Preparing Simulative Evaluation of the GLOSA Application

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Abstract

The deployment of vehicular communications (V2X) opens the field for a large variety of new applications which aim at improving traffic safety and traffic efficiency. One of the most prominent ones is GLOSA – Green Light Optimized Speed Advisory. This V2X-based driver assistance system suggests a speed which allows to pass the next traffic light at green. Within this paper, we will present simulative evaluations of GLOSA. Measuring GLOSA's effects on traffic efficiency, these evaluations focus on predicting results of real-world test drives. This work was performed as an initial validation step of one of the V2X simulator environments used in the DRIVE C2X project, co-funded by the EC.

Keywords:

Vehicular communication, V2X, cooperative systems, microscopic traffic simulation, green light optimized speed advisory, GLOSA, traffic efficiency

Introduction

The upcoming vehicular communication technology (V2X) promises to increase traffic safety and traffic efficiency by exchanging status messages between involved traffic participants and/or infrastructure. One of the applications built on top of this technology is "GLOSA", Green Light Optimized Speed Advisory. It aims at increasing traffic efficiency by informing the driver about the speed which should be maintained in order to pass the next traffic light at green. Technically, traffic lights send information about their programs and timings to vehicles. Knowing the distance to the traffic light from an internal road map and/or the GPS position, a vehicle which receives such a message can compute the speed needed to reach the traffic light on time. This speed is displayed on a human-machine-interface (HMI) and the driver is free to follow or ignore the instructions. GLOSA is included in ETSI TC ITS' Basic Set of Application (BSA), which lists V2X-based applications that "can be deployed within a three year time frame after its standardization completion" ([1]). GLOSA is one of the V2X applications that will be evaluated within the DRIVE C2X project ([2]), co-funded by the

European Commission.
Our investigations targeted on predicting the behaviour of drivers during test drives – real world experiments performed to evaluate and present the application's functionality. The scenarios presented here differ from field operational tests (FOTs), as their set-up is artificial: equipped vehicles are not injected into real traffic as in FOTs, but rather aligned in time and space for showing the application's behaviour. Simulation-based evaluations of GLOSA's performance on real traffic can be found in the literature, see [3, 4].
As GLOSA targets on traffic efficiency mainly, its simulative evaluations are usually performed using microscopic traffic simulations. Within this simulation class vehicular movement is computed using car-following models, which describe how the simulated driver chooses his speed in dependence to the driver before him. In comparison to driver-centred sub-microscopic models, microscopic models are too coarse for measuring changes in traffic safety, but are more capable of dealing with large-scale scenarios. Though we list the application's effects on vehicular emissions, more detailed evaluation of this topic has already been performed, see [3] where a more detailed emission model (PHEM) was used.
The rest of the document is structured as following: at first, the used simulation system is described, briefly. Then, different simulation runs are presented, together with their results, starting with evaluation of the used GLOSA application, and moving towards the simulation of test/presentation scenarios. We conclude with notes on further steps in evaluating GLOSA, and a summary.

Simulation Model

The evaluations were performed using the traffic simulation SUMO ([5, 6]) coupled to a network communication simulation and a model of the GLOSA application. The following sub-sections introduce these simulation sub-systems, as well as the used scenario and performance metrics.

Traffic Simulation SUMO

SUMO (Simulation of Urban Mobility) is a traffic simulation developed by the German Aerospace Center (DLR) since 2001. SUMO is microscopic what means that each vehicle is simulated explicitly and has its own information about speed and position in the traffic network. For giving the user access to a running traffic simulation an interface called TraCI (Traffic Control Interface) was integrated into SUMO ([7]). TraCI allows to receive information about simulation objects such as roads, vehicles, traffic lights, etc. – and to modify these objects online, e.g. to change the signals of a traffic light or a simulated vehicle's speed.

Communication Simulation

Communication was simulated using an own communication model coupled to SUMO via TraCI. The model is described in [8]. It uses the CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) mechanism with exponential back-off. The CSMA/CA is a basic access mechanism from IEEE 802.11e which is using the listen-before-talk scheme ([9]). The model has been proven to deliver results similar to other communication models, though state-of-the-art message propagation modelling including non-line of sight (NLOS) is not considered, here.

Application Model

The application model consists of three parts: the first covers the technical realisation of the GLOSA application, including message generation, sending, and retrieval. The second one is responsible for computing the speed that shall be presented to the driver. The last part is user acceptance and behaviour.

