On the requirements on models and simulator design for integrated VANET Simulation

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Abstract*— *Wireless communication can reduce risks for collision between vehicles by the exchange of kinematic data. Vehicular safety applications based on such information sharing must be tested before it is deployed in real world. For this purpose simulation is a valuable complement to expensive outdoor experiments. Analysis of VANET applications requires that both a vehicle motion and a data network simulator can be used at the same time, feeding simulation data to each other. Tools exist for this purpose but most of them have problem with their integration. This article discusses how to simulate vehicular networks influenced by micro level vehicle motion and macro level traffic flow pattern models to analyze its effect on wireless communication. We discus the shortcomings of current VANET simulators and then provide recommendations for how to perform useful VANET simulations.

I. INTRODUCTION

Wireless communication influence many different areas. Mobile Ad Hoc Networks (MANETS) is a term coined for the slowly varying network topology needed by computer users moving with human speed. Vehicular Ad Hoc Networks (VANETS) has more dynamic network topology with rapidly moving vehicular nodes. The nodes in VANETS can move around with no boundaries on their direction and speed, although they normally will be constrained by the road network and its geometry. This motion of vehicles poses new challenges in terms of designing a protocol made more specifically for VANETS. For evaluations purposes many tests can be carried out in simulated environments to check the way VANET applications perform before they are deployed in commercial settings in the real world.

The complex environment and topology of VANETs makes it difficult to evaluate them. Real world outdoor experiments can be used to evaluate VANET protocols and applications but can be difficult and expensive to implement due to the high number of vehicles and large real-life scenarios involved. It is further difficult to perform empirical performance measurements because of the inherently distributed, complex environment. To overcome these limitations, simulation tools are needed to analyze VANET.

VANET analysis requires the merge of two kinds of simulations for its smooth functioning, namely traffic and network simulation. Network simulators are used to evaluate network protocols and applications in a variety of conditions. Vehicle traffic simulators are aimed for road traffic and transport analysis/engineering. Such traffic simulators can be used independently but to satisfy analysis needs for VANET a solution is required that enables use of both these two kinds of simulators in a cooperative and integrated way. Numerous simulators have been tried to resolve the issues introduced with VANET but all has had their shortcomings. There are quite large numbers of traffic and network simulators that with some effort can be used as a VANET simulator.

It is not only desired to elaborate and suggest a good simulation tool for VANET but it is also to highlight the needs for a more complete simulator that could simulate and analyze the effects of environment and mobility induced stimuli in the communication among vehicles. This article aims at presenting and analyzing the shortcomings of current simulators for VANETS.

II. RELATED WORK

One challenge associated with models applied to VANETs is the different forms of mobility modeling needed at the Macroscopic and Microscopic level [1]. In general the Mobility Models governs the set of rules that define the VANET nodes movement patterns in an ad-hoc network. The nodes' mobility as a traffic system with arrival rates and traffic flow influenced by streets, lights, buildings etc is classified as Macroscopic, whereas the movement of individual vehicles and their behaviors are Microscopic.

In contrast to existing VANET simulation models, which treat all nodes identically, GloMoSim supports a role based mobility (RBM) model [6] that differentiate nodes by their roles, allowing nodes to have different roles and strategies based on both micro and macro mobility models. Results show that the problem of unrealistic traffic patterns and situations, not reflecting real-life, can be overcome using this role-based mobility model. However, this model has some limitations in that it is incapable of simulating complex traffic elements such as overpasses, bridges and tunnels.

In [7] VGSim, an integrated networking and microscopic vehicular mobility simulation tool and platform is proposed that can accurately model traffic mobility. The authors claim that it fulfils most of the requirements of an accurate simulation, namely closed-loop integration of realistic vehicular traffic and a wireless communication simulation module. They argue that VGSim is highly flexible, and more resource efficient compared to similar approaches and can easily adopt different mobility models.

The mobility model in [8] includes a *Traffic generator* and a *Motion generator*. It also describes a framework for handling of maps covering lanes, roads, streets, mobility obstacles, communication model, car velocities based on traffic densities related to how the simulation time could be varied, vehicular distribution on roads and intelligent driving pattern, see figure 1.

