Improving the Performance of AODV(-PGB) based on Position-based Routing Repair Algorithm in VANET

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Abstract

Vehicle ad hoc networks (VANET) are one of the most important technologies to provide various ITS services. While VANET requires rapid and reliable transmission, packet transmission in VANET is unstable because of high mobility. Many routing protocols have been proposed and assessed to improve the efficiency of VANET. However, topology-based routing protocols generate heavy overhead and long delay, and position-based routing protocols have frequent packet loss due to inaccurate node position. In this paper, we propose a position-based routing repair algorithm to improve the efficiency of VANET. This algorithm is proposed based on the premise that AODV (-PGB) can be used effectively in VANET, if the discovery, maintenance and repair mechanism of AODV is optimized for the features of VANET. The main focus of this algorithm is that the relay node can determine whether its alternative node exits and judge whether the routing path is disconnected. If the relay node is about to swerve from the routing path in a multi-hop network, the node recognizes the possibility of path loss based on a defined critical domain. The node then transmits a handover packet to the next hop node, alternative nodes and previous node. The next node repairs the alternative path before path loss occurs to maintain connectivity and provide seamless service. We simulated protocols using both the ideal traffic model and the realistic traffic model to assess the proposed algorithm. The result shows that the protocols that include the proposed algorithm have fewer path losses, lower overhead, shorter delay and higher data throughput compared with other protocols in VANET.

Keywords: Routing repair, routing protocol, AODV, VANET, ad-hoc

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1. Introduction

The new field of Intelligent Transport Systems (ITS) (which is a new paradigm in electronics, communication and traffic engineering) may be described as a combination of information technology (IT) and automotive technology. Research and development in ITS involves the intersection of mobile computing and intelligent automobiles. In particular, vehicular communication in ITS is the most important technology to connect a driver, a vehicle and a service provider. Relevant research in wireless communication focuses on fast, accurate and reliable exchange of information.

Solutions for vehicular communication based on IEEE 802.11 are described in IEEE 802.11p [1]. IEEE 802.11p, "Wireless Access in the Vehicular Environment (WAVE)" defined amendments to IEEE 802.11 that were necessary to support ITS applications. To promote safe and efficient highways, the Federal Communications Commission (FCC) of the United States has allocated the 5.850-5.925 GHz band for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications. VANET using 802.11-based WLAN technology has recently received considerable attention from many projects (e.g., VIC'S, CarTalk 2000, IntelliDrive) and industry groups (e.g., the Car2Car Communication Consortium) [2].

Vehicle Ad Hoc Network (VANET) arose from the desire to provide various services and reduce the costs of infrastructure. In the long run, VANET is the key to the realization of cooperative platoon traveling to provide complete safety and the highest traffic efficiency. To improve VANET efficiency, many protocol researchers have studied routing protocol based on the Mobile Ad-hoc Network (MANET). Although the concept of ad hoc network protocol emphasizes quality of service (QoS) and data throughput based on MANET, VANET has different features that require dynamic high mobility and low delays on the restricted roads. The most difficult challenge in VANET is to deal with frequent route breakages caused by traffic patterns and the dynamic high-mobility of vehicles on the road [3].

Traditionally, mobile ad hoc routing protocols are classified as either topology-based or position-based. Previous studies of VANET showed that the Ad hoc On-demand Distance Vector (AODV) [4] has the highest efficiency in topology-based protocol [5], and Greedy Perimeter Stateless Routing (GPSR) [6] is the best position-based protocol. When comparing two routing protocols, position-based routing is known to be scalable with respect to the size of the network and is therefore a good candidate for inter-vehicle communication [2]. However, routing protocol designed in MANET is not effective because of the VANET feature described above.

A number of routing protocols for VANET have been proposed and evaluated. Among them, the position-based routing greedy forwarding protocol of VANET such as Geographic Source Routing (GSR) [7], perform well. However, those protocols are designed under the assumption of a random and uniform distribution of vehicles on road with just higher maximum vehicle speed [8]. When the distribution of vehicles is more complex and the mobility is less random on the road, then many of the suggested position-based greedy forwarding routing protocols of VANET experience performance problems [9], just as previous literature shows that the results of performance studies of ad hoc networks depend heavily on the chosen mobility model [10][11]. Also, this kind of protocol may easily hide the effect of inconsistent destination positions on protocol performance because a realistic location service has not been evaluated. References [2][9] show problems of GPSR and GSR on realistic vehicular traces. Therefore, the results of [7] don't make it clear that GSR is more efficient than AODV. In addition, because the position-based routing protocol doesn't maintain the routing path and doesn't generate the notifications of the disconnected paths, the source node continues to send packets until it is discarded on time-out or the transmission is completed [2]. It causes a low data throughput, a low transmission rate and bandwidth waste across the whole network. This problem is especially serious on sparse VANET with the many path losses. The discovery, maintenance, and repair of the routing path are needed for reliable transmission in VANET, although they may increase overhead and cause delay. If they are optimized for VANET, the overhead and the delay can be reduced effectively.

The results of [9] show that AODV can be more effective than GSR in VANET, considering that GSR includes the overhead of a location service to acquire destination position and wasted bandwidth due to routing path losses. Also, the authors proposed the improved AODV in VANET. This protocol, AODV-Preferred Group Broadcasting (PGB), reduces control message overhead and obtains stable routes by modifying a RREQ broadcasting mechanism to use the location and power of received signal information. However, AODV-PGB also waits until the construction of new routes when the existing route is broken like AODV, although the most difficult challenge in VANET is to deal with frequent route breakages caused by traffic patterns and the dynamic high-mobility of vehicles on the road. The frequent route failures result in a significant amount of time needed to repair existing routes or reconstruct new routes [3].

