Analysis of Video Streaming Performance in Vehicular Networks

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Abstract—**Vehicular Ad-hoc Networks (VANETs) have been mainly motivated for safety applications, but non-safety applications can also be very helpful to impulse vehicular networks. Among non-safety applications, video streaming services can provide attractive features to many applications and can attract a great number of users. However, VANETs high mobility characteristics and packet loss during communications blackouts difficult the deployment of video services in vehicular networks. In this paper, the performance of a video streaming service has been analyzed to study the deployability of a video on demand service in a highway environment for vehicular users. It has been analyzed the packet loss produced by network reconfiguration during handoffs and its influence in the video streamed quality. Using Mobile IP without and with fast handoffs we have gauge the effects of mobility over the video transmission. We show that although fast handoffs techniques minimize blackouts, they limit the deployment of video streaming services in vehicular networks.**

Index Terms—**vehicular network emulation, mobility management, video streaming.**

I. INTRODUCTION

Mobility has changed the way people communicate. Nowadays, as Internet becomes more global, demands for mobility are not restricted to single terminals. Road and vehicle circulation systems are one of the most important infrastructures and are supporting the humans daily life. Intelligent Transportation Systems (ITS) aim to optimize the social costs of road systems and enhance their security as well as drivers comfort by allowing such services as fleet management, navigation, billing, multimedia applications, etc. Vehicular Ad-hoc Networks (VANETs) are becoming a reality mainly focused on navigation safety applications, but vehicular networks are not only useful for safety applications. Another kind of applications are also very important for the successful deployment of vehicular networks. In this way, infotainment services offer information and/or entertainment, e.g., Internet access, multiplayer games, multimedia applications, videoconference. These services can be an impulse not only for users, but also for network operators that could find infotainment applications an interesting business opportunity.

In this sense, vehicular networks are mainly impulsed in Europe by Car2Car Communication Consortium [1]. The C2C-C Consortium is an industry consortium of car manufacturers and electronics suppliers that focuses on the definition of an European standard for vehicular communication protocols. The consortium defines a C2C-C protocol stack that offers specialized functionalities and interfaces to safety-oriented applications and relies as a communication technology on a modified version of IEEE 802.11 [2]. This protocol stack is optionally placed beside a traditional TCP/IP stack (see Fig. 1), exclusively based on IPv6, which is mainly used for non-safety applications or potentially by any application that is not subject to strict delivery requirements, including Internet-based and multimedia applications. To allow vehicles to move from one network to another while maintaining the connection to the Internet, the C2C-C architecture optionally uses a Mobile IP solution [3] for host mobility or a Network Mobility (NEMO) Basic Support solution [4] for network mobility.
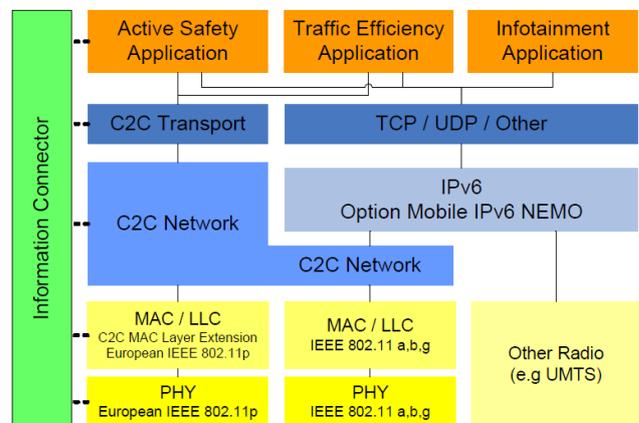
Fig. 1. Protocol architecture defined by the Car-to-Car Communication Consortium[1]

Multimedia data, specially video, if feasible, is very useful for entertainment, and it also will help to enhance navigation safety. For example, video on demand services could be very interesting during long travels in highways. Another example of video streaming services in vehicular networks are videos clips of nearby accidents or dangerous situations. These videos can provide drivers warning advertisements with precise information. This will allow them to make a more informed decision (whether to proceed or turn back) based on

personal priorities and/or on vehicle capabilities.

