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Enhanced User Datagram Protocol for Video Streaming in VANET

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***Abstract*—Research and development on video streaming over vehicular ad hoc networks (VANETs) have expanded rapidly in the last few years. In order to improve road safety and to satisfy road users requirements, video streaming has been proposed to disseminate continuously, an accurate video data, concerning traffic circumstance, travel information, divertissement, etc. High quality video streaming in vehicular environment is very challenging due to the very high dynamic of VANET topology and its intermittent connection, stringent requirements of video transmission such as reduced propagation delay and decreased signal to noise ratio. In this paper, we propose a new protocol called Enhanced User Datagram Protocol (EUDP) for video streaming in VANET. Unlike User Datagram Protocol (UDP) which did not consider any recovery mechanism of erroneous packets, EUDP uses Sub-Packet Forward Error Correction (SPFEC), and adopts the unequal protection of video frame types (i.e. I, P, B) to improve the video streaming quality. After a set of simulations and comparisons with UDP and EUDP without unequal protection of video frame types (EUDP-E), our proposal showed a significant improvement in terms of error recovery rate, PSNR and MOS of transmitted video.**

***Keywords*—Vehicular Ad hoc NETwork; Video Streaming; User Datagram Protocol; Sub-Packet Forward Error Correction**

I. INTRODUCTION

Vehicular Ad hoc NETwork (VANET) is a recent research area that suggests a self-organized network allowing a wireless communication between vehicles and transmission infrastructures installed along sides of the road called Roads Side Units (RSUs) [1]. Two kinds of communication could be established by a VANET namely Vehicle to Vehicle communication (V2V) and Vehicle to Infrastructure communication (V2I). Each vehicle is equipped with an on-board unit (OBU) device allowing V2V or V2I communications [2]. VANET is characterized by a high dynamic of its topology due to high speed of vehicles.

One of the most challenges tackled recently by VANET research community is the video streaming. Video streaming in VANET allows dissemination of rich information to drivers and passengers comparing to a textual message. Using cameras installed on vehicle or on a RSU, a real time video may be forwarded to vehicles and RSUs and then to the authorities (e.g. hospital, public safety and emergency preparedness, police, etc.) in order to inform about any event that occurred in the road. For instance, an accident case, an animal crossing the road, a festival event, a conference, or other events can be broadcasted by a VANET video streaming. The video streaming can increase the traffic security, for example in the case of accident, the vehicle near to this accident can alert other drivers to choose another route. Another example related to the mobile health where an ambulance can send a video to doctors located at a distant hospital, to indicate clearly the situation of the sick [3].

The video streaming can also used to improve the comfort of passengers like the interactive communication, download music, internet connection etc. In this domain, an efficient protocol of communication is needed to ensure the good reception of video streaming at the level of the end user in terms of Quality of Service (QoS) metrics like packet delivery ratio, transmission delay, Peak Signal to Noise Ratio (PSNR), and in terms of Quality of Experience (QoE) metrics like Mean Opinion Score (MOS), Structural Similarity Index Measure (SSIM).

Two main problems could deteriorate the video streaming quality in VANET, which are the packet loss and the transmission delay. Many causes can lead to these problems such as high vehicles density, high speed of vehicles, environment obstacles, etc.

In VANET literature, several recent works were proposed to deal with these issues; we classified these works into three categories: video encoding and error resiliency category, cooperative relays based category, and adaptive category. The first one applied different mechanisms of video encoding and video streaming error resiliency in order to improve video streaming quality, mainly at the application layer level. The second one defines a scheme at network layer level, which is responsible for vehicles relays selection between video source and its destination, trying to find the most reliable path (or paths), which would improve the quality of video streaming. The adaptive category adapts some video transmission parameters to improve the video quality like the size of contention window at the MAC layer level, adapt the number of video layers at the application layer level etc.

User Datagram Protocol (UDP) is a protocol of communication proposed at the transport layer, which did not contain an error recovery mechanism contrary to other protocols like Transmission Control Protocol (TCP). TCP uses a retransmission technique to overcome erroneous packets, which introduces additional delays.

In the literature of image processing, many video techniques and standards were proposed to encode the video like Motion

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Picture Expert Group (MPEG), Scalable Video Coding (SVC) and Multiple Description Coding (MDC). MPEG compression standard [4] encodes the video as a Groups of Pictures (*GoPs*). Each *GoP* is a sequence of frames. There are three kinds of frames in MPEG: Intra-coded frame (*I*-frame), Predictive frame (*P*-frame), and Bi-directionally predictive-coded frame (*B*-frame). *I*-frame and *P*-frames in a *GoP* are the most important frames, representing the reference of other frames *B* of the same *GoP*.

