SIMULATION AND TESTING OF VANET PROTOCOLS

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Summary

Dynamic network topology of VANETs (Vehicular Ad-Hoc Networks) brings challenges in designing various routing protocols. Common approach in testing of these VANET protocols is using the simulators that are able to simulate the real traffic environment and based on the simulation results protocols are evaluated. Currently, it is almost impossible to make experiments in real environment since the huge number of vehicles with computations and communication capability is needed. Implementation of these devices is expensive and complicated and it would be difficult to enable it on a large scale, with large number of vehicles in various conditions and environments. Therefore, we present several different VANET simulators and discuss possible method for easier and cheaper real world VANET experiments.

1. INTRODUCTION

Vehicular Ad-Hoc Networks (VANETs) enable wireless data communication among vehicles and, where it is possible, between vehicles and roadside equipment. VANETs have become an important research field due to their use in road safety and other commercial applications. Need for research comes from the fact that realization of such network in the real world is a challenging task. Vehicles are constantly moving and making network topology very dynamic. Buildings, traffic signalization and other obstacles are disrupting wireless communication. On other side, vehicle movements are constrained by roads and traffic regulations, making mobility patterns that can be predicted to some extent. A lot of research has to be done to design VANET protocols that will overcome mentioned problems and take into account predictability to optimize communication and provide required functionality.

Although there exist many different protocols for communication optimization in VANETs there are no possibilities for real world experiments and protocol evaluation. The main reason is that real world experiments require huge number of vehicles with communication and computation capabilities. Implementation of these devices is expensive and complicated and it would be difficult to enable it on a large scale, with large number of vehicles in various conditions and environments. As far as we know so far there have been only several real world VANET protocol experiments and they were part of specific projects. Furthermore, they were used only for testing of specific protocols and there was no possibilities to evaluate protocols outside these projects. Therefore, in order to evaluate their protocols, scientist are mostly using various VANET simulators.

VANET simulation tools are the easiest, fastest and most efficient way to evaluate VANET protocols. The latest approach is to use VANET simulation tools with bidirectional coupling of road traffic micro-simulation and network simulation. Although, some of them can provide high degree of realism there are still numerous factors from real world environment that can influence the mobility and network traffic. In order to get realistic VANET protocols evaluations real world experiments should be conducted. Therefore, in this paper we propose the method for easier and cheaper real world VANET experiments. Method is based on using smartphones for communication between vehicles. Mobile application and central server architecture are described.

The rest of the paper is organized as follows: Section II reviews several different VANET simulators. In Section III, we present two real world large scale field experiments and in Section IV then discuss possible method for easier and cheaper real world VANET experiments. Section V concludes the paper and points out future research plans.

2. SIMULATION TOOLS

VANET simulation is typically segregated into traffic simulation and network simulation. Traffic simulators, such as SUMO and VISSIM, have been used to generate realistic mobility traces of vehicle traffic and network simulators, such as

Omnet++, ns-2 and ns-3 are used for measuring network performance. Below, three popular VANET simulation tools that completely integrate the mobility and network components are described.

Veins (Vehicles in Network Simulation) [4] is a hybrid simulation framework that enables bidirectional coupling between the INET framework from the network simulator OMNeT++ with the road traffic simulator SUMO through a TCP connection. Is allows simulating complex heterogeneous scenarios to a high degree of realism and allows for road traffic to be influenced by network communication. OMNeT++ is an event-based simulation environment that is used to model realistic communication patterns of VANET nodes. Sumo is the microscopic road traffic simulation package that enables import of city maps from a variety of file formats, high-performance simulations of huge networks with roads consisting of multiple lanes, intra and inter junction traffic and traffic lights. Vehicle types are freely configurable and traffic flows can be assigned manually, computed based on demand data or random generated. In Veins, bidirectional-coupling is achieved by extending both frameworks with a dedicated communication module. Therefore, Oment++ and SUMO are able to exchange commands and this allows network simulator to react to the received mobility data by introducing, deleting or moving nodes and in road traffic simulator it alternate driver behavior and influence vehicles routing decision. Recently, Veins is one of the most popular VANET simulators and is used for different purposes as shown in [5], [6] and [7].

