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Dynamical Topology Analysis of VANET Based on Complex Networks Theory

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Abstract *A Vehicular Ad hoc NETwork (VANET) is a special subset of multi-hop Mobile Ad hoc Networks, in which the vehicles wireless interfaces can communicate with each other, as well as with fixed equipments alongside city roads or highways. Vehicular mobility dynamic characteristics, including high speed, predictable, restricted mobility pattern significantly affect the performance of routing protocols in a real VANET. Based on the existing studies, here we propose a testing network according to the preferential attachment on the degree of nodes and analyze VANET model characteristics for finding out the dynamic topology from the instantaneous degree distribution, instantaneous clustering coefficient and average path length. Analysis and simulation results demonstrate that VANET has a small world network features and is characterized by a truncated scale-free degree distribution with power-law degree distribution. The dynamic topology analysis indicates a possible mechanism of VANET, which might be helpful in the traffic congestion, safety and management.*

Keywords: *VANET, dynamic topology, complex network, instantaneous degree distribution, clustering coefficient.*

1. Introduction

With the development of economy and China city urbanization, cars are increasing in families, which makes the traffic conditions in the city more complex. In order to solve this problem, Vehicular Ad hoc NETworks (VANET) emerge as the time requires it.

Recent years have seen a lot of advances in wireless communication technology. VANET as a special application has become a promising approach for facilitating the traffic safety, traffic management, environmental protection and vehicular communication [1]. Safety applications are important to reduce the number of accidents on city roads and highways, including all driver assistance applications, i.e., overtaking the support, emergency braking notification, accident information, traffic jam warning, optimal route selection, and security distances, etc., in order to avoid accidents and promote road safety. VANET assists drivers while providing information about the traffic conditions on the road so that it makes their journey safe. It also provides information about the particular traffic conditions with the ultimate goal to avoid road congestion for the smooth flow of traffic and comfort, internet-connectivity, and entertainment of on-road passengers and drivers. Moreover, a parking navigation system [2], digital billboards for VANET [3], business activities through on-road streaming [4] are all examples under the category of t delivery applications. In VANET, due to its dynamic characteristics, the communication between vehicles can be exchanged quickly. Vehicles are moving at high speed, the motion trajectory is limited on the road, the topology is rapidly changing, so that vehicles pay more attention to the road traffic ahead. The high speed moving is one of the key factors that lead to the decline of the network performance and network expansion. VANET is a wireless communication technology for vehicle communications in Ad-hoc networks.

Reliable communication can provide relevant information and valuable security to the vehicles and drivers, and provide data of the traffic management system. With the popularization and improvement of VANET, it will become one of the most important ways to solve the traffic jam, quickly handle traffic accidents and optimize the traffic flow. VANET can provide a more intelligent communication way, e.g., different city ITS communications, vehicles communication, and different kinds of information platform communications, etc. Through these interactions, the vehicle can choose a more reasonable travel route before a trip. To avoid possible traffic jams in the travel, VANET can upload relevant traffic information.

As a result, the network topology analysis is an important issue, which should be helpful in the transportation infrastructure. VANET can be deployed through integration of government authorities and network service providers to address three vehicular scenarios, i.e., highway, urban and rural [5]. In recent years, a complex networks theory provides a new viewpoint and method for studying the complex systems. The finding of a small-world network and scale-free network makes a revolution in network science, since it attracted a great deal of researches of complex networks. The network structure can decide the network function. Urban traffic network affects VANET, which is a typical complex network. It is a base research that connects the complexity of the topological structure of VANET with complex network theory. Through the research on network topology, we can find out the inner acting force in the network and the driving force of the external one, interpret the mechanism and regular pattern of VANET on a macro scale. These researches will be dedicated to the traffic congestion alleviation and prevention, the spatial-temporal structure planning of a city, disasters prevention and response, reliability improvement of VANET. This paper combines the complex network theory with traffic flow theory and concentrates on the topology and reliability of VANET, spatial-temporal complexity of VANET and the influence of the traffic network structure on VANET.

