Design and Implementation of Vehicular Network Simulator for Data Forwarding Scheme Evaluation

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***Abstract*—Simulation is a common method used to examine the models and protocols before they are implemented in real systems. Vehicular networks present different characteristics which render most of their simulations inapplicable to real-world Vehicular Ad Hoc Networks. In these days, the important advancement has been made toward the realistic simulators. OMNeT++, SUMO and Veins provide a decent way for vehicular network researchers. This paper introduces the design and implementation of data forwarding schemes in vehicular networks. We discuss the implementation of two data forwarding schemes, such as Vehicle-Assisted Data Delivery and Trajectory-Based Data Forwarding. Both are the forwarding schemes that rely on Expected Delivery Delay.**

***Index Terms*—VADD, TBD, EDD, Data forwarding, TraCI.**

I. Introduction

Along with the popularity of Vehicular Ad Hoc Networks (VANET) in these days, different data forwarding schemes have been proposed to offer better forwarding among vehicles. Knowledge-based opportunistic forwarding [1], Vehicle-Assisted Data Delivery (VADD) [2], Trajectory-Based Data (TBD) forwarding in light vehicle networks [3], and rapid traffic information dissemination [4] are data forwarding schemes for VANET. All of them aim at achieving the disruption tolerant vehicular networks.

The study and testing of those data forwarding schemes are mainly performed through simulations. Computer simulations are viable solutions of testing various protocols and architecture for VANET [5]. But it is still challenging to simulate models that can be applicable due to VANET properties [5]. The mobility and behaviors of drivers are the main challenges in VANET simulations. Thus, VANET simulation research is made toward realistic mobility models in VANET simulation [6], [7].

VADD [2] is one of the proposed data forwarding methods. VADD proposes the Expected Data Delivery (EDD) to be a metrics of data forwarding from packet source to its destination. In a similar way, TBD [3] proposes EDD to be a forwarding metric. However both TBD and VADD proposed the similar metrics EDD, but they are different. TBD and VADD dissimilarities are essentially based on the way both schemes evaluate shortest path for vehicle packet carrier moving along a road segment toward their destination. VADD proposes that the carrier should forward the packet to a vehicle that is moving on an edge with the smallest angle to the destination. However, it has been proved that not in all cases the smallest angle does always give shortest path [8]. In contrast, TBD proposes that the packet carrier will forward the carried packet to vehicle which is making the geographical shortest path to the packet destination [8].

In fact, Vehicle in Network Simulation (Veins) [7] offers a suite realistic environment for VANET simulations. This paper simulates both TBD and VADD using realistic simulation. We have simulated both TBD and VADD with inter-vehicle communication with simulator called OMNeT++ and Simulation of Urban Mobility simulator called SUMO. OMNet++ is a simulation library and framework for building network simulations. SUMO allows for the modeling of intermodal traffic systems including road vehicles, public transport and pedestrians. We take advantage from realistic of Veins, and describe the implementation of TBD and VADD data forwarding schemes in OMNeT++.

The remaining part of this paper is organized as follows: Section II describes related work. In Section III, we briefly discuss the tools That we use in this study and what we benefit from them. Section IV discusses the step by step simulation of TBD and VADD in OMNeT++ and SUMO through Veins. Finally, in Section V, we conclude this paper along with future work.

II. Related Work

Despite the need of simulation tools to test VANET model, most of them are still more heterogeneous. VANET presents different characteristics compared to primitive Mobile Ad Hoc Networks (MANET). In VANET, mobiles nodes move faster, and are changing directions in road networks in highly dynamic way. This is the reason why, most of the pre-existing solutions available for MANET [9], are not applicable in VANET. Data forwarding in VANET depends on various things such as road network structure, speeds of vehicles, traffic density and type of vehicles.

