Poster: A Simulator for Heterogeneous Vehicular Networks

Florian Hagenauer, Falko Dressler and Christoph Sommer
Distributed Embedded Systems Group, Department of Computer Science, University of Paderborn, Germany
{hagenauer,dressler,sommer}@ccs-labs.org

***Abstract*—We are aiming to better investigate heterogeneous vehicular networking technologies to overcome the shortcomings of using just a single wireless technology. Performance evaluation is usually done using simulation, for which we need integrated tools supporting WiFi, IEEE 802.11p, cellular technology, and mobility feedback. The established vehicular networking simulators such as *Veins*, *iTETRIS*, or *VSimRTI*, however, currently have no support for such heterogeneous networking, in particular for Long Term Evolution (LTE). We present a new integrated simulation framework based on the popular and mature Veins framework named *VeinsLTE*. We present early results that clearly demonstrate the potential of this integrated approach.**

I. Introduction

Initial work on using multiple network stacks emerged for example in 2005 with Cavalcanti et al. [1] proposing a framework where WLAN is combined with cellular technologies. More recently this idea is also emerging in vehicular networks and already lead to a few publications evaluating the use of multiple technologies in *heterogeneous vehicular networks*. One of them is *MobTorrent* [2], which is built on 3G and Wi-Fi technologies. This framework allows distributed download of data via access points and other vehicles. Some more recent publications focus on the clustering of vehicles to distribute messages [3], [4]. Both try to reduce the delay and the number of messages but do not use a feedback loop for mobility simulation. Generally there is need for heterogeneous networking because both the popular WLAN and the already deployed Long Term Evolution (LTE) networks have their shortcomings:

- WLAN technologies like IEEE 802.11p may not be able to cover dense urban areas. Furthermore the penetration rate will be initially very low as older cars are not equipped with the necessary modules.
- LTE-based technologies cannot support a high frequency of messages because the capacity may not be high enough [5]. Furthermore the overall service quality for other (non-vehicular) users might be degraded because of messages flooding the network. Additionally there is also a core network involved which can increase the delay compared to direct sending via WLAN.

This sentiment has also been mirrored in the context of the Dagstuhl Seminar 13392 [5]. Because of both LTE and IEEE 802.11p having their disadvantages, heterogeneous vehicular networks are being seen as a solution.

There exist three different application scenarios for vehicular networks: *Safety*, *Information*, and *Entertainment*. As the main tool for researchers in this area is simulation there already exist many good simulators for this purpose. To simulate the vehicles' mobility one can use traces that have been generated prior to simulation. But this approach might not be the best in many cases of *Safety* and *Information* scenarios where vehicles have to be able to react in various ways to received messages. This includes for example route changes or speed adaption. To achieve such behavior a feedback loop is needed. In such a loop the mobility simulator is run in parallel to the network simulator and is directly connected. Via this connection the mobility simulator is able to react on events sent by the network simulator. In the community exist well established tools which support this behavior: *Veins*, *iTETRIS* and *VSimRTI*. All of them have good support for mobility but are missing the tools to simulate heterogeneous networks, especially support for LTE networks is missing. As the only missing thing in *Veins* is LTE support we chose to merge it with the LTE framework developed by Virdis et al. [6]. To make it easier to perform research and develop new algorithms for such heterogeneous vehicular networks we built and released a complete new framework named *VeinsLTE*.[1]

II. VeinsLTE

Based on the OMNeT++ core we have chosen a few frameworks to extend its capabilities. As a mobility simulation framework we are using Veins [7] which couples OMNeT++ with the mobility simulator SUMO.[2] This tool enables a very fine-grained simulation of vehicular networking aspects and also offers an implementation of IEEE 802.11p. Another addition to OMNeT++ is the *SimuLTE* framework[3] developed by Virdis et al. [6]. This recently published simulator allows the simulation of LTE and offers a detailed model of the complete LTE stack with some minor abstractions. The integration of *SimuLTE* was hard because it was not developed with vehicles dynamically entering and leaving the network in mind. All components of *SimuLTE* had been written so all initialization happened during the start of the simulation. That means if the network changed by adding or deleting vehicles, the whole LTE stack stopped working. Therefore we added these capabilities to the LTE network stack from the Network Interface Controller (NIC) up to the application layer.

