HINTS: A Novel Approach for Realistic Simulations of Vehicular Communications

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Abstract— One of the main challenges in the Vehicular Ad-Hoc Networks (VANETs) research domain is the simulation of vehicular communications using realistic mobility models. Several efforts have been put lately in this purpose; yet, the proposed models are either inappropriate, or carry significant disadvantages. In this paper, we propose a novel approach for realistic simulations in vehicular networks, inspired from the hierarchical video and image compression technique. We developed HINTS (Hybrid Integration of Network and Traffic Simulators), the correspondent platform, engendered from the integration of SUMO, a traffic simulator and NS-3, a network simulator after adding some supplemental modules to both simulators. Its efficiency and performance are demonstrated in a proof-of-concept study, based on a realistic traffic management scenario.

Keywords— Network simulator, Traffic simulator, Mobility model, integration, NS-3, SUMO.

I. INTRODUCTION

Vehicular Ad hoc Networks (VANETs) are a special kind of Mobile Ad-Hoc Networks (MANETs) adapted to the communications between vehicles. Vehicular networks attract both research and industry communities. Recently, they focus their efforts to grow vehicular communication and networking into maturity by moving it from research field into real implementation (Field Operational Test, FOT); aiming to provide not only more safety in the transportation systems but also other high quality-of-service (QoS) based applications. However, such applications need to be analyzed, tested and validated using costly real testbeds (FOT), or simply using lower cost simulations.

Simulations can be seen as a good starting point to evaluate VANET protocols and applications as they allow researchers and engineers to evaluate and validate their solutions before proceeding with expensive real testbeds. However, this might not be as straightforward as it seems since simulation in vehicular networks require the use of two types of well-known simulators namely a Communication Network Simulator and a Vehicular Traffic Simulator. Indeed, the communications between vehicles and with the road infrastructure affect the mobility of vehicles. In turn, the mobility of the vehicles affects the communications scheme.

Many solutions have been proposed in the last few years to cope with this problem, however, this is far from being done. In fact, the proposed solutions are either inappropriate due to their lack in realism, or carry significant disadvantages like expensive computational cost, extremely long simulation times not to mention the scalability problems.

In this work, we advocate a novel simulation approach and develop a corresponding optimized platform for realistic simulations of vehicular communications. Our hybrid approach has the advantage of combining the best of state-of-the-art solutions so it overcomes the limitations of one using the other and vice versa.

The reminder of this paper is organized as follows: The next Section is a quick review of the most popular related works in the literature. We describe our approach and its architecture in Section III; evidence of its performance is given in Section IV. Finally, Section V presents our conclusion and future perspectives.

II. RELATED WORK

The most common classification for the different integration approaches, referred to in [1] for coupling network and traffic simulators, sort the literature solutions into three distinct categories: (i) isolated or offline simulators, (ii) embedded simulators, and (iii) federated or online simulators.

In the first category, the interaction between the network and the traffic simulators is petty or non-existent as the mobility model is bounded to a static mobility trace. As an example for the first category, we quote MOVE (MObility model generator for VEsicular networks) [2], a dedicated open source tool that generates mobility traces readable in network simulators like NS2 [3] and Qualnet [4].

In the embedded approach, the traffic and the network simulators are natively coupled as they are incorporated to form a unique entity. MoVES [5], NCTUns [6] and VCOM [7] the embedded module in VISSIM [8] fall into this category. However, these solutions suffer from the limited capabilities either from a network or a traffic point of view as they were designed for only one purpose initially.

The third category was introduced to overcome the limitations of the two previous approaches. In this case, a bidirectional communication is established between the simulators. TraNS [9] was the first implementation of this approach (SUMO [10] and NS2) followed by iTERIS [11], Ovnis [12] (SUMO and NS-3 [13]) and Veins [14] (SUMO and OMNET++ [15]).
The reason behind the miscarriage of the latest category, even though it presents the most realistic results one can get from the literature tools, is the long simulation times and the high computational cost.

Our approach, named HINTS, advances all state-of-the-art solutions in terms of performance as it uses resources more efficiently and considerably reduces the computational cost and the simulation time. The combination of the online and the offline approaches brought forth a new approach that uses one full mobility trace and a feedback loop, for an active exchange and a real-time interaction between the network and the traffic simulators.

III. HINTS: DESCRIPTION AND ARCHITECTURE

HINTS stands for Hybrid Integration of Network and Traffic Simulators. This approach is inspired from the hierarchical approach for image and video compression, where a first image is stored entirely as a background and the next images are obtained from storing the parts of the image that differ from the original one. We noticed many similarities between our problem and the image/video compression problem as both aim for reducing the computational cost and the size of data transferred in each time step, and reducing the size of data stored respectively. We noticed also that if an event occurs, this will be likely to alter the state of only a few nodes in the network while the bigger percentage of nodes will not be affected by this event.