2. Related works and background

With the increase of the vehicles in the city, traffic congestion has become an important problem. It is difficult to meet the growing traffic demand, relying on a new road or expansion of the network scale. Intelligent Transportation Systems (ITS) put forward some fundamental solution to these problems. VANET is one of key technologies in ITS and the Internet of Things, aiming to increase the traffic safety and comfort. The core idea of the system is to apply the advanced data communication, positioning, sensor, electronic control and other related information technology to transportation. With the development of Intelligent Transportation, VANET has gradually attracted the attention of researchers. On one hand, the vehicle mobile model is summarized and classified in [6]. The authors in [7] introduce a VANET model generation tool VanetMobiSim, similar to the real vehicle environment that is widely used in Ad Hoc Networks. On the other hand, the scholars pay more attention to the real scene simulation of Vehicular Ad Hoc Networks. The authors in [8] use real vehicle trajectory mobility models to test VANET routing protocol performance. In [9] Shanhai Vehicle Ad Hoc Network is constructed through the floating data and analysis of its routing protocol performance.

2.1. Complex networks theory

Many of the real-world networks have been described by complex networks theory which was put forward by Erdos and Renyi in 1960-ies, such as the scientific collaboration network, computer network, transportation network, electric power networks, interpersonal relationship network, and so on. Strongatz [10], Strongatz and Watt [11] and Newman [14] proposed a WS small-world network model in 1998 which realized the transition from a regular network to a random network. WS model describes the small-world property successfully. However, the nodes degree distribution for WS model does not conform to real-world network. Then Barabási and Albert [13] proposed the BA scale-free network model, constructing in 1999 a network with power-law distribution of nodes degree. The coefficient of BA model is small for large-size networks, indicating that BA model does not show a significant small-world property.

Many natural systems can be examined by models of complex networks. Studying real-world networks indicated that most networks showed a small-world property which means the network has a high degree of clustering coefficient and a small average path length, or has a power-law distribution.

2.2. VANET characteristics

In practical applications, due to price factors, in a transportation system it is difficult to equip all vehicles with an On BoarD unit (OBD). VANET should be given priority to public transport vehicles, such as taxi, and further construct a city public traffic vehicle ad hoc network.

VANET has the following characteristics:

i. Mobility. VANET is composed of mobile nodes and fixed nodes. The mobile nodes' geographical location may change at any time based on variable speed moving. So the topology of the network changes, but does not affect the overall operation of the network. In fact, this is the biggest difference between VANET and a fixed structure network.

ii. Wireless. The wireless channel is not stable, vulnerable to interference and monitoring, security has become an important research topic.

iii. Multi hop. Due to the fact that the wireless transmit power and signal coverage is limited, while communicating with other nodes outside the coverage, it must be multi hop to complete with an intermediate point.

iv. Self-organization. Each node moves quickly, independent of the network composition. All nodes are coordinated according to the distributed algorithm. This is the important reason VANET to have good prospects for application.

v. High dynamics. The mobile nodes can open and close the network according to their own needs when the network is affected by antenna coverage. VANET topology also changes quickly.

The difference between VANET and other wireless network is shown in Table 1.

Table 1. The difference between VANET and a wireless network

Content	The traditional cellular wireless network	VANET
Topology	Fixed	Dynamic, flexible
Infrastructure	Yes	Little
Safety and quality of service	Better	Poor
Configuration speed	Slowly	Quickly
Cost	High	Low
Survival time	Long	Short
Route selection and maintenance	Easy	Difficult
Network robustness	Low	High
Relay equipment	Basic station and wired backbone network	Wireless nodes and wireless backbone network
Backbone network characteristics	High speed, reliable	Low capacity, high error

3. Methodology and model

In this paper the complex network is a new method to study VANET dynamical topology in currently available methods. The process is as follows: it analyzes the network characteristics and describes the network models that shape the testing network; introduces the parameters concept defined to apply to the network we would make use; later the results of simulation and theoretical value on the testing networks are shown.

3.1. Network backbone

Each node has a communication and computing device that can transmit information. The mobile nodes communicating with each other compose a self-organizing network. As shown in Fig. 1, it reflects the real-life network infrastructure.