It was shown that when employing well-studied micro-simulation models and wireless ad hoc network models in simulation, it produces a wide different results than the ones relying on commonly used simplistic models [10]. This is due to the fact that realistic simulation employs the real

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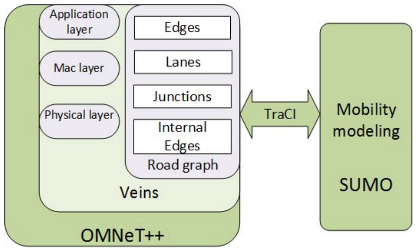

Fig. 1. OMNeT++ and SUMO communicate through TraCI in Veins

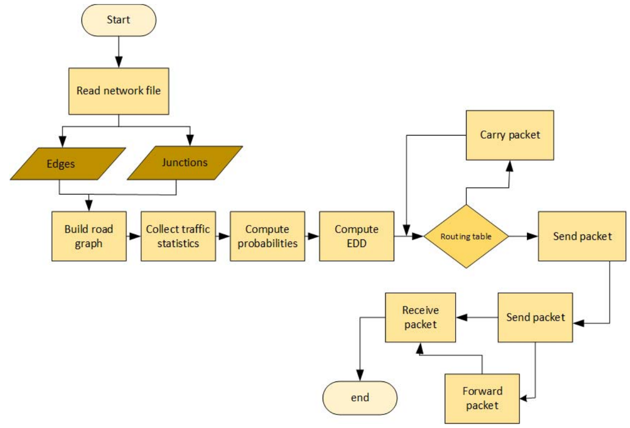

Fig. 2. Simulation working flaw

realities that were neglected in simple simulator, and end up sacrificing performance. Realistic VANET simulation models are needed to test forwarding schemes in VANET before they are employed in real network data handling.

SUMO simulation platform is used to simulate realistic traffics scenarios [11] [12]. It represents real word networks as graphs where nodes are intersection and roads represent edges [12].

An open source framework to run vehicular network simulation known as Veins helps to model our road traffics. However other simulators, such as Network Simulator3 (ns-3), Java in Simulation Time (JiST) etc, are available Veins remains suitable for realistic simulations [5] [13].

Based the need of simulations to evaluate the new protocols and models before being applied in the real-word implementation, many efforts have been made to obtain realistic simulation of urban mobility networks. It is of high importance to simulate and examine the forwarding models which have been studied before those simulation availability, to see their influence. VADD and TBD, are both modeled before Veins gains its popularity. One more reason to simulate both VADD and TBD is to learn the influence of realistic simulation models on road Network data forwarding.

TBD like VADD presents a data forwarding among vehicles toward the destination based on EDD. However, in the previous studies the road network was highly static. All vehicles are considered to be moving on a constant speed [3]. In contrast, SUMO offers a more advanced real possibility. Vehicles are following a changing speed. In SUMO, vehicles move on different speeds. This last will have influence on both link delay model and EDD value. Realistic simulations help to clarify those differences.

III. A brief description of realistic simulators

Upon an open source framework for running vehicular networks called Veins, we simulate our both VADD and TBD data forwarding models. Veins is based on two simulators, OMNeT++ and SUMO [14]. In Veins, means applicable to vehicular network simulation are available to build a comprehensive and detailed vehicles network simulations.Veins is a suitable model for realistic vehicular network simulation.

On the other hand, SUMO is a simulation package that is designed to handle road network simulation. It provides a wide Range of planning and simulation application. SUMO includes tools for importing road networks from different sources such as Open Street Map, Yahoo Map etc, [15] and allows modelling of traffics. As Fig.1 states, through Traffic Control Interface (TraCI), we can access road traffic simulation and retrieve information that will be useful in OMNeT++, which in turn will control and manipulate their behavior.

OMNeT++ is a modular simulation library for building network simulations. It is a powerful open-source discrete event simulation tool available since 1997 [16]. An OMNeT++ simulation model, consists of simple and compound modules that communicate by message passing. Network Definition (NED) is used by a user to describe the structure of the simulated network. In OMNeT++, a user can edit the network by either graphical or NED source interface. OMNeT++ presents an interesting aspect of separating models topology from C++ file codes which models behaviour of the simulated network. We exploit from this good practice while simulating both VADD and TBD.