Packet Forward Error Correction (PFEC) is an error recovery mechanism based on redundancy technique. PFEC splits the video stream into some blocks, each block is composed of original packets and redundant packets. Sub-Packet Forward Error Correction (SPFEC) is a specific type of PFEC, in which the block is consisted of original and redundant sub-packets.

We propose in this paper a new protocol called the Enhanced User Datagram Protocol (EUDP), which integrates UDP with SPFEC error recovery mechanism and the unequal protection of video frame types (*I*, *P*, *B*) coded based on MPEG standard. The purpose of EUDP is to improve the video streaming quality at the level of the receiver vehicle in terms of QoS and QoE metrics.

The rest of the paper is organized as follows. Section II reviews the state of the art of error resiliency techniques for video streaming in VANET. Section III describes our proposed EUDP. The performance evaluation by simulation of EUDP is presented in section IV. Finally, section V concludes the paper.

II. RELATED WORK

This section presents similar works on error resiliency techniques to overcome the video errors in wireless and VANET networks. We classify the video error resiliency techniques in VANET into two main classes: redundancy-based techniques and retransmission-based techniques.

A. Redundancy-based techniques

In this category, the sender adds a duplicated data with the original one to be transmitted to the receiver. When this latter receives all packets, it can recover the original lost data by its copies. There are some error resiliency techniques based on the redundancy like Packet Forward Error Correction (PFEC) and interleaving.

The basic idea of PFEC proposed in [5] is the encoding of video as a set of blocks of size fixed at *n*. Each block consists of *k* source packets and *n-k* redundant packets. The good reception of *k* packets of any block allows the decoding of *k* source packets of this block. PFEC suffers from network overload due to redundant packets. Also this technique can recover only the uniform errors (errors occurring in a sequence of packets independently with uniform distribution) and cannot recover the burst errors (consecutive lost packets).

Interleaving technique presented in [6] transforms burst errors into a set of uniform errors to enhance video perception quality. To achieve this, at the sender level interleaving separates original frames by a distance, this distance represents a number of redundant frames. After arriving at the receiver, the frames are then reconstructed in its original order.

Many variations of PFEC for video streaming in wireless networks are proposed to deal with PFEC limits, such as Forward-Looking FEC (FL-FEC) [7], Enhanced Random Early Detection FEC (ERED-FEC) [8], Adaptive and Interleaving FEC (AIFEC) [9], FEC with Path Interleaving (FEC-PI) [10]. These mechanisms suffer from the high network overload due to the use of PFEC. The authors of [11] proposed Sub-Packet FEC (SPFEC) in the aim of improving the video streaming quality over wireless network. SPFEC divides the video packet into *k* original sub-packets and *n-k* redundant sub-packets at the sender, when the receiver received the packet, he can retrieve original sub-packets which represent original packet without waiting other packets. The result of this work proved that SPFEC reduces network overload and increases the recovery rate compared to PFEC, for this reason, we propose to enrich UDP protocol with the integration of SPFEC. SPFEC should be improved by adding traffic load control in the calculation process of redundant sub-packets to avoid congestion problem.

Like the wireless network works, there are some studies of VANET video streaming that use PFEC mechanism. The authors of [12] proposed an adaptive QoE-driven COntent-awaRe VidEo Transmission optimisation mEchanism (CORVETTE) based on Hierarchical Fuzzy System (HFS) to adjust dynamically the redundancy rate of video packets in function of network state and video characteristics at the relay vehicles. The simulation showed that CORVETTE improves the video quality in terms of QoE in different cases of network density. Note that CORVETTE can be tested with more realistic VANET mobility models and CORVETTE did not deal with the problem of burst errors. The authors of [13] proposed FEC and Interleaving Real Time Optimization (FIRO) to recover erroneous video packets. FIRO is based on three following techniques: PFEC to recover uniform errors, interleaving to recover burst errors and reporting technique to estimate the loss ratio of channel transmission. According to this estimation the sender dynamically adapts the parameters of FEC and interleaving. FIRO improves the streaming video transmission quality compared to FEC and interleaving techniques, however, FIRO must be generalized to reach the same results when the density of the network is high. The authors of [14] proposed Enhanced Adaptive Sub-Packet Forward Error Correction mechanism (EASP-FEC) for video streaming in VANET. EASP-FEC improves the SPFEC by calculating the number of redundant sub-packets at the sender and relay vehicles in function of traffic condition, traffic load and the importance of video frame types (I, P, B) to recover uniform errors, to avoid the congestion problem and to increase the video streaming quality. This work cannot deal with the problem of burst errors of video in VANET.

