A Reliable Packet Aggregation Mechanism for Vehicular Wireless Networks

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Abstract— **In this paper we focus on the packet aggregation mechanism and the path of transmitting packets in vehicular wireless networks. In VANETs, nodes move at high speed and the network topology changes frequently. Consequently, collision may increase due to the excessive packets. Moreover, packets transmitting on a single path could reduce the redundancy packets but increase the probability of transmission failed. We proposed a method that uses the aggregation mechanism and the concept of shortcuts to transmit. First, nodes aggregate packets which have the same output directions to reduce the number of packets. Second, nodes search shortcuts to destinations and transmit packets on these paths to increase the successful probability. Finally, we use mathematical model to evaluate the times of packets transmission and the successful probability, and the numerical results show that the proposed method could reduce the times of packets transmission and increase the successful probability.**

Keywords—**packets aggregation mechanism, multiple paths, vehicular ad hoc networks (VANETs), reliable transmission, collision**

1. INTRODUCTION

In VANETs, the technique and application range are growing up, people attach more importance to the safety and the comfort while driving. However, safety and comfort applications require changing information continuously. Therefore, packets delivery in VANETs is a good issue to investigate.

There are various applications in VANETs, e.g., user can connect to Internet to search information or watch movies, stores can send advertisements to travellers, and the computer in the vehicle can exchange information with other vehicles to warn the driver of road status. The developing applications increase the number of packets and cause collisions. More collisions lead to more packets loss.

Besides, existing delivery method is one transmission sends one packet. However, the packet may have a little information. Sending a packet by one transmission may add the number of packets in the networks and increase the probability of collision happening. If packets could be aggregated together and sent out by one transmission, packets collision can be reduced.

For transmitting packets to a specific destination node, the normal method is to find a single path and transmit packet through it. The sender node will retransmit packet if the previous transmission failed. However, transmitting packets on a single path increases the probability of transmission failed in unreliable vehicular wireless networks. The transmission may fail because of the sparse density of vehicles or weak network connectivity of the path. On the other hand, the retransmission mechanism increases the packets latency. If nodes use the characteristic of wireless networks which can share information to all neighbors to send packets on multiple paths simultaneously, the destination node can receive packets even some of the paths failed. Transmitting packets on multiple paths increases the probability of packets delivery.

In [1], authors use the coding method to aggregate packets and the characteristic of sharing to transmit packets. The detailed method is that nodes aggregate packets by XOR after collecting packet. The feature of XOR is it does not increase the packet size but requires other N-1 packets to decode the N-th packet. In the part of transmitting, [1] uses the characteristic of sharing to send packets to many directions at the same time. The broadcasting nature of wireless networks ensures destination nodes have enough information to decode the aggregation packet.

In this paper, we propose an aggregation method that decrease the times of packets transmission and increase the packets reliability. For packets aggregation, nodes keep the packets instead of transmitting immediately. After a while, nodes aggregate the packets which have the same output directions and then send out by one transmission. Aggregating packets increases the packet information sent by one transmission and decreases the number of packets in the networks. On the other hand, to increase the packets reliability, we use the concept of shortcut to find paths which have the same least hop counts, and nodes use the characteristic of sharing to send packets on these paths by one transmission. If one of the shortcut paths failed, there still are other paths to transmit packets. Transmitting packets through multiple paths increases the successful rate of packets delivery without retransmission.

The remains of the paper are organized as follows. Section 2 describes the proposed reliable transmission method. Section 3 describes the mathematical models that we evaluate the times of transmission and the successful probability. Section 4 analyses the numerical results and compares with other mechanisms. The final section is the conclusion.

2. RELIABLE PACKET AGGREGATION MECHANISM

This section describes the proposed reliable transmission method. The proposed method has two purposes: the first one is using the aggregation mechanism to decrease the times of transmission and collisions; the second one is using the multiple paths to transmit packets to increase the successful rate of packets delivery without retransmission.

2.1. The default environment

The default environment in this paper is Manhattan streets model in the urban. Each crossroad has a road side unit (RSU) and vehicles move on the streets. Packets are sent from and received by RSUs, and they are taken by vehicles instead of through the wire networks between RSUs.

2.2. Packets aggregation mechanism

We use a simple aggregation method in this step. Nodes gather the packet information for an aggregation packet and then send them out. But the aggregation packet size cannot be larger than Maximum Transmission Unit (MTU).

