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Rumor Spreading in Vehicular Social Networks

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Abstract: Regarding vehicles as social objects is justifiable, since, they have been intelligent. The transportation systems have positively changed due to this vehicular advance technology. Nowadays, vehicles can interact with each other using wireless transceiver devices. Besides, they also have a special hardware which helps them to make decisions. All these facilities enable vehicles to behave as social objects. As information sharing is a main purpose for designing Social Networks (SNs), this study tries to link both SNs and Vehicular Networks (VNs) to produce a new multidisciplinary research field Vehicular Social Networks (VSNs). It is going to share information among only vehicles that have common interests instead of all. The rumor spreading is easy well-known algorithm for spreading information in graphs. So, this algorithm will be implemented in VSNs with name Vehicular Rumor Spreading Algorithm (VRSA) taking in account the main constraints of VNs. The results emphasis that the communication cost of VRSA is lower than both of the contagion model and multicasting model. However, in terms of delivery delay it still has a higher deliver delay than the both models. It is concluded that the VRS may be suitable for diffusing less important information when the communication cost is carefully considered. On the other hand, the contagion model is a perfect way to share information in real time applications.

Key words: Contagion model, complex agent network, multicasting model, information sharing, rumor spreading, VSNs

INTRODUCTION

Considering vehicular networks as social networks is practically reasonable as long as the vehicles are intelligent self-organization devices (Vegni and Loscri, 2015). Indeed, they can communicate with other vehicles and make decisions depending on the obtained information which is shared in the network. Just thinking to allow vehicles creating the social groups is a challenge. Another challenge is how to make vehicle's relationships (Vegni *et al*., 2017). In other words, there is a need to define criteria according to which vehicles will be grouped. Once they are gathered in social groups, exchanging their experiences becomes easy and justifiable.

As vehicles are immigrating to the next generation of smart vehicles, more social benefits and applications can be achieved that materialize the concept of vehicular societies. In this scenario, social vehicles can easily share their knowledge with each other as long as they are interested by Mahdi and Hasson (2017). For example, vehicle which is a member in a social group can immediately share traffic congestions. So, its friends will avoid this issue. Not only that, objectives of the safety applications can be met. Besides, the entertainment applications also have a chance to be achieved. For example, mobile multimedia networking can be created to share videos and audios among social groups of vehicles. Drivers and passengers who are going to the same destination can interact together to share their videos or audios (Alam *et al*., 2015). On the other hand, recommendation systems may be suggested to travelers according to the collected data of social vehicles. This study believes that bridging techniques of Social Networks (SNs) and Vehicular Networks (VNs) has a strong society impact. It contributes in growing scholarly knowledge of the efficient grouping of social vehicles. It will grow the scholarly knowledge in using Vehicular Social Networks (VSNs) to share information using Vehicular Rumor Spreading Algorithm (VRSA) for improving the transportation systems.

Aims and nature of the project: While VNs are high mobile networks and vehicle's behavior is difficult to predict an efficient mobile model is required to meet the constraints of VNs. Moreover, sharing information among vehicles is also one of the main purposes of designing VNs. In this Study, bridging two research directions Sns and VNs will contribute in designing an efficient information sharing algorithm. Indeed, a piece of information will be shared among only vehicles that are interested in this information and no vehicle else. In this

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event, a vehicle will share its information with only its social friends. Since, VNs represents complex systems due to its high mobility and dynamic, researchers are encouraged to develop an efficient algorithm to share information. The cost of communication and delivery delay will be considered in designing information sharing algorithms.

Literature review: The different literatures have proposed different mobility models and different data sharing techniques. So, the next subsections will discuss some literatures that are related to these research directions.

Modeling mobility of VNs: Several mobility models have been suggested to model traffic road in VNs. However, specific characteristics of traffic urban scenario are not taken in account in all of these models (Sommer *et al*., 2011). These mobility models are either unidirectional simulations or bidirectional simulations.

