VEHICLE-TO-VEHICLE CHANNEL LOAD BALANCING THROUGH VEHICULAR ROUTING

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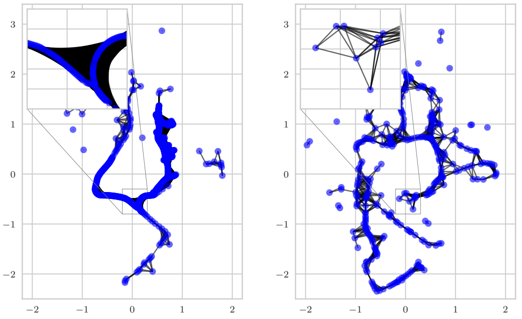
INTRODUCTION

With the advent of self-driving cars, the need for inter-car communication, as well as vehicle-to-infrastructure communication arises. This is necessary to provide information across the Vehicular Ad-Hoc Network (VANET), to mitigate dangerous situations and avoid accidents. However, dense urban traffic poses a challenge to communication systems due to the large amount of communication nodes within range, leading to high channel loads. We demonstrate that usage of the communication channel can be drastically improved by cooperative road routing of the vehicles.

ROAD ROUTING AND NETWORK FORMULATION

In [1], the authors demonstrated that routing vehicles cooperatively through a city brings an almost unanimous speed gain for all cooperating vehicles. The simulations took among others, the city of Linz in Upper Austria, and gave 3000 vehicles start and endpoint, and let them drive, once egoistically (*unrouted*) and once using a routing algorithm (*routed*).

We take the generated traces, and now assume that all traffic nodes are equipped with a wireless communication system. This communication system will detect the presence of a signal, if the received signal power P_{rx} is above a given threshold. Combined with a given transmit power, and the pathloss encountered in the urban environment, we get a maximum distance where node i is aware of node j transmitting. For simplicity, we assume this distance to be the same in all directions, regardless of the obstructions. We now define all nodes that are within this range of each other as being connected by an edge $e(i,j)$, and thus construct the communication graph $G=(V,E)$ from the set of all nodes V and the set of all edges E. We then define the distance $d(i,j)$ as the minimal path length from i to j, that is the minimal number of hops required to get from i to j. Then, we introduce the set of neighbors of i as the set of all nodes with $N(i)=\{j|d(i,j)=1\}$, and the order of that set is given as $|N(i)|$.



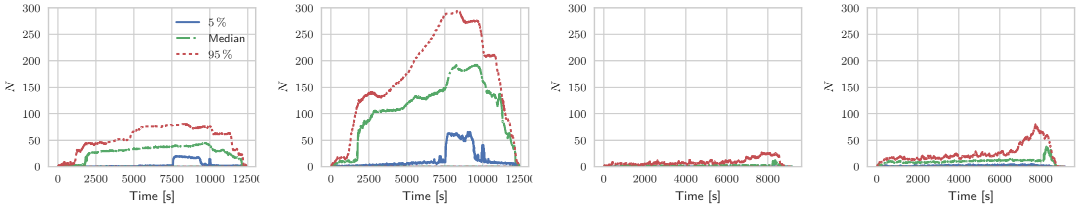
(a) Unrouted **(b)** Routed

Figure 1: Network graph of the vehicular traffic for multiple communication ranges.

Figure 1 demonstrates these graphs for a snapshot time and a communication range of 300 m, both for routed and unrouted scenarios. This was chosen because communication ranges of up to 300 m have been demonstrated for vehicular standards [2] in measurements. When assuming Non-Line-of-Sight conditions (NLOS), ranges of at least 100 m were measured [3]. We therefore use these values as optimistic and pessimistic estimates for our further analysis.

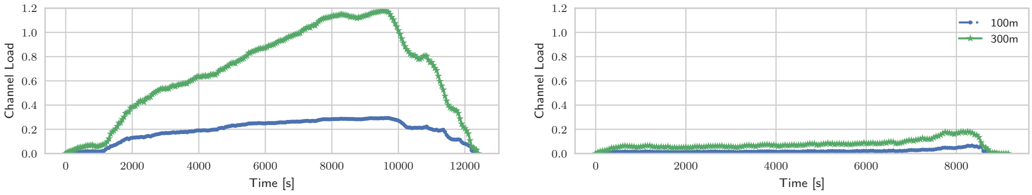
RESULTS AND DISCUSSION

Figure 2 depicts the size N below which 5, 50 and 95 % of the orders of the neighbor sets lie as a function of simulation time. The figure shows the results for routed and unrouted, as well as the two given communication ranges. As can be seen, the unrouted scenarios produce traffic jams very quickly, and the traffic nodes see large amounts of neighbors. The routed scenario, on the other hand, avoids this completely, staying at small sizes throughout the simulation. We now assume that every vehicle communicates $P_s = 10$ times per second, with an average duration of $l = 667\,\mu$s. This corresponds to typical signaling communication for safety messages in vehicular standards. Then, we can introduce the channel load as the expected value of the product $\mathrm{E}(NP_s l)$. Figure 3 shows that the unrouted scenario sees heavily loaded communication channels, while routing completely eliminates the excessive channel load.



(a) 100m, unrouted **(b)** 300m, unrouted **(c)** 100m, routed **(d)** 300m, routed

Figure 2: Time evolution of the cluster sizes for 100 and 300 m, routed and unrouted simulations.



(a) Unrouted **(b)** Routed

Figure 3: Channel load as a function of time for the unrouted and routed scenarios.

CONCLUSION

Cooperative driving effectively mitigates the problem of high perceived channel load and ensures that safety communication is able to be transmitted without experiencing excessive delays. Very important in this context is the fact that the routing was not aiming to achieve this, but the target geometric spread of the routing algorithm aligns very well with a similar target for low channel loads.

REFERENCES

[1] C. Backfrieder, G. Ostermayer, and C. Mecklenbräuker, *Increased Traffic Flow Through Node-Based Bottleneck Prediction and V2X Communication,* IEEE Transactions on Intelligent Transportation Systems, 99, pp. 1-15, 2016.

[2] J. Karedal, N. Czink, A. Paier, F. Tufvesson, and A. F. Molisch, *Path Loss Modeling for Vehicle-to-Vehicle Communications,* IEEE Trans. Veh. Technol., vol. 60, no. 1, pp. 323-328, 2011.

[3] T. Mangel, O. Klemp, and H. Hartenstein, *A validated 5.9 GHz Non-Line-of-Sight pathloss and fading model for inter-vehicle communication,* in Proc. 11th Int. Conf. ITS Telecommun., pp. 75-80, 2011.