# Enhanced Adaptive Sub-Packet Forward Error Correction mechanism for Video Streaming in VANET

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***Abstract*—Video streaming over vehicular ad hoc network (VANET) provides accurate information about road traffic situation, digital services requested by drivers and passengers, compared to textual messages. Video dissemination in VANET is considered as a hard task because of high dynamic topology of vehicles, stringent requirements of video like real time transmission and the volatility of wireless medium channels. In this paper, we propose a new video streaming scheme called enhanced adaptive sub-packet forward error correction (EASP-FEC) aiming to improve video transmission quality in VANET. Unlike existing packet forward error correction (PFEC) mechanisms proposed for video streaming in VANET, which generate redundant packets for each block of original packets, EASP-FEC divides a packet into a set of original sub-packets, then it generates redundant sub-packets for each packet, to enhance the error recovery rate and video streaming quality. EASP-FEC also avoids the network congestion problem compared to sub-packet forward error correction (SPFEC) mechanism. We propose to apply EASP-FEC at the sender and relay vehicles, where the calculation process of redundant sub-packets take in consideration the traffic condition, the traffic load and the importance of video frame types (I, P, B). A set of simulations proved that EASP-FEC provides better error recovery rate than PFEC and avoids network congestion against SPFEC.**

***Keywords*—VANET; video streaming; Forward Error Correction**

## I. INTRODUCTION

Vehicular Ad hoc Network (VANET) is a recent domain which attracts the attention of many research areas like: electronics, network, security, software engineering, automotive, transportation, etc. Intelligent Transportation System (ITS) provides a mobile applications and services for the traveling public and improves safety and security of VANET network [1]. The different applications in VANET are classified in three categories: transportation safety, transportation efficiency and user services delivered to the vehicle [2]. VANET is a special case of Mobile Ad Hoc Networks (MANET) [3], where nodes are either mobile vehicles or fixed roadside units. VANET is a wireless networks, where the routing process is decentralized, characterized by the high dynamic of its topology, its high capacity of processing, storage, power supply and the predictability of its mobility model. The U.S. Federal Commission Communication allocated 75 MHZ of the Dedicated Short Range Communication (DSRC) spectrum at 5,9 GHZ to be used for Vehicle to Vehicle (V2V) or for Vehicle to Infrastructure (V2I) communications [4]. Transmission of video streaming in VANET allows rich information to the passengers than a textual message, for example in the case of accident in an urban environment, a video captured by camera of a vehicle near to the accident allows to other vehicles to see precisely the scene and location of this accident. In VANET the two mains problems decreasing the streaming video quality are the packet errors and transmission delay. Many causes can lead to these problems such as: high vehicles density, high speed of vehicles, environment obstacles, etc. Forward Error Correction (FEC) is an error recovery mechanism conceived to deal with streaming video errors in the basis of the use of redundant data sent with the original data, this later can successfully reconstructed at the receiver end even some data are lost during transmission.

This paper describes a new proposed solution which improves error resiliency approaches for video streaming in VANET, we named this approach Enhanced Adaptive Sub-Packet Forward Error Correction mechanism (EASP-FEC). EASP-FEC allows to sender and relay vehicles to calculate the redundant sub-packets of each packet based on network conditions (effective packet error rate), network load (queue length) and frames types of the transmitted video. The objective of EASP-FEC is to increase the recovery efficiency, to avoid network congestion and to guarantee a high quality of video streaming.

The rest of the paper is organized as follows. Section II reviews briefly the related work. Section III outlines the proposed EASP-FEC for video streaming in VANET. The performance evaluation by the simulation of EASP-FEC is presented in section IV. Finally, conclusion, opportunities and future trends are presented in section V.

