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Uncoordinated Multi-user Video Streaming in VANETs using Skype

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***Abstract*—Real-time video delivery in Vehicle-to-Infrastructure (V2I) scenario enables a variety of multimedia vehicular services. We conduct experiments with Dedicated Short Range Communications (DSRC) transceivers located in the mutual proximity and exchanging Skype video calls traffic. We demonstrate that the lack of coordination between the users both at the application as well as Medium Access Control (MAC) layers results in problems with quality of service provisioning even for the setup without vehicular mobility.**

I. INTRODUCTION

Real-time multimedia services such as Whatsapp, Viber or Skype [1] are popular among users around the globe nowadays. Typically users make voice or video calls from computers, tablets and other devices over Internet via an wireless networking technology such as 4G broadband infrastructure base stations or IEEE 802.11 Wi-Fi access points. In vehicular case, users are mobile and may perform calls e.g. while driving a car. In such scenarios, dedicated ETSI ITS-G5 or IEEE 802.11p DSRC protocols might be used.

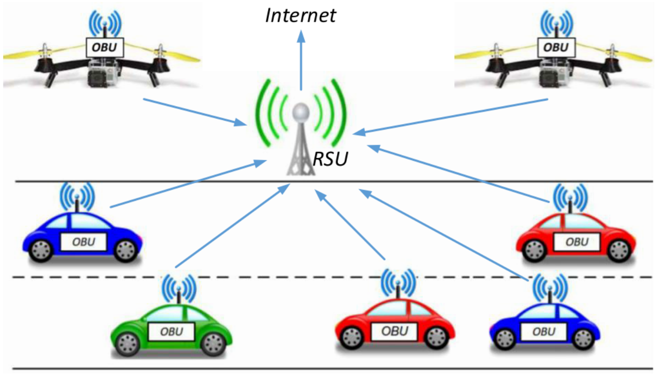


Fig. 1. Vehicle-to-Infrastructure scenario

The IEEE 802.11p follows an approach of the entire Wi-Fi standards family and adopts Carrier Sense Multiple Access (CSMA) as a Medium Access Control (MAC) protocol. Therefore, each user contends for the transmission opportunity in the broadcast wireless channel. In contrast to the 4G cellular networks, the IEEE 802.11p road-side unit (RSU) does not provide centralized scheduling of channel resources among transmitting users. Therefore, one of the main challenges for video transmission in the CSMA-based vehicular ad-hoc network (VANET) is the uncoordinated bandwidth allocation which would control channel congestion (e.g. when the users upload a lot of video data simultaneously) and provide fair allocation of the channel resources (e.g. when each user gets the same channel bandwidth).

Independently on the enabling communication technology and architectural solution, we assume that future vehicles will be equipped by On-Board Units (OBUs) consisting of video camera, video codec and wireless transceiver [2]. A video data from each OBU will be compressed and transmitted to a RSU in the Vehicle-to-Infrastructure (V2I) VANET scenario, Fig. 1. This will enable a variety of novel dedicated multimedia services [3] such as in-vehicle video surveillance, when public transport is monitored in real-time by the control center to help counteracting crimes, or traffic conditions video surveillance, where the information from the geographical area of interest is transmitted from the vehicles to the management center [4], [5]. At the same time traditional Skype video calls between road users remain an attractive application in vehicular scenarios and their quality provisioning deserves more attention.

Skype the is end-to-end solution which estimates available bandwidth and packet loss rate with the use of sophisticated channel estimation algorithm and, depending on the channel situation, makes a decision about parameters of the video compression and transmission, i.e., target video bit rate, output frame resolution and frame rate for the video codec as well as the level of video bit stream protection [6]. One of the basic assumptions for such a system is that users participating in each call do not coordinate the utilization of the communication channel among themselves. While this is a valid approach for the video calls over large-scale heterogeneous networks (e.g. Internet), it becomes limiting when the users are located within the same wireless local area network. As a result, one can expect that in VANETs the a fair bandwidth allocation for the Skype users participating in the calls simultaneously will not guaranteed. However, up to the authors' knowledge, there are no published experimental results which demonstrate the unfairness of the bandwidth allocation in such a scenario of a physical proximity between the users.

