Optimizing the Transmission of Multimedia Content over Vehicular Networks

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***Abstract*—The multi channel operation mechanism of the IEEE 1609.4 protocol, used in vehicular networks, may impact network performance if applications do not care about its details. Packets delivered from the application layer to the MAC layer during a Control Channel time slot have to wait to be transmitted until the following Service Channel time slot arrives. The accumulation of packets at the beginning of this time slot may introduce additional delays and higher collision rates when packets are transmitted. In this work we propose a method, which we call SkipCCH, that deals with this issue in order to make a better use of the wireless channel and, as a consequence, increase the overall network performance. With our proposal, streaming video in vehicular networks will provide better reconstructed quality at the receiver side under the same network conditions. Furthermore, this method has particularly proven its benefits when working with QoS techniques, not only by increasing the received video quality, but also because it avoids starvation of the lower priority traffic.**

***Index Terms*—MAC layer, Multimedia, Video, Wireless Networks, VANET**

I. Introduction

Among the applications and services of Intelligent Transportation Systems (ITS) several applications have emerged that require efficient video transmission capabilities, from entertainment/consumer related applications (video conferencing, contextual advertising, tourist information, etc.) and road safety (assisted overtaking, blind spot removal, etc.), to applications that can be crucial for the life of the passangers inside a vehicle (automatic emergency video call - eVideoCall, etc.). Video transmission over vehicular networks is a challenging task due to several factors such as the high bandwidth required, the continuously changing network topology (high mobility), and the wireless channel (shared medium, Doppler effect, signal shading, poor coverage, etc.).

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In this work, video transmission over Vehicular Ad-hoc Networks (VANETs) and its performance at the MAC (Medium Access Control) layer have been studied.

From the analysis that we did, a new mechanism is proposed to reduce packet loss (mainly due to collisions). This method works better when the QoS (Quality of Service) feature of protocol IEEE 802.11p is used, which is a recommendation for protecting video packets in critical and road safety related ITS applications.

The remainder of this paper is organized as follows. First, in Section II, some works in the literature related to the analyzed issue are presented. Next, in Section III, the proposed mechanism is depicted. In Section IV, the setup of the simulation tools, vehicular network scenario, and video sequence used are explained. Some results of this ongoing research work are presented and discussed in Section V. Finally, in Section VI, conclusions are drawn and some future work is introduced.

II. Related Work

By analyzing the experimental data of our previous works [1], we detected that, when transmitting video packets, there were higher packet losses at the MAC layer just at the beginning of the Service Channel (SCH) time slot. After analyzing it, we determined that the issue was due to the synchronization effect caused by the channel hopping of the IEEE 1609.4 protocol. This happens because the video packets which are delivered to the MAC layer during the Control Channel (CCH) time slot are scheduled for transmission at the beginning of the next SCH time slot. This fact causes an accumulation of packets and they are transmitted in bursts. It has a negative effect especially when sending video data. This issue has also been studied in works like [2], but not for video streaming applications (with high bandwidth demands and the intrinsic characteristics of compressed video data).

Solutions for this issue have been presented in works like [3] and [4]. In these works, the authors analyze this issue for the transmission of video data, and provide a solution by aligning this transmission to the SCH time slot, but they do

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not take into account the video frame rate. The way in which we address the solution to the issue takes into consideration that the frame rate of the video sequence has to be maintained in order to keep a good Quality of Experience in the final reconstructed video sequence. Also, they do not analyze the different scenarios that may appear when QoS is used.

Our work takes into account both the specificity of the data transmitted (video streams) and the cases where QoS is utilized.

III. Proposed Method

In the WAVE (Wireless Access in Vehicular Environment) protocol stack, used in VANETs, the MAC layer is driven by IEEE 802.11p and IEEE 1609.4 protocols. The first one implements QoS by means of EDCA (Enhanced Distributed Channel Access), which allows the differentiation of four data packet types and the assignment of a different priority to each one of these four Access Categories (AC). These categories, ranging from the one with the highest priority to the one with the lowest priority, are the following: AC_VO (voice), AC_VI (video), AC_BE (best effort), and AC_BK (background). The MAC layer handles one packet queue for each one of these categories. The use of the AC_VI queue for the transmission of critical video data packets (used in road safety and emergency applications) has proven to be very useful in the protection of the video stream over the rest of the network traffic.