Each RSU has four packet buffers to store packets which are sent to four directions respectively, as illustrated in Fig. 1. The node keeps the packet when receiving it, and stores the packet in the corresponding buffer according to the output direction of the packet. Each buffer has a timer called Waiting Time (WT). The WT counts the time how long the node could wait for aggregating packets to prevent the packets in the buffer waiting too long to send.

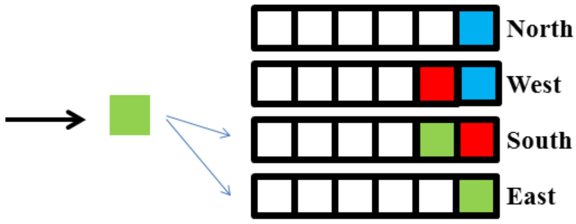

Fig. 1 The diagram of packets buffers.

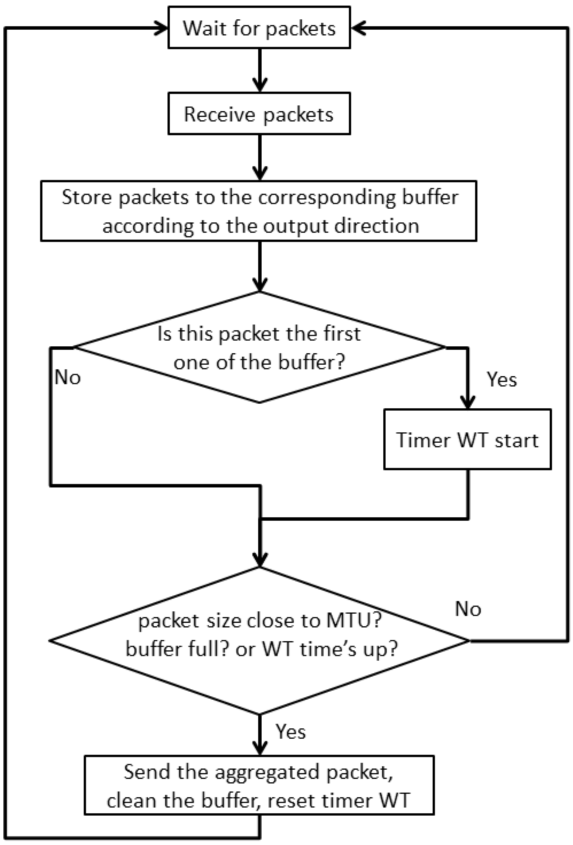

Fig. 2 The flowchart of aggregation method.

The following is the process of the aggregation method: nodes do not transfer the packet immediately when receiving it. Instead, nodes store the packet to the corresponding buffer according to the packet output direction and wait for other packets to come in. The timer WT starts when receiving the first packet in the buffer, and counts how long to wait for other packets. When timer WT is expired, the aggregated packet size is closing to MTU, or the buffer is filled full, then the node sends the aggregated packet, stops the timer WT, cleans the buffer, and keeps waiting for packets. Fig. 2. is the detail flowchart of the process.

There are three conditions to stop waiting for packets and to send the aggregated packet out: the timer WT is expired, the aggregated packet size is closing to MTU, or the buffer is filled full. If one of the three conditions is satisfied, the node has to send the aggregated packet out. Setting the condition of the timer WT is to prevent that there are packets in the buffer waiting too long to be sent out. The aggregated packet has to be sent when the timer is expired even there is only one packet payload in the packet. On the other hand, because the buffer size is finite, nodes have to send the aggregated packet when the buffer is filled full. Finally, since a packet has the size limit, nodes cannot aggregate packets unlimited. Nodes have to send the aggregated packet out when the packet size is close to MTU.

2.3. Multiple paths transmission

Transmitting packets on a single path decreases the successful rate of transmitting packets to destinations at the first time. This paper transmits packets in multiple paths, and uses the concept of shortcut to find these paths.

The following is the concept of shortcut: packets are sent through all paths which are getting closer to the destination but the paths which are getting farther to the destination, as illustrated in Fig. 3. Following the above principle, the packet gets closer to the destination at each transmission, and these paths are shortcuts to the destination.

