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Improved Paired Cluster-Based Routing Protocol in Vehicular Ad-Hoc Networks

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Abstract

In VANET, frequent movement of nodes causes dynamic changes of the network topology. Therefore the routing protocol, which is stable to effectively respond the changes of the network topology, is required. Moreover, the existing cluster-based routing protocol, that is the hybrid approach, has routing delay due to the frequent re-electing of the cluster header. In addition, the routing table of CBRP has only one hop distant neighbor nodes.

PCBRP (Paired CBRP), proposed in this paper, ties two clusters in one pair of clusters to make longer radius. Then the pair of the cluster headers manages and operates corresponding member nodes. In the current CBRP, when the cluster header leaves the cluster the delay, due to the re-electing a header, should be occurred. However, in PCBRP, another cluster header of the paired cluster takes the role instead of the left cluster header. This means that this method reduces the routing delay. Concurrently, PCBRP reduces the delay when routing nodes in the paired cluster internally. Therefore PCBRP shows improved total delay of the network and improved performance due to the reduced routing overhead.

Keywords: *VANET, AODV, Cluster Based routing, AD HOC Networks, PCBRP.*

1. Introduction

With the rapid development of computers and wireless communications, the mobile computing has already become the major field of the computer communication. The vehicular ad-hoc network (VANET) is a self-configuring network without the aid of infrastructure such as base stations or access points. In VANET, The network topologies are changed dynamically (and may vary) from time to time. Moreover, since nodes can come in and leave out, more routes may be frequently changed with requiring frequent route discovery among communication parties. Thus, in order to communicate efficiently, the robust routing protocol must be developed.

Ad Hoc Network routing protocols are classified in three main types: Proactive (Table-driven), Reactive (On-demand) and Hybrid. In proactive routing schemes, routing information is obtained and updated

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periodically regardless of requests for the route initiation. Proactive routing schemes, such as the destination-sequenced distance vector (DSDV) [1] protocol, perform well in terms of delay for the route initiation because the route information is readily available before a route request is initiated.

In reactive routing schemes, such as the ad hoc on-demand distance vector (AODV) [2], the route information is obtained when a route request is initiated. When a node needs to send data to another node in the network, the node starts the route detection process within the network. The node that needs a connection broadcasts a route request (RREQ) and receives their responses called a route reply (RREP).

Hybrid routing schemes, such as Cluster-based routing protocol (CBRP) [3][4], are a combination of a proactive and reactive routing schemes. In general, proactive routing schemes are used to obtain and update periodically the routing information within an arbitrary hop-distance from a node, and reactive routing schemes requests a route detection process only for a node over given hop-distance.

In CBRP, selecting a path and routing are performed by the cluster header in each cluster, but this approach has routing delay due to the re-electing a new cluster header. Therefore, more effective methods for electing and managing the header should be found first [5][6][7]. PCBRP, proposed in this paper, ties two clusters in one pair of clusters to reduce routing delay so that PCBRP achieves improved total delay and performance.

2. Related Works

In the cluster-based routing protocol, the concept of the cluster is used to divide nodes of a network into clusters. A cluster is composed of a cluster head node, cluster gateway nodes, and cluster member nodes. A cluster consists of nodes within a one-hop range. A cluster header functions as the coordinator of the cluster. A cluster header manages and operates its member nodes and maintains the routing information of the cluster. A node belonging to two or more clusters becomes a gateway, and it connects two neighbor clusters. A node belonging to a cluster, but not a cluster header as well as not a gateway node, is a member node.

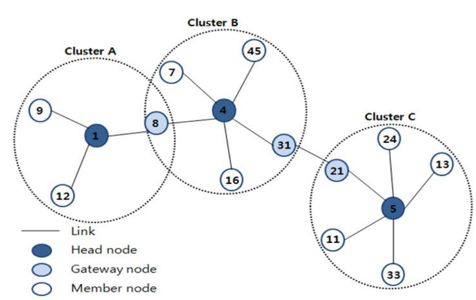

Figure 1. General Structure of CBRP

Figure 1 shows an example of the cluster based routing protocol with three clusters. Cluster A and B are overlapped, and cluster C is separated. Cluster A having four nodes composes of one head node (Node 1), two member nodes (Node 9, 12) and one gateway node (Node 8). The cluster header is elected each cluster to maintain cluster membership information.