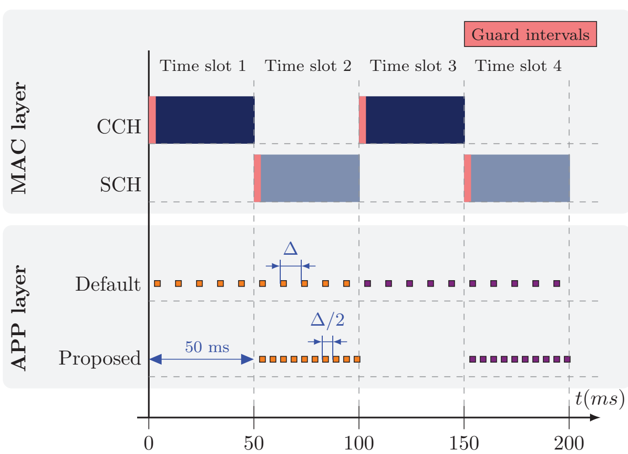

Fig. 1. Multi channel operation at the MAC layer for the WAVE architecture (top), and packet scheduling for the default and proposed methods at the Application layer (bottom).

On the other hand, the IEEE 1609.4 protocol is in charge of multi-channel operation. This mechanism works as follows. There is a Control Channel (CCH), where vehicles transmit safety messages and beacons with vehicle information, and there are four Service Channels (SCH), where vehicles transmit the applications' data. Although the CCH and the SCHs use different frequency bands, they do not transmit simultaneously. There is a time division multiplexing to perform the channel switching operation. The CCH and the SCHs use alternatively time slots of 50 ms to carry out their communications. At the beginning of each time slot there is a guard interval (of 4 ms), which is used to guarantee that every device has completed the switching to the corresponding channel. This mechanism is represented in the upper part of Fig. 1, where the time division for CCH and SCHs is clearly depicted.

Let's now explain how the original method works and, after that, the new proposal will be presented. Regarding video streaming, the transmission of data packets bursts has a negative effect in the final reconstructed video. On the one hand, the packet loss rate usually increases and, due to the characteristics of compressed video data, the resilience against packet losses also decreases, i.e., at a same packet loss ratio, isolated packet loss is less harmful than burst packet loss. In order to avoid the negative consequences of transmitting data in bursts, the original method sends video data by distributing the available time among the network packets. To carry out this scheduling, the inter-packet time, which we name Δ, is computed first by dividing the total time between the number of video packets of the sequence. If the time to begin sending the video is t_0, then the first packet will be scheduled in the application (APP) layer to be sent at that moment ($t_1 = t_0$), and the following packets will be scheduled to be sent with an increase of Δ ($t_2 = t_1 + \Delta$, $t_3 = t_2 + \Delta$, $\ldots$). The graphical representation of this scheduling is shown in the lower part of Fig. 1 labeled as "Default". The corresponding implementation is depicted in the flow chart in Fig. 2 (SkipCCH = "off"). In this operation mode, if a packet is scheduled in APP layer at a time t_i which corresponds to a SCH time slot (slots 2, 4, 6, 8, ...), then it will be sent to the MAC layer and the MAC layer will send it to the network. But if t_i corresponds to a CCH time slot (slots 1, 3, 5, 7, ...), then the packet will be sent to the MAC layer, but it will remain in the corresponding SCH queue until the next SCH slot arrives. All the queued data packets will be sent as a burst at the begining of the next SCH slot, leading to a great number of collisions and, consequently, packet losses.

To avoid this issue we have proposed a new method (which we have named SkipCCH) for scheduling video packets at the APP layer. The APP layer synchronizes with the SCH in such a way that video packets are only scheduled aligned with the SCHs time slots. Now, the inter-packet time will be $\Delta/2$ so that all the video packets fit in SCH time slots (as we skip the CCH time slots, the frequency has to be doubled so we halve the inter-packet time). Also, if t_i corresponds to a CCH time slot, then the scheduling time will be increased by the size of one time slot (50 ms), so that the packet is scheduled within the next SCH time slot. This mode is graphically represented in the bottom part of Fig. 1 labeled as "Proposed" and its implementation is shown in Fig. 2 (SkipCCH = "on").