## II. RELATED WORK

This section presents briefly some pertinent works on FEC mechanism for video streaming in wireless and VANET networks. The main problem of traditional FEC mechanism is the network overloading because of the high redundancy rate which increases collisions and interferences, and the problem of burst errors. Many works proposed a variations of FEC mechanism to deal with these problems for video streaming

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in wireless network like Forward-Looking Forward Error Correction (FL-FEC) [5], Enhanced Random Early Detection Forward Error Correction (ERED-FEC) [6], Adaptive and Interleaving FEC (AIFEC) [7], FEC with Path Interleaving (FEC-PI) [8]. These studies coped with network overloading issue, burst errors, where the video quality is improved at the end user (the receiver). Nevertheless, these schemes suffer from some limitations like the long delay and the high redundancy rate due to the used Packet FEC (PFEC) mechanism.

In [9], the authors proposed a Sub-Packet FEC (SPFEC) mechanism to improve the video streaming quality over wireless network in terms of recovery performance and jitter compared with traditional Forward Error Correction (FEC) mechanisms. SPFEC divides the video packet into $n$ sub-packets and then, it applies the FEC mechanism on these sub-packets. A set of simulations proved that SPFEC outperformed Packet FEC (PFEC) in terms of video streaming quality and the transmission jitter. We mention that SPFEC could be improved by adding traffic load control in the FEC performing process to avoid network congestion.

In VANET literature, there are some studies that applied the FEC and redundancy mechanisms for video streaming. The authors of [10] proposed a Reactive, Density-Aware and Timely Dissemination protocol (REACT-DIS) for video streaming broadcasting in VANET network. REACT-DIS is based on the Receiver Based Forwarding (RBF) for the selection of relays vehicles. Authors of this work proposed also to add the redundancy mechanism and network coding to REACT-DIS to recover loss packets and decrease the unnecessary transmissions. Moreover, [11] proposed an adaptive QoE-driven COntent-awaRe VidEo Transmission optimisation mEchanism (CORVETTE) which is based on Hierarchical Fuzzy System (HFS) in order to adjust dynamically every hop the redundancy degree of video packets in function of network state and video characteristics. CORVETTE was compared with adaptive and non-adaptive mechanisms and has showed an improvement of video quality in terms of QoE whatever the vehicles density. In order to ensure more realistic results, CORVETTE could be tested on varied VANET mobility models. The authors of [12] proposed an error recovery technique of video packet in VANET network named FEC and Interleaving Real Time Optimization (FIRO). FIRO is based on three following techniques: FEC conceived to recover uniform errors, Interleaving introduced to recover burst errors and reporting technique proposed to estimate the loss ratio of channel transmission. According to this estimation, the sender adapts dynamically FEC and Interleaving parameters. FIRO improved streaming video quality compared to FEC and interleaving techniques, it remains to test FIRO in urban environment when the network capacity is limited. We conclude that all studies in VANET video streaming used the PFEC mechanism and its adaptations for packet loss resiliency. SPFEC mechanism outperforms PFEC because SPFEC reduces the effective packet error rate, it reduces the redundancy overhead and also it reduces the end-to-end delay because the sender waits the generation of only one packet to perform the FEC mechanism and when the receiver received one packet it can decode this packet without waiting other packets contrary to PFEC mechanism.

Many others video streaming works in wireless and VANET networks were proposed like frame-based mapping mechanism (FBM) [13], Intelligent Network Selection (INS) scheme [14], intelligent Mobile Video Surveillance System (MVSS) [15], QoS-aware hierarchical web caching (QHWC) scheme in Internet-based VANETs (IVANETs) [16]. These schemes do not use the redundancy mechanism to overcome the occurrence of error during the transmission of video streaming.

## III. Enhanced Adaptive Sub-Packet Forward Error Correction mechanism for video streaming in VANET (EASP-FEC)

As aforementioned in Section II, the SPFEC divides the packet into a set of sub-packets and calculates the FEC sub-packets (redundant sub-packets) according to effective packet error rate in the network. The congestion problem increases the packet error rate in VANET, specifically when the density of vehicles is high. We propose in this paper an Enhanced Adaptive Sub-Packet Forward Error Correction mechanism for video streaming in VANET (called EASP-FEC) which improves SPFEC mechanism by adding traffic load factor to avoid the congestion problem. Also, EASP-FEC adds the strongness of sub-packets type to increase the video streaming quality at the end receiver vehicle.