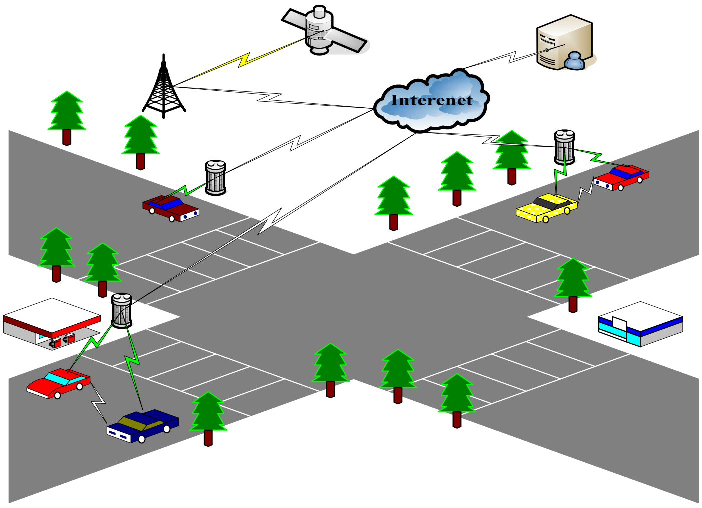


Fig. 1. VANET domains in reference architecture

VANET system structure consists of two parts: one is the communication between the vehicle and the fixed infrastructure, the communication of the road and vehicle (RVC), vehicle and the fixed infrastructure (V2I). The fixed infrastructure mainly refers to the RoadSide Unit (RSU); on the other hand is the communication between vehicles, i.e. the vehicle communication (IVC) or vehicle to vehicle communication (V2V). The On-Board Unit (OBU) includes a vehicle state parameters acquisition module, GPS positioning module, input and output devices and a communication module. The vehicle state parameters module collects the data and inverts to an analog signal and a digital signal by input and output devices. GPS module acquires the positioning information from a satellite. The vehicle communication module realizes the communication between the vehicle and RSU infrastructure. The input and output devices provide VANET platform for the driver. The driver can input information to the network, warning information through the audio output device and gain the VANET vehicle situation through the video output equipment. RSU, installed along the road, is responsible for the communication; on one hand it communicates with OBU, reports the traffic information within the coverage region to the control center, at the same time it provides a feedback from the control center to vehicles. The control center connects with all roadside units, summarizes and analyzes the vehicle status information by monitoring, manages the traffic. The passengers can use a mobile phone connected to OBD and RSU by a wireless network. They also obtain related information as shown in Fig. 2.

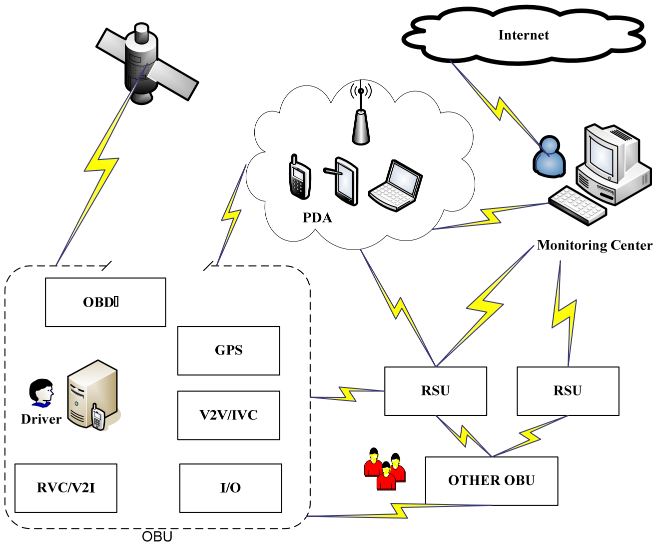


Fig. 2. VANET architecture

In a microcosmic model, the Random WayPoint (RWP) is one of Ad Hoc Network common models. The nodes random movement in RWP cannot objectively reflect the moving characteristics in VANET because the vehicles are affected by the traffic lights, traffic signs and traffic marking that makes the difference between them. IDM_IM and IDM_LC are closer to the reality scenes. They use an intelligent driver model to generate the vehicle trajectory and increase the crossroads and multi lane, so that simulation of the whole traffic network is not suitable.

In the system, the vehicle is equipped with a sensor, the sensors of all vehicles constitute a mobile ad hoc network to share the road conditions, traffic and weather information. In addition, the roadside units are static nodes. The location of the static nodes is fixed. As shown in Fig. 3, the roadside units will send the limited information to the vehicle which is convenient for the vehicle to prepare in advance.

