Graph Visualization Tool for Vehicular Ad-Hoc Networks

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Abstract— **In this demo we describe VIVAGr, a graphical-oriented real time visualization tool for vehicular ad-hoc network connectivity graphs. This tool enables the effective synthesis of structural, topological, and dynamic characteristics of VANET graphs, with a variety of parameters that affect the shape and characteristics of a vehicular ad hoc network.**

Keywords- real-time graph visualization; VANETs; interference

I. Introduction

VIVAGr is a tool that allows the analysis of the structural, topological, and dynamic characteristics of Vehicular Ad-Hoc Networks (VANETs) using real time visualization of VANET connectivity graphs, based on nodes' mobility patterns and the underlying telecommunication system. VIVAGr allows researchers to explore and understand problems and issues related with vehicular networks that face today significant design challenges [1]. The tool is able to present all active connection of the network in real-time mode using mobility traces. A visual encoding syntax is used to represent semantic meanings and highlight the effect of mobility and topology on vehicular network specific properties.

Our design approach differs from known graph visualization tools by enabling the effective synthesis of structural and topological characteristics of VANETs with a variety of parameters that affect the shape and the characteristics of a wireless vehicular ad hoc network, wireless range, mobility models, network topology, market penetration ratio, signal propagation and exhibited interference.

II. Overview and Design

VIVAGr provides a link between formalism for representing network connectivity and graph visualization. It is a portable, multiplatform, and modular tool including various independent modules that could be used jointly or as separate functions, easily modified according to specific needs and requirements. In our design we give emphasis in three key areas for graph visualization: interactivity, visual encoding, and real-time representation of nodes' mobility patterns.

Our tool imports trace files describing the mobility patterns of nodes over time. At each time instance a connectivity undirected graph is created. Nodes are depicted as vertices and links as edges between two vertices. As nodes' positions change over, animation is used to show the transition of the newly created graph on canvas. It is able to collect and export specific statistical data for later analysis, focus and monitor the activity of a vehicle (or a group of vehicles) within the networking environment. The graph layout module is operating in real time mode. The user is able to select specific connectivity models allowing the creation of links between operating nodes. The user is also able to alter the viewing angle of the created graphs and to highlight specific link and node characteristics.

An important issue in vehicular networking is the time-evolving characteristics of the created communication graphs and the effect of the mobility patterns, using a geographical map, on the properties of the networking environment. With VIVAGr, the user is able to monitor in real time all corresponding changes in graph topology and connectivity during time as nodes follow a specific mobility pattern. The user can control the networking conditions under which a link can be formed, or not by, changing the properties of the underlying telecommunication system. In the current implementation we employ three different types of connectivity models, which can be enabled using the control panel, simple wireless range, interference limited range [3] and transmission rate mapping (see Figure 1).

Using VIVAGr the user is able for a specific mobility scenario to select different connectivity option and observe the effect of the corresponding graph in real time. For all these cases, during the real time graph visualization process, the user can: i) calculate and represent specific properties and attributes of all vertices and/or edges of the graph; ii) control the time frame of operation, described by the mobility scenario; iii) select the market penetration ratio of the network. Also, all the above graph visualization and animations processes, appearing on the drawing canvas, can be recorded and exported into a video file in order to be available for later studies.

For creating the connectivity graph we need to import information about the mobility pattern of the vehicles. This information is described in pre-processed mobility trace files on a regional or urban area. An animation of the nodes movement is created allowing the user to observe how and in what extend different topographical layouts influence the spatio-temporal characteristics of a VANET communication graph.

VIVAGr allows users to extract results on a number of metrics used to describe the shape and the properties of a vehicular network. These metrics [2] (i.e. Node degree, Effective Diameter, Density, Betweenness Centrality, Lobby

Index, Link duration, Connected periods, Link re-healing time, number of clusters and communities) can be used to identify the "highest-quality" vehicles in terms of connectivity (i.e., nodes with high betweenness centrality/lobby index values), as well as identify the laws that govern the temporal evolution of VANET-graph properties. The tool is able either to present them during the visualization process or to export structured data that could be analyzed in a later time, even using other graph analysis tools.

