronics (GCCE), 2014 IEEE 3rd Global Conference on, 2014, pp. 16-17.

[58] W. He, G. Yan, and L. Da Xu, "Developing vehicular data cloud services in the IoT environment," IEEE Transactions on Industrial Informatics, vol. 10, pp. 1587-1595, 2014.
[59] Y. J. Li, "An overview of the DSRC/WAVE technology," in International Conference on Heterogeneous Networking for Quality, Reliability, Security and Robustness, 2010, pp. 544-558.
[60] A. Zanella, N. Bui, A. Castellani, L. Vangelista, and M. Zorzi, "Internet of things for smart cities," IEEE Internet of Things journal, vol. 1, pp. 22-32, 2014.
[61] A. D. Wilson, "PlayAnywhere: a compact interactive tabletop projection-vision system," in Proceedings of the 18th annual ACM symposium on User interface software and technology, 2005, pp. 83-92.
[62] G. DeRuwe and R. Wall, "Pedestrian navigation and integration with distributed smart signal traffic controls," in Industrial Electronics, 2008. IECON 2008. 34th Annual Conference of IEEE, 2008, pp. 2923-2928.
[63] A. Milenković, C. Otto, and E. Jovanov, "Wireless sensor networks for personal health monitoring: Issues and an implementation," Computer communications, vol. 29, pp. 2521-2533, 2006.
[64] S. C. Mukhopadhyay, "Wearable sensors for human activity monitoring: A review," IEEE sensors journal, vol. 15, pp. 1321-1330, 2015.
[65] K. Hirsch, V. Kafka, C. Tymstra, R. McAlpine, B. Hawkes, H. Stegehuis, et al., "Fire-smart forest management: a pragmatic approach to sustainable forest management in fire-dominated ecosystems," The Forestry Chronicle, vol. 77, pp. 357-363, 2001.
[66] H. Soliman, K. Sudan, and A. Mishra, "A smart forest-fire early detection sensory system: Another approach of utilizing wireless sensor and neural networks," in Sensors, 2010 IEEE, 2010, pp. 1900-1904.
[67] B. Liu, B. Khorashadi, D. Ghosal, C.-N. Chuah, and H. M. Zhang, "Analysis of the information storage capability of VANET for highway and city traffic," Transportation Research Part C: Emerging Technologies, vol. 23, pp. 68-84, 2012.
[68] M. Bernaś, "VANETs as a part of weather warning systems," CCIS Computer Network, vol. 291, pp. 459-466, 2012.
[69] A. Singh, M. Kumar, R. Rishi, and D. Madan, "A relative study of MANET and VANET: Its applications, broadcasting approaches and challenging issues," Advances in Networks and Communications, pp. 627-632, 2011.
[70] Y. Liu, Y. Guo, and C. Liang, "A survey on peer-to-peer video streaming systems," Peer-to-peer Networking and Applications, vol. 1, pp. 18-28, 2008.
[71] O. Abboud, K. Pussep, A. Kovacevic, K. Mohr, S. Kaune, and R. Steinmetz, "Enabling resilient P2P video streaming: survey and analysis," Multimedia Systems, vol. 17, pp. 177-197, 2011.
[72] B. Vandalore, W.-c. Feng, R. Jain, and S. Fahmy, "A survey of application layer techniques for adaptive streaming of multimedia," Real-Time Imaging, vol. 7, pp. 221-235, 2001.
[73] S. Misra, M. Reisslein, and G. Xue, "A survey of multimedia streaming in wireless sensor networks," IEEE communications surveys & tutorials, vol. 10, 2008.
[74] I. F. Akyildiz, T. Melodia, and K. R. Chowdhury, "A survey on wireless multimedia sensor networks," Computer networks, vol. 51, pp. 921-960, 2007.
[75] S. Ehsan and B. Hamdaoui, "A survey on energy-efficient routing techniques with QoS assurances for wireless multimedia sensor networks," IEEE communications surveys & tutorials, vol. 14, pp. 265-278, 2012.