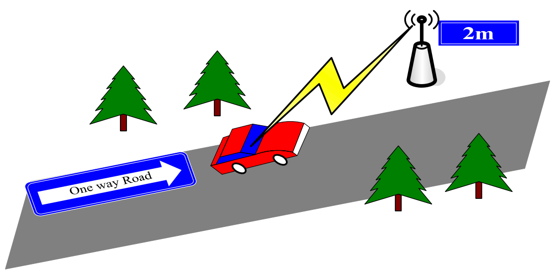


Fig. 3. A case of roadside units

3.2. Network backbone

Consider an acyclic directed graph $G = (V, E)$ where V is the set of vertices connected by a set of unit capacity edges E. These vertices and edges symbolize the nodes and channels of a wireless communication system as shown in Fig 4; where the nodes that transmit data packets into the network are source nodes (V1 and M2), and the nodes that ultimately receive messages are called receiver nodes (V3 and M3) for a particular multicast session. Due to the limitation of the transmission range, the data packets have to pass through intermediate nodes that act as relay nodes between the sources and receivers. The nodes V2 and M2 are in the transmission range of the source nodes V3 and M3, respectively.

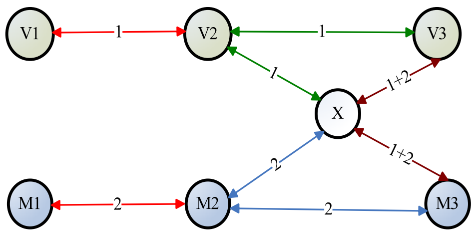
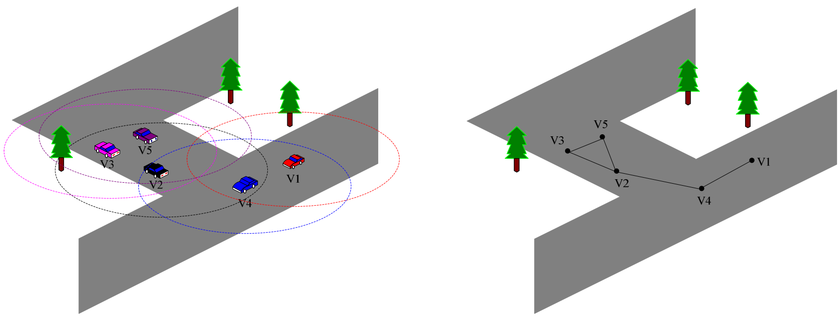


Fig. 4. Illustration of a wireless network in multicast session

Based on the analysis above made, VANET, having complex characteristics, is a typical complex network. Our strategy is given the initial network G0 with nodes N0 and M0 links. According to certain rules insert some modular to produce a new network, at that the most famous method is the small-world network and the scale-free network. A complex network can describe the statistical properties of the systems based on a graph. There are serial basic statistical parameters, including the degree distribution, the clustering coefficient, the average shortest path length, etc. in a complex network. WS small-world network model (WS model) means that it has a high degree clustering coefficient and a small average path length. WS model lies between regular networks to random networks. In WS model the clustering coefficient is high; however, the degree distribution of the nodes does not conform with the real networks. The classic research on a complex network indicated that most networks showed power-law degree distribution, defined as BA scale-free network model. Due to the growth and preferential attachment they are proximate to the growth of many network systems in real world. We propose the BA scale-free network model as the network morphology of the new network model in this paper.

In a real network, there are usually three cases of connection between the nodes that are fully connected and randomly connected or falling in between. Following the Freeway mobility model [15], the simulations are carried out for a 3-lane highway (depicting one side of the highway) by a length of 10 km and a width of 5 m per a lane. In all simulations, with a transmission range of 250 m, each mobile node speed is taken as 100 km/h. Each communication scenario consisting of five mobile nodes (V1, V2, V3, V4 and V5) has been taken into account in a way that V1 and V4 are within the communication range of each other, as well as V2 and V3 and V5 are within a communication range of each other, as shown in

Fig. 5a. It is assumed that each node has knowledge of its own location, as well as of its one-hop neighboring nodes. The vehicles are fully connected within the scope of coverage, which is fully connected as shown in Fig. 5b. Based on the above description, for any given $t \geq 0$, $N(t)$ is expressed as the total number of the network changes. If $N(t)$ is a random process, $G(t)=(V(t), E(t))$ is called a complex network. Note that $N(t)=|V(t)|$, $M(t)=|E(t)|$, $\lim_{t\to\infty} E\left[N(t)\right] = N$, where $E\left[N(t)\right]$ express the node average at t moment in VANET.