IV. Simulation Framework

In order to evaluate our proposal, we have used a simulation setup which is similar to the one used in some of our previous works [1]. We have used the Video Delivery Simulation Framework over Vehicular Networks (VDSF-VN)

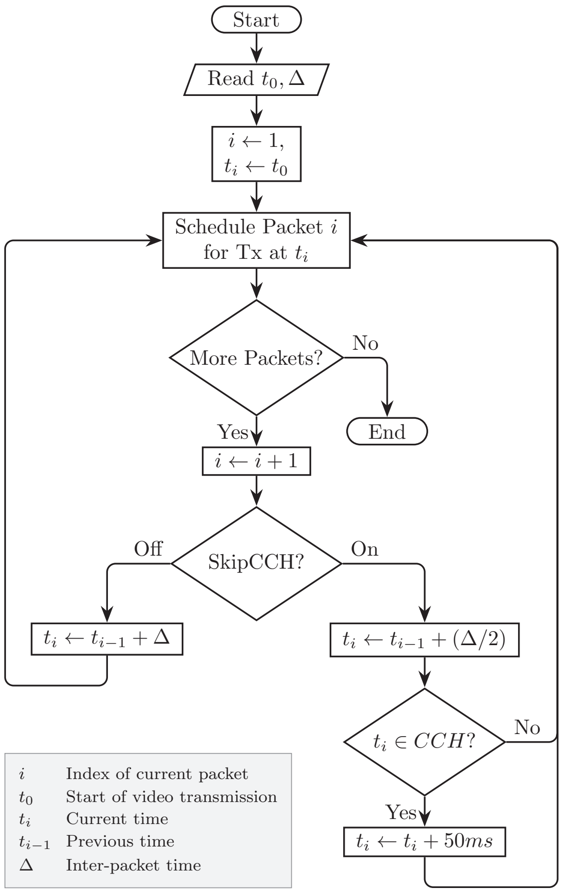

Fig. 2. Flow-chart for the original (SkipCCH=Off), and the proposed (SkipCCH=On) methods.

[5], a simulation tool that simplifies, overall, the performance evaluation process, from the design of the appropriate vehicular network scenario (maps, nodes, mobility, etc.) and the simulation management (scheduling, running, results storage), up to the processing of evaluation results and their representation (graphs, plots, reports, etc.). This framework uses some public domain simulators which work together to simulate with a high degree of fidelity the vehicular wireless network. This third-party software consists of the OMNeT++ v5.6.2 network simulator [6], together with the Veins (VEhicles In Network Simulation) v5.1 framework [7], and the SUMO (Simulation of Urban MObility) v1.8.0 mobility simulator [8].

With respect to the network scenario, we have downloaded a real map of a 2000m × 2000m square area of Las Vegas (around Dean Martin Drive) by using OSM (Open Street Map) database [9] and converting all the map data to a format which can be handled by SUMO, OMNeT++ and Veins, with the help of our mentioned toolbox (VDSF-VN). This area is shown in Fig. 3. For the experiments, we have placed an RSU (Road Side Unit) near the center of the scenario. This RSU is a fixed antena, part of the infrastructure, which is in charge of transmitting the video sequence. Also, in the scenario, we have inserted 11 vehicles which will be driving near the RSU at a maximum speed of 14 m/s (50 km/h). One of them is the video client, the one which will receive the video stream. The other 10 vehicles will be injecting background traffic at different rates to simulate real network conditions, ranging from ideal conditions (no background traffic) to conditions which lead to channel saturation. Each one of the 10 vehicles injects packets with a payload of 512 bytes (4096 bits) at these different packets-per-second (pps) rates: 0 pps, 12 pps, 25 pps, 50 pps, 75 pps, and 100 pps. These pps rates provide a total background traffic of 0 Mbps, 0.49 Mbps, 1 Mbps, 2 Mbps, 3 Mbps, and 4 Mbps, respectively. The total time of the simulation is 200 s.

For the compression of the video sequence, we used HEVC (High Efficiency Video Coding) reference software encoder HM v9.0 [10]. The selected video sequence is named "BasketBallDrill" and belongs to the collection of video sequences included in the Common Test Conditions of HEVC [11]. This sequence has a resolution of 832×480 pixels, a rate of 25 fps (frames per second), and a length of 250 frames. The compression of the sequence has been carried out in All Intra (AI) mode, with a value of 31 for the Quantization Parameter (QP), what has yielded a resulting bitrate of 3.4 Mbps.