The application was implemented in Python, embedded into the aforementioned communication model. The road side units (RSUs) at simulated traffic lights are sending information about their state with a frequency of 2Hz using so-called SPAT (Signal Phase and Timing) messages, as defined in [10]. These messages are also used in the German simTD project ([11]) as well as in DRIVE C2X.

Different approaches for the advised speed computation exist in the literature ([4, 12]). The complete algorithm, used within the investigations presented here, can unfortunately not be given due to the page limit. The algorithm takes into account the following three traffic light cycles, and sets a lower limit for the advised speed – a driver is not advised to run slower than 20km/h. When approaching a red light, a speed is advised which let the vehicle pass the intersection 2s after the light turns green.

Within the presented simulations, every driver of an “equipped” vehicle has perfect compliance and execution. That means he intends to follow every advice and does so successfully.. Despite driver reaction times and ability to follow the guidance, this assumption should be valid for the planned real-world test runs we want to simulate, as following the advices should be the duty of equipped vehicles’ test drivers. The impact of the reaction time and the drivers’ ability to keep the advised speed is still a matter of research.

Helmond Scenario

Road network and infrastructure information was retrieved from Open Street Map ([13]). Instead of using the complete area between Helmond and Eidhoven, a scenario covering only the entry from the highway into the city of Eidhoven was generated for increasing the simulation speed. The scenario is shown in figure 1.

North: ~51.48°

South: ~51.47°

West: ~5.59°

East: ~5.66°

Figure 1 - Used GLOSA scenario, including its geo-coordinates

As OpenStreetMap data is targeted towards routing applications, it does not contain all the information necessary for microscopic simulations such as traffic light plans, and information about which lanes may be used to reach the next edge. Other information is frequently incomplete such as the correct number of lanes – especially extra lanes in front of intersections, and traffic light positions. To remedy this, the road networks where corrected manually by comparing them with images from Google Earth ([14]).

In a next step, the traffic light programs for the relevant intersections were set up based on educated guessing. All traffic lights were set to use a fixed plan with an overall duration T of 90 s, having 35 s green and 5 seconds yellow for each direction and two additional all-red phases of 5 s. The traffic lights in Helmond are adaptive and are switched in dependence to traffic. The replication of real-world programs would not only require the switch plans, but also the implementation of the adaptation algorithm. Both were not available. For simulating GLOSA, each traffic light controlled intersection has been equipped with a simulated RSU. The RSUs were placed in the centre of the according intersection.

For vehicles, standard SUMO parameters have been used, despite setting the driver imperfection to zero for obtaining less stochastic, easier to understand results. For the same reason, the allowed speed of all roads within the network was set to 50 km/h.

Performance Metrics

Within the investigations, the following performance indicators will be used, all as defined in [15]: travel time (in s), waiting time (in s), as well as the amount of emitted CO_2 (in g), and the amount of emitted PM_x (in g). Measures such as fuel consumption (in l), and the amount of emissions for the pollutants CO, HC, and NO_x (in g, respectively) were collected, too. Though, as GLOSA's effects on these measures are similar to those on CO_2/PM_x, they will be not presented here.

Initial GLOSA Performance Tests

The aim of the first set of simulation runs was to validate the functioning of the GLOSA application's implementation and to evaluate how well it improves a single vehicle's movement through a controlled road network. As during initial implementation tests vehicles seemed not to benefit from GLOSA in all cases, we tested all (90) possible time offsets to approach an intersection. Technically, this was achieved by performing 90 simulation runs with a single equipped vehicle, and 90 simulation runs with a single unequipped vehicle. For both (equipped/not equipped) settings, the vehicles' depart times were incremented by 1 s between each simulation run, respectively. The maximum communication range was set to 300 m. Figure 2 shows the vehicles' movement through the network.