In recent years, many researchers have tried to refine existing mobility models in order to make them more realistic by exploiting real-world mobility traces. The main idea behind such models is the use of available measurements to generate synthetic traces that are characterized by the same statistical properties as real VANET scenarios. We present a few models that generate traces useful as mobility models.

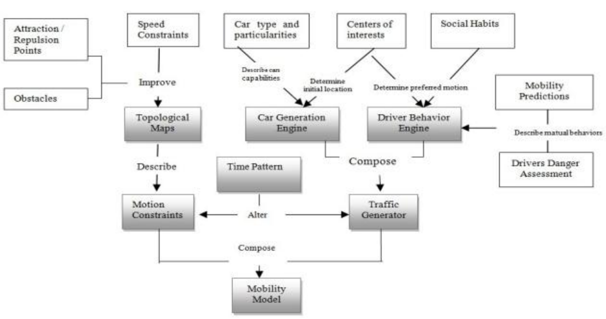

Fig.1. Mobility Model Framework [8]

A. Survey Models

Survey models, can be used to create realistic human behavior models in urban mesh environments, that rely on data collected through logging of human activities. One of the large surveys [5] came from US Department of Labor, which performed a survey by recording workers behavior and their activities at lunch time, communicating with them, pedestrians, lunch and breaks time etc and collected the statistics, which later on helped in creating a generic mobility model. The survey was recorded for the human performance, tasks, and activities.

B. Event Driven Models

Event driven models, also called trace models, can be used to monitor the movement of human beings and vehicles, analyzing them and generating traces based on their mobility. In [8], the author presented a WLAN mobility model, in which the traffic characteristics of WLAN users were modeled across a campus. In [9], the author observed how WLAN users connect with an infrastructure network.

Event driven models can be used to develop a probabilistic mobility model that reflects the real movement on the map. This probabilistic mobility model helped to develop a discrete event Markov chain, which considered the source, destination paths, and the current and previous location. The problem with this model is that only the characteristics of mobile nodes with fixed access points were considered; no relationship between the mobile nodes was modeled. As a result, probabilistic models cannot support the ad hoc mode of VANET.

C. Software Oriented Models

To generate the traces of urban microscopic traffic VANETMobiSim [10] uses the TIGER database and Voronoi graphs to extract road topologies, maps, streets and other similar details. The problem is that it operates only at the macroscopic traffic level. Moreover the inter-operability with other network simulators is insufficient.

D. Synthetic Models

A lot of work has been carried out in the area of synthetic modeling, using mathematical equations to develop realistic mobility models. The strength of these models is validated by comparing them with real mobility data. According to [2] synthetic models can be divided into Stochastic model, Traffic Stream model, Car Following model, Queue model and Behavioral models. Synthetic models capture real physical relationships at some abstraction level but lack human behavioral parameters.

III. SIMULATOR BASED EVALUATION

VANET relies on and is related to two other kinds of simulation, namely that of vehicle traffic and data communication network behavior. *Traffic simulators* are used for road transportation and vehicle traffic engineering. *Network simulators* are used to evaluate communication protocols and application in a variety of conditions. To satisfy the need of VANET simulation, a solution is required that combines these two kinds of simulators in an integrated fashion. Numerous traffic and network simulators have attempted to address VANETs but each solution has its shortcomings, e.g. they do not interact well with each other due to format mismatch.

To qualify for VANET simulation, candidates must satisfy both the vehicle *traffic level* and vehicle *motion level* criteria. To capture sufficient details at traffic level, the simulations must include movement topologies, start and end position, trip through different positions, selection of track, speed of vehicles etc. After all the details at the traffic level have been captured, the motion level criteria are used to create topologies between the nodes and analyze their behavior based on the details gathered at traffic level (e.g., a car may change its lane and try to overtake). The VANET simulator should support a Graphical User Interface (GUI) and be able to generate communication event trace files, useful by other simulators such as NS-2 or QualNet.

It is important to explore what kind of graphs that the traffic simulators can produce? What kind algorithms are used to generate shortest path to destination? What kind of antenna and maximum number of nodes does a network simulator support? Exploring such features will give a better picture of what each kind of simulator provide.

