



Research Paper

A research study on a public transport system routing protocol for VDTN

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ABSTRACT

Opportunistic routing is a hotspot in areas of study regarding DTN routing and attracts the attention of numerous researchers. The most important issue in opportunistic routing is the selection of relay nodes. Due to nodes having stable social attributes and social relationships, taking the nodes' social attributes into account when selecting relay nodes will result in better forwarding strategies. This study focuses on a new relay selection mechanism based on multiple social attributes in opportunistic routing, combining the energy consumption of nodes when forwarding data with the mobile features and nodes' social attributes. This study uses QualNet to build two different simulation models for the opportunity routing algorithm based on multiple social attributes and traditional DTN routing protocols. By comparing the average number of hops, network throughput, message delivery latency and other key performance metrics in the two different environments, we find that the opportunity routing algorithm based on multiple social attributes performs better than traditional DTN routing protocols.

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INTRODUCTION

DTN is a special wireless mobile self-organizing network with intermittent connectivity, long message latency, high BER, an asymmetric data rate, etc. (Wei and Zeng, 2013). A new protocol layer, the Bundle layer, was proposed for the first time in 2003 in a study of Interstellar Network by Burleigh et al. (2003). It was inserted between the application layer of the node and the transport layer to act as the storage-carry-forwarding mechanism of the packet, overcoming the network because the node was not in the same connected zone. The resulting network segmentation and link connection resulted in a larger delay. It overcomes the large delay of the network segmentation and link connection in the network caused by the nodes that are not in the same connected area (Fan et al., 2008).

Because of the sparsity and the mobility of the nodes in the vehicle network, the network is frequently disconnected, which leads to rapid changes in VANET network topology. Therefore, VANET belongs to a limited network, such as for the expressway, for night driving, and for special vehicle communications scenarios. The car network application message distribution requires the

"storage-carry-forwarding" mechanism to participate, so that it can be viewed as a vehicle delayed tolerance network Cuka et al. (2017), or a VDTN (Vehicular Delay Tolerant Network). In this special network, the communication area is segmented, and the end-to-end path does not exist in the network. The traditional MANET Network routing protocol cannot be applied to this new architecture, and the performance improvement of network communication becomes the main problem of the VDTN. This study proposes a public transport routing protocol for a VDTN based on the VDTN routing protocol that aims to improve routing efficiency and reduce the packet loss rate and end-to-end delay.

RESEARCH STATUS

Vehicular delay tolerant network routing is still a challenging problem, and the protocol design is faced with many problems: (1) If the frequent phenomenon of packet re-transmission and the optimal transmission path is

updated, there is no immediate end-to-end path between any node in the network; (2) The life cycle of the packet is limited; (3) The movement and randomness of the vehicle and the sudden stopping movement of the vehicle may result in an inability to establish the correct path. Based on the above problems, many research institutes have studied the VDTN routes.

The distribution-based routing mechanism transmits the packet to the destination node by spreading packets across the network, increasing the probability of meeting between the nodes, which can guarantee a relatively small delay. Vahdat and Becker (2000) proposed the Epidemic routing algorithm, and the protocol is essentially a Flooding route, which is a routing algorithm that replicates cached messages for each of the nodes that carry packets, exchanging copies of packets to be transferred so that every node in the network carries packets to be passed.

To avoid blindly forwarding packets to all or part of a neighbor node in a distribution-based routing mechanism, the characteristics of the DTN Network and node and those of human society are taken into account by the authors' proposal of a routing mechanism based on historical information. Therefore, nodes predict the relay node to choose and decide whether to transmit packets or to wait for better timing. Based on the Separated Transport Model (DTC) (Chen and Murphy, 2001) routing protocol, a global communication model of multi-hop separation adhoc networks is established and uses the Network Layer routing protocol DSR (Hou et al., 2015) in clusters, and the middleware layer routing algorithm is used between clusters. The PROPHET routing protocol is a probabilistic routing protocol proposed by Lindgren et al. (2012). It uses the prior knowledge of the network to predict both the meeting probability of the relay node and the probability of reaching the destination node and selects the optimum relay node to complete the communication.

