

Cross-Layer Solutions for Enhancing Multimedia Communication QoS over Vehicular Ad hoc Networks

Ali Hassoune Mustafa, Mekkakia Zoulikha and Bendella Fatima

Department of Computer Engineering,
University of Sciences and Technology of Oran
Oran, Algeria

{mustafa.aliassoune; zoulikha.mekkakia; fatima.bendella}@univ-usto.dz

Abstract—Vehicular Ad hoc NETWORKS (VANET) are a new emergent technology based on wireless ad hoc networks. They are characterized by their high speed nodes, which affect on network topology. This can affect network services, especially those having big packet size and need high bandwidth, such as Multimedia services. Many solutions have been proposed in the literature in order to serve a better multimedia communication over VANET. In this paper, we will focus on cross-layer solutions because of their high performance in term of Quality of Service (QoS). We present a survey of existing cross-layer solutions, which try to enhance multimedia services over VANETs. Works will be classified depending on the nature of information exchanged and their belonging to OSI Layers.

Keywords- Cross-Layer; QoS; Multimedia; VANET.

I. INTRODUCTION

Vehicular Ad hoc NETWORKS (VANET) are the main interesting instantiation of mobile Ad hoc networks, which could have an important role in future services. They are characterized by their high mobility due to high speed nodes, which affect on network topology. They are composed of vehicles equipped with On-Board Units (OBUs), and Gateways installed in the streets, which are called Road Side Units (RSUs). VANETs can be deployed in different kind of roads, such as “Highways” where nodes move with high speed (80-120 km/h) and have generally low density. Also, VANETs can be deployed in “Urban roads” where nodes move with less speed (20-60 km/h), which affects network density. The urban roads are also characterized by the existence of buildings, which act as obstacles for VANET communications.

VANETs use a special MAC protocol called 802.11p, which is an enhancement of 802.11, using two types of channels: Control Channel (CCH) and Service Channels (SCH). The CCH is used for the periodical dissemination of control information and for the dissemination of traffic safety messages. The SCH is used to disseminate non-critical information for infotainment applications, such as the Video Streaming. In addition, VANET applications can be classified into Safety and Non-Safety applications (like downloading files or accessing the internet). Safety applications can help to prevent accidents and road congestions, while the non Safety applications may be used for user’s convenience like video streaming or Video on Demand (VoD) applications, such as TV Broadcasting.

Sending these kinds of data in such networks is very challenging because of large data size, link breaks, and sensibility to losses. These features are rare in such

networks where nodes move with high speed and where topology changes rapidly. Therefore, robust multimedia applications encounter many challenges that oblige applications to be able to tolerate link failures and packet losses in order to have a high quality video at the receiver side. Hence, many solutions have been proposed in the literature in order to enhance Multimedia QoS to serve better video services in VANET. We shall focus in this paper on cross-layer solutions where information is exchanged between different layers in order to have a better multimedia service. These techniques will be classified depending on data exchanging nature.

This paper is organized into three sections. In Section I, we survey existing cross-layer solutions and techniques, which enhance multimedia QoS. Section II is reserved for discussing the solutions and presenting open issues. In Section III, we conclude our work and present future works.

II. CROSS-LAYER SOLUTIONS FOR ENHANCING MULTIMEDIA QOS OVER VANET

Cross-layer approach is an ‘escape’ from the Open Systems Interconnection (OSI) model, which applies virtually strict boundaries between the layers, data are kept within a given layer. Protocol architectures follow strict layering principles, which ensure interoperability, fast deployment, and efficient implementations. However, lack of coordination between layers limits the performance of such architectures due to the specific challenges posed by wireless nature of the transmission links. Cross-layer solutions remove such strict boundaries to allow communication between layers. Its core idea is to maintain the functionalities associated to the original layers but to allow coordination, interaction and joint optimization of protocols crossing different layers.

In this paper, it is notable that all studied mechanisms are cross-layer solutions, which serve a high quality video on the receiver’s end. We can distinguish between the aforementioned techniques based on exchange nature, as shown in Table 1.

TABLE 1. STUDIED CROSS-LAYER TECHNIQUES

Works	APP	NET	MAC	PHY
[1;2;3;4;6;7;8]	√			√
[9;10;11;12]	√		√	
[13;14;15;16;17;18;19;20;21]	√	√		
[22;23;24;25;26;27;28]			√	√
[29;30;31]		√	√	
[32;33;34]		√	√	√

We classified these works into six categories shown above. The next paragraphs, we present the different works found in the literature.

A. Physical-Application exchange solutions

Physical-Application (PHY-APP) exchange solutions adapt physical layer parameters like vertical handoff periods in function of application layer information. They are presented in this section.

