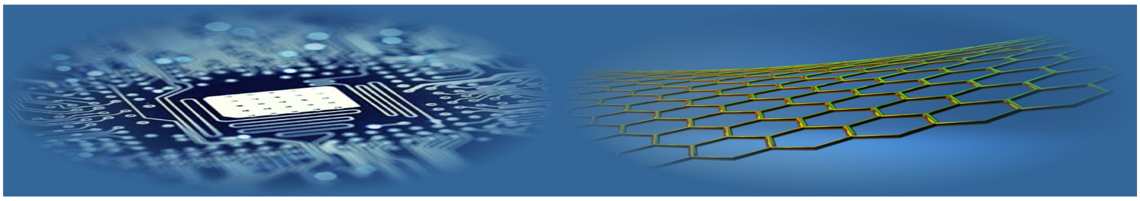

The effect of moving agents on the network formation in smart-city applications

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Abstract

Agent based simulation has an ever-increasing popularity between simulation methods since the actual evolution of the technology now allows scientists to run even really complex simulations using these techniques. However simplification of models is still a key point when running these simulations. Even though our resources seem to be infinite at the first sight one can soon find the limitations in case of modelling such complex systems as e.g. smart city scenarios. In these simulations usually the model contains a set of moving agents that may be connected to each other forming an evolving network. When the interaction of these agents is studied authors usually can choose from two options. i.) Get the network topology at a given point of time and run e.g. information spreading simulations on this constant network or ii.) run the simulations while moving the agents in the same time. This paper tries to reveal in what scenarios it is necessary to count with the evolution of the network and in what cases is it enough to make a snapshot of the network decreasing the needed amount of resources while having almost similar results.

Key words

ABS, ad-hoc networks, smart-city

1 Introduction

Investigation of the communication of smart vehicles is in the focus of research in the previous couple of years, since the emerging new technologies make engineers to face problems have not seen before. One of the most interesting topics around this field is the spreading of information between these devices. Even though for the process itself there are official standards like Dedicated Short Range Communication (DSRC) or for example IEEE 802.11p standard [1 - 3] some questions are still open and interesting to investigate. The spreading of information on these networks is interesting because in contrary to the viewpoint of some works these topologies are evolving and this evolution may highly affect the spreading as well.

Previous studies have analyzed the topological properties of urban road maps [4, 5] and the traffic flow was measured and studied [6] in some other works in order to increase the efficiency of these intelligent transportation systems. Several different algorithms and methods were developed to simulate the motion of vehicles and generate traffic in urban or in highway environment [7 - 9].

In our work we study the evolution of the networks formed by smart communication devices held by moving agents. Our findings may be useful to understand the background of some phenomena related to information spreading on these networks.

2 Model system and dynamics

In our model we represent members of the traffic by moving agents on a topology. For the sake of simplicity as a first step we use a simple row as the underlying topology representing a simple straight road. In order to eliminate effects of the ends we apply periodic boundary condition. If we use a long enough topology this condition does not affect our simulation results while it makes some parts much easier to be implemented. Each agent *a* knows its position P_a on the underlying topology. Each agent is holding a short-range communication device whose possible communication area is also a property of the agent d_a. I a steady state of the model we say that agent a_j is a neighbor of agent a_i if for the position of it $P_{a_i}-d_{a_i}\leq P_{a_j}\leq P_{a_i}+d_{a_i}$ holds. Note that as a first setup this relation is not necessarily symmetric. Leading to the possibility of the formation of directed graphs during the evolution. Each agent $_a$ has its own speed S_a as well. In order to keep our model close to real applications at least on this level we say that the speed of the agent S_a is measured in *m/s*.

The model is updated in discrete timesteps. To keep here in real world metrics as well we say that timesteps are measured in seconds. As a default setup 1 timestep is 1 second. In each timestep all agents move according to their speed. If the speed is negative they move to the opposite direction compared to the case of having a positive speed.

The set of neighbors of agent *a* is updated as follows: At the very beginning of the evolution the set of neighbors is cleared and only those agents will be neighboring ones that are in the area of agent a plus the speed of the agent. With this property of the model we try to catch the natural phenomenon that a faster vehicle meets more others while it moves. While this simplification lets us to catch a relevant property of the real world it makes the evolution much easier to follow.