The coding-based routing mechanism improves the performance of the network by adding some redundant information and decoding algorithms. Wang and others summarize the EC routing algorithm (Leong, 2014) based on previous research. The source nodes in this algorithm first split the entire packet and are evenly distributed to the same number of nodes within the network, and when the destination node receives some of the messages that each intermediate node carries, the message is reorganized through the operation. The H-EC routing algorithm (Liu et al., 2013) is a hybrid routing protocol based on the abovementioned routing mechanism from Ling. The source node first copies the encoded part of the message to the relay node when the message forwarding contains two copies and is forwarded to it when the appropriate relay node is encountered, thereby making full use of each connection opportunity for optimum forwarding performance. Although the above research has made some progress, it is seldom considered for reliability of the link connection; therefore, this study proposes a bus cluster

routing protocol based on the urban bus system PTSRP.

SYSTEM MODEL

Ordinary vehicle randomness makes the packet delivery success rate very low, while the network overhead is relatively large, and the public transportation system covers a wide range of city traffic. Because the line and time are fixed, the bus in the car network message transmission and information distribution possesses a great advantage. Therefore, the use of the public transport system for data transmission will reduce the complexity of the routing protocol and improve reliability.

Clustering model

The system model established in this study uses direct transmission of data between bus nodes and the ordinary node auxiliary forwarding packet. This system model uses the clustering mechanism. The formation of clusters is mainly divided into the following two parts: cluster head node selection and cluster division. The pattern is shown in Figure 1. This research adopts the approach of the two-lane urban traffic environment. This traffic section contains the ordinary vehicle node and the bus node. Because the bus node has the fixed running route and a stable running time, it is selected as the cluster head node. The division of the cluster follows. In this part, the decision of the ordinary vehicle node division is completed. After the first part completes the selection of the cluster head node, the cluster node sends the message request to join the ordinary node, and the ordinary vehicle node judges the ability of the cluster node to join the cluster.

Cluster maintenance time

Definition 1: Relevance- Relevance is the degree of similarity between two nodes in the process of moving, denoted by R_{ij} :

$$R_{ij} = \frac{|P_i(t) \cap P_j(t)|}{|P_i(t) \cup P_j(t)|} \quad (1)$$

where $P_i(t)$ represents the intersection of the neighbor nodes of nodes i and j at time t , $|P_i(t) \cap P_j(t)|$ denotes the intersection of the neighbor nodes of nodes i and j at time t , and $|P_i(t) \cup P_j(t)|$ denotes a union.

Definition 2: Stability- In the process of movement, if the node topology is relatively stable, then the two nodes may be in an information exchange; however, frequent changes

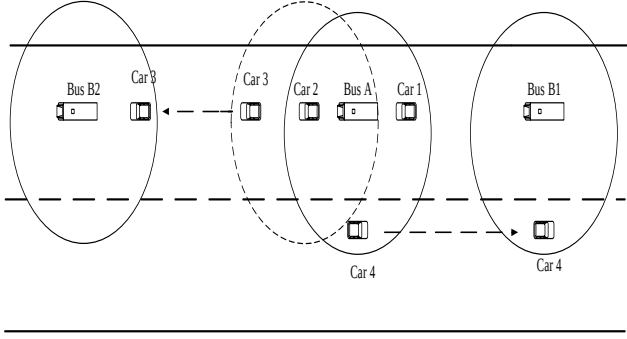


Figure 1: System model.

in the topology will lead to a message forwarding failure. In this study, we use the change gradient of the node's neighbor node to represent its own stability, denoted by S_i :

$$S_i = \frac{|P_i(t) \cap P_i(t+\tau)|}{|P_i(t) \cup P_i(t+\tau)|} \quad (2)$$

where τ is the scanning period of the node and $|P_i(t) \cup P_i(t+\tau)|$ denotes that the node i is merged at the two time neighbors.