(a) (b)

Fig. 5. VANET simulation layout with a Freeway mobility model

3.3. Method description

In VANET the nodes are divided into two categories, fixed nodes and mobile nodes. Fixed nodes refer to RSU, and mobile nodes refer to the moving vehicles on the road. In this paper the nodes refer to the moving nodes in the following text. Fig. 6 shows that V1 and V4 connect each other, as well as V2 and V4, in addition V2, V3, and V5 connect together at this time. In the initial network, the number of nodes is $n_0 = 5$, and the number of edges is $m_0 = 5$. At each time step, a module composed of several nodes is added to the network. When the time step t is large enough, so that the network size is large, new nodes are chosen based on the mechanism of preferential attachment. The new nodes would be connected to the existing nodes of the network with a larger degree priority, and the number of connections is m ($m \leq m_0$) [16]. We assume that in the rewiring probability $\prod k_i(t)$, the node i was chosen in the network depending on the degree $k_i(t)$ at t moment with probability $p(t)$ of the triangle connected. $\Omega(i)$ represents the node i neighbor set, and

$$\prod k_i(t) = \frac{\partial k_i(t)}{\partial t} = \tag{1}$$

$$= \left((m-1)\left(1-p(t)\right)+1\right)\frac{k_i(t)}{\sum_i k_i(t)} + (m-1)\,p(t)\frac{k_{j,j\in\Omega(i)}(t)}{\sum_i k_i(t)}\frac{1}{k_{j,j\in\Omega(i)}(t)}k_i(t) = m\frac{k_i(t)}{\sum_i k_i(t)}.$$

As can be seen, k rate of change is proportional to $\prod k_i(t)$, $\sum_i k_i(t) \approx 2(m_0+m)t$, $k_i(t_i) = m$. Then

$$k_i(t) = m\left(\frac{t}{t_i}\right)^{\frac{m}{2(m_0+m)}}. \quad (2)$$

In VANET the nodes move in unpredictable ways and different speed, and appear or disappear without certain regularity. The nodes movement leads to links frequently and disconnections between nodes, which cause a change of the network topology. At this point, VANET and the wired network have a significant difference.

In the references, the vehicle mobility model is usually divided into a macroscopic model and a microscopic model [17]. Each vehicle has its own characteristics. There are a lot of factors to affect the vehicle trajectory, for example, the topological structure of the road, some of the city streets and highways restrictions on the vehicle movement, the road speed limit, overtaking and rules of safe driving, traffic signs.

4. Network properties analysis

4.1. Instantaneous degree distribution

The node degree k is the number of nodes it is directly linked to, and its strength can be viewed as an indication of its centrality. The average k is express as $\langle k\rangle$, and $p(k)$ describes its degree distribution. A randomly selected node degree is exactly the probability of k, also equal to the degree number k of nodes in the total number of network nodes. Traditionally, for a network G, the degree distribution could be denoted as $p(k)=\frac{N_k}{N}$, where N_k is the node number of degree k; N is the number of nodes in the network. The value of $p(k)$ is between [0, 1]. Usually another representation method is used, that is cumulative degree distribution. Its meaning is the probability distribution of the node degree over k, then $p(k)=\sum_{k'=k}^{\infty} p(k')$.

If there are $\lim_{t\to\infty} p\{k_i(t)=k\} = p_i(k)$, k=0, 1, 2,…, and $\sum_{k=0}^{\infty} p_i(k)=1$, $\{p_i(k)\}$, the node i expresses steady-state degree distribution. As shown in Fig. 5, the nodes V2 degree is 3, and the node X degree is 4 at t moment. In VANET each node degree distribution is instantaneously changing. There is a corresponding structure in the network model proposed; the transient average degree distribution is proposed to describe the real time degree distribution in a network. According to Newman, Strogatz and Watts study [18] the instantaneous degree distribution is expressed as

$$p(t,k) = \frac{1}{E[N(t)]}\sum_{i\in V(t)} p\{k_i(t)=k\}. \quad (3)$$

If there are $\lim_{t\to\infty} p(t,k) = p(k)$, k=0, 1, 2,…, and $\sum_{k=0}^{\infty} p(k) = 1$, $\{p(k)\}$ the node i is called instantaneous degree distribution.

