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Research on Layered-Partition Communication Model on Intelligent Urban VANET

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Abstract: Urban VANETs as an important part of intelligent transportation in the future, provides an effective solution to solve the city traffic problem. Most of the existing transmission schemes have low performance on efficiency and reliability, because they can´t solve the problems of high speed mobile vehicle, complex urban traffic environment and different traffic density. The text follows the urban environment of signal propagation, stopped on red, fixed and cycled bus movement, proposing layered-partition communication model. The model transfers the complex and uncertain transmission protocol between the vehicles to collaborative and certain three layered, which taking advantages of the fixed trace of bus and using the cluster head strategy to optimize communication between ordinary vehicles and buses. single hop selection mechanism according to the signal propagation attenuation model and vehicle mobility model is designed, and mechanism of multi hop forwarding in delay probability, which can ensure the reliable and efficiency on bus-assistant forwarding. On the other hand, cluster head trigger strategy which can adapt to the vehicle density is designed. The simulation results show that, the whole scheme can achieve good data delivery and low delay, which has good adaptability on high dynamic and special road situation of urban VANET.

Key words: layered-partition communication model; self-adjustment regional optimized; red light stop

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0 Introduction

Since the 20th century, the sixties and seventies, the rapid development of the world economic and the sharp increase in the number of cars, traffic also will continue to deteriorate. Development of urban transports promoting the continuous development of urban society and economy, people not only are enjoying urbanization, motorization convenience, but also suffer due to a series of urban traffic problems caused by traffic congewtion[1]. How to combine emerging information technologies with the existing road traffic characteristics, proposed to adapt to future smart cities intelligent transportation vehicle sensor network technology, has become the key problem that researchers are urgent to overcome. However, the vehicle sensor network is a special applications in mobile ad hoc networks and wireless sensor networks, it not only has the similarity of distributed and self-organization, but also has the characteristic of high-speed mobility and frequently changes in topology. Its intermittent connectivity brings a new challenge to design vehicle communication.

Document [2] analyzes the characteristics of intermittent network, and propose on using storage-forwarding mechanism to transmission the information in this network. Currently, existed routing methods are mostly based on chance connectivity between nodes and using store-forwarding to achieve[3-6]. Therefore, the key issue of bus opportunity forwarding routing protocol design is how to design forwarding strategy to reduce network communication delay, while ensuring reliable data forwarding. Unlike ordinary vehicles, bus moving has particularity. It contains fixed runs tract, departure

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time,and with regularity of periodic cycle.

Document [7] clues the bus as a mobile gateway, establish data transmission optimization model between bus and road based on bus mobile gateway forwards, by solving the model obtain the optimal forwarding policy about data transmission of mobile bus gateway. Under the conditions of meeting the transmission successful rate, this method can obtain a expectation about minimum transmission delay[8]. According to historical data of bus running on bus mobility vehicle network, A routing metrics model which consideration the path of survival and the signal quality to achieve better performance. Document [9] proposed the use of real-time network delay estimation for each road, by obtain the neighbor node information at real time, and combine with the direction of movement of vehicles. It estimated the various sections of network delay. Document [10] developed a self-adaption algorithm based on the QoS of streaming media, designed and deployed the bus surveillance system to improve the system performance. Document [11] based on the history of pre-loaded traffic status, it find the next section of forwarding packets to reduce the delay by prediction of vehicle movement. The estimation of data transfer delay each of section which based on some statistics such as average of vehicle density. However each section of the car density various from time. Thus, this calculation method of delay shortest path which based on pre-loaded historical statistical data can not reflect the true optimal path[12]. The bus is moving cyclical law, but because of the real-time traffic environment in urban, if only rely on the number of encounters, times, location between the bus to guide bus route forwarding in real-time, an efficient and reliable routing efficiency is unable to obtain. And most of these strategies failed to considerate the influence of communication signal quality for transmission reliability in [13-15]. Therefore, forwarding strategy design is need to ensure delay the effectiveness but also reliability of data transmission.