### A. General Architecture of EASP-FEC

EASP-FEC mechanism consists of three components, as shown in Fig. 1: (1) Traffic condition estimator, (2) FEC redundant sub-packets generator and, (3) Traffic load monitor. The vehicle sender encapsulates the video data in Real-time Transport Protocol (RTP) packets and the EASP-FEC is applied at the level of the sender and relays vehicles. When the relay vehicle received the packet, the traffic condition estimator estimates current Bit Error Rate (*BER*) and Sub-Packet Error Rate (*SPER*). FEC redundant sub-packets generator generates the redundant sub-packets for received packet based on estimated *SPER* which provides maximum video quality in terms of Decodable Frame Rate (*DFR*) at the next relay vehicle. Traffic load monitor adapts the number of generated redundant sub-packets according to network load (indicated by relay vehicle queue length) to avoid the congestion problem and also according to the importance of video sub-packets (*I*, *P*, *B*) to allow a high quality of video streaming for the vehicle in the next hop. In Fig. 2, the source vehicle (in red color) applies EASP-FEC mechanism and sends the packet to the relay vehicle in the next hop (i.e. green vehicle). When a relay vehicle received the packet, it recalculates the redundant sub-packets following EASP-FEC and transmits the packet to the next hop and so on, until arriving the packet to the destination vehicle (in blue color). It is worth noting that the redundant sub-packets of one packet are regenerated at each hop.

### B. Analytical Model of EASP-FEC

In our proposed mechanism, the Effective Packet Error Rate (*EPER*) is estimated based on *SPER* of video streaming in

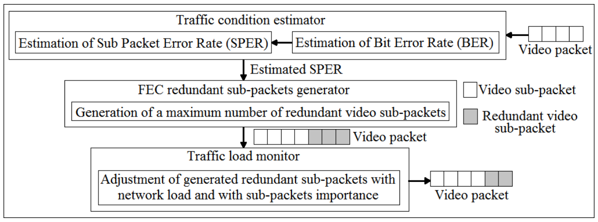

Fig. 1. Architecture of EASP-FEC mechanism

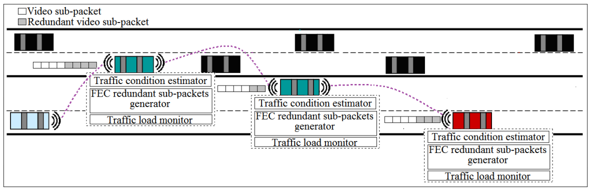

Fig. 2. Video streaming transmission using EASP-FEC mechanism

VANET and *SPER* is estimated based on *BER*. We assume that the video streaming composed of $N$ video packets, the maximum size of video packet is $n$ bit, also the number of sub-packets in a packet is fixed at $m$.

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

$$SPER = 1 - (1 - BER)^{\frac{n}{m}} \tag{1}$$

*2) Effective Packet Error Rate (EPER):* Effective Packet Error Rate represents the probability that a video packet cannot be recovered, it is given by the following formula:

$$EPER = 1 - \left(\sum_{i=k}^{k+h} C_i^{k+h} * (1 - SPER)^i * SPER^{k+h-i}\right) \tag{2}$$

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

*3) Estimation of Bit Error Rate (BER):* We estimate the *BER* each interval of time *dt*, by the following equation:

$$BER(dt) = 1 - \left(1 - \frac{success(dt)}{Total(dt)}\right)^{\frac{1}{Total(dt)}} \tag{3}$$

Where *success(dt)* represents the number of successful received packets without FEC mechanism to current relay vehicle during the interval time *dt*, *Total(dt)* represents the total number of transmitted packets to this relay vehicle during the interval time *dt*.

