Live video streaming in IEEE 802.11p vehicular networks: demonstration of an automotive surveillance application

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***Abstract*—Prospective IEEE 802.11p-enabled automotive video applications are identified. Preliminary experimental results of inter-vehicular live video streaming for surveillance applications are presented. A test-bed for the demonstration of the achievable visual quality under different channel conditions is described.**

***Index Terms*—Video applications, vehicle-to-vehicle communications, real-world measurements, VANET, IEEE 802.11p.**

I. Introduction

IEEE 802.11p and its European counterpart ITS-G5, developed by ETSI, are the basis for wireless communication between vehicles (V2V) or between the vehicles and the infrastructure (V2I) in so-called vehicular ad hoc networks (VANETs). In both the USA and EU a set of frequency channels at 5.9 GHz has been set aside for automotive applications. Those have been divided into one control channel and several service channels. The control channel will carry position messages and hazard warnings produced by all vehicles in the system. However, there are still service channels which real-time video streaming based applications can use.

Video camera capability has been standard in premium cars and in certain special vehicles such as garbage trucks to increase the awareness horizon for the drivers. Now, it is time to take it a step further: share what the video camera produces and distribute it to the vehicles in its neighborhood in real-time to enable new applications that can increase road traffic efficiency, safety and public security.

A summary of the prospective applications is provided in Section II. Some experimental results for one of the applications, namely a surveillance system, are reported in Section III. The proposed demonstration of live video streaming for channels with severe packet losses, is introduced in Section IV. The paper accompanies a public demonstration of our results.

II. Prospective applications

Live video streaming has become an everyday life feature and applications such as the built-in FaceTime for iPhones enable new ways to interact with the environment. Very often the ”last mile” for delivery of real-time video streams is based on the ubiquitous wireless local area network standard IEEE 802.11, which is the basis for IEEE 802.11p. However, a plethora of new applications, which are briefly explained in Table I, can be developed based on providing video streaming both in V2V and V2I modes and by combining the live video streams with position messages and hazard warnings that are already in place. In this paper we focus on the study of a V2I surveillance application.

TABLE I
Prospective IEEE 802.11p-enabled video applications

Application	*Objective*	*Mode*	*Idea*
Pedestrian crossing assistance	Urban mobility safety	V2V	Live video is exchanged between the vehicles approaching a pedestrian crossing for protecting vulnerable road users.
Public transport assistance	Public transportation road safety	V2V	Live video is delivered from the bus at the stop to the vehicles passing by for protecting disembarking passengers.
In-vehicle video surveillance	Public security	V2I	Public transport is monitored in real-time by the control center to help counteract vandalism and other crimes.
Traffic conditions video surveillance	Traffic control	V2I	The current situation at a given road section, an intersection or even a lane is transmitted from the nearest vehicle to the management center.
Overtaking assistance	Rural roads safety	V2V	Live video information is delivered from the truck vehicle to the vehicles behind on rural roads.
Video conferencing in platoons	Infotainment	V2V	Group video conferencing is organized between vehicles in a platoon for a pleasant journey.
Police assistance at a crime scene	Public Security	V2V, V2I	Live video is exchanged between the emergency vehicles at the crime scene.

III. Experiments with a video surveillance system

A video system has been implemented on Windows OS based on the DirectShow framework and performs video capturing from a USB video camera, video encoding, decoding, packet loss protection based on inter-packet Reed-

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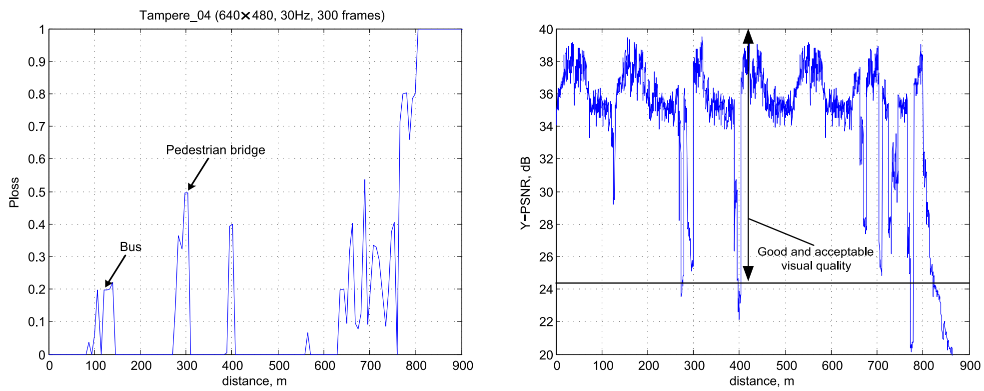