The text follows the urban environment of signal propagation, stopped on red, fixed and cycled bus movement, proposes layered urban vehicle ad-hoc network routing protocol on bus mobile assistant. The model transfers the complex and uncertain routing protocol between the vehicles to collaborative and certain three layered routing, which taking advantages of the fixed trace of bus and using the cluster head strategy to optimize communication between ordinary vehicles and buses. A single hop selection mechanism according to the signal propagation attenuation model and vehicle mobility model is designed, and mechanism of multi hop forwarding in delay probability, which can ensure the reliable and efficiency on bus-assistant forwarding. On the other hand, cluster trigger strategy which can adapt to the vehicle density is designed. The whole scheme can achieve good data delivery and low delay with sufficient hops.

1 Layered-Partition Communication Model

1.1 Characteristics Analysis of Urban VANET

Analyzing the bus mobility vehicle network in urban environments, it can find that it has many characteristics such as traffic light rules, the distribution of urban banded road and complex urban environment and so on. It brings a series of challenges to the communication of Bus Mobility Vehicle Network. First, the text analyzed the characteristics of the routing transmission of bus mobility vehicle networks in urban environments.

1) The fast-moving vehicle causes intermittent connection of network and uncertain in forwarding intermediate node. It has increased the difficulty of the route forwarding. Therefore, advantage of the bus cyclical movement law to design routing forwarding is used.

(i) Bus has fixed running routes and departure time, and make the fixed and cyclical movement. The number of encounters, times and location between different buses are various from the real-time traffic environment in urban. If the model can be establish and repeate operation, and figure out the probability of a vehicle encounters, then use the relation of periodic probability as a guide to routing forwarding. It is an important breakthrough to vehicle network routing forwarding.

(ii) The high speed bus has the feature of banding route, and has the same and opposite direction when they meet. It is a meaningful way to improve the reliability of network transmission through the property of bus direction as a basis of communication.

2) Communication channel has severely attenuation due to Doppler effect. In actual urban traffic environment, not only due to high-speed movement of vehicles, but also the disruption of tall buildings, bridges, tunnels and a green belt make communication channel attenuation becoming more serious. The design of protocol vehicle forwarding in ideal environment is unable to suitable for data transmission of urban vehicle network. As a result, the factor of signal quality when design routing forwarding index of urban vehicle network [8] should be consider .

3) Urban transport vehicle communication node characteristics:

(i) Single node itself basically loaded vehicle GPS locator, can get their precise location information, and can provide uninterrupted power to support, therefore we can take full advantage of its location knowable characteristics with ignoring the low power requirements of ordinary sensor networks.

(ii) Traffic due to the delay of a larger emphasis on communication channel dense traffic area competition issues retraction caused as a reliable transport network routing to provide protection during intensive.

1.2 LPCM Descripition

Considering all kinds of characteristics of the city traffic synthetically, the model of hierarchical routing protocol for collaboration was design , and divide vehicles into three levels: ordinary vehicle nodes、the cluster head nodes and the bus nodes. Also routing protocol between the cars convert to public transport as the main body and the cluster head as assistance for routing cooperative way among the three layers of nodes. Each layer routing plays a part in making the characteristics of city traffic work, which is beneficial to modeling, optimizing by separating the cluster head between bus layer and ordinary vehicle communication. The ways of three layers nodes are as follows:

1) The bus nodes: taking advantages of the buses that has fixed mobile trajectory as forwarding nodes of the whole network main data. The bus nodes use the bus layer mobile assisted routing protocol to communicate with each other and forward information. But the buses only communicate with the cluster head of the range of next hop, not with the ordinary vehicles.

