TraNS: Realistic Joint Traffic and Network Simulator for VANETs *

M. Piórkowski M. Raya A. Lezama Lugo P. Papadimitratos M. Grossglauser J.-P. Hubaux
firstname.lastname@epfl.ch
Laboratory for computer Communications and Applications (LCA)
School of Computer and Communication Sciences
EPFL, Switzerland

Realistic simulation is a necessary tool for the proper evaluation of newly developed protocols for Vehicular Ad Hoc Networks (VANETs). Several recent efforts focus on achieving this goal. Yet, to this date, none of the proposed solutions fulfil all the requirements of the VANET environment. This is so mainly because road traffic and communication network simulators evolve in disjoint research communities. We are developing TraNS, an open-source simulation environment, as a step towards bridging this gap. This short paper describes the TraNS architecture and our ongoing development efforts.

I. Introduction

Vehicular networks are emerging as a new research area in mobile networking, as wireless ad hoc communication can enable equipped vehicles to exchange safety, transportation efficiency, and other information. The development of protocols for VANETs is a challenging problem, especially when one considers their evaluation. Simulations have long been used in the context of mobile computing and notably mobile ad hoc networking. But, VANET protocols have a unique mix of characteristics and requirements [8] that call for a *new* simulation approach. Selecting a network simulator, such as the widely adopted ns2 [3], and simply adding a set of road mobility models would yield results that do not reflect the features of VANETs. This is so because VANETs are perhaps the first instance of mobile networks with a direct influence by communication on the behavior and, in particular, mobility of nodes. Consider the example of a *safety* application: the dissemination of alert information from one vehicle to other nearby vehicles can immediately affect their mobility.

In this work, we advocate a simulation approach and develop a corresponding new tool for realistic simulations of vehicular communications. In brief, our **Tra**ffic and **N**etwork **S**imulation Environment (**TraNS**) links two open-source simulators: a traffic simulator, SUMO [2], and a network simulator, ns2. Thus, the network simulator can use realistic mobility models and influence the behavior of the traffic simulator based on the communication between vehicles. We stress here that TraNS is the first *open-source* project that attempts to realize this highly pursued coupling for application-centric VANET evaluation. The goal of TraNS is to avoid having simulation results that differ significantly from those obtained by real-world experiments, as observed for existing implementations of mobile ad hoc networks in [9].

Similar efforts to ours have been undertaken by other researchers, highlighting the importance of new simulation tools for VANETs. Notably, the last three years have witnessed a major proliferation of tools that attempt to integrate traffic and networks simulators [10, 11, 12, 13, 14, 15, 16, 17, 18]. Both [10] and [18] use real maps to create random waypoint mobility traces; [11] uses microscopic traffic models on artificial Voronoi graphs; [12] uses the traffic simulator SUMO to generate mobility traces for ns2; [16] is a modular integrated traffic and network simulator from scratch, but it lacks validated communication modules; [17] uses a microscopic traffic simulator on the real maps of one city (Zürich).

The shortcoming of most of these tools is that information exchanged in VANET protocols cannot influence the vehicle behavior in the mobility model. There exist exceptions, e.g. [13, 14], which achieve real-time interaction between a traffic and a network simulator: VISSIM or CARISMA and ns2 respectively. Unfortunately, VISSIM and CARISMA are commercial products, and thus the tools described in [13, 14] are not publicly available. Moreover, highly integrated simulators, such as NCTUns [15] can help in evaluating VANETs, as they allow run-time control of vehicle movements through an intelligent driving behavior module. However, the mobility component

*Part of this work was funded by the EU project SEVECOM (http://www.sevecom.org).

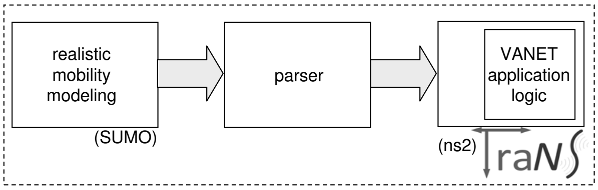

Figure 1: The network-centric mode of TraNS

is highly integrated with the network simulator. This makes it hard to utilize realistic road traffic simulators, such as, those developed within the Intelligent Transportation Systems (ITS) community. Hence, our solution is more generic because it can combine potentially any realistic road traffic simulator with any network simulator.