In this paper, we propose the AODV(-PGB) routing repair algorithm based on the position, speed, and direction information of each node, and focusing on the frequent routing path loss. The proposed algorithm provides high data throughput and low end-to-end delay by immediately repairing the routing path after predicting the path loss, and maintaining it continuously in VANET.

Although a periodical beacon of all vehicles for sending their information (location, speed and direction) to neighboring vehicles explosively increases network load and overhead, using the information is the best advantage of VANET (because of using GPS and Navigation in Vehicle). The information is also mandatory to provide a fundamental service for driving safety in VANET. Most projects and committees of VANET recognize that periodical transmission of the information is one of the essential factors. IntelliDrive defines the information broadcast by each vehicle every 100 ms as mandatory information [12] to provide driving safety service. In addition, vehicle information is critical for the efficient function of ITS services, such as safety service, points of interest (POI) service, collision avoidance service, public vehicle data provision and collection service, and traffic information service. In particular, the popularization of Navigation and Global Positioning Systems (GPS) is vitalizing the use of location, speed, and direction information in VANET.

This research was conducted with the idea that AODV can be used effectively in VANET with frequent routing path loss if the discovery, maintenance, and repair mechanism of AODV's routing path is optimized for the features of VANET. It can solve the aforementioned problem of topology-based protocol, as well as that of position-based greedy forwarding protocol. The proposed algorithm was designed under the condition that the relay node (which is the intermediate node to transmit packets between the source and destination node) can recognize alternative relay nodes in order to replace it when a routing path loss occurs. That is because the routing path is identical to the path of the road and the radio range of the node includes the road width (a minimum radio range of WAVE is 200 m). This algorithm reduces the heavy overhead and long delay required to repair or reconfigure routing path when path loss occurs. Also, it maintains connectivity of the routing path and provides seamless service by alternating the path before path loss occurs. If the relay node discovers any alternative relay nodes, the node notifies the source node of the disconnection of the routing path to prevent bandwidth waste. The focus of this algorithm is to improve network performance through routing path maintenance and the repair algorithm in VANET, which has frequent path loss in high-mobility. We assessed the performance improvement by comparing the AODV(-PGB) protocol including the routing repair algorithm with pure AODV, pure AODV-PGB, and GSR in a realistic traffic environment using the Qualnet 4.5 [13] simulator.

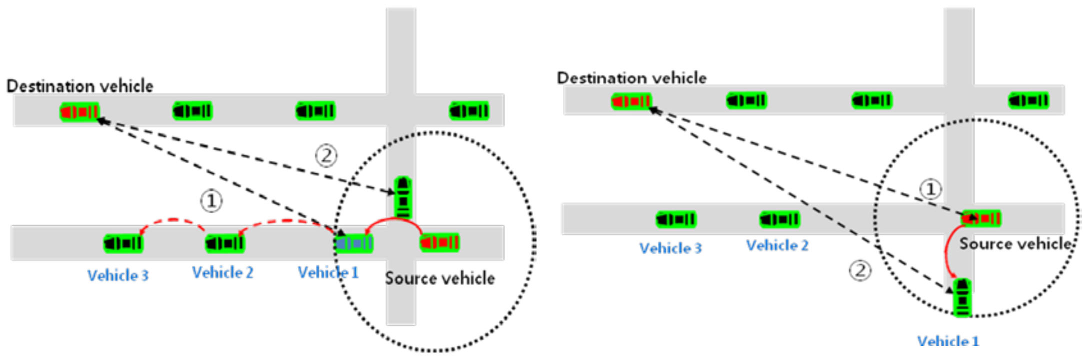
This paper is organized as follows. Chapter II reviews relevant literature about VANET routing protocols and routing repair algorithms. Chapters III and IV describe the proposed position-based routing path maintenance and repair algorithm of AODV (-PGB) in VANET and the simulation environment used to evaluate the proposed algorithm. Chapter V describes our assessment of the performance and compatibility of the proposed routing repair algorithm using a Qualnet simulator. The last chapter concludes with a summary of this paper.

2. Relevant Works

In this section, we present a qualitative comparison of routing protocols for VANET. We describe GPSR and GSR among position-based routing protocol, and AODV and AODV-PGB among topology-based routing protocols, all of which perform well in VANET.

2.1 GPSR and GSR in VANET

GPSR protocol was proposed by Brad Karp and H. T. Kung of Harvard University in 2000. This protocol is wireless datagram networks that use the positions of routers and a packet's destination to make packet forwarding decisions. The protocol makes greedy forwarding decisions using only information about a router's immediate neighbors in the network topology. When a packet reaches a region where greedy forwarding is impossible, the algorithm recovers by routing around the perimeter of the region [6]. Each node in the network periodically broadcasts its own position information to make a table of neighbor nodes. The source node performs greedy forwarding by selecting the closest node to the destination node, using position information of neighbor nodes (assuming the source node already obtained the location of the destination node). If the source node can't detect a closer node than itself, then GPSR is operated in perimeter mode. The advantage of Greedy forwarding is its reliance only on knowledge of the forwarding node's immediate neighbors [6].



(a) Greedy forwarding mode on VANET **(b)** Perimeter mode on VANET

Fig. 1. GPSR protocol in VANET

In VANET, however, when the source vehicle wants to send a packet to a destination vehicle, the source vehicle relays the packet through vehicles 1, 2, and 3 in greedy forwarding mode after selecting vehicle 1 as a relay node as shown in **Fig. 1-(a)**, because vehicle 1 is closest to the destination vehicle in source radio range. When the distance of ① is shorter than that of ② in the source vehicle's radio range as shown in **Fig. 1-(b)**, the source vehicle selects vehicle 1 as a relay node in perimeter mode. These eventually cause the packet loss. These problems occur quite frequently at intersections. Also, the routing path of VANET can easily cause routing looping due to the high mobility of vehicles.