*4) Estimation of video streaming quality:* in order to estimate the quality of video streaming at the next hop according to the estimated *EPER* following EASP-FEC, we use Decodable Frame Rate Model (*DFR*), *DFR* evaluates the quality of GoP at the application layer, it gives more accurate evaluation than *EPER*. *DFR* model calculates the number of decodable frames *I*, *P* and *B* in a given *EPER*. The value of *DFR* varies between zero and one, higher value of *DFR* indicates the best quality of video streaming. The number of decodable frames *I* is given by the formula:

$$NdecodeI = (1 - EPER)^{aI} * NGoP \tag{4}$$

Where *NGoP* is the total number of GoPs in the video stream, *aI* is the average packets number in *I* frame.

The number of decodable frames *P* is given by the equation:

$$NdecodeP = (1 - EPER)^{aI} * \sum_{i=1}^{nP} (1 - EPER)^{i*aP} * NGoP \tag{5}$$

Where *nP* is the total number of *P* frames in a GoP and *aP* is the average packets number in *P* frame.

The number of decodable frames *B* is given by the equation:

$$NdecodeB = [(1 - EPER)^{aI*nP*aP} + \sum_{j=1}^{nP} (1 - EPER)^{j*aP} * (1 - EPER)^{aB}] * (M - 1) * (1 - EPER)^{aI+aB} * NGoP \tag{6}$$

Where *aB* is the average packets number in *B* frame and *M* is the distance between *I* frames and *P* frames in a GoP. The percentage of total number of decodable video frames *I*, *P* and *B* at the next relay vehicle is given by the equation:

$$DFR = \frac{(NdecodeI + NdecodeP + NdecodeB)}{Ntotal} \tag{7}$$

## C. EASP-FEC algorithm

The pseudo-code of EASP-FEC algorithm is presented in Fig. 3. When a new packet arrived at the relay vehicle, the traffic condition estimator component of this vehicle estimates current *BER* and *SPER* by formulas (1) and (3) (step 1 of EASP-FEC pseudo-code shows this estimation). After that, the FEC redundant sub-packets generator component recalculates for each packet the maximum number of redundant sub-packets (*h*) which provides a maximum quality of video streaming in terms of *DFR* (*MaxDFR*) at the next hop following equations (2), (4), (5), (6), (7) (step 2). Finally, traffic load monitor component of this vehicle adjusts the number of redundant sub-packets according to the current network load to avoid the congestion problem. This later increases the packet error rate and the end-to-end delay especially when the density of vehicles is high. In our proposed mechanism the relay vehicle estimates the network load based on the length of its queue (step 3 of EASP-FEC pseudo-code presents this adjustment).

We propose that the queue of current relay vehicle has two thresholds: THreshold High (*THH*) and THreshold Low (*THL*). When Queue Length (*Qlength*) is lower than *THL*, it means that the current network load is lower, then the adjusted number of generated redundant sub-packets is set to the maximum number of generated redundant sub packets. If the *Qlength* is high than *THH*, it means that the current network load is high, then the adjusted number of generated redundant sub-packets is set to zero. When *Qlength* is between *THL* and *THH*, the adjusted number of generated redundant sub-packets is calculated based on the following formula :

$$\begin{aligned} &Number\_generated\_redundant\_subpackets = \\ &Max\_number\_generated\_redundant\_subpackets \\ &* \frac{(THH - Qlength)}{(THH - THL)} \end{aligned} \tag{8}$$

Our proposed mechanism uses MPEG standard based on the three types of frames: *I*, *P* and *B* following to its importance. EASP-FEC is based on the idea of unequal protection of video sub-packets, the most important sub-packets must have high protection. Unequal protection is indicated by dynamic updating of *THH* and *THL* according to the type of current generated redundant sub-packets. The *THH* for the most important sub-packets is higher than lower important sub-packets, for instance, when the network is heavily congested, the generated redundant sub-packets *B* and *P* are set to 0 and only generated redundant sub-packets *I* are adjusted. Unlike *THH*, the *THL* for all sub-packets type is the same, in lightly congested network the maximum number of generated redundant sub-packets *I*, *P* and *B* must be transmitted to allow a high quality of video for the vehicle in the next hop.