When the cluster node broadcasts the cluster message to the network, the ordinary node k judges whether the cluster should join according to the capability value of the cluster head node. The functional value of the node i is defined as $\{R_{ik}, S_i\}$, and for the ordinary node k , the cluster head node with greater correlation is selected while the node with the higher stability is selected if the correlation is the same. Therefore, for ordinary nodes, high correlation is selected in order for topological connectivity to be relatively stable to be joined, and the cluster will be completed given the following conditions listed in formula (3):

$$\begin{cases} R_{ik} \geq R_{jk} \\ S_i > S_j \end{cases} \quad (3)$$

Node A is the cluster head node, with the coordinates (X_A, Y_A) , where the speed of operation is V_A , and the direction is α . Node B is the ordinary vehicle, with the location coordinates (X_B, Y_B) , where the speed is V_B , and the direction is β . V represents the relative velocity of nodes A and B . When the relative velocity of A and B is 0, it indicates that the cluster can be maintained continuously. This state is the ideal state. If the relative velocity is not 0, the maintenance time of the cluster is calculated.

From Figure 2, ordinary vehicle nodes that maintain the maximum length of the cluster can be obtained:

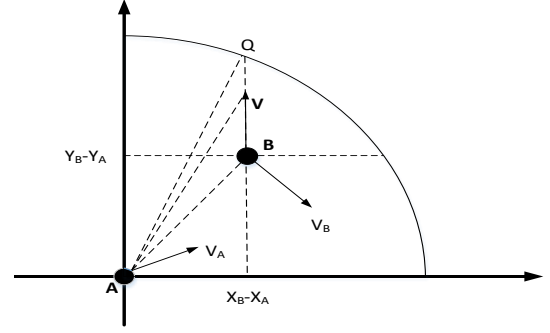


Figure 2: Cluster maintenance time calculation model.

$$t_{\max} = \frac{S_{\max}}{V} \Rightarrow LET_{AB} = \frac{\max(S_{AB})}{|V_A - V_B|} \quad (4)$$

Thus, the maximum maintenance time of the cluster is:

$$\begin{aligned} LET_{AB} &= \frac{\max(S_{AB})}{|V_A - V_B|} \\ &= \frac{|BQ|}{|V|} \\ &= \frac{\sqrt{(V_i^2 + R^2) - (V_i Y_j - X_i V_j)^2 - (V_i X_i + V_j Y_j)}}{V_i^2 + V_j^2} \end{aligned} \quad (5)$$

When the cluster head node A receives the return message from all the nodes, the time corresponding to each node is compared, and the minimum maintenance time is selected as the existence time of the cluster. After the time is finished, the cluster is restarted according to the steps in formula (5).

PUBLIC TRANSPORT ROUTING PROTOCOL FOR VDTN

Cluster routing

When the vehicle nodes m and n are both at cluster A , the nodes with high correlation are added to the same cluster due to the correlation and stability of the nodes in the process of cluster construction. Therefore, in the nodes belonging to the same cluster, the road connection rate is higher than that of the inter-cluster nodes. Thus, for the forwarding mode of the cluster message, only the retention time of the link connection between the nodes in the cluster is considered. The node with the longest connection time is selected as the best relay node. The calculation of the value of the connection hold time will be shown in the next section in detail. This forwarding mode will select the best relay node until the packet is forwarded to the destination node, which will effectively improve the message forwarding success rate.

Inter-cluster routing

When the source node that carries the message and the destination node belong to different clusters, the forwarding mode is called the inter-cluster route. First, the source node uses the QoS, quality of service, to select a set of alternative forwarding sets, and then, the path is obtained to maintain the connection time. For the alternative forwarding sets to find the optimal relay node, the message is forwarded to the cluster head node. The cluster head node forwards the message to the cluster head node of the appropriate cluster according to the relevant information of the destination node. If the cluster has a destination node, then cluster routing is used or the forwarding is continued until the destination node is reached. The specific process is shown in Figure 3.

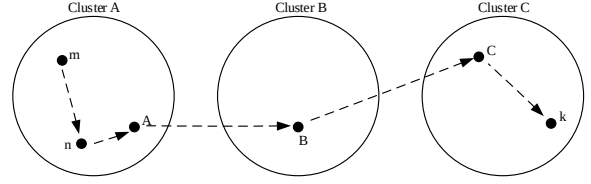


Figure 3: Schematic diagram of inter-cluster routing.