The following simulators satisfy the above criteria (traffic level and motion level): MOVE [11], Trans [12], VanetMobiSim [10], NCTUns [13].

CanuMobiSim [14] is designed to generate only traffic level details and has limited capability to generate motion level details, unlike MOVE and NCTUns simulators. NS [15] and GlomoSim [16] are mainly network simulators.

IV. CHOOSING THE BEST SIMULATOR

A. CANUMobiSim

CanuMobiSim provides mobility models including smooth mobility model, pedestrian, graph walk, fluid traffic, and activity based mobility models. The patterns drawn by CANUMobiSim are derived from Markov Graphs. CanuMobiSim lack ability to generate random graphs and does not include radio wave obstacles in the simulation of wireless networks. CanuMobiSim extracts topology files from Geographical Data Files (GDF) or from user-defined graphs. During simulation, CanuMobiSim takes micro-mobility into consideration and generates traces for NS-2 and GlomoSim. CanuMobiSim is a complex traffic simulator, in which path calculation is made on the basis of Dijkstra's algorithm, also known as the Shortest Path First (SPF) algorithm, and generates trips based on how users create different motion patterns. CanuMobiSim provides a solution for generating mobility traces for network simulators. Improvements are underway to enhance its capabilities, e.g. to include radio propagation model for network simulators.

B. NS2 and NS3

For wireless simulations, NS-2 supports only free space and two ray ground reflection models and cannot simulate path loss, multi-path fading, and shadowing phenomena. The authors of [4] developed the *MIRACLE (Multi InteRfAce Cross Layer Extension)* extension to NS-2 to give a full space propagation model and cross layer support.

NS-2 also has limitations when it comes to more than one wireless interfaces per node. In [3] the author addresses this shortcoming. The research encompassed 802.11 technologies with exception for 802.11a and 802.11b. Besides, NS-2 only supports Bi-directional and Omni-directional antenna for signal propagation and waypoint mobility model for node movement. While simulating wireless networks using NS-2, the nodes must be programmed to sense and transmit data among each other. There is no built-in scanning facility to sense other nodes around.

Another constraint with NS-2 is that it cannot simulate a large mobile network. In [17], the author proved that approximately 5.6 GB of memory is required to simulate 500 nodes in 118.93 minutes hence simulation of 1000 plus nodes practically looks impossible for NS-2.

The emergence of NS-3 promised a better replacement compared to its predecessor. For simulating huge networks NS3 was equipped with support for distributed and federated simulation tasks.

TABLE 1
Motion Level Features of Network Simulators

Simulator	***GloMoSim***	***NS-2***	***NCTuns***
Signal to Noise Ratio Calculation	Cumulative	Difference in two Signals	Cumulative
Signal Reception	SNRT, BER	SNRT	Sender: Transmitting power Receiver: Power threshold, Distance
Fading	Rayleigh, Ricean	No	Rayleigh, Ricean
Path Loss	Free Space, Two Ray	Free Space, Two Ray	Free Space, Two ray, Free space with shadowing
Support for Multiple Wireless Technology	Yes	No	Yes
Antenna's Support	Bi-directional, Omni-directional	Bi-directional, Omni-directional	Directional, Bi-directional, Rotating
Distributed Simulation	Yes	No	Yes
Time required for Simulating 5000 Nodes (sec)	6191	Fail	Fail
Memory Required for Simulating 5000 Nodes (KB)	27.5	Fail	Fail
GUI	Yes	No	Yes

C. GlomoSim

GlomoSim (*Glo*bal *Mo*bile Information System *Sim*ulator) is a second most popular network simulator after NS-2. GlomoSim has the ability to run in parallel on symmetric multi processing (SMP) machines and helps to divide the network into separate modules each running as a distinct process. Because of this feature of multi-tasking, GlomoSim is able to run many thousands of nodes in a single simulation. It is also packaged with rich libraries including varieties of mobility models such as Random Drunken (template for designing new mobility models and node chooses its direction from four choices to choose a path randomly) and Trace Based models (model provided by user) apart from the Random Waypoint mobility model. GlomoSim has two-ray and free-space radio propagation models. SNR (Signal to noise interference ratio) is cumulative i.e. SNR of the given signal is calculated on interference power. GloMoSim has gone commercial now and is known as QualNet.