IV. Simulating VADD and TBD in OMNeT++

Simulating VADD in OMNeT++ requires to keep track of SUMO road structure, vehicles mobility information and statistics. The mobility information such as vehicle speed, vehicle position, vehicle moving edges etc, are available in SUMO side and accessible in OMNeT++ side via TraCI. While simulating, we have two kinds of road networks. First is in SUMO side, which offers TraCI coordinates for position of a vehicle. The Second is OMNet++ playground, which in turn offers the OMNeT++ coordinates, for vehicle positions. Even though both coordinates differ, but it is possible to convert from TraCI coordinates to OMNeT++ coordinates and vice versa. This is well important in computing best angles based on vehicle position.

Fig. 2 is a description of our simulation working flow. In OMNeT++ we simulate in C++. In Fig. 3, we describe our simulation classes and main functions. Below, we describe step by step simulation of our vehicular network.

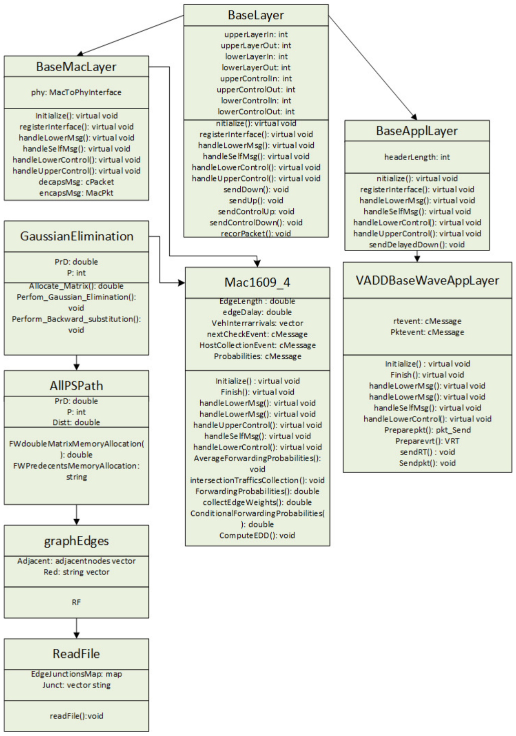

Fig. 3. Simulation classes structure

A. Building Road Network Graph

SUMO models road networks that it imports from different sources, into manageable entities stored in form of XML files. These XML files, contain all necessary information we need to modal road network graphs. It has information about junctions ids, edges ids, internal edges ids and lanes ids which are the capital information in our road Graph.

- A junction is a place in a road network where two or more different edges intersect. Junctions can also be referred as intersections.
- An edge is a path way from one intersection to another. Within road network, for two intersection i and j, the edge e_{ij} from i to j differs from edge e_{ji} from j to i.
- Internal edges are edges inside an intersection. When a vehicle reaches a given intersection, it will head to a certain intersection's internal edge based on its next edge direction. Fig. 4 describes a typical edges intersection with its internal edges.
- By lane, we refer to a part of edge segment that is designed for a single vehicle. A road can be made of single lane, means accommodating a single vehicle; or of multiple lanes, means allowing multiple vehicles to move in parallel in the same road segment.

Having all the above described information, from SUMO XML network file, we build a road graph in OMNeT++ that models similar information. It is a directed graph, where being on given intersection, we get information of adjacent intersections. We use the graph to collect statistics information.