While a huge number of video-related applications are expected to be deployed in a VANET, in this article we focus on video services where network mobility is involved, e.g., video on demand services. These video services will be deployed in environments where there exists a network infrastructure. Thus, a video server is placed in the infrastructure domain and vehicular nodes access to this server during a travel. In that case, vehicular nodes need global mobility to be reached from the Internet. In vehicular networks, packets may be corrupted and lost due to channel errors and collisions. These type of packet losses tend to be random and locally diverse and thus can be countered efficiently with a local recovery strategy. However, in a scenario where a video on demand service is offered, the main packet loss cause is the great amount of handoffs due to network mobility during the whole communication.

There exists several studies in the literature related with video streaming services in VANETs, such as [5], [6]. However, these studies are focused in video streaming applications where the communications take place among peers, i.e., inter-vehicular communications, and the analysis of how video streaming services are affected by ad-hoc routing protocols or medium access control protocols in vehicular networks. There also exists an article [7], that studies network mobility performance (e.g., packet loss rate and delay) in similar scenarios. This paper can be considered an extension of this work analyzing a specific application - video on demand services in vehicular networks - in the same context

The novelty of this paper is the analysis of video on demand services in a highway infrastructure scenario using real video applications in emulated vehicular networks and how network mobility protocols limit the quality of a video streamed. Firstly, we present a study for the potential deployment of video on demand services in vehicular networks where a Mobile IP solution is used. Then, we compare the results with a vehicular network where Fast Handovers for Mobile IP (FMIP) are used for seamless communications during network mobility handoffs [8]. Moreover, we analyze the quality obtained in the movie clip streamed and we measure the video degradation during communication blackouts.

The reminder of this article is organized as follows. In Section II, the tools used for the simulations are described. The video streaming performance evaluation is presented in Section III. The reference scenario is presented in Section III-A, and the simulations results are analyzed in Section III-B. Section IV concludes the paper.

II. VEHICULAR NETWORK EMULATION

Academia and industry use simulation tools to debug and test the reliability and QoS of several applications. This makes simulation a very important step towards the deployment of wireless communication networks. A simulation is only useful if the simulation results match as closely as possible with the testbed results. However, despite all the technological achievements and cutting edge research occurring in the field

of mobile wireless networks, there are growing concerns regarding the reliability of results generated by wireless network simulators.

Emulation means the ability to introduce the simulator into a live network using a soft real time scheduler which tries to tie the event execution within the simulator with the real time. Emulation permits to test real time applications in a simulated network. The emulation is divided in three modules based on its functionality. Moreover, emulation provides a more realistic approach. In this sense, in this article we have developed an application to emulate video streaming over VANET. Figure 2 shows the modules of the emulation platform: application virtualization, network emulation and traffic mobility simulation.
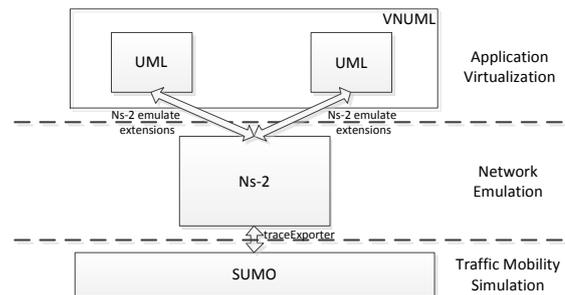
Fig. 2.   Vehicular network emulation

The emulation modules are detailed in the paragraphs below:

A. Application Virtualization

The emulated network consist of a set of User Mode Linux (UML) [9] virtual machines running in a host machine. The UML virtual machines virtualize the network nodes. In our simulations, a UML machine represents the video server in the wired domain, and another UML machine represents a vehicular node in the wireless domain. The applications run inside the virtual machines and do not notice that they communicate through an emulated network, so the applications are executed as in a real-system. The network is emulated as a vehicular network transparently to the tested applications. UML virtual machines are managed using VNUML software [10].

