Distortion-Optimized Retransmission for Low-Delay Robust Video Communications Over 802.11 Intervehicle Ad Hoc Networks

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ABSTRACT

Wireless Access in Vehicular Environment (WAVE) communications standards have recently been approved for trial use and other standards, such as 802.11p, are under active development. However, providing reliable communication services in the vehicular environment still remains a challenging task. Thus efficient solutions are needed to increase robustness and performance. This paper presents a new distortion-optimized transmission algorithm which exploits the non-uniform importance of multimedia data to optimize the transmission of video data captured by on-board cameras to another vehicle in proximity, using ad hoc 802.11 wireless technology and the H.264 video coding standard. A low delay video communication is simulated using actual intervehicle packet loss traces. The results show that the proposed system achieves higher quality video communication (up to 2 dB PSNR) compared to two reference techniques, i.e. the standard MAC-layer retransmission scheme and a delay-constrained retransmission technique.

Categories and Subject Descriptors: C.2.1 [Computer-Communications Networks]: Network Architecture and Design — *Wireless Communication*

General Terms: Algorithms, Design, Experimentation, Performance

Keywords: Multimedia, intervehicle communications, v2v, 802.11, videoconference, ARQ

1. INTRODUCTION

The potential applications of intervehicle wireless communications are numerous. Warning signals are the most immediate applications, but more complex forms of communications, and video in particular, are possible and they could be used by innovative applications such as multi-vehicle-based visual processing of road information for obstacle avoidance and automatic driving, and more generally communications among cars traveling along the same road.

Communications standards such as WAVE are expected to facilitate intervehicle communications, addressing issues such as security, management of multiple radio channels and system resources. The IEEE 802.11p standard, an extension of the well-known 802.11 used in this work, is expected to cover protocol and networking services in WAVE.

Several researchers have already performed vehicle to vehicle and to roadside communication experiments based on the 802.11 standard [5]. Most of these works, however, addressed generic data communication applications and did not exploit the peculiar characteristics of multimedia, such as the non-uniform importance, to optimize the communication performance.

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2. PROPOSED ALGORITHM

In this work we propose a new distortion-based retransmission algorithm and we compare it to two reference retransmission algorithms. The proposed algorithm uses packet importance values, computed according to the method proposed in [1], which provides a low-complexity algorithm to estimate the importance of each packet in terms of the distortion that would be introduced at the decoder by the loss of that specific packet.

Under the assumption that the distortion D of a sequence at the receiver can be computed, as a first approximation, as the sum of the distortion of the not correctly received packets, the D value can be minimized giving priority, at each transmission opportunity, to the packet which presents the highest distortion value. Thus, each time a new packet can be transmitted, the one with the highest distortion value is selected and sent. The validity of this assumption is confirmed by the simulation results. Note that, if the lost acknowledgment case is neglected, the sender always knows the status of the communication by means of the MAC acknowledgment packets, i.e. it knows which packets have been received and which have not. Note also that there are no a priori limits on the number of times a packet can be retransmitted, differently from the other two techniques. However, the average number of retransmissions is similar for all the algorithms. The proposed retransmission algorithm will be referred to as Distortion-Based ARQ (DB-ARQ).

We compared the proposed algorithm with both the standard MAC-layer ARQ scheme, which retransmits non-acknowledged packets up to a certain number of times, given by the retry limit value, and a modification of the standard MAC ARQ scheme, in which packets are immediately eliminated from the transmission queue when they cannot reach the receiving node on time for playback. The algorithm is referred to as "Delay-Constrained MAC-layer ARQ" (DC-ARQ).

Table 1: **Characteristics of the packet loss traces.**

Trace #	0	1	2	3
Avg. packet loss rate (%)	9.6	27.5	28.0	36.7
Avg. car-to-car distance (m)	320	360	398	415

Table 2: PSNR performance (dB) of the three ARQ techniques. Retry limit is seven, maximum delay is set to 150 ms (best conditions for all schemes.) The value in brackets is the encoding quality.