The CBRP chooses the node with the lowest ID as a cluster head node.

Inter-cluster routing scheme performs routing process between clusters when a source node and a destination node are not in the same cluster. In this case, when a source node sends RREQ to the head node for setting up a path to a destination node, the head node floods the RREQ via cluster gateway nodes. When RREQ is arrived, a cluster header checks whether the destination node is in its cluster or not. If yes, then the cluster header unicasts RREP to the cluster header of the source node. If no, the cluster header floods RREQ to its adjacent cluster headers.

In CBRP, all the nodes in the network are separated in clusters and every cluster has its own cluster header which manages and operates so as to reduce the traffic for setting up a path and improve the performance of routing. However, whenever the cluster header moves out from the cluster or has some problems, a new cluster header should be re-elected. So, the cost of the routing overhead for reelecting a new header increases too much because all the management and operation of nodes depend on a cluster header.

3. The Proposed Protocol

In the proposed protocol, two clusters, based on the existing CBRP, are bound with a pair, and one bigger cluster is made. In other words, two adjacent clusters are made into one paired cluster.

The cluster finds the adjacent cluster whose stability is high in order to make the paired cluster with one cluster among the adjacent clusters. The adjacent cluster of high-stability is the cluster which has many gateway nodes connected with many other clusters. For example, there are three gateway nodes connecting the cluster A and cluster B, and one gateway node connecting the cluster A and cluster C. In this case, the cluster A and cluster B comprise the pair cluster. If the number of gateway node of the adjacent clusters is identical, the paired cluster is comprised with the adjacent cluster which recently gives HELLO message.

In this paper, for the sake of convenience in illustration, its own cluster is called C_M in the paired cluster. The other cluster is called C_P. Each cluster has the head node. Therefore, the paired cluster has both of the head node C_M and C_P. The head nodes of the paired cluster share the cluster information. That is, each head node of the paired cluster has two member tables. One is the member information of C_M, and the other one is the member information of C_P. Basically, the inner cluster routing is identical with the present CBRP.

3.1 Inter Paired Cluster Routing

In the existing CBRP, the inter cluster routing follows the proactive routing method. That is, the head node has the routing table about the member nodes and the routing information is used for routing. Even in case of routing with the adjacent cluster, setting up the route by using the control message is needed. In the proposed protocol, two adjacent clusters establish a pair, and it reduces the control message for communication between two nodes in a paired cluster.

Figure 2 shows the flow of the RREQ message in the method of route setting to the adjacent cluster in the existing CBRP. It is the case where the destination node belongs to the cluster A and the source node belongs to the cluster B. The source node transmits the RREQ message to its own cluster head node for setting the path. The head node confirms that there is no destination node in its own cluster B. The head node forwards the RREQ message to the gateway node in order to flood the RREQ message to the adjacent clusters. The gateway node receiving the RREQ message floods the RREQ message to the adjacent clusters A, C, and E. This process is repeated until the greatest limit number of hops ($RREQ_{MAX}$) of the RREQ messages. $RREQ_{MAX}$ prevents the excessive traffic of the RREQ message and is the maximum transmission distance for the loop-free. And it counts the number of hops in each head node. If the head node of the cluster A where the destination node exists receives the RREQ message, it unicasts The RREP message to the source node. As there are lots of the adjacent clusters, there should be lots of the flooding of the RREQ message, so big traffic is generated according to it.

Here, when the number of adjacent clusters is C_{ADJ}, the amount of the traffic of RREQ message required for the path setting can be found by the equation (1).

$$C_{adj} + \sum_{i=1}^{RREQ_{MAX}} C_{adj} \times (i-1) \times (C_{adj} - 1) \quad \cdots\cdots\cdots\cdots (1)$$

Figure 3 shows the method of path setting for the routing for the paired cluster in PCBRP. The cluster ID and the location of the source node and destination node are identical with Figure 2. This is the case that the source node and destination node belong to the paired cluster A. The source node transmits the RREQ message to the head node in order for the routing request. The head nodes of PCBRP share the routing information of members. The head node of C_M confirms the route to the destination node by using the shared member routing information as soon as it receives the RREQ message since it knows the member routing information of C_P. Next, the head node of C_M unicasts the RREP message to the source node.

