Design and Development of a WAVE Simulator Interoperable with Traffic Simulators

Won Hwa Lee
Department of Electronics and Computer Engineering
Hanyang University
Seoul, Korea
lwh0987@hanyang.ac.kr

Tae Hoon Kwon
Department of Electronics and Computer Engineering
Hanyang University
Seoul, Korea
taevly@hanyang.ac.kr

Minjin Baek
Department of Electronics and Computer Engineering
Hanyang University
Seoul, Korea
mjbaek@hanyang.ac.kr

Sang-Sun Lee*
Department of Electronics and Computer Engineering
Hanyang University
Seoul, Korea
ssnlee@hanyang.ac.kr

***Abstract*—Vehicular communication technologies have gained recognition for their potential contribution to the improvement of the road safety and the traffic congestion. Despite the growing research interest in vehicular communications, currently available network simulators have shortcomings with respect to generation of accurate vehicle driving information. In this paper, we present a network simulator that is interoperable with traffic simulators for the purpose of utilizing more accurate vehicle driving information. The carrier sense multiple access with collision avoidance (CSMA/CA) of the IEEE Wireless Access in Vehicular Environment (WAVE) standard is implemented in the network simulator. The interface between the network simulator and the traffic simulator is designed to convert traffic simulation results into an acceptable input format for the network simulator. Our simulation results show that the proposed network simulator successfully demonstrates the inherent characteristic of the CSMA/CA of the IEEE WAVE standard.**

Keywords—WAVE; V2X communications; network simulator; vehicular networks

I. Introduction

Automobiles are continuously evolving, and they are more and more developed through the convergence of technologies. As a result, self-driving cars and connected cars are emerging. Advanced driver assistance systems (ADAS) are currently being developed by use of multiple types of sensors, such as cameras, radars, and lidars. However, the performance of these sensors is adversely influenced by the weather and driving conditions. Bad weather conditions, including fog, rain, and snow, as well as non-line-of-sight conditions pose great challenges in detection of surrounding objects. More reliable and robust information acquisition of surrounding objects can be possible via vehicle-to-everything (V2X) communications. IEEE Wireless access in vehicular environment (WAVE) is one of the most promising technologies for V2X communications. The WAVE standard is defined in IEEE 802.11p and IEEE 1609 series.

V2X communication technology is also a key component of intelligent transportation systems (ITS). With V2X communications, it is possible to provide traffic congestion control service by gathering traffic data and driving information of each vehicle. The development and testing of V2X-based technologies such as traffic congestion recognition and control often require a large number of vehicles equipped with V2X communication devices. Due to the high cost of the test equipment and the lack of and/or limited access to ITS test sites, network simulators, such as NS-2 network simulator [1] and QualNet [2], are actively used for research on V2X communications. However, the vehicle driving information generated within the simulators is very limited, and road traffic environments cannot be accurately modeled.

In this paper, we propose a WAVE simulator that is interoperable with existing traffic simulators, such as SUMO [3] and VISSIM [4]. The proposed design includes an interface between the network simulator and the traffic simulator, such that the traffic simulation results are converted into an acceptable input format and fed to the network simulator. This approach enables utilization of accurate vehicle driving information generated in close-to-real road traffic environments.

II. Related Work

A. Network Simulators

In recent years, flow level network simulators, which can perform significantly faster simulations than conventional packet level network simulators, have been receiving attention. Most widely used network simulators are NS-2 and QualNet. NS-2 has been developed specifically for the purpose of simulating computer network communications. NS-2 is an event-driven simulator, and provides an efficient and convenient user interface. The simulator uses object tool command language scripts that allow users to easily set up the parameters of algorithms written in C++. QualNet supports an intuitive network simulation modeling functions for user convenience through application programming interface. In addition, users can visualize the state of communications which occurs in the application layer. When running designed network scenarios, the simulator additionally supports a graphic user interface, which allows users to monitor the dynamic performance graph in real time. However, these

*Corresponding author.

This work was supported by Korea Agency for Infrastructure Technology Advancement (KAIA) grant funded by the Korea government (MOLIT). (No.16TLRP-C105654-02, Development and Verification of Signal Operation Algorithms in Local Intersection Network utilizing V2X Communication Infrastructure).

network simulators do not provide capabilities to construct detailed transportation networks, and have limitations of setting up various road traffic scenarios.

