Technische Universität Braunschweig

Institute of Operating Systems and Computer Networks

OrbWeaver: Towards Comparable High-Load V2X Simulations

Garlichs, Keno and Willecke, Alexander and Hagau, Andreas-Christian and Wolf, Lars

Authors post-print published on 2020-07-22

Originally published in *Accepted at IEEE Vehicular Technology Conference (VTC2020-Fall) Workshop 6 - Network-assisted Collaborative Automated Driving*

Publisher version available at TBD

DOI: TBD

Abstract:

Vehicle-to-Vehicle communication is available inproduction cars only since end of 2019. Therefore, the load ofthese communication channels in real-world streets is very lownowadays. But market penetration rates will eventually increaseand so will the channel loads. It is therefore crucial to designprotocols and communication mechanisms in a way that they willperform well under high-load conditions, too. In order to test andevaluate them, a couple of simulators and traffic scenarios havebeen developed. However, so far researchers tend to re-createdifferent versions of similar scenarios over and over again. Thisleads to results which are not easy to reproduce and compare toeach other. Therefore, this paper proposes OrbWeaver: An opensource tool automatically generating fully customisable, spiderweb shaped traffic scenarios which are suitable for high-loadsimulations. Simply by publishing the used input parameters,researchers can enable the community to easily generate the samescenario and compare their results. Three different scenariosgenerated with OrbWeaver are evaluated and their channel loads,message drop and transmission rates are compared, showingthe feasibility of the generated scenarios for the evaluation ofprotocols under different network loads.

OrbWeaver: Towards Comparable High-Load V2X Simulations

Keno Garlichs, Alexander Willecke, Andreas-Christian Hagau, Lars C. Wolf
Insitute of Operating Systems and Computer Networks
Technische Universität Braunschweig
Germany
garlichs,willecke,hagau,wolf@ibr.cs.tu-bs.de

***Abstract*—Vehicle-to-Vehicle communication is available in production cars only since end of 2019. Therefore, the load of these communication channels in real-world streets is very low nowadays. But market penetration rates will eventually increase and so will the channel loads. It is therefore crucial to design protocols and communication mechanisms in a way that they will perform well under high-load conditions, too. In order to test and evaluate them, a couple of simulators and traffic scenarios have been developed. However, so far researchers tend to re-create different versions of similar scenarios over and over again. This leads to results which are not easy to reproduce and compare to each other. Therefore, this paper proposes OrbWeaver: An open source tool automatically generating fully customisable, spider web shaped traffic scenarios which are suitable for high-load simulations. Simply by publishing the used input parameters, researchers can enable the community to easily generate the same scenario and compare their results. Three different scenarios generated with OrbWeaver are evaluated and their channel loads, message drop and transmission rates are compared, showing the feasibility of the generated scenarios for the evaluation of protocols under different network loads.**

***Index Terms*—simulation, channel load, sumo**

I. Introduction

Vehicular communication has the potential to enhance driver assistance systems by providing additional information about other traffic participants, safety hazards and general context which was not available before. However, vehicles sending information via wireless communication share the same broadcast domain and hence, the common resource, the medium, has to be managed. To address this, the European Telecommunications Standards Institute (ETSI) specified the Decentralized Congestion Control (DCC) mechanism [1], deployed on each European Intelligent Transport Systems Station (ITS-S) which limits the usage of the medium. DCC monitors the Channel Busy Ratio (CBR) and determines a message rate at which the ITS-S is allowed to transmit its messages and thereby prevents channel saturation. Similar approaches can be found in the U.S. equivalent defined by SAE [2].

The CBR itself is influenced by three factors:

1) Emitted Messages: The actual number of messages emitted by an ITS-S is hard to estimate and highly situational. Firstly, it depends on the number of services the ITS-S is running, such as Cooperative Awareness Service (CA Service) [3] and Collective Perception Service (CP Service) [4]. Secondly, each service emits messages following their respective triggering conditions and message generation rules. The CA Service considers the dynamics of the ego vehicle itself, generating a message whenever its speed, heading or position changed by more than a certain threshold with respect to the last Cooperative Awareness Message (CAM). The CP Service applies similar rules for every object it perceives with its sensors and generates a Collective Perception Message (CPM) whenever at least one object needs to be transmitted. It then includes all objects meeting the above criteria.