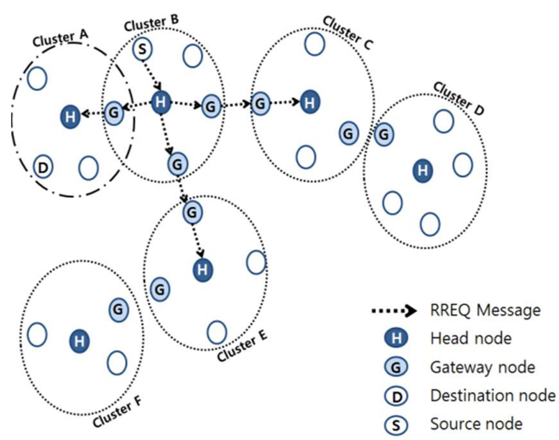

Figure 2. RREQ flow of CBRP (Case of the adjacent cluster)

In this case, the traffic of the control message decreases in comparison with the existing CBRP since the head node of C_M doesn't flood the RREQ message to the adjacent clusters. At this time, the route setting is possible by one time transmission of the RREQ message regardless of C_{ADJ} and $RREQ_{MAX}$.

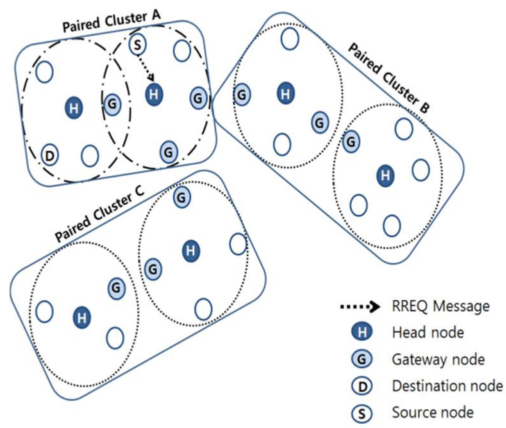

Figure 3. RREQ flow of PCBRP
(Case of the adjacent cluster)

3.2 Intra Paired Cluster Routing

In the existing CBRP, the intra cluster routing routes the member nodes with the reactive routing scheme. At this time, the traffic of many control messages is generated proportionally to C_{ADJ} and $RREQ_{MAX}$ as shown by the equation (1). In the proposed PCBRP, it makes a paired cluster by pairing the cluster with the adjacent cluster. And then it uses the member information of C_P and this results in decreasing the traffic of the control message in comparison with the existing CBRP.

Figure 4 shows the RREQ message flow in the case that the destination node and the source node are not the members of the same cluster as well as they are not the adjacent clusters. It is the case where the source node belongs to the cluster B and the destination node belongs to the cluster D. The source node transmits the RREQ message to the head node of the cluster B to set up the path. The head node searches the destination node and it confirms that the destination node is not in its own cluster. The head node forwards the RREQ message to the gateway node in order to flood the RREQ message to the adjacent cluster. The gateway node received the RREQ message floods the RREQ message to adjacent clusters A, C, and E. This process is repeated till the arbitrary $RREQ_{MAX}$. The cluster, which does not have the destination node, repeats to flood till $RREQ_{MAX}$, and the traffic of the control message is generated. If the head node of the cluster D, which includes the destination node, receives the RREQ message, it unicasts the RREQ message to the source node. As shown in Figure 2, in the existing CBRP, the route setting process for adjacent clusters is nearly identical to the route setting process for the clusters far from more than one cluster.

In CBRP, the traffic volume of the RREQ message for the route setting is calculated as the equation (1) if they are far away over two clusters each other.