Many unidirectional simulators have been used for VNs (Martinez *et al*., 2011). NS2 is used to simulate network of vehicles (Sebastian and Jeyaprakash, 2014). However, traffic simulation can be achieved through another simulation. GloMoSim is another simulator that has ability to simulate the mobility (Hassan, 2009). It is designed to simulate wired and wireless networks. VanetMobSim is widely used to simulate vehicular networks (Alwakeel, 2016). It represents an extension of the CanuMobiSim. NetLogo can be also used to simulate the behavior of vehicles (Shanshan and Chunxiao, 2013). by Hasson and Hasan (2016) suggest a road model approach using NetLogo.

On the other hand, bi-directionally coupled simulations have been also proposed to combine two simulations. First one is to simulate road traffic whereas another one is to simulate the network. By Su *et al*. (2014) SUMO is suggested as a traffic simulation. It is coupled with NS-3 to simulate the network. By Poonia and Bhargava (2016) researchers simulate the road traffic using VanetMobSim simulation and NS-2 as a network simulation. VISSIM is derived from the German sentence “Verkehr In Stadten-SIMulationsmodell” (that means “Traffic in cities-simulation model”). It is coupled with NS-2 as a realistic simulation for VANETs (Sun *et al*., 2016). SUMO and VEINS are linked to model mobility of urban traffic by Hasson and Mahdi (2017).

Information sharing in vehicular social networks: By Achour *et al*., a new simple and efficient data sharing technique is proposed depending on density of surrounding vehicles. According to that each vehicle can use a suitable probability to rebroadcast messages to reduce the number of sent messages. By Dubey *et al*. (2016), researchers assert that priority can be based to reduce transmitted data. They suggest a new scheduling technique depending on expiry time. Suma and Lalitha (2010) propos a hybrid algorithm to collect data using RFID to prevent fake messages. By Hussain *et al*. (2016) researchers use cooperative awareness among vehicles to share traffic data. According to this study each vehicles share its Traffic Data Unit (TDU) with a number of received TDUs from other vehicles. Complex network theory is used to share taxi dataset (Wang *et al*., 2016). In this study, clustering is used to select the station and model is designed to select the source of information. The context of data is based to share information by Amjad *et al*. (2016). The cluster heads aggregate data according to the context. Cluster Based Semantic Data Aggregation (CBSDA) is proposed by Mammu *et al*. (2015). The road is broken into different sections depending on cluster-ID and then data aggregated in each cluster. Cost awareness Multicasting has been suggested by Ji *et al*. (2016). In this study messages are delivered for a specific number of vehicles. By Rehman *et al*. (2016), a new multi-hop broadcast algorithm has been proposed depending on link quality of neighboring vehicles. According to, the previous literatures data sharing is recent challenge in VNs.

MATERIALS AND METHODS

Complex agent networks: The term complex agent network is a combination of two techniques. It comes from combining both Agent Based Model (ABM) and Complex Network (CN) to model the mobility in VSNs. While the former is to model mobility of VSNs at the individual level, the latter is to have a good picture of the entire network (Mei *et al*., 2015). VN is one of several complex systems around us that contain adaptive and autonomous agents. Interaction of these agents with each other creates a complex collective behavior. To define such systems there is a need to model their agents at individual level. This modeling is to independently understand behavior of each agent. There is also a need to investigate the comprehensive behavior of these agents. In this event, ABM and CN are combined to cover both concepts of individual behavior and comprehensive behavior of the system’s agents. On the other hand, the environment to implement the model has to be considered. For this purpose, a small part of urban road traffic is designed. Further, three main types of agents can interact with each other. Vehicles, roadside units and traffic lights can communicate in this scenario which is shown in Fig. 1.

This model creates a small section of a city. It simulates the interactions between two types of agent vehicles and traffic lights as shown in Fig. 1. Vehicles in