Fig. 3. Selected area of Las Vegas downloaded to create the scenario of the tests.

V. Results and Discussion

In this section, some results of the present ongoing research work will be presented and discussed. In a previous work [1], we studied video transmission over VANETs applying QoS techniques to priorize the video stream data packets. The results have shown great improvements in network performance, both in the reduction of packet losses and in the final quality of the reconstructed video sequence. QoS is highly indicated for video streaming, especially for critical and road safety related ITS applications. In the present work, we evaluate a new mechanism, which we have named SkipCCH, both in the presence and in the absence of QoS techniques. We have run our simulations for the six different background traffic rates and enabling and disabling both, QoS and SkipCCH.

In Fig. 4, we show the number of times that the MAC layer has entered into a backoff state to invoke the contention window. This measures the number of times that the nodes invoke the contention window. We can see that both the ○ and △ curves (QoS=off; SkipCCH=off/on) have values very similar between them for all the range of background traffic, and that the one with the SkipCCH method activated is slightly better. On the other hand, the two curves which represent the measurements when QoS is on (× and +) show a noticeable increase in the number of times into backoff. This result might lead us to think that, when we use QoS, there is a poorer utilization of the channel and lots of packets remain in their queues waiting to be transmitted. But, in fact, as the contention windows used for the AC_VI queue are narrower than the normal ones, the packets in those windows are waiting less total time, even if there is a higher number of times into backoff. This leads to an optimization of the access to the wireless channel.

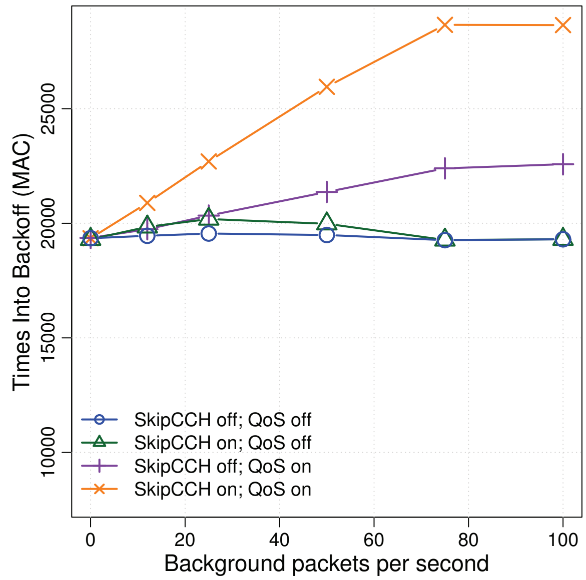

Fig. 4. Times into backoff at the MAC layer for different network conditions.

In Fig. 5 and Table I, the ratio of the received video packets with respect to the overall video packets sent is shown for the different background traffic rates. We can see that the experiments with SkipCCH enabled always have a better packet reception ratio. When QoS is used, which is the recommended case for the delivery of critical video streams, the difference between the SkipCCH and non-SkipCCH experiments is even higher, and the improvement is in the range 4%-6% for all of the background traffic conditions. In this chart, in line with the results of our previous works, we can also appreciate the great advantage of using QoS, especially for medium to heavy background traffic loads.

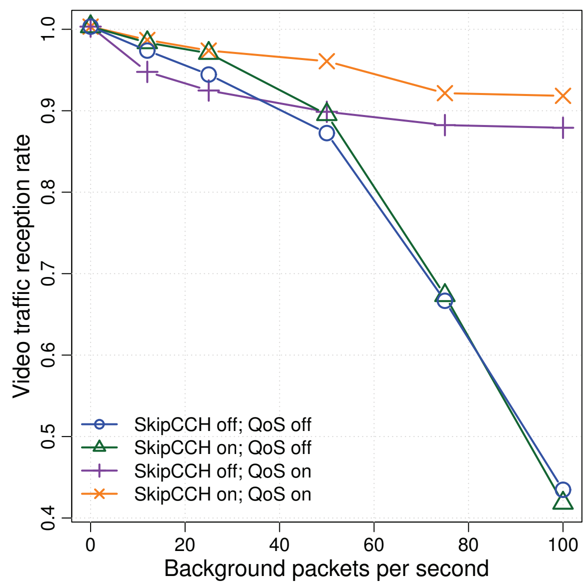

Fig. 5. Video traffic packet reception ratio for different network conditions.

