A NEW TRAFFIC AND VEHICULAR COMMUNICATION SIMULATOR TRASI

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Abstract: There are numerous approaches leading to increase in throughput of the existing route networks. However, only few have been investigated in detail. For proper analysis of impact of distributing traffic information to drivers it is essential to use a traffic simulator combined with communication simulation for ITS applications. That is why we decided to create a simulator called TRASI (TRAffic SImulator), which combines traffic and vehicular communication simulations.

Keywords: ITS, traffic simulator, communication simulator

1. INTRODUCTION

Due to the increase in the transportation demand (both people and cargo) traffic congestions are becoming serious problem, especially in the big cities. Traffic congestions cause not only delays and increase in environmental pollution, but also lead to a degraded use of the available infrastructure.

In [1] are described several methods, such as driver information and route guidance systems, advanced signal control strategies or store-and-forward based concepts, to increase the throughput of the existing route networks.

Another approach is described in [2], showing that using telematic route guidance system or vehicle-to-infrastructure communications (V2I) can lead to higher effectiveness of a route network. This approach has several disadvantages such as problems with communication range, data transfer or reliability.

Different approach using wireless communication to increase the throughput of the route network is vehicle-to-vehicle (V2V) communications. In this architecture every vehicle is a node in the communication network and travel information is distributed among other vehicles in a defined area. This architecture is more fault-tolerant then the V2I architecture. However, for computing the fastest route for a vehicle a substantial amount of data must be received and processed [3].

Hybrid architecture, making use of advantages of both the V2I and V2V communications is described in [3]. The highly distributed V2V provides fault tolerance, while fast queries and accuracy is given by the V2I systems. This can reduce the bandwidth requirements on the central servers, while still retaining the accuracy of the V2I architecture. The main problem associated with traffic rerouting and the use of alternate routes is the increased traffic flow through the alternate routes, which can lead to congestion on the alternate route and even make the situation worse [1].

2. TRASI SIMULATOR

The main reason for development of a new simulator (TRASI – TRAffic SImulator) when other simulators exist is the need for an integrated approach combining both traffic and communication simulation. The combination of traffic and communication simulation is important for simulating

ITS applications. The simulator needs to be simple enough to enable large-scale simulations of urban areas. Some simulators have separate interface to control the simulation and enabling interconnection with a network simulator such as ns2 (for example the SUMO simulator has a TraCI interface), but this is not convenient for simulating more complex ITS applications [4]. The TRASI simulator is microscopic simulator and it is based on multi-agent approach.

2.1. BASIC DESCRIPTION OF THE TRASI SIMULATOR

The TRASI simulator is completely written in C#, combining a traffic simulator, V2X communication simulator and a graphical user interface (called SimCity, see Figure 1.). In the central part is shown the map of a traffic situation, the left part contains list of components in the simulation and icons for mapmaking, in the right part properties of a selected component can by changed and the bottom part shows controls.