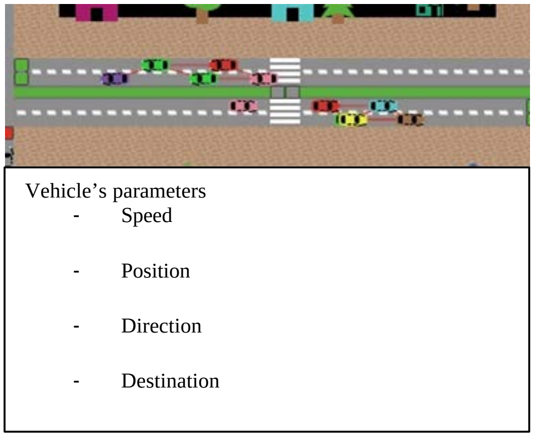

Fig. 1: Modeling mobility of VSNs

Fig. 2: ABM for VSNs

this model can accelerate or decelerate their speed. Besides, they can change their direction at the road intersections. They also can change their lane staying at the same direction. In this context there are two way roads in two different directions. Each road has two lanes in every direction. Vehicles can accelerate without preceding the maximum allowed speed. When a vehicle encounters a slower speed vehicle there are two options for the vehicle. Either, it changes its lane or it slows its speed matching speed of the slower vehicle. At the traffic light, each vehicle will stop if the light is red. In contrast, if the light is green, vehicles will make their decisions either turn or going in the straight direction. In the case that vehicles change their direction, vehicles at the right lane must choose the right direction and vice versa. They also must check other vehicles at opposite direction.

The model has two main buttons SETUP and GO. SETUP is to create the roads, the traffic lights and the vehicles. While Go is to run the required procedures in the model. There are also three main slides to set the number of vehicles, the interval of traffic lights and the communication range. On the other hand, there are others for setting speed, acceleration, deceleration, etc. The next two subsections are related to both ABM and CN.

Agent based model: In ABM, there are a number of agents that are interacting with each other to model behavior of dynamic systems. As many agents (vehicles) in VSNs behave in self-organization manner, ABM may be a good option to model such these systems. Hiroki Sayama defines ABM as "Computational simulation models that involve many discrete agents". In the context of VSNs, ABM can be simply defined as a computational model that uses many discrete vehicles. According to this definition, there are two keywords need to be explained. The first one is "Computational". In fact, ABM is a computer model not

Table 1: Feature of vehicles in ABM

Properties	Features
Status	Vehicles should be discrete objects
	Vehicles may have their own parameters
	Vehicles should have their own states
	Vehicles should have spatial location
Behavioral	Vehicles may be behaving with their environment
	Vehicles behavior is basing on predefind rules
	Vehicles is interacting with others
	ABM is often unsupervised learning

a mainly mathematical model. This means ABM involves computer to model behavior of agents instead of using mathematical methods. Hiroki claims that this is especially advised in social sciences. Really, supporting this argument is fair enough. Discrete means on the other side, each vehicle has its own parameters that determine the relationship between itself and its neighboring agents. Not this onl, each vehicle does an appropriate action depending on its status and the statuses of surrounding agents. It is argued that, there are certain features of agents (vehicles) should be taken in account when designing ABM for VSNs. Figure 2 shows a snapshot of the ABM's schema including the most parameters of vehicles that have been set in modeling mobility of the VSN. On the other hand, Table 1 contains the most features of social vehicles in the proposed VSN.

Complex networks: Since, one of the main contributions of this paper is to investigate and model the mobility of VSNs, analyzing the entire VSN needs to be carefully considered. So, analysis of topology and structure of the network will help in understanding how vehicles are gathered in social groups. However, the constraints of

VSNs make this task more difficult. Due to high mobility the system does not have a stable topology as well as its behavior unpredictable. In this case analysis of the system over the running time is required. There are a variety of metrics which are used to analyze the network. Nonetheless, the next paragraphs will discuss the most related to VSNs. Connected component: some vehicles that have a common interest will be grouped in a social community. When all members in a social group can communicate with each other directly or indirectly such this group is called a connected component (Sayama, 2015).

Size of group, it indicates to how many vehicles and links in a social group. Even though, this metric is not to tell how vehicles are arranged in their groups it is important to compare with other groups (De and Dehuri, 2014). Density and diameter of group, it is important to know a fraction (0-1) of the number of links or edges to all possible vehicle's edges in a certain social group (Sayama, 2015). To define this metric:

$$D(G) = L/N(N-1)/2 \quad (1)$$

Where:
G = A social group of vehicles
(N) = vehicles and (L) links
D = The density of G

