Demo Abstract: Decentralized Traffic Information Systems and Adaptive Rerouting in Urban Scenarios

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***Abstract*—We demonstrate the impact, both positive and negative, of a dynamic vehicle re-routing mechanism that is based on real-time traffic information. For this, we employ a simulative prototype implementing a Traffic Information System (TIS) operating in an urban setting. The simulative prototype can be interacted with in real time to manually introduce traffic obstructions in the running simulation. The effects of these obstructions and the impact of dynamic vehicle re-routing can then be observed. In particular, we integrated the Adaptive Traffic Beacon (ATB) protocol within our Vehicles in Network Simulation (Veins) framework. Vehicles use ATB to continuously exchange part of their knowledge bases in the form of periodical beacons, the interval of which is dynamically adapting to the estimated usefulness of information and to channel conditions. This way, the average channel utilization is continuously optimized, and over-use avoided, at all times.**

I. Motivation

Rising traffic volumes on city roads threaten the safety of road users and harm the environment as well as the economy. Traffic Information Systems (TISs) might offer a solution to make high traffic volumes manageable both by the network as a whole and by the individual driver [1]. A common use of TIS is for the dynamic re-routing of vehicles around congested roads, so as to improve the overall utilization of the road network. Such a re-routing mechanism is especially appealing if there are only small delays between reports of congestions and the vehicles being informed, as this would decrease the number of vehicles getting caught in the jam.

We implemented such a real-time TIS in a simulative prototype, which offers two advantages: While the simulator still affords the static evaluation of protocols with respect to almost all common metrics, e.g. message delays, travel time, fluidity of traffic, and emission, it also allows researchers to intuitively grasp their benefits and shortcomings by interacting in real time with the protocols under consideration. Using this testbed, we demonstrate the impact of a dynamic vehicle re-routing mechanism that is based on real-time traffic information. In this way, both the positive and the negative effects of a specific TIS on road traffic can be studied.

II. Traffic Information System protocol

We believe that beaconing systems are well suited for TIS data exchange [2]. In general, a system's optimal configuration is highly dependent on environmental conditions, e.g. the number of vehicles or channel load. Thus, protocols have to cope with very dynamic network.

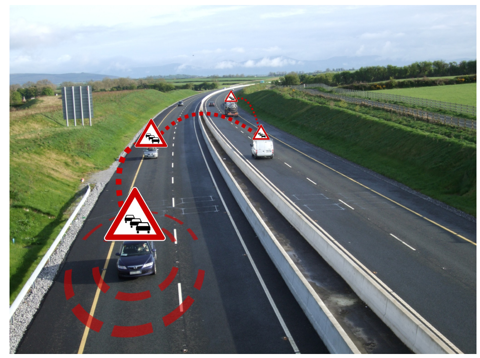

Fig. 1. Conceptual visualization of the beacon mechanism. Vehicles communicate by periodically exchanging parts of their knowledge bases.

The TIS we chose to simulate is therefore based on our Adaptive Traffic Beacon (ATB) protocol [3]. ATB distributes information about traffic-related events, e.g. accident or congestion information, by means of periodical 1-hop broadcasts, i.e. beacons, containing TIS data. These beacon messages are prepared to contain only those information elements most relevant to the node. In order to avoid congestion of the wireless channel while ensuring good information distribution, the interval between two messages is adapted based on two metrics: the perceived channel congestion and the importance of the message to send.

Similar to other beacon-based systems, each vehicle maintains a knowledge base. ATB sorts this knowledge base by assigning a priority value to each entry, which is based on its estimated utility to other vehicles. Each beacon then contains a subset comprised of the highest-priority entries, such that at most one radio frame is transmitted. This way, the frame size is optimally used and problems with stateful handling of messages split into multiple frames are inherently avoided.

When updating a local knowledge base, only the most recent information is stored for each route segment, i.e. new information elements either update already existing records or are appended to the knowledge base. Furthermore, the knowledge base is checked after processing the received beacon to identify events on the current route of the vehicle. If an incident is found, an alternative route is calculated using the Dijkstra shortest path algorithm. Similarly, resolved traffic congestions trigger a re-calculation of the route to check whether there is now a shorter route to the destination.