When $t \to \infty$ $\quad E[N_K(t)] \approx (t + m_0)p(k)$.

For the network model proposed and (2), we can write

(4) $$p\{k_i(t) < k\} = p\left\{t_i > \left(\frac{m}{k}\right)^{\frac{2(m_0+m)}{m}} t\right\}.$$

The probability density function of time t_i can be written as $p(t_i) = \frac{1}{m_0 + t}$. Then the probability will be obtained, which would be repeated m times. Equation (4) can be written as

(5) $$p\left\{t_i > \left(\frac{m}{k}\right)^{\frac{2(m_0+m)}{m}} t\right\} = 1 - \frac{t}{(t+m_0)}\left(\frac{m}{k}\right)^{\frac{2(m_0+m)}{m}}.$$

Then

(6) $$p(k) = \frac{\partial p\{k_i(t) < k\}}{\partial k} = \frac{2(m_0+m)t}{m(m_0+t)} m^{\frac{2(m_0+m)}{m}} k^{-\frac{2m_0}{m}-3}.$$

When $t \to \infty$ $\quad p(k) \sim 2m^{\frac{2(m_0+m)}{m}} k^{-\frac{2m_0}{m}-3}$.

From (6), $p(k)$ is related to t, m, m_0 and k, which obeys a power-law distribution with an exponent $\gamma = \frac{2m_0}{m} + 3$, where the value of γ depends on m_0 and m. We have fixed $m = 5$, $m_0 = 5$, relevant parameters N=10000, $n_0 = 5$, then we can obtain $\gamma = 5$ that is irrelevant with t, as shown in Fig. 6; $p(k)$ has the same trend at different t.

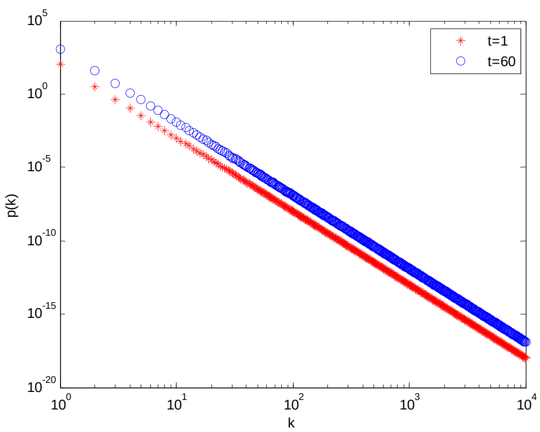


Fig. 6. Degree distribution with t = 1 and t = 5 from analytical results

4.2. Instantaneous clustering coefficient

In VANET network the clustering coefficient $C_i(t)$ [19] of the node i (the degree $k_i(t)$) is defined as the ratio of between the actual number of edges among the given neighbor nodes and the theoretical number of edges at t moment. There are actually $E_i(t)$ edges among the selected node i and $k_i(t)$ neighbours, linked to each other. Then the instantaneous clustering coefficient of node i is

(7) $$C_i(t)=\frac{2E_i(t)}{k_i(t)\left(k_i(t)-1\right)}.$$

The instantaneous clustering coefficient $C(t)$ of the network with $E[N(t)]$ nodes is the average of $C_i(t)$. It is expressed as

(8) $$C(t)=\frac{1}{E\left[N(t)\right]}\sum_{i\in V(t)}C_i(t).$$

Fronczak et al [19] give the equations of $C_i(t)$ and $C(t)$

(9) $$C_i(t)=\frac{m^2(m-1)}{8\left(m\sqrt{t}+\sqrt{t_i}\right)}\left(\ln^2 t+\frac{4m}{(m-1)^2}\ln^2 t_i\right),$$

(10) $$C(t)=\frac{m^2(m-1)}{4t}\left(\ln^2 t+\frac{16m}{(m-1)^2}\ln^2\zeta\right)\left(\ln\frac{(m+1)\sqrt{t}}{m\sqrt{t}+1}+\frac{m}{m+1}-\frac{m\sqrt{t}}{m\sqrt{t}+1}\right),$$

where $\zeta\in\left(1,\sqrt{t}\right)$. When $t\to\infty$

(11) $$C(t)=\frac{m^2(m-1)}{4t}\left(\ln^2 t+\frac{16m}{(m-1)^2}\ln^2\zeta\right)\left(\ln\frac{m+1}{m}+\frac{1}{m+1}\right).$$