B. *Traffic Simulators*

Traffic simulators, such as SUMO and VISSIM, enable users to set up vehicle states which include position, velocity, acceleration, size, and moving direction at any particular simulation time. Using these simulators, detailed characteristics of road traffic environments can be designed, and the signal cycle of each traffic light can be modified. The simulators offer a graphic user interface as well as an animation of the traffic flow. Also, the simulators provide vehicle movement models, such as a car-following model and a lane-changing model.

III. Proposed Simulator Design

For designing a WAVE simulator, we used event-driven scheduling that provides quick and accurate event management [5]. Event-driven scheduling organizes events that already exist and treats appointed system action sequentially. The next event is made by a user-defined event or an event driven by previous events. The network simulator scheduler looks for the next event simultaneously while one of the events is being processed. Every time an event occurs, the network simulator checks the result and saves the data. The simulation process terminates when there is no additional event. In addition, we created an interface between the network simulator and the traffic simulator in order to utilize accurate vehicle driving information generated from traffic simulations. The proposed simulator design consists of the following three parts.

1) Algorithm part: Contains WAVE protocol algorithms and executes network simulations.

2) Data saving part: Stores data in various formats.

3) Interfacing part: Connects the network simulator and the traffic simulator.

A. *Interface between the Network Simulator and the Traffic Simulator*

The interface between the WAVE simulator and the traffic simulator is designed to compensate for the processing speed difference between the network simulator and the traffic simulator. When the traffic simulation data are fetched from the traffic simulator, the interface checks whether the network simulation is in progress or not. If the network simulation is not running, through TCP socket communication, the interface converts the traffic simulation data into an acceptable input format and feeds to the network simulator. The algorithm for the interface is as shown in Figure 2.

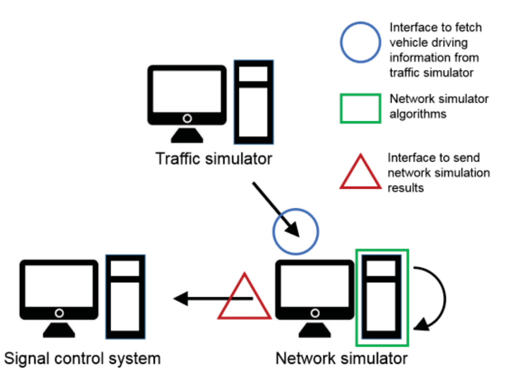

Fig. 1. Overall design of the network simulator and the interface.

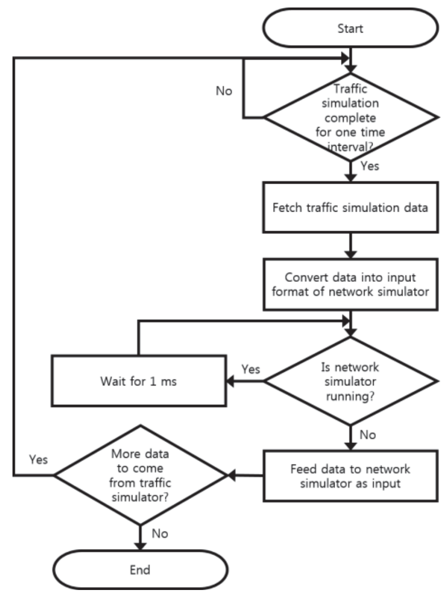

Fig. 2. Simulator interface algorithm flowchart.

B. *Network Simulator Algorithm*

The network simulator consists of two main components. One is a carrier sense multiple access with collision avoidance (CSMA/CA) algorithm. When vehicles transmit data, random values are assigned to each vehicle to determine data transmission opportunities. The other is a vehicle random selection algorithm. This algorithm randomly selects vehicles in a transportation network and provides them with the capability of wireless communications. This allows the simulation of the WAVE communication performance depending on the number of vehicles receiving ITS services. Figure 3 illustrates the network simulator algorithm.

TABLE I. Simulation Parameters

Parameter	Value
Data Rate	6 Mbps
Slot Time	13 µs
SIFS	32 µs
AIFS (AC0)	149 µs
CWmin	15
CWmax	1023
Packet Size	512 byte
Multi Channel Operation	Alternating mode (CCH: 50 ms, SCH: 50 ms)
Data Generation Rate	1 Hz