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Step 1. Estimation of current Bit Error Rate (BER) and Sub-Packet Error Rate (SPER) in VANET by equations (3) and (1)

Step 2. Determination of number of redundant sub-packets (h) in accordance with the network conditions, which provides maximum quality of video streaming (MaxDFR) in terms of Decodable Frame Rate (DFR) at the next hop
  $h \leftarrow 0$
  while $DFR < MaxDFR$ do
    1. Determination of Effective Packet Error Rate (EPER) by equation (2)
    2. Determination of number of decodable I-frames (NdecodeI) by equation (4)
    3. Determination of number of decodable P-frames (NdecodeP) by equation (5)
    4. Determination of number of decodable B-frames (NdecodeB) by equation (6)
    5. Determination of DFR by equation (7)
    $h \leftarrow h + 1$
    $Max\_number\_generated\_redundant\_subpackets \leftarrow h$
  end while

  Step 3. Adjust the number of redundant sub-packets in accordance with the network load
  if $Qlength < THL$ then
    $Number\_generated\_redundant\_subpackets \leftarrow Max\_number\_generated\_redundant\_subpackets$
  else if $Qlength < THH$ then
    $Number\_generated\_redundant\_subpackets \leftarrow Max\_number\_generated\_redundant\_subpackets * (\frac{THH - Qlength}{THH - THL})$
  else
    $Number\_generated\_redundant\_subpackets \leftarrow 0$
  end if
```

Fig. 3. EASP-FEC PSEUDO-CODE

## IV. VALIDATION OF EASP-FEC MECHANISM

To validate the effectiveness of the proposed EASP-FEC mechanism, a set of EASP-FEC simulations are performed using MATLAB. The confidence intervals are calculated with 95 % of confidence level and Student's distribution function using Statistics Toolbox of MATLAB. The obtained results have been compared with the simulated PFEC and SPFEC mechanisms in terms of *EPER*, *DFR* and the number of redundant sub-packets. As cited above, EASP-FEC mechanism is applied at the sender and relay vehicles in a VANET. Moreover, in our simulations, we applied EASP-FEC, PFEC and SPFEC mechanisms to be compared at one relay vehicle where the video is encoding with MPEG-4 standard in a QCIF format with a GoP structure of IBBPBBPBB. Table I shows parameter settings of these simulations.

TABLE I
PARAMETER SETTINGS OF SIMULATIONS

| **Parameter** | **Value** | **Parameter** | **Value** |
|---|---|---|---|
| Bit Error Rate | {0,..., 0.005} | Average packets number in P frames | 10 |
| Packet size | 1000 bits | Average packets number in B frames | 10 |
| Number of sub-packets in a received packet | 10 | Total number of P frames in a GoP | 2 |
| Number of original sub-packets in a packet | 8 | The distance between I frames and P frames in a GoP | 3 |
| Number of GoPs in the video stream | 10 | *Qlength* | {0,..., 50 packets} |
| Average packets number in I frames | 10 | *THL* | 10 |
| Maximum desired DFR of video stream | 1 | *THH* | 25 |