The vertical handoff was proposed by Yan et al. [1]. They presented an algorithm based on the prediction of the traveling distance of a vehicle within a wireless cell. These try to minimize the probability of unnecessary handovers. This probability was constructed by using a speed ratio, which is the ratio between instantaneous speed of a vehicle and maximum speed, function of the technologies radius cell coverage, and of the average handover latency.

Another algorithm, based on physical layer parameters as handover latency and the received signal strength, presented by Kwak, et al. [2], had an objective of reducing the loss of throughput. Their valid ideas are limited to horizontal handovers in Wireless Local Area Networks (WLAN) though with homogeneous topologies.

Chen et al. [3] presented an approach in which a novel network mobility protocol for VANETs was presented. It was a solution that limits vertical handover drawbacks and reduces both packet loss rate and handoff latency.

Another critical issue in any system is the handoff decision policy. Zhu et al. [4] proposed a work for train-ground communication, which can be applied in VANETs. They suggested that video distortion is the most direct QoS performance metric from the perspective of end users, which can be estimated by packet loss rate and encoding parameters. It is formulated as a Semi-Markov Decision Process (SMDP), which is a generalization of a Markov Decision Process (MDP) [5]. The optimal handoff decision and application layer parameters adaption policies can be obtained from the value iteration algorithm of SMDP.

In addition, a new strategy was presented which analyses users' interactive viewing behavior by estimating video segment playback order. That employed pre-fetching of the expected segments, by smoothening the video playback. A cellular network had relatively high stable connectivity merits, but it was more expensive. So, by using VANET, vehicles can forward data to other nodes or RSUs at low costs. However, VANETs easily become disconnected in situations with low vehicle density and high mobility, which needs to switch to another technology. Four novel mechanisms were introduced: distributed grouping-based video segments storage scheme, video segment seeking scheme, multipath data delivery mechanism, and Speculation-based pre-fetching strategy.

Alternatively, Changqiao et al. [6] proposed a Quality of Experience (QoE)-driven solution for VoD services in urban vehicular network environments. Vehicles create a

low VANET layer with Wireless Access In Vehicular Environments (WAVE) interfaces and create an upper layer Peer-To-Peer (P2P) Chord overlay on top of a cellular network via 4G interfaces. A novel storage strategy was proposed that distributes the video segments along the Chord overlay, reducing segment seeking traffic and achieving a high success rate and very good video data delivery efficiency.

Sadiq et al. [7] proposed an Intelligent Network Selection (INS) scheme, which ranks available wireless network candidates using three input parameters: Faded Signal-to-Noise Ratio, Residual Channel Capacity, and Connection Life Time. In this proposed scheme, when a vehicle is in busy-mode, its wireless channel can execute various real time and non-real time applications. In order to identify and select the most qualified network candidate as the next wireless access point, each vehicle executes the INS algorithm in the network access area. This avoids any unnecessary handover decisions during real-time sessions. Results showed that INS is more efficient at decreasing handover delays, end-to-end delays for VoIP and video applications, and packet loss ratios.

An adaptive QoS handoff priority scheme was proposed by Zhuang et al. [8] for wireless networks, which reduces the probability of call handoff failures in a mobile multimedia network with cellular architecture. This approach used the ability of most multimedia traffic types to adapt some QoS at the packet level to achieve a smaller probability of dropping at handoff, which has an impact on the multimedia received QoS. So, calls with adaptive traffic can opt to use lower amounts of bandwidth and handoff successfully. Also, it proposed the Adaptive Quality of Service (AQoS) scheme proved more flexibly and efficiently in guaranteeing QoS and proposing a modification, called the Modified Adaptive QoS (MAQoS), which can admit new calls even when the system is in the congestion state, e.g., emergency calls. In addition to the flexibility inherited from the AQoS scheme, MAQoS is even more flexible in decoupling the different components (dropping, and blocking probabilities) of the grade of service metric. The adaptive QoS handoff priority scheme and its modification are studied analytically and compared to those of the non priority handoff and the guard-channel handoff schemes, and have shown better results.

B. MAC-Application Exchange solutions

MAC-Application (MAC-APP) exchange solutions adjust MAC parameters like retransmissions or frame rate in terms of Multimedia QoS like latency or loss rate received from the application layer.