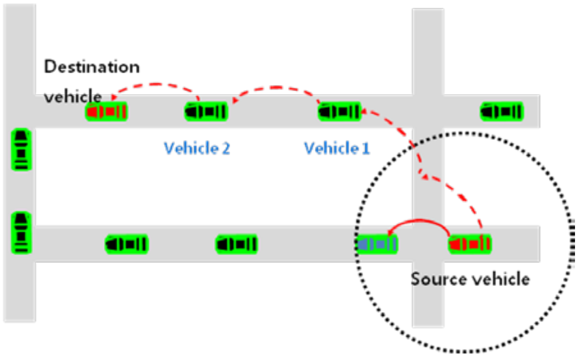


Fig. 2. GSR protocol in VANET

GSR was proposed by NEC Europe Ltd. in 2003, which tries to overcome the disadvantages of GPSR approaches designed for MANETs when applied to VANETs in urban scenarios. Using a street map and position information about each vehicle, this protocol computes a route for forwarding messages to a destination along the street. The source vehicle computes a sequence of intersections that must be traversed in order to reach the destination [14]. However, if vehicles are not populated on the road path between source and destination pairs in a sparse traffic environment, GSR is unable to find the routing path even if the source vehicle selects the path of dotted arrows based on the street map as shown in **Fig. 2**.

Compared with other protocols in a random network with uniformly distributed vehicles on a straight highway, GPSR and GSR protocols demonstrate better performance and scalability. However, irregular patterns on realistic traffic trace models prevent GPSR and GSR protocols from finding existing and populated paths between source and destination pairs [2]. Also, since there is no notification about connection and disconnection of the routing path, the source vehicle continues to send packets through a disconnected path until timeout occurs, whereas the broadcast-based route discovery of AODV normally reaches the destination vehicle if any connected path exists and the path can be managed by vehicles. In particular, the overhead of GPSR and GSR to acquire location service is almost the same as that of AODV to discover a path. The inconsistency of neighbor and destination positions while transmitting the packet leads to significant problems in GPSR and GSR protocols.

2.2 AODV and AODV-PGB in VANET

An AODV routing protocol was proposed by C. Perkins of the Nokia Research Center in 1999. This protocol made the best of both Destination-Sequenced Distance Vector (DSDV) and DSR to solve the point at issue of those protocols. It also showed the optimal efficiency in VANET out of existing topology-based MANET protocol. That's because AODV maintains the established routing path in the given period and copes well with fast-changing network topologies and high relative vehicle speeds [15].

AODV uses an on-demand approach to find routes. A routing path is established only when it is required by a source node for transmitting data packets. The source node then broadcasts a Route-Request (RREQ) packet to the destination node and receives a Route Response (RREP) packet from the destination node. The source node and intermediate nodes store next-hop information corresponding to the flow of data packet transmission. A major difference between AODV and other on-demand routing protocols is that AODV uses a destination sequence number to identify up-to-date routes. The main advantage of AODV is that delay in connection setup is reduced because destination sequence numbers are used to identify up-to-date routes to a given destination.

However, uncontrolled RREQ flooding of AODV generates many redundant transmissions, which may cause the so-called *broadcast storm problem* [16]. Packet flooding along the road expressly generates more broadcast storm and collision in VANET. That causes much delay and low throughput.

To improve AODV in VANET, [9] proposed AODV-PGB, which aims to reduce control message overhead and obtain stable routes by modifying RREQ broadcasting mechanisms. This protocol uses the location and power of received signal information when intermediate nodes reboradcast RREQ to establish a routing path. Intermediate nodes of the zone defined by signal power and location information rebroadcast the RREQ packet with delay, thus avoiding collision. That quickly establishes a routing path and reduces the hop count between source and destination.

Another disadvantage of AODV is that the node informs the end nodes of the path loss by sending an unsolicited Route-Error (RERR) packet until the end nodes acknowledge the notification when a path break is detected at an intermediate node [17]. AODV incorporates two types of routing repair methods: local repair and reconfiguration. A local repair protocol operates when the hop count between the intermediate node and the destination node is less than MAX_REPAIR_ TTL. The intermediate node broadcasts a RREQ after increasing the sequence number. However, if the hop count is greater than MAX_REPAIR_TTL or the intermediate node does not receive a RREP during the discovery period, the intermediate node transmits a RERR to the source node to reconfigure the routing path. AODV therefore incurs overhead and delay when reconfiguring or locally repairing a new route, because the AODV protocol requires additional overhead such as RERR, RREQ, and RREP on a global network. This is more serious in VANET because it has frequency routing path loss.

AODV(-PGB) waits for the construction of new routes when the existing route is broken. The frequent route failures result in a significant amount of time needed to repair existing routes or reconstruct new routes [2]. In VANET, path loss frequently occurs due to the high speed of vehicles. Therefore, maintenance and repair of established routing paths is necessary for the effective use of AODV(-PGB) in VANET.

In MANET, [18][19] proposed Router handoff as a preemptive approach to deal with route failure on AODV. Router handoff tries to detect a weakening link before it fails, and tries to find suitable nodes in the vicinity that can participate in routing around the affected link. If no suitable node can be found to perform the handoff, standard AODV route repair occurs as a matter of course after the link breaks [18]. Each node in this algorithm maintains a Neighbor Power List (NPL) and Power Difference Table (PDT), which contain the last received signal strength for Hello packets originating from active neighbor nodes. Every node that is part of an active route checks its predecessor link and the next link strengths periodically. If the link strengths are predicted to fall below the Handoff Threshold that is defined by the paper, the router handoff packet is initiated in one hop and the routing path is alternated before it fails. The handoff packet contains the addresses of the predecessor, next, handoff, and destination nodes, and the corresponding routing table entries. We confirm that this algorithm performs well in MANET in [18][19]. However, irregular patterns of signal strength in VANET, such as Doppler Effect due to high mobility and interference due to obstacles (e.g. buildings), make it difficult to apply this repair algorithm. Also, opposite direction vehicles temporarily have high signal strength, but should not be selected as alternative node because of short life time.

