



A Real-Corridor SUMO and ns-3 Testbed for VANET Traffic Congestion Studies on NH-16, Visakhapatnam

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Abstract: Vehicular ad hoc network (VANET) applications for traffic congestion need to be tested on roads that look like the ones they are meant for, yet most simulation studies still rely on synthetic grids. This paper describes a simulation testbed built on a real Indian corridor: the 6.48 km stretch of NH-16 between Old Gajuwaka and NAD Junction in Visakhapatnam. The road network is taken from OpenStreetMap, and seven roadside units (RSUs) are placed at identifiable roadside sites such as bus stands. SUMO, controlled through TraCI, moves ten vehicles whose routes are weighted by segment congestion levels and applies a repeatable jam on one segment. The resulting mobility is replayed in ns-3, where on-board units and RSUs exchange IEEE 802.11p beacons. In the reference scenario, seven of the nine vehicles that entered the network reached the jam zone and dropped below 5 km/h. Their mean speed there was 3.8 km/h against 44.1 km/h elsewhere, the queue grew from five to seven vehicles as later arrivals drove into it, and all vehicles recovered within a few seconds of the jam being lifted. The testbed provides a realistic and repeatable base for studying congestion-aware VANET services on Indian roads.

Keywords: VANET, IEEE 802.11p, SUMO, NS-3, TraCI, Roadside Unit, Traffic Simulation, Traffic Congestion, OpenStreetMap

I. INTRODUCTION

Visakhapatnam's stretch of NH-16 carries a mix of city buses, trucks from the port and industrial area, and private vehicles. Queues build up there almost daily near bus stands and junctions, and once a queue forms, drivers approaching it have few ways to learn about it in time. Vehicular ad hoc networks (VANETs) are a natural fit for this problem, since vehicles and roadside units (RSUs) can exchange short messages directly over IEEE 802.11p without any cellular infrastructure [1]-[3].

Many congestion-related VANET methods have been proposed, from control of congestion on the wireless channel [4], [5] to learning-based detection of congestion on the road [6], [7]. Before such methods can be judged for an Indian city, though, they need a simulation environment that reflects local road geometry, realistic infrastructure positions and a repeatable traffic situation. In practice most studies use synthetic grid networks or maps from other countries, and coupling a traffic simulator with a network simulator [8] is usually set up again for every project.

This paper presents a testbed built for that purpose on NH-16 in Visakhapatnam. Its contributions are:

- 1) A SUMO road network of a 6.48 km NH-16 corridor with seven RSUs placed at real roadside sites.
- 2) A two-stage pipeline that turns segment congestion levels into vehicle demand, runs SUMO through TraCI and replays the resulting mobility in ns-3 with IEEE 802.11p radios.
- 3) A repeatable congestion scenario and a characterisation of how the jam forms, grows and clears on the corridor.

Section II reviews related work, Section III describes the testbed and Section IV the corridor. Section V sets out the scenario and the network model, Section VI reports the results, and Section VII concludes.

II. RELATED WORK

Coupled simulation is the usual way to study VANET applications. SUMO [9] simulates individual vehicles on road networks imported from OpenStreetMap, ns-3 [10] models the wireless network, and TraCI [11] lets an external program read and steer a running SUMO instance. Sommer et al. [8] coupled traffic and network simulators in both directions and built Veins [12] around that idea, while ms-van3t [13] links SUMO with ns-3 and supports several vehicular access technologies. Weber et al. [14] compare the available simulators and point out how strongly results depend on realistic mobility.

Studies set on Indian roads are fewer. Bodkhe and Tanwar [15] released a SUMO-based dataset of Indian traffic scenarios for misbehaviour detection, which shows the value of local scenarios but does not deal with congestion. On the infrastructure side, Guerna et al. [16] survey how RSUs can be deployed and how coverage is traded against cost. Congestion itself has mostly been studied at the channel level [4], [5] or with learning-based detectors [6], [7], often on



simplified road layouts. What is missing is a ready testbed on a real Indian corridor, with RSUs at identifiable sites and a congestion scenario that can be repeated exactly.

III. TESTBED ARCHITECTURE

The testbed is organised in two stages that exchange only files (Fig. 1). The input stage prepares the road network, the RSU positions and the vehicle demand. The simulation stage runs SUMO and ns-3 and keeps logs for analysis. Because every stage reads and writes files, any scenario can be run again with identical input.