2) The cluster head nodes: to optimize routing communication mode between ordinary vehicles and buses, the ordinary vehicles nodes could not be triggered as the cluster head under different conditions. After the cluster head receives ordinary vehicles nodes′ information that reaches to a certain degree or the start-stop time interval of collecting data reaches a certain threshold, choosing the nearest bus to forward, and then, restoring to ordinary vehicle nodes. Designing the adaptive traffic density of vehicle cluster head triggering mechanism, the cluster head nodes cannot communicate with each other. The cluster head as forwarding nodes of normal vehicles′ information.

The normal vehicle nodes: besides the bus and cluster head nodes, others are ordinary vehicle nodes. The ordinary vehicle nodes start routing transmit based on the vehicle layer of cluster head selection routing mechanism to choose the cluster head in the range of communication.

The ordinary vehicle V bases on certain formula. The automatic trigger is the cluster head V. Then, choosing one cluster head in the range of communication to start routing transmit. The cluster head V_1 node is constantly at activation state, when the collecting data reaches a certain degree or the start-stop time interval of collecting data reaches a certain threshold, find the bus node B in the range of next hop to forward the whole collecting information and restore to ordinary node V. The bus B only collect the information of cluster head node V_h, and operating Multi-hop transmit among the bus B. Eventually, the information will send to destination node (destination of cluster head vehicle or the road side static auxiliary units RSU) .

Under this model of hierarchical routing protocol for collaboration, the bus mobile assisted routing forwarding protocol and MAC protocol between ordinary vehicles and the cluster head need more attention. In this paper, mobile communications between auxiliary bus routing forward and ordinary car cluster is the key research object.

2 The Rules of Bus-Assisted Routing

The bus collects information from cluster head and complete the wide range of routing and forwarding, which is carrying the important forwarding tasks. To ensure the whole network routing forward, the efficient and reliable bus routing should be ensure first. A single hop signal attenuation and multi hop forwarding delay probability routing protocol is designed . In the single hop, must ensure the data will not be lost on the effect of the signal attenuation and ensure the transfer probability on multi-hop in a limited delay.

2.1 Single-hop Signal Attenuation

As to the complexity of the urban environments, the impact of signal attenuation, the movement direction and speed of vehicle need to be considered in link survival indicators. According to the bus mobile environment, this paper describes the radio propagation of bus communication with classic shadowing model [8]. It reflects the signal strength and the relationship between two communication buses in reality. According to shadowing model:

$$P_r(d) = P_s(d_0) \times 10^{(-10\beta \lg(d/d_0) + \sigma \times N^{-1}(\theta))/10},$$

$P_r(d)$ is the signal strength of the received node when the distance of wireless transmitting node is d. d_0 is the reference distance, $P_r(d_0)$ represent the received percentage which distance from wireless node is d_0. $P_r(d_0)$ can be calculated by Friis. σ is the standard deviation of shadowing model variables, It reflects the probability of a distance communication. θ is a random variables which distributed between $[0,1]$. $N^{-1}(\ )$ is an Anti-normal distribution function. β is channel fading index.

If given signal value q_c, according the formula, the effective reception range R_v can be calculate. When the communication range is less than R_e between two buses, the communication is valid. Otherwise, communication deemed invalid.

Then integrate with relative speed of vehicle, it can be calculate link survival time between buses and between buses and RSU. If the absolute distance between the bus i and j is $|d_{ij}|$, speed is expressed as v_i and v_j, and the movement direction is expressed as f_i and f_j. d_i is the distance between i and RSU. The link survival LBB between i and j and LBR between bus and RSU are:

$$L_{BB} = \begin{cases} (R_v - |d_{ij}|)/|v_i - v_j| \,(f_i = f_j, v_i > v_j, i \text{ in front of } j), \\ (R_v + |d_{ij}|)/|v_i - v_j| \,(f_i = f_j, v_i > v_j, j \text{ in front of } i), \\ (R_v - |d_{ij}|)/|v_i + v_j| \,(f_i = -f_j, v_i > v_j, i \text{ away from } j), \\ (R_v + |d_{ij}|)/|v_i + v_j| \,(f_i = -f_j, i \text{ drive to } j), \end{cases}$$

$$L_{BR} = \begin{cases} (R_v - |d_i|)/v_i(i \text{ away from } AP), \\ (R_v - |d_i|)/v_i(i \text{ drive to } AP). \end{cases}$$