2) Message Size: In addition to the number of emitted messages, the CBR also depends on the message size. The sizes of the messages emitted by the services can vary over time as, e.g., CPMs can include different amounts of perceived objects. When the number of emitted messages is constant, longer messages lead to higher CBRs simply because they occupy the medium for a longer time when they are sent.

3) ITS-S' in Reception Range: Lastly, the CBR depends on the number of sending ITS-S' in reception range, their services and corresponding message sizes.

Especially in scenarios with high vehicle density, like multi-story interchanges and megacities, and with the rising market penetration rate of ITS-S in the upcoming years, mechanisms like DCC will be put to test. Hence, a detailed performance evaluation in such congested conditions is necessary for congestion control mechanisms, like DCC itself, as well as for the message generation policies of services. Since conducting tests with many vehicles is expensive due to necessary equipment, personnel and organisation, simulation studies are preferred, allowing for fine-granular configuration, observability and reproducibility. To enable comparable studies of Intelligent Transport Systems (ITS) communication protocols, we propose OrbWeaver, which leverages Simulation of Urban Mobility (SUMO) to generate predictable high-load scenarios, with parameterisable traffic conditions like general road shape, vehicle density and vehicle dynamics.

The remainder of the paper is organised as follows. Section II analyses different scenarios used throughout literature to simulate and evaluate ITS protocols, discussing their application and their drawbacks regarding high-load simulations. In Section III, we describe our requirements for such scenarios and introduce the design of our scenario generator OrbWeaver. An exemplary evaluation of three generated scenarios is presented in Section IV, followed by the conclusion in Section V.

II. Related Work

When it comes to the evaluation of mechanisms in the domain of Vehiclular Ad-hoc Networks (VANETs), the most prevalent traffic simulator is SUMO [5] and there are some traffic scenarios which are frequently used. They can generally be divided into two partitions, the first of which is formed by realistic traffic scenarios, modelling the traffic demand in specific real world cities. Among the commonly used ones are Bologna [6], Luxembourg SUMO Traffic (LuST) [7] and Monaco SUMO Traffic (MoST) [8]. They are not many because of the effort it takes to make them actually realistic but indispensable if performance under realistic conditions is to be evaluated. When the effect of mechanisms like DCC is to be evaluated, the absolute worst-case scenarios are especially interesting. However, in realistic scenarios, areas with high network load are hard to isolate if at all present in the few existing scenarios. The actual realism of the scenarios on the other hand is not as crucial to study the effects of high load.

Therefore, and for the relative ease of creation, a number of artificial traffic scenarios are frequently used in research as well. They form the second partition of scenarios. One well renown representative of those scenarios is the Manhattan Grid Scenario [9]. It mimics the road layout of large (U.S.) cities like Manhattan and forms a grid of roads with different amounts of lanes for each direction. It is often used with the Manhattan Mobility Model [10] where vehicles drive with a predefined maximum speed and have a probability of 0.5 for going straight and 0.25 each for turning left or right at intersections. The disadvantage of this scenario is that vehicles are turning from time to time and therefore drive rather slowly. Since the triggering conditions of some messages like, e.g. CAMs and CPM depend on the sending vehicle's speed, this is not optimal to create high, constant channel loads since messages will be sent at a relatively slow rate.

Another often used type of scenario is the highway. Usually, it is comprised of a single, straight road segment with a varying number of lanes for each direction. Vehicles are driving with highway speeds at varying vehicle densities. Highway scenarios have been used in scientific publications, as well as simulations published in official standards (e.g., [4], [11]).

In addition to that there are more artificial scenarios, mimicking other situations like, e.g., parking lots [1].

