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The selective use of redundancy for video streaming over Vehicular Ad Hoc Networks

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A B S T R A C T

Video streaming over Vehicular Ad Hoc Networks (VANETs) offers the opportunity to deploy many interesting services. These services, however, are strongly prone to packet loss due to the highly dynamic topology and shared wireless medium inherent in the VANETs. A possible strategy to enhance the delivery rate is to use redundancy for handling packet loss. This is a suitable technique for VANETs as it does not require any interaction between the source and receivers.

In this work, we discuss novel approaches for the use of redundancy based on the particularities of video streaming over VANETs. A thorough study on the use of redundancy through Erasure Coding and Network Coding in both video unicast and video broadcast in VANETs is provided. We investigate each strategy, design novel solutions and compare their performance. We evaluated the proposed solutions from the perspective not only of cost as bandwidth utilization, but also the offered receiving rate of unique video content at the application layer. This perspective is fundamental to understanding how redundancy can be used without limiting the video quality that can be displayed to end users.

Furthermore, we propose the selective use of redundancy solely on data that is more relevant to the video quality. This approach offers increases in overall video quality without leading to an excessive overhead nor to a substantial decrease in the receiving rate of unique video content.

1. Introduction

Video streaming over Vehicular Ad Hoc Networks (VANETs) is necessary or highly beneficial to a variety of envisioned services. A camera installed in a traffic light could stream the captured video chips of a local accident to either an incoming ambulance or to the nearest hospital. This could be done to provide valuable information to paramedics and physicians for a timely treatment response to improve the chances of survival in road accidents. Video chips of current traffic congestion, natural disaster or fire could be broadcasted to nearby vehicles to provide an accurate source of information to drivers, so that they are able to visualize road traffic and weather conditions ahead and take right decisions regarding safer or faster routes.

In this work, we refer to video streaming as the transmission of video content close to or in real time with no need for interaction between receivers and transmitters. This means that it is subject to more stringent requirements

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than those of stored videos (e.g., movies, shows) but that its requirements are slightly more lenient than those of interactive video (e.g., video conferencing).

Sending redundant information with the original packets is a common method that enables the receiver to reconstruct lost packets and to achieve a higher delivery ratio. The use of redundancy in VANETs has already been suggested [1–3], but, in this work, we go through an extensive analysis of its benefits for the specific case of video streaming. We discuss the advantages and disadvantages of using Erasure Coding and Network Coding for an efficient use of redundancy. This work covers the scenarios for both video unicast and video broadcast. Unicast covers the transmission from one point (source) to another one (destination), whereas broadcast deals with the transmission from a single source to multiple interested parties. This work also evaluates two distinct coding techniques: Random Linear Coding (RLC) and XOR-based Coding. RLC is a technique used to improve the network's throughput, so it is an efficient method to add redundant information. On the other hand, XOR-based coding is another effective adding redundancy method based on pure XOR operation during coding computation.

The contributions in this work are divided in four parts: (i) a thorough study on the issues inherent in using redundancy for video streaming over VANETs for both unicast and broadcast; (ii) an evaluation on the benefits of two novel coding solutions for Network Coding and Erasure Coding: XOR-based Coding and Linear Coding; (iii) the demonstration of the improvements on a novel approach that uses additional redundancy selectively in I-frames data only; and, (iv) an extensive comparison provided on solution performance through the perspective of the receiving rate of unique video content.

The importance of the latter contribution is due to the strong correlation between the video quality that can be displayed to users and the data rates by which videos can be received at applications on receivers. The benefit on the use of redundancy to handle packet loss is always a trade-off between increases in delivery ratio and cost. Normally, cost is given by the increased used of bandwidth, however, as we discuss in this work, for video streaming over VANETs, the impact on the receiving rate of unique video content is even more crucial.

An analysis of the most relevant and current studies in the literature is shown in the next section. Section 3 provides a summarized discussion regarding the use of coding strategies for an efficient use of redundancy. The peculiarities involved in the use of redundancy for video unicast and video broadcast are discussed in Sections 4.1 and 4.2, respectively. Section 5 describes the selective use of redundancy in I-frames and presents a thorough performance comparison of the different strategies for both video broadcast and unicast. Finally, Section 6 presents our conclusions and future work.

2. Related work

The study of VANETs is a relatively recent topic that has been studied in the literature. In this section, we list and discuss some of the existing studies in the literature. We also evaluate those solutions suitability to video streaming and compare them to the solution we propose in this work.

In particular, studies on video streaming over VANETs are very limited, but data dissemination, a more general case of video streaming, has been widely explored. For instance, VIRTUS [4], LIAITHON [5] and Unicast Analysis of Multipath [6] are examples of data dissemination protocols for the routing layer.

Rezende et al. [7] proposed REACT-DIS protocol to resolve three problems found in data dissemination in VANETs: reactiveness, density-awareness and time. Reactiveness requires the protocol to quickly respond to changes in the network topology, and, thus, the selection of the relaying or forwarding nodes is performed at the receiver's side. Sometimes a node needs to decide how to forward a packet after the packet transmission time expires. In this situation, density-awareness is applied to nodes to forward packets based on the density of the overheard duplicated retransmissions. Waiting time at each hop is also important, and REACT-DIS decides which node is more appropriate to be the relay node.

Rezende et al. [4] proposed a tracking-based unicast scheme, called VIRTUS, for video dissemination in VANETs. The authors focused on designing a balancing strategy to select the relay node. Initially, a time window is used to scale the connectivity of the relay node to the previous node. Furthermore, the location of vehicles is recoded and calculated together with predicted positions to estimate the direction of the relay node selection. On the top of that, since VIRTUS is a decoupled framework, both density-aware mechanisms and the time-aware policy are able to be exploited.

Wang et al. [5] developed a concurrent data transmission protocol, called LIAITHON, based on VIRTUS. LIAITHON is also a receiver-based scheme, which uses the location and time-aware information to select the relay node. Its main improvement is the use of two relatively short paths with minimum route coupling effect. By treating the urban road network as a graph, the closeness degree is used to discover two relatively short paths with minimal route coupling effect. In this way, the traffic load could effectively be distributed onto two paths. Besides, more QoS requirements are able to be fulfilled by calculating the waiting time and route coupling prevention.

Tsirigos and Haas [6] studied an analytical framework to maximize the probability of data dissemination over a multipath. The multipath routing scheme is based on the assumption that the mean time to transmit packets is much smaller than the mean time between changes to the topology. In this way, the probability of having a failure path is constant. The authors use a group of experiments to show that the packet delivery rate is increased as available paths are added. In another work, Tsirigos et al. [8] provided a simple approximation method to improve the algorithm to a polynomial time, as well as to maximize the optimal path to be utilized.

Rezende et al. [9] also proposed the REDEC protocol to decouple the data content from the selection of a relay node. At the beginning of data transmission, a control packet is transmitted to select the suitable relay nodes. The degree of suitability is based on the amount of time