B. Network Emulation

To emulate the network is used the widely known network simulator ns-2 [11] using the emulation feature, providing the ability to introduce the simulator into a live network and emulate a network that provides real applications in real time. This simulator is actively used for wired and wireless network simulations. We have introduced some to ns-2 in order to enhance its capabilities. In this sense, ns-2 Emulation Extensions [12] are used to enable ns-2 to emulate wireless networks

using UML virtual machines. These extensions implement an interface between virtual machines and ns-2 using TAP devices [13]. They also improve the emulation of wireless networks in ns-2, enhancing the scheduler of the network simulator for the correct emulation of wireless networks. Another extension added to ns-2 is NO Ad-Hoc Routing Agent (NOAH) [14]. This extension emulates the behavior of a mobile node without using adhoc routing, so the mobile nodes only connect with the base stations. Finally, to provide FMIP support an extension developed by Robert Hsieh [15] is also added to ns-2.

C. Traffic Mobility

The last part of the emulation platform is the traffic mobility module. This module is responsible for creating the node movements such as a vehicle following the different itineraries defined by the road maps and the different configurable parameters, e.g., max speed limits, road lanes, crossroads, speed and acceleration of the cars, etc.

The traffic mobility module is mainly formed by SUMO [16]. The emulated network uses this traffic mobility simulator to provide node mobility traces to ns-2. This mobility traces provide to the network simulator/emulator information about the nodes positions and the speed of their movements necessary to calculate the network conditions. The mobility traces are obtained using the tool provided with SUMO software called traceExporter, which converts the dumps from SUMO to traces that can be used in ns-2.

III. Video Streaming Performance

Video streaming over vehicular networks can actually be applicable. The car engine can provide enough power for intensive data computation and communication. Vehicles can also be provided by large *On-board* storage. Thus the node in vehicular networks is powerful enough to forward continuous video data to other vehicles or roadside receivers. Furthermore, the IEEE 802.11g standard can support up to 54Mbps transmission rate, or the vehicular specific IEEE 802.11p [2] standard support up to 27Mbps. It is reasonable to expect a 1Mbps data rate between high speed driving vehicles within a highway using ad-hoc communications [17]. Therefore, using the transmission data rate required by compressed video, there is enough bandwidth to support video streaming for vehicles. However, the scenario analyzed in this paper involves communications between vehicles and the infrastructure. A vehicle, using a video player, is connected to a central video streaming server placed in the Internet. In this case, the handoffs between different subnets access points limit the expected bandwidth.

A. Reference Scenario

The test scenario designed for this purpose is an infrastructure scenario where a set of base stations are deployed over a highway in an overlapped manner. Therefore there are no coverage blackouts in the road. All the base stations are connected to a central router and this is also connected to a video streaming server. The base stations belong to different subnets, so every handoff in the scenario is a layer 3 handoff.

The video streaming server and a vehicular node with a video player installed are emulated by UML virtual machines. The Mobile IP Home Agent is also placed in the video streaming server to simplify the scenario (see Fig. 3).
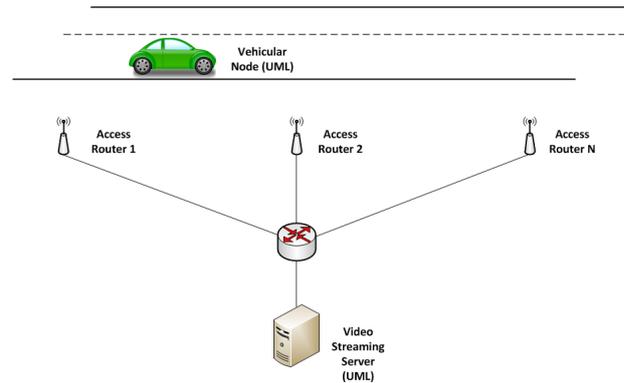
Fig. 3. Reference scenario

The routing between the video server and the car node is performed always as a single hop between the vehicular nodes and the base stations. Therefore no ad hoc routing is used in this testbed. The goal of the simulations is to carry out a study of a video streaming service over a highway with a lot of handoffs between base stations and analyze how video streaming services perform in a vehicular network using network mobility solutions. In Table I the parameters used in the simulation are detailed.