Considering G as an undirected graph then N(N-1)/2 is the number of possible edges in the Group (G). The more density the less diameter of the group (Sayama, 2015). Giant component, the largest social group in the entire network is called giant component. It is a valuable portion of the entire network sometimes indicates to the connectivity of the network (De and Dehuri, 2014). Clustering coefficient is also to measure the connectivity of group (De and Dehuri, 2014; Hasson and Abd, 2016). It refers to whether two vehicles are linked with a common neighbor creating a triple. A closed triple means that all three vehicles are fully connected. Therefore, a ratio between the number of closed triples and on the other hand all triples in the group is called a clustering coefficient of that group:

$$CC_i = \frac{\text{No. of closed triples when i is center}}{\text{No. of triples when i is center}} \quad (2)$$

CC_i it is local clustering coefficient of vehicles on the other side to compute global clustering coefficient, Eq. 3 illustrates that:

$$CC = \frac{\text{No. of close dtriples in the whole network}}{\text{No. of triples inthe whole network}} \quad (3)$$

Figure 3 shows the structure diagram of the mobility model. There are two main steps of this model. The first one is related to ABM whereas the second is about how to parse the events which have been already happened in the first step to convert them into graphs. This bi-directionally manner can provide a brilliant picture to analyze the topology of VSNs. NetLogo is a good simulation for modeling ABM (Hasson and Hasan, 2016; Monett and Navarro-Barrientos, 2016). GraphStream, on the other side is a Java library that provides good tools to analyze stream of graphs.

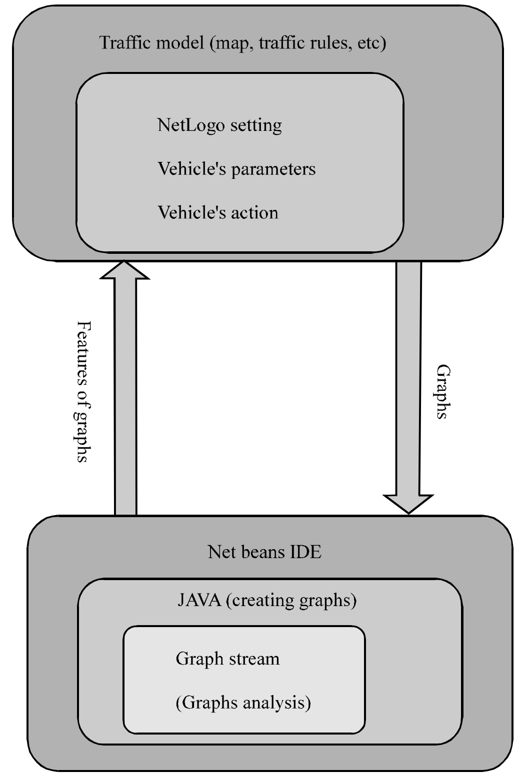

Fig. 3: Diagram of mobility model

Grouping vehicles in social communities: Grouping vehicles in social communities is a challenge due to the difficulties of creating social relationships among vehicles. We suggested in previous works two algorithms to gather vehicles in social groups (Mahdi and Hasson, 2014). The first one is to group vehicles that have permanent friendships. This algorithm is named Formal Social Grouping Algorithm (FSGA). It focuses on creating social groups of vehicles according to their social behaviors. On the other side, Casual Social Grouping Algorithm (CSGA) is to temporary group vehicles in social communities according to their direction and the allowed communication range. The communication range was IEEE 802.11p (Bhoi and Khilar, 2013).

Diffusing rumor in vehicular social networks: As we previously mentioned, Rumor spreading model is a simple and widely used to spread a piece of information (rumor) in a graph (Giakkoupis, 2011). This subsection will present and discuss using a Vehicular Rumor Spreading Algorithm (VRSA) in VSNs. At the first round, the source vehicle which has detected an event will randomly choose a one vehicle from its casual group to send the rumor. At each next round, will there be two kinds of vehicles. These are informed vehicles that have already received the rumor and uninformed vehicles that have not yet received the rumor. So, at each next round informed vehicles will arbitrary choose a friend from its casual group to send the rumor. The results emphasize that the VRSA has a less communication cost than contagion and multicasting models. However, it is a slow algorithm in terms of delivery delay. So, this model is suitable for diffusing unimportant events. While in the real time applications, the rumor spreading model may be not appropriate. The following next steps illustrate the work of the Vehicular Rumor Spreading Algorithm (VRSA) for VSNs.