2.2 Delay Probabilistic Model of Multi-hop Discrete Stochastic Dynamic Program

In order to make full use of the characteristic of fixed and cyclical bus track, we intend to use stochastic dynamic programming method [5] to establish the transmission probability model associate with delay. In this way we can obtain optimal multi-hop path which successful submission the data to the objective bus in limited delay. This paper discussing the research from four aspects: Modeling events, Discrete time, Select cycle and transmission probability model with Function space iterative method. The specific implementation steps are as follows:

1) Discrete stochastic dynamic programming delay probability model. The probability that current node can successfully transmit data to the specified sections in effective delay time from specified time. Make event A express that transmit a message to the designated sections S successful. And then

$$P^s_{Ta,n}(v_i)_{(t.start, t.start + \Delta t.delay)}$$

express the probability that take v_i as the source point, through max jump n, and finally to event A occurs in $\Delta t.delay$ from $t.start$.

$T_a = \{carry, forward\}$ is activities collections, it show that nodes transmission information follow as a active in activities set T_a in the period of time at any times. $P(v_i, v_j)_{(x)}$ is the probability of the meeting between v_i and v_j in x slot.

Continuous-time probability can be converted to the discrete-time probability because of the time can deal with discrete.

$P^s_{Ta,n}(v_i)_{(x,\Delta y)}$ indicate the probability of A after continuous slots Δy from first slot x. Where $x = [t.start/\Delta t_{slot}]$ show that the initial slot number corresponding to the start, $\Delta y = [\Delta t.delay/\Delta t_{slot}]$ show that the slot number which corresponding to the duration. Therefore, the delayed probability model:

$$P^s_{Ta,n(x,\Delta y)} = \max(\prod_{r_j d/(v_i)(x,\Delta y)} (1 - P(v_i, v_j)_{(r)})$$

$$\left(P^{s}_{cany}(v_i)_{x,j} - \left(1 + P^{i}_{cany}(v_i)_{(x,j)}\right) P^{s}_{Ta,n}(v_i)_{(x+1,\Delta_y-1)}\right) + \sum_{v_j d/(v_i)_{(x,\Delta y)}} P(v_i, v_j)_{(x)} P^{s}_{Ta,n}(v_j)_{x,\Delta y}) .$$

2) Function space iterative method of transmission probability model. For any value which satisfied $x \geqslant 1$, $\Delta y \geqslant 1$ (x, Δy are positive number), if want to get the solution that associated with v_i and optimal probability equation, and obtain the highest success rate of the transmission path during Δy after v_i multi-hop. It increasing the complexity of the problem that $P^{s}_{Ta,n}(v_i)_{(x,\Delta y)}$ and $P^{s}_{Ta,n}(v_i)_{(x+1,\Delta y-1)}$ are stand in the equation of two side. Thus, the functional equation is not recursive equation, it must need adopt function space iterative method to solve it. The steps are as follows:

(i) First, select the initial function

$$P^{s}_{T_a,0}(v_i)_{(x,\Delta y)} = \sum_{z=x}^{x+\Delta y} P(v_i, s)_{(z)} \times \prod_{w=x}^{z-1} \left(1 - P(v_i, s)_{(w)}\right),$$

$P^{s}_{T_a,0}(s)_{(x,\Delta y)} = 1$ is a boundary conditions.

