Survey on Simulation Framework for Intelligent Transportation Systems

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Abstract. The ongoing efforts to apply advanced technologies to help solve transportation problems include the growing trend of integrating mobile wireless communications into transportation systems. In particular, vehicular ad hoc networks (VANETs) allow vehicles to constitute a decentralized traffic information system on roadways and to share their own information. In this paper, we provide a comprehensive survey on various simulation methods for VANET systems.

1. Introduction

To date, numerous VANET simulators have been proposed in the literature, and the quality of VANET simulation has grown over time. Yet, there remain limitations in existing methods and the state of art is far from fulfilling the needs that VANET research community calls for. In this section, we briefly review prior work on VANET simulation and discuss their unique properties as well as the differences from our framework.

Based on architecture, we categorize existing VANET simulators into four. (i) Mobility-trace-based VANET simulator uses an existing network simulator with vehicular mobility trace fed into the simulator as a static input. (ii) Mobility-implemented network simulator extends an existing network simulator by implementing vehicular mobility model within the framework. (iii) Mobility-network integrated simulator combines two existing simulators, one for mobility and the other for network, by implementing inter-simulator interface. (iv) Tightly-coupled VANET simulator is a standalone framework with two components (mobility and network) tightly coupled, and usually developed from the scratch.

2. Traffic Only Simulator

In order to simulate various vehicle movements such as car following, lane changing, shock waves and queuing, microscopic transportation simulators were employed in many studies.

SUMO is an open source microscopic transportation simulator designed for large road network [9] and MOVE is an extension of SUMO with GUI support [10].

The limitation of SUMO and MOVE is that their features do not include any lane change or obstacle mobility models [13]. VanetMobiSim is a widely used mobility trace generator that supports macro-mobility features and micro-mobility features [7]. FreeSim [5] is another customizable macroscopic and microscopic transportation simulator licensed under the GNU. These transportation-oriented tools simulate various traffic circumstances but not the network communications. Corsim [4] and Paramics [17] are well-known traffic simulation tools that implement aforementioned mobility models.

3. Network Only Simulator

GloMoSim is a network simulator that currently supports purely wireless network protocols [12]. It was designed similar to the OSI seven layer. QualNet, a commercial version of GloMoSim [19], is very powerful in a sense that it supports a large set of physical and link layer models and parallel architecture which makes it extremely scalable (up to tens of thousands of nodes). OPNET [16] is a commercial network simulator that has a large amount of network elements available, and it enables various network configuration functionalities. Ns-2, an open-source program, is the most widely used network simulator that simulates link-layer and limited physical layer characteristics [15]. However, ns-2 does not scale well (up to a few thousands of nodes) and its quality of simulation in physical layer is insufficient for highly dynamic nature of VANET. SWANS [6] is a network simulator similar to ns-2 or GloMoSim, but it supports larger networks.

4. Mobility-trace-based network-centric simulator

Blum et al. [1] used CORSIM [4] and CARLINK [3] used VanetMobiSim to generate a mobility trace, which is fed into ns-2. This method, however, cannot simulate how the inter-vehicle communication can affect driving behavior; for example, it cannot show how vehicles can change their paths or lanes to avoid congestion, based on traffic information collected by VANET. In the following, we call a simulator with such network-to-transportation feedback bidirectional-feedback simulator; otherwise, we call unidirectional. Without bidirectional-feedback support, the simulator is only appropriate for infotainment applications.

5. Mobility-implemented network simulator

Instead of using trace for vehicle movement, ASH [8] and Wischhof et al. [23] implemented mobility model directly inside the network simulator. Wischhof et al. [23] implemented a mobility model based on a cellular automation model, but bidirectional-feedback was not implemented. ASH (Application-aware SWANS with Highway mobility) takes the same approach. ASH implements IDM (Intelligent Driver Model) with car following and MOBIL lane changing model, inside SWANS network simulator. ASH supports bidirectional feedback.

6. Mobility-network integrated simulator

Wu [24] combined QualNet with CORSIM by implementing an interface called CQCL. Authors focused on optimizing communication overhead between simulators, while supporting only unidirectional feedback.

TraNS [18] is integrates transportation simulator SUMO [8] with ns-2 via an interface called TraCI. TraNS translates mobility commands of ns-2 into primitive driving directions, then are sent to SUMO. TraNS provides bidirectional feedback between ns-2 and SUMO. SWANS++ [22] is a tightly integrated simulator that added mobility model STRAW (STreet RAndom Waypoint) [21] into SWAN. STRAW is a random waypoint model over streets and supports no lane changing. SWANS++ only supports unidirectional-feedback. Veins (Vehicles in Network Simulation) [20] is another tightly coupled simulator that integrates a transportation simulator SUMO with a network simulator OMNet++ through a TCP connection.