While speed of vehicles is not same, hopefully there are many joins-in to casual groups; joined-in informed vehicles also will spread the rumor with their new casual groups.

RESULTS AND DISCUSSION

Regarding the mobility model, samples of graphs in Fig. 4 which are obtained from GraphStream show how density of vehicles (D) and communication Range (R) can affect the topology of VSNs (algorithm 1).

Algorithm 1; VRSA:

Input Let Vehicle = ($vehicle_1$..$vehicle_N$) set of vehicles
Let N = 50,100 or 200
Let Time = ($time_1$..$time_K$) set of time units
Group vehicles in formal groups using FSGA
Group vehicles in casual groups using CSGA
Let V_s is the source of information
Let G is a formal group of V_s
Output All vehicles in G have the interesting information
Begin
1: Once an event occurs, the piece of information will be diffused by the source of information to reach its all formal friends (interested vehicles)
2: While not all friends in G have not received the rumor Do
3: Each informed vehicle will randomly choose an uninformed vehicle from its casual group to send the rumor to it
4: End while
End

Table 2: Parameters for testing VRSA

Parameters	Values
No. of vehicles	Variables 50, 100 and 200
No. of casual groups	7 groups
Comunication range	Varriables 15, 50 and 100 m
Speed	10-16 (km/h)
No. of runs	10 for each scenario
Channel type	Wireless
Radio standard	IEEE 802.11p

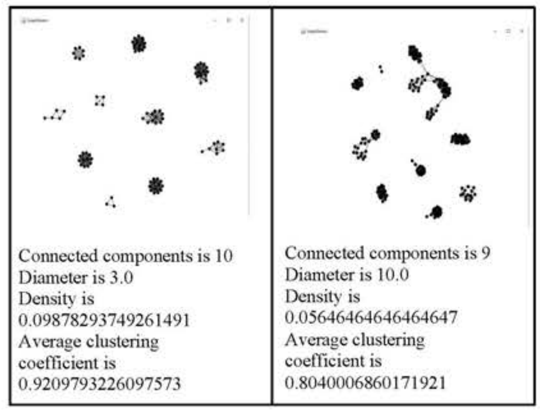

Fig.4: Samples of graphs and sme metrics to analyze the VSN

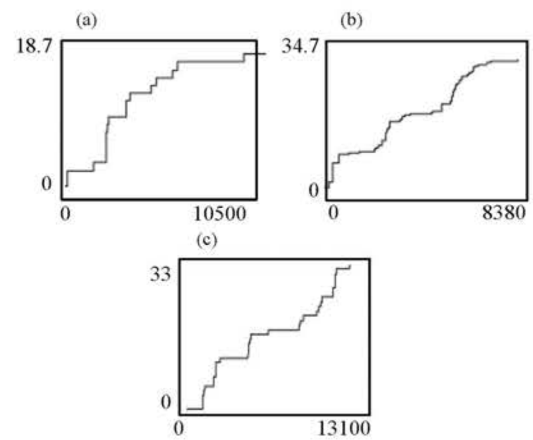

Fig. 5: Number of spreading messages in VRSA, where R = 100: a) N = 50; b) N = 100 and c) N = 100

Rumor spreading model on the othe side is simple and easy as it has been previously mentioned. At the most, one message is spread at each time unit in each group. This scenario makes it does not need a high communication cost. Nonetheless, it has a high deliver delay comparing with contagion and multicasting models. So, it may be suitable for spreading unimportant messages. The obtained results are run in NetLogo Version 5.3.1 under some condition and parameters as illustrated in Table 2.