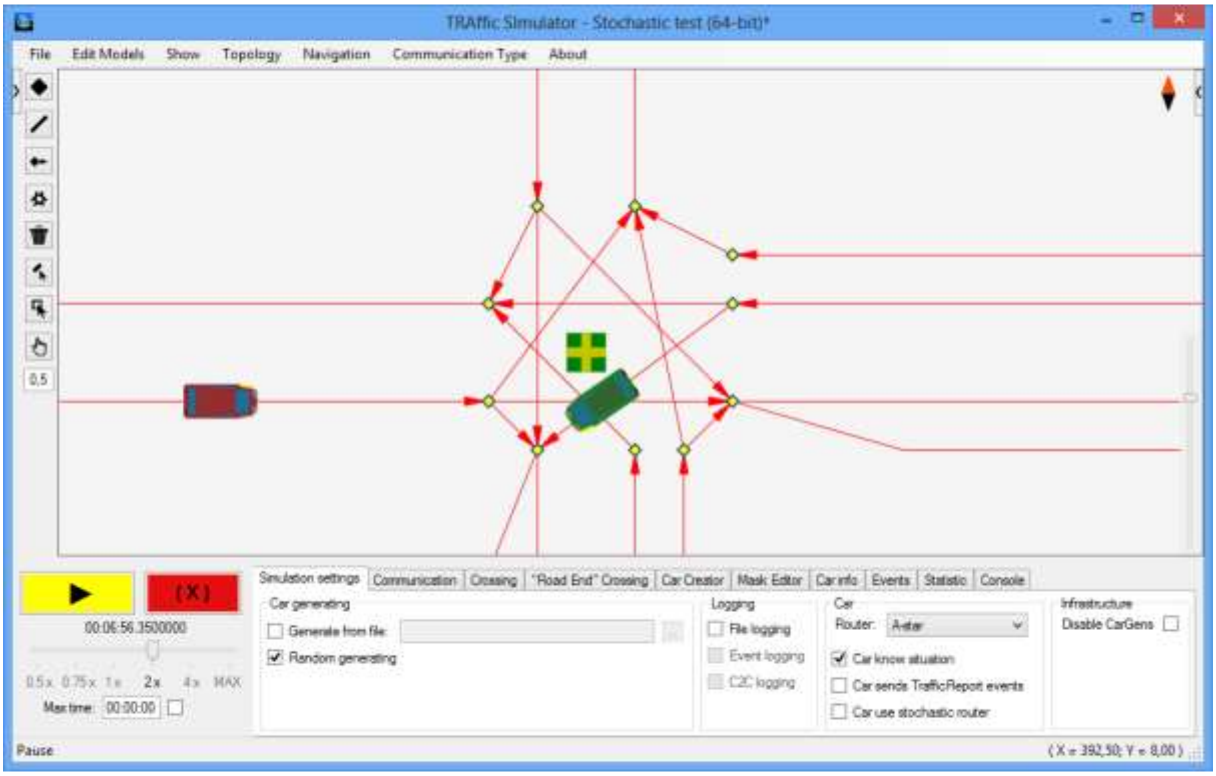

Figure 1: SimCity – GUI for TRASI simulator

Other tools, such as an object creator (PolyEdit), are standalone applications. The simulator implements each vehicle as an object with its own decision making. This enables defining various vehicle types, but also vehicles with different characteristics of driver behavior. The vehicles move over topological layer defining the map. The edges and nodes of the topological map are used to guide the vehicle, but the actual trajectory depends on the vehicle and its characteristics. Sample topological representation of a crossroad and a sample vehicle trajectory is shown in the Figure 2. below, the red lines represent edges (routes) and yellow points represent nodes (turnings). The yellow cross on a green background is a symbol for crossroad (object composed from edges and nodes).

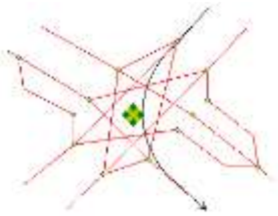

Figure 2: Topological layer of the TRASI simulator (red) and a vehicle trajectory (black)

2.2. CAR MODEL USED IN TRASI

Car-following behavior, which describes how a pair of vehicles interacts with each other, is an important consideration in traffic-simulation models. The TRASI simulator uses a simple linear car-following model. In this model a driver of a follower vehicle responds to the speed of a leader car relative to the follower car. Every vehicle in the simulation is identified by a discrete coordinate that varies in time, then the location of *n*th vehicle is marked as $x_n(t)$. So the response (acceleration) of the diver of the follower vehicle (n+1) is [5]:

$$\frac{d^2 x_{n+1}(t)}{dt^2} = -K_p\left(\frac{dx_{n+1}(t)}{dt} - \frac{dx_n(t)}{dt}\right) \qquad (1)$$

The parameter K_p is a sensitivity of the drivers and is a constant. Then we can integrate once to get:

$$\frac{dx_{n+1}(t+T)}{dt} = -K_p(dx_{n+1}(t) - dx_n(t)) + C_{n+1} \qquad (2)$$

Where the T is a delay time of the driver and C_{n+1} is arbitrary constant with dimensions of speed. If we assume that all vehicles have the same length, we can define the density of vehicles on the road, k, as:

$$k = \frac{L_R}{N_R} = \frac{1}{x_n(t) - x_{n+1}(t)} \qquad (3)$$

Where L_R is the length of section of the road and N_R is the number of vehicles on that section. If we further assume that all vehicles are traveling at the same speed v, we can find that the speed can by expressed as:

$$v = \frac{K_p}{k} + C \qquad (4)$$

Now, from the relation between the density k and traffic flow rate q, called the principle of conservation of cars:

$$q = kv \qquad (5)$$

and from a measured data [5] we can see that maximum speed v_{max} occurs when the density is close to zero and decreases as the density rises. At maximum density, k_{jam}, the traffic is bumper-to-bumper and the speed is zero. From that we can determine the constant C. After fixing the speed for density close to a zero, we can form the speed-density relationship:

$$v(k)=\begin{cases} v_{\max} & k<k_{crit} \\ K_p\left(\frac{1}{k}-\frac{1}{k_{jam}}\right) & k\geq k_{crit} \end{cases} \tag{6}$$

Where k_{crit} is critical density at which the traffic flow reaches its capacity and is:

$$k_{crit}=\left(\frac{v_{\max}}{K_p}+\frac{1}{k_{jam}}\right)^{-1} \tag{7}$$

The traffic flow rate corresponds to the speed-density relationship:

$$q(k)=\begin{cases} kv_{\max} & k<k_{crit} \\ K_p\left(1-\frac{k}{k_{jam}}\right) & k\geq k_{crit} \end{cases} \tag{8}$$

2.3. EVALUATING THE IMPLEMENTED CAR-FOLLOWING MODEL

For evaluating the implementation of the linear car-following model and overall performance of the TRASI simulator we use an experiment in which we simulated a part of a highway. In Figure 3. the relation between traffic flow rate and density is shown. The different types of points represent different numbers of vehicles generated during the simulation and the line represents theoretical values calculated according to (8). The relation between traffic speed and density is shown on Figure 4., the content is similar to a flow/density relation, only we used (6). Since the simulated values are consistent with theoretical assumptions, we can consider that the model is implemented correctly.