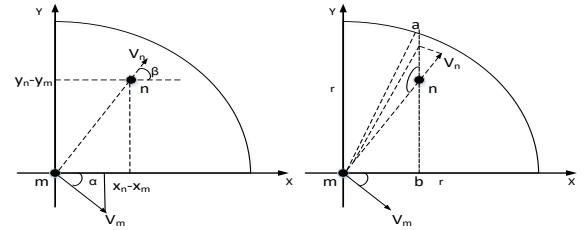


Figure 4: Calculation model of the link connection time.

Research on routing based on QoS quality of service

The Epidemic protocol adopts the flooding mechanism and does not consider the next hop performance. In this paper, the next hop relay node implements QoS, including bandwidth and delay. To facilitate the study, the VANET network under the bus system scenario can be expressed as a weighted graph $G(V, E)$, where V can be expressed as all sets representing the vehicle nodes, E is a set of links for the formation of the vehicle nodes, and the transmission radius of each vehicle node is the same. Then, a route is found that satisfies the following formula (6), which describes a constraint between the source vehicle node and the target vehicle node:

$$\begin{cases} B \geq Band(K) \\ D \leq Delay(K) \end{cases} \quad (6)$$

where $Band(K)$ and $Delay(K)$ are the mean of all paths, and the nodes that satisfy the constraint are added to the candidate forwarding sets V . 3.2.2 Hold time of the transmission link.

When the transmission link distance d_{ij} between the adjacent two vehicle nodes i and j is not greater than the inter-vehicle communication distance R , the nodes i and j are considered to be within the effective communication range, and since the link between the nodes has been connected, Δt is the LET (Link Expire Time), known as the link lifetime. In this study, the node with the largest LET is selected as the relay node. It is assumed that the nodes m and n can communicate the Δt with each other, and the link hold-time can be calculated by the mathematical model shown in the Figure 4.

From Figure 4, let $a = V_n \cos \beta - V_m \cos \alpha$, $b = V_n \sin \beta - V_m \cos \alpha$, $c = X_n - X_m$, and $d = Y_n - Y_m$, and the transmission range between vehicles is r . It can be shown from the model that assuming the elapsed time is t , the

Pythagorean theorem, $(c+at)^2 + (d+bt)^2 = r^2$, applies, and as shown in equation (7), Δt is solved for:

$$\Delta t = \frac{-(ac - bd) - \sqrt{r^2(a^2 + b^2) - (bc - ad)^2}}{a^2 - b^2} \quad (7)$$

Cache management algorithm

The algorithm takes the natural logarithm of the message's survival time, and the message's lifetime and forwarding times are of the same order of magnitude. The two values are as shown in the normalization process:

$$th = \ln(\text{time}) + n \quad (8)$$

The larger the th , the greater the existence of the message. Additionally, the greater the number of times it is forwarded, the higher the success rate of sending and the lower the priority of the message. If the CMA algorithm is enabled when the cache is overflowed, then the time it takes to delete the cached message increases the transmission delay of the current message. Therefore, the threshold for the buffer is set to 80%, and if this threshold is exceeded, the CMA algorithm is used to delete the message.

SIMULATION AND EXPERIMENT

The design of the routing protocol is simulated by the ONE platform. In the simulation process, the typical DTN stochastic routing protocols Epidemic and PTSRP were chosen and simulated repeatedly under the same scenarios, and an analysis of the performance of the two protocols