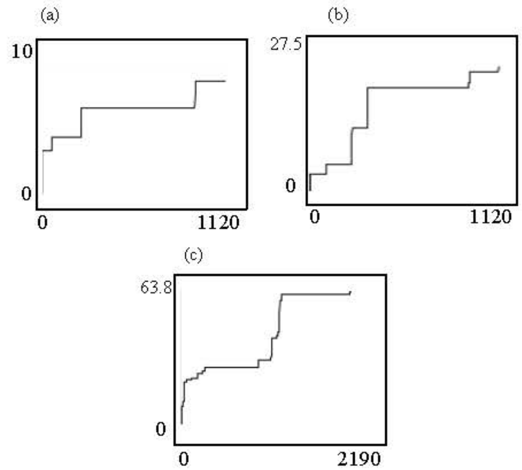

Fig. 6: Number of spreading messages in multicasting model, where R = 100m: a) N = 50; b) N = 100 and c) N = 200

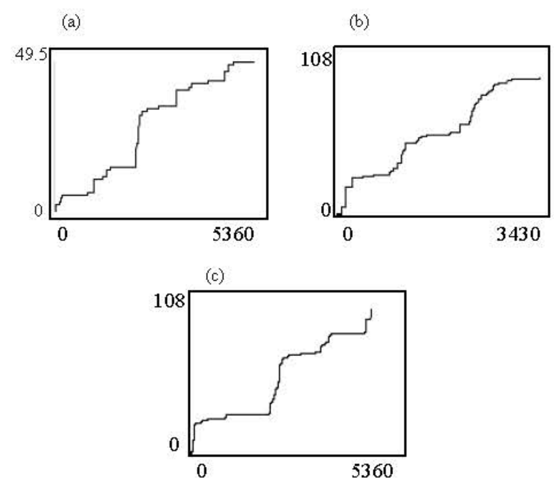

Fig. 7: Number of spreading messages in contagion model where R = 100: a) N = 50; b) N = 100 and c) N = 100

It is also shown in Fig. 5 the communication cost is low. It is reasonable due to simplicity of the model. It is obviously the curves are slightly rising. Comparing with Fig. 6 and 7 which are related to messages spreading in multicasting model and Contagion model, respectively shows that how the communication cost of rumor spreading model is very less than the communication cost of multicasting model and contagion model. Multicasting model (Ji *et al.*, 2016) is related to the VRSA and contagion model. The main difference between the contagion model and the multicasting model is that the former diffuses information through all vehicles no matter how much interested in it is Louni and Subbalakshmi

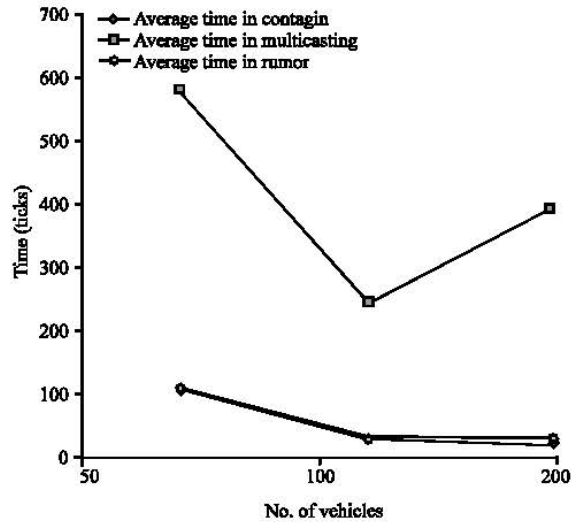

Fig. 8: Aaverage time in VRSA, multicasting and contagion models

(2014). So, the number of spreading message is higher. The latter on the other hand, disseminates information for only vehicles which are interested in this piece of information. As a result, the number of spreading messages is less than as in the contagion model. Comparing Fig. 5 with its corresponding Fig. 4, emphasizes this fact. Nonetheless, the average time to diffuse messages in the contagion model is less than that in the multicasting model Fig. 6.

For comparison purpose Fig. 8 emphasizes that VRSA has high delivery delay comparing with contagion and multicasting models. However, its low communication cost may make it suitable for spreading less important information in not real time applications.

CONCLUSION

As long as vehicles are immigrating to the intelligent next generation, it is justifiable to consider them as social objects. Grouping them in social communities will help to share information with only vehicles that are interested in this information. In this study, a comprehensive solution has been proposed to model social behavior of vehicles and to support information diffusion in VSNs. The proposed comprehensive solution includes several methods and techniques ranging from modeling mobility of social vehicles to diffusing information which are particularly designed for the VSNs. The results emphasize that VRSA may be suitable for spreading the less important information when the delivery time is not strongly considered.

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