In this work-in-progress paper we evaluate the bandwidth allocation mechanism of an uncoordinated Skype users in a simplified Dedicated Short Range Communications (DSRC) environment and compare the visual quality of the users. We use a testbed with the interconnected 5.9 Ghz DSRC transmitters. The main difference from the real vehicular conditions is the radio environment: in the testbed all the users are located in a mutual proximity and they are all fixed during the experiment. In a real-world V2I scenarios the video quality provided by Skype might be even worse than reported here due to the user mobility which might result in complex patterns of wireless links quality fluctuations. Our results show that the uncoordinated bandwidth allocation does not lead to a satisfactory fairness performance, because the allocated bit rate (and as a result – the video quality) for each user differs significantly. We conclude that at least the basic multi-user coordination is required.

The paper is organized as follows. Section II presents the experimental setup and methodology. Section III provides the experimental results, while Section IV concludes this paper.

II. TESTBED AND EXPERIMENT DESCRIPTION

A. Estimation of upload bit rate and visual quality

In the Skype network each client should be able to set up a table of reachable nodes, such table is known as the host cache (HC) and contains the IP address and the port number of each node. A Skype client, once logged in, opens a TCP and a UDP port for listening. Usually a TCP channel is required for background communication of information about the network, while the UDP channel is used for payload data transmission between the users. Skype provides certain information about its operation such as video codec type, upload video bit rate and packet loss rate via the *Call Technical Info*.

The main challenge in Skype operation is the requirement to have Internet connection for all the users. When the application is launched, it sends the IP address of the computer to its servers and receives back those the IP addresses which are connected to Skype. When the call is requested, the IP address is the key to find the computer to call, i.e., a connection to the server is always required for both the users as long as the call is not started. Therefore, in the experiments conducted, all users are connected to the Internet. Herewith, 5 minutes after the call has been initiated, Internet connection is plugged off, so that only local IEEE 802.11p DSRC network is used.

We apply techniques similar to the ones proposed in [6] to send the video bit rate measurements. A test video sequence has been used as an input for a camera emulator ManyCam [8], which sends the video sequence to Skype in a loop, see an example for a pair of users in Fig. 2. All the users participated in the experiment have the same test video sequence Foreman (352×288@30Hz) available in [7]. When Internet connection is plugged off, the upload video bit rate measurements start for all the users.

Skype does not allow storing a received video stream for visual quality measurements. To estimate an objective visual quality we calculate an *equivalent* metric in the following way. First, we compress the test video sequence using real-time software implementation of the H.264/AVC video coding standard [9] at different video bit rates and calculate the Peak Signal-to-Noise Ratio (PSNR) as