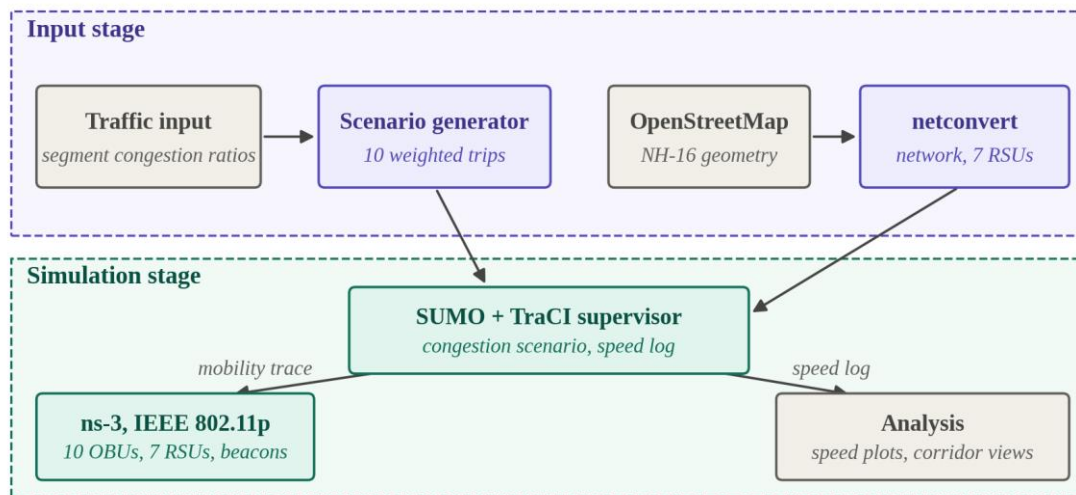


Fig. 1. Architecture of the testbed

A. Input Stage

The corridor was extracted from OpenStreetMap and converted into a SUMO network with netconvert, and the RSU positions were matched to the nearest points on the main carriageway. Traffic conditions on each of the six RSU-to-RSU segments are described by a congestion ratio, the travel time in traffic divided by the free-flow travel time, and by a level from free to jam. For the runs reported here these values come from a recorded file, so that every run starts from the same input; the stage is written so that the ratios can also come from a live traffic source. Ten vehicle trips are then generated, spread over the segments in proportion to their ratio and released over the first 120 s.

B. Simulation Stage

A Python supervisor drives SUMO through TraCI in steps of 1 s. It applies the congestion scenario, records the speed, road edge and position of every vehicle each second, and writes an ns-2 format mobility trace. ns-3 then replays this trace for ten on-board units (OBUs) and places the seven RSUs as static nodes at their positions, with an IEEE 802.11p radio on every node. The speed log is used afterwards to produce speed plots and corridor views.

IV. STUDY CORRIDOR

The corridor follows NH-16 northbound from Old Gajuwaka to NAD Junction, a length of about 6.48 km. It passes the New Gajuwaka and Sheelanagar bus stands, the BHPV junction and several industrial entrances. Seven RSUs are placed along it at existing roadside sites, as shown in Fig. 2(a). The spacing between neighbouring RSUs ranges from 0.60 km to 2.08 km. Table I lists the RSUs and the conditions assigned to each segment in the reference scenario, and Fig. 2(b) shows part of the imported network running in SUMO.