Those scenarios are all suited for performance evaluation but one issue most of them share is that results are hard to compare because researchers tend to reinvent them over and over again. Even when sharing parameters such as vehicle speeds and densities, some details, like driver models and specific spawn behaviours, often remain unclear in publications. Another issue, especially with highway-like scenarios, can be that new vehicles enter the scenario while others leave it during the simulation time. As CPM generation rules, e.g., require all new objects to be included in a CPM, this can lead to unfavourable side effects like pulsating CBRs, especially if vehicles spawn at a fixed rate. A scenario with a constant set of vehicles is therefore favourable.

III. The OrbWeaver Generator

The aforementioned pros and cons of existing scenarios can be condensed into specific requirements to scenarios suitable for the use case at hand.

1) Accessibility: All related scenarios are described in the respective publications, which is the most important aspect to enable comparability. But oftentimes the exact configuration, like driver-models and traffic flows, are not published along the scenario layout, which hinders direct comparison of results. For fully reproducible and comparable results, the scenario and configuration must be accessible for the research community in its entirety. Additionally, the scenarios should be available for SUMO, a commonly used traffic simulator in the ITS research community which we use in our studies, too.

2) Flexibility: Simulation studies in the ITS domain may focus on different aspects that can be observed in different traffic situations, requiring multiple different scenarios. While they can be generally similar, many detailed aspects should be parameterisable to the respective study's needs.

3) High Channel Load: The scenario must be able to create the prerequisites necessary for achieving a high channel load by often triggering the message generation conditions of the services used in the simulation.

4) Continuity: Traffic in the scenario must be continuous, allowing vehicles neither to enter nor leave the simulation scenario, as that would cause the inclusion of network stacks in an unsteady state. Additionally, spawn patterns of vehicles may cause synchronisation effects in the simulation results and therefore need to be avoided.

Since none of the available scenarios fulfil all those requirements, a new scenario is needed. However, due to variety of traffic situations which may be of interest to researchers, one scenario is not sufficient and multiple scenarios are required. Therefore, we conclude that an open-source generator for high load scenarios is necessary.

A. Scenario Generation

For that purpose we introduce our open source tool OrbWeaver[1] which allows for automatic road network and traffic flow generation. Scenarios generated by OrbWeaver can be fully customised to the specific demands of the studies at hand but will generally all consist of concentric, circular roads with continuous traffic flows, as depicted in Figure 1.

1) Road Network: As foundation for the road network, the `netgenerate` tool of SUMO is used for generating a spider web with a parameterisable number of rings R, distance between rings d_r and the number of edges n, approximating the rings as n-gons. These parameters give researchers the flexibility to abstract different road network densities, such as country roads, cities or highway junctions. Each ring consists of two lanes, where the traffic on the inner lane flows clockwise and counter-clockwise on the outer lane. `netgenerate`

[1] https://github.com/ibr-cm/orbweaver

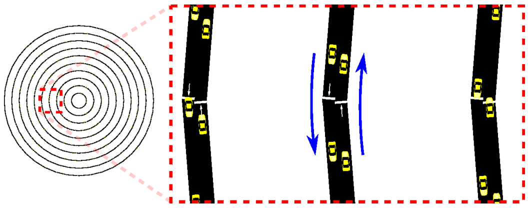

Fig. 1. Scenario generated by OrbWeaver. Each ring consists of two lanes with two traffic flows driving in opposite directions.

connects all rings with straight road segments along the dashed lines in Figure 2.

These are removed in the next step of the road network generation such that only the rings remain in the scenario. This way, vehicles cannot leave the ring they were spawned on, keeping the vehicle density per ring constant. Additionally, turning decision making of the driver model from the simulation is eliminated and therefore, movement of every vehicle in the scenario is predictable throughout the whole simulation duration. This avoids problems other scenarios like, e.g., the Manhattan Grid scenario have.

2) Traffic Generation: In addition to the road network, OrbWeaver generates the vehicles flows with a constant speed v for the scenario, eliminating randomness of decision making and driving behaviour. This enables the configuration of the scenario in a way that triggers message generation of the CA Service at maximum frequency due to exceeding the speed threshold.