First, an adaptive MAC retransmission limits adaptation scheme proposed by Asefi et al. [9], in which the adaptation was based on an optimization of video streaming quality. It adjusts MAC retransmission limit using channel information and periodically feeds to RSU. It is used to calculate the probability of media access between the RSU and the vehicle. In the Enhanced Distributed Channel Access (EDCA) of 802.11p, Video packets are associated with lower priority compared to

safety messages. To solve this problem, this scheme applies a multi-objective optimization framework at the RSU, which tunes the MAC retransmission limit with respect to channel statistics (packet error rate and packet transmission rate) in order to minimize the probability of playback freezes and start-up delay of the streaming.

To address the problem of adaptive QoS, Mercado and Liu [10] proposed a solution, which choosing the Signal-to-Interference and Noise Ratio (SINR) of each user's channel as the QoS index depending on the nature of multimedia. They tried to solve two problems. The first by increasing the SINR levels for multimedia users. Different users have distinct desired SINR levels according to their requested service types; their algorithm uses an iterative method to drive the SINR levels as close as possible to those desired levels. The SINR levels are improved without deteriorating quality for other types of users. It showed a significant increase in the average SINR levels for multimedia users. The second problem is how to initiate new users into the network by using lower complexity algorithms. The proposed algorithm also included a fast activation scheme that reduces the computational complexity involved in some parts of call initiation, by using a coarser and faster method for finding feasible SINR.

Another solution, presented by Venkataraman et al. [11], is a hybrid IEEE 802.11p-based multihop network communication solution (QOAS). This delivered quality-oriented real-time multimedia data to high-speed vehicles by using both infrastructure and ad hoc modes. A client-server feedback was used in order to support high multimedia quality. QOAS estimates how a user perceives quality and sends feedback to the server, which adjusts video transmission rate. They are based on the fact that random losses have a greater impact on the perceived quality than a controlled reduction. It was specially used to send video stream with high quality to moving vehicles at high speed, and where there was a quick handover between different relay nodes and the sender.

The last MAC-Application solution studied was the work proposed by Bonuccelli et al. [12], which focused on situations of traffic congestion. The transmitter reduces the transmission rate by 50%, when two consecutive frames are not received. The application layer reduces the rate when congestion is detected in MAC level. The transmitter decides whether a packet will reach the receiver in time. If not, the transmitter either drops it or sends it, which may be useful for decoding the next packet.

C. Network-Application exchange solutions

In this section, we present Network-Application (NET-APP) exchange solutions, which adjust parameters of routing or clustering in function of feedback received from the application layer.

A novel user-oriented cluster-based solution for multimedia delivery over VANETs proposed by Irina et al. [13], which is able to personalize multimedia content and its delivery based on the preferences of the passengers and their profiles. It includes two algorithms. The first one

focuses on cluster head selection, which makes sure that cluster head function is efficiently distributed among vehicles. The second one is the cluster formation algorithm, which aims to group vehicles based on vehicle characteristics and user interest in content.

Both algorithms take into account the velocity of the mobiles, direction of travel and position of the vehicles. The proposed solution used a client-server architecture based on a hybrid vehicular communication network model. The vehicles are organized in clusters based on the user interest in multimedia content, location, direction of travel and velocity.

Another new application-centric solution is proposed as a routing protocol for streaming video in multihop for VANET. It is based on exchanging information between the application layer and the network layer aiming to select the path. This minimizes the application layer's frame distortion rate, which is the average distortion of the video frames at the destination vehicle. It was proposed by Asefi et al. [14]. A subset of candidates is selected by the node carrying data and is transmitted with video frames of high quality applying application centric optimization.

Another solution, proposed by Asefi et al. [15], focused on routing, which had shown the enhancement of video quality. This was achieved by minimizing distortion, the startup delay and streaming freezes. A virtual link is created between the destination vehicle and the access router and not RSU. They proposed a new protocol, Quality-Driven Routing Protocol. The proposed data delivery model had two modes of operation. The first one is the "straight way" where the vehicle carrying the packet to be forwarded selects N neighboring vehicles that are in its transmission range and are geographically closer to the destination vehicle. It then selects the next hop that minimizes the frame distortion. The second mode is "Intersection" where the vehicle selects the next straight path to forward the packet.

Sajimon and Sojan [16] applied a spatio-temporal similarity measure using Points of Interest (POI) and Time of Interest (TOI). The similarity formed will be used by the remote database to broadcast trigger-based messages to participating vehicles in a neighborhood for a future route. A large quantity of collected trajectories were published and shared across users on many websites. Additionally, it demonstrated a binary encoding scheme in managing road network data, and proposed a structural and sequence similarity measure between travel locations in finding a spatial similarity.

