Analytical model for clustered vehicular ad hoc network analysis

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Abstract: Clustering of vehicles is an important technique to reduce the high mobility effect of vehicles. This paper proposes an analytical model to evaluate the performance of a clustered vehicular ad hoc network (VANET). The analytical model is developed to evaluate three important parameters, namely packet delivery ratio, throughput, and delay. The results obtained from the analytical model are also accompanied by simulation results. This model can be further extended by researchers working on clustered VANET scenarios and will be helpful in modeling their protocols or algorithms. Furthermore, this model can verify the simulation results obtained from any network simulator.

Keywords: ITS, VANET, Vehicle-to-vehicle communication, Clustering, Analytical modeling

1. Introduction

Recently, particularly in this decade, there has been a phenomenal growth of research in connecting vehicles to facilitate intelligent transportation systems (ITSS). ITSS use advanced information and communication technologies to enable vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I) and vehicle-to-device (V2X) communication. The main objective of the research in this area is to make roads accident free and safe, thus saving invaluable human lives. However, in the current scenario of increasing road networks and highly mobile vehicles, reducing the number of accidents caused by human errors is a challenging task. Hence, a technology support system that enables drivers to reduce mistakes on roads significantly is important. In this context, the potential of connected vehicles has been acknowledged.

A radio spectrum has been allocated by the Federal Communications Commission (FCC) for the dedicated short-range communications (DSRC)[1] to facilitate ITSS. It is a 75-MHz spectrum containing 7 channels (1 control channel (CCH) and 6 service channels (SCHs)) in the 5.9-GHz band ranging from 5.85–5.925 GHz. The Institute of Electrical and Electronics Engineers (IEEE) has proposed an amendment named IEEE802.11p[2] to IEEE802.11 standard for wireless LANs to add wireless access in vehicular environments (WAVE)[3].

The applications of vehicular ad hoc networks (VANETs) are broadly classified into safety and non-safety applications. The network time in a VANET is divided into 100-ms intervals called the synchronization interval (SI). SI is further divided into control channel interval (CCHI) and service channel interval (SCHI), both 50 ms. During CCHI, all the vehicles are switched to CCH and during SCHI, vehicles are switched to any of the SCHs.

There are several challenges in VANETs, such as high node mobility, hidden terminal problem, limited number of channels, frequent disconnections, and time-bound service. Researchers have proposed several solutions to these problems. Clustering is one of the solutions proposed. In clustering, vehicles with same characteristics (i.e., velocity and acceleration) form a group termed as a cluster. A cluster head (CH) is selected among vehicles of a cluster to perform controlling activities within a cluster. Clustering reduces frequent disconnections and the effect of high mobility, thus enhancing the overall performance of the network.

The major contributions of this paper are summarized as follows:

A. Analytical modeling for the performance analysis of the clustered VANET scenario.
B. Comparison of clustered VANET performance with that of the non-clustered scenario to demonstrate its superiority.
C. Analytical results are validated with simulation results.

The rest of the paper is organized as follows. A brief discussion of current clustering techniques is presented in section 2. An analytical model is developed in section 3. Section 4 describes the analytical and simulation results, and finally, section 5 concludes the paper.

2. Current clustering techniques

A study of latest algorithms is required to mathematically analyze clustering algorithms. In [4], authors proposed an adaptive mobility and range-based clustering (AMRBC) algorithm that takes mobility as
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