[76] I. F. Akyildiz, T. Melodia, and K. R. Chowdhury, "Wireless multimedia sensor networks: Applications and testbeds," Proceedings of the IEEE, vol. 96, pp. 1588-1605, 2008.
[77] B. Fu, Y. Xiao, H. Deng, and H. Zeng, "A survey of cross-layer designs in wireless networks," IEEE communications surveys & tutorials, vol. 16, pp. 110-126, 2014.
[78] H. Luo and M.-L. Shyu, "Quality of service provision in mobile multimedia-a survey," Human-centric computing and information sciences, vol. 1, p. 5, 2011.
[79] M. Lindeberg, S. Kristiansen, T. Plagemann, and V. Goebel, "Challenges and techniques for video streaming over mobile ad hoc networks," Multimedia Systems, vol. 17, pp. 51-82, 2011.
[80] M. A. Hoque, M. Siekkinen, and J. K. Nurminen, "Energy efficient multimedia streaming to mobile devices—a survey," IEEE communications surveys & tutorials, vol. 16, pp. 579-597, 2014.
[81] S. Mantzouratos, G. Gardikis, H. Koumaras, and A. Kourtis, "Survey of cross-layer proposals for video streaming over mobile ad hoc networks (MANETs)," in Telecommunications and Multimedia (TEMU), 2012 International Conference on, 2012, pp. 101-106.
[82] T. Taleb, E. Sakhaee, A. Jamalipour, K. Hashimoto, N. Kato, and Y. Nemoto, "A stable routing protocol to support ITS services in VANET networks," IEEE Transactions on Vehicular technology, vol. 56, pp. 3337-3347, 2007.
[83] Y. Wang and Q.-F. Zhu, "Error control and concealment for video communication: A review," Proceedings of the IEEE, vol. 86, pp. 974-997, 1998.

[84] U. Horn, K. Stuhlmüller, M. Link, and B. Girod, "Robust internet video transmission based on scalable coding and unequal error protection," Signal Processing: Image Communication, vol. 15, pp. 77-94, 1999.
[85] J. Harri, F. Filali, and C. Bonnet, "Mobility models for vehicular ad hoc networks: a survey and taxonomy," IEEE Communications Surveys & Tutorials, vol. 11, 2009.
[86] S. Yousefi, M. S. Mousavi, and M. Fathy, "Vehicular ad hoc networks (VANETs): challenges and perspectives," in ITS Telecommunications Proceedings, 2006 6th International Conference on, 2006, pp. 761-766.
[87] D. B. Rawat, D. C. Popescu, G. Yan, and S. Olariu, "Enhancing VANET performance by joint adaptation of transmission power and contention window size," IEEE Transactions on Parallel and Distributed Systems, vol. 22, pp. 1528-1535, 2011.
[88] J. Sahoo, E. H.-K. Wu, P. K. Sahu, and M. Gerla, "Binary-partition-assisted MAC-layer broadcast for emergency message dissemination in VANETs," IEEE Transactions on Intelligent Transportation Systems, vol. 12, pp. 757-770, 2011.
[89] P. Gomes, C. Olaverri-Monreal, and M. Ferreira, "Making vehicles transparent through V2V video streaming," IEEE Transactions on Intelligent Transportation Systems, vol. 13, pp. 930-938, 2012.
[90] A. Vinel, E. Belyaev, K. Egiazarian, and Y. Koucheryavy, "An overtaking assistance system based on joint beaconing and real-time video transmission," IEEE Transactions on Vehicular Technology, vol. 61, pp. 2319-2329, 2012.
[91] M. Amadeo, C. Campolo, and A. Molinaro, "Enhancing IEEE 802.11 p/WAVE to provide infotainment applications in VANETs," Ad Hoc Networks, vol. 10, pp. 253-269, 2012.
[92] E. Belyaev, P. Molchanov, A. Vinel, and Y. Koucheryavy, "The use of automotive radars in video-based overtaking assistance applications," IEEE Transactions on Intelligent Transportation Systems, vol. 14, pp. 1035-1042, 2013.