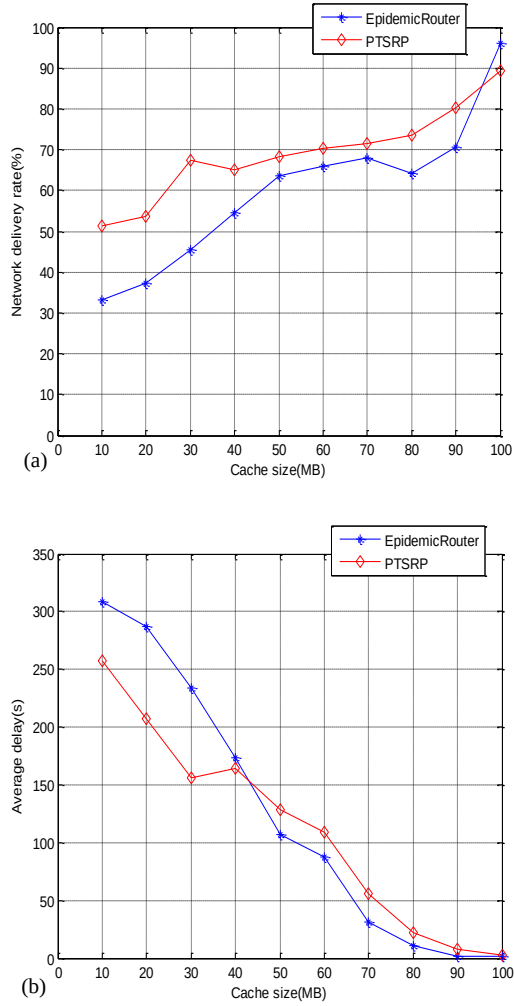


Figure 5: Impact of buffer size on protocol performance. (a) The packet delivery rate and the size of the buffer. (b) The average delay and the size of the buffer.

was performed by comparing the simulation results.

Protocol performance under different cache sizes

As shown in Figure 5(a), the packet delivery rate of the Epidemic Routing protocol and PTSRP tends to rise with the increase in the buffer area of the nodes in the network. It can be seen from the figure that the delivery rate of PTSRP is higher than Epidemic Routing because the protocol is improved for the cache, and the redundant message can be discarded in time. When the buffer is larger than 80 MB, the buffer is large enough. The delivery rate of Epidemic Routing is better than PTSRP due to the network protocol of having more than one copy of the message; however, with the increasing buffer cache, the delivery rate of both protocols will reach 100%.

The average end-to-end delay in Figure 5(b) shows a decreasing trend as the buffer zone increases. When the

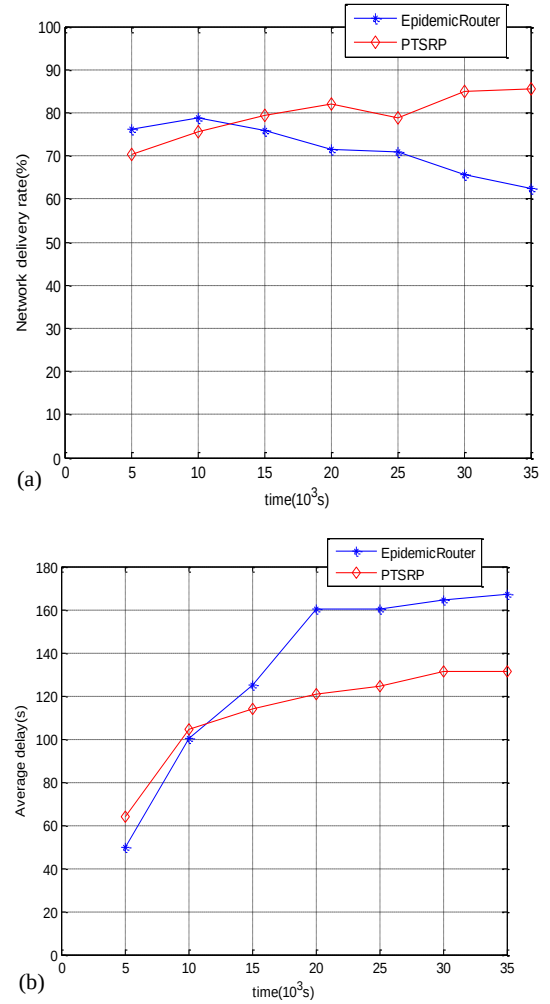


Figure 6: Impact of time changes on protocol performance. (a) The rate of packet delivery varies with time. (b) The average delay varies with time.

buffer area is less than 40 MB, network congestion is prone to occur during the transmission using Epidemic Routing. Therefore, the average end-to-end delay is larger than that of the PTSRP. As the cache increases, the delay will continue to become smaller. PTSRP therefore yields a greater advantage in the case where the buffer area of the node is smaller.

Protocol performance under different time periods

Figure 6(a) shows the effect of time on protocol performance. The Epidemic protocol in the initial stage of the delivery rate is high and increases more quickly but is gradually reduced after 10,000 s. The PTSRP delivery rate has improved significantly over time, and the congestion strategy has discarded redundant packets, which improves the forwarding rate of packets in the whole network.