(ii) Calculate $P^{s}_{T_a,n}(v_i)_{(x,\Delta y)}$ by the following recurrence relations, as follows, Calculate all of bus j which meets i.

$$P^{s}_{T_a,n}(v_i)_{(x,\Delta y)} = \left(1 - P(v_i, v_j)_x \left(P^{s}_{carry,0}(v_i)_{(x,1)} + \left(1 - P^{s}_{carry,0}(v_i)_{(x,1)}\right) P^{s}_{T_a,n}(v_i)_{(x+1,\Delta y-1)}\right) + P(v_i, v_j)_{(x)} P^{s}_{T_a,n-1}(v_j)_{(x,\Delta y)}\right.$$

Calculate delay probability distribution matrix $P^{s}_{T_a,n}(v_i)$ according to different value of n, finally get the optimal solution.

$$P^{s}_{T_a,n}(v_i) = \begin{bmatrix} P^{s}_{T_a,n}(v_i)_{(1,1)} & P^{s}_{T_a,n}(v_i)_{(1,2)} & \cdots & P^{s}_{T_a,n}(v_i)_{(1,m)} \\ P^{s}_{T_a,n}(v_i)_{(2,1)} & P^{s}_{T_a,n}(v_i)_{(2,2)} & \cdots & P^{s}_{T_a,n}(v_i)_{(2,m)} \\ \cdots & \cdots & \cdots & \cdots \\ P^{s}_{T_a,n}(v_i)_{(m,1)} & P^{s}_{T_a,n}(v_i)_{(m,2)} & \cdots & P^{s}_{T_a,n}(v_i)_{(m,m)} \end{bmatrix}.$$

3 Communication Strategies between Ordinary Vehicles′ Cluster

For city traffic vehicle network has characteristics of high dynamic and large-scale, MAC communication between ordinary vehicles and cluster head, which due to the problems of unstable links, channel conflict, the broadcast storm and other problems, leads to serious problem of packet loss. This paper adopts the optimization of regional flooding broadcast protocol based on section partition and fully integrate with traffic and vehicle running conditions and according to the condition and distribution of node movement on the road and so on, to design a MAC protocol that can adapt adjustment of related parameters dynamically to optimize performance, and to improve the reliability of information broadcast. The design of road domain of red light stop intersection cluster head mechanism, by dividing the network into independent, autonomous sub-cluster, and limiting the transmission of broadcasting information between the cluster within the same section of the road and limited nodes of the section. The red light stop band with the communication mode makes communication vehicles remains stationary in the red stop and the same lane traveling in the same direction of regional clusters at relatively static environment, which can greatly improve the success rate of data transmission, combined with adaptive environment of MAC contention window mechanism, and also the network topology model on high dynamic, and the special road state, which has better adaptability.

3.1 Contention Window Backoff Model

The cluster head gets the current length of road information L_r, according to the position of vehicles. Because of the similar lengths of vehicles, the length of vehicles uses the average L_c (including the safety distance between vehicles). In view of characteristic of band lane, every intersection can gets a cluster head again, and each cluster head responses for the vehicle information transmission of a lane, and different clusters still bring competitions, however, due to close distance in different clusters of same road, which can simplify the competition mechanism between different clusters, the different clusters′ competitions of the same road normalization will be normalization, and adopt a unified contention window backoff model in all cluster nodes of same road. So, The max competitive vehicle nodes of unified contention window backoff model is $N = \Gamma L_r / L_c \times n$ (n is the number of current lane). According to multi-hop relay settings, The max competitive vehicle nodes in every hop is $N_{\text{hop}} = \Gamma(R_c / L_c) \times n$

The cluster head nodes put information of their position, logo of clusters, the competition of nodes in the cluster and single hop, multi hop broadcast relay distance into broadcast pocket. After each vehicle node receives the cluster head of broadcast pocket, the node current position must be compare, relative speed with the node position of cluster head, and calculate the relative distance d, to obtain the number factor of communication $\zeta = d/\Delta$ (Δ is the heads of two cars' distance) .