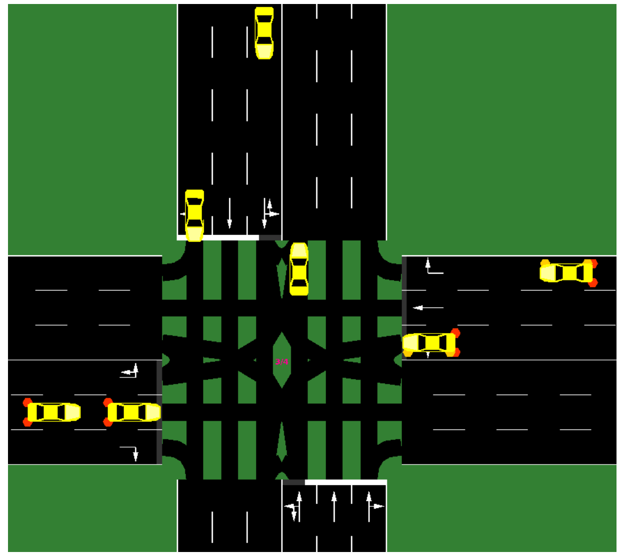

Fig. 4. Junction Description

We deploy Road Side Units (RSUs) in our road network. RSUs ensure that packets are generated forwarded and received successfully [17]. In our topology, RSUs are deployed at the level of roads intersections. Fig. 5 is a representation of RSU deployment in our road network. We assume when a packet is generated, it is forwarded toward a destination RSU through a connected Ad Hoc network.

B. Road Graph Statistics Collections

In the beginning of the simulation, we keep collecting statistics that will in turn be used in the future computations. We collect the time each vehicle accessed a certain intersection or edge. We gather vehicles inter-arrivals, and for each intersection, we keep tract the next intersection vehicle moves toward among its adjacent ones. We keep mirroring the total number of vehicles which accessed the intersection.

The information such as vehicle speed, vehicle position, vehicle route etc, are accessible in SUMO via TraCI. Each time we need those information, by access to TraCIMobility, we can fetch the data we are looking for.

C. Computing Probabilities

For a vehicle carrying a packet that arrives at an intersection with m neighboring intersections; neighbors will be sorted in an increasing order based on their geographical path length to packet destination RSU, to determine the suitable next carrier edge, the packet will be forwarded. However, the packet forwarding is probabilistic as not each time the best edge in terms of shortest path will be having a vehicle to forward to.

1) Link Delay Model: Within a single road segment, with vehicle arrival rate λ, and a communication range R; the vehicles continuously pass through it at different speeds. Regardless of that, SUMO provides a possibility of accessing the edge mean speed of this edge. Vehicles form a network as soon as their can communicate either via a one hop or a

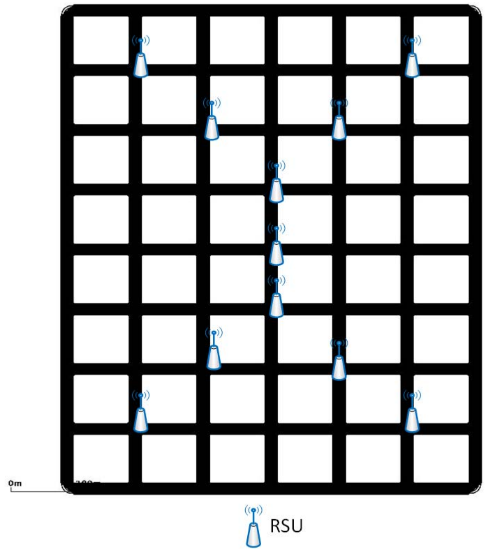

Fig. 5. Deployment of RSUs in road network

multihop connected Ad Hoc Network. Either by carry or by forward, vehicle will keep exchanging packet in a connected Ad Hoc Network. Fig. 6 is a typical SUMO road segment that represents both edges 2/4to3/4 from junction 2/4 to junctions 3/4 and 3/4to2/4 from junction 3/4 to junction 2/4. As stated in [3], where d_{ij} notate link delay of a road segment from intersection *i* to *j*, with length *l* and edge mean speed *v*, link delay will be computed as follows:

$$d_{ij} = \frac{l_c}{v}, \quad (1)$$

where l_c=l-l_f, and l_c, l_f are carry and forwarding distances respectively.

2) Probabilities Computation: Both TBD [3] and VADD [2] in a detailed way illustrates how probabilistic data forwarding at a given junction is to be computed. We computer probability of a vehicle at the intersection to encounter another at the intersection. That is contact probabilities. After sorting adjacent edges in increasing order based on geographical shortest path for TBD and smalled angle for VADD to destination, we are able also to Compute the forwarding probability.

Conditional forwarding Probability is the the chance of a vehicle to forward a packet to a vehicle that is moving to a different edge other than the one the carrier heads to. After calculating the branching probabilities to know the ratio of vehicles that moved from an intersection toward each of its neighbouring intersections; we end up evaluating the Average forwarding probability. Average forwarding probability is used in the computation of EDD.