### A. Validation of traffic condition estimation and effect of EPER on delivered video quality

The validation of EASP-FEC traffic condition estimation and the effect of *EPER* on delivered video quality is performed by comparing the *EPER* and *DFR* obtained by EASP-FEC and PFEC. The number of original sub-packets in one packet is assumed equal to 8 and the number of redundant sub-packets generated by the current relay vehicle is fixed at 4 in the case of EASP-FEC. The same parameters are assumed in the case of PFEC (number of original packet in a block is 8 and number of redundant packet in one block is 4). As shown in Fig. 4, with the same redundancy rate, the *EPER* of PFEC increases greatly than EASP-FEC with a varying *BER*, because in the same network condition the sub-packet is more susceptible to be recovered than the entire packet. Fig. 5 shows the variation of *DFR* with *BER* for EASP-FEC and PFEC. When the *BER* increases and with the same redundancy rate, the *DFR* of PFEC decreases greatly than EASP-FEC, because the *EPER* of PFEC increases greatly than EASP-FEC.

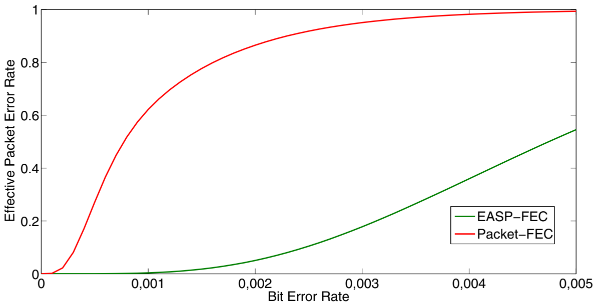

Fig. 4. Variation of Effective Packet Error Rate with Bit Error Rate

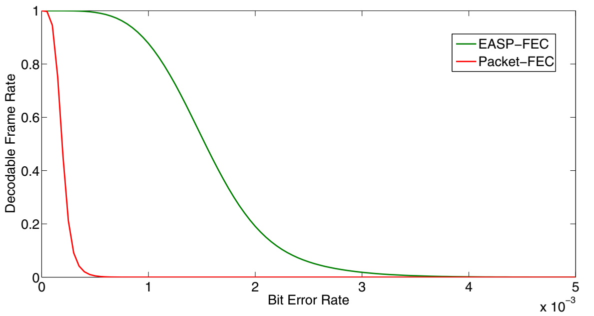

Fig. 5. Variation of Decodable Frame Rate with Bit Error Rate

### B. Validation of generation of redundant sub-packets and effect of redundancy rate on delivered video quality

To verify the effectiveness of redundant sub-packets generation used to recover the original sub-packets, the *EPER* is compared with variation of redundancy rate in the case of EASP-FEC and PFEC. The redundancy rate represents the percentage of redundant sub-packets compared to original sub-packets in the case of EASP-FEC and the percentage of redundant packets compared to original packets in the case of PFEC. As shown in Fig. 6, when the redundancy rate increases, the *EPER* of EASP-FEC decreases greatly than PFEC in three cases: *BER* = 0.005, 0.0005 and 0.00005, for example with 50% of redundancy rate (4 redundant sub-packets or packets) the *EPER* = 0.27 with EASP-FEC while with PFEC the *EPER* = 0.55, because in the case of PFEC the packet is dropped even if one part of this packet is erroneous, it is contrary to EASP-FEC in which only the sub-packet containing this part is dropped. Fig. 6 shows also that when *BER* increases, the *EPER* increases in both EASP-FEC and PFEC, consequently the redundancy rate must be high to recover the erroneous bits. Fig. 7 shows the variation of *DFR* of video stream with redundancy rate, as seen in this figure for both mechanisms EASP-FEC and PFEC that when redundancy rate increases, the *DFR* increases because the *EPER* decreases and when *BER* increases the *DFR* decreases because the *EPER* increases. This figure shows also that *DFR* of EASP-FEC is always higher than PFEC, because always the *EPER* of EASP-FEC is lower than PFEC.

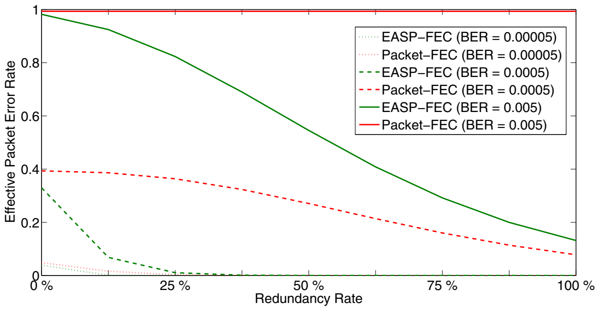

Fig. 6. Variation of Effective Packet Error Rate with Redundancy Rate

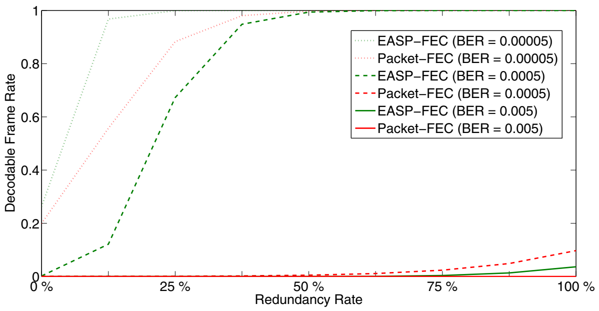

Fig. 7. Variation of Decodable Frame Rate with Redundancy Rate