HINTS consists of three essential blocks which are the traffic simulator, the network simulator, and the ITS application. These three blocks interact with each other in real time via some dedicated communication interfaces. To benefit from the best tools in the literature, we chose the widely spread traffic simulator SUMO that has proved its reliability and performance within the Intelligent Transportation Systems community; and the successor of the most used network simulator: NS-3 also validated in the academia.

A. The general hybrid platform architecture

Fig. 1 shows the general overview of the architecture. In this figure, the traffic simulator in the leftmost box manages the nodes’ mobility and generates both static traces and dynamic micro-traces. The middle box represents the network simulator whose role is handling the data dissemination via wireless communications, in addition to translating received data about the nodes movements; and that, in order to implement its own realistic mobility model based on the decisions taken by the rightmost box, which represents the user level model. This latter block represents the communication protocol or user VANET application to be analyzed. The communication between these three blocks is provided by the TraCI [16] client/server interface which allows real-time, bidirectional communication between the network and the traffic simulators.

This efficient feedback loop is extended with the insertion of a mobility trace that includes the movements of all nodes from the entire simulation duration, and which represents a background image of the network; and thereby, considerably reduces the amount of data transferred between the traffic simulator and the network simulator in each time step since only the positions of nodes concerned by a certain event are exchanged.

B. Simulation flow overview

As the simulation starts, SUMO generates one complete mobility trace to constitute the base structure of the mobility model. This mobility trace is injected into the network simulator and the two simulators are launched simultaneously with NS-3 as the client application and SUMO as the server application. NS-3 reads from the previously generated mobility trace and sends commands to SUMO via TraCI to execute simulation steps in order to stay synchronized in time. Information about the surrounding environment of a node (speed, route, destination…) is provided by SUMO while the cooperative awareness messages (CAM) [17] exchanged between these nodes (safety messages, traffic state messages…) are provided by NS-3. All these information are operated in the ITS application in order to decide whether a node should change its behavior (speed, trajectory, route or destination). Once the decision is taken for a node to change its trajectory, the corresponding information will be retrieved on each time step and until the node reaches its destination, and overload the values given by the static mobility trace. Fig. 2 shows the flow of events in HINTS.
IV. PERFORMANCE EVALUATION

In order to prove the efficiency and the performance of the developed platform, we considered testing it on a Manhattan grid scenario. The performance of HINTS is justified using the percentage of subscriptions metric while the efficiency is substantiated using a metric called Mean Sojourn Time or the Mean Travel Time metric in our case: the average time vehicles spend on the road before reaching their destinations, calculated for the arrived vehicles at the end of each simulation step.

A. Application’s operating mode

In the following, we assume that vehicles are equipped with interfaces for wireless communications, and also with an onboard GPS that keeps track of the current road id. The following algorithm shows the iterative behavior of the application embedded on vehicles:

```
1: if (stop_condition) then
2:       StopApplication();
3: end if
4: current_road ← GetRoadId();
5: if (road_is_blocked) then
6:       BroadcastPacket(time , current_road);
7: end if
8: if (ReceivePacket(time, roadId)) then
9:       if (current_road = roadId) then
10:          ChangeRoute();
11: end if
12: end if
```

B. Results

We can notice that the number of subscriptions doesn’t exceed 25% of the loaded vehicles over the event occurrence period; while an online implementation requires the subscriptions of 100% of the loaded vehicles. This allows deceasing the simulations’ computational cost letting the simulation run faster.

The efficiency of our platform is shown using the Mean Travel Time metric. The results reflecting the fluidity of road traffic obtained after launching the tested application are illustrated in Fig. 4. Fig. 4 (a) shows the mean travel time of vehicles without the application reaching higher than 4000s in some cases. The enhancement can be observed in Fig. 4 (b), showing the mean travel times with the application launched, as the maximum travel time is slightly higher than 3000s.
V. CONCLUSION

In this paper, we introduced a novel approach for realistic simulations of vehicular communications, and the design of the platform HINTS, the corresponding implementation. It reposes on SUMO for the realistic mobility of nodes, and on NS-3 for the wireless communications. The goal of this new approach is to decrease the simulations’ times and their computational costs in order to trivialize VANET application simulations. Future works will focus on improving the open source platform HINTS, and using it for its main purpose, that is, to evaluate VANETs protocols and applications.

REFERENCES

[17] ETSI TS 102637-2 Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service