D. MOVE

MOVE (The MObility model generator for VEhicular networks (MOVE) is built on SUMO (Simulation of Urban Mobility) with GUI support. MOVE has a good visualization tool and focuses on traffic level features. It also supports custom graphs defined by the user as well as random generated graphs.

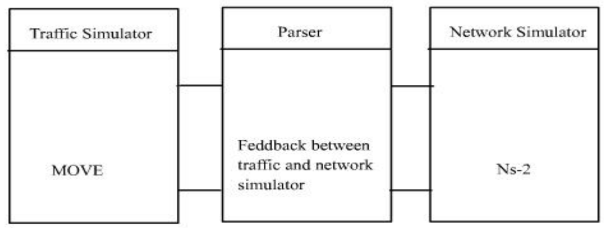

Fig.2. MOVE (Federated)

While generating mobility traces, MOVE takes micro-mobility into consideration. The micro-mobility feature does not include Lane-changing or Obstacle mobility models. The intersection management follows a simplistic stochastic model [2] and therefore random movement of a node in the topology is not considered. MOVE utilizes the federated approach, in which it can communicate with other simulators via a parser, see figure 2. Traces from the traffic simulators are sent to a parser for translation and then processed by the network simulator. The network simulator passes back an updated file to the traffic simulator via the parser. The problem with this approach is that the interaction between the two simulators is not done in a timely manner. MOVE further does not support simulation of radio wave obstacles.

E. TraNs

TraNS is a Java-based tool built to integrate SUMO and NS-2 with VANET simulation and visualization in mind. SUMO translates the traffic file to a dump file which is later used by a network simulator. The output obtained from NS-2 cannot be passed back to SUMO (i.e., NS-2 generates its output to *file.out* file and during VANET simulation; this *file.out* cannot be passed to SUMO for regeneration of traces. Thus, the two loosely coupled simulators fail to produce results similar to real life examples. Also no support for stimuli objects in vehicular communication.

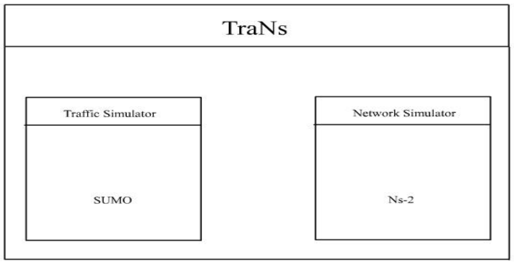

Fig.3. TraNs (Integrating SUMO and NS-2)

F. VANETMobiSim

VanetMobiSim is a version of CanuMobiSim extended to handle the high level of detail and realism needed for VANET simulation It can in this version extract road topologies from random and custom topologies. It allows users to generate trips and can configure the path between the source and destination based on the Dijkstra, road-speed shortest, or density-speed shortest algorithm. VanetMobiSim contains a parser to extract topologies that can be used by network simulators. VanetMobiSim integrate well with network simulators for VANET Simulation. The problem is that the traces that it generates cannot be fed back to the network simulator or the traces generated by network simulator cannot be used as input to VanetMobiSim.

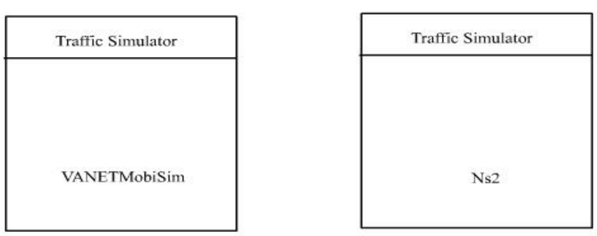

Fig.4. Separate Traffic and Network Simulator

TABLE 2
Traffic Level Features of Various Simulators

Attribute	*SUMO/MOVE/TraNs*	*VanetMobiSim*	*NCTuns*
Custom Graphs	Supports	Supports	Supports
Random Graphs	Grid Based	Voronoi Graphs	SHAPE-File
Graphs from Maps	TIGER database	GDF	Bitmap image
Multilane Graphs	Support	Support	Support
Start/End position	AP, Random	AP, Random	Random
Trip	Random Start - End	Random Start – End	Random
Path	Random Walk, Dijkstra	Random Walk, Dijkstra	Random Walk
Velocity	Road Dependent, Smooth	Road Dependent, Smooth	Road Dependent, Smooth