TABLE I
PARAMETERS OF THE NETWORK AND ROAD TRAFFIC SIMULATIONS

Parameter	Value
minimum beacon interval I_{min}	1 s
maximum beacon interval I_{max}	60 s
channel quality weighting w_C	2
interval weighting w_I	0.75
neighborship data expiry	60 s
TIS data expiry t_{store}	120 s
report traffic incident after queuing	10 s
processing delay	1 ms to 10 ms
max. beacon size	80 entries
channel bitrate	11 $\mathrm{Mbit\,s^{-1}}$
approx. transmission radius	180 m
vehicle mobility model	Krauss
max. speed	34 $\mathrm{m\,s^{-1}}$
max. acceleration	3.3 $\mathrm{m\,s^{-2}}$
driver imperfection σ	0.5
max. deceleration	4.5 $\mathrm{m\,s^{-2}}$

III. SIMULATION ENVIRONMENT

Serving as the basis of the simulative prototype is our *Veins*[1] simulation environment, which is based on OMNeT++[2] for event-driven network simulation and SUMO[3] for road traffic microsimulation [4]. OMNeT++ is a simulation framework free for academic use, runs discrete, event-based simulations of communicating nodes and is becoming increasingly popular in the field of network simulation. Its *INET Framework* extension offers a set of GPL-licensed simulation modules for simulating computer networks. SUMO is a GPL-licensed microscopic road traffic simulation environment. It performs simulations running both with and without a GUI and can import city maps from a variety of file formats including freely available *OpenStreetMap* data. SUMO allows high-performance simulations of huge networks with roads consisting of multiple lanes, as well as of intra-junction traffic on these roads, either using simple right-of-way rules or traffic lights. Vehicle types are freely configurable with each vehicle following statically assigned routes, dynamically generated routes, or driving according to a configured timetable.

Both simulators have been extended by modules that allow the road traffic simulation to communicate with its network simulation counterpart via a TCP/IP connection. In particular, this also allows the network simulation to directly control the road traffic simulation and thus to simulate the influence of the TIS on road traffic [4], [5]. The current version of Veins integrates with the newly created TraCI interface to SUMO.

Veins thus provides a fine-grained control interface between both simulation domains. This not only supports the active exchange of control and statistics data but also the real-time interaction between the network simulation and the road traffic microsimulation as well as interaction with a running simulation and collection of simulation results on the fly.

[1]http://www7.informatik.uni-erlangen.de/veins/
[2]http://www.omnetpp.org/
[3]http://sumo.sourceforge.net/

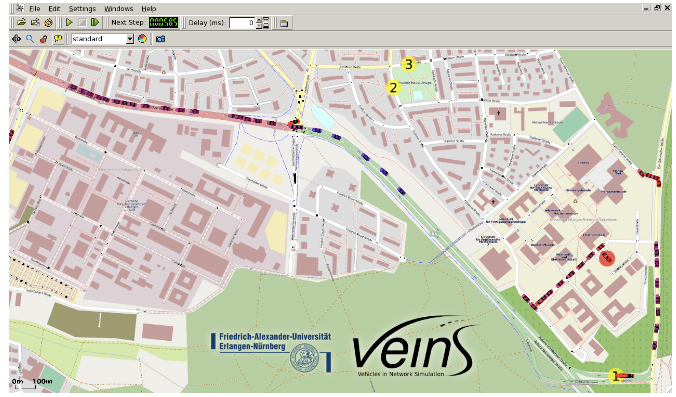

Fig. 2. Screenshot of the running simulative prototype. A contiguous stream of vehicles, leaving the university campus and heading to a business park, was interrupted by a traffic obstruction at point ①. Dynamic re-routing has started.

IV. DEMO SETUP

We model vehicles capable of exchanging information via ATB by implementing the protocol in Veins according to the principles described earlier. ATB data is encapsulated in UDP/IP packets and sent via broadcast messages. The radio channel and an IEEE 802.11b NIC transmitting at $11\,\mathrm{Mbit\,s^{-1}}$ are modeled by the *INET Framework*.

We chose a road network based on OpenStreetMap data of the city of Erlangen. The modeled section of the city comprises the university campus and a business park about $5\,\mathrm{km}$ away. Both are connected by two trunk roads, but are reachable also via several residential roads, as illustrated in Figure 2. On this network, we configure a contiguous flow of vehicles, one starting every $5\,\mathrm{s}$, leaving the university campus and heading to the business park. Vehicles move with a maximum speed of $34\,\mathrm{m\,s^{-1}}$ and according to the Krauss mobility model. The full set of simulation parameters used can be found in Table I.

Traffic obstructions can be introduced interactively, inhibiting the flow of vehicles at any combination of points ①, ②, and ③. These points are located directly on the fastest route to the vehicles' common destination, as well as the two most common detours, respectively. A vehicle trying to cross one of these points will find it blocked, so vehicles of this flow soon find themselves caught in the jam, or, if informed early enough, are able turn back and pick an alternate route.

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