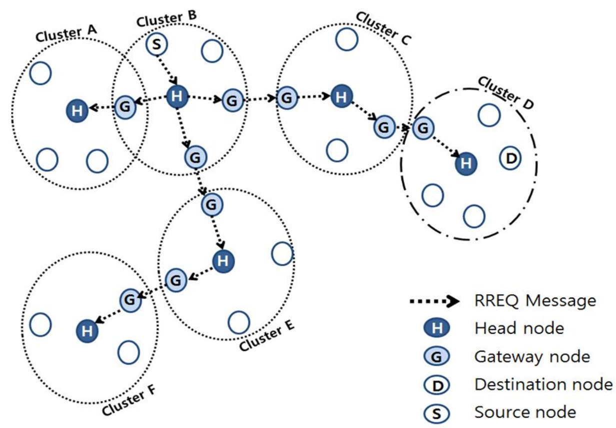

Figure 4. RREQ flow of CBRP (Case of two clusters at least)

Figure 5 shows the RREQ message flow in the method of route setting in the case that they are not adjacent clusters as well as the source node and destination node are not in the same cluster. That is the case that the source node belongs to the pair cluster A and the destination node belongings to the pair cluster B. The source node transmits the RREQ message to the head node of C_M which belongs to the paired cluster A in order to set up the path. The head node of C_M investigates the information of the destination node from the member information of C_M and C_P, then it confirms that the destination node is not in its own paired cluster. The head node of C_M forwards the RREQ message to the gateway node in order to flood the RREQ message to the adjacent paired cluster just like the existing CBRP forwards. After the head node of the cluster C received the RREQ message recognizes the destination node from the member information of C_P in the paired cluster, it unicasts the RREP message towards the source node. In PCBRP, the header of each paired cluster has more member information than that of the existing CBRP, so it finds the destination node faster. In addition, since it finds the destination node rapidly, the amount of control message can be reduced as well.

In PCBRP, all RREQ messages aren't flooded till $RREQ_{MAX}$ because all clusters are tied with pair. Concurrently, it doesn't flood the RREQ message to all adjacent clusters because the paired cluster shares member information. Therefore, in PCBRP, the less value can be used than $RREQ_{MAX}$ and C_{ADJ} in the equation (1), then the traffic volume of the RREQ message for the route setting is decreased in comparison with the existing CBRP.

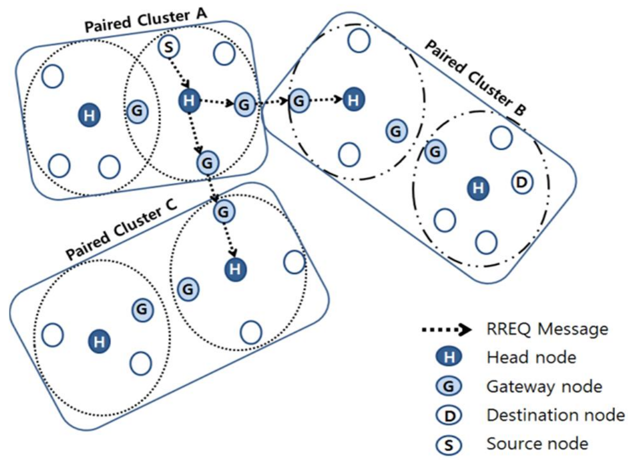

Figure 5. RREQ flow of PCBRP (case of two clusters at least)

3.3 Re-electing of The Head Node in PCBRP

In CBRP, the case of re-electing the head node can be happened since the head node goes out of the cluster or the energy runs out. In this case, the nodes belonged to the cluster join in the other cluster, or generate another cluster by electing their own head node with nodes who do not belong to any cluster. While the new head node is reelected the routing delay is generated to the nodes belonged to the existing cluster. The proposed PCBRP reduces the routing delay which is required due to the reelecting the head node since the head node of C_P routes the nodes of the paired cluster instead of the head node of the existing C_M. That is, in PCBRP, the head node of C_M basically establishes a path as the existing CBRP does. If the head node of C_M cannot communicate, the head node of C_P controls the routing of all nodes in the paired cluster during the delay which is generated due to reelecting new header.