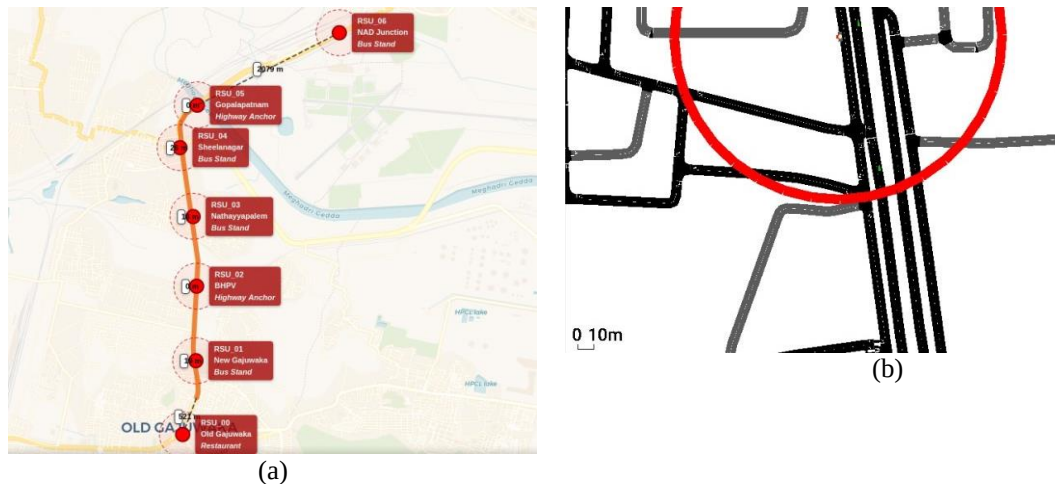


Fig. 2. (a) RSU placement along NH-16, with dashed circles showing the 300 m radio range (map data © OpenStreetMap contributors, © CARTO); (b) SUMO view of the network near Sheelanagar, with the range of one RSU in red

TABLE I
RSU SITES AND SEGMENT CONDITIONS IN THE REFERENCE SCENARIO

RSU	Location	Site	Latitude, Longitude	To next (km)	Ratio	Level	Trip s
rsu_00	Old Gajuwaka	Restaurant	17.685048, 83.203902	0.98	1.05	free	1
rsu_01	New Gajuwaka	Bus stand	17.693737, 83.205536	0.97	1.25	light	1
rsu_02	BHPV	Highway anchor	17.702503, 83.205661	0.91	2.20	jam	3
rsu_03	Nathayyapalem	Bus stand	17.710709, 83.205199	0.91	1.85	heavy	2
rsu_04	Sheelanagar	Bus stand	17.718771, 83.203601	0.60	1.45	moderate	2
rsu_05	Gopalapatnam	Highway anchor	17.723778, 83.205720	2.08	1.15	light	1
rsu_06	NAD Junction	Bus stand	17.732260, 83.223209	-	-	-	-

V. SCENARIO AND NETWORK MODEL

A. Congestion Scenario

The BHPV to Nathayyapalem segment, which has the highest ratio in Table I, is used as the jam zone. From $t = 60$ s to $t = 350$ s the supervisor limits the maximum speed of every edge inside this zone to 1.2 m/s (about 4.3 km/h); afterwards the limit is set back to 13.89 m/s (50 km/h). Applying the jam as a speed limit rather than waiting for one to emerge gives the same jam in the same place on every run, which is what a testbed needs. Vehicles follow the Krauß car-following model [17], SUMO's default.

B. Network Model

In ns-3 every OBU and RSU carries an IEEE 802.11p radio on the 5.9 GHz band with a 10 MHz channel, a 6 Mb/s data rate and 20 dBm transmit power. With Friis free-space propagation this gives a usable range of about 300 m. Nodes use the ad hoc MAC, and each OBU sends a UDP broadcast beacon carrying its identifier and position once per second. Table II lists the main parameters of both simulators.



TABLE II
SIMULATION PARAMETERS

Parameter	Value	Parameter	Value
Simulated time / step	600 s / 1 s	MAC / PHY	IEEE 802.11p, ad hoc
OBUs / RSUs	10 / 7	Channel / data rate	5.9 GHz, 10 MHz / 6 Mb/s
Car-following model	Krauß (SUMO default)	Tx power / range	20 dBm / about 300 m
Vehicle type	car, 4.5 m, min. gap 2.5 m	Propagation	Friis, constant-speed delay
Accel. / decel. / σ	2.6 / 4.5 m/s ² / 0.5	Beacon interval	1 s
Free-flow speed	50 km/h	RSU antenna height	1.5 m
Departure spread	0 to 120 s	Transport	UDP broadcast
Jam speed limit	1.2 m/s, t = 60 to 350 s	Teleport timeout	300 s

The runs were carried out with Eclipse SUMO 1.25.0, ns-3-dev and Python 3 on Kali Linux in a VMware virtual machine.

VI. RESULTS AND DISCUSSION

A. Vehicle Speeds

Nine of the ten trips entered the network; the tenth was rejected because the edge chosen as its start does not allow passenger cars. Fig. 3 shows the speed of every vehicle over the 600 s run. Seven vehicles reached the jam zone while the speed limit was active, and each of them fell below 5 km/h and stayed there until the limit was removed. The other two travelled ahead of the zone at 45 to 50 km/h and left the network at about 319 s and 331 s. One vehicle waited at its starting edge for about a minute before it could enter traffic, which appears as the flat line near zero at the start of the plot.

