An Improved Cluster Routing Algorithm Based on ZRP Protocol

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Abstract. Hybrid routing protocol combines proactive with reactive techniques, with the advantages of high reliability and low routing overhead. The Zone Routing Protocol (ZRP) is a typical hybrid routing protocol. This paper presents an improved ZRP routing protocol based on cluster domain mechanism. This protocol replaces partition in ZRP routing protocol with clusters in hierarchical network, and proposes a new domain routing method to avoid redundant or duplicate route requests. Theory analysis and simulations show that the ETE delay, routing overhead and packet delivery ratio performance of the protocol proposed here are superior compared to the traditional ZRP protocol.

Keywords: Ad-hoc · Zone routing protocol · Clustering
Hierarchical network structure

1 Introduction

Mobile Ad-hoc network, a special wireless mobile communication network system, consists of a set of wireless mobile nodes. In such a network, each node is free to move randomly and acts as router and server. Because of these, such a wireless network topology may change rapidly and unpredictably, which is the greatest feature of Ad-hoc network. Ad-hoc networks has broad application prospects, which with flexible networking modes and robustness. Existing routing protocols based on the wired network are not suitable for dynamically changing network environment of the Ad-hoc networks. So routing technology becomes one of the key technologies of the Ad-hoc network. At present, the routing protocol used by Ad-hoc network mainly includes proactive routing protocol, reactive routing protocol, and hybrid routing protocol combining the above two routing ideas. In the proactive routing protocol, the node maintains the latest and consistent routing information of all nodes in the network through the periodic broadcast routing information grouping. The advantage of this is that when a node needs to send data packets, the node maintains the routing information table in real time through interactive information, so the data delay is very small [1]. Though it performs well in data delay, it needs a large number of storage spaces. However, the reactive routing protocol is just the opposite. In the reactive routing protocol, when the source node needs to communicate with the destination node, the node of this protocol does not need to maintain the routing table at all times, thus makes

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it save storage space. The reactive routing protocol needs periodic broadcast information to update the routing. The advantage is that the routing overhead is small, but it may cause a little more time to transmit data. To solve the problems of these two kinds of protocols, hybrid ones tend to exploit the advantages of both proactive and reactive approaches. We focus on a typical hybrid routing protocol called ZRP (Zone Routing Protocol) [2].

Zone routing protocol is a hybrid routing protocol. It uses two different protocols in the web: the nodes in the region use the proactive routing protocol to maintain routing information; the external nodes out of the region adopts reactive protocol. And the size of the region can be adjusted to adapt to the changes of the network dynamically. So the overall performance of the network can be the best [3].

2 The Zone Routing Protocol

2.1 Architecture

Generally speaking, the ZRP protocol is mainly composed of three parts: IARP, IERP and BRP, and its architecture is shown in Fig. 1. Figure 1 shows how these three sub protocols interact to provide an efficient routing protocol that acts proactively in zone and reactively out of zone.

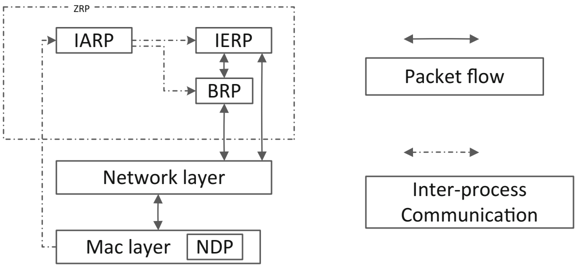

Fig. 1. ZRP components

All nodes in the ZRP network are based on their own center, and the number of nodes in the zone is related to the set radius. The IARP protocol maintains a routing table for other members within the region using a proactive routing algorithm in the region [4].

Interval routing protocol IERP is used to set up temporary routing. Packet delivery radio is implemented through the BRP protocol. ZRP declares an NDP protocol in order to detect whether new neighbor nodes and connections fail [5].

2.2 IARP

The intra-area routing protocol (IARP) is a pre-routing protocol within a limited area. It maintains routing information and routing tables between nodes through periodic broadcasts. It proactively monitors the connectivity of the regional network and provides support for route discovery and routing maintenance for nodes as needed. If a node needs to communicate with the nodes in the area, it can provide the route directly, thus reducing the cost of route discovery [6].

2.3 IERP

IERP is an inter-regional routing protocol. The protocol routes the communication of nodes in different regions and is responsible for reactively creating routes for nodes out of the zone. When the node is communicating, the target node and the source node are detected weather in the same area. If the destination node is outside of the region, we will enable the IERP protocol and send the routing request to the boundary nodes. After receiving the routing request, the boundary node looks up the routing table. If the destination node is found, it sends a routing reply to the source node. If not, it continues to forward the routing request to its boundary node, so that it can be searched until the destination node is found.

2.4 BRP

The Border-cast Resolution Protocol (BRP) is proposed to improve the efficiency of routing queries in IERP, thereby reducing the waste of radio resources due to redundant or repeated broadcasts. The BRP is responsible for forwarding the IERP routing request to the peripheral nodes of the border broadcast nodes. Although only the neighbor nodes receive the boundary broadcast packets, the BRP sends a query to the IERP at each hop. BRP records the node path that the request has been overwritten. When a node receives a query packet, it reconstructs the boundary broadcast tree to mark the peripheral node of the previous boundary broadcast node. Then the node becomes a new border broadcast node. The connection status is saved so that the query can be forwarded correctly from the higher layer before the query is sent to a higher level.