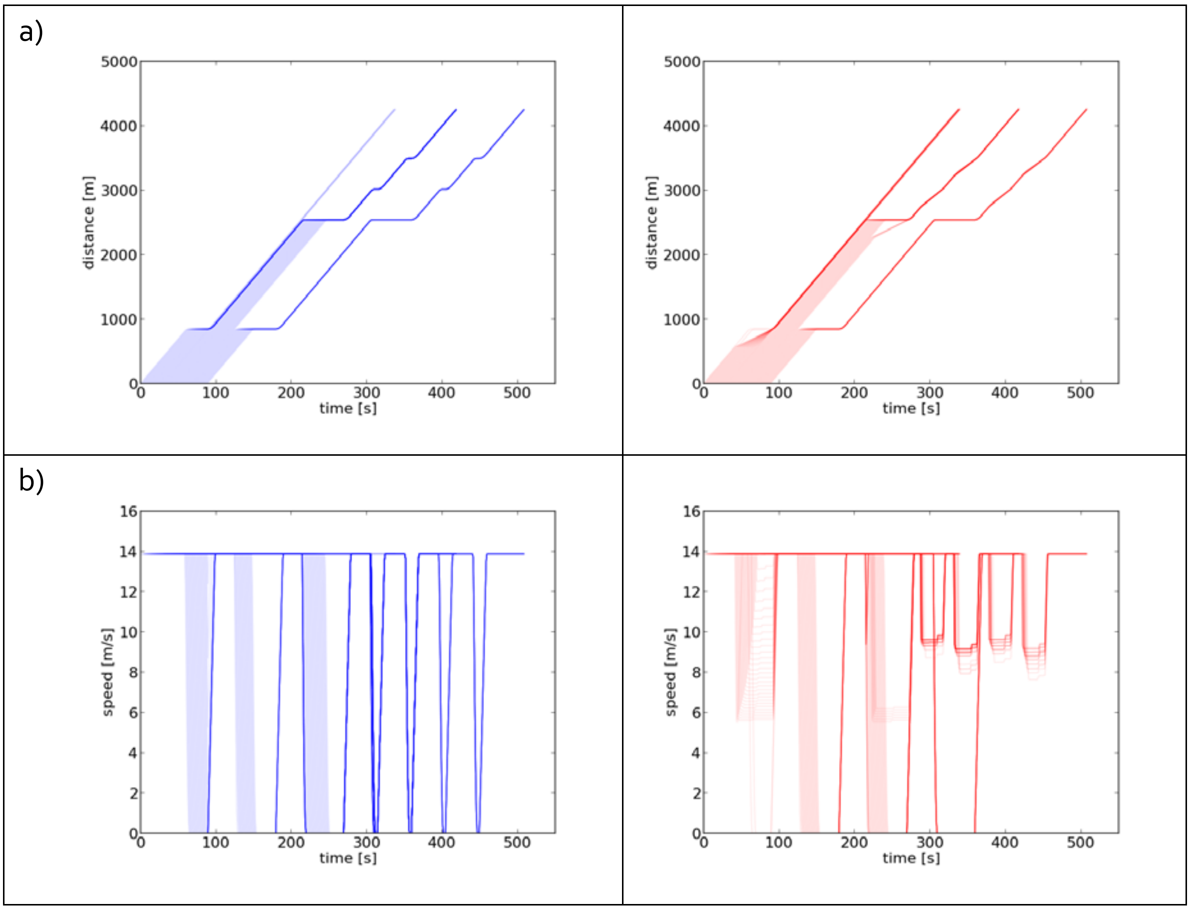

Figure 2 - Differences between progressing through the network for 90 unequipped (left, blue) and 90 equipped (right, red, communication range of 300 m) vehicles; from top to bottom: a) distance over time; b) speed over time

It can be seen, that GLOSA helps vehicles to get through the network. Though, only some vehicles do not need to halt at all, some have to stop.

The assumed reason for halting was that vehicles are informed too late about the traffic lights state, so that no speed adaptation matching the rules can take place. To validate this assumption, a further set of simulations was performed which should reveal how a change in the communication distance affects GLOSA's performance. The evaluation was done by iterating over the communication distance between 100 m and 1000 m in steps of 100 m. Each of these iterations included 90 simulation runs using one equipped vehicle, as described previously. Instead of using a medium-aware communication model, a lossless one was used. This means, that all messages within the communication range were received correctly by the simulated equipped vehicles. The results are presented in Figure 3.