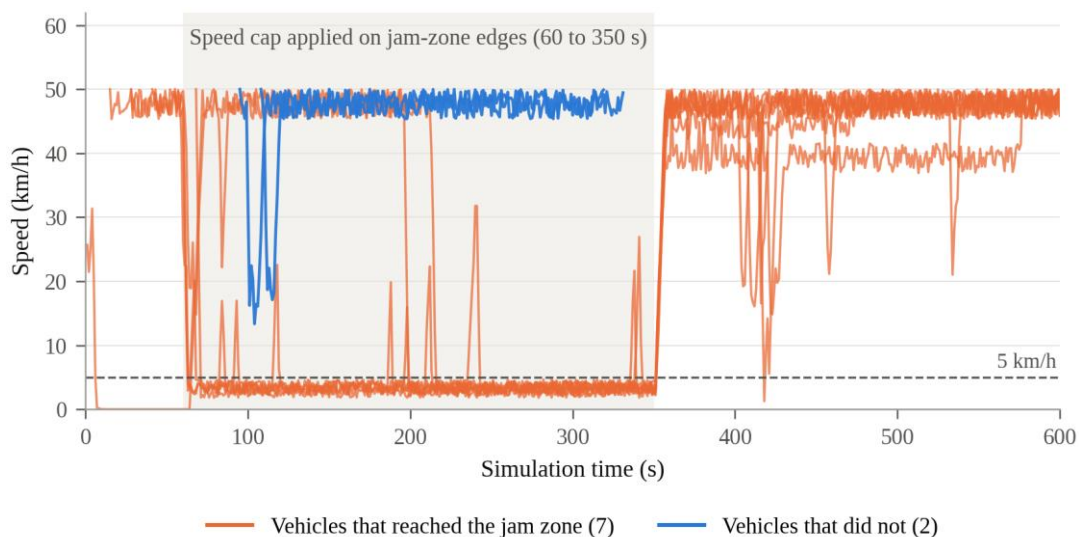


Fig. 3. Per-vehicle speed in the reference scenario; the shaded band marks the period in which the jam speed limit was applied

TABLE III
TRAFFIC BEHAVIOUR IN THE REFERENCE SCENARIO

Measure	Value
Trips that entered the network	9 of 10
Vehicles that reached the jam zone and fell below 5 km/h	7 of 9
Mean speed inside the jam zone (60 to 350 s)	3.8 km/h
Mean speed outside the jam zone (60 to 350 s)	44.1 km/h
Vehicles below 5 km/h at 81 s / peak (at 216 s)	5 / 7
Later arrivals that joined the queue	2 (at 199 s and 216 s)
All vehicles above 20 km/h again by	355 s
Mean speed of all vehicles after 370 s	45.8 km/h



B. Queue Formation and Recovery

Fig. 4 counts the vehicles below 5 km/h at each second. Within 21 s of the jam starting, five vehicles that had been released early were already held in the zone. The queue then grew to seven when two vehicles that had started further back reached it at 199 s and 216 s, about 140 s and 155 s after the jam began. Fig. 5 shows the same growth on the map: at $t = 40$ s vehicles are spread along the southern half of the corridor, while at $t = 250$ s they are gathered around BHPV and Nathayyapalem and only the two lead vehicles are still moving.