3 The applied scenarios

After gathering real world data from external sources and running test runs with different scenarios we found that the following parameter setups are tuned well to fit to real world scenarios while they also give interesting to study results.

We set the length of the road to L=10000m. And we put N=5000 vehicles on it at random positions. Note that the modelled road is considered to be a highway that has more than one lanes and two directions, so more vehicles can take place at the same position (maybe in different lanes). The transmission area *d* is set to be constant for all agents and its exact value is a control parameter of the model. So as the maximal speed v_{max} of the agents. The exact speed of agent *i* is generated as a random value so that $0\leq v_{a_i}\leq v_{max}$. These values are gathered to Table 1.

4 Results

As it can be seen above at this early step of our investigations we focused on two key parameters of the model. Namely, we analyzed the effect of the maximal speed of agents v_{max} and the transmission area *d* on the structure

TABLE 1 The basic setup of the model. We tuned the parameters to have a real world close parameter set and interesting to study results in the same time

Road length (L)	10000m
# of agents (N)	5000
agents' transmission area (d)	similar for all agents, parameter
agents' speed	Random value between 0 and vmax, vmax is parameter
timestep	1s

of the network topology formed by connected agents. Note that both above parameters affect the topology formation through the amount of agents possibly able to be reached for transmission in each timestep. So first we started to run simulations with constant area d=50 and different max speeds v_{max}=10, 20, 30, 40, 50, 60, 70, 80, 90.

Since the first and most informative property of such networks is the degree distribution [10] we plotted it for the different speeds at different timesteps. On Figure 1 one can note that because of the random initial placement of agents the degree distribution follows a Gaussian form. However increasing the maximal speed v_{max} of agents results in lower maximal values of the distribution. This is by the way not really surprising knowing that the increased speed increases the transmission area as well, so the amount of possibly reached agents is increasing. Also, note however that during the evolution of the system this distribution does not change to much showing that the effect of the movement of agents cannot be caught by this value.

Even though at different timesteps we found almost similar degree distributions for the topology intuitively one knows that these networks cannot be the same. In order to catch the differences between topologies formed at different timesteps we introduced a new measure – network similarity – motivated by [11]. This property of a network shows that how much the topology is different compared to the one at a previous state. More precisely we check all agents of the network and count how many edges have been removed from the topology in order to get to the new state. The ratio of the number of the remaining edges and the number of the old edges gives us the final value.

This number is scaled to a value in %. As a next step of our studies we have investigated the similarity of topologies in forwarding timesteps for different speeds and area sizes.

Figure 2 shows the average similarity of these topologies. One the fig one can see that