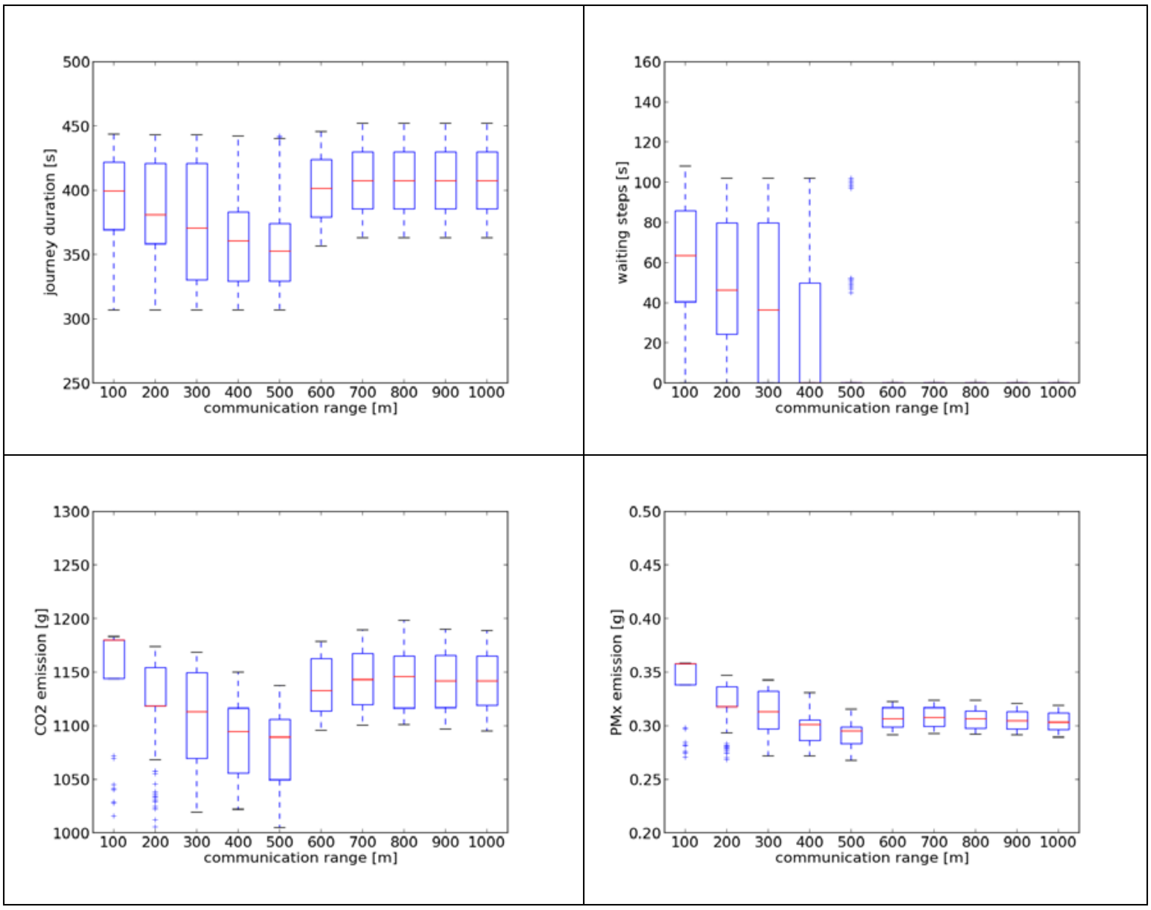

Figure 3 - Performance indicators in dependence to the communication range; densities collect values for different departure times between 0 and T

Not surprising, vehicles have to be informed early enough about the state of traffic lights, and the obtained results are similar to those presented in earlier investigations. On the other hand, one may notice that though the number of halts decrease with an increasing communication range, journey duration and CO_2 emission do not. Figure 4 shows that a communication range of 1000 m gives all of the 90 simulated vehicles the needed information to pass the network without any halt.