[93] A. S. Sadiq, K. A. Bakar, K. Z. Ghafoor, J. Lloret, and R. Khokhar, "An intelligent vertical handover scheme for audio and video streaming in heterogeneous vehicular networks," Mobile Networks and Applications, vol. 18, pp. 879-895, 2013.
[94] A. Bradai, T. Ahmed, and A. Benslimane, "ViCoV: Efficient video streaming for cognitive radio VANET," Vehicular Communications, vol. 1, pp. 105-122, 2014.
[95] H. Xie, A. Boukerche, and A. A. Loureiro, "MERVS: A Novel Multichannel Error Recovery Video Streaming Protocol for Vehicle Ad Hoc Networks," IEEE Transactions on Vehicular Technology, vol. 65, pp. 923-935, 2016.
[96] N. Kumar, S. Zeadally, and J. J. Rodrigues, "QoS-aware hierarchical web caching scheme for online video streaming applications in internet-based vehicular ad hoc networks," IEEE Transactions on Industrial Electronics, vol. 62, pp. 7892-7900, 2015.
[97] J.-S. Park, U. Lee, S. Y. Oh, M. Gerla, and D. S. Lun, "Emergency related video streaming in VANET using network coding," in Proceedings of the 3rd international workshop on Vehicular ad hoc networks, 2006, pp. 102-103.
[98] M. Atenas, M. Garcia, A. Canovas, and J. Lloret, "A MPEG-2/MPEG-4 quantizer to improve the video quality in IPTV services," in Networking and Services (ICNS), 2010 Sixth International Conference on, 2010, pp. 49-54.
[99] A. M. Mezher, J. J. Oltra, L. U. Aguiar, C. I. Paredes, C. T. Barba, and M. A. Igartua, "Realistic environment for VANET simulations to detect the presence of obstacles in vehicular ad hoc networks," in Proceedings of the 11th ACM symposium on Performance evaluation of wireless ad hoc, sensor, & ubiquitous networks, 2014, pp. 77-84.
[100] F. Soldo, C. Casetti, C.-F. Chiasserini, and P. A. Chaparro, "Video streaming distribution in VANETs," IEEE Transactions on Parallel and Distributed Systems, vol. 22, pp. 1085-1091, 2011.
[101] N. N. Qadri, M. Fleury, M. Altaf, and M. Ghanbari, "Multi-source video streaming in a wireless vehicular ad hoc network," IET communications, vol. 4, pp. 1300-1311, 2010.
[102] C. Xu, F. Zhao, J. Guan, H. Zhang, and G.-M. Muntean, "QoE-driven user-centric VoD services in urban multihomed P2P-based vehicular networks," IEEE Transactions on Vehicular Technology, vol. 62, pp. 2273-2289, 2013.
[103] F. Naeimipoor and A. Boukerche, "A hybrid video dissemination protocol for VANETs," in Communications (ICC), 2014 IEEE International Conference on, 2014, pp. 112-117.
[104] A. Torres, P. Piñol, C. T. Calafate, J.-C. Cano, and P. Manzoni, "Evaluating H. 265 real-time video flooding quality in highway V2V environments," in Wireless Communications and Networking Conference (WCNC), 2014 IEEE, 2014, pp. 2716-2721.
[105] T. A. Q. Pham, K. Piamrat, and C. Viho, "Qoe-aware routing for video streaming over vanets," in Vehicular Technology Conference (VTC Fall), 2014 IEEE 80th, 2014, pp. 1-5.
[106] C.-H. Lee, C.-M. Huang, C.-C. Yang, and H.-Y. Lin, "The K-hop cooperative video streaming protocol using H. 264/SVC over the hybrid vehicular networks," IEEE Transactions on Mobile Computing, vol. 13, pp. 1338-1351, 2014.

[107] A. Torres, C. T. Calafate, J.-C. Cano, P. Manzoni, and Y. Ji, "Evaluation of flooding schemes for real-time video transmission in VANETs," Ad Hoc Networks, vol. 24, pp. 3-20, 2015.