### C. Validation of adjustment of redundant sub-packets number in accordance with the network load

In this subsection, the adjustment of generated redundant sub-packets number of the proposed EASP-FEC mechanism is evaluated as a VANET congestion metric. A comparison between EASP-FEC and SPFEC is performed. Fig. 8 shows the variation of adjusted number of redundant sub-packets with queue length, we note that the number of redundant sub-packets before the adjustment is generated randomly. As seen in this figure, when queue length is lower than *THL* which means that the density of vehicles is low, the adjusted number of redundant sub-packets of EASP-FEC and SPFEC is the same. When queue length is between *THL* and *THH* which means that the density of vehicles is medium, the adjusted number of redundant sub-packets of SPFEC is higher than EASP-FEC, because SPFEC does not have a mechanism which controls the congestion problem. When the queue length is higher than *THH* which means that the density of vehicles is high, the adjusted number of redundant sub-packets of SPFEC is high contrary to EASP-FEC which is equal to zero, because the traffic load monitor of current relay vehicle detects that the network is heavy loaded, hence it stops the generation of redundant sub-packets to avoid the congestion contrary to SPFEC which cannot prevent network collusion leading also to interferences.

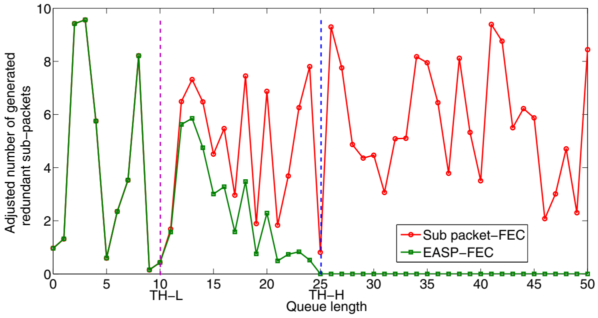

Fig. 8. Variation of adjusted number of redundant sub-packets with Queue length

### D. Validation of unequal protection of video frames

Fig. 9 depicts the variation of number of decodable frames with *BER*. This figure shows that when the *BER* increases, the number of decodable frames *B* decreases greatly than decodable frames *P* and this later decreases greatly than *I* frames. For example when $BER = 0.002$, the number of decodable frames $I =$ number of decodable frames $P =$ number of decodable frames $B = 5$, because according to dependencies between frames of MPEG, an error of *I* frame influences on the *P* and *B* frames and the error of *P* frame influences on the *B* frames, for this reason, EASP-FEC proposes to distinguish values of *THL* and *THH* for different video frame types (*I*, *P*, *B*).

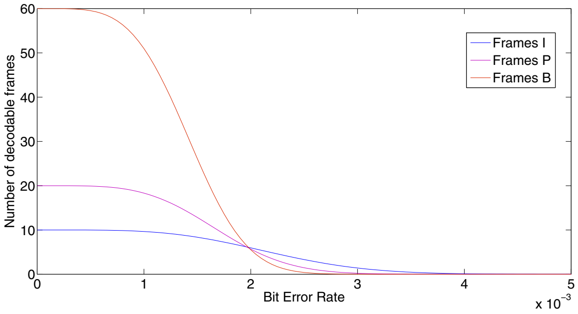

Fig. 9. Variation of Number of decodable frames with Bit Error Rate

## V. CONCLUSION

In this paper, a new mechanism for video streaming in VANET called Enhanced Adaptive Sub-Packet Forward Error Correction is presented. Contrary to Packet FEC which calculates the redundant packets for each block of packets, EASP-FEC calculates the redundant sub-packets for each packet allowing more error resiliency. Moreover, EASP-FEC considers network load and the strongness of video frame types to avoid the congestion problem and increase the video streaming quality, compared to Sub-Packet FEC which calculates the redundant sub-packets only in the basis of network condition. EASP-FEC is applied not only at the sender vehicle of video but also at the relay vehicles to guarantee an accurate estimation of network condition and network load. The experimental results have shown that EASP-FEC provides higher *DFR* of video stream than PFEC with the same redundancy rate. In addition, our proposal avoids network congestion problem compared to SPFEC and improves the video streaming quality. As a future study, we project to improve the performance of EASP-FEC by interleaving technique to avoid the burst errors of video in VANET.