The amount of vehicles spawned in the whole scenario can be configured by the density parameter ρ, specifying the number of vehicles per kilometre of road. Depending on its perimeter, OrbWeaver calculates the amount of vehicles which need to be spawned on a ring and inserts them in equidistant intervals during the warm-up time of the simulation scenario, filling the whole ring with vehicles. The geometric layout of the spawn interval calculation is depicted in Figure 2. First, the perimeter of the i-th ring ($i \in [1, R]$) has to be determined. Since each ring is approximated by a regular polygon with the number of edges equal to n, its perimeter $p(i)$ is calculated as follows:

$$p(i) = n \cdot l_e(i) \tag{1}$$

l_e being the edge length of the regular polygon, which can be calculated as:

$$l_e(i) = 2 \cdot r(i) \cdot sin\left(\frac{\pi}{n}\right) \tag{2}$$

The radius $r(i)$ of i-th ring needs to be compensated by half of the lane width w to calculate the actual length of the vehicles' driving paths which depends on whether it is on the inner or outer lane:

$$r(i) = i \cdot d_r \pm \frac{w}{2} \tag{3}$$

The time to circuit the ring is $T_c(i) = p(i) \cdot v^{-1}$. To determine the spawn interval T_s it is divided by the total

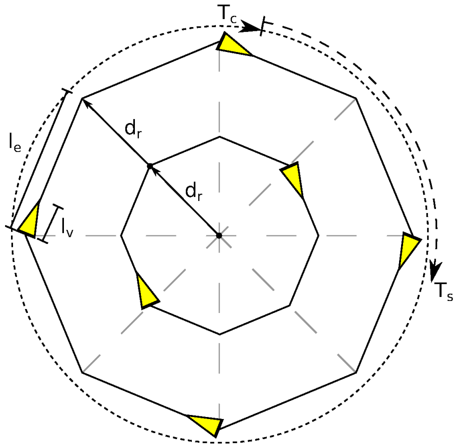

Fig. 2. Traffic Flows generated by OrbWeaver

number of vehicles for ring i, defined by vehicle density parameter ρ and the ring perimeter:

$$T_s(i) = \frac{T_c(i)}{\lfloor \rho \cdot p(i) \rfloor} \tag{4}$$

Beginning from the departing edge of its ring, each spawned vehicle drives with a configurable but constant speed towards the arrival edge, the predecessor edge of the departing edge, which closes the ring. To achieve continuity of traffic flows, special traffic rerouters are placed on the departing and arrival edge, which reconfigure the passing vehicle's destinations. The departing rerouter sets the vehicle destination to the arrival edge and vice versa, causing vehicles to continuously and indefinitely drive around the ring.

IV. Evaluation

This section will now demonstrate how the previously described OrbWeaver can be used to generate different simulation scenarios and analyse the results that can be obtained. Three different scenarios were generated for that purpose: `country-roads`, a low density, medium speed scenario comparable to roads in rural areas, `traffic-jam`, a low speed scenario with an extremely high vehicle density - inspired by situations like traffic jams in large cities and `highway`, a high density and high speed scenario comparable to traffic in the area of large highway hubs. Their generation parameters are listed in Table I. The parameters not mentioned were kept at their default values.

TABLE I
Generation parameters for the simulation scenarios

Scenario	R	d_r $[m]$	ρ [Vehicles/km]	v $[m/s]$
`country-roads`	5	200	5	22
`traffic-jam`	3	50	80	4
`highway`	10	100	40	42

In order to not only simulate traffic, but communication between the moving vehicles, different choices for simulators are available like iTETRIS [12], Veins [13] and Artery [14].

TABLE II
SIMULATION PARAMETERS

Parameter	Value
Communication technology	ITS-G5
Radio Channel	180 (Control Channel)
Data Bitrate	$6\,\mathrm{Mbit\,s^{-1}}$
Transmission Power	200 mW (23 dB m)
Vehicle antenna height	1.5 m
Radio Propagation Model	Two Ray Interference Model [16]
CAM TC	2 [17]
CPM TC	3
DCC Finite State Machine	TRC, 3x Active, 500 µs T_{on} [18]
DCC Queue Length (All TCs)	1
Radar Sensor Range	150 m
Radar Sensor Angle	360°
Simulation Duration	5 s