III. USE CASE STUDY SCENARIO

We will demonstrate how VIVAGr can be used in order to get answers on critical issues about VANET design. The traces used describe the position of nodes in specific time intervals (of one second) and follow a steady state behavior where the number of vehicles in a given region remains constant over time. We will demonstrate VIVAGr using both real and realistic mobility traces over real-world, accurate, city maps. Real traces have been collected from taxis as these were traveling throughout Shanghai, China, in a 24-hour time period. Realistic traces have been generated using the VanetMobiSim vehicular mobility generator. Specifically, the data set include two vehicular mobility scenarios referring to central regions of two big US cities, namely a: 2Km x 2Km area in New York city (Manhattan area) and a 2Km x 2Km area in and around the city center of Los Angeles. These sets describe the mobility of 700, 7000 and 7000 vehicles for Shanghai, New York and Los Angeles respectively.

Initially, VIVAGr will translate the vehicular traces into a structured MATLAB vector form. Then, these data will be imported back to VIVAGr allowing the user to create and display, in real time, the corresponding connectivity graphs for these examples and observe the shape and the properties of the network.

With the navigation capabilities of VIVAGr, the user can change the viewing angle and position on the drawing graph canvas. Different models for network connectivity will be selected, observing how the underlying telecommunication networking system affects the corresponding connectivity graph and network topology. Using the control panel the user will define the networking conditions under which a link can be feasible or not (Figure 1). We will also see how node connectivity is affected by a) the road-map topology on which the vehicles move; b) the presence of Road Side units (RSUs); c) the market penetration.

Visualizing the vehicular networks using VIVAGr, we will try to provide answers to key questions about the shape and the large-scale behavior of vehicular communication network, such as: How the underlying telecommunication systems affect the vehicular network topology? How does the penetration ratio affect the networking shape of VANETs? Which are the "highest-quality" vehicles in terms of connectivity? What are the laws that govern the temporal evolution of VANET-graph properties? Can we identify communities in a VANET? How does the road-map topology affect the VANET graph properties? What is the best deployment strategy for RSUs in order to maximize information dissemination?

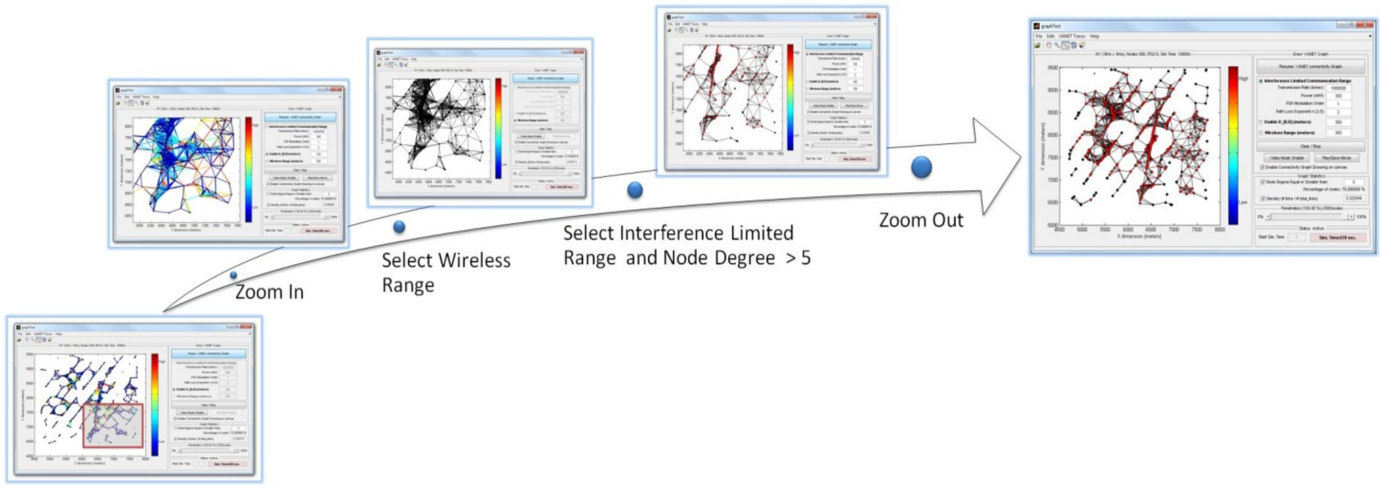

Figure 1. VANET Graph Visualization Tool: Road Side Units (RSUs) are highlighted with green color

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