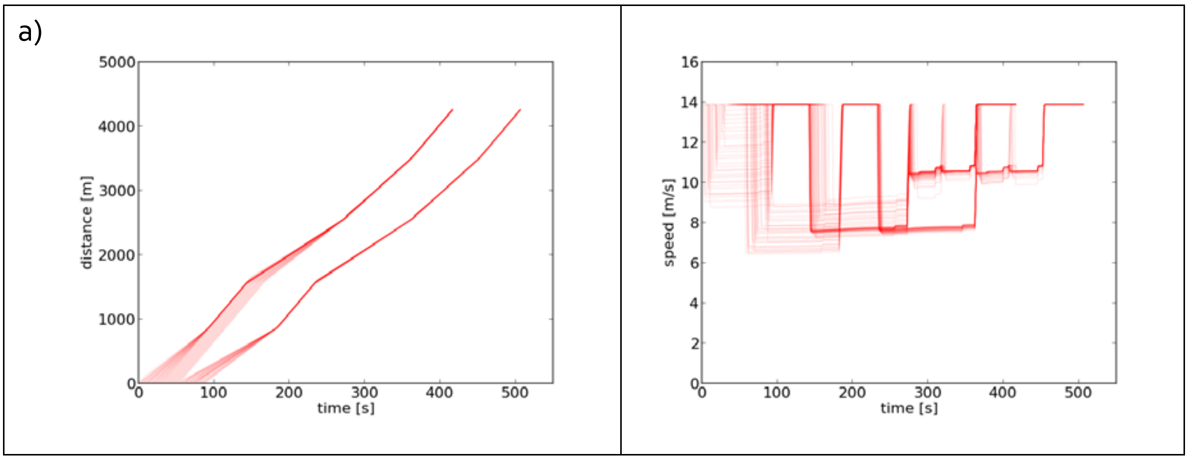

Figure 4 – Progress through the network for 90 equipped vehicles with a communication range of 1000 m; left: distance over time; right: speed over time

Behaviour of a Group of Equipped Vehicles

The motivation of the following runs was to determine how a real-world demonstration of the GLOSA Use Case could be set up. In a first step, only equipped vehicles were modelled. Their number was increased along simulation runs by a factor of 2 in comparison to the prior run, starting with one vehicle, and ending with 64 vehicles. For each vehicle number, 90 runs were performed, accordingly to the first tests presented. Vehicles were inserted into the network with a time headway of 5 s. The evaluations, shown in Figure 5, depict that increasing the number of vehicles reduces the benefit for all performance measures, even though all vehicles are equipped.

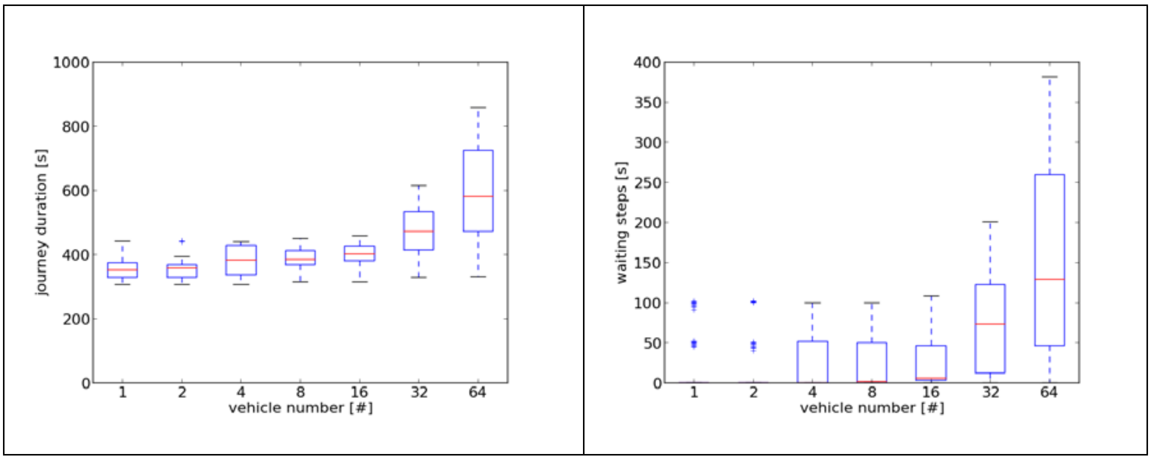

Figure 5 - Performance indicators in dependence to the number of vehicles; all vehicles are equipped; densities collect values for different departure times between 0 and T

Behaviour of a mixed Group

Equipped Vehicles Starting Before Unequipped Vehicles

The next step was to investigate the performance for mixed traffic – including equipped and unequipped vehicles. The first set of simulations considered a scenario where equipped vehicles are at the front of the simulated platoon, followed by unequipped vehicles. The number of equipped vehicles was again increased as described above. The number of following unequipped vehicles was 10, 20, 40, 100, 200, and 400 along a second loop. Different departure times were not investigated. Figure 6 shows the obtained results.

