Reliable connectivity and efficient data dissemination in VANETs

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Abstract: Connectivity and data dissemination in vehicular ad hoc networks (VANETs) have recently received considerable attention. Due to the unique characteristics of VANETs, the network connectivity is poor and reliable transmission in VANETs is hard to achieve. In this paper, we analyze the connectivity of randomly deployed vehicles on a road in VANETs and show the relation among the connectivity, the vehicle density and the communication radius. The reliable data dissemination scheme based on assisted nodes is studied. The simulation results show our novel scheme increases the network performance in terms of data dissemination rate.

Key words: connectivity; data dissemination; vehicular ad hoc networks(VANETs)

CLD number: TP393 **Document code:** A

Article ID: 1674-8042(2012)03-0243-05 **doi:** 10.3969/j.issn.1674-8042.2012.03.009

0 Introduction

With the rapid development of urbanization, the increase of the vehicle number in cities leads to very serious problems such as traffic congestions and safety hazards. Thanks to the effective technical integration of electronic sensing, wireless communication and computational technology, each vehicle could be equipped with a smart terminal to sense its environment information and communicate with other vehicles timely[1]. These vehicles form a vehicular ad hoc network (VANET) which provides increasing convenience and efficiency to drivers and plays a vital role in the urban road traffic management[2,3].

However, the VANET, as a special mobile ad hoc network, brings researchers many design challenges[4]. Due to the rapidly changing link topology of the VANET and the poor connectivity among vehicles, VANETs face so difficult challenge of maintaining connectivity that a node may not establish a communication link to any other node in the network. Therefore, the efficient, reliable and real-time data dissemination is difficult to realize.

Due to the rapidly changing network topology and the poor connectivity, reliable transmission in VANETs is hard to achieve[5]. In this paper, we analyze the connectivity of randomly deployed vehicles on a road in VANETs and show the relation among the connectivity, the vehicle density and the communication radius. The reliable data dissemination scheme based on assisted node is studied, which is useful to guarantee the reliable data delivery among vehicles. Assisted node based scheme could help to increase the network connectivity and data dissemination efficiency. The simulation results show that our novel scheme increases the network performance in terms of data dissemination rate.

The rest of this paper is organized as follows: Section 1 describes system model. Section 2 analyzes the network connectivity. Section 3 describes the reliable data dissemination protocol in VANETs. Section 4 presents the performance analysis and section 5 provides the conclusion.

1 System model

The aim of data dissemination in VANETs is to disseminate urgent information about the road condition, such as traffic accidents, and to help drivers adjust the route dynamically to avoid traffic jam. In addition, data dissemination can also be used to disseminate some commercial advertisements to drivers who are interested in such kinds of information. In Fig.1, data source S disseminates data information to its adjacent area to help vehicles nearby know the information at S.

We assume that vehicles communicate with each other and with the assisted nodes through a short-

※ **Received data:** 2012-04-16

Foundation item: Shandong College Research Project of Science & Technology (NO. J12LN13)

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range wireless channel (100 – 300 m). A vehicle knows its location through global positioning system (GPS) device, which is already popular in new cars and will be common in the future. Vehicles exchange beacon messages periodically to get the neighbor vehicles' moving velocity, direction and location, so each vehicle can conduct and update a neighbor list.

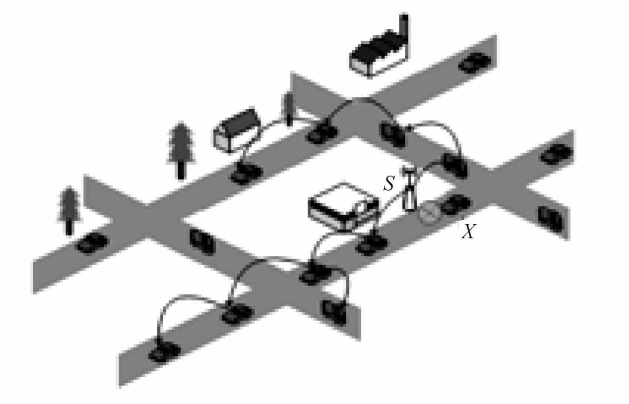


Fig. 1 Data dissemination in VANETs

Additionally, we consider the road has two directions, and vehicles running in the same direction form the transmission network. So, each vehicle's neighbor list only contains vehicles running in the same direction.

