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Adaptive video streaming based on TFRC protocol in vehicular ad-hoc networks (VANETs)

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Abstract

In this paper, an efficient video transmission technique is proposed for vehicular communications using the TCP Friendly Rate Control (TFRC) transport protocol. It allows video adaptation at the transmitter side through a channel state estimation feedback. Simulation results demonstrate the effectiveness of the method in terms of received video quality.

Keywords: Video transmission, TFRC, VANET, IEEE 802.11p.

1. Introduction

Vehicular ad-hoc networks (VANETs) allow vehicles to communicate with each other (V2V) or with existing roadside infrastructure (V2I) without any deployed fixed network architecture. Developing effective video communications in such networks will provide drivers with better support, safer navigation, better traffic control, and access to business and infotainment applications. Indeed, the transmission of video data in VANETs represents a major challenge due to channel fading, network congestion and limited and variable bandwidth, etc. Especially with the development of autonomous vehicles and their future generalization, entertainment applications are becoming more prevalent in the vehicular communications landscape. Future vehicles will provide a range of multimedia content including HD movies, TV shows and sports (YouTube, Netflix, Amazon Prime Video, etc.). In addition, multiple video streams must be able to be delivered in the same vehicle. Other applications of commercial or tourist type will see the light of day, with advertisements when passing by the shops or tourist information conveyed in visual form. This will contribute to accelerate the development of vehicular communications and the public assimilation.

On the other hand, the IEEE 802.11p standard is one of the technological solutions for vehicular communication. It is already available and has the advantage of not having to subscribe with fees in contrast to cellular technologies [1].

Recently video transmission over VANETs have attracted the interest of research community. For example, in [2] a QoS-based evaluation using internet protocol television (IPTV) transmission in VANETs is provided. In [3] Xie et al. proposed an error recovery mechanism for real-time video streaming in VANETs. The multi-channel proposed protocol transmits frames using 2 different transport protocols: TCP and UDP taking advantage of their distinct characteristics.

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Solutions for adapting video content are increasingly used on the internet, including dynamic adaptive streaming over HTTP (DASH). Moreover, many flow matching mechanisms exist to accommodate to channel variations [4]. These solutions are even more effective in wireless networks with greater channel variability [5]. In this work, we propose to use a video adaptation mechanism in VANETs. The mechanism is based on the TCP friendly rate control (TFRC) transport protocol.

2. Cross-layer design based on TFRC

TFRC is a congestion control mechanism for unicast streams. Unlike TCP, it does not require user data retransmission and aims to be reasonably fair when competing for bandwidth. Compared to TCP, the bitrate of TFRC varies less with time, resulting in slow response to available bandwidth. Thus, it is ideal for multimedia applications. Basically, TFRC adjusts the server bitrate using an additive increase/additive decrease (AIAD) scheme. This is done through a bitrate estimation based on the round-trip time (RTT) and packet loss rate [6]. Thus, the TFRC flow equation is defined by:

$$X_{TFRC} = \frac{s}{R\sqrt{\frac{2bp}{3}} + t_{RTO}(3\sqrt{\frac{3bp}{8}})p(1 + 32p^2)}, \quad (1)$$

where: X_{TFRC} is the transmission bitrate, s the packet size, R the RTT, p the loss event rate, t_{RTO} is the TCP retransmission timeout value and b the number of packets acknowledged by a single TCP ACK.

Based on this protocol, several systems adapt the content to the channel state. In [7] an adaptive video communication system is proposed that allows a server with several video sequences of different qualities, i.e., multiple bitrates, to transmit the appropriate sequence based on the estimated bitrate returned by the TFRC. In the proposed system, called Evalvid-RA, the video quality adaptation, i.e., the choice of the video bitrate to be transmitted, is done at the group of pictures (GOP) beginning. Based on multiple bitrates video trace files encoded in MPEG-4, Evalvid-RA is able to simulate adaptive multimedia data transmission depend on bitrates.