$$PSNR = 10 \lg \frac{(2^B - 1)^2}{d}, \tag{1}$$

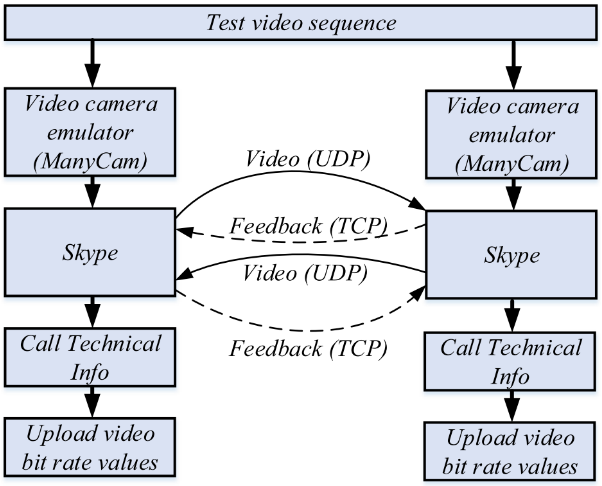


Fig. 2. Video bit rate measurements for two Skype users

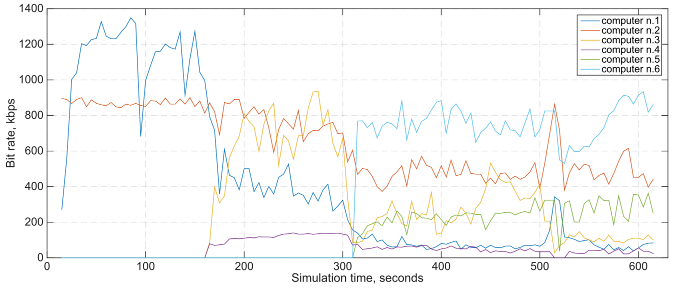
Fig. 3. The testbed equipment

where $B = 8$ is number of bits per pixel in uncompressed video format, and

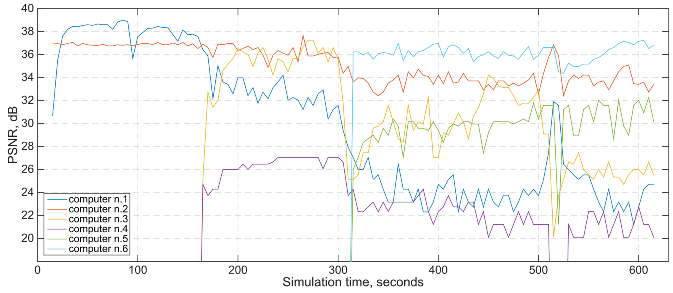
$$d = \frac{1}{F \cdot W \cdot H} \sum_{i=1}^{F} \sum_{x=1}^{W} \sum_{y=1}^{H} \Big(\mathbf{X}_i(x,y) - \hat{\mathbf{X}}_i(x,y) \Big)^2, \tag{2}$$

where $\mathbf{X}_i(x,y)$ and $\hat{\mathbf{X}}_i(x,y)$ are luminance values of pixels with coordinates (x,y) in frame i in the original and reconstructed video sequences, respectively, $W \times H$ is a video frame size in pixels, and F is number of frames in a sequence.

The equivalent PSNR shows the video quality under the assumption that the distortion in the received video is caused only by the quantization during video compression and does not take into account distortion caused by the packet losses in a channel, i.e., it is an upper bound of the actual video quality. Finally, we assign corresponding PSNR values for the measured upload video bit rate.



(a) Uplink bit rate



(b) Equivalent visual quality in PSNR

Fig. 4. Resource allocation results for six Skype users

B. *Experiment description*

The experimental testbed is illustrated in Fig. 3. In the scenario considered, three pairs of Skype users (six computers in total) call each other and compete for the broadcast IEEE 802.11p CSMA wireless communication channel. The main goal of the experiment is to evaluate Skype video bit rate allocation in case when increasing number of users launches their video transmissions, what mimics the dynamic number of OBUs with simultaneous calls under the coverage area of the RSU in VANETs.

To achieve the effect of interest, at the beginning of the experiment the first pair of users (computer 1 and computer 2) establishes a call. Then after 150 seconds the second pair of users (computer 3 and computer 4) starts their call, and after 150 seconds more the third pair of users (computer 5 and computer 6) starts their call. Total duration of the experiment is ten minutes. Taking into account the IEEE 802.11p MAC layer overheads [10] as well as the allocations between the uplink and the downlink, the overall upload bandwidth for all the Skype users appears to be not higher than 2.4 Mbps. More technical information about the experimental testbed can be found in [11].

III. EXPERIMENTAL RESULTS

Fig. 4 shows the upload video bit rate and the corresponding equivalent visual quality obtained during the experiment. With this data as well as the information collected from the *Call Technical Info*, we observed the following effects:

- Even when all the users are transmitting the same video sequence compressed by the same video codec, the upload video bit rates for each user are different. For example, in the case of 6 users an average bit rate is 300 kbps per user, while Skype allocates from 50 to 900 kbps. Moreover, this large difference in a bit rate allocation is not eliminated when the number of users in the network is kept fixed during the 300 sec of the experiment.
- Some users have very good visual quality, while others have an unacceptably low video quality (lower than 24 dB in PSNR). For example, if the bandwidth is allocated equally, then the PSNR value would be 31.5 dB for the 6 users. However due to the unfair resources allocation we observe the PSNR values in the range from 20 to 36 dB.
- In some cases a video bit rate allocated to a user can be very close to zero what practically means the termination of the video delivery.
- Addition of a new active user in the network leads to a significant increase of a packet loss rate, so that during a short interval of time (1–2 sec) all the users experience bad video quality.

IV. CONCLUSION

The performance of the uncoordinated multi-user Skype video streaming in vehicle-to-infrastructure scenario is not satisfactory since there is a significant difference in a visual quality of video received by different users as well as high packet losses when a new user starts the call. We conclude that at least basic coordination between the users is crucial to improve the fairness of bandwidth allocation and improve the quality of video service. This work-in-progress study is towards the design of a support for the high-quality video calls within the IEEE 802.11p-enabled platoons [12].

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