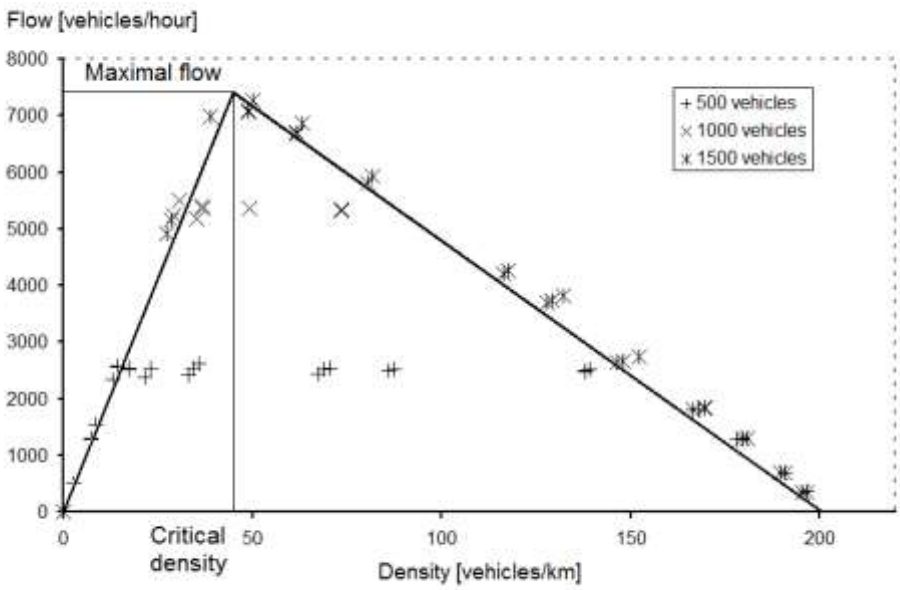

Figure 3: A relation between traffic flow rate and density in evaluating experiment

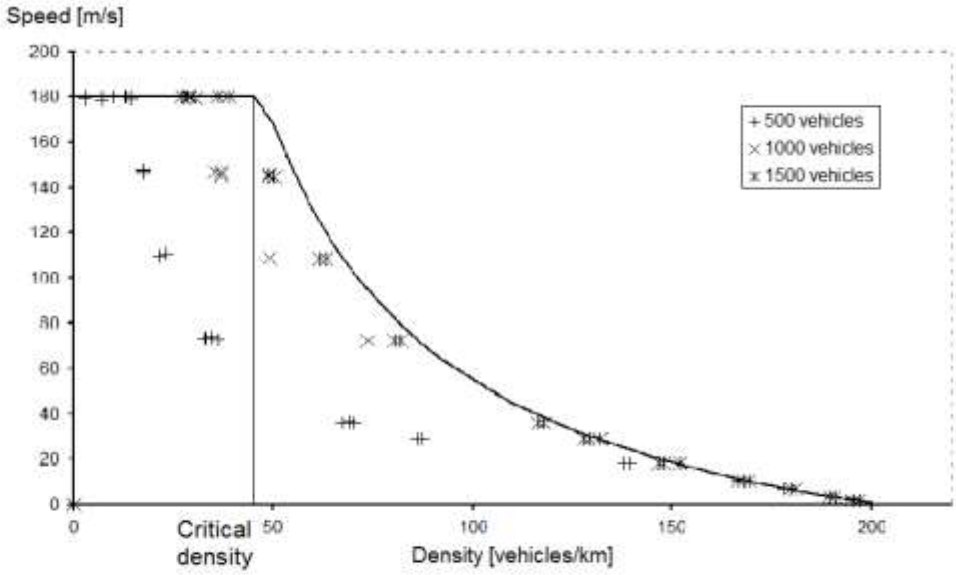

Figure 4: A relation between traffic speed and density in evaluating experiment

3. CONCLUSION

For proper evaluation of different methods to increase throughput of the existing route networks and other applications we developed a new traffic simulator called TRASI. This simulator combines traffic and communication simulations.

ACKNOWLEDGEMENT

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