An application layer forwarding algorithm incorporating VANET routing, called Intelligent Adjustment Forwarding (IAF), proposed by Jung-Shian et al. [17], in which a segment-to-segment transmission paradigm was used to enhance the video data delivery. IAF started by performing an intelligent routing discovery process to establish a transmission path to the destination, where the source obtains the position information of all the nodes along the transmission path and then determines which of these nodes should be nominated as Intermittently Connected Points (ICPs). Then, data is

transmitted to the destination by the ICPs using a store-and-forward paradigm. If the source node is unable to locate the destination, the data is transmitted to the segment endpoint, which performs a store-carry-and-forward function in order to deliver the data to the destination.

Also, Asefi et al. [18] proposed a cross-layer protocol whose routing decision was based on application layer objective function. It discussed the encoded transmissions, decoding reception and error prone channels. The appropriate route is chosen to achieve an optimized Peak Signal-to Noise Ratio (PSNR) in different densities networks. In that proposed Cross-Layer Path Selection Scheme, the video streaming was sent from RSU to a vehicle using multi-hop communication. An encoding rate was allocated to each video session at the RSU side. This scheme selects the path with lowest end-to-end distortion for each video packet and for the entire video stream where the total distortion is the summation of all the packet distortions of a video stream.

IBCAV, abbreviation of Intelligent Based Clustering Algorithm in VANETs, was proposed by Mottahedi et al. [19]. Their proposal sought to improve routing algorithms in VANETs by employing inter-layered methods, where cluster size, speed and density of nodes are the factors, which have been taken into account. Results show that the IBCAV performs better than other routing protocols in terms of packet delivery ratio, end-to-end delays and throughput.

A cooperative overtaking assistance systems based on VANETs is another network-application solution proposed by Vinel et al. [20]. A video stream, captured by a camera installed at the vehicle, is compressed and broadcast to any vehicles driving behind it. They demonstrate that the performance of their scheme can be significantly improved if codec channel adaptation is undertaken by exploiting information from the beacons about any forthcoming increase in the load of the multiple access channel used. Their proposal results give the guarantee of low latency and acceptable visual quality by making use of the additional information obtained from the beaconing.

Finally, DVAC was proposed by Yung-Cheng and Nen-Fu [21]. Distributed Vehicles Adaptive Clustering is an application layer solution for delivering live video streams by forming clusters. This algorithm was designed to form and maintain clusters. They create clusters with vehicles moving in the same direction. The vehicles decide whether they are cluster head, tail or member. It also suggested Vehicles-Adaptive PEer-to-Peer relay (VAPER) method, which was responsible for avoiding duplicates in streaming in the cluster. Both the head and tail act as redirectors in communications between vehicles in the same cluster, and they act as peers in communication between clusters. It showed that even if the signal is lost, there is a continuous play of live video streaming for a considerable time.

D. Physical-MAC exchange solutions

The cross-layer solutions in this section are mainly

based on the information flow between MAC layer and PHY layer (PHY-MAC). For example, transmission rate adaptation is the ability to adjust the modulation rate at which packets are transmitted according to the observed channel qualities, such as SNR and packet loss rate.

Camp and Knightly [22] investigated cross-layer designs for modulation rate adaptation in vehicular networks targeted at urban and downtown environments. Their work involved high-level interaction between the MAC and physical layers. They studied two protocols for rate adaptation, which are Loss-triggered and SNR-triggered. The transmitters determine the packet loss rate by monitoring the frame receptions of the packet transmission in MAC layer. If an Acknowledgement (ACK) is received before the timeout event then the transmission is considered to be successful. This type of information is shared between MAC and PHY layers. The transmitter increases the transmission rate after consecutive successful transmissions and decreases the rate after observing consecutive failures.

SoftRate is a bit rate adaptation protocol proposed by Vutukuru et al. [23]. The receivers used physical layer calculated information that was exported to higher layers via an interface called the SoftPHY interface. SoftPHY estimates the channel Bit-Error Rate (BER) upon receiving packet frame.

Also, Chen [24] developed a novel IEEE 802.21 Media Independent Handover (MIH) mechanism for next generation vehicular multimedia network, and they proposed also an adaptive QoS management mechanism. The proposed MIH framework can determine the best available network by obtaining received signal strength parameters. Results showed that using this mechanism can increase overall throughput, which is satisfactory compensation for increased handover time.

Another cross-layer solution, proposed by Rawat et al. [25], is a joint adaptation between MAC and physical layer that mainly focuses on adaptation of transmission power and QoS message prioritization based on node density and contention window size. Network calculates the node density by gathering the neighbors' information within. By adopting a traffic flow model as proposed by Artimy et al. [26], using length of road segment, estimated vehicle density, and traffic flow constant parameters, it calculates the new transmission range. The transmission power is a function of transmission range. To support QoS applications, authors proposed two distinct functionalities to adjust the priority of the packets – transmission power level in physical layer and MAC channel access parameters, such as minimum contention window (CW_{min}), maximum contention window (CW_{max}), and arbitration interframe space (AIFs).