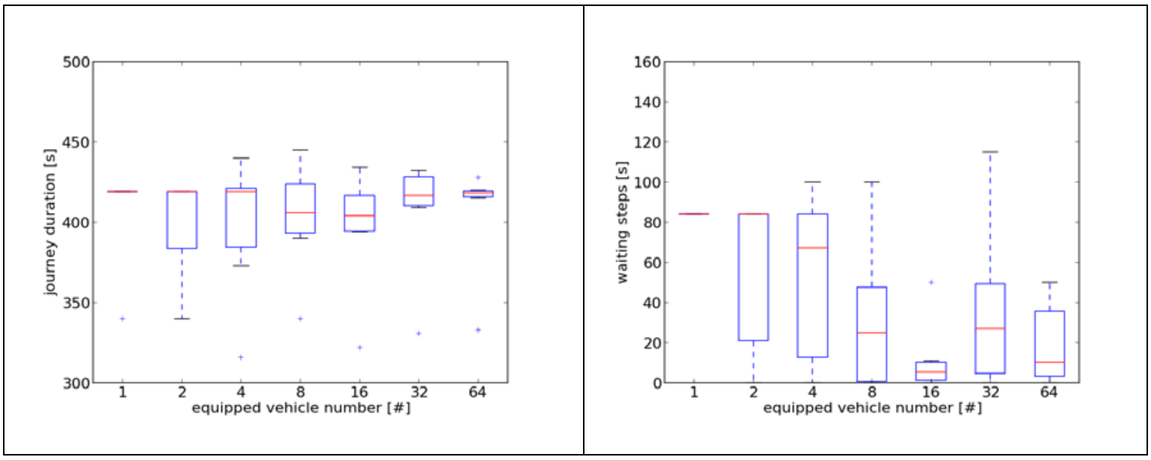

Figure 6 - Performance indicators in dependence to the number of equipped vehicles; densities collect runs with a different number (see text) of unequipped vehicles starting behind the equipped ones

Equipped Vehicles Starting Between Unequipped Vehicles

The last set of performed simulations was set up similar to the previously described one, but equipped vehicles were randomly distributed within the platoon. The numbers were kept as in the previous set. Again, the collected measures are given in Figure 7.

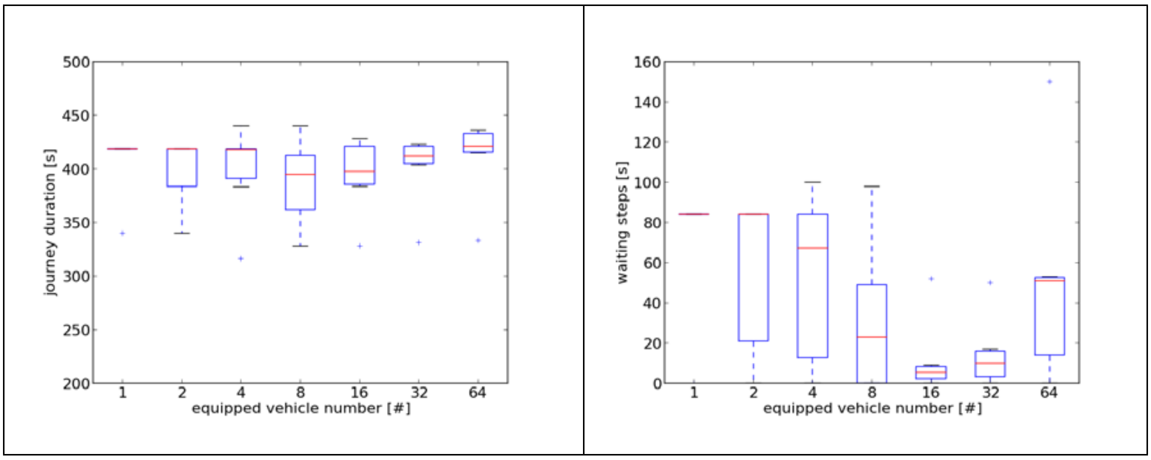

Figure 7 - Performance indicators in dependence to the number of equipped vehicles; densities collect runs with a different number (see text) of unequipped vehicles starting between the equipped ones

Summary

The main motivation of the presented work was to prove our simulation models' capabilities to simulate the GLOSA application in a realistic scenario. As the collected results are similar to those presented in prior work, we assume this work to be successful. The investigations that followed the initial verification have shown degradation in GLOSA performance with an increasing number of equipped vehicles. This should be investigated in following work.

The fact that different algorithms for the computation of the advised speed exist in the literature should be tackled in later research, too. It should be also verified whether the approach used here – letting the vehicle pass the intersection 2 s after the light turns green – is acceptable by the driver.

Within the DRIVE C2X project, traffic simulations shall accompany FOTs, predicting their results, and improving models based on the measures taken from them. Though microscopic traffic simulations can already be used for simulating GLOSA, some extensions seem to be needed. For example, normal driver should be assumed to predict a light turn to red if they are approaching it for a long time already. In this case, they will adapt their speed before the light turns red, a behavior that is not yet implemented in any traffic simulations we know. Also, the drivers' reaction times to HMI signals and their ability to keep the advised speed should be investigated.

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