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Comparison of propagation and packet error models in vehicular networks performance

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ABSTRACT

Over the years, we have witnessed how wireless communications and transportation technologies converge. Likewise, the research on the so-called vehicular ad hoc networks (VANETs) makes more and more sense. Due to the high costs and effort of deploying vehicles in real scenarios, network simulation is a popular alternative when studying the performance of vehicular networks. However, the dynamism of such environments makes their simulation a rarely simple task. In fact, many parameters have to be considered by VANET simulation, such as a dynamic topology, omnipresent obstacles, traffic flow, different mobility models, traffic lights, changing vehicular speeds, etc. Unsurprisingly, the way how some events are modeled in a simulation might bias the performance measures of vehicular communications. Accordingly, in this paper, we concentrate on assessing the impact of packet error modeling on VANET simulations. With this aim, we measure different parameters such as losses, end-to-end delay, and number of hops over a realistic urban scenario. We also test three different densities of nodes and three channel capacities. The performance metrics obtained after our simulations suggest that, in the best cases, the basic packet error model may obtain reliable results (i.e., results similar to those from a realistic error model). This evaluation is performed over a multi-hop scenario in which the antenna is configured with high sensitivity values. This simple technique bases on the assumption that interference levels will not exceed the SINR (Signal to Interference and Noise Ratio) threshold when errors begin to appear. This requirement may not be met in all simulations, for example in simulations with very high traffic load.

1. Introduction

Vehicular networks appear as a natural evolution of conventional ad hoc networks given the increasing time that people spend mobilizing through vehicles and thanks to the technology that might enable such vehicles as communicating nodes. Nevertheless, the dynamic characteristics of this scenario (e.g., the movement of vehicles) may require more robust networking protocols to guarantee a stable communication. Research on this field is even more important considering the critical applications of vehicular communications.

These applications of VANETs, e.g., road safety, traffic efficiency, and comfort, and their interesting potential benefits have captured the attention not only of the academy but also of governments and the industry. In fact, these powerful actors have become really interested in global solutions in this realm, pointing to the so-called Intelligent Transportation Systems (ITS) [1]. These systems, e.g., could take advantage of the great amount of information generated by vehicles to automatically adapt the traffic flow in case of an accident. Undoubtedly, these benefits comes at the cost of complexity of the communication environment.

When studying VANETs, such complexity, along with the cost involving a real implementation of vehicular networks, significantly complicates the analysis and evaluation of the performance of services. Fortunately, simulation makes such analysis possible for researches at a significantly lower cost. However, some assumptions have to be made in order to bound the deployment of a VANET. Sadly, such assumptions could make the simulated scenario unrealistic.

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For instance, the radio propagation models used in popular MANET simulators assume an obstacle-free area and a free line-of-sight among all communicating partners. As a consequence, the communication range is modeled by a simple circle around the mobile device. However, this poorly reflects radio wave propagation in a typical outdoor scenario, like a city center, on which buildings significantly affect the communication among nodes. In fact, for VANETs, simple radio propagation models are commonly offered that neglect the obstacles of a propagation environment.

Certainly, VANET environments involve multiple parameters such as congestion, dynamic vehicular speeds and topologies, multi-path fading and visibility obstacles, traffic flow and mobility models, traffic lights, etc. But in general, another fundamental parameter that defines a vehicular communication scenario is the error inherent to a context where nodes move dynamically. Evidently, these parameters have to be considered in order to design realistic communication protocols. Fortunately, simulation software facilitates the manipulation of these parameters over controlled scenarios and thus the analysis and evaluation of services and applications related to VANETs.

Particularly, the choice of the radio propagation model has an important impact on the performance of a routing protocol [2] since the propagation model determines the number of nodes within a collision domain, which is an important input for evaluating the contention and interference. To illustrate this importance, recall how the continuous movement of nodes in VANETs will cause these nodes to move in and out of each other's transmission range on a frequent basis. Consequently, depending on the propagation model, a node may share a collision domain with tens or hundreds of other nodes, or with only a handful when the model considers the presence of buildings [3]. Also, in this work, we analyze the effects of packet error models on the behavior of simulated vehicular networks. Such effects are measured in terms of packet losses, end-to-end delay and number of hops, in realistic scenarios and also comparing this work with a previous study.

