TraNS: Realistic Joint Traffic and Network Simulator for VANETs

Michał Piórkowski, Maxim Raya, Ada Lezama Lugo, Panos Papadimitratos, Matthias Grossglauser, and Jean-Pierre Hubaux
Laboratory for computer Communications and Applications (LCA)
School of Computer and Communication Sciences
EPFL, Switzerland
firstname.lastname@epfl.ch

ABSTRACT

Realistic simulation is a necessary tool for proper evaluation of newly developed protocols for Vehicular Ad Hoc Networks (VANETs). Several recent efforts focused on achieving this goal. Yet, to this date, none of the proposed solutions fullfills 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.

1. INTRODUCTION

Vehicular networks are emerging as a new research area in mobile networking, as wireless ad hoc communication will 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. One option is the deployment of testbeds, with communicating vehicles having all necessary software and hardware mounted on-board. However, this is costly even for a handful of vehicles. More important, evaluations of most networking and data dissemination protocols, and enabled applications, would be meaningful only at a large scale, for hundreds of nodes. Furthermore, the repeatability of experiments would be particularly hard. Thus, *realistic simulations* emerge as a practical and valuable evaluation tool.

Simulations have been long used in the context of mobile computing and notably mobile ad hoc networking. However, VANET protocols have a unique mix of characteristics and requirements [11] 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 of communication on the behavior and, in particular, mobility of nodes. Consider the example of a *safety* application: dissemination of alert information from one vehicle to other nearby vehicles can immediately impact 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 [16].

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 [13, 14, 15, 17, 19, 20, 21, 22]. Both [13] and [22] use real maps to create random waypoint mobility traces; [14] uses microscopic traffic models on artificial Voronoi graphs; [15] uses the traffic simulator SUMO to generate mobility traces for ns2; [20] is a modular integrated traffic and network simulator from scratch, but it lacks validated communication modules; [21] 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. [17, 18], 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 [17, 18] are not publicly available. Moreover, highly integrated simulators, such as NCTUns [19] can help in evaluating VANETs, as they allow run-time control of vehicle movements through an intelligent driving behavior module. However, the mobility component is highly integrated with the network simulator. This makes it hard to utilize realistic road traffic simulators, for example, those developed within the Intelli-

This work is partially supported by the National Competence Center in Research on Mobile Information and Communication Systems (www.mics.ch) and by the European project SeVeCom (www.sevecom.org).
.

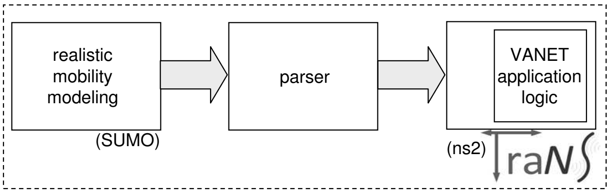

Figure 1: Network-centric evaluation oriented architecture of TraNS

gent Transportation Systems (ITS) community. Hence, our solution is more generic, as it can combine potentially any realistic road traffic simulator with any network simulator.

2. 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 breaking, collision avoidance, etc) are such examples. We present in detail these two architectures next.

2.1 Network-Centric

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. Given a road network map and the *dump file*, which contains mobility-related information about all vehicles simulated in the road traffic simulator, the parser translates this dump file into a format acceptable by the network simulator.

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 JiST/SWANS simulator [5], while a specific extension to the latter is applied [7].

This architecture allows to generate the mobility traces prior to the network simulation. Note that this can be done only once and then used multiple times by the network simulator.

2.2 Application-Centric

The second modes allows controlling the network simulator to control the mobility of certain vehicles in simulation runtime. We achieve this by using a specific interface for coupling 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, for example SmartPark [8]. We illustrate this application-centric architecture of TraNS in Fig.2.