TraNS [3] is an open-source VANET simulator, and is designed to be extendable to support multiple road traffic and network simulators. Current version supports the SUMO traffic simulator and the ns-2 network simulator. TraNS offers two operation modes: First is the "network-centric" mode that can be used to evaluate VANET communication protocols that do not influence in real-time the mobility of nodes. Second is the "application-centric" mode that can be used to evaluate VANET applications that influence node mobility in real-time. Network-centric mode uses parser which translates road traffic simulator's results into a format acceptable by the network simulator. This architecture allows to generate the mobility traces prior to the network simulation, which makes possible to generate mobility trace ones and use it multiple times as input for network simulator. Application-centric mode allows the network simulator to control the mobility of certain vehicle in simulation at runtime. Interaction between road traffic and network simulator is made through a specific interface called TraCI. TraCI updates network simulator with mobility trace changes and provides a feedback interface through which the atomic mobility commands can be executed to manipulate vehicle's mobility. Atomic mobility commands such as "stop", "change lane" and "change speed", are mobility patterns that are recognized as common, no matter what VANET application is used. Another important TraNS module is driver's behavior model. VANET application that is being evaluated on the simulator, interacts with this module when it is necessary to adjust mobility attributes of simulated vehicle. Driver's behavior model decides which sequence of atomic mobility commands and when they will be executed over the TraCI interface. Although development of TraNS is suspended it has been used in numerous research papers [8].

VNS (Vehicular Networks Simulator) [9] also provides bi-directionally interaction between a microscopic mobility model and network simulators. The mobility model is based on DIVERT 2.0 that is capable to import realistic road maps in different formats, model vehicles with different driver behaviors and has realistic traffic generation model. VNS supports both NS-3 and OMNET++ network simulators. In order to increase the performance and scalability of VNS, the wireless module of NS-3 was extended to enable rapid neighbor searching during wireless transmissions. With performance evaluation they showed that their improvements resulted in significant performance gains, enabling simulations of large scale vehicular networks. Since VNS is relatively new it is not widely used currently, and it has mostly been used by authors in their research. However, due to the above mentioned characteristics, it could be expected that soon it will become very popular VANET simulator.

3. LARGE SCALE REAL WORLD VANETS EXPERIMENTS

VANET simulation tools are able to generate realistic mobility traces and network communication. However, since they cannot completely simulate realistic factors that can influence the traffic, the degree of realism and simulation quality is sometimes questionable. Therefore, it is always better to preform experiments in real environment and conditions. Currently, it is very difficult and expensive to conduct a real world VANET protocols testing. As far as we know only two real world experiments with high number of vehicles were implemented and they are described below.

The simTD project (Safe and Intelligent Mobility – Test Field Germany) [2] tested car-to-x communication (car-to-car, car-to-infrastructure) in real world large-scale test field infrastructure around the Hessian city of Frankfurt am Main. The project was aimed to pave the way for the political, economic and technological framework to successfully set up car-to-x communication. The test fleet comprised 100 controlled test vehicles and approximately 300 external fleet vehicles. There was a 100 roadside stations installed, enabling the vehicle test fleet to interchange data with traffic lights, road signs and traffic control center. The area is characterized by high traffic density and therefore allows experiments on all road safety and traffic efficiency functions under normal everyday conditions. Hessian region offered excellent infrastructure equipment to collect traffic data and also traffic control facilities as well as all relevant road categories. The simTD architecture is based on three main sub-systems: The in-vehicle sub-system enables wireless communication with other cars and roadside equipment, provides human-machine interface, allows access to vehicle information and carries in-vehicle applications. The infrastructure sub-system involves roadside stations and central station. Central station is actual simTD backend system. The test sub-system has its share in all architecture components. Its main function is to carry out the simTD tests and experiments, to support data collection, evaluation and validation.

The Mobile Century large scale field experiment is described in [1]. The main goal of this experiment was to provide a proof of concept for a traffic monitoring system based on GPS-enabled mobile phones. It was conducted in the San Francisco Bay Area, California, with 100 vehicles carrying a GPS-enabled Nokia N95 phone driving loops on a 10-mile stretch for 8 h. Data were collected using VTL (Virtual Trip Lines) based sampling strategy, which has geographical markers stored in the mobile devices and when the phone intersects a VTL, the mobile device sends an update to a back end server with position, speed and direction information. The system had four layers: GPS-enabled smartphones in vehicles (driving public), a cellular network operator (network operator), cellular phone data aggregation and traffic estimation (Nokia/Berkeley), and information dissemination (Info Consumers). On each participating mobile device (or client), an application is executed which is responsible for the following functions: downloading and caching trip lines from the VTL server, detecting trip line traversal, and filtering measurements before transmissions to the service provider.