Live555 [18] is used to test the multimedia applications in the testbed. Using these libraries a video streaming server is configured in one side of the communication and a VLC media player [19] or a MPlayer [20], with live555 libraries to get real time features, in the vehicular node.

Parameter Name	Value
Wired links	Bandwith: 100Mb Propagation delay: 5ms
Propagation model	Nakagami
Wireless access	IEEE 802.11p
Distance between APs	300m
Ad-hoc routing protocol	NOAH
Video characteristics	352x288 MPEG-2 CBR 500Kbps

TABLE I
SIMULATION PARAMETERS

B. Simulation Results

To check the deployability of a video on demand service over a highway, a set of simulations are performed. The main problem that can limit the deployment of a video service is the packet loss that occurs during the handoffs due to network mobility. The vehicle's high speeds in the roads and the amount of handoffs must be analyzed to deploy a video service.

1) Packet Loss: To analyze packet loss, a Constant Bit Rate (CBR) UDP traffic, without any Forward Error Correction

(FEC) or Automatic Repeat reQuest (ARQ) method, is sent from the server to the vehicular node, simulating a CBR class video streaming. To simulate this CBR stream and calculate packet loss, the Iperf tool [21] is used during 300 seconds per each bitrate and vehicle speed. Next graphs show the packet loss rate obtained using Mobile IP. The first graph, Figure 4, shows the packet loss rate of four different vehicular nodes speeds and its evolution when the CBR data rate is increased. The second graph, Figure 5, shows the packet loss rate using four different data rates, and the evolution when the vehicle speed is increased. It can be seen that packet loss rate increase as vehicle speed increase. In some cases the packet loss rate decreases for higher speeds. This is due the packet loss rate depends on the number of handoffs and it can be decreased increasing the vehicle speed. It also must be considered that the network reconfiguration time in Mobile IP during handoffs is an opportunistic value, in contrast with FMIP handoffs.
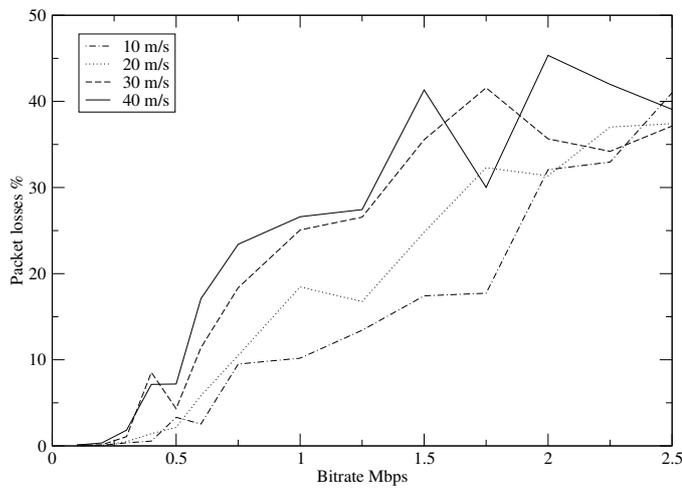
Fig. 4. Packet loss rate per bitrates using Mobile IP
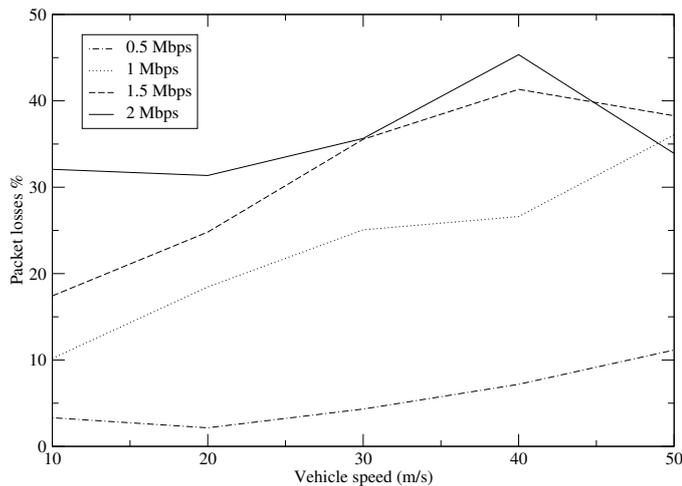
Fig. 5. Packet loss rate per speeds using Mobile IP