2 Connectivity analysis of VANETs

In VANETs, link topology is limited by the road layout, and the data dissemination mainly depends on the multi-hop transmission among neighbor vehicles, so the network connectivity on the road can affect the data dissemination performance directly. In this section, the vehicles connectivity is analyzed.

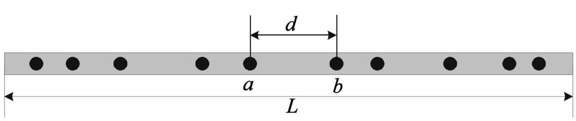


Fig. 2 Connectivity analysis of VANETs

We assume the vehicles on a road obey Poisson distribution with density λ. Assume R is the communication radius of a vehicle and $L(L \gg R)$ is the length of the selected road. Since L is much greater than the road width generally, the vehicles obey 1-D Poisson distribution. As shown in Fig. 2, if the network on the road is connected, the distance d between two arbitrary vehicles a and b must be subject to $d \leqslant R$. This means the arbitrary road section with the length of R on this road must contain at least one vehicle to make sure the network on the road is connected.

The probability that there exists at least one vehicle on the arbitrary road section with the length of R is

$$P(N_R \geqslant 1) = 1 - P(N_R = 0) = 1 - \frac{(\lambda R)^0 e^{-\lambda R}}{0!} = 1 - e^{-\lambda R}, \tag{1}$$

where N_R is the number of the vehicles on the road section with the length of R. From Eq. (1), it is obvious that the connectivity of vehicles on the road section is affected by the vehicle density and communication radius. The relation curve is shown in Fig. 3. When the vehicle density is a constant, the larger the communication radius is, the better the network connectivity is; when the communication radius is a constant, the larger the vehicle density is, the better the network connectivity is.

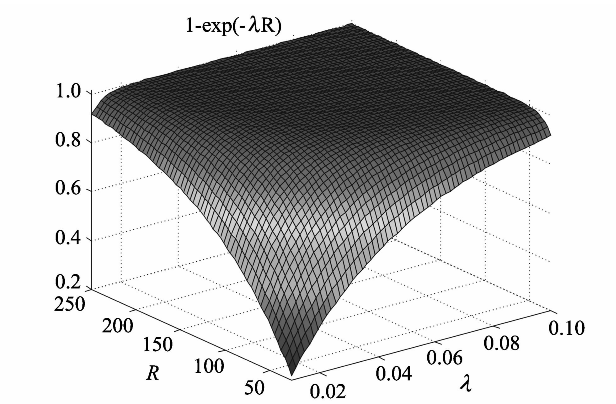


Fig. 3 Relation among the connectivity of VANETs, vehicle density and communication radius

3 Reliable data dissemination protocol in VANETs

In this section, both the rapidly changing link topology and poor connectivity of VANETs are taken into consideration to design the data dissemination scheme. The assisted node deployed at the intersection is considered to increase the efficiency of data dissemination, which is used to satisfy both the reliable communication and the drivers' diverse requirements for the information.

The analysis in section 3 shows that the network connectivity can be better due to the increase of the vehicle density, but much traffic on roads would cause serious communication channel conflict, which can lead to low data dissemination efficiency. In this section, assisted nodes deployed at the intersections are used to alleviate the deficiency of the network disconnection.

An assisted node can be the popular roadside unit that is widely used in VANETs or a simple computing device with a small amount of memory and a wireless card (e. g., IEEE 802. 11b). These stand-alone assisted nodes can be easily installed at the intersection to communicate with the passing-by vehicles and process the data information. Since they are not required to connect to the wired network, the deployment cost is low.

As shown in Fig. 4, the data from the data source, through multi-hop transmission among vehicles mentioned in section 3.1, is delivered to assisted nodes A_1 and A_4 which are located at both ends of the road. In the same way, through the multi-hop transmission on a road, the data is delivered from one assisted node of the road section to the other. And thus, the assisted nodes could receive the data one by one. That is to say, the data delivery between two assisted nodes is achieved with the help of the data dissemination among vehicles. For instance, to deliver the data from A_1 to A_2, the data packets need to be consecutively broadcast along the road by other vehicles such as $A_1 \rightarrow c_1 \rightarrow c_2 \rightarrow A_2$.