So that:

(12) $$\frac{m^2(m-1)}{4}\left(\ln\frac{m+1}{m}-\frac{1}{m+1}\right)\frac{\ln^2 t}{t}<C(t)<\frac{m^2(m+1)^2}{4(m-1)}\left(\ln\frac{m+1}{m}-\frac{1}{m+1}\right)\frac{\ln^2 t}{t}.$$

4.3. Average path length

The distance between two nodes i and j in a network d_{ij} is defined as the edges number of the shortest path of connecting two nodes. The diameter of the network is the maximum distance between two nodes, D = max d_{ij}. The network average path length L *is* defined as the average distance between all nodes:

(13) $$L=\frac{2}{N(N-1)}\sum_{i,j\in G,i\neq j}d_{ij}.$$

Newman, Strogatz and Watts [18] gave the average path length using a heuristic method. In it A, B and C are constant, $L=A\ln(N-B)+C$. Bollobás and Riordan proved that the average path length of BA model is $L\sim\frac{\ln(N)}{\ln\ln(N)}$.

5. Simulations and discussions

5.1. Simulation experiments

The theoretical analysis is verified by simulation experiments. In view of the taxonomy of VANET simulation software, in Martinez et al. [21] have divided them into three categories, i.e., realistic mobility generators (or traffic simulators), network simulators, and VANET simulators.

Table 2. Simulation Parameters

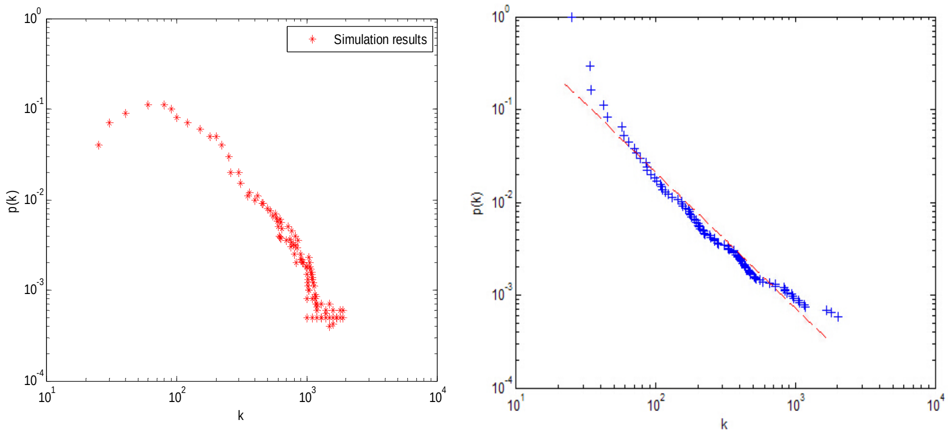
Parameter	Value
Simulation tool	OMNet++, Matlab
Simulation time	1-300 s
Mobility model	Freeway or linear mobility model
Topology size	10 km × 30 m
Number of lanes	3
Lane width	5 m
Node density	10
Source nodes (data flows)	4
Nodes speed	15-20 km/h
Transmission range	250 m

The method above proposed is simulated in this section. In light of the complexity of the computing instantaneous degree distribution, the clustering coefficient and path length of a network, we first set up one basic network to evaluate the validity of our method.

5.2. Discussion

In Figs 7-10 the simulation screenshots in MATLAB are presented. The degree distributions clearly show the characteristics of a scale-free network at the middle section. When the node degree k is small, $p(k)$ has distribution increasingly similar to the small-world network model in Fig. 7a (loglog axis) and then decreases after the peak. Therefore, $p(k)$ obeys the power-law distribution since the node degree k is large in Fig. 7b.

In Fig. 8 with N increasing, the clustering coefficient remains at a high level with $m = 0, 3, 5, 10, 15, 20$ respectively, which indicates that the network shows a small-world network property. When the network size for this case is about 5000 and more, the clustering coefficient remains essentially unchanged. In Figs 8 and 9 the instantaneous clustering coefficient is increasing with the value of m. In Fig. 10 with N increasing and $m = 3, 5, 10, 15$ respectively, the average path length increases slowly. For a large number of network nodes, the average path length is short. This indicates that the network proposed also shows a small-world property. In conclusion, the value of N does significantly change both the clustering coefficient and the average path length.