Finally, in Fig. 6 (the corresponding data is in Table II), we show an interesting chart. This chart shows how background traffic is affected by the different combinations of enabling/disabling both QoS and SkipCCH. As well as the protection of critical video packets, another objective is not to excessively penalize the rest of the network traffic. As it can be seen, when the SkipCCH method is enabled a higher background packet delivery performance is achieved, especially when using the QoS service. When the SkipCCH method is not used, the activation of QoS heavily penalizes the background reception ratio. But if we add the SkipCCH method to the QoS experiment, this penalization decreases in all the range and, especially, for low to medium background traffic loads, where the reception ratio increases in the range of 3%-11%.

Therefore, from figures 5 and 6, we can come to the conclusion that applying the SkipCCH method to the video transmissions not only always improves the video packet reception ratios, but also reduces the negative impact on the rest of the network traffic.

TABLE I
VIDEO TRAFFIC RECEPTION RATIO

VID Reception Ratio		***Background Packets Per Second (pps)***					
SkipCCH	***QoS***	0	12	25	50	75	100
off	off	1.00	0.97	0.94	0.87	0.66	0.43
on	off	1.00	0.98	0.97	0.90	0.67	0.42
off	on	1.00	0.95	0.93	0.90	0.88	0.88
on	on	1.00	0.99	0.97	0.96	0.92	0.92

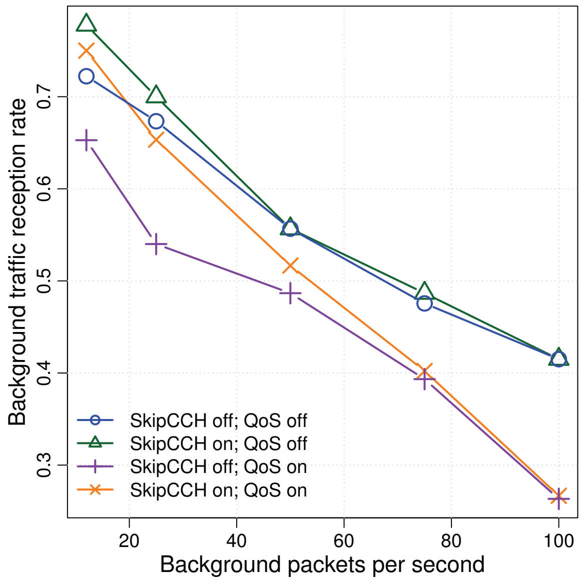

Fig. 6. Background traffic packet reception ratio for different network conditions.

TABLE II
BACKGROUND TRAFFIC RECEPTION RATIO

BK Reception Ratio		***Background Packets Per Second (pps)***				
SkipCCH	***QoS***	12	25	50	75	100
off	off	0.72	0.67	0.56	0.48	0.42
on	off	0.78	0.70	0.56	0.49	0.42
off	on	0.65	0.54	0.49	0.39	0.26
on	on	0.75	0.65	0.52	0.40	0.27

VI. CONCLUSIONS AND FUTURE WORK

In this work, a method to improve the packet reception ratio of video streaming over VANETs has been proposed and evaluated. This method shows good performance, moderating the impact on performance of multi channel operation which appears at the beginning of the SCH time slots, especially for video delivery applications (which require a high bandwidth). The proposed mechanism skips the CCH time slot in the scheduling of the sending of video packets in the application layer and distributes this scheduling proportionally within the next SCH time slot, reducing the packet loss as a result. It has shown good performance in all conditions, especially when it is combined with QoS. It has also shown good performance in reducing the penalization that the QoS mechanism causes to the rest of the network traffic.

In order to extend and complete the present ongoing work, we will evaluate the performance of the SkipCCH mechanism regarding the final reconstructed video quality of the transmitted sequence. Also, we plan to add two more HEVC encoding modes, LP (Low-delay P) and LB (Low-delay B), and adapt the QoS mechanism to the type of every single frame which is being transmitted.

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