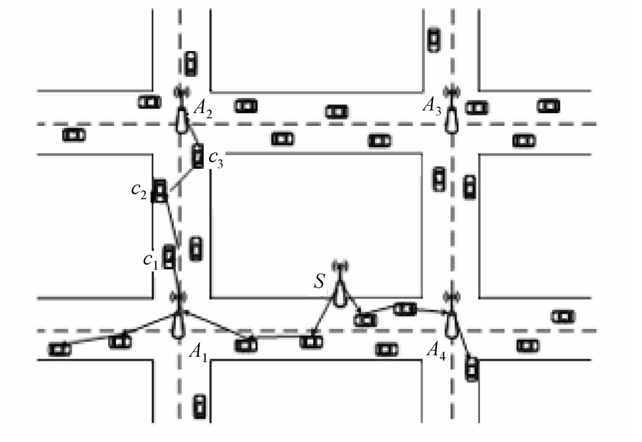


Fig. 4 Data dissemination in VANETs

An assisted node broadcasts the data periodically to passing-by vehicles to help drivers select a better route. In addition, they can help to store and deliver the data to other assisted nodes farther away from the data source.

When the data dissemination region increases, more vehicles are expected to receive the data from the data source. This also means the increased network traffic overhead, longer delivery delay and higher probability of the communication channel conflict and data packet loss.

In reality, drivers at different distances from the data source may not have the same requirement degree for the information. Generally, drivers who are farther away from the data source may not need the data source's complete information, while drivers who are nearer to the data source would like to know more detailed information of the data source. For instance, when the data source sends traffic warning information about a car accident, drivers farther away may just need to know the location of the accident, but the driver nearby would like to require more information, including the accident type, the destructiveness, and even the picture of the accident spot.

4 Performance evaluation

In this section, we evaluate the performance of the flooding dissemination scheme (FLOOD)[6], the assisted-node-based data dissemination scheme (ADD), the no assisted node data dissemination scheme (NADD). FLOOD does not use the prediction method, and the other schemes use the prediction method.

4.1 Simulation model

We developed the Matlab-based vehicular network simulator (MVNS) to evaluate the proposed schemes. The media access control(MAC) layer and the physical layer of the wireless network base on an open project wireless network simulator (WNS).

The simulation area is a 3 800 m × 3 800 m square region. There are 4 horizontal roads and 4 vertical roads in this region, and hence 16 intersections. The length of each road section between 2 intersections is 1 200 m.

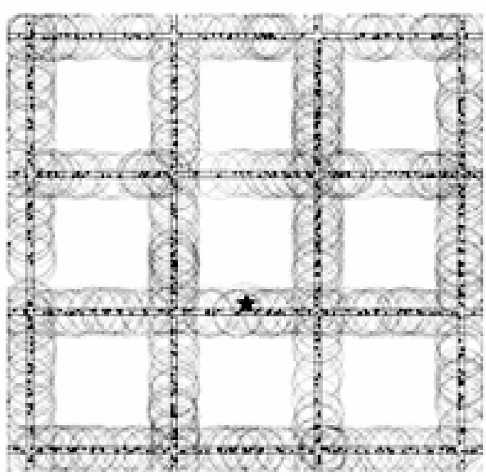


Fig. 5 Snapshot of the simulation setup area

To simulate the vehicle traffic on the roads, we initially randomly deploy 760 vehicles on the road (vehicle density λ is 25 vehicles per kilometer) and let them move with the changing speed $V \in [15,80]$ m/h. Those vehicles, when meeting the intersection, randomly select a direction from left, right and front to move on. When the vehicle arrives at the edge of the simulation region, it moves back in order to mimic a continuous traffic flow. Fig. 5 shows a snapshot of the simulation area. The pentagram stands for the data source and assisted nodes are deployed at each intersection. The circle stands for the communication radius of a vehicle.