(a) (b)

Fig. 7. The p (k) of simulation results with $m0$ = 3, m = 3 (a); dependences of p (k) on k with $m0$ = 6, m = 3 (b); + marks represent the simulation results; – marks denote the numerical results

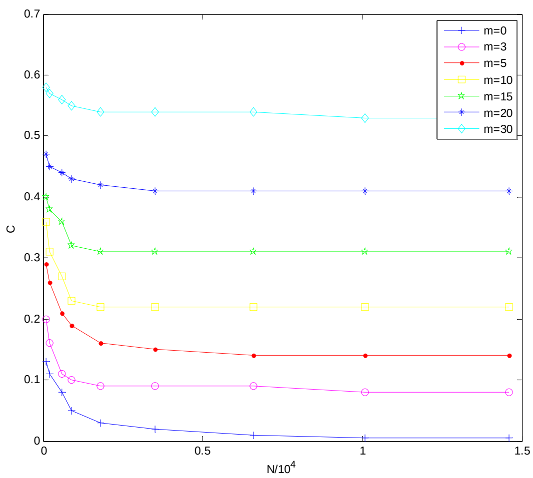


Fig. 8. The clustering coefficient results, using our method with m = 0, 3, 5, 10, 15, 20, 30 respectively

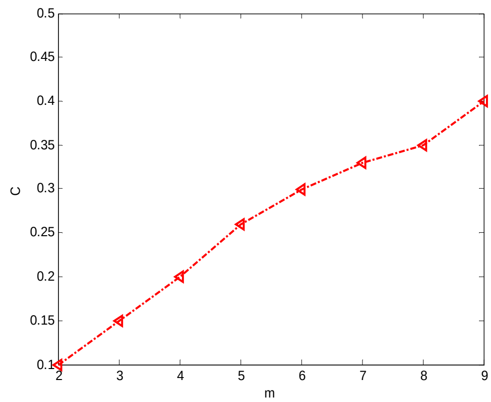


Fig. 9. The clustering coefficient results, using our method with N = 10 000

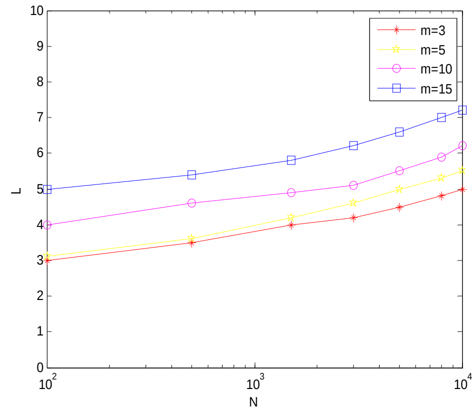


Fig. 10. The path length results, using our method with m = 3, 5, 10, 15 respectively

6. Conclusions

In this paper we focus on the dynamical topology with the application of the complex network theory. In the viewpoint of the mean field theory, the concept of a small-world network and a scale-free network is first defined, and VANET model is then proposed for simulating and computing the instantaneous degree distribution, instantaneous clustering coefficient and average path length; Methods of improving the complex network parameters are also discussed in this paper, such as developing the instantaneous degree distribution, and increasing the factors. Among them, the instantaneous degree distribution and the clustering coefficient are the most direct and efficient parameters to analyze the dynamical topology. A numerical simulation is carried out with the proposed method, the results being better related to the analytical results, so that the analysis is strengthened. As seen from the analysis results, the instantaneous degree distribution shows the characteristics of the WS small-world network for a small node degree k and a BA scale-free network with a power-law distribution as the network scale increases. The clustering coefficient remains at a high level with m = 0, 3, 5, 10, 15, 20 respectively and increases with the value of m. The average path length is short that shows that the small-world property is affected little by the network size.

The BA model characteristics are preferential attachment and growth, and the growth is infinite. However, the life of many networks in reality is limited, as WWW network almost every time has a new webpage entering the system and an old webpage leaving. In VANET, when the nodes arrive to the destination, they would exit the system. Therefore, we will study the topology of the network and the edges exit probability after the system goes into a saturation state in the future.

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