Similarly, Caizzone et al. [27] proposed a mechanism that adjusts the transmission power adaptively based on number of neighbors. Each vehicle starts with initial transmission power and incrementally increases the transmission power as long as the number of neighbors is within a minimum threshold, or it reaches maximum transmission power. The transmission power is decreased if the number of neighbors is greater than maximum

threshold.

Finally, Rawat, et al. [28] presented a new scheme for dynamic adaptation of transmission power and Contention Window (CW) size to enhance performance of information dissemination in VANETs. That was achieved by incorporating the EDCA mechanism of 802.11e and using a joint approach to adapt transmission power at the physical layer and QoS parameters at the MAC layer. The transmission power adapted was based on the estimated local vehicle density to change the transmission range dynamically, while the CW size was adapted according to the instantaneous collision rate to enable service differentiation. In the interest of promoting timely propagation of information, VANET advisories were prioritized according to their urgency and the EDCA mechanism is employed for their dissemination. Results show that this scheme brings better throughput and lower average end-to-end delay compared with other similar schemes.

E. Network-MAC exchange solutions

The cross-layer solutions in this section are mainly based on the information flow between MAC layer and Network layer (NET-MAC).

First, Zhang et al. [29] proposed the "in network aggregation" mechanism by employing a cross-layer design. Because the communication traffic statistical data of MAC layer affects the traffic density and the data arrival, they determine the aggregation period on the basis of traffic statistics of MAC layer. Its objective in-network aggregation was to reduce the amount of data to be transmitted as much as possible. They intended to apply SMDP to optimize the aggregation period and gave an approximate solution by exploiting a real-time Q-learning algorithm.

Another NET-MAC approach was the route selection through link prediction. Menouar et al. [30] proposed Movement Prediction-based Routing (MOPR), which was an approach proposing a movement prediction based routing protocol for Vehicle to Vehicle (V2V) communication in VANETs. It takes vehicle movement information available in MAC layer, such as position, direction, speed, and network topology into consideration, in order to improve the routing process. MOPR predicts the future location of intermediate relay nodes, which help in selecting the most stable routes containing stable nodes that are traveling in the same direction or with the similar speed or on the same road as of the destination/source nodes.

Similar to MOPR, Chen et al. [31] proposed a multipath routing protocol to reduce the frequency of route rediscovery. They proposed a cross-layer Ad hoc On-demand Multipath Distance Vector (R-AOMDV) protocol. This method made use of a routing metric that combines hop count and transmission counts at MAC layer by taking into consideration the quality of intermediate links and delay reduction. It relied on two control packets: Route REQuest (RREQ) and Route REPLY (RREP). The intermediate first hop nodes in RREQ and RREP packets were used to distinguish between

multiple paths from source to destination. To measure the quality of the entire path, we add two additional fields to RREP packets: the Maximum Retransmission Count (MRC) that is measured in MAC layer and the total hop count that is measured in network layer.

F. Physical-MAC-Network exchange Solutions

Solutions in this section are based on the information flow between PHY, MAC and NET layer (PHY-MAC-NET).

A novel CAC algorithm was proposed by Bejaoui [32]. It provides the desired throughput guarantees on the basis of the vehicle density and the nodes' transmission range in 802.11p VANETs. They considered vehicle-to-roadside communications as essential to manage traffic situations. In order to enhance the performance of vehicular communications, this scheme adapts the transmission power physical layer and optimizes the contention window size (in MAC layer) depending on information coming from NET Layer as the vehicle density estimation. Results have shown that this solution improves the performance of the vehicular communication.

Also, Sofra et al. [33] proposed an approach using a Link Residual Time (LRT), which was calculated by using the received power from the physical layer. This value can be used by other layers to make better decisions for handover, scheduling time, and routing decisions. Each vehicle monitors parameters like the arrival time and the received power level for each packet that was received on the link. The estimation of LRT starts by removing the noise from the data, and checks if the link quality is deteriorating, then, it estimates the model parameters required for calculating LRT. Finally, renewing LRT is estimated.

Finally, Singh et al. [34] presented the use of link connectivity information among neighbors to help in addressing the challenges in designing routing protocols for VANET environments. They proposed a cross-layer protocol called Signal Strength Assessment Based Route Selection for OLSR (SBRS-OLSR). In this framework, the link connectivity was based on SNR measurement, and the routing protocol was based on existing Optimized Link State Routing (OLSR). By capturing SNR information from the physical layer, the network layer can provide a better route that improves throughput and delay performance.