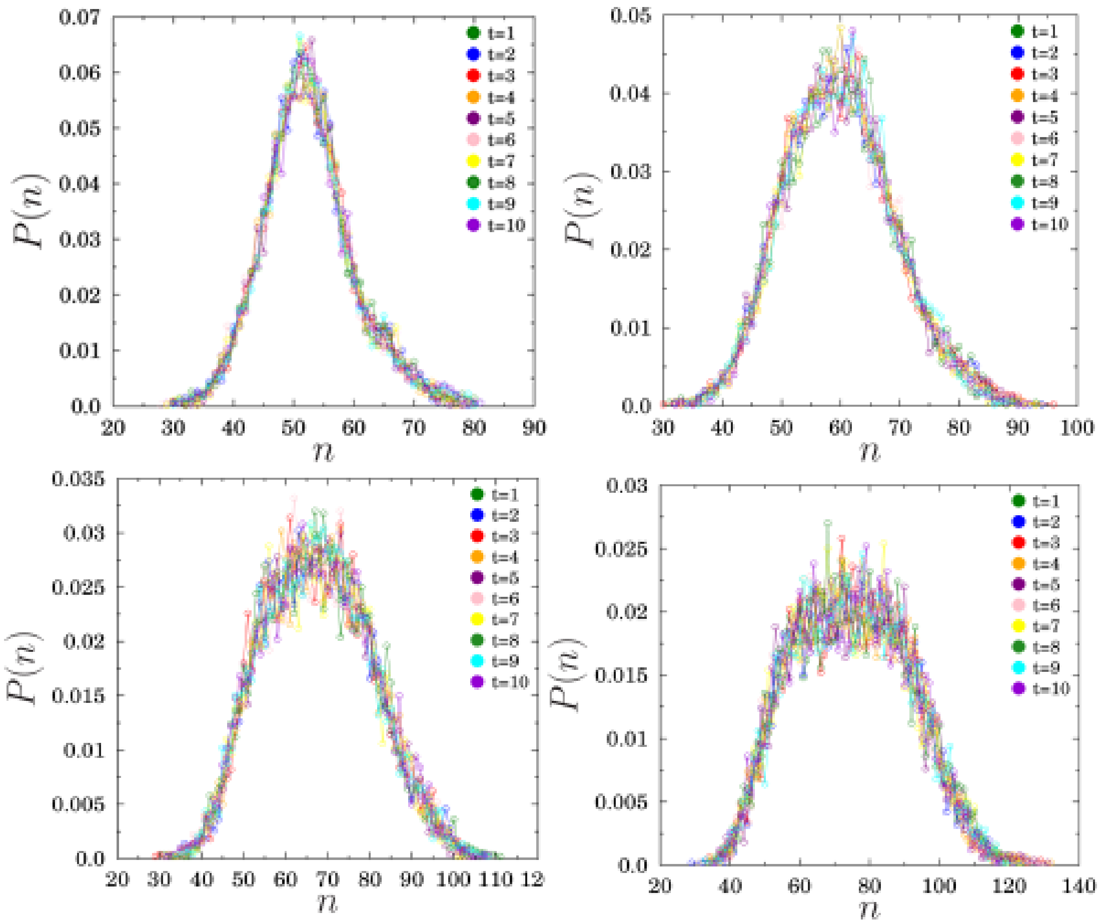

FIGURE 1 Degree distribution of the formed topologies at the first some timesteps of the model evolution. The figures are for different maximal speeds (upper left v_{max}=10, upper right v_{max}=40, lower left v_{max}=70, lower right v_{max}=100).

the similarity increases either we lower the speed or increase the area size. This shows us that as the possible number of agents to be reached by another decreases we face with a more dynamically changing topology.

In order to make one more step to the direction of real world scenarios we have studied the case of having some much faster vehicles than others. One can think on these agents as being e.g. taxi cars always wandering through cities or even more likely priority cars such as police, fire, and ambulance cars. Namely we have set a couple of vehicles' speed to be the double of the maximal speed used during the generation of car speeds. Naturally this leads to extreme situations in some cases. E.g. when the maximal speed is about 100 km/h of course 200 km/h as the constant speed of a car does not sound reasonable, however it is still acceptable enough to be used in our simulations. Figure 3 presents the results of setting 1% and 10% of vehicles' speeds to this new one. Note that while affecting only 1% of the vehicles the overall similarity properties does not change too much. However, when we increase the speed of 10% of the vehicles the similarity of the evolving network decreases more than expected.

Note the case of v_{max}=50 and v_{max}=100 on Figure 3 (middle). Starting from the random speeds in the system supposing that the maximal speed is v_{max}=10 if we increase the speed of 10% of the cars to 100 we get an average speed of 32.5 that is similar to the