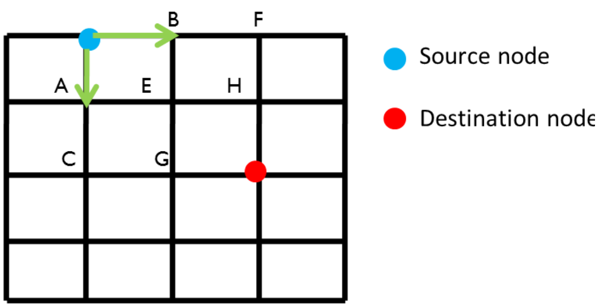

Fig. 3. Concept of shortcuts.

Moreover, packets are transmitted to the vehicles which are approaching to the sender node, moving on the shortcut, and going to the direction of the destination location. The vehicles receive and take packets to the relay node of the next crossroad. Then the relay node transfers the packet to the vehicles pass by. Repeat the processes until the packet are sent to the destination.

3. Performance Model

This section proposes a mathematical model to evaluate the number of transmission and the successful rate of packets delivery without retransmission in the proposed method.

3.1. Compared methods

We evaluate three methods in this paper: single path (unicast), multi-path (shortcut), and the proposed method (aggregation + shortcut).

Unicast uses a single path to transmit packets to the destination node. If a node receives the same packet again, it does not transmit the packets to avoid redundancy.

Multi-path uses the concept of shortcuts to find multiple paths to transmit packets. Since the node does not record previously transmitted packets, nodes will transmit the same packet again when receiving that packet at second time.

The proposed method uses the aggregation mechanism and the concept of shortcut, so the nodes use multi-path to transmit packets. And the nodes in the proposed method records previously transmitted packets, the packet will be transmitted by a node only once.

All the nodes and paths that transmit packets construct a dissemination tree. We use this dissemination trees to analyse the number of transmission and the successful probability.

3.2. The number of transmission

Table 1 shows the mathematical model to evaluate the number of transmission using different methods in 1-to-1 (1-source, 1-destination) and 1-to-M (1-source, M-destinations) mode. We assume that nodes aggregate all packets successfully in the three methods.

There are some notations used in the model. Let M denote the total number of destination nodes. N_i denotes the number of nodes of the dissemination tree that constructed by source nodes and the i-th destination node. N denotes the number of nodes of a dissemination tree. n_j denotes the j-th node in the dissemination tree.

In the unicast (single-path) method that using a single path to transmit packets, each destination node constructs the dissemination tree with the source node. Thus, there are M dissemination trees when the number of destination nodes is M. Each node in the dissemination tree transmits packets except the destination node, so the number of transmission is N-1.

In the shortcut (multi-path) method, nodes transmit the same packets again. Thus, evaluating the number of transmission has to count the number of parent nodes of each node in each dissemination tree. But the source node and destination node do not be considered since the source has no parent node and the destination do not transmit packets.

In the proposed method, all nodes except the destination node in the dissemination tree transmit native packets or aggregated packets only once. Therefore, the number of transmission is N-1.

TABLE 1
THE MODEL OF EVALUATING NUMBER

	Number of transmission
Unicast	T= $\sum_{i=1}^{M}(N_i - 1)$
Shortcut	$\sum_{i=1}^{M}(\sum_{J=1}^{N-2} n_j\,.parent\_number + 1)$
Aggrega-tion with shortcut	N-1

3.3. The successful rate of packets delivery without retransmission

The successful probability is defined as the probability that the destination node receives each kind of packet without retransmission.

Table 2 shows the mathematical model to evaluate the successful rate of packet delivery without retransmission. There are some notations used in the model. Let P_S denote the successful transmission probability in single hop. T_i denotes the number of transmission of using unicast method. left.p and right.p denote the left and right parent node of a node respectively. left.p_pn denotes the number of parent nodes of the left parent node of a node. right.p_pn denotes the number of parent nodes of the right parent node of a node.

In the unicast method, the probability is the product of the probabilities of each packet. And in the shortcut method and the proposed method, we use the recursive function to calculate the successful probability. Starting from the destination node, the function calculates the probability of receiving packets from parent nodes. Besides, nodes in the shortcut method may transmit packets many times, therefore, the calculation must consider the times of duplicate transmissions.

TABLE 2
THE MODEL OF EVALUATING PROBABILITIES.

