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A receiver-based video dissemination solution for vehicular networks with content transmissions decoupled from relay node selection

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ABSTRACT

The provision of video dissemination capabilities over vehicular networks improves the service experience from users' side for applications such as heavy traffic notification, hazard warnings and event advertisement. However, the combination of video streaming's stringent requirements and the dynamic topology of Vehicular Ad Hoc Networks (VANETs) poses severe challenges for efficient and effective video dissemination.

We propose in this work a receiver-based solution that conducts video transmissions decoupled from the relay nodes selection mechanism, namely REDEC. This solution takes advantage of the reactive nature of the receiver-based approach without incurring excessive collisions and overhead due to the transmission of videos large packets at a high frequency. We have also conducted extensive simulation experiments using variety of scenarios with different densities and data exchange rate. Our results indicate clearly that our proposed REDEC protocol outperforms other solutions and is scalable while fulfilling the end-to-end delay requirements of video streaming. Furthermore, we have observed that REDEC also offers higher video reception rates when compared to existing video streaming solutions.

1. Introduction

Vehicles have been increasingly equipped with new technology and there is a strong tendency to connect all of this on-board hardware to other vehicles as well as external networks. On-board technology is highly influential on drivers decisions to buy vehicles, for instance, Koppel et al. [1] show how safety equipment/technology is seen as more important than results on crash/safety tests. Connecting technology already present in vehicles enhances users' overall satisfaction with the services provided. Inter-vehicle or vehicle to infrastructure communication would certainly improve the quality of services already provided and make available the possibility of offering novel solutions even more valuable than existing ones.

The dissemination of video content improves users' experience even further by providing a way to offer users information with a rich presentation. The disseminated information could relate to safety issues such as pavement conditions or accidents on the road ahead, traffic conditions of selected or alternative routes, or advertisements for local services. The dissemination of this content in the form of video is much more valuable than that of a simple text-based notification.

One specific example of the value of video dissemination over vehicular networks is that of the dissemination of videos for the purpose of warning drivers of animals crossing the roadways. In the United States alone, it is

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estimated that there are between one and two million accidents involving wildlife/vehicle collisions [2]. Cameras and sensors could be deployed in more dangerous spots where animal crossing occurs more often and drivers' visibility is reduced so that when movement alongside highways is detected, captured video is disseminated and displayed to drivers. This provides richer information than the simple broadcasting of an alert which could be neglected by drivers. The interface of such application would have to be seamless to prevent drivers from unsafe reactions (an augment reality enabled windshield could be a solution).

Infotaiment applications could also benefit from video dissemination capabilities. The dissemination of videos of ongoing festivals, conferences or other events could be broadcast to vehicles on the vicinity of such events. Sport venues could disseminate live content to incoming patrons stuck in traffic. Festival organizers could enhance their promotion activities by broadcasting a live feed of what is currently happening. On-board games for passengers could enhance collaboration between nearby gamers that share videos of their gameplay. These are some examples of a vast number of options for applications to offer rich services by taking advantage of video dissemination capabilities over VANETs.

In this work, video streaming refers to the transmission of live video content that is either instantly sampled from a local camera or stored. The live aspect of the video means that its content is of interest to users only for a small time window after it is transmitted. For example, a video that is used to show traffic conditions is useful to help drivers in deciding which route to take if it shows recent street/road conditions.

The challenges regarding the provision of video streaming dissemination over vehicular networks are due to the combination of video's stringent requirements and vehicular networks' dynamic topology. Video streaming requires the timely transmission of a large portion of data under a small rate of loss. CISCO has quantified some of these requirements [3] for general video streaming. Delay should not be higher than 4 or 5 s, while loss should not exceed 5%. Bandwidth requirements depend on applications and jitter imposes no significant requirements. The transmission of video is expected to demand the use of high amounts of network resources but it cannot be excessive.

In this work, we focus on Vehicular Ad Hoc Networks (VANETs) which are vehicular networks that rely only on vehicle-to-vehicle communication. Although vehicular technology is expected to be assisted by road side access points, it is unlikely that such infrastructure is always going to cover the majority region of a city or highway. Therefore, even in models where infrastructure is available, part of the communication is performed between vehicles.

We propose a REceiver-based solution with video transmission DECoupled from relay node selection (REDEC). This solution takes advantage of the reactive characteristic of receiver-based solutions while preventing occurrences in which the transmission of video content suffers from high end-to-end delay and eventual collisions due to relay node selection. We have conducted an extensive and thorough evaluation of REDEC's performance and we have compared it to state of the art solutions. REDEC has achieved the best performance; and, in the majority of scenarios it outperformed other solutions achieving more than 10 percentage points higher delivery ratios, a higher Peak Signal-to-Noise Ratio (PSNR) and thus maintaining high video reception rates, very low end-to-end delay and a reasonable number of transmissions. REDEC's performance was shown to be stable for increases in density.

In the next section, we discuss some of the existing works related to video dissemination over VANETs, including the solutions that we have quantitatively compared to REDEC. All the details and peculiarities of REDEC are described in Section 3. Additionally, we conduct some preliminary evaluations of REDEC's performance in order to understand the impact of the variation of its underlying parameters; this discussion takes place in Section 4. REDEC's performance is compared to state of the art solutions and the results and their analyses are presented in Section 5. Section 6 shows our final consideration, summarizes this work's contributions and discusses future works.

2. Related work

Wireless Sensor Networks [4] (WSNs) has been widely studied with some works even considering nodes mobility [5]. However, their applicability to Mobile Ad Hoc Networks [6] or even more specifically to VANETs. VANETs peculiarities have to be taken into consideration for the development of suitable solutions.

There are works on data dissemination in VANETs in the literature but they have a substantially different perspective. In [7], the authors discuss dissemination techniques for the exchange of messages containing either traffic conditions or vehicles current status information (e.g. speed and direction); thus, the authors focus on a scenario where information shared is not as large (in terms of bytes) as videos. Besides that, every node in the network is not only an interested party but also a potential source of data.

Fogue et al. [8] also discuss the same issue and they provide a solution that considers the availability of map information as well as the ability to observe vehicle density. The authors suggest the use of this information for a more effective dissemination of alert messages. In [9], the authors also focus on the application of informing vehicles about traffic conditions in their surroundings. Dornbush et al. propose a mechanism for vehicles to estimate traffic conditions and, through a clustering approach, disseminate the obtained information to vehicles in the network.

In [10], the authors propose a data pouring scheme based on available roadside infrastructure that take in consideration vehicles' movement in order to avoid an excessive number of transmissions. Furthermore, the authors suggest placing this roadside infrastructure strategically on intersections in order to optimize coverage of each transmission. However, this solution assumes that applications are reasonably delay tolerant which it is not suitable to describe video-streaming services.

Ishihara et al. [11] propose different mechanisms for the dissemination of data in VANETs where the interest of receivers is based on location premises. They discuss