3. Position-based Routing Repair Algorithm of AODV (-PGB) in VANET

VANET creates overhead, transmission delay, and packet loss in order to repair and reconfigure the disconnected routing path caused by frequent path losses based on irregular traffic patterns with high mobility. Position-based greedy forwarding routing protocols were proposed to remove the network load for maintenance and repair of a routing path using position information in VANET. As mentioned previously, however, the protocols can't guarantee the reliability of packet transmission because they don't establish the path between the source node and destination node. The fact that AODV-PGB (which establishes a stable routing path based on the information of location and signal power) is more effective than GSR or GPSR proves the effectiveness of maintaining the path. An algorithm that can minimize network load generated by the maintenance and repair of the routing path and stabilize the routing path is needed for AODV and AODV-PGB to be an effective and optimal routing protocol in VANET. In this chapter, we explain this algorithm.

This algorithm aims to reduce network overhead and delay by repairing the routing path right after predicting the path loss, so as to eliminate redundant transmissions and obtain stable routes. Despite its irregular high dynamic mobility, VANET has regularity in that it moves in a fixed direction and in a limited area. Also, various information such as location, speed, and direction can be used in VANET. In practice, all routing paths are almost identical to the real road path, because vehicles must follow the road, and the radio range of each vehicle includes the road width (a minimum radio range of WAVE is 200 m). If the network experiences path loss, recovery of the routing path is executed by selecting the most stable node among the neighbor nodes of the relay node. The fact that the relay node with the possibility of path loss can select an alternative relay node means that it does not have to transmit the RREQ, RREP, and RERR to the global network to repair a routing path when it is broken, as may occur in MANET.

For quick repair and better maintenance of routing paths in VANET, an alternative relay node is selected before path loss. In this algorithm, we define the *threshold-zone* in order to detect the possibility of a routing path break. If a relay node detects a threshold-zone, the relay node transmits a *handover packet* to the previous node, the alternative nodes, and the next node with the aim of maintaining and repairing the routing path. This handover packet contains the node ID and the location, speed, and direction information of the predecessor, the alternative, and the next node. It also contains the destination address and the corresponding table entries.

3.1 Definition of Threshold-Zone

A relay node should lie in the relay domain that can transmit a packet. The relay domain space is defined by combining the radio range of the node sequence. In **Fig. 3**, node B is the relay node that delivers a packet from the previous node (A) to the next node (C). If node B leaves the domain, the routing path (AB→C) will be broken. As shown in **Fig. 3**, the threshold-zone is determined according to the speed of the relay node, and maximum time to repair the routing path is based on the radio range of the previous node and the next node. When a routing path is established, a relay node periodically calculates the threshold-zone.

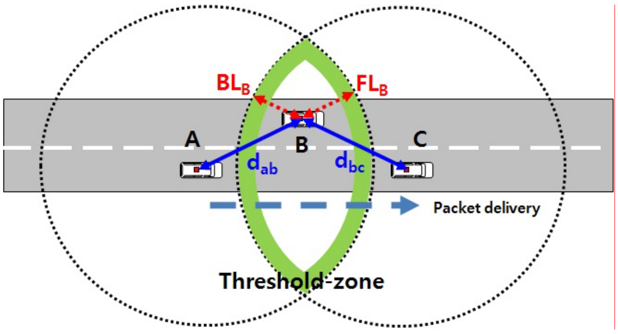


Fig. 3. The threshold zone of path loss

In this algorithm, the maximum time allowed for repairing the routing is computed on the basis of the transmission time of the Handover Packet (B→C, B→D, B→A) and the feedback time of the Maintenance-RREP (MRREP) packet from the next node to the previous one (C→D (alternate relay node)→A). Here the MRREP packet is the one defined to identify the alternative routing path. It may not be used as an optional message. In this paper, the maximum time for repair is set for 0.24 s, which is double is the time taken for transmitting handover and MRREP using the default value of node travel time according to the AODV standard: 0.04 s. If MRREP isn't used here, the maximum time will be 0.08 s. Therefore, the threshold-zone is set for 0.24V_{node} m. When the routing path is set, the possibility of path loss can be identified every time the information of the neighboring node is received. If the Movement Limit (ML = minimum distance) of node B is less than the Th_B (threshold-zone) of node B, then node B detects the possibility of path loss. The ML of node B is defined by the minimum value between the Forward Limit (FL) and the Backward Limit (BL). The function is as follows.

$$Th_B = T_{recover} * V_{node\ B} \tag{1}$$

$$ML_B = min\ (FL_B, BL_B) \tag{2}$$

$$FL_B = r_a - d_{ab} \tag{3}$$

$$BL_B = r_c - d_{bc} \tag{4}$$

$T_{recover}$: Maximum time for repairing routing path
Th_B: Threshold-zone value
ML_B: Minimum distance until relay zone
V_{node}: Relay node speed
r_a: node A radio range
r_c: node C radio range
d_{ab}: Distnace between A and B
d_{bc}: Distnace between B and C

3.2 Routing Repair Algorithm

In VANET with high mobility, routing path breaks can happen in two cases: when the relay node moves out of the relay zone, and when the relay domain space narrows because the distance between the predecessor node and the next node increases.