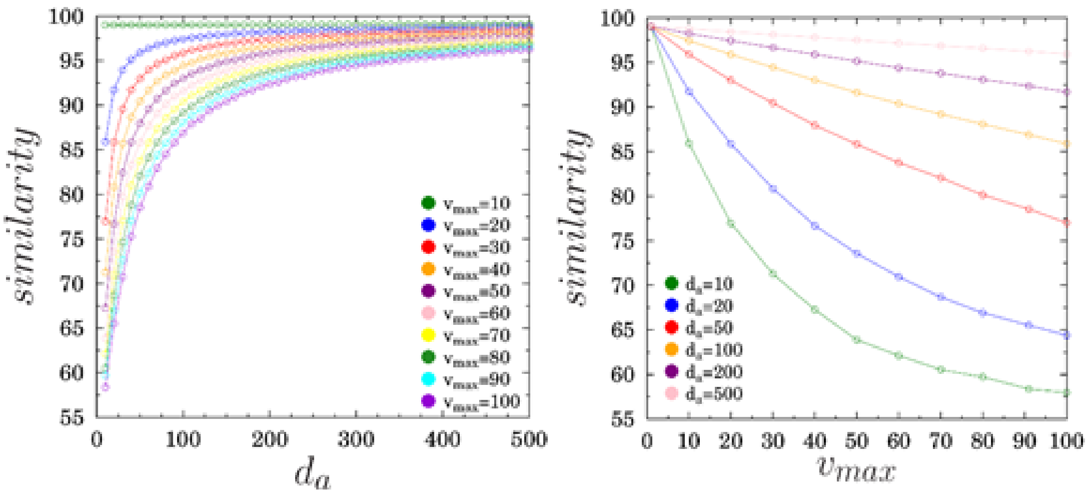

FIGURE 2 The similarity of network topologies at forwarding timesteps plotted as a function of the area size a for different maximal speeds (left) and as a function of maximal speeds for different areas (right). Increasing the amount of possible neighbors naturally increases similarity, so in case of high speed or low transmission area size we will have more dynamic networks.

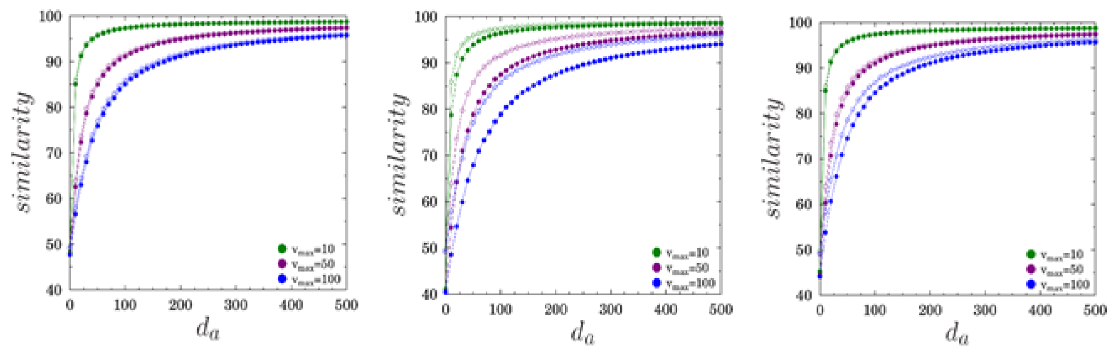

FIGURE 3 The similarity of the evolving network as a function of area size when we introduce a group of special cars in the system. (left): 1% of the cars have a speed twice as fast as the maximal speed in the system. (middle): 10% of cars have this higher speed. (right): 10% of vehicles have a speed of 0. Note that decreasing the speed of this small group of agents has similar effect on the similarity of the network as increasing it. Non-filled markers show the original scenarios, when there are no special speed agents.

case when the speeds are randomized with maximal speed 65. A bit surprisingly however we found that the similarity property shows a bigger difference. Namely if we increase the speed of only 10% of the cars we get almost similar results as we had before for the case of maximal speed v_{max}=100. This means that increasing the average speed of the system has a bigger effect of the similarity of the evolving network if we strongly increase the speed of only a small number of vehicles than in the case of increasing the speed of each vehicle a little.

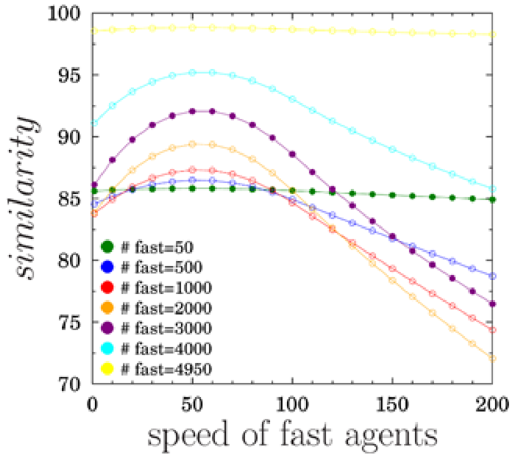

FIGURE 4 The similarity of the evolving network as a function of the speed of a group selected agents. Note that the curves do not change in a monotonic way, but they have a maximum at the place of the average speed of the original system. Note also that the group size may have different effect on the similarity for different speeds of these special agents.