II. TraNS Architecture

TraNS has two distinct modes of operation, each addressing a specific need. The first mode, which we term *network-centric*, can be used to evaluate, for realistic node mobility, VANET communication protocols that do not influence in real-time the mobility of nodes. One example is user content exchange or distribution (e.g. music or travel information). The second mode, termed *application-centric*, can be used to evaluate VANET applications that influence node mobility in real-time, and thus during the traffic simulation runtime. Safety applications (e.g., abrupt braking, collision avoidance, etc.) are such examples. We present in detail these two architectures next.

II.A. Network-Centric Mode

While operating in this mode, TraNS provides the network simulator with realistic mobility traces from the traffic simulator.

The main component of the network-centric mode is the *parser*, which resides between the road traffic simulator and the network simulator. We illustrate the network-centric architecture of TraNS in Fig. 1. The traffic simulator outputs a road network map and the *dump file* that contains mobility-related information about all vehicles; the parser translates this dump file into a format acceptable by the network simulator. This architecture allows for generation of the mobility traces prior to the network simulation.

The current version of TraNS supports the SUMO traffic simulator [2] and the ns2 network simulator [3]. However, the mobility traces for ns2 generated by TraNS can also be used by the JiST/SWANS simulator [10] with some modifications.

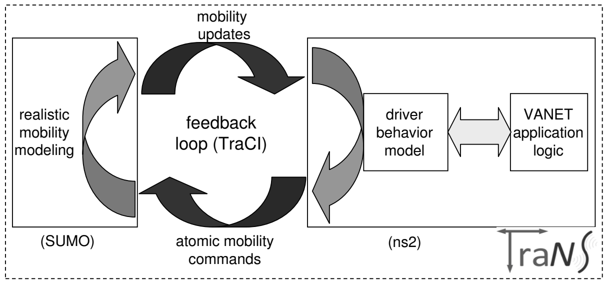

Figure 2: The application-centric mode of TraNS

II.B. Application-Centric Mode

The second mode allows the network simulator to control the mobility of certain vehicles in simulation runtime. It is possible to modify the mobility of selected vehicles, depending on the simulated scenario. For example the network simulator may decide that the mobility of vehicles moving only on a specific road segment must be changed. Thus the network simulator will instruct the road traffic simulator to change their mobility attributes, while other vehicles, that are moving elsewhere, will follow the mobility process as it is controlled by the road traffic simulator only. We achieve this coupling by using a specific interface for interlinking road traffic and networking simulators, called TraCI [4]. While working in the application-centric mode, it is possible for TraNS to perform a full-blown evaluation of VANET applications that influence vehicle's mobility, i.e., safety and traffic efficiency applications (e.g. SmartPark [6]). We illustrate this application-centric architecture of TraNS in Fig.2.

In this mode, the mobility traces are not generated prior to network simulation, rather both simulators operate simultaneously. Note that in this mode no mobility trace files are stored on a data storage device, as is the case for the network-centric mode. This becomes important, especially when large scale and long-term simulation scenarios are considered, for which mobility trace files might become very large. The feedback loop provided by TraCI is active in this mode, thus it is possible to modify the mobility of individual vehicles due to information exchange within VANET. The TraCI interface uses the *atomic mobility commands*, such as *stop*, *change lane*, *change speed*, etc. to manipulate vehicle mobility. Our intuitive observation is that any complex vehicle mobility pattern, influenced by a VANET application, can be broken down into a collection of consecutive atomic mobility actions performed by the driver. Thus we approximate the driver's mobility behavior as a time sequence of the atomic mobility actions. For example, in both the Traffic Congestion Warning and the Merging Assistance applications proposed by the Car-to-Car Communication Consortium [7], vehicles may have to first *change speed* and then *change lane*. For the detailed description of the TraCI interface please refer to [4].