(a) Packet loss rate depending on the distance (b) Visual quality depending on the distance

Fig. 1. Real-world experimental results for the proposed V2I video surveillance system

Solomon codes and playback in real-time. For Real-Time Protocol (RTP) streaming the open-source JRTPLIB library was used. The end-to-end latency is less than 6 sec which is acceptable for video surveillance applications such as the "Police assistance at a crime scene" and "In-vehicle video surveillance" found in Table I. For video compression and robust transmission we use a video codec based on the three-dimensional discrete wavelet transform (3-D DWT) [1]. In comparison to traditional video coding standards such as MPEG-2 or H.264/AVC, the video stream generated by the 3-D DWT codec is much less sensitive to packet losses and has significantly less computational complexity [2]. That makes it very attractive for video transmission over highly unreliable wireless channels as well as for real-time software implementation on low-power devices. Componentality FlexRoad routers were used in our experiments.

The experiment was conducted [3] outdoors in major street close to the university campus in Hervanta, a suburb of Tampere, Finland. The video data was transmitted when the vehicle was moving at the velocity of 50 km/h starting from the distance 0 meters. Figure 1, *a)* shows the measured packet loss rate depending on the distance, while Figure 1, *b)* presents corresponding visual quality for video sequence Tampere_04 [4], which is typical for road surveillance applications. During the experiment, the traffic was moderate and some cars, buses and a pedestrian bridge occasionally obstructed the line of sight between the transmitting vehicle and receiving roadside unit (see labels on Figure 1, *a)*). In our experiment continuous video playback was provided when the distance between the vehicle and the roadside unit was less than 800 meters and a good visual quality was achieved for the distances 0–600 meters.

IV. Demonstration

To mimic the conducted measurements in [3], we use laptops with IEEE 802.11 (a.k.a. Wi-Fi) interfaces instead. Different realistic channel conditions are modeled by dropping packets according to a probabilistic distribution.

Our demonstration test-bed includes three laptops connected via Wi-Fi as shown in Figure 2. Laptop 1 captures video by a USB camera, compresses video by 3-D DWT codec [1], protects the compressed video bit stream using Reed-Solomon inter-packet codes as it is proposed in [2] and transmits the resulting video stream to Laptop 2 in real-time. Laptop 2 retransmits received packets to Laptop 3, which decodes and plays back the video stream.

For testing of the visual quality under different channel conditions Laptop 2 can drop packets received from Laptop 1 according to the Gilbert-Elliot packet loss model. The parameters of the model, such as average packet loss rate and average packet loss burst length, can be adjusted to reflect realistic VANET environments [5] and simulate different possible quality conditions of a wireless channel. Therefore, a user can perceive the video quality depending on the selected channel conditions in real-time.

Fig. 2. The proposed demonstration

References

[1] E. Belyaev, K. Egiazarian and M. Gabbouj, "A low-complexity bit-plane entropy coding and rate control for 3-D DWT based video coding", *IEEE Transactions on Multimedia*, 15(8), pp.1786 1799, 2013.

[2] E. Belyaev, K. Egiazarian, M. Gabbouj and K. Liu, A Low-complexity joint source-channel video coding for 3-D DWT codec, *1st International Symposium on Communication and Information Theory*, Chengdu, December 2013.

[3] A. Vinel, E. Belyaev, O. Lamotte, M. Gabbouj, Y. Koucheryavy, K. Egiazarian, "Video Transmission over IEEE 802.11p: Real-World measurements", *IEEE ICC-2013 (workshop)*, Budapest, June 2013.

[4] http://www.cs.tut.fi/~belyaev/v2v.htm.

[5] A.F. Molisch, F. Tufvesson, J. Karedal, C.F. Mecklenbrauker, A survey on vehicle-to-vehicle propagation channels, *IEEE Wireless Communications*, 16(6), pp. 12-22.