The data packets are sent by the data center repeatedly. In this paper, the data packet is considered to be with a fixed size of 2 500 bits. Each vehicle sends beacon message every 0.5 s to report its own location and speed.

For each measurement, 30 simulation runs are used, and each simulation run lasts for 300 s. Most experiment parameters are listed in Table 1.

Table 1 Simulation setup

Parameter	Value
Simulation time	300 s
Simulation area	3.8 km ×3.8 km
Total number of vehicles	760
Communication radius of vehicles	200 m
Communication radius of assisted nodes	200 m
Vehicle density	25 per kilometer
Data packet size	2 500 bit
Data source broadcast cycle time	2 s
Vehicle speed	15 – 80 m/h
Data amount of source *S*	100 – 700 packets
Beacon interval	2 beacon / s
Control packet size	512 bit

4.2 Connectivity of VANETs

The analytical relation among the connectivity of VANETs, the vehicle density and the communication radius is presented in section 2. In this section, the connectivity of VANETs is studied by the simulation experiment and the effect of assisted nodes on the connectiwity is also shown. We define the network connectivity rate as the number of the connected vehicles from the data source divided by the total number of vehicles in the simulation region.

Fig. 6 shows the simulation relation among the connectivity rate of VANETs, the vehicle density and the communication radius. When the communication radius increases, the network connectivity rate rises. And for a fixed communication radius, the larger the vehicle density is, the better the network connectivity is. As shown in Fig. 6, when communication radius is 200 m and vehicle density is 15, 20 and 25 vehicles per kilometer respectively, the network connectivity rate is nearly 0.44, 0.68 and 0.83, accordingly.

The comparison of the network connectivity with and without assisted nodes is shown in Fig. 7 when the vehicle density is 20 vehicles per kilometer. It shows that the network connectivity rate with assisted nodes is higher than that without assisted nodes. For instance, when the communication radius is 200 m, the network connectivity rate with and without assisted nodes is nearly 0.74 and 0.68, respectively.

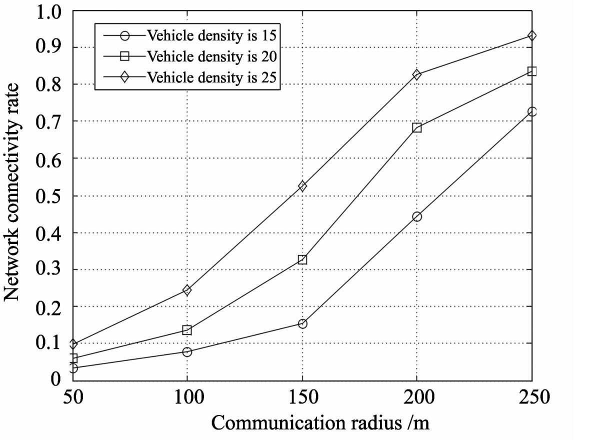


Fig. 6 Relation among the connectivity rate of VANETs, vehicle density and communication radius