In a safety application, as it would be communicated to the driver, the command *avoid crash* can be translated into the following three consecutive mobility commands: *change speed(reduce)*, *change lane* and *change speed(increase)*. The decision about when and which mobility commands should be sent to the traffic simulator are taken by the *driver behavior model*. Ideally the decision-making process should depend on both the information about the driving infrastructure, such as the number of lanes on a road segment or the number of cars ahead, and the VANET-related information. Currently, we are implementing a simple driver behavior model that makes decisions upon reception of messages exchanged between vehicles. Nevertheless, it is possible to implement more sophisticated behavioral patterns of motorists, because the TraCI interface allows for the polling of the road traffic simulator for the information related to the driving infrastructure.

In our architecture, the VANET applications are implemented in the network simulator. As depicted in Fig. 2, the module that embodies the VANET application logic, interacts with the driver behavior model module when it is necessary to adjust mobility attributes of a simulated vehicle.

In both modes, the communication channel between simulators is set up over a dedicated TCP/IP connection such that two separate hosts might be used to perform the simulation. In this case, TraNS needs to be installed on both hosts. TraNS also provides a graphical user interface that allows for quick and simple set up of all the required simulation parameters like road network topology, simulation time, TCP communication ports, dump and scenario files, etc.

III. Conclusion

In this short paper, we present the concept and design of an integrated realistic simulation environment for VANETs called TraNS. Our main goal is to enable detailed and realistic evaluation of VANETs at network-centric, as well as application-centric levels. The current release of TraNS [1] implements the network-centric mode and provides a set of usage examples, including mobility scenarios for actual large-scale road networks. The next TraNS release will implement both the network-centric and the application-centric mode. We collaborate with other open-source simulation tools for VANETs, notably [5]. We also solicit contributions via [1] towards the development of an open-source simulation tool for an emerging area of mobile computing.

References

[1] `http://trans.epfl.ch`

[2] `http://sumo.sourceforge.net`

[3] `http://www.isi.edu/nsnam/ns`

[4] `http://sumo.sf.net/wiki/index.php/TraCI`

[5] `http://www.auto-nomos.de`

[6] `http://smartpark.epfl.ch`

[7] `http://www.car-2-car.org`

[8] J. Blum, A. Eskandarian, and L. Hoffman "Challenges of intervehicle ad hoc networks," *IEEE Transactions on Intelligent Transportation Systems*, 5(4):347–351, 2004.

[9] W. Kiess and M. Mauve "A survey on real-world implementations of mobile ad-hoc networks," *Ad Hoc Networks*, 5(3):324–339, 2007.

[10] D. Choffnes and F. Bustamante "An integrated mobility and traffic model for vehicular wireless networks," *VANET'05*.

[11] J. Härri, M. Fiore, F. Fethi, and C. Bonnet "VanetMobiSim: generating realistic mobility patterns for VANETs," *VANET'06 (Poster)*.

[12] F. Karnadi, Z. Mo, K. Lan "Rapid Generation of Realistic Mobility Models for VANET," *WCNC'07*.

[13] C. Lochert, A. Barthels, A. Cervantes, M. Mauve and M. Caliskan, "Multiple simulator interlinking environment for IVC," *VANET'05 (Poster)*.

[14] S. Eichler, B. Ostermaier, C. Schroth and T. Kosch, "Simulation of Car-to-Car Messaging: Analyzing the Impact on Road Traffic," *MASCOTS '05*, 507–510, 2005.

[15] S.Y. Wang, C.L. Chou, Y.H. Chiu, Y.S. Tseng, M.S. Hsu, Y.W. Cheng, W.L. Liu and T.W. Ho, "NCTUns 4.0: An Integrated Simulation Platform for Vehicular Traffic, Communication, and Network Researches," *WiVec'07*.

[16] R. Mangharam, D. Weller, D. Stancil, R. Rajkumar and J. Parikh "GrooveSim: a topography-accurate simulator for geographic routing in vehicular networks," *VANET'05*.

[17] V. Naumov, R. Baumann and T. Gross "An evaluation of intervehicle ad hoc networks based on realistic vehicular traces," *MobiHoc'06*.

[18] A. Saha and D. Johnson "Modeling mobility for vehicular ad-hoc networks," *VANET'04 (Poster)*.