B. Retransmission-based techniques

The retransmission is based on the idea of solving the issue of the lost packets at the receiver level. To acheive this, the receiver sends a negative acknowledgment to the sender to retransmit the required packet.

There are some video streaming works in VANET considered as retransmission-based techniques. The authors in [15] proposed a video streaming transmission solution in VANET, based on multi-path routing to transmit the *I*-frames through a first path according to TCP protocol, and transmit the *P*-frames and *B*-frames through a second path according to UDP. The proposed solution improves the video transmission quality compared to PFEC and UDP in terms of PSNR, SSIM, receiving data rate, but this solution suffers from a high delay because of retransmission mechanism of TCP. The authors of [16] proposed a Multi-channel Error Recovery Video Streaming (MERVS) based on the same idea of the study [15], nevertheless this paper improves MERVS delay by using three techniques: Priority Queue, Quick Start and Scalable Reliable Channel (SRC). The simulation showed that the proposed solution provides a low delay and also provides a good quality of the transmitted video. The retransmission often reduces the bandwidth overhead compared to redundancy technique, however the transmission delay is increased.

Many others video streaming works in VANET were proposed like Intelligent Network Selection (INS) scheme [17], intelligent Mobile Video Surveillance System (MVSS) [18], QoS-aware hierarchical web caching (QHWC) scheme in Internet-based VANETs (IVANETs) [19]. These schemes do not use an error recovery mechanism to overcome the occurrence of error during the video transmission.

III. Enhanced User Datagram Protocol (EUDP) for Video Streaming in VANET

Many video streaming works in VANET use UDP and/or TCP control protocols at the transport layer. Unlike TCP protocol which uses retransmission mechanism to recover the erroneous packets, UDP has not any resiliency mechanism. We propose in this paper an Enhanced User Datagram Protocol (EUDP) for VANET video streaming. EUDP is an integration of UDP protocol with two techniques, namely SPFEC and unequal protection of video frame types (*I*, *P*, *B*). The first one allows the recovering of uniform errors of packets and reduces the Effective Packet Error Rate (*EPER*) as well as the redundancy overhead. Also, SPFEC reduces the end-to-end delay compared with PFEC. The second one reduces the overload of the network and increases the video quality.

A. General architecture of video transmission using the proposed EUDP

Figure 1 illustrates the basic architecture of our proposed protocol of video streaming in VANET. As shown in this figure, the sender vehicle (in red colour) generates video packets. Each video packet consists of originals sub-packets and redundant sub-packets. The sender vehicle calculates the number of redundant sub-packets based on the type of their video packet (*I*, *P*, *B*). The sub-packets of frames *I* and *P* must have higher protection level than frames *B*. The sender encapsulates the video data in Real-time Transport Protocol (RTP) packets and sends them toward the receiver (the destination) via a multi-hop transmission. When the receiver vehicle (in blue colour) receives the video packet, it retrieves the packet information (header and data), estimates the Bit Error Rate (*BER*), calculates the Sub-Packet Error Rate (*SPER*) and *EPER* based on the estimated *BER* following SPFEC mechanism. According to the calculated *EPER*, the receiver accepts or rejects the received packet.

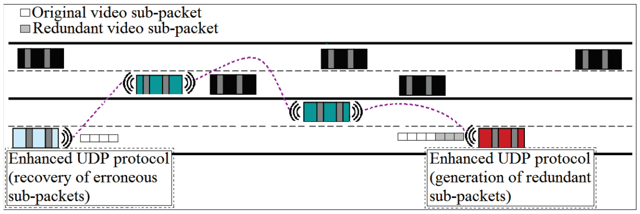

Fig. 1. Video streaming using EUDP protocol

To allow receiver to calculate *SPER* and *EPER*, we propose to add a new header field called "eudp header" in the packet header. Figure 2 presents video packet format in proposed EUDP protocol. As shown in this figure, "eudp header" of the video packet consists of the following sub-fields:

- *video_pkt_id*: a sequence number of video packet.
- *video_pkt_type*: the type of video packet frame (*I*, *P*, *B*).
- *sub_pkt_size*: the length of one sub-packet of video packet.
- *nb_source_sub_pkts*: the number of original sub-packets *k* of video packet.
- *nb_redundant_sub_pkts*: the number of redundant sub-packets *h* of video packet.