D. EDD Computation

Now that we know the probabilities from each intersection toward neighboring edges, and that we have a knowledge of each edge delay, we can evaluate the EDD values in our road network [3]. For a graph with n edges will result to a

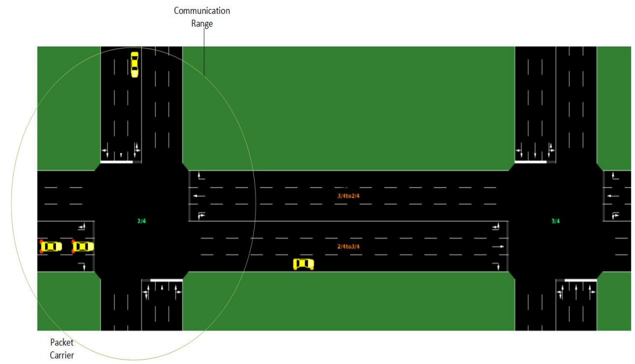

Fig. 6. A typical SUMO road segment

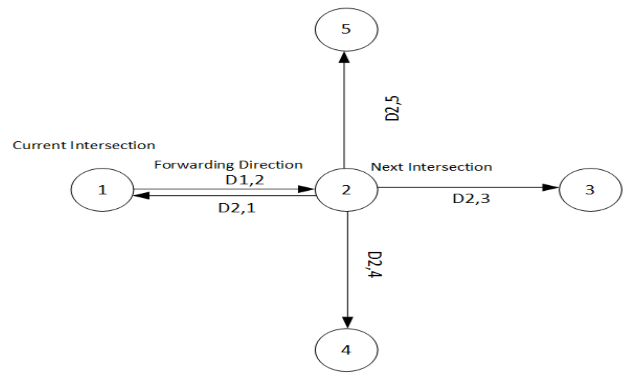

Fig. 7. Edge *e12* EDD computation

system equation of n variables and after solving it by Gaussian Elimination, we obtain EDDs.

$$D_{ij} = d_{ij} + \sum\nolimits_{k \in N(j)} P_{jk} D_{jk} \quad (2)$$

For a vehicle moving from junction *1* toward intersection *2*, where this last has 4 neighbours from Fig. 7, the EDD of edge *e12* will be computed as:

$$D_{12} = d_{12} + P_{21} + P_{23}D_{23} + P_{24}D_{24} + P_{25}D_{25} \quad (3)$$

The equation 3 is an example of how compute EDD for a given edge. EDD will in turn be a metric value for data forwarding.

E. Forwarding Design

Vehicles periodically exchange beacon message which contains information about their position, address and EDD. Using DSDV routing protocol, vehicles will keep constructing their routing tables [18]. By beacons exchange, vehicles keeps updating theirs routing tables. As a vehicle moves through road segment, it keeps updating its EDD accordingly.

When a vehicle receives a routing table message, it adds new vehicles appearing in a connected Ad Hoc network and updates the EDD and best next hop toward the destination.

Meanwhile, the vehicle also checks for entry routing table whose Time To Live (TTL) has expired and drops it from routing table. TTL expires when a vehicles does not receive its beacon routing table message for a certain fixed amount of time.

While there is a connected network toward the destination, and that there is a packet to be forwarded to destination, a vehicle will initiate the packet forwarding either via single hop or multihop communication.

V. Conclusion

In this paper, we described the benefits from using realistic simulators compared to other simulators. We introduced the implementation of a typical VANET simulation using Veins. Veins though OMNeT++ and SUMO, provides a good simulation environment that is highly realistic.

We described the implementation of both data forwarding models in VANET, such as VADD and TBD. EDD is a metrics both methods rely on to determine best route to forward a packet. The being dynamic and high speed of mobile nodes in VANET makes it difficult stand on traditional mobile data forwarding schemes. In the future, we will compare the performance of VADD and TBD in a realistic OMNeT++ and SUMO simulation environment.

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