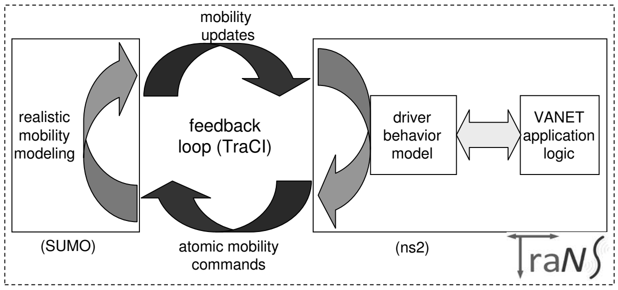

Figure 2: Application-centric evaluation oriented architecture of TraNS

In this mode, the mobility traces are not generated prior to network simulation, but, rather, both simulators operate simultaneously.

The feedback loop provided by TraCI is active in this mode, thus it is possible to modify mobility of individual vehicles due to information exchange within VANET. The *atomic mobility commands*, such as *stop*, *change lane*, *change speed*, etc. used by the TraCI interface to manipulate vehicle's mobility, are designed based on the observation that there are many similarities in vehicle movement patterns, no matter what VANET application is in use. In brief, a 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. For example, in both the Traffic Congestion Warning and the Merging Assistance applications proposed by Car-to-Car Communication Consortium [10], 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 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 number of lanes on a road segment or number of cars in front, and the VANET-related information. Currently, we are implementing a simple driver behavior model, which takes decisions upon reception of messages exchanged between vehicles. Nevertheless, it is possible to implement more sophisticated behavioral patterns of motorists, since the TraCI interface allows to poll 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.

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 modes. We are currently implementing the driver behavior model module as well as exemple safety and traffic efficiency VANET applications, as those considered by the Car to Car Communication Consortium [10] and projects such SeVeCom [**?**].

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 that case, TraNS needs to be installed on both hosts. TraNS also provides a graphical user interface that allows 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.

3. PLANNED FEATURES

Our ongoing efforts focus on:

- Integrating a more realistic IEEE 802.11p physical layer model, based on recent results described in [12] and [23] (publicly available traces).
- Enabling large-scale simulations (10000 nodes or more), using tools such as [5].
- Modeling the cost of securing VANET protocols [**?**, 9], in particular message overhead and processing and other delays. The cryptographic primitives and parameters are user-selectable. These features additionally distinguish TraNS from other tools.
- Comparison to other simulators, in order to come up with an objective benchmark of VANET simulators.

4. CONCLUSION

In this short paper, we present the concept and design of an integrated realistic simulation environment for VANETs called TraNS. Its main goal is to enable exhaustive evaluation of VANETs at network-centric as well as application-centric levels. We collaborate with other open-source simulation tools for VANETs, notably [6] and [7]. We also solicit contributions via [1] towards the development of an open-source simulation tool for an emerging area of mobile computing.

5. 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://jist.ece.cornell.edu/`

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

[7] `http://vanet.info/`

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

[9] `http://ivc.epfl.ch/`

[10] R. Baldessari, B. Bödekker, M. Deegener, A. Festag, W. Franz, C. Kellum, T. Kosch, A. Kovacs, M. Lenardi, C. Menig, T. Peichl, M. Röckl, D. Seeberger, M. Straßberger, H. Stratil, H.-J. Vögel, B. Weyl and W. Zhang "Car-2-Car Communication Consortium - Manifesto (Version 1.1)," *IEEE Vehiclular Technology Conference*, 2007. `http://www.car-2-car.org/index.php?id=570`

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

[12] Q. Chen, D. Jiang, V. Taliwal, and L. Delgrossi "IEEE 802.11 based vehicular communication simulation design for NS-2," *VANET'06.*

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

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

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

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

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

[18] 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.

[19] 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.*

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

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

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

[23] H. Füβler, M. Torrent-Moreno, M. Transier, R. Krüger, H. Hartenstein, and W. Effelsberg "Studying vehicle movements on highways and their impact on ad-hoc connectivity," *ACM SIGMOBILE MC2R (MobiCom Poster Abstract)*, 10(4):26–27, 2006.