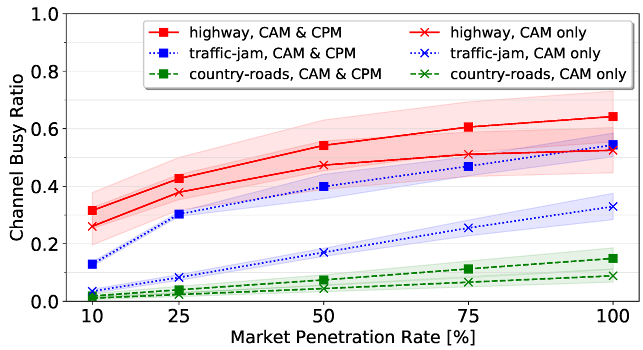

Fig. 3. Results CBRs ($\mu \pm \sigma$) for all three scenarios with either only CAMs or both CAMs and CPMs being sent for different MPRs

Since all those simulators use SUMO for traffic simulation, the scenarios generated with OrbWeaver should be compatible with all of them. In this paper, Artery was chosen because it includes a full Cooperative Intelligent Transport Systems (C-ITS) network stack according to the ETSI specifications – including DCC and a CA Service. In the past, it has also already been extended with a CP Service [15] which makes use of the environment model that Artery features and provides an abstract radar sensor implementation enabling vehicles to perceive each other.

In Artery, the Market Penetration Ratio (MPR) of V2X communication hardware can be set. In this analysis, 10%, 25%, 50%, 75% and 100% were used to study the influence on resulting CBRs. Since the CA Service is a Day 1 service which is already deployed today, it was always running on all equipped vehicles. The CP Service on the other hand is currently not yet available in production cars but will be one key technology for Day 2 [19]. Therefore, simulations where also run where all V2X enabled vehicles sent both CAMs and CPMs. The CAM was assigned to Traffic Class (TC) 2 according to [17]. The CPM's TC was not set by any standards body yet and was set to 3 in these simulations. I.e., the lower prioritised CPMs were dropped in favour of CAMs when the message budget set by DCC was depleted. These and the remaining relevant simulation parameters are listed in Table II.

A. Results

One of the main goals of this kind of scenario was to achieve high channel loads. This was also formulated in requirement 3 and is indeed possible, depending on the parameterisation, as Figure 3 demonstrates.

It shows the average CBRs and the according standard deviation aggregated over all vehicles in each of the three scenarios for different market penetrations. It is evident, that CBRs are very different in the respective scenarios as demanded by requirement 2. The lowest CBR was observed in `country-roads` because it has the lowest vehicles density and vehicles drive at medium speeds. This leads to CAMs also being generated at medium rates. The distance between the rings is 200 m which means only vehicles on the same ring are within the radar perception ranges. As a result, CPMs contain only a few objects and are rather small, leading to a low additional CBR induced by the CP Service.

This is different in `traffic-jam` with its extremely high vehicle density and much smaller ring distance. The CPMs include many objects which makes them large and they therefore occupy the channel longer. Hence, the runs with both the CA Service and CP Service enabled show a much high CBR when compared to the runs without the CP Service. The CBR is still much higher than in `country-roads` just because of the sheer number of vehicles in the scenario, although they do not transmit messages as often as the general pace is much slower.

`highway` still has a high vehicle density, but only half the density of `traffic-jam`. At the same time, the vehicles' speed is above $40\,\mathrm{m\,s^{-1}}$ which triggers a CAM every 100 ms (c.f. CAM Dissemination in [3]). Consequently, the mean CBR is above 50 % even without the CPM at 100 % MPR.

The high vehicle speed also constantly requires all sending vehicles to include all objects they perceive in the CPMs which are then also created every 100 ms (c.f. CPM Dissemination Concept in [4]). Sending many messages which, in case of the CPM, are also very large, ultimately results in even higher CBRs. However, with increasing CBRs, DCC allows less messages to be sent and therefore, the difference between the runs with and without the CP Service is not as drastic. The channel is simply already saturated by the CAM alone.