III. DISCUSSION AND OPEN ISSUES

In section II, we surveyed the existing cross-layer techniques and solutions for enhancing multimedia QoS. Cross-layer solutions are efficient in serving a better video service by adjusting layers' parameters in regard of other layers' information. Cross-layer approaches try to overcome the lack of coordination between layers that limits the performance of wireless networks. These solutions allow coordination, interaction and joint optimization of protocols crossing different layers.

For example, PHY-APP exchange solutions, which adjust physical layer parameters in terms of application

layer information, can increase Multimedia QoS using efficient handoff solutions. Additionally, MAC-APP solutions significantly help in offering a reliable video communication in VANET by adjusting contention windows and frame rate depending on QoS information received from the application layer. Furthermore, NET-APP solutions help in finding the best route in terms of QoS to disseminate packets, or choosing the optimal cluster head, which will act as a broadcaster of Multimedia data. This in turn results in order to have a better multimedia service.

According to the literature, PHY-APP and MAC-APP are the most effective solutions, which adapt Physical and MAC parameters in terms of interaction with Application layer. Since Physical and MAC layers are the closest to nodes, their impact can be higher than other solutions.

However, there are several issues that need further attention. Below; we will try to evaluate these studies and describe open research problems, which will need to be studied, in addition.

A. Evaluation metrics and tools

The evaluation of existing techniques is one of the most relevant open issues, as it is not easy to measure Multimedia communication QoS and it is more subjective rather than objective. The aforementioned works did not necessarily use the same common metrics. Some of studied works simulations use packet loss rate, and/or end to end delay, and/or throughput which are not necessarily significant for Multimedia QoS. Some papers use other metrics like PSNR, Mean Opinion Score (MOS), Video distortion, or other video metrics [35]. In addition, they do not necessarily use the same simulation tools. There are several network simulators, such as NS2, NS3, OMNET++, OPNET, etc.[36]. This makes it more difficult to compare between the results of different solutions. So thus, finding a common tool and metrics function can significantly help in evaluating and comparing different solutions.

B. Global solution

As evident from existing research described in the last section, many protocol designs focus on a specific problem in multimedia communication QoS. Some of them try to solve end to end delay problem; others try to reduce packet loss rate. Other works by trying to stop or minimize freezes and video play drawbacks. However, most of these protocols ignore to design a complete solution for Multimedia over VANET, which can take into consideration most of the problems encountered in Multimedia communication QoS in VANET. This kind of solution, to the best of our knowledge, has not been alluded to or studied in the literature. Such solutions can be presented as a global solution working on different ISO layers at the same time (data are exchanged between multiple layers). Therefore, it is still an open research issue to develop a global solution, which takes into account many other factors at time. Our paper may help in developing such complete solutions.

C. Mobility models

Another important issue is “the mobility models” which represent the movement of mobile vehicles in changing their positions, speeds and accelerations all the time. Therefore:

- It is very important to use realistic mobility models that reflect reality. This can be very important in analyzing the performance of the different proposed solutions.
- Also, as everyone knows, there are many mobility scenarios types: highway scenarios, intersection scenarios, rural scenarios, etc. Most of works focus their proposed solution on a specific mobility scenario type (even if it is realistic). So it is very important to design a solution which can be compatible with all existing mobility scenarios types.

D. Existence of other applications in the network

Most of the mentioned solutions focus on a specific problematic, which is “Multimedia QoS”. They try to provide a better video service. However, this may negatively affect on other applications behavior, because the channel is shared by many devices, so it is difficult to fulfill QoS guarantees. Also, most of these studies realize their simulations without taking into account existence of other applications in the network which may distort their results, such as file transfer, video applications or any other launched application. Therefore, it is still an open research issue to study and develop solutions for. This might take into account existing of other applications in the network.

E. QoS support in a multicast streaming

It is an area which requires attention and studies in cross-layer solutions in VANET.

F. Cross-Layer design and instability

Additionally, any Cross-Layer design should take attention as undesirable effect on the system performance can occur due to Cross-Layer exchanges. Frantic and extensive Cross-Layer exchanges may lead to a complex mixture design and may lack standardization and compatibility and portability features. So, it is important to have a deep analysis and design of the Cross-Layer solution because it may lead to a state of instability [37], which is very important, especially in VANET, because of large number of nodes (vehicles and RSUs), and multiple sources and destinations.

IV. CONCLUSION AND FUTURE WORKS

In this paper, we focused on the problem of video communication between vehicles in VANET. Many solutions have been proposed in the literature in order to enhance multimedia QoS and provide better video services between vehicles or between RSUs and vehicles.