Figure 6(b) shows the effect of time delay on the average

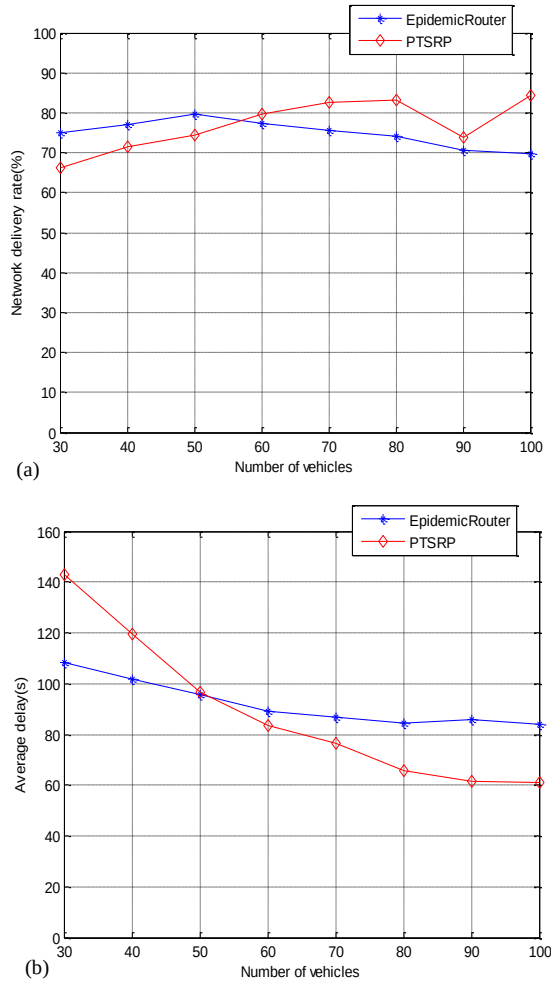


Figure 7: Impact of the number of vehicles on protocol performance. (a) The packet delivery rate and the number of vehicles. (b) The average delay and the number of vehicles.

end-to-end delay. The Epidemic protocol is low at the initial delay, but the delay is increasing with time. After approximately 12,000 s, the PTSRP delay gradually becomes lower than that of the Epidemic protocol. Because PTSRP limits the choice of relay nodes, the delay in the whole process increases. As time increases, the rising trend of the delay gradually slows down and slowly becomes stable, which reduces the average latency in the network.

Protocol performance under different numbers of vehicles

In Figure 7(a), the packet delivery rate with the number of vehicles increased in a generally upward trend. When the number of vehicles is small, the Epidemic protocol copy mechanism makes the delivery rate higher than the PTSRP. When the number of vehicles is gradually increased, the

number of links available for forwarding increases, and since the PTSRP has a very good management mechanism, the delivery rate will also rise. However, the Epidemic protocol causes the delivery rate to drop as a result of network congestion. Therefore, considering the whole performance of the Epidemic protocol, the delivery rate of the PTSRP maintains a greater advantage.

Figure 7(b) shows the average end-to-end delay as the number of vehicle nodes increases. The PTSRP delay is large before the number of nodes reaches 50 because there are too few nodes to establish a link. When the number of vehicles is increased to 50, the PTSRP delay will gradually be lower than the Epidemic protocol. When the number of nodes is greater than 90, the delay rate of the two protocols begins to slow down.

CONCLUSION

In this study, the advantages of a fixed line and stable running time are used in the public transport system. This paper proposes a VDTN routing protocol based on the public transport system that adopts a transport model of the public transport system and chooses the optimal route based on this model, so that the message can be transmitted according to the optimal route. This saves the enormous overhead of the DTN routing strategy, which has been used in the past. The simulation results show that the algorithm has good network performance, and the model of node stochastic motion, with the increase in buffer and node size, shows that the performance of the algorithm is better than the Epidemic routing protocol and has a good network adaptation performance. However, the method for the platform optimization of the public transport system in this study is simplified, and it does not take into account the VANET middle-side element (RSU). In ongoing research, utilizing RSU, reasonably designing the relevant routing protocol algorithm and improving network performance will be future research directions.

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