From Figures 4 and 5 it can be concluded that packet losses using Mobile IP solution are too high to deploy a

video on demand service in a vehicular network. It is possible to appreciate that only for very low bitrates packet loss is acceptable. Therefore, Mobile IP is useless for a quality video streaming. Moreover, the handoff delay that follows the original Mobile IP can be up to seconds. For this reason, a protocol to get a seamless communication to an appropriate video reproduction is needed.

FMIP can reduce the handoff delay by either introducing L2 triggers to anticipate the handoff in advance or managing most of the handoff operations inside a local domain. It can be seen that FMIP protocol can reduce the handoff delay to get between 0.18 and 0.4 seconds in the 99.3% of the cases [7]. Minimizing the delay handoff, the FMIP standard reduces the amount of packet loss during the L3 handoff. In spite of FMIP's objective, it could not always guarantee the successful fast handoff if the moving speed of mobile node is very high. Since the L3 handoff of Mobile IP is controlled by the mobile node on a connectionless network, several messages should be exchanged among nodes to control handoff process, and handoff process of FMIP tightly depends on L2 triggering. These two features can increase the possibility of failure because the trigger does not consider the state of mobile node's L3 and delivers triggers only based on variable wireless signal state. So, although in FMIP the packets are buffered and supplied to the MN after the handoffs to avoid packet loss, these failures produce some packet loss that affect to the video streaming services. Figures 6 and 7 analyze the packet loss using the FMIP protocol.
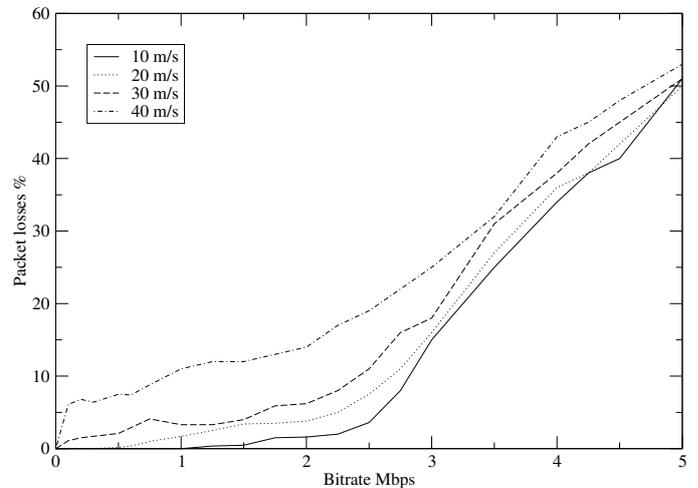
Fig. 6. Packet loss rate per bitrates using FMIP

Figure 6 suggests that using FMIP techniques video streaming can be feasible for 10, 20 and 30 m/s vehicle speeds. However, at 40 m/s some problem will occur while reproducing a video stream without any special technique due to the high packet loss rate. For 30 m/s, a video bitrate greater than 500 Kbps can produce some troubles. However, with this bitrate it is possible to reproduce a video with an interesting quality. For the last two speeds, 20 and 10 m/s, the problems arise at 1 and 2 Mbps. This means that for urban mobility a video
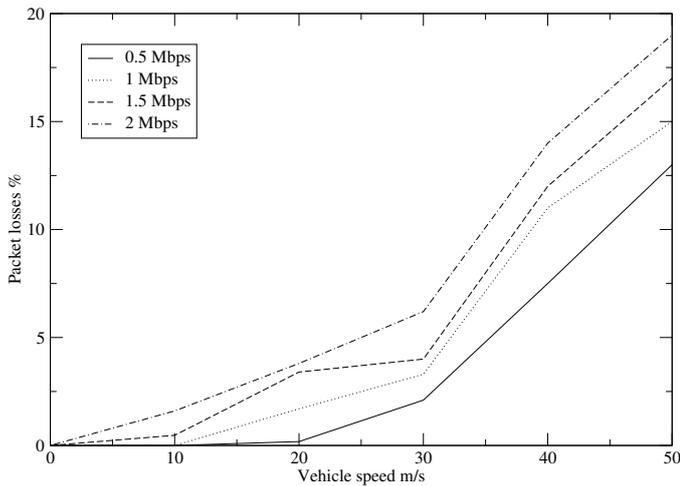
Fig. 7.   Packet loss rate per speeds using FMIP