7. Monolithic VANET simulator

NCTUns [14] is a standalone VANET simulator that integrates transportation simulation capabilities with network simulation capabilities. The network protocol of NCTUns is integrated with the Linux kernel protocol stacks, making any Linux network application compatible with NCTUns. GrooveNet [11] is a hybrid VANET simulator that allows communication between simulated vehicles and real vehicles on the road. GrooveNet's modular architecture incorporates mobility, trip, and message broadcast models over a variety of link and physical layer communication models. GrooveNet and NCTUns are becoming widely accepted as VANET simulation tools, but they still need further improvement and extension to meet various needs of transportation research [13].

REFERENCES

1. Blum, J., Eskandarian, A., and Hoffman, L. (2004). Challenges of intervehicle *ad hoc* networks. IEEE Transactions on ITS, 5(4), pp. 347–351.
2. Bononi, L., Felice, M. D., D'Angelo, G., Bracuto, M., and Donatiello, L. (2008). MoVES: A framework for parallel and distributed simulation of wireless vehicular ad hoc networks. Computer Networks, Vol. 52, No. 1, Elsevier, pp. 155-179.
3. CARLINK::UMA (2008). Simulation and evaluation of realistic MEU ad-hoc communications in CARLINK scenarios by using VanetMobiSim/Ns-2. Technical report, D 1.3.9, Spain.
4. CORSIM: Microscopic Traffic Simulation Model. http://www.strategicforecasting.com
5. FreeSim, 2008. Available at: http://www.freewaysimulator.com/
6. Barr, R., Haas, Z.J., and Renesse, R., "JiST: Embedding Simulation Time into a Virtual Machine," Proc. EuroSim Congress on Modelling and Simulation, 2004.

7. Haerri J, Fiore M, Fethi F, Bonnet C. VanetMobiSim: generating realistic mobility patterns for VANETs. Institut Eurécom and Politecnico Di Torino, 2006. Available at: http://vanet.eurecom.fr/
8. Ibrahim, K. and Weigle, M.C., ASH: Application-aware SWANS with Highway mobility, in Proceedings of IEEE INFOCOM Workshop on MObile Networking for Vehicular Environments (MOVE), Apr. 2008
9. Krajzewicz D, Rossel C. Simulation of Urban Mobility (SUMO). German Aerospace Centre, 2007. Available at: http://sumo.sourceforge.net/index.shtml
10. Lan, K-C and Chou, C-M, Realistic mobility models for Vehicular Ad hoc Network (VANET) simulations, 8th International Conference on ITS Telecommunications, 362 – 366, 2008
11. R. Mangharam, D. S. Weller, R. Rajkumar, P. Mudalige and Fan Bai, GrooveNet: A Hybrid Simulator for Vehicle-to-Vehicle Networks, Second International Workshop on Vehicle-to-Vehicle Communications (V2VCOM), San Jose, USA. July 2006
12. Martin J. GloMoSim. Global mobile information systems simulation library. UCLA Parallel Computing Laboratory, 2001. Available at: http://pcl.cs.ucla.edu/projects/glomosim/
13. Martinez, F, Toh, C.K., Cano, J-C, Calafate, C.T., Manzoni, P., A survey and comparative study of simulators for vehicular ad hoc networks (VANETs), Wireless Communications and Mobile Computing, DOI: 10.1002/wcm.859, 2009.
14. NCTUns 5.0, 2008. Available at: http://nsl10.csie.nctu.edu.tw/
15. Network Simulator - ns-2, http://www.isi.edu/nsnam/ns/
16. OPNET Technologies, Inc., http://www.opnet.com/
17. Paramics Homepage. Quadstone Paramics, UK. http://paramics-online.com
18. Piorkowski M, Raya M, Lugo AL, Papadimitratos P, GrossglauserM, Hubaux J-P. TraNS (Traffic and Network Simulation Environment). Ecole Polytechnique Fédérale de Lausanne, EPFL, Switzerland, 2007. Available at: http://trans.epfl.ch/
19. QualNet Homepage. Scalable Network Technologies, California. http://www.scalable-networks.com
20. Sommer, C., German, R. and Dressler, F., "Bidirectionally Coupled Network and Road Traffic Simulation for Improved IVC Analysis," IEEE Transactions on Mobile Computing, vol. 10 (1), pp. 3-15, January 2011.
21. STRAW - STreet RAndom Waypoint - vehiclar mobility model for network simulations (e.g., car networks), 2008. Available at: http://www.aqualab.cs.northwestern.edu/projects/STRAW/index.php
22. SWANS++ Homepage. Aqua Lab, http://www.aqualab.cs.northwestern.edu/projects/swans++/
23. Wischhof, L., Ebner, A., and Rohling, H. (2005). Information dissemination in self-organizing intervehicle networks. IEEE Transactions on ITS, 6(1), pp. 90-101.
24. Wu, H. (2005). Analysis and design of vehiclualr networks. Ph. D. dissertation, Georgia Institute of Technology, Atlanta, US.