Cross-layer adaptations are essential for guaranteeing QoS in Multimedia Communications over VANET. We surveyed existing cross-layer techniques and solutions that enhance multimedia QoS. A classification is provided depending on data exchange type (belonging to ISO layers). We present many types of techniques and systems: PHY-APP, MAC-APP, NET-APP, PHY-MAC,

NET-MAC and NET-MAC-PHY, where each layer changes its parameters in function of other layer information. As a future work, a comparison between different classes is needed, in order to deduct the most effective class and technique of mentioned Cross-Layer solutions.

REFERENCES

- [1] Z. Yan, H. Zhou, H. Zhang, and S. Zhang, "Speed-Based Probability-Driven Seamless Handover Scheme between WLAN and UMTS", 4th International Conference on Mobile Ad-hoc and Sensor Networks, Los Alamitos, CA, USA, 2008, pp. 110–115.
- [2] D. Kwak, J. Mo, and M. Kang, "Investigation of handoffs for IEEE 802.11 networks in vehicular environment", ICUFN 2009, Hong Kong, June 7-9, 2009, pp. 89–94.
- [3] Y. S. Chen, C. H. Cheng, C. S. Hsu, and G. M. Chiu, "Network Mobility Protocol for Vehicular Ad Hoc Network", IEEE WCNC 2009, Budapest, Hungary, April 5-8, 2009, pp. 1–6.
- [4] L. Zhu, F.R. Yu, B. Ning, and T. Tang, "Cross-Layer Design for Video Transmissions in Metro Passenger Information Systems", IEEE Transactions on Vehicular Technology, vol. 60, iss. 3, March 2011, pp. 1171 - 1181.
- [5] R. S. Sutton, D. Precup, and S. Singh, "Between MDPs and Semi-MDPs: A Framework for Temporal Abstraction in Reinforcement Learning", Journal of Artificial Intelligence, vol. 112, 1999, pp. 181–211.
- [6] X. Changqiao et al., "QoE-driven User-centric VoD Services in Urban Multi-homed P2P-based Vehicular Networks", IEEE Transactions on Vehicular Technology, vol. 62, iss. 5, June 2013, pp. 2273 – 2289.
- [7] A. S. Sadiq et al., "An Intelligent Vertical Handover Scheme for Audio and Video Streaming in Heterogeneous Vehicular Networks", Mobile Networks and Applications, vol. 18, iss. 6, December 2013, pp. 879-895.
- [8] W. Zhuang, B. Bensaou, and K. C. Chua, "Adaptive Quality of Service Handoff Priority Scheme for Mobile Multimedia Networks", IEEE Transactions On Vehicular Technology, vol. 49, no. 2, March 2000, pp. 494 – 505.
- [9] M. Asefi, W. Jon, and Xuemin Shen, "A Mobility-Aware and Quality-Driven Retransmission Limit Adaptation Scheme for Video Streaming over VANETs", IEEE Transactions on Wireless Communications, vol. 11, iss. 5, May 2012, pp. 1817 – 1827.
- [10] A. Mercado and K. Liu, "Adaptive QoS for Wireless Multimedia Networks Using Power Control and Smart Antennas", IEEE Transactions On Vehicular Technology, vol. 51, no. 5, September 2002, pp. 1223 - 1233.
- [11] H. Venkataraman, et al., "Performance Analysis of Real-Time Multimedia Transmission in 802.11p based Multihop Hybrid Vehicular Networks", 6th International Wireless Communications and Mobile Computing Conference, 2010, pp. 1151-1155.
- [12] M.A. Bonuccelli, G. Giunta, F. Lonetti, and F. Martelli, "Real-time video transmission in vehicular networks", Mobile Networking for Vehicular Environments, May 2007, pp. 115-120.
- [13] Irina et al., "User-oriented Cluster-based Solution for Multimedia Content Delivery over VANETs", IEEE Computer Society, 2012, pp. 1-5.
- [14] M. Asefi, W. Jon, and Xuemin Shen., "An Application-Centric Inter-Vehicle Routing Protocol for Video Streaming over Multi-Hop Urban VANETs", IEEE International Conference on Communications, June 2011, pp. 1-5.
- [15] M. Asefi, S. Cespedes, Xuemin Shen, and W. Jon, "A Seamless Quality-Driven Multi-Hop Data Delivery Scheme for Video Streaming in Urban VANET Scenarios", IEEE International Conference on Communications (ICC), June 2011, pp. 1-5.