TABLE 3
Motion Level Features of Various Simulators

Attribute	*SUMO/MOVE/TraNs*	*VanetMobiSim*	*NCTuns*
Human Patterns	Car Following Models	Intelligent driver model, Intelligent driver model with intersection management, Intelligent driver model with Lane changes	Intelligent driver model with car following, Intelligent driver model with Lane changing, Intelligent driver model with intersection management
Intersection Management	Stoch turns	Traffic lights and signs	Traffic lights
Lane changing	No Support	MOBIL	Supports
Radio Obstacles	No Support	Supports	Supports

G. NCTUns

NCTUns [18] can simulate 80.211 a, b, g and p technologies and multiple wireless interfaces within one node including 802.11.p interface. It includes free space, two ray ground and free space radio wave propagation with a shadowing path loss model. It further includes Rayleigh and Ricean fading models and implements directional, bidirectional and rotating antenna types. The Signal to Noise Ratio calculation is cumulative and signal strength is determined from the sender's and receiver's perspective.

NCTUns also can model hinders between wireless signals. For example, the Wall object can completely block the wireless signal or attenuate the signal with a specified value.

However, there is a limitation in NCTUns. Most of the Network simulators allow multiple TCP/IP versions (Tahoe and New Reno) inside single simulators whereas NCTUns allows only a single TCP/IP version. NCTUns uses integrated approach and unlike other simulators, there is a strong feedback between traffic and network simulator. NCTUns can only simulate 4096 nodes in a single instance but due to support for distributed simulation, it is possible to simulate more than 4096 nodes, if running on multiple CPU.

Figure 5 below shows the strength of the various types of simulators discussed related to VANET.

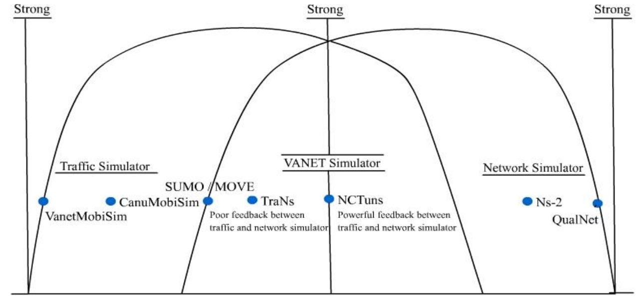

Fig.5. Strength relations between simulator types

V. CONCLUSION AND FUTURE WORK

Wireless communication between vehicles can be used to avoid potential road traffic accidents. Before we set out to test solutions in reality it is important to cover all possible constraints in a simulated environment since outdoor experiments are costly and may not provide us with all the necessary stimuli. Software based simulations are an alternative to obtain needed results. VANET simulation can for example be used for testing a protocol suitable for VANET. This requires the use of realistic mobility models generating realistic mobility patterns.

VANET simulation requires that a traffic and network simulator can be jointly used with feedback between them to render the simulation results as accurate as real life. We presented important traffic and network simulators and also certain VANET simulators and their features. We also presented various possibilities for combining the two. Our overall conclusions are as follows:

Separate Traffic and Network simulator:
VanetMobiSim and NS-2. Problem: Traces are generated once and thus no feedback is allowed.

Integrating Traffic and Network simulator:
TraNs Problem: Loose coupling, the feedback process is slow.

Federating Traffic and Network simulator:
MOVE and NS-2 / QualNet Problem: Still lack interaction.

The work presented could be extended in future by searching for simulators able to run with both real and modeled vehicles and acquire the traffic patterns directly from a video camera. More radio obstacles like the effect of rain, fog, magnetic field could also be added to see different effects.

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