This becomes evident in Figure 4. It shows the ratio of messages that DCC dropped out of all messages that the services of a vehicle produced. (The DCC gatekeeper drops messages either when they expired or when the queue is full and a new message arrives [18].) It can be seen that in `country-roads`, no messages had to be dropped at all, while in `highway`, starting at an MPR of only 25 %, more than 90 % of all messages were dropped by DCC when both the CA Service and the CP Service were activated. However, even without the CP Service, drop ratios increase with MPR, showing how the CAM saturates the channel. In `traffic-jam`, due to the low vehicle speeds (and thus CAM generation frequency), no messages are dropped without the CP Service being active. When activating it, considerable

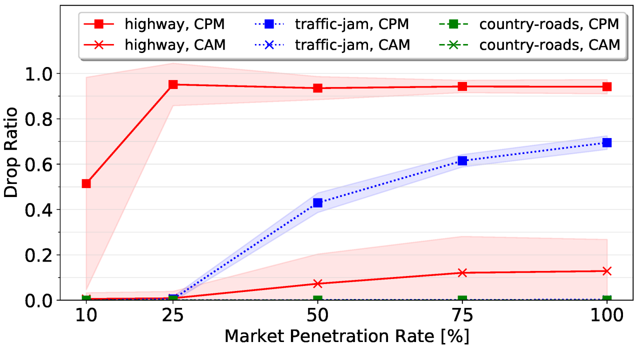

Fig. 4. Drop ratio of messages (CAMs & CPMs) over MPR ($\mu \pm \sigma$) in runs with both services active

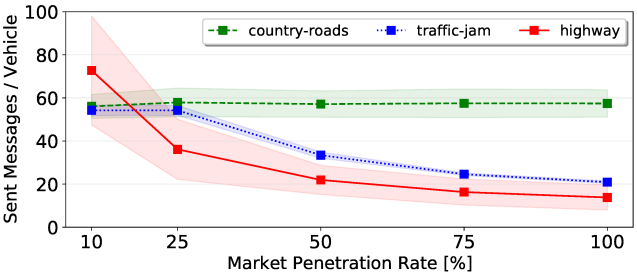

Fig. 5. Total number of successfully transmitted messages (CAMs + CPMs) per vehicle ($\mu \pm \sigma$) throughout the simulation duration of 5 s

amounts of messages are dropped - depending on the MPR.

Figure 5 yields another perspective on this. It shows the amount of actually successfully transmitted messages (CAMs + CPMs) per vehicle over the duration of the simulation. Since in `country-roads` no messages had to be dropped, this number is relatively constant over all MPRs. In `highway` and `traffic-jam`, that number decreases with increasing MPRs (i.e. an increasing number of communicating vehicles).

A detailed analysis of the CP Service's performance in high-load conditions can be found in [4] and [20]. One of the two scenarios used for that analysis was called `spider-max-load` and was already generated with OrbWeaver, demonstrating its usefulness in real-world simulation studies.

V. Conclusion

When evaluating communication mechanisms under high channel load conditions, researchers tend to create similar, but still not necessarily comparable artificial scenarios. In this paper, we introduced OrbWeaver, an open source tool that allows to easily parameterise and create scenarios that are suited for those evaluations. By simply publishing its input parameters, researchers enable everyone to recreate the same scenario and reproduce and compare results.

Three different exemplary scenarios were created with OrbWeaver and simulated with Artery. The analysis proved the versatility of the created scenarios in terms of, e.g., resulting Channel Busy Ratios. In conjunction with realistic scenarios like MoST [8], the artificial scenarios created by OrbWeaver can supplement the development and evaluation of communication mechanisms by isolating specific situations.

References

[1] ETSI TS 102 687 V1.1.1, *Intelligent Transport Systems (ITS); Decentralized Congestion Control Mechanisms for Intelligent Transport Systems operating in the 5 GHz range; Access layer part*, ETSI Std., Jul. 2011.

[2] SAE DSRC Technical Committee, "On-Board System Requirements for V2V Safety Communications," in *SAE Standard J2945/1*, Mar. 2016.

[3] ETSI EN 302 637-2 V1.4.1, *Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service*, ETSI Std., Apr. 2019.