[108] F. Sun, B. Liu, F. Hou, H. Zhou, J. Chen, Y. Rui, et al., "A qoe centric distributed caching approach for vehicular video streaming in cellular networks," Wireless Communications and Mobile Computing, 2015.
[109] C. Xu, S. Jia, M. Wang, L. Zhong, H. Zhang, and G.-M. Muntean, "Performance-aware mobile community-based VoD streaming over vehicular ad hoc networks," IEEE Transactions on Vehicular Technology, vol. 64, pp. 1201-1217, 2015.
[110] A. Mammeri, A. Boukerche, and Z. Fang, "Video streaming over vehicular ad hoc networks using erasure coding," IEEE Systems Journal, vol. 10, pp. 785-796, 2016.
[111] C. Quadros, A. Santos, M. Gerla, and E. Cerqueira, "QoE-driven dissemination of real-time videos over vehicular networks," Computer communications, vol. 91, pp. 133-147, 2016.
[112] R. Immich, E. Cerqueira, and M. Curado, "Towards a QoE-driven mechanism for improved H. 265 video delivery," in Ad Hoc Networking Workshop (Med-Hoc-Net), 2016 Mediterranean, 2016, pp. 1-8.
[113] C. Quadros, E. Cerqueira, A. Santos, and M. Gerla, "A multi-flow-driven mechanism to support live video streaming on VANETs," in Computer Networks and Distributed Systems (SBRC), 2014 Brazilian Symposium on, 2014, pp. 468-476.
[114] R. Wang, C. Rezende, H. S. Ramos, R. W. Pazzi, A. Boukerche, and A. A. Loureiro, "LIAITHON: A location-aware multipath video streaming scheme for urban vehicular networks," in Computers and Communications (ISCC), 2012 IEEE Symposium on, 2012, pp. 000436-000441.
[115] M. Asefi, J. W. Mark, and X. Shen, "A cross-layer path selection scheme for video streaming over vehicular ad-hoc networks," in Vehicular Technology Conference Fall (VTC 2010-Fall), 2010 IEEE 72nd, 2010, pp. 1-5.
[116] I. Tal and G.-M. Muntean, "User-oriented cluster-based solution for multimedia content delivery over VANETs," in Broadband Multimedia Systems and Broadcasting (BMSB), 2012 IEEE International Symposium on, 2012, pp. 1-5.
[117] C.-H. Lee, C.-M. Huang, C.-C. Yang, and H.-Y. Lin, "K-hop packet forwarding schemes for cooperative video streaming over vehicular networks," in Computer Communications and Networks (ICCCN), 2012 21st International Conference on, 2012, pp. 1-5.
[118] C. Rezende, H. S. Ramos, R. W. Pazzi, A. Boukerche, A. C. Frery, and A. A. Loureiro, "Virtus: A resilient location-aware video unicast scheme for vehicular networks," in Communications (ICC), 2012 IEEE International Conference on, 2012, pp. 698-702.
[119] H. Wu and H. Ma, "Opportunistic routing for live video streaming in vehicular ad hoc networks," in A World of Wireless, Mobile and Multimedia Networks (WoWMoM), 2014 IEEE 15th International Symposium on, 2014, pp. 1-3.
[120] R. Wang, M. Almulla, C. Rezende, and A. Boukerche, "Video streaming over vehicular networks by a multiple path solution with error correction," in Communications (ICC), 2014 IEEE International Conference on, 2014, pp. 580-585.
[121] C. Rezende, A. Mammeri, A. Boukerche, and A. A. Loureiro, "A receiver-based video dissemination solution for vehicular networks with content transmissions decoupled from relay node selection," Ad Hoc Networks, vol. 17, pp. 1-17, 2014.
[122] M. De Felice, E. Cerqueira, A. Melo, M. Gerla, F. Cuomo, and A. Baiocchi, "A distributed beaconless routing protocol for real-time video dissemination in multimedia VANETs," Computer communications, vol. 58, pp. 40-52, 2015.