The rest of the paper is organized as follows: Section 2 presents the main characteristics of vehicular networks and the protocol used for the evaluation, MMMR [4]. Section 3 briefly explains the operation of channel and physical modules in a network simulator. A description of propagation and packet error models is presented in Section 4. Section 5 describes the packet error models used in this paper to analyze their impact on the performance of VANETs. Afterwards, Section 6 presents the simulation settings and describes the results of our study. Finally, Section 7 draws our conclusions.

2. Background

VANETs are wireless networks that have emerged thanks to the advances in wireless technologies. A vehicular ad hoc network is a MANET where the nodes are moving vehicles communicating among each other and also with a static infrastructure through wireless interfaces [5,6].

Due to the variability of network topologies in VANETs and the inherent characteristics of communication channels, finding and maintaining routes is a very challenging issue. Hence, routing protocols play an important role in the performance of VANET applications. In fact, routing in VANETs is extensively studied [7] and several solutions have been proposed. One of these solutions is Global State Routing (GSR) [8], which combines position-based routing and topological knowledge. Also, Anchor-based Street and Traffic Aware Routing (A-STAR) [9] is a mechanism that adopts anchor-based routing and street awareness (through a street map) to compute the sequence of junctions through which a packet must pass in order to reach its destination. On the other side, Greedy Perimeter Coordinator Routing (GPCR) [10] was designed to deal with the challenges of city scenarios; its main idea is to forward data packets using a restricted greedy forwarding procedure. Most of the current investigation builds on routing protocols supported by geographic information since they are, to the best of our knowledge, the ones offering the best performance [11].

Among geographic routing protocols we have MMMR [4], a traffic-aware, delay-tolerant routing protocol that can be seen as an improvement of Greedy Buffer Stateless Routing-Building detection GBSR-B [12] that is based on GPSR [13]. MMMR determines if a neighbor is reachable and unobstructed. MMMR uses three routing metrics (vehicle density, vehicle trajectory and available bandwidth) and the distance to select the best next forwarding node towards its destination. A node evaluates and assigns a total multi-metric qualification to each neighbor when it has to route a packet, applying a geometric average of the four metrics evaluated. A geometric score is used because it is less sensitive than the arithmetic metric in the extreme values of the metric components. As a starting point, MMMR assigns equal weights to each metric in the qualification of each neighbor. The neighbor with the highest score is chosen as the next forwarding node. If there is not any suitable next hop, MMMR stores the packet in a buffer (i.e., the node carries the packet). Packets have a timeout to limit their transmission time in the network. MMMR includes a map-aware capability that takes into account the presence of buildings when choosing the next forwarding node.

Being obstacles omnipresent in VANETs, they may significantly alter the communication among nodes. Thus, propagation models represent an important topic in ad hoc networks simulation. Several research works focus on this topic. The authors of [2] analyze the performance of MANET protocols and applications by giving insights on the effect of different propagation models for MANETs on indoor and outdoor environments; the model proposed in this work is based on data of the simulation area in a urban scenario. In [14], different radio propagation models are described and their performance is compared when using the AODV routing protocol, from the security point of view that considers the presence of a black-hole attack. In [15], the authors demonstrate that the usage of more accurate radio propagation models considerably changes simulated topologies. Also the authors show that there are many scenarios in which the application of such a complex propagation model is unnecessary. However, researchers must be aware of significant difference between real connection topologies and those obtained using the simple models offered by MANET simulation tools. In [16], authors show that radio propagation models (RPMs) in VANETs may require a high level of realistic detail due to several reasons: mobility requirements, nature of the network, technology limitations, and urgency of information dissemination. Hence, developing realistic RPMs in VANETs is a challenging task. The research presents a taxonomy of existing RPMs and the major challenges involved in modeling realistic radio propagation for VANETs, especially in urban environments. The authors in [17] state that the propagation model used in a VANET simulation has great influence on the results. The propagation model determines which nodes are able to communicate and the probability of correct reception. As a result, it can affect the speed at which messages propagate through the network, then directly influencing the end-to-end delay in a multi-hop scenario. The probability distribution of correct reception also influences the overhead with respect to collisions and medium utilization. A real-world implementation could behave different from the simulation, so care must be put when mapping a model and their parameters to the target environment.