From the document [7], the numerical relationship between the value of window backoff and the number of nodes can be conclude . Under this model, sending data can obtain the throughput of the best normalized nodes. Setting the current number of competitive nodes in the cluver as N_c, and P_t、P_c、W_i are the optimal transmission probability and backoff window. Original N_c takes $N_{hop}/2$ as a value, Through derivation, the relationship of mathematical model between backoff window and the number of competitive nodes in cluster are as follows:

$$P_t = 1/(N_c + 1), \quad (1)$$

$$P_c = 1 - 1(1 - P_t)^{N_c}, \quad (2)$$

$$W_i = \frac{2}{P_r}(1 + 1/\sum_{i=0}^{M} P_c^{\,i}). \quad (3)$$

3.2 Backoff Mechinism

When a node gets into the backoff state i, it is different from the common uniform distribution rule but follows the zonal distribution rule, and using whose number factor of communication to distinguish different zonal distribution to different vehicles. From the current backoff window $\left[0, \frac{W_i}{N_{hop}/n - \zeta} - 1\right]$ chooses a value T_i as a backoff waiting time, while sets the backoff waiting timer as T_i. Here the time slot as a discrete time scale unit. The node will always monitor to the channel state, if the current time slot channel is idle, decrease the value of backoff waiting time counter; If the channel is busy, the backoff waiting time counter hangs, meanwhile stoping the backoff and continuing to monitor channel, until the next idle time slot arrives. When the backoff waiting time counter is reduced to 0, the node can send a message. If the message failure to send, node backoff plus 1 series counter, node metastasis to the backoff state $i+1$; if the message sends successfully, the node's backoff stage counter is reset to 0, the node metastasis to the backoff state $i=0$. In addition, if the backoff stage counter reaches the maximum backoff stage M that has set, namely the sending node congests broadcast, adjusting the value NC, followed by 2, up to N. To calculate W_i.

In a multi hop relay range of forwarding nodes, labeling itself as the assisted cluster head node and being responsible for forwarding data. in the range of each single hop, all is adopting the RTS/CTS + ACK transmission mechanism, and the assistant cluster head nodes has smaller number factor of communication, so as to ensure that the effective transmission of data aggregation.

4 Simulation and Analysis

Road simulation based on real map building layout, we select a piece of land in East Lake District to do the simulation test is selected directions are draw by actual road data in experiment, and device traffic lights in road intersection. In order to make it consistent with the actual, the lights changes in time to fine-tune in actual obtains. According to the actual bus, operation has been adjusted, weight different bus lines and make it running with loop in the region at the same time. Do the simulation tests according to the number of buses, other relevant simulation parameters as shown in Table 1.

Table 1 Simulation Parameters

Transmission range	250 m	Packet Size	10 byte
d_0	1 m	Data generation rate	per 10 s
σ	4.0	Cluster head for data collection threshold	1 000 byte
β	1.8	Vehicle speed	0 ~ 50 km/h
ζ	0.5	Communication signal quality	0.9

Experiments are performed to test our proposed bus mobile assisted routing protocol (LPCM-routing) and inter cluster MAC protocol (LPCM-MAC) of the packet loss rate and delay in comparison to other protocol.

It can be seen from Figures 1 and 2, that the proposed LPMC-MAC algorithm has better performance in both packet loss rate and delay than the 802.11p. The packet loss rate of LPMC-MAC will not not grosth fast but a fine state of change when reaches a certain threshold. Therefore，LPMC-MAC is suit to the dense traffic. In the sparse traffic，rarely not has packet loss，delay depends on vehicle running to the crossroad. But in sparse environment，LPMC-MAC has better performance than 802. 11p.