We also studied the case of introducing steady vehicles (or stations) to the system by setting the speed of some agents to 0. Note on Figure 3 *(right)* that the effect is interestingly similar to the case of introducing fast agents. The fact that for given parameter sets adding a group of fast vehicles have similar effect as adding a group of steady ones predicts a complex behavior at the background. In order to study this complex behavior we have investigated the similarity of the evolving network stages as a function of the speed of the selected group of vehicles for different group sizes. A really interesting finding of ours was that the plotted curves have a maximum at the place of the average speed of the original system. No matter which direction, but if we get more far from this point the similarity will decline. We also found that naturally the group sizes also have an effect on the similarity. Note on Figure 4 that the same group size may imply bigger or smaller similarity compared to another size based on the speed of the vehicles of the group. These results may be useful when planning information dissemination in ad-hoc systems. Namely they mean that introducing some steady agents to the system may have similar effect as adding fast ones that may be more much more expensive in most of the cases.

5 Conclusions

In this paper we have introduced a new model of vehicular network formation. In order to have an easy to manage setup we have not used already available tools of the market, but created our own codes to do the studies. Namely we modelled moving vehicles on a highway without crossroads being able to communicate with each other using short range devices.

We used the transmission area size and the maximal speed of agent as control parameters. We have found that even though these parameters do not have a surprising effect on the properties of the network topologies, the similarity of the evolving networks is highly affected by them.

We showed that if we select a group of agents in the system and change their speed based on the size of this group the similarity of the evolving network may change in a complex non monotonic way. Similar results were found in connection with the speed of the agents of this group.

Even though in the scope of this paper we had a chance only to introduce our model and show some simple first results, we are sure that further research using our framework will result in more interesting findings. Making it easier to understand the background processes while we analyze e.g. information spreading on these networks. During the research in order to be able to dynamically see the changing network properties we have started to develop our own graph processing framework in Java language. It would be a good side profit of this work to improve that tool to be enough general to serve for our other projects as well.

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References

[1] Malla A M, Sahu R K 2013 A Review on Vehicle to Vehicle Communication Protocols in VANETs *International Journal of Advanced Research in Computer Science and Software Engineering* **3** 409-14

[2] Salvo P, Felice de M, Baiocchi A, Cuomo F, Rubin I 2013 Timer-based distributed dissemination protocols for VANETs and their interaction with MAC layer *IEEE 77th Vehicular Technology Conference, Dresden* 1-6

[3] Xu Q, Sengupta R, Mak T, Ko J 2004 Vehicle-to-Vehicle Safety Messaging in DSRC *Proceedings of the 1st ACM international workshop on Vehicular ad hoc networks* 19-28

[4] Jiang B 2007 A Topological Pattern of Urban Street Networks: Universality and Peculiarity *Physica A* **384** 647-55

[5] Porta S, Crucitti P, Latora V 2006 The network analysis of urban streets: A dual approach *Physica A* **369** 853-66

[6] Yan Y, Zhang S, Tang J, Wang X 2017 Understanding characteristics in multivariate traffic on time series from complex network structure *Physica A* **477** 149-60

[7] Bátfai N, Besenczi R, Mamenyák A, Ispány M 2015 Traffic simulation based on the Robo-car World Championship initiative *Infocommunications Journal* **7** 50-8

[8] Fiore M, Harri J, Filali F, Bonnet C 2007 Vehicular Mobility Simulation for VANETs *40th Annual Simulation Symposium (ANSS '07)* Norfolk 301-9

[9] Zeadally S, Hunt R, Chen Y S, Irwin A, Hassan A 2012 Vehicular Ad Hoc Networks (VANETS): Status, Results, and Challenges *Telecommunication Systems* **50** 217-41

[10] Newman M E J 2010 *Networks - An introduction* University of Michigan and Santa Fe Institute 627-75 Oxford University Press

[11] Zager L A, Verghese G C 2008 Graph similarity and matching *Applied Mathematics Letters* **21** 86–94

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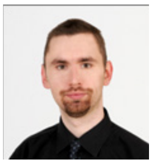

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