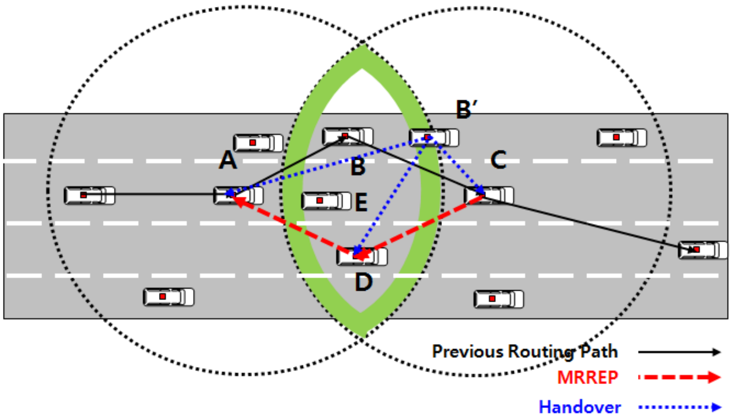


Fig. 4. Routing path repair on first case

In the first case (as shown in **Fig. 4**), if node B moves to B', then the node detects that it is in the threshold-zone by comparing ML_B with Th_B. Node B then selects the alternative relay node based on the latest information table of the neighbor nodes, which includes node ID, position, speed, and direction. In **Fig. 4**, candidates for the alternate relay node are nodes E and D. Node D is selected because of the long lifetime calculated by the relative velocity among the predecessor node, next node, and candidate nodes. Node B then transmits a handover packet to the previous node A, the next node C, and the alternative relay node D to announce its own state and start the repair algorithm. The next node receiving the handover packet generates and transmits MRREP to the predecessor node through the alternate node to confirm the routing path (A→D→C).

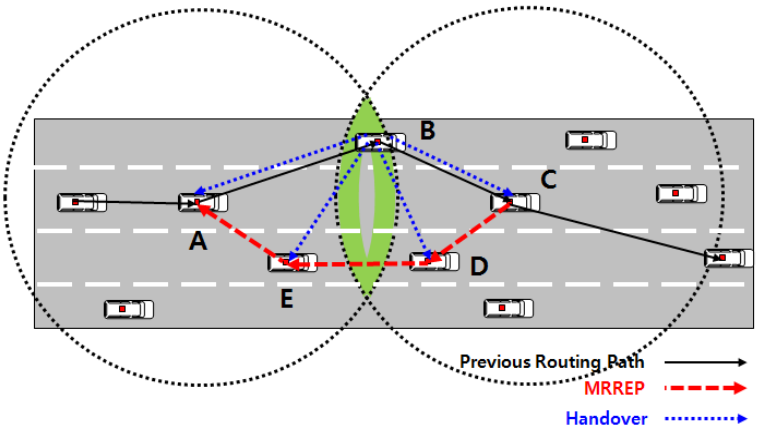


Fig. 5. Routing Path Repair on Second Case

In the second case, node B detects the threshold-zone because the relay domain space narrows, as shown in **Fig. 5**. That means that the hop count between nodes A and C is added. Relay node B then selects alternate relay nodes (D and E) and transmits the handover packet to announce the state of the network and operate the algorithm. The decision mechanism of alternate relay nodes is identical to the first case.

This algorithm can predict the path loss using the position information periodically updated from neighbor nodes and select an alternative path within 0.24 seconds. This time is a lot shorter than the two seconds taken for the existing AODV(-PGB) to check only path loss through the Hello packet. This algorithm also requires less overhead for path recovery than the previous handoff algorithm, because it uses only one handoff and one MRREP. If no suitable candidates for an alternative relay node are found on the information table of a relay node, then a relay node sends RERR to the source node to announce the routing path loss. That prevents bandwidth waste in the whole network. **Fig. 6** shows a procedure for the proposed position-based routing repair algorithm for AODV(-PGB) in VANET.

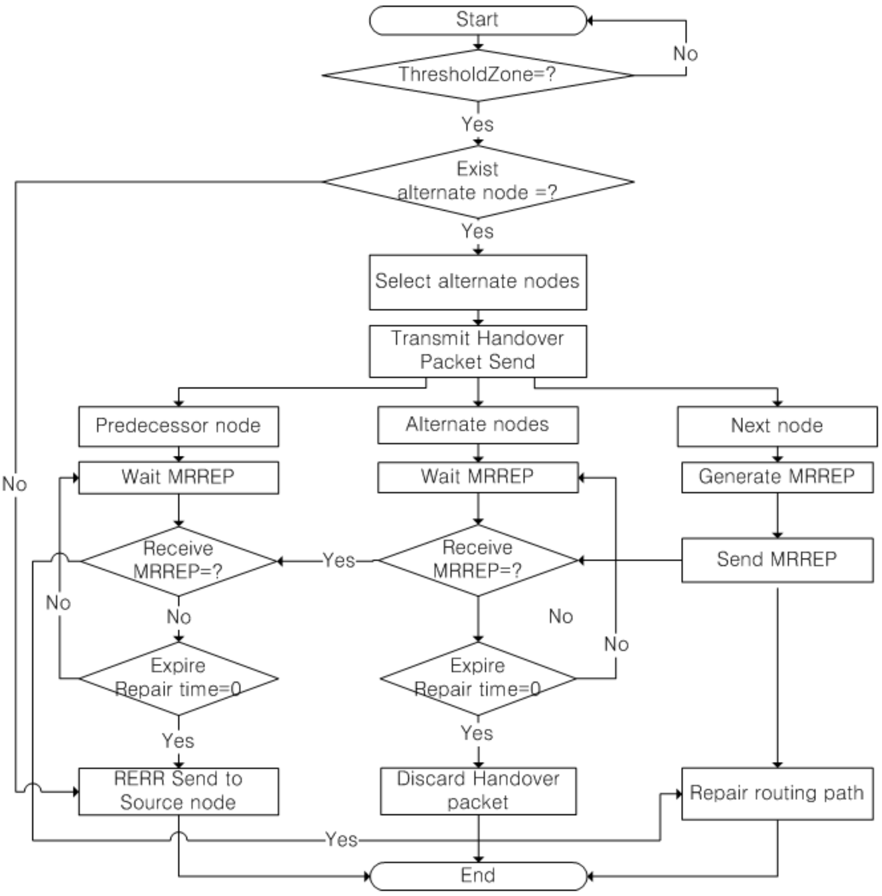


Fig. 6. Position-based routing repair algorithm procedures

4. Simulation Environment

This paper proposes and assesses a position-based routing repair algorithm for AODV(-PGB) that can be used effectively in VANET. This chapter presents its simulation environment. We simulated the algorithm using both an idealized mobility highway traffic model and a realistic mobility highway traffic model to verify performance.