[123] N. Kumar, J.-H. Lee, and J. J. Rodrigues, "Intelligent mobile video surveillance system as a bayesian coalition game in vehicular sensor networks: learning automata approach," IEEE Transactions on Intelligent Transportation Systems, vol. 16, pp. 1148-1161, 2015.
[124] A. Al-Ani and J. Seitz, "QoS-aware routing for video streaming in multi-rate Ad hoc Networks," in Wireless and Mobile Networking Conference (WMNC), 2016 9th IFIP, 2016, pp. 193-198.
[125] Y.-L. Hsieh and K. Wang, "Dynamic overlay multicast for live multimedia streaming in urban VANETs," Computer networks, vol. 56, pp. 3609-3628, 2012.
[126] N. Kumar and J. Kim, "Probabilistic trust aware data replica placement strategy for online video streaming applications in vehicular delay tolerant networks," Mathematical and Computer Modelling, vol. 58, pp. 3-14, 2013.
[127] C. Rezende, A. Boukerche, H. S. Ramos, and A. A. Loureiro, "A reactive and scalable unicast solution for video streaming over VANETs," IEEE Transactions on Computers, vol. 64, pp. 614-626, 2015.
[128] J. Joshi, K. Jain, Y. Agarwal, M. J. Deka, and P. Tuteja, "COMIP: Cluster based overlay and fast handoff mobile IP system for video streaming in VANET's," in Smart Instrumentation, Measurement and Applications (ICSIMA), 2015 IEEE 3rd International Conference on, 2015, pp. 1-6.

[129] C.-M. Huang, C.-C. Yang, and Y.-C. Lin, "An adaptive video streaming system over a cooperative fleet of vehicles using the mobile bandwidth aggregation approach," IEEE Systems Journal, vol. 10, pp. 568-579, 2016.
[130] R. Dosselmann and X. D. Yang, A formal assessment of the structural similarity index: University of Regina. Department of Computer Science, 2008.
[131] N. Kumar, J. J. Rodrigues, J. Lloret, and A. Dua, "Replication-aware data dissemination for vehicular ad hoc networks using location determination," Mobile Networks and Applications, vol. 20, pp. 251-267, 2015.
[132] N. Kumar, J. P. Singh, R. S. Bali, S. Misra, and S. Ullah, "An intelligent clustering scheme for distributed intrusion detection in vehicular cloud computing," Cluster Computing, vol. 18, pp. 1263-1283, 2015.
[133] H. Xie, A. Boukerche, and A. A. Loureiro, "TCP-ETX: A cross layer path metric for TCP optimization in wireless networks," in Communications (ICC), 2013 IEEE International Conference on, 2013, pp. 3597-3601.
[134] S. McCanne, S. Floyd, K. Fall, and K. Varadhan, "Network simulator ns-2," ed, 1997.
[135] T. R. Henderson, M. Lacage, G. F. Riley, C. Dowell, and J. Kopena, "Network simulations with the ns-3 simulator," SIGCOMM demonstration, vol. 14, 2008.
[136] A. Varga and R. Hornig, "An overview of the OMNeT++ simulation environment," in Proceedings of the 1st international conference on Simulation tools and techniques for communications, networks and systems & workshops, 2008, p. 60.
[137] Q. N. Simulator, "Scalable network technologies," Inc.[Online]. Available: www. qualnet. com, 2011.
[138] X. Zeng, R. Bagrodia, and M. Gerla, "GloMoSim: a library for parallel simulation of large-scale wireless networks," in Parallel and Distributed Simulation, 1998. PADS 98. Proceedings. Twelfth Workshop on, 1998, pp. 154-161.
[139] S.-Y. Wang, C. Chou, C. Huang, C. Hwang, Z. Yang, C. Chiou, et al., "The design and implementation of the NCTUns 1.0 network simulator," Computer networks, vol. 42, pp. 175-197, 2003.
[140] U. s. G. Matlab, "The mathworks," Inc., Natick, MA, vol. 1992, 1760.
[141] J. Härri, F. Filali, C. Bonnet, and M. Fiore, "VanetMobiSim: generating realistic mobility patterns for VANETs," in Proceedings of the 3rd international workshop on Vehicular ad hoc networks, 2006, pp. 96-97.