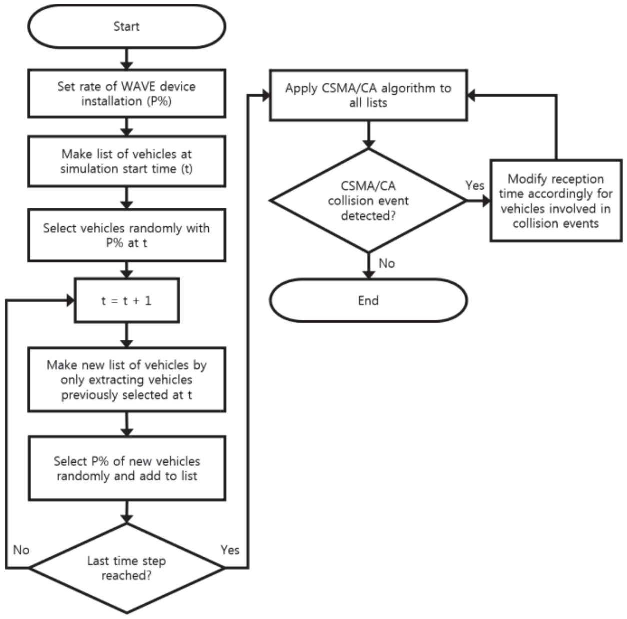

Fig. 3. Network simulator algorithm flowchart.

IV. Simulation Results

In order to obtain preliminary results from the proposed WAVE simulator, we assumed the test scenario as follows. We considered a vehicle information collecting scenario in a single intersection. A road side unit (RSU) advertises the service in the control channel (CCH) interval, and vehicles that receive the advertisement message transmit the driving information to the RSU during the service channel (SCH) interval. The simulation parameters used in this study are presented in Table 1.

Figure 4 shows the simulation results. As the number of vehicles that participate in wireless communications increases, the data reception rate at the RSU decreases. This is the inherent characteristic of the CSMA/CA of the WAVE protocol. When collision events occur, the participants choose a random number within the contention window and the data transmission is delayed accordingly. The more the vehicles participating in wireless communications, the higher the chance of selecting the same random number, which results in longer wait time for data transmission.

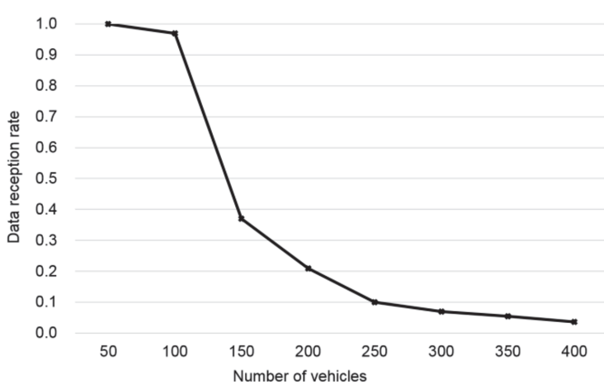

Fig. 4. Simulation results for the data reception rate at the RSU.

V. Conclusion

In this paper, we propose a design of a network simulator that is interoperable with traffic simulators, such as SUMO and VISSIM. The network simulator consists of WAVE protocol algorithms and an interface between the network simulator and the traffic simulator. When vehicle driving information is generated from the traffic simulator, the interface converts the data into a suitable input format and sends them to the network simulator. Our simulation results show that as the number of vehicles equipped with a vehicular communication device increases, the data reception rate at the RSU decreases, which successfully exhibits the characteristic of the CSMA/CA of the IEEE WAVE standard.

For future work, we plan to further develop our network simulator by including propagation and fading models for more accurate simulation results.

References

[1] Q. Chen, et al., "Overhaul of IEEE 802.11 modeling and simulation in NS-2," Proceedings of the 10th ACM Symposium on Modeling, Analysis, and Simulation of Wireless and Mobile Systems, Chania, Greece, Oct. 2007, pp. 159–168.

[2] I. Alocci, S. Murphy, A. Nafaa, and J. Murphy, "Development of an IEEE 802.11s simulation model for QualNet," Proceedings of Networking and Electronic Commerce Research Conference, Riva del Garda, Italy, Sep. 2008.

[3] M. Behrisch, L. Bieker, J. Erdmann, and D. Krajzewicz, "SUMO—simulation of urban mobility: An overview," Proceedings of the 3rd International Conference on Advances in System Simulation, Barcelona, Spain, Oct. 2011.

[4] M. Fellendorf, "VISSIM: A microscopic simulation tool to evaluate actuated signal control including bus priority," 64th Institute of Transportation Engineers Annual Meeting, Dallas, TX, USA, Technical Paper, Session 32, Oct. 1994.

[5] J. R. Evans and D. L. Olson, Introduction to Simulation and Risk Analysis, Upper Saddle River, NJ: Prentice Hall, 2001.