- [16] S. Abraham and P. Sojan Lal, "Spatio-temporal similarity of network-constrained moving object trajectories using sequence alignment of travel locations", Data Management in Vehicular Networks, vol. 23, August 2012, pp. 109–123.
- [17] L. Jung-Shian, L. I-Hsien Liu, K. Chuan-Kai, and T. Chao-Ming, "Intelligent Adjustment Forwarding: A compromise between end-to-end and hop-by-hop transmissions in VANET environments", Journal of Systems Architecture, vol. 59, iss. 10, November 2013, pp. 1319-1333.
- [18] M. Asefi, W. Jon, and X. Shen, "A Cross-Layer Path Selection Scheme for Video Streaming over Vehicular Ad-Hoc Networks", VTC 2010-Fall, September 2010, pp. 1-5.
- [19] Mottahedi, et al., "IBCAV: Intelligent Based Clustering Algorithm in VANET", IJCSI International Journal of Computer Science Issues, vol. 10, iss. 1, no 2, January 2013, pp. 538.
- [20] 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, iss. 5, June 2012, pp. 2319 – 2329.
- [21] C. Yung-Cheng and H. Nen-Fu, "Delivering of Live Video Streaming for Vehicular Communication Using Peer-to-Peer Approach", Mobile Networking for Vehicular Environments, May 2007, pp. 1-6.
- [22] J. Camp and E. Knightly, "Modulation rate adaptation in urban and vehicular environments: cross-layer implementation and experimental evaluation", 14th ACM International Conference on Mobile Computing and Networking, 2008, pp. 315–326.
- [23] M. Vutukuru, H. Balakrishnan, and K. Jamieson, "Cross-layer wireless bit rate adaptation", ACM SIGCOMM Computer Communication Review, vol. 39, no 4, 2009, pp. 3–14.
- [24] C. Jiann-Liang, "An Adaptive QoS mechanism for multimedia applications over next generation vehicular network", 5th International ICST, CHINACOM, August 2010, pp. 1-6.
- [25] D.B. Rawat, G. Yan, D. Popescu, M. Weigle, and S. Olariu, "Dynamic Adaptation of Joint Transmission Power and Contention Window in VANET", 2009, pp. 1–5.
- [26] M. Artimy, W. Robertson, and W. Phillips, "Assignment of dynamic transmission range based on estimation of vehicle density", 2nd ACM International Workshop on Vehicular Ad Hoc Networks, 2005, pp. 48.
- [27] G. Caizzone, P. Giacomazzi, L. Musumeci, and G. Verticale, "A power control algorithm with high channel availability for vehicular ad hoc networks", IEEE International Journal on Communications, 2005, pp. 3171–3176.
- [28] D.B. Rawat, et al., "Enhancing VANET Performance by Joint Adaptation of Transmission Power and Contention Window Size", IEEE Transactions on Parallel and Distributed Systems, vol. 22, no. 9, September 2011, pp. 1528-1535.
- [29] L. Zhang et al., "QoS-Oriented Data Dissemination in VANETs", IEEE 26th International Parallel and Distributed Processing Symposium Workshops & PhD Forum, 2012, pp. 2518 – 2521.
- [30] M. Menouar, M. Lenardi, and F. Filali, "A movement prediction based routing protocol for vehicle-to-vehicle communications", 66th Vehicular Technology Conference, 2007, pp. 2101 - 2105.
- [31] Y. Chen, Z. Xiang, W. Jian, and W. Jiang, "A Cross-layer AOMDV Routing Protocol for V2V Communication in Urban VANET", 2009, pp. 353– 359.
- [32] T. Bejaoui, "QoS-Oriented High Dynamic Resource Allocation in Vehicular Communication Networks", The Scientific World Journal, 2014, pp. 1-9.
- [33] N. Sofra, A. Gkelias, and K. Leung, "Link residual-time estimation for VANET cross-layer design", 2009, pp. 1–5.
- [34] J. Singh, N. Bambos, B. Srinivasan, and D. Clawin, "Cross-layer multi-hop wireless routing for inter-vehicle communication", TRIDENTCOM, 2006, pp. 92–101.
- [35] A. Chan, K. Zeng, P. Mohapatra, S. Lee and S. Banerjee, "Metrics for Evaluating Video Streaming Quality in Lossy IEEE 802.11 Wireless Networks", INFOCOM, March 2010, pp. 1-9.
- [36] S. Siraj, A. K. Gupta, and R. Badgular, "Network Simulation Tools Survey", IJARCC, vol. 1, iss. 4, June 2012, pp. 201-210.
- [37] B. Jarupan, E. Ekici, "A survey of cross-layer design for VANETs", Ad Hoc Networks journal, vol. 9, iss. 5, July 2011, pp. 1-18.