## REFERENCES

[1] Y. Qian and N. Moayeri, “Design of secure and application-oriented VANETs,” pp. 2794-2799, 2008.

[2] P. Papadimitratos, A. La Fortelle, K. Evenssen, R. Brignolo and S. Cosenza, “Vehicular communication systems: Enabling technologies, applications, and future outlook on intelligent transportation,” IEEE Commun. Mag., vol. 47, no. 11, pp. 84-95, 2009.

[3] S. Bitam A. Mellouk and S. Zeadally “Bio-inspired routing algorithms survey for vehicular ad hoc networks,” IEEE Communications Surveys & Tutorials, vol. 17, no. 2, pp. 843-867, 2015.

[4] D. Jiang and L. Delgrossi. “IEEE 802.11 p: Towards an international standard for wireless access in vehicular environments,” pp. 2036-2040, 2008.

[5] M. Tsai, C. Shieh, T. Huang and D. Deng, “Forward-Looking Forward Error Correction Mechanism for Video Streaming Over Wireless Networks,” IEEE Systems Journal, vol. 5, no. 4, pp. 460-473, 2011.

[6] C. Lin, C. Shieh and W. Hwang, “An Access Point-Based FEC Mechanism for Video Transmission Over Wireless LANs,” IEEE Trans. Multimedia, vol. 15, no. 1, pp. 195-206, 2013.

[7] Tin-Yu Wu, S. Guizani, Wei-Tsong Lee and Po-Chang Huang, “An enhanced structure of layered forward error correction and interleaving for scalable video coding in wireless video delivery,” IEEE Wireless Commun., vol. 20, no. 4, pp. 146-152, 2013.

[8] M. F. Tsai, C. H. Ke, , C. I. Kuo and C. K. Shieh, “Path dependent adaptive forward error correction with multipath interleaving control scheme for video streaming over wireless networks,” pp. 1236-1239, 2009.

[9] M. Tsai, C. Shieh, C. Ke and D. Deng, “Sub-packet forward error correction mechanism for video streaming over wireless networks,” Multimed Tools Appl, vol. 47, no. 1, pp. 49-69, 2009.

[10] C. Rezende, R. W. Pazzi and A. Boukerche, “A reactive solution with a redundancy-based error correction mechanism for video dissemination over vehicular ad hoc networks,” pp. 343-352, 2012.

[11] R. Immich, E. Cerqueira and M. Curado, “Adaptive QoE-driven video transmission over Vehicular Ad-hoc Networks,” pp. 227-232, 2015.

[12] P. Bucciol, J. L. Zechinelli-Martini and G. Vargas-Solar, “Optimized transmission of loss tolerant information streams for real-time vehicle-to-vehicle communications,” pp. 142-145, 2009.

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

[14] A. Sadiq, K. Bakar, K. 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, no. 6, pp. 879-895, 2013.

[15] N. Kumar, J. Lee and J. Rodrigues, “Intelligent Mobile Video Surveillance System as a Bayesian Coalition Game in Vehicular Sensor Networks: Learning Automata Approach,” IEEE Trans. Intell. Transport. Syst., vol. 16, no. 3, pp. 1148-1161, 2015.

[16] N. Kumar, S. Zeadally and J. Rodrigues, “QoS-Aware Hierarchical Web Caching Scheme for Online Video Streaming Applications in Internet-Based Vehicular Ad Hoc Networks,” IEEE Trans. Ind. Electron., vol. 62, no. 12, pp. 7892-7900, 2015.