4.1 Mobility Model Environment

Fig. 7 shows an idealized mobility traffic model to verify operation of the algorithm in VANET. We designed a model in which the relay nodes generate path loss with time. In this model, 13 nodes proceed at 120 km/h. The communication range is 200 m, and the distance between nodes is 150 m in lane.

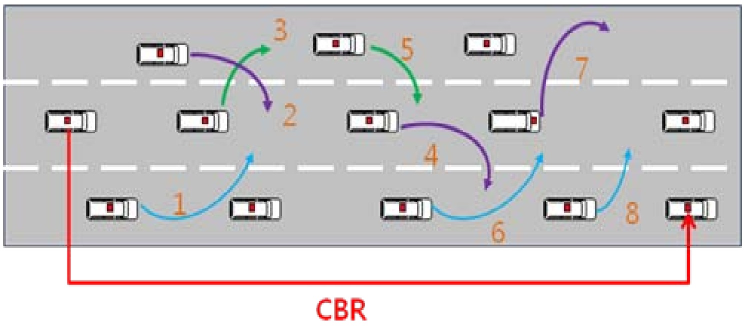


Fig. 7. The unrealistic mobility traffic model

Previous research has shown that the choice of specific mobility models for network simulations has significant effects on the simulation results [20]. Hence, realistic movement patterns are important for network simulations. We also simulated the algorithm in a realistic traffic environment to evaluate its performance fairly.

Mobility traffic models depend on the layout of the road, traffic density, and the behavior of the drivers. Simulation models of vehicular flow are typically classified as macroscopic or microscopic [10][22]. Macroscopic approaches focus on system parameters like traffic density (number of vehicles per kilometer per lane) or traffic flow (number of vehicles per hour crossing an intersection) in order to compute the road capacity or the distribution of traffic on a stretch of a road. In general, vehicular traffic is viewed from a macroscopic perspective as a fluid; therefore, existing fluid models are applicable. In contrast, in a microscopic approach, the movement of each individual vehicle is characterized primarily in terms of spatial and temporal characteristics. For wireless ad hoc routing experiments to generate vehicle movement patterns, one clearly has to follow a microscopic approach, since the position of each individual vehicle needs to determine whether a pair of vehicles can communicate with a certain range of radio communication [3]. Accordingly, the realistic mobility traffic model is based on a microscopic model. The mobility patterns for the model were generated by VISSIM, a simulator that produces traffic flow models similar to real traffic patterns. Highway traffic patterns are classified into five types according to road capacity and vehicle density. The following describes the feature of each type [21].

Type A: Perfect free-traffic condition
Type B: Good free-traffic condition
Type C: Stable traffic condition
Type D: Temporarily unstable traffic condition
Type E: Considerably unstable traffic condition

In this simulation, a realistic mobility highway traffic model is used in three types: A, B, and C. **Table 1** shows parameters of VISSM according to each type.

Table 1. Parameter of the realistic mobility traffic model

Parameter	Type A	Type B	Type C
Number of time septs[0.5sec]	120 [60sec]	120 [60sec]	120 [60sec]
Max speed of nodes	220km/h	220km/h	200km/h
Min speed of nodes	77km/h	76km/h	77km/h
Average Speed of nodes	140km/h	134km/h	128km/h
Number of nodes	108	236	340
Average node density [node/km]	9	20	29
Number of lane per direction	2	2	2

4.2 Network Simulation Environment

We assessed and analyzed two traffic mobility models with Qualnet [13]. The source node continually transmits a Constant Bit Rate (CBR) of 512 bytes to confirm path loss. All layers except the routing protocol were established based on IEEE802.11p WAVE. We modified AODV and AODV-PGB to apply the proposed repair algorithm and compare the modified protocols (AODV with repair algorithm and AODV-PGB with repair algorithm) with pure AODV, pure AODV- PGB, and GSR. A beacon was set up to transmit node ID and information about position, speed, and direction to neighbor nodes in one hop each second. The data transmission rate was assumed to be 6 Mbps, and the wireless communication range was set to 200 m based on default values of WAVE characteristics. **Table 2** shows the parameters of the network simulator.

An idealized mobility traffic model was set up by one CBR link to check routing path loss and operation of the routing repair algorithm based on **Table 2**, as shown in **Fig. 7**. The proposed algorithm is completed by 10 % background CBR traffic on a realistic traffic model.

Table 2. Parameter of network simulation environment

Parameter	Value
Application link	CBR
Transport	UDP
Network (Routing)	IPv4 (AODV, AODV-PGB, GPSR)
MAC	IEEE802.11p IP message
PHY	IEEE802.11a 6Mbps
Frequency	5.9GHz band 10MHz Single channel
Radio range	200m

5. Evaluation and Analysis

We set the default parameter values of AODV and AODV-PGB (except the repair algorithm) to evaluate and analyze the algorithm. Operation of the proposed algorithm was confirmed by simulations using the idealized traffic model. The network efficiency of the algorithm is analyzed in the realistic traffic model.