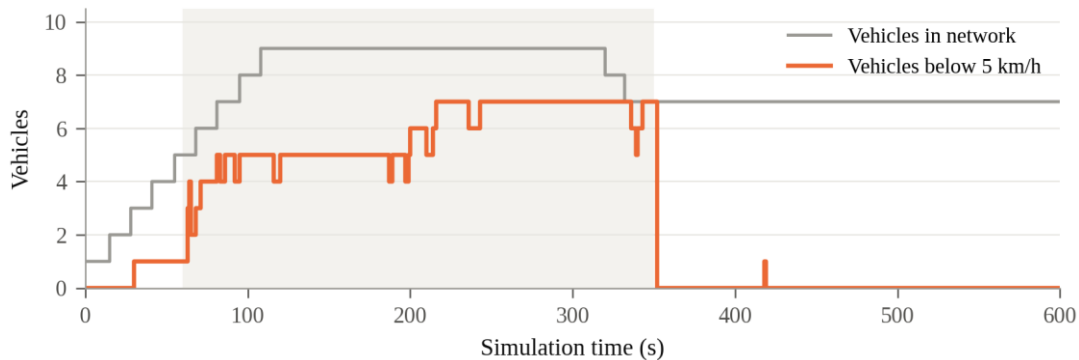


Fig. 4. Number of vehicles in the network and number below 5 km/h over time

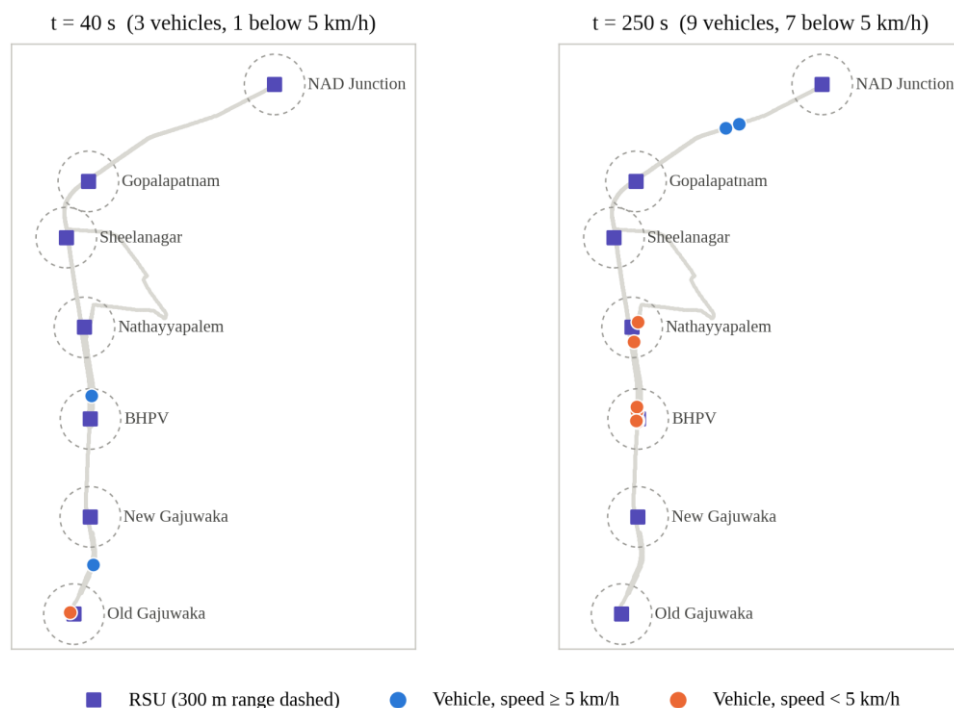


Fig. 5. Vehicle and RSU positions on the corridor at $t = 40$ s and $t = 250$ s

Once the limit was lifted at 350 s, every vehicle was back above 20 km/h within 5 s, and after 370 s the mean speed across all vehicles was 45.8 km/h, close to the 50 km/h free-flow value. Table III summarises these measures. Two points stand out. First, because the jam is applied in the same way on every run, the scenario can serve as a fixed reference for comparing methods. Second, the two vehicles that joined the queue late had driven towards it for more than two minutes with no information about it. On this corridor both of them passed the New Gajuwaka RSU before reaching the queue, which is exactly the kind of situation that congestion-aware VANET services aim to improve.

VII. LIMITATIONS AND FUTURE WORK

The testbed has limits that should be kept in mind. SUMO and ns-3 are coupled sequentially, so events in the network cannot change vehicle movement within the same run. The scenario has ten vehicles and no background traffic, so channel load at high density is not represented. Friis propagation overestimates range among buildings, only the northbound direction is modelled, and the jam is applied as a speed limit rather than arising from demand. Future work will use the



testbed with live traffic input and denser traffic to study how congestion can be detected on the corridor and how that information can reach approaching vehicles through the RSUs.

VIII. CONCLUSION

This paper described a simulation testbed for VANET congestion studies on a real Indian corridor, the NH-16 stretch from Old Gajuwaka to NAD Junction in Visakhapatnam. The testbed combines an OpenStreetMap road network, seven RSUs at identifiable roadside sites, SUMO controlled through TraCI and ns-3 with IEEE 802.11p radios. In the reference scenario a jam applied on the BHPV to Nathayyapalem segment slowed seven of nine vehicles to a mean of 3.8 km/h, grew as later vehicles arrived, and cleared within seconds of being lifted. The testbed gives a realistic and repeatable base on which congestion-aware VANET services for Indian roads can be developed and compared.

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