[4] ETSI TR 103 562 V2.1.1, *Intelligent Transport Systems (ITS);Vehicular Communications; Basic Set of Applications; Analysis of the Collective Perception Service (CPS); Release 2*, ETSI Std., Dec. 2019.

[5] P. A. Lopez, M. Behrisch, L. Bieker-Walz, J. Erdmann, Y.-P. Flötteröd, R. Hilbrich, L. Lücken, J. Rummel, P. Wagner, and E. Wießner, "Microscopic Traffic Simulation using SUMO," in *IEEE Intelligent Transportation Systems Conference (ITSC)*, 2018.

[6] L. Bieker, D. Krajzewicz, A. Morra, C. Michelacci, and F. Cartolano, "Traffic Simulation for All: A Real World Traffic Scenario from the City of Bologna," in *Proceedings of the SUMO2014 Modeling Mobility with Open Data*. Deutsches Zentrum für Luft- und Raumfahrt e.V., 2014.

[7] L. Codeca, R. Frank, S. Faye, and T. Engel, "Luxembourg SUMO Traffic (LuST) Scenario: Traffic Demand Evaluation," *IEEE Intelligent Transportation Systems Magazine*, vol. 9, no. 2, pp. 52–63, 2017.

[8] L. Codeca and J. Härri, "Towards multimodal mobility simulation of C-ITS: The Monaco SUMO traffic scenario," in *IEEE Vehicular Networking Conference (VNC)*, 2017.

[9] TR 102 861 V1.1.1, *Intelligent Transport Systems (ITS);STDMA recommended parameters and settings for cooperative ITS; Access Layer Part*, ETSI Std., Jan. 2012.

[10] G. Jayakumar and G. Gopinath, "Performance Comparison of MANET Protocols Based on Manhattan Grid Mobility Model," *Journal of Mobile Communication*, vol. 2, no. 1, pp. 18–26, 2008.

[11] TR 101 612 V1.1.1, *Intelligent Transport Systems (ITS); Cross Layer DCC Management Entity for operation in the ITS G5A and ITS G5B medium; Report on Cross layer DCC algorithms and performance evaluation*, ETSI Std., Sep. 2014.

[12] M. Rondinone, J. Maneros, D. Krajzewicz, R. Bauza, P. Cataldi, F. Hrizi, J. Gozalvez, V. Kumar, M. Röckl, L. Lin *et al.*, "iTETRIS: a modular simulation platform for the large scale evaluation of cooperative ITS applications," *Simulation Modelling Practice and Theory*, vol. 34, pp. 99–125, 2013.

[13] C. Sommer, R. German, and F. Dressler, "Bidirectionally coupled network and road traffic simulation for improved IVC analysis," *IEEE Transactions on Mobile Computing (TMC)*, vol. 10, no. 1, pp. 3–15, 2011.

[14] R. Riebl, H.-J. Günther, C. Facchi, and L. C. Wolf, "Artery: Extending Veins for VANET applications," in *International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS)*, 2015.

[15] K. Garlichs, M. Wegner, and L. C. Wolf, "Realizing Collective Perception in the Artery Simulation Framework," in *IEEE Vehicular Networking Conference (VNC)*, 2018.

[16] C. Sommer, S. Joerer, and F. Dressler, "On the applicability of Two-Ray path loss models for vehicular network simulation," in *IEEE Vehicular Networking Conference (VNC)*, 2012.

[17] CAR 2 CAR Communication Consortium, "Basic System Profile 1.5.0," Tech. Rep., Mar. 2020.

[18] ETSI TS 102 687 v1.2.1, *Intelligent Transport Systems (ITS); Decentralized Congestion Control Mechanisms for Intelligent Transport Systems operating in the 5 GHz range; Access layer part*, ETSI Std., Apr. 2018.

[19] CAR 2 CAR Communication Consortium, "Guidance for Day 2 and Beyond Roadmap," Tech. Rep., Sep. 2019.

[20] K. Garlichs, H.-J. Günther, and L. C. Wolf, "Generation Rules for the Collective Perception Service," *IEEE Vehicular Networking Conference (VNC)*, 2019.