5.1 Idealized Mobility Traffic Model

The proposed routing repair algorithm rapidly set up an alternative routing path by changing the relay node right after anticipating a routing path loss. It is designed to reduce overhead and delay in the event of frequent routing path loss. In the idealized traffic model, we only compare AODV including the proposed routing repair algorithm with pure AODV to verify that the proposed algorithm shows improvement in VANET.

VANET routing paths are identical to real road paths, and therefore alternative routing paths are established by neighbor nodes. However, pure AODV almost initiates reconfiguration from the beginning whenever path loss occurs, resulting in additional overhead and end-to-end delay. **Fig. 8** shows the result of simulations with the idealized traffic model. AODV including the proposed algorithm reduces link breaks by selecting an alternative relay routing path and substituting the path before routing path loss occurs. Consequently, the overhead of RERR for notifying the source node of the link breaks and of RREQ-RREP for acquiring the new path decreases considerably. The four numbers of the link breaks don't generate RERR through the performance of local repair on AODV. This result verifies that the proposed algorithm operates effectively, increasing data throughput and decreasing delay in VANET.

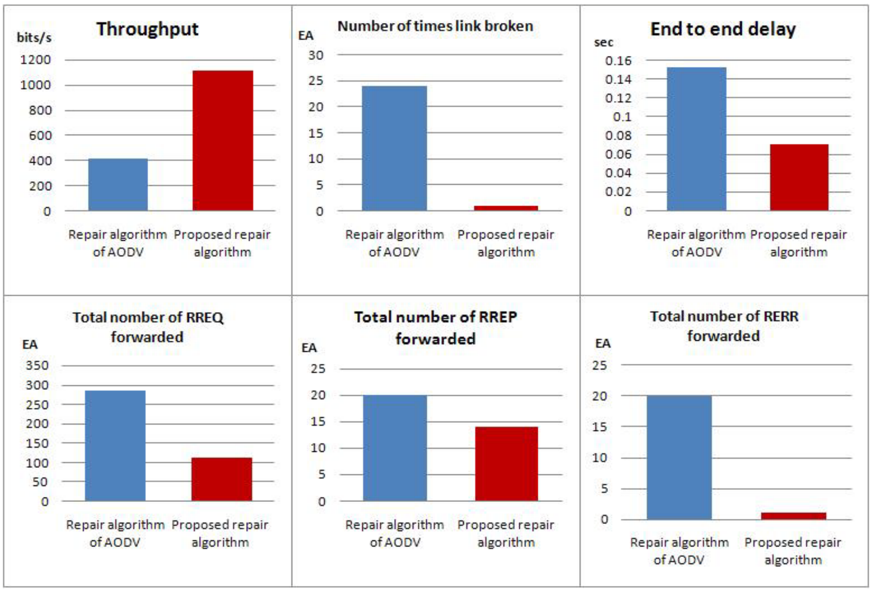


Fig. 8. Simulation result of idealized mobility traffic model

Fig. 9 shows the total overhead of the network layer and each node when pure AODV and AODV including the proposed repair algorithm are simulated in the same condition. With the transmission of an additional handover packet before path loss, the overhead of the proposed algorithm steadily increases during the simulation except in the early stage. Beginning overhead appears to initialize the routing path. It maintains a certain rate of overhead by reducing routing path loss and maintaining the routing path persistently based on information from neighbor nodes. For pure AODV, the overhead of the whole network increases sharply from the middle of a simulation because of the frequent RREQ, RREP, and RERR needed to perform local repair and reconfiguration of a path, which are generated from the frequent path loss caused by vehicle mobility. Moreover, analyzing the overhead of each node shows that the overhead of the proposed algorithm in the nodes with a path loss is less than that of pure ADOV for a routing repair.

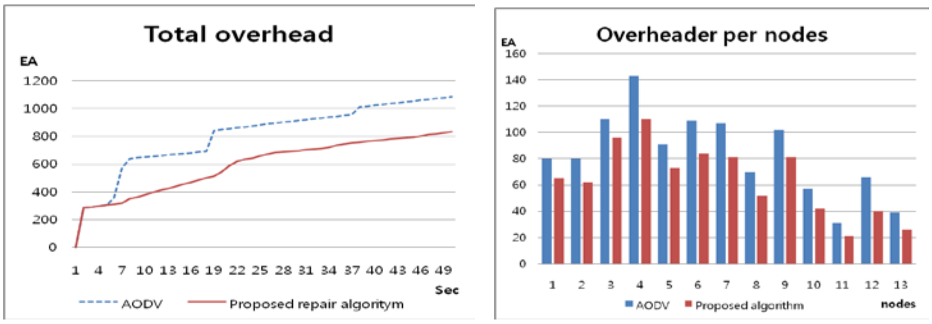


Fig. 9. Overhead of network layer of idealized mobility traffic model

5.2 Realistic Mobility Traffic Model

In the previous chapter, we confirmed that the proposed routing repair algorithm maintains an optimal routing path and performs rapid routing path repair in the event of path loss. In this chapter, we analyze the efficiency of the proposed algorithm in a realistic traffic environment and how much it improves performance when compared with the other protocols (pure-AODV, pure- AODV-PGB, and GSR).