Figure 6 shows the transmitting algorithm for the RREQ message when the head node of C_M cannot communicate with the source node in PCBRP. The source node transmits the RREQ message to the head node of C_M for the routing request. At this time, if the reply doesn't come from the head node, the PairedClusterHead field of the RREQ message is set in order to request the route to the head node of C_P. And the RREQ message is flooded to all nodes of C_M simultaneously.

```
RouteRequest Send(){
  if(ClusterHead.timeout){
    set field.PairedClusterHead true;
    RouteRequest broadcast;
  }
}
```

Figure 6. The transfer algorithm of RREQ message for the source node

Figure 7 explains the receiving algorithm for the RREQ message of nodes in which the head node has some problems like the above in PCBRP. If the node belonged to C_M receives the RREQ message, it checks the Paired Cluster Header field of the RREQ message. Generally, the node except the head node doesn't operate anything with the RREQ message. However, if the Paired Cluster Header field of the RREQ message has been set, it checks whether itself is the gateway node of the paired cluster or not. If it is the pair gateway node it floods the RREQ message to the head node of C_P. If not, the node floods the RREQ message to the pair gateway node to transmit the RREQ message to the pair gateway node. The head node of C_P received the RREQ message uses the shared routing information and member information. The header floods or unicasts the RREQ message to set the path by using this information.

```
RouteRequest recevie(){
  if(field.PairedClusterHead==true){
    if(node.role==PairedGateway){
      RouteRequest forword to PairedClusterHead;
    }
    else
      RouteRequest broadcast;
  }
}
```

Figure 7. The receive algorithm of the RREQ message

4. Simulation

4.1 The environment of the simulation

In order to evaluate the performance of the PCBRP proposed in this paper, we implements the simulation under following environment. As in the table 1, the network area is 1,200m x800m and the total number of node is 50. Each node is randomly located, and moves with maximum 10m/s. We use the Two-ray Ground Reflection Way for nodes and they have 100m transmission range. The total simulation time is 1,000 seconds and the simulation compares the performance of the existing CBRP and proposed PCBRP.

Table 1. Simulation Parameters

Parameters Name	Parameters Value
Protocol	CBRP, PCBRP
Simulation time	1000s
Simulation area	1200m x 800m
Nodes number	50
Transmission range	100m
Node speed	0~10m/s
Propagation model	Two-ray Ground Reflection
Packet type	UDP, CBR

4.2 Performance metrics

The metrics used to compare the performance of PCBRP we proposed and the existing CBRP are as follows:

1) Routing overhead: The ratio of the total messages of the network (data message + routing message) vs. routing message.

2) Packet delivery ratio: Ratio of data messages transmitted from the source node vs. data messages

received from the destination node

3) End to end delay: Delay time for Data messages successfully delivered from the source node to the destination node.

4.3 The simulation results

In this section, we compare the results using the performance metrics with the existing CBRP and the proposed PCBRP in VANET environments.

Through simulation, we can see the improvement of the performance in terms of routing overhead, end-to-end packet transmssion ability, latency.

Figure 8 shows the routing overhead over the time. As shown in Figure 8, the control message for routing occupies the whole of the message at the beginning of the simulation. However, it also shows that the ratio of the control message according to the whole message is gradually stabilized as the time is going on. Except the starting part of the simulation, we can see that the routing overhead of PCBRP is reduced in comparison with CBRP. If it is not the inner routing in a cluster the flooding of the RREQ messages is generated because the head nodes in CBRP have only the information of their own cluster members. On the other hand, PCBRP reduces the flooding of the RREP messages effectively because the head node of C_M shares the member information of C_P. This means that PCBRP reduces the control messages for investigating a route from the source to the destination about 25% in comparison with CBRP.