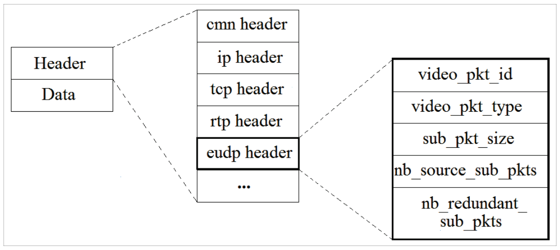

Fig. 2. Video packet format in EUDP protocol

B. General algorithm of EUDP protocol

Figure 3 presents the pseudo-code of EUDP algorithm at the sender vehicle. When this vehicle needs to send a video packet to a receiver, it firstly applies Step 1 to calculate the number of redundant sub-packets (*nb_redundant_sub_pkts*) in function of frame type (*I*, *P*, *B*) of the video packet. The unequal protection of video frame types strategy is applied in EUDP protocol by unequal redundancy rate of frames types (*RR_I*, *RR_P*, *RR_B*). Then, the sender generates the video packet and sends it to the receiver (Step 2).

Figure 4 presents the pseudo-code of EUDP at the receiver level. When the destination vehicle receives the video packet, it retrieves packet header information (*sub_pkt_size*, *nb_redundant_sub_pkts*, *nb_source_sub_pkts*) (Step 1) used to calculate *EPER*. In EUDP, *EPER* is calculated based on *SPER*, which is calculated in its turn by the estimated *BER* (Step 2). In this study, it is assumed that the total number of video packets is *N*.

1) Estimation of Bit Error Rate (BER): EUDP estimates the *BER* at each interval of time *dt*, by the following formula:

$$BER(dt) = 1 - (1 - \frac{success(dt)}{Total(dt)})^{\frac{1}{Total(dt)}} \tag{1}$$

Where, *success(dt)* represents the number of successful received packets without applying SPFEC mechanism during the interval time *dt*, *Total(dt)* represents the total number of transmitted packets to receiver vehicle during the interval time *dt*.

2) Sub-Packet Error Rate (SPER): SPER represents the probability that a sub-packet video cannot be recovered at receiver vehicle, it is given by the formula:

$$SPER = 1 - (1 - BER)^{sub\_pkt\_size} \tag{2}$$

3) Effective Packet Error Rate (EPER): EPER represents the probability that a video packet cannot be recovered at receiver vehicle, it is given by the formula:

$$EPER = 1 - (\sum_{i=k}^{k+h} C_i^{k+h} * (1 - SPER)^i * SPER^{k+h-i}) \tag{3}$$

Where *k* is the number of original sub-packets and *h* is the number of redundant sub-packets in a packet.

When the *EPER* is calculated, the receiver vehicle generates a uniform random number *r* varied in the interval [0, 1], and checks the probability of acceptation of video packet (Step 3). If the *r* value is higher than *EPER*, the receiver makes sure that the packet is recovered and then it accepts the packet, otherwise the receiver rejects the packet because it is not recovered.

```
Input: $video\_pkt\_type$, $nb\_source\_sub\_pkts$, $RR\_I$, $RR\_P$, $RR\_B$
Output: $nb\_redundant\_sub\_pkts$
  $Initialisation: nb\_redundant\_sub\_pkts \leftarrow 0$
  Step 1.
  if $video\_pkt\_type = I$ then
    $nb\_redundant\_sub\_pkts \leftarrow (\frac{RR\_I}{100}) * nb\_source\_sub\_pkts$
  else if $video\_pkt\_type = P$ then
    $nb\_redundant\_sub\_pkts \leftarrow (\frac{RR\_P}{100}) * nb\_source\_sub\_pkts$
  else
    $nb\_redundant\_sub\_pkts \leftarrow (\frac{RR\_B}{100}) * nb\_source\_sub\_pkts$
  end if
  $video\_pkt\_id \leftarrow video\_pkt\_id + 1$
  Step 2.
  Generation of video packet
  Send of generated video packet toward receiver vehicle
```

Fig. 3. EUDP algorithm at sender vehicle

```
Input: Video packet, interval time dt
Output: Accept or reject decision of received video packet
  $Initialisation: EPER \leftarrow 0, SPER \leftarrow 0$
  if video packet is received then
    Step 1.
    Extract sub_pkt_size (n)
    Extract nb_redundant_sub_pkts (k)
    Extract nb_source_sub_pkts (h)
    Step 2.
    Estimate BER by equation (1)
    Calculate SPER by equation (2)
    Calculate EPER by equation (3)
    Step 3.
    Generate uniform random number r in the interval [0, 1]
    if $r > EPER$ then
      Accept video packet (recovered packet)
    else
      Reject video packet (no recovered packet)
    end if
  end if
```