[1] http://veins.car2x.org/
[2] http://sumo-sim.org/
[3] http://www.simulte.com/

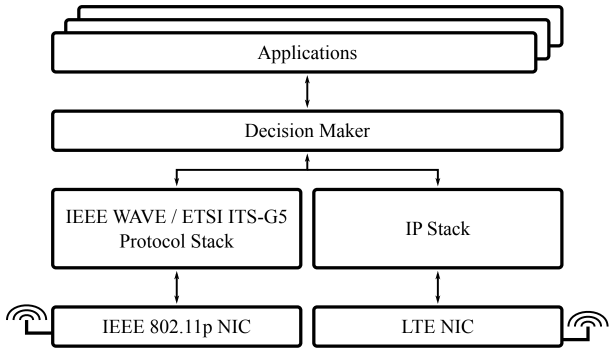

Figure 1. Protocol layers of simulated cars, including both an LTE and an IEEE 802.11p network interface to form a heterogeneous vehicular network.

In Figure 1 our developed heterogeneous network stack is depicted. In the upper part a single *application layer* and one *decision maker* are placed. The applications should be able to either explicitly decide which network stack to use or let the *decision maker* decide. Different algorithms for the *decision maker* could make for some interesting future work.

Below the *decision maker* there are two stacks, one for each technology. Both of them have a special *adaptation layer* where additional information is added to the packets. Such data can be flags and headers which are not needed by the other network technology. Below the *adaptation layer* each stack has a Medium Access Control (MAC) layer and a NIC. If a NIC receives a packet over the air it is forwarded the other way round to the *application layer*. For more details about the MAC and NIC layers we refer to the associated standards and the works describing the LTE [6] and the DSRC framework [7].

Due to the nature of our stack it is easy to develop new applications using our simulator. With OMNeT++ it is straightforward to modify the different parameters of the various layers and only the application itself has to be developed. OMNeT++ (and therefore *VeinsLTE*) also comes with a development IDE based on Eclipse and a useful GUI of the running simulations. These aspects make it a good choice for classroom use and help with a fast and easy progress during development, validation, and evaluation.

III. Early Simulation Results

Because both *Veins* and *SimuLTE* have been evaluated individually [6], [7] we used a simple scenario and performed a huge number of smoke tests. This allowed us to make sure that all aspects of *VeinsLTE* are still working correctly when used together. After evaluating simple scenarios we also implemented the heterogeneous clustering algorithm by Tung et al. [4] and performed simulations in a realistic Manhattan scenario. This algorithm uses DSRC to generate clusters of vehicles. The heads of these clusters then share information about the cluster via LTE with others. Such data can be used for intersection management or traffic improvements. Figure 2 shows the uplink delay for LTE messages which clearly increases with the frequency of sent messages, while the decreasing slope between 10 Hz and 20 Hz indicates packet loss. We also investigated the clusters created via DSRC. Some early results can be seen in Figure 3. The small number of members with a long lifetime indicates many small clusters consisting of one or two vehicles, due to a high number of short streets. Therefore the distribution of the cluster head lifetimes gives a better impression.

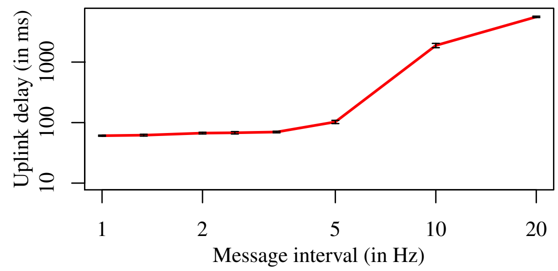

Figure 2. LTE message interval vs. LTE uplink delay (mean and 95 % confidence interval) for an allocation of 100 RB (20 MHz bandwidth). Note that both scales are logarithmic.

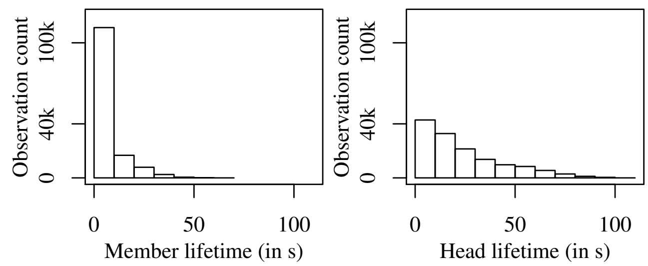

Figure 3. Histograms of the durations the cars have been member (left) and head (right) of a cluster.

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