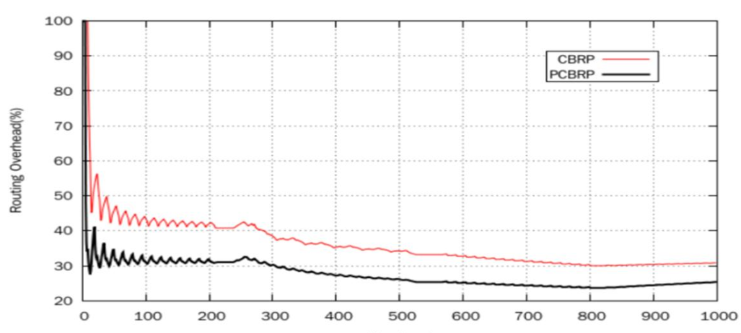

Figure 8. The routing overhead rate over time

Figure 9 shows the packet delivery ratio over time. It shows the unstable packet delivery ratio until the beginning 35 second. At the second term, it also shows that as time goes on after 30 second the packet delivery ratio gradually stabilizes. After that, the packet delivery ratio has been stabilized completely since 200 second from the beginning. The simulation shows that PCBRP has the higher packet delivery ratio than CBRP for the entire time.

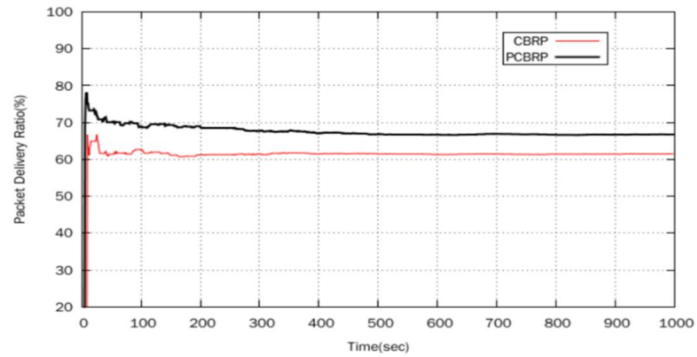

Figure 9. The packet delivery ratio over time

Figure 10 shows that end to end delay over time. As we can see in Figure 10 the unstable end-to-end delay exists at the beginning interval. At the vicinity around 270 seconds end to end delay shows similar delay time between CBRP and PCBRP, and then, we can see, the delay time decreases during the rest time. Here we could get the result which shows PCBRP has less end-to-end delay than CBRP for the entire time.

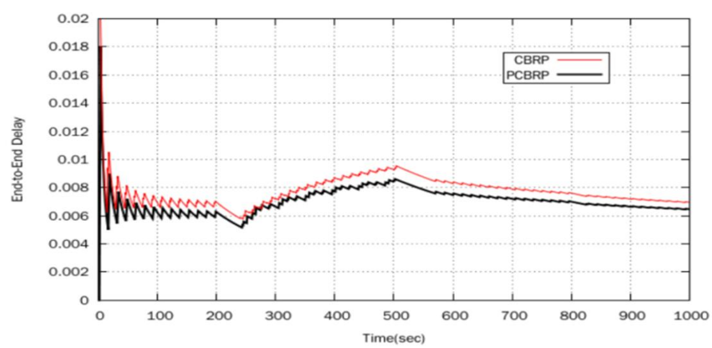

Figure 10. The end to end delay over time

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Type your main text in 11-point Times New Roman, single-spaced. Italic type may be used to emphasize words in running text. Bold type and underlining should be avoided. Do not use double-spacing. Leave a space between word and parenthesis. Special words of Latin or French origin should be in italic (*e.g., in vitro, et al.*). Be sure your text is fully justified-that is, flush left and flush right.

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5. Conclusions

In this paper, we propose an improved protocol called as PCBRP which makes a paired cluster. The cluster is an ordinary cluster in CBRP. PCBRP binds the clusters with a pair and makes the paired cluster whose radius becomes bigger than that of the existing cluster. In the paired cluster, a pair of two cluster headers manages and operates the member nodes. In the current CBRP, the delay due to the route setting and the traffic of control messages must be generated. On the other hand, in PCBRP, the delay due to the routing request and the traffic of control messages can be both reduced because PCBRP uses the proactive routing scheme in a paired cluster which consists of two adjacent clusters. Therefore, the performance of PCBRP is improved by the reduction of the total delay in the network and the traffic of the control messages.

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