[142] M. Piorkowski, M. Raya, A. L. Lugo, P. Papadimitratos, M. Grossglauser, and J.-P. Hubaux, "TraNS: realistic joint traffic and network simulator for VANETs," ACM SIGMOBILE mobile computing and communications review, vol. 12, pp. 31-33, 2008.
[143] M. Behrisch, L. Bieker, J. Erdmann, and D. Krajzewicz, "SUMO–simulation of urban mobility: an overview," in Proceedings of SIMUL 2011, The Third International Conference on Advances in System Simulation, 2011.
[144] A. Mahajan, N. Potnis, K. Gopalan, and A. Wang, "Urban mobility models for vanets," in 2nd IEEE International Workshop on Next Generation Wireless Networks, 2006.
[145] F. Bai, N. Sadagopan, and A. Helmy, "IMPORTANT: A framework to systematically analyze the Impact of Mobility on Performance of RouTing protocols for Adhoc NeTworks," in INFOCOM 2003. Twenty-second annual joint conference of the IEEE computer and communications. IEEE societies, 2003, pp. 825-835.
[146] M. Báguena, S. M. Tornell, Á. Torres, C. T. Calafate, J.-C. Cano, and P. Manzoni, "Vacamobil: Vanet car mobility manager for omnet++," in Communications Workshops (ICC), 2013 IEEE International Conference on, 2013, pp. 1057-1061.
[147] J. Klaue, B. Rathke, and A. Wolisz, "Evalvid–A framework for video transmission and quality evaluation," in International Conference on Modelling Techniques and Tools for Computer Performance Evaluation, 2003, pp. 255-272.
[148] M. Xing, S. Xiang, and L. Cai, "Rate adaptation strategy for video streaming over multiple wireless access networks," in Global Communications Conference (GLOBECOM), 2012 IEEE, 2012, pp. 5745-5750.
[149] N. Chowdhary and P. D. Kaur, "Addressing the characteristics of mobility models in IoV for smart city," in Computing, Communication and Automation (ICCCA), 2016 International Conference on, 2016, pp. 1298-1303.
[150] F. Bonomi, R. Milito, J. Zhu, and S. Addepalli, "Fog computing and its role in the internet of things," in Proceedings of the first edition of the MCC workshop on Mobile cloud computing, 2012, pp. 13-16.
[151] L. Da Xu, W. He, and S. Li, "Internet of things in industries: A survey," IEEE Transactions on industrial informatics, vol. 10, pp. 2233-2243, 2014.
[152] P. Spiess, S. Karnouskos, D. Guinard, D. Savio, O. Baecker, L. M. S. De Souza, et al., "SOA-based integration of the internet of things in enterprise services," in Web Services, 2009. ICWS 2009. IEEE International Conference on, 2009, pp. 968-975.
[153] A. Ahmed, A. A. Hanan, K. Omprakash, M. Usman, and O. Syed, "Mobile Cloud Computing Energy-aware Task Offloading (MCC: ETO)," in Communication and Computing Systems: Proceedings of the International Conference on Communication and Computing Systems (ICCCS 2016), Gurgaon, India, 9-11 September, 2016, 2017, p. 359.
[154] C. M. Medaglia and A. Serbanati, "An overview of privacy and security issues in the internet of things," in The Internet of Things, ed: Springer, 2010, pp. 389-395.

[155] R. H. Weber, "Internet of Things–New security and privacy challenges," Computer law & security review, vol. 26, pp. 23-30, 2010.
[156] L. Zhou and H.-C. Chao, "Multimedia traffic security architecture for the internet of things," IEEE Network, vol. 25, 2011.
[157] H. C. Pöhls, V. Angelakis, S. Suppan, K. Fischer, G. Oikonomou, E. Z. Tragos, et al., "RERUM: Building a reliable IoT upon privacy-and security-enabled smart objects," in Wireless Communications and Networking Conference Workshops (WCNCW), 2014 IEEE, 2014, pp. 122-127.