	Road video (38.83)			Driver's face (44.16)		
Trace #	Std.	DC-	DB-	Std.	DC-	DB-
0	38.36	38.40	38.54	43.38	43.55	43.80
1	34.09	35.23	35.78	38.80	40.19	40.89
2	33.53	34.79	35.17	39.06	39.97	40.29
3	31.58	32.93	33.82	37.32	37.82	39.11

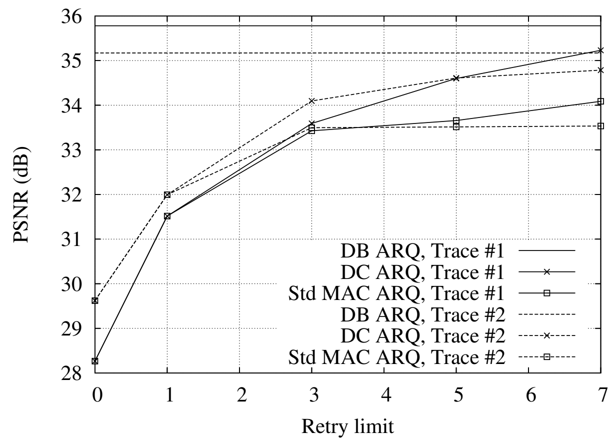

Figure 1: PSNR performance comparison. Maximum delay is 150 ms, sequence: "road video".

3. SETUP AND RESULTS

We performed trace-based [3] (see Table 1) packet level simulations of an 802.11b transmission between two vehicles traveling along the same road. Main simulation settings are: 640x480 video, 30 fps, fixed quantization stepsize, H.264 codec v.JM11, IP/UDP/RTP protocol stack, 12-frame GOP with 11 P-frames, video segment length of 30s, results averaged over four simulations for each loss trace.

We focus on two different application scenarios, which however present similar constraints. In the first one, road video is captured from a front on-board camera, then compressed with the state-of-the-art H.264 [4] video compression standard and sent to the second vehicle, which can use it, for instance, for cooperative visual processing of road information. In the second scenario, the video of the driver's face is captured by an on-board camera and sent to the other vehicle, thus simulating, for instance, a conference application (unidirectional for video) between the driver and a passenger in the other car. The video of the driver's face might be important to prevent potentially dangerous situations. The other speaker, in fact, looking at the driver's face, might avoid distracting him in case he is temporarily busy with driving actions such as lane change, turns etc.

In order to evaluate the performance of the proposed schemes, we used the PSNR distortion measure. Figure 1, which refers to the case of transmission of road video, shows a performance comparison for the three schemes, as a function of the retry limit for the standard MAC-layer ARQ and the DC-ARQ algorithms. The video quality increases as a function of the retry limit for both the standard MAC-layer ARQ and the DC-ARQ algorithms. When they achieve the maximum performance, that is the retry limit is set to seven, the proposed DB-ARQ technique still presents a gain up to 0.5 dB and 1.6 dB over the DC-ARQ and MAC-layer ARQ techniques, respectively. Moreover, note that discarding packets which cannot arrive on time at the receiver (DC-ARQ algorithm) greatly improves the quality performance over the standard MAC-layer ARQ, more than 1 dB when the retry limit is equal to seven. The results for the case of the camera aimed at the driver's face, not shown due to space constraints, are similar in performance trend and gain.

For completeness, Table 2 compares the PSNR performance obtained for all the four packet loss traces presented in Table 1, showing the consistency of the performance gain achieved by the proposed DB-ARQ technique over different communication conditions. For the case of Trace #0, the performance gap is limited since most packet losses can be recovered, thus values are close to the maximum, that is the quality achieved by the H.264 encoding process, shown as a reference in brackets.

4. CONCLUSIONS

We presented a new ARQ algorithm which can effectively transmit video data captured by an on-board camera to another vehicle in proximity using 802.11 wireless technology with very low delay. The algorithm is based on exploiting the non-uniform importance of packets in terms of the distortion which they may cause at the decoder in case of loss. Results obtained by simulations using packet level error traces show that the proposed algorithm achieves a consistently higher quality video communication compared to two reference ARQ techniques, with gains up to about 2 dB PSNR.

5. ACKNOWLEDGMENTS

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