	Times of transmission
Unicast	$\prod_{i=1}^{M} P_S{}^{T_i}$
Shortcut	P(node) = 1-[1-P(left.p)$^{left.p\_pn}$]* [1-P(right.r)$^{right.p\_pn}$]
Proposed Method	P(node) = 1-[1-P(left.p)]*[1-P(right.p)]

4. NUMERICAL RESULTS

In this section, we compare the performance results of the methods using single path (unicast), multiple path (shortcut), and the proposed method (aggregation + shortcut).

We assume the Manhattan model is used in vehicular wireless networks. In evaluations, we set the number of nodes (RSUs) in the Manhattan model is 25 (5*5), 100 (10*10), and 225 (15*15). The failure rate for single hop is 0.2, and the number of evaluation is 10. The evaluations are in the 1-TO-1 mode and 1-TO-M mode (M=2).

4.1. The number of transmission

Fig. 4. shows the number of transmission for three method in two modes. In the 1-TO-1 mode, the method using single path outperforms the method using multiple paths in terms of the number of transmission. Comparing with the

single-path method, there are more nodes require transmitting packets by using multi-path method.

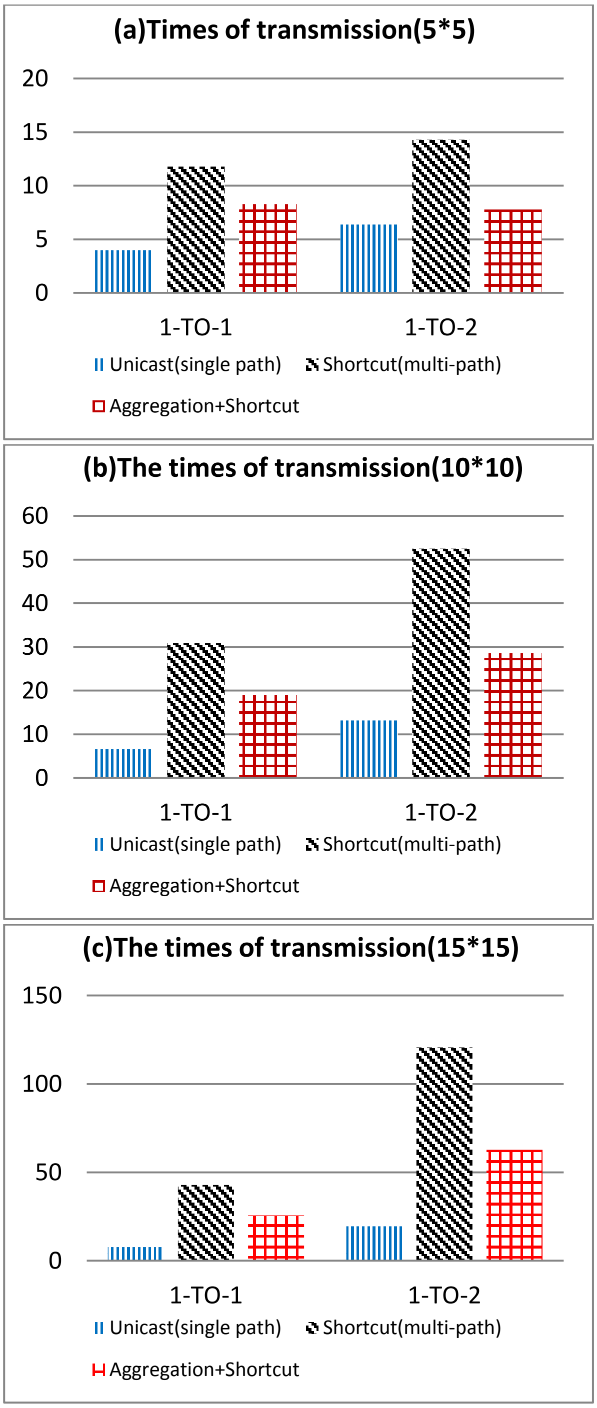

Fig. 4. The times of transmission

On the other hand, in the 1-TO-M mode, the method using single path outperforms the method using multiple paths in terms of the number of transmission based on the same reason. But the times of the proposed method is less than the multiple paths method due to the proposed method using the aggregation mechanism to aggregate packets, and nodes record the transmitted packet to prevent sending duplicate packets. The proposed method uses the two concepts to reduce the times of transmission.