3. Performance evaluation

Many simulations were performed in a realistic vehicle environment. For this, the SUMO (Simulation of Urban Mobility) environment was considered. This open source simulator models the behavior of urban mobility vehicles and takes into account the interaction between vehicles. Thus, we use realistic urban traffic maps of Valenciennes (France). We then use the road mobility generated by SUMO in NS2, the chosen network simulator, to which Evalvid-RA was integrated. The radio propagation model used is Nakagami, which gives a fairly realistic representation of the vehicular channel. In addition, as described, the standard used is 802.11p, which includes a MAC layer using CSMA/CA with QoS support and a PHY layer operating in the 5.9 GHz frequency band using OFDM modulation.

For the tests carried out, we have chosen the commonly used 352×288 resolution "sign irene" video sequence. The video was encoded, with the MPEG-4 encoder, with 31 different video qualities representing the 31 quantization parameter values (QP) allowed by the encoder. Thus, at the transmitter, the server has 31 different encoded video sequences, each with its own bitrate and visual quality. The videos were encoded with a GOP of 12 frames. The video evaluation was carried out with the well-known objective video metric: the peak signal to noise ratio (PSNR). It measures the difference between the reconstructed received video and the original one.

Fig. 1 shows the frame by frame PSNR variation for an adaptive video transmission simulation over VANETs. Four curves are displayed, where three of them are for video sequences encoded with QP:

4, 5 and 6. The red curve concerns the transmitted sequence, which is superimposed on some parts of the curve to one of the other three curves. This means that the transmission switches from one to another video quality. Furthermore, curve superposition means that the transmission was performed without packet loss. A PSNR greater than 25 dB being considered acceptable, the average PSNR of the sequence is 35.14 dB. However, except for the images 92-96, the rest of the sequence has a PSNR greater than 25 dB.

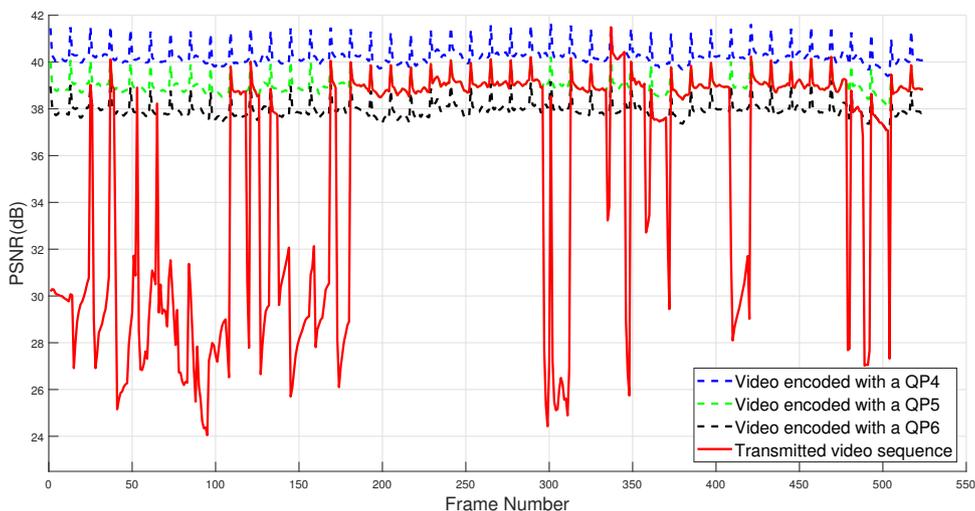


Figure 1: PSNR variation for adaptive video transmission.

4. Conclusion

Video adaptation in VANETs seems to be an effective solution that will allow development of several applications. An adaptive video mechanism based on TFRC protocol was proposed that provides rather interesting results. We are currently working to improve the system, particularly with respect to the periodicity of the bitrate decision currently being calculated for each GOP. Indeed, the high variability of the vehicular networks requires an accorded video adaptation to limit the packets losses and thus the degradation of the video quality on the receiver side.

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