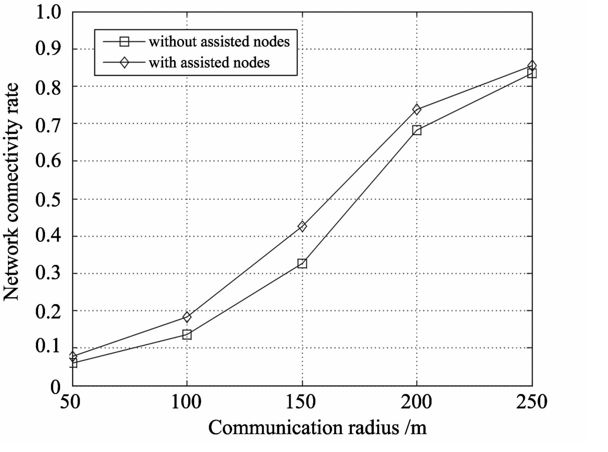


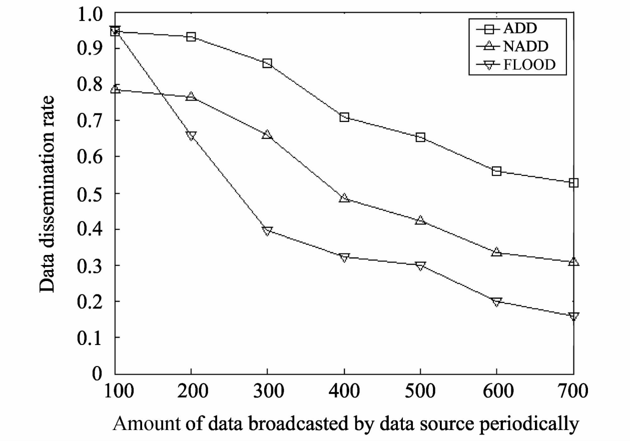
Fig. 7 Comparison of the network connectivity rate (vehicle density is 20 vehicles per kilometer)

Although the increase of vehicle density or the communication radius may help to improve the network connectivity, the consequent communication channel conflict would decrease the data dissemination rate and increase the delivery delay. Thus, the deployment of assisted nodes is an effective way to increase network connectivity and data dissemination efficiency.

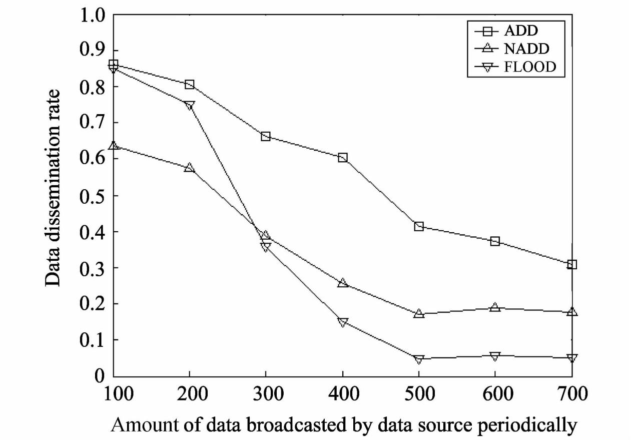
4.3 Data dissemination rate in VANETs

The performance of the scheme is measured by data dissemination rate: for each vehicle, the data dissemination rate is the total number of the received nonidentical data packets divided by the total number of the dissemination data packets broadcasted by the data source.

Fig. 8 shows the relation between the dissemination rate and the amount of data broadcasted by the data source periodically, when the network density is 25 vehicles per kilometer and the communication radius is 200 m. Fig. 8(a) shows the data dissemination rate when the simulation is implemented on road layout with 1-grade assisted nodes, and Fig. 8(b) shows the data dissemination rate when the simulation is implemented on road layout with 2-grade assisted nodes.



(a) Data dissemination rate when the simulation with 1-grade assisted nodes



(b) Data dissemination rate when the simulation with 2-grade assisted nodes

Fig. 8 Relation between the data dissemination rate and amount of data

When the amount of data increases, the data dissemination rates under all four schemes decrease. This is because more network traffic may lead to severe congestion and significantly reduce the data dissemination rate. The data dissemination rate of FLOOD drops faster than the other schemes when the disseminated data packets increase. This is because all the vehicles are involved in broadcasting, which would lead to more redundant data and channel conflicts. As shown in Fig. 8(a), when the amount of data is 100, the data dissemination rate of FLOOD is nearly 0.95, but it drops to 0.64 when the amount of data is 200.

From Fig. 8(a) and Fig. 8(b), it is clear to see that the schemes based on assisted node (ADD) have a relatively higher data dissemination rate. This is because with the help of the assisted nodes, better network connectivity increases the chances to disseminate data in the network.

5 Conclusion

Due to the rapidly changing network topology and the poor connectivity, reliable transmission in VANETs is hard to achieve. In this paper, the network connectivity and reliable data dissemination scheme based on assisted nodes are studied. We analyze the connectivity of randomly deployed vehicles on a road in VANETs and show the relation among the connectivity, the vehicle density and the communication radius. Assisted node based scheme could help to increase the network connectivity and data dissemination efficiency. The simulation results show our novel scheme increases the network performance in terms of network connectivity and data dissemination rate.

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