Fig. 4. EUDP algorithm at receiver vehicle

IV. PERFORMANCE EVALUATION AND RESULTS

A. Simulation setup

To validate the effectiveness of the proposed EUDP in the scenario of VANET, we have performed many simulations using ns-2 network simulator version 2.35 [20]. In our simulations, three video streaming protocols are compared:

- **EUDP**: it is the proposed protocol, which integrates UDP with SPFEC and unequal protection of video frame types.
- **EUDP-E**: it is the integration of UDP with SPFEC, but without unequal protection of video frame types.
- **UDP**: it is the traditional UDP protocol without SPFEC and unequal protection of video frame types.

We assume that in the case of EUDP-E, there is an equal number of redundant sub-packets for all video packets (*I*, *P*, *B*). In addition, we assume that in EUDP, the number of redundant sub-packets of packet *I* and *P* is twice the number of redundant sub-packets of packet *B*, because the packets *I* and *P* are most important than packets *B*. Simulation settings are presented in table I.

TABLE I
GENERAL PARAMETERS OF SIMULATION

Parameter	Value	Parameter	Value
Number of vehicles	100	Scenario	V2V
Video file	Foreman.yuv	Routing protocol	AODV
Video packet size	1024 bits	Sub-packet size	100 bits
Communication range	300 m	Bit Error Rate	{0,, 0.005}
Propagation model	TowRayGround	Number of video frames	400
Evaluation metrics	EPER, delivery ratio, PSNR, MOS		

In our simulations, the Evalvid framework [21] was used to generate the trace of video stream at the sender and receiver vehicles. We have also used SUMO [22] to generate vehicles mobility pattern required by ns-2. Additionally, we have simulated the transmission of video stream in urban area, the generated mobility model is based on the downtown of Oum El Bouaghi city in Algeria, imported from Open Street Map [23] and showed in figure 5. We have chosen AODV as a routing protocol, V2V scenario and we have used the following QoS and QoE metrics: *EPER*, delivery ratio, *PSNR* and *MOS*, to evaluate the quality of video streaming. The chosen video benchmark is the MPEG-4 foreman.yuv which consists of 400 frames, with GoP structure of IBBPBBPBB.

Fig. 5. Studied urban area for video streaming in VANET

B. Results

In this section, we present the obtained results of simulations and discuss them. Figure 6 and Figure 7 show the variation of the average *EPER* and the delivery ratio of video packets in function of the estimated *BER* following UDP, EUDP-E and EUDP protocols. It can be seen in figure 6 that when *BER* increases the average *EPER* following UDP increases greatly than EUDP-E and EUDP, because UDP has not a recovery mechanism of erroneous packets unlike EUDP-E and EUDP which use the redundancy to recover the erroneous sub-packets. Figure 6 shows also that the average *EPER* of EUDP-E is higher than the average *EPER* given by EUDP, because in EUDP the redundancy rates of frames *I* and *P* are higher than the redundancy rate of frames *B* which guarantees more error resiliency contrary to EUDP-E which did not distinguish between the types of frames. Figure 7 shows that the delivery ratio of EUDP is higher than those given by EUDP-E and UDP, because the average *EPER* following EUDP is lower than average *EPER* in the cases of EUDP-E and UDP.