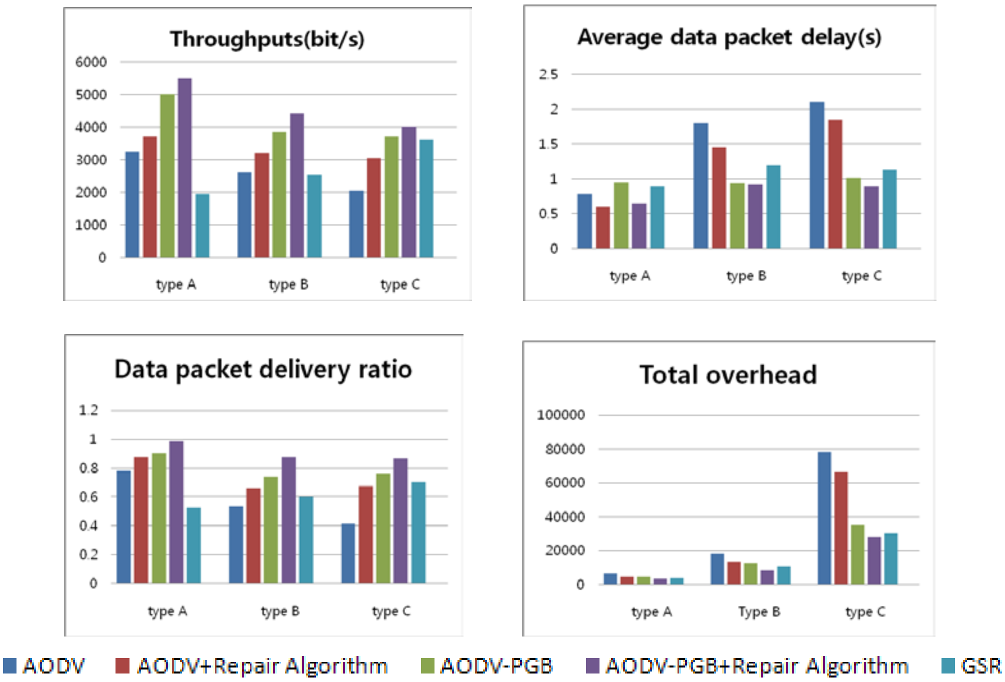


Fig. 10. Simulation result of realistic mobility traffic model

We confirm high performance of the protocols (including the routing repair algorithm) in a realistic traffic environment. The result is shown in three realistic traffic models according to the normal traffic volume. The protocols that include a position-based repair algorithm (AODV+ Repair algorithm and AODV-PGB+Repair algorithm) show improvement in data throughput and the data packet delivery ratio by immediately determining an alternative routing path when there is the possibility of path loss, as shown in **Fig. 10**. The protocols that include the algorithm show better performance than GSR, except for total overhead. GSR has no overhead, as there is no discovery, maintenance, or reconfiguration of the path. However, irregular and fast mobility of the destination node and intermediate nodes causes packet loss and bandwidth waste, resulting in long delay, low delivery ratio, and low throughput.

Although the proposed algorithm shows better performance than the other protocols in all realistic models, we confirm that network efficiency is different from vehicle density on the road. When path loss happens during low density, an alternative relay node may not be discovered on VANET when a node’s position is restricted. The fact that the relay node can't find an alternative node means that the routing path is completely disconnected. It also means that there are no forwarding nodes for position-based greedy forwarding protocol. In this situation, the proposed algorithm makes a relay node report path loss immediately to a source node instead of repairing the routing path. It prevents bandwidth waste, and makes a source node quickly find a new routing path.

The routing protocols with high density have more stable routing paths and a lower risk of path loss in VANET because there are many nodes of low mobility between the source node and destination node. However, if routing path loss is caused in VANET with high density, VANET generates a lot of overhead to repair or reconfigure the routing path. The proposed algorithm prevents this problem by substituting an alternative routing path in advance. In particular, an abundance of alternative relay nodes enables the relay node to select the most stable alternative routing path. GSR performs better as the node density increases. Although node density increases, additional overhead to establish or maintain a routing path doesn't occur, and it becomes more stable with the increase of the number of forwarding nodes. However, the fundamental problem of the packet loss caused by the moved position of the destination node is not solved.

The protocols including the proposed algorithm perform better than other protocols through stable path maintenance and fast path recovery. In particular, they perform better in low density than in high density in VANET. By maintaining a routing path, this location-based routing path repair algorithm is expected to show more improved efficiency, especially in a real traffic environment that has more possibilities of path loss due to many unpredictable traffic flows.

6. Conclusions

VANET requires rapid and reliable transmission, but with high mobility, topology-based routing protocol generates frequent routing path losses, high delay, and a lot of overhead. Although many position-based routing protocols have been proposed and assessed, their performances depend on factors of the traffic environment, such as irregular traffic patterns and node density. In particular, inaccurate node position information causes serious degradation of network performance because it doesn't establish a path between the source node and destination node.

While VANET has irregularity due to the high mobility of nodes, it also has regularity in that each node in VANET is located only on the road and moves in a fixed direction. In particular, it has the advantage that a vehicle can acquire additional information (location, speed, and direction) in VANET using GPS and Navi. These kinds of information are already being used as mandatory information in many ITS services. In this paper, we designed a routing path repair algorithm ADOV(-PGB) that is suitable for VANET in its features and simulated protocols, both in the ideal traffic model to judge the accuracy of the operation of the algorithm and in the realistic traffic model to verify its performance improvement in VANET.

The proposed algorithm predicts the possibility of routing path loss on a defined critical domain in advance, and maintains and quickly repairs the routing path by substituting for the relay node that may cause routing path loss. This reduces transmission delay, overhead, and packet loss, and increases data throughput. The focus of this algorithm is that the relay node can determine whether its alternative node exits, and judge whether the routing path is disconnected. It guarantees the continuity and the reliability of packet transmission by substituting the routing path depending on the network situation before path loss. Also, it prevents bandwidth waste by reducing packet loss according to the network situation in sparse VANET.

AODV-PGB including the proposed algorithm copes with the change of node density by efficient discovery, maintenance, and recovery of the routing path, overcoming the defects of both protocols (the heavy overhead and long delay of AODV, and the frequent packet loss of GSR due to the inaccurate node position). Accordingly, this protocol can be used efficiently in VANET, which has irregular topology change.

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