4. PROPOSAL OF SYSTEM FOR REAL-WORLD TESTING OF VANET APPLICATIONS AND PROTOCOLS

As already discussed in this article, real-world experiments by using the real prototype equipment is too expensive, and protocol evaluation with VANET simulation tools is limited since complete real-world traffic conditions are hard to simulate. Therefore, our proposal is to develop an alternative way for real-world experiments. Proposed system that will use smartphone devices in vehicles instead of real VANET terminals, and relay on existing smartphone communication capabilities, substituting the real VANET terminal equipment and emulating peer-to-peer communication among them. Moreover, use of such system could be considered as extension of VANETs that will help to achieve a high initial deployment level of VANET equipped vehicles, which is required to make VANETs efficient.

Proposed system will be consisted of smartphone devices connected to the central server, over which the peer-to-peer communication among VANET nodes will be simulated. Communication to the server will be made using the 3G/LTE mobile Internet connection over a cellular network provider. To simulate visibility between two VANET nodes, calculation of visibility will be made according to geo-location of nodes, taking into account positions of possible obstacles between. Node geo-locations will be obtained utilizing the GPS system integrated into smartphone devices. Geo-locations of possible obstacles will be requested from 3rd party service, such as Open Street Maps.

Mobile application, as shown on Fig. 1, consists of the Test VANET application part that is currently being tested and a framework part that will simulate VANET datagram communication. Framework part is consisted of a background service that has two main functions: First, to listen on GPS location changes and periodically register mobile device (VANET node) with its geo-location data on the central server. Second, to provide a low level API to the Test VANET application for sending and receiving VANET datagrams over the simulated VANET network.

Central server, as shown on Fig. 1, maintains the database of connected VANET nodes and mediates in the communication among mobile applications running on those nodes. Components of Central server are:

- VANET nodes database: VANET nodes are smartphones that periodically send data about their geolocation. In case of node timeout, all data about node will be deleted and it will not be visible anymore to the other nodes.
- Node data connector: is used for communication towards smartphones and forwarding data communication between smartphones.
- Wireless visibility resolver: calculate visibility between VANET nodes and decides is communication between two nodes possible.
- System control and analytics: controls the system, collects necessary data and perform

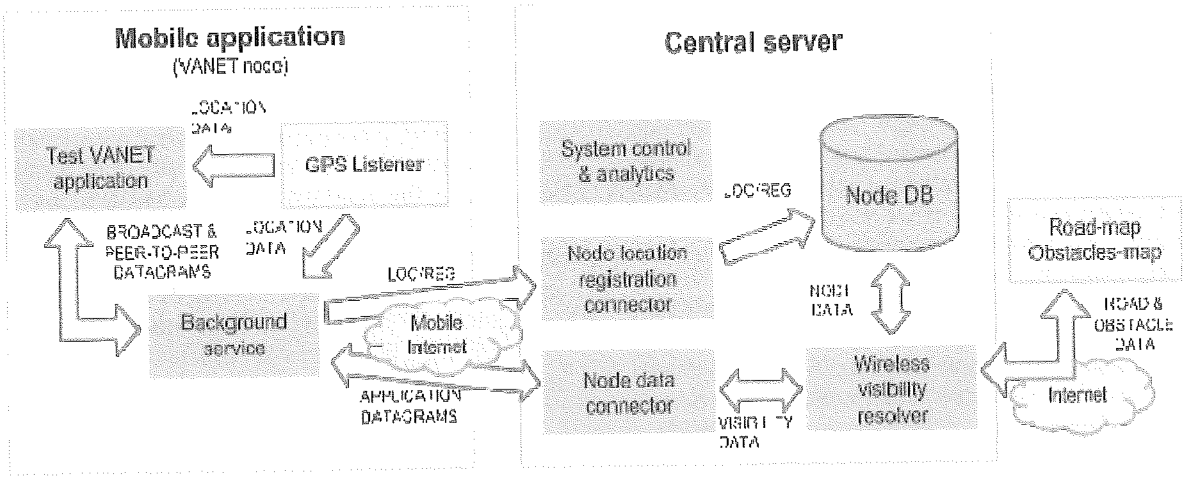

Fig. 1. Proposed system architecture

calculations that are required for analysis of experiments results.

- Node location registration connector: periodically reports geolocation of smartphones.

5. CONCLUSION AND FUTURE WORK

In this paper, we survey the most popular VANETs simulators, describe large scale VANETs experiments and propose the idea for easier and cheaper large scale experiments by using the mobile applications. Recent VANETs simulators provide realistic simulation environment that enable evaluation of VANETs at network and application level. However, real world experiments would be the best way to get the realistic evaluation but they are very expensive and hard to implement. Therefore, we propose the easier and cheaper way to preform real world experiments by using the smartphones and mobile applications. As future work we plan to develop and test the proposed open source mobile application.

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