service can be deployed with a packet loss rate that can support an enough video rate to assure a high video quality and, for highway mobility also can be supported a video service, but with a lower video bitrate and a poorer video quality.
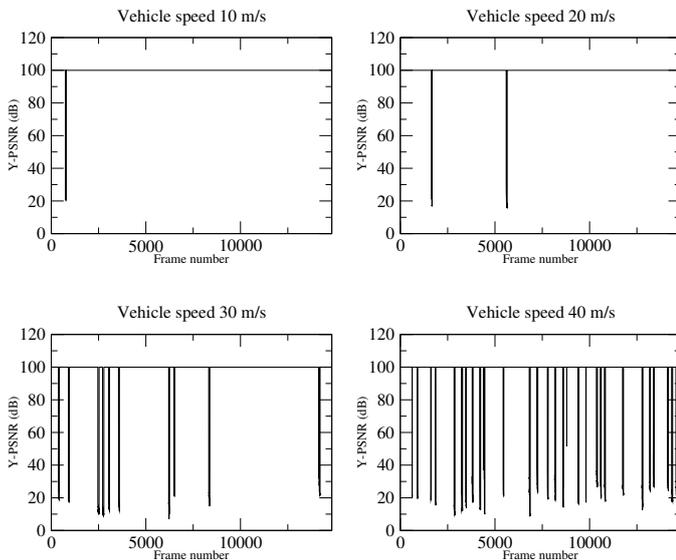
Fig. 8.   PSNR of the video received compared with the transmitted video, for different vehicle speeds

2) Video quality: The objective of this test is to investigate how the quality of a video clip streamed in a vehicular network is affected by the handoffs occurred during the communication, measuring the quality of the video received compared with the original video using the Peak Signal-to-Noise Ratio (PSNR). The video used in the simulations is a 352x288 MPEG-2 video coded at 500 Kbps. To recover the gaps that are lost during the communication, an error-resilient decoder, based on an enhanced version of MPEG-2 decoder [22], is used. When this decoder is not able to recover the lost frame, the previous frame is represented. In Figure 8 the PSNR for different speeds is represented. When the video received is the

same as the original video, the PSNR is represented as 100 dB. In this figure, the video quality degradation due to packet loss caused by the handoffs can be observed. For 40 m/s, a lot of gaps occur during the video reproduction. Therefore, this speed could be unfeasible to play a video during a travel using these scenario parameters. For slower speeds, as can be 10, 20 or 30 m/s, it can be observed that the quality degradation during the video reproduction is reduced drastically, so it could be feasible to play a video during a travel over a highway going at these speeds.

IV. CONCLUSIONS AND FURTHER WORK

In this article, a set of simulations of live video streaming over vehicular networks have been presented. This set of experiments analyze the way handoffs limit the overall quality of a video streamed during a travel over a highway. The packet loss rate grows with the video bitrate and the vehicle speed increments, decreasing the video quality perceived by the client that is estimated with the PSNR of the decoded video. Although fast handoffs techniques to minimize handoffs blackouts are used, the packet losses limit the deployment of video streaming services in vehicular networks. For this reason it can be convenient in further research to analyze video streaming using reliable protocols to avoid packet loss during the communication. Further research will extend the video streaming analysis over vehicular networks to TCP transport protocol analyzing different TCP flavors behaviors.

Moreover, other network mobility techniques to prevent video streaming blackouts will be studied in further plans. This mobility proposal will present transport layer mobility instead of network layer mobility, including multi-path and multi-homing features and optimizing the communication data rate during the handoffs and preventing from network disconnections.

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