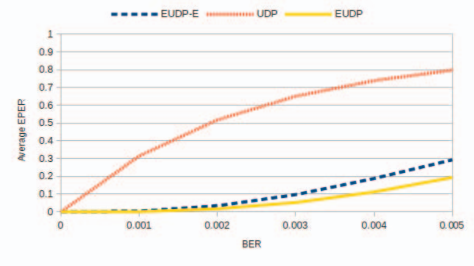

Fig. 6. Variation of average EPER of video packets with BER

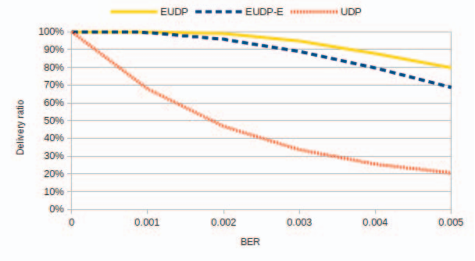

Fig. 7. Variation of delivery ratio of video packets with BER

Figure 8 depicts the *PSNR* of all video frames when the *BER* equal to 0.002. As shown in this figure, the *PSNR* values of video frames following EUDP are greater than EUDP-E PSNR values, because this latter does not allow an enhanced protection of video frames *I* and *P*, leading to decrease the video quality of others frames *B*. The figure 8 shows also that the *PSNR* values of video frames following UDP are lower compared to EUDP and EUDP-E, because UDP cannot recover erroneous video packets which increase its quality. Like figure 8, figure 9 presents the *MOS* values of 400 video frames when *BER* equal to 0.002. We show in this figure, that in EUDP the video quality of most video frames is good (*MOS* = 4), contrary to EUDP-E and UDP which is bad (*MOS* = 1).

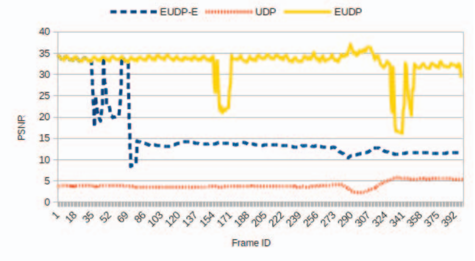

Fig. 8. PSNR of video frames in the case of BER = 0.002

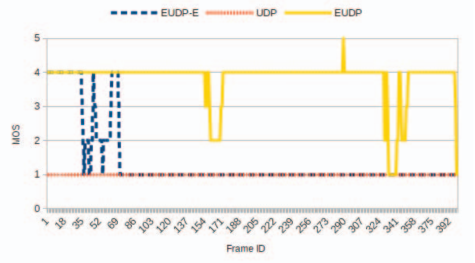

Fig. 9. MOS of video frames in the case of BER = 0.002

Figure 10 shows the variation of average *PSNR* of video packets with *BER*. We can see in this figure that regardless of *BER* the average *PSNR* of UDP is lower than EUDP and EUDP-E, because the delivery ratio of UDP is lower than EUDP and EUDP-E. It is seen also that the average *PSNR* of EUDP is higher than E-EUDP, because EUDP provides higher protection of *I* and *P* frames which allows the decoding of all frames contrary to EUDP-E. Figure 11 depicts the variation of the average *MOS* of video frames with *BER*. As shown in this figure, when *BER* is lower than 0.003, EUDP gives good quality of video streaming in terms of the average *MOS*, EUDP-E gives the good quality only when *BER* is lower than 0.002 and UDP gives the good quality when *BER* is lower than 0.001. The strong error recovery mechanism of EUDP, allows a higher average *MOS* value than EUDP-E and UDP.

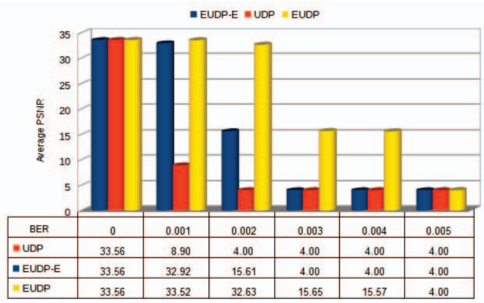

Fig. 10. Variation of average PSNR of video frames with BER

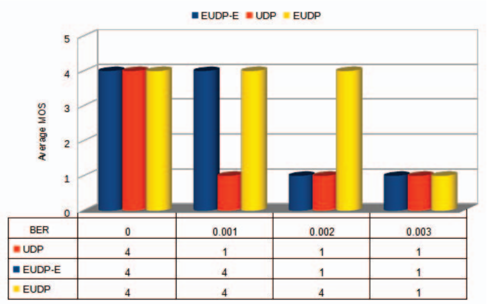

Fig. 11. Variation of average MOS of video frames with BER

V. CONCLUSION

This paper presented our proposed Enhanced User Datagram Protocol (EUDP) to improve video streaming transmission over VANET. Contrary to UDP which did not consider any recovery mechanism of errors, EUDP applied the Sub-Packet FEC to recover the erroneous sub-packets, and applied also the unequal protection of video frame types to improve the video quality at the receiver vehicle. The experimental results have shown that EUDP provides lower *EPER* and higher delivery ratio of video stream compared with UDP and EUDP without unequal protection of video frame types (EUDP-E), and also EUDP improves the video quality in terms of *PNSR* and *MOS*.

In a future study, we intend to improve the performance of EUDP by an interleaving technique to avoid the burst errors of video in VANET.

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