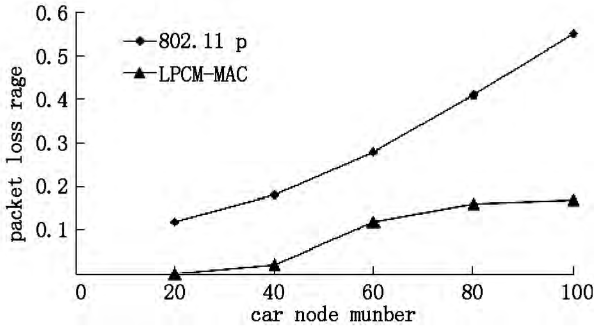

Figure 1　Different mac of packet loss rate

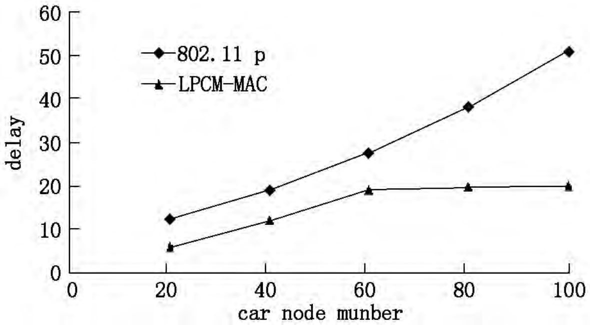

Figure 2　Different mac of delay

Take the maximum number of hop to 6，By setting different bus departure interval. The performance in the transmission successful rate and delay between SSMHR and SF（Spray and Focus）and SW（Spray and wait）under different numbers of bus are compared.

As can be seen from Figures 3 and 4，SSMHR′s transmission successful rate are significantly higher than the SF and SW，and are also superior in terms of delay performance. Although SW and SF are multi-protocol，which based on a single copy of the agreement to limit the number of copies in expansion，It enhances the utilization of network resource effectively. And then，SF is also increased based on the SW，the effectiveness of the forwarding mechanism is introduced in the second stage. Therefore，it improves transmission performance again. However，the two algorithms are only depend on the one-hop neighbor nodes range effectiveness，and do not take advantage of indirectly multi-hop connectivity features in ubiquitous network. The SSMHR makes full use of the cycle characteristics of node movement in network. Based on this，it has better performance in reliability and latency performance，because of the reliable filtering of single-hop combined with the transmission delay probability of multi-hop node.

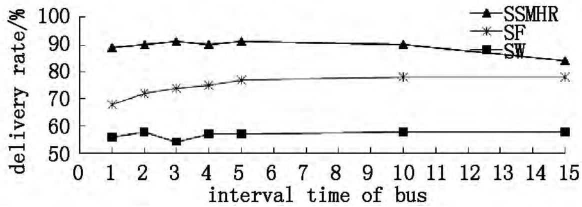

Figure 3　Different routing of delivery rate

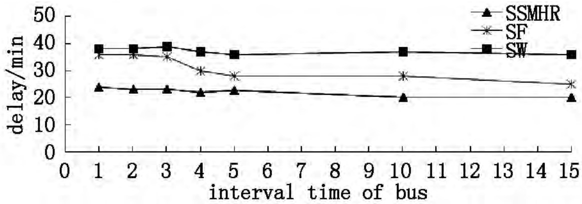

Figure 4　Different routing of delay

In summary，the layered-partition communication model can achieve good network performance both on the MAC layer and routing layer，especially suitable for highly dynamic，large-scale urban VANET communication.

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智能城市车载网络分层分区协作通信模型研究

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摘要:城市车载网络能为解决城市交通问题提供有效的方法. 大多数已存在的传输模型由于不能解决车辆的高速移动、复杂城市交通环境和多变的交通密度问题,导致传输效率低、可靠性能差. 该文紧紧围绕城市环境信号传输衰减、红灯等停、固定和周期的公交运行模式,提出分层分区的通信模型. 该模型充分利用公交的固定路线运行和普通车辆与公交之间的簇首节点转发策略进行优化,将车辆之间复杂的不确定的传输协议转换成协作的、稳定的 3 层模型. 设计了有限时延内的单跳转发机制,以保证公交协助转发的可靠性和有效性;设计了簇首触发转发机制以适应不同的车辆密度. 仿真实验表明,整体模型具有较高的传输效率和较低的时延,且对于具有高移动性和复杂道路环境的城市车载网络具有较好的适应性.
关键词:分层分区通信模型;自适应区域优化策略;红灯等停

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