4.1. Successful rate

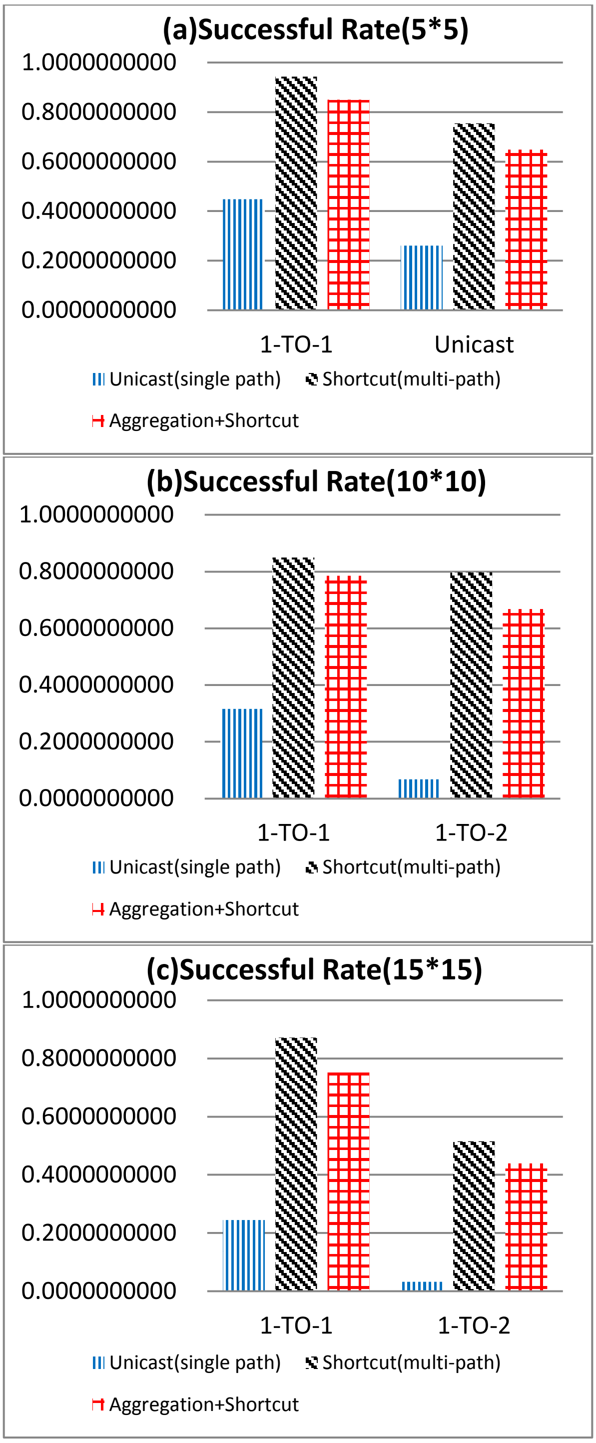

Fig. 5. Successful rate

Fig. 5. shows the successful rate without retransmission for three methods in two modes. In the 1-TO-1 mode, the successful rates of the shortcut method and the proposed method are higher than that of unicast method. Due to the

unicast method uses single path to transmit packets, the packet will not be transmitted to the destination node through other paths when the first transmission failed. On the other hand, the shortcut and proposed method use multi-path to transmit packets, there are other paths to transmit packets if one path failed.

In 1-TO-M mode, the successful rate of the shortcut method and the proposed method are higher than that of unicast method due to the same reason. But the rate of the proposed method is less than that of shortcut method. The reason is that the proposed method records the previously transmitted packets, such that each packet will be transmitted only once. If the transmission of some node failed, there is no second chance to transmit the packet again. Therefore, the successful rate of the shortcut method which may transmit the same packet twice or more are higher than that of the proposed method.

5. CONCLUSIONS

In this paper, we propose an aggregation mechanism which uses the concept of shortcut to transmit packets on multiple paths. The proposed mechanism could reduce the times of transmission and increase the successful probability of packet delivery without retransmission.

In the evaluation, the numerical results show that the proposed method could reduce the number of transmission compared with the single path and multi-path method, and increase the successful rate of packet delivery without retransmission compared with the single path method.

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