2.5 Discussed Problems

Though ZRP performs well in large scenarios, it still has some problems. The traditional ZRP protocol has planar structure, and the planar structure is not scalable. As each node in the scenario maintains a route table, there are lots of overlapping areas in the whole scenario. Those overlapping areas produce redundant or duplicate route requests. The best way to solve this problem is to use the appropriate clustering algorithm to construct a hierarchical topology. A group of nodes that are adjacent to each other form a cluster. The members of the cluster can be divided into cluster heads, cluster members and gateways. The communication between the cluster members is done through the cluster head, and the communication between the clusters is forwarded through the gateway. This reduces redundant routing requests.

3 A Strategy for Generating Clusters

The election of cluster heads is critical to the performance of the network, and a node's ability is affected by a lot of factors. Based on the above considerations, a self-adaptive on-demand weighted clustering algorithm is adopted. We give a certain weight to the various factors that affect the performance of the algorithm, and obtain the comprehensive weight [7] (Fig. 2).

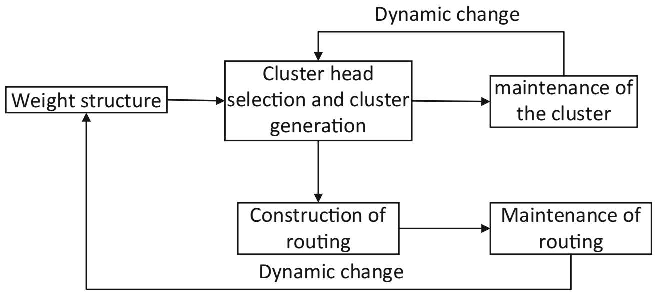

Fig. 2. Clustering algorithm

Because the cluster head node has to carry out its own information transmission, and also responsible for cluster message, group information maintenance and so on, so energy consumption is generally higher than the ordinary nodes. We put the node's residual energy as a factor. In addition, the node connectivity, that is, the number of neighbors is also an influencing factor. Based on the above factors, we define a value named N to measure the ability of the node to manage the network. When N is bigger, it is more capable of becoming a cluster head node. We have that

$$N = d \times T_{\mathrm{i}} \tag{1}$$

Where d is the degree of the node i, T_{i} is the time of the node i to be the head. The average energy consumption rate of the group is

$$E_{\mathrm{avg}} = \frac{E_{\mathrm{s}}}{T_{\mathrm{s}} - T_{\mathrm{e}}} \tag{2}$$

Where E_{s}, T_{e} refer to the node is selected as the first group of energy and time respectively. T_{s} indicates the current time. Assuming the node's node set be N_{i}, e_{ij} is the amount of energy that the unit data is sent to its neighbors. K_{ij} is the data flow from node i to j. Then the total energy consumption of node i is

$$E_{\mathrm{i}} = \sum_{\mathrm{j} \in N_{\mathrm{i}}} e_{\mathrm{ij}} k_{\mathrm{ij}} \tag{3}$$

The time T_{i} that node i can serve as the head is

$$T_i = \frac{E_{ic} - E_i}{E_{avg}} \tag{4}$$

The cluster formation algorithm can be described as follows:

Step 1: Each node checks its own value N within a specified radius of the area. Then the node whose N is the maximum is selected to be a managing node. If there are more than one node owning the maximum value, we choose the node whose ID number is smaller.
Step 2: We consider the selected cluster head as the center. The nodes within the specified radius of the center form a zone.
Step 3: The cluster head node broadcasts information to the neighbor nodes and announces the establishment of a new cluster. The neighbor node sends a join message to the cluster head node, which includes itself and the group number to be added. If the node receives more than two messages, the node is a gateway node. The gateway node needs to send its own degrees, energy and other group numbers that can be reached to the cluster head node.
Step 4: Repeat the above process until all nodes join a cluster (Fig. 3).

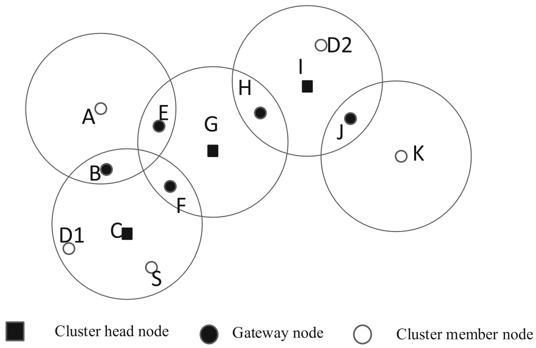

Fig. 3. Example of clustering algorithm

4 Improved Cluster Zone Routing Protocol

4.1 Improved Routing Mechanism

By clustering the network structure, the ZRP protocol has obvious advantages compared with the direct division of the network structure directly on the plane network structure. The characteristics of the improved cluster-based ZRP are: (1) by using cluster algorithm to form a domain, it is avoided that each node forms the domain by itself, thus reducing the number of domains and avoiding the entry of one node into multiple domains. (2) In the improved IARP protocol, only the central node maintains the route table in the cluster, and other nodes do not maintain the route table. So that the overhead of the node is reduced, the efficiency is improved, and the location information is used to trigger the update messages. (3) In the improved IERP protocol, inter-domain routing uses a hierarchical structure to reduce the number of routing request packets and improve the efficiency of the boundary nodes. This method has a good network scalability, and the joined nodes are only related to the cluster structure they join, so they will not affect the topology of the whole network. All in all, the improved IERP protocol is suitable for large-scale network [8].

When the data packet arrives at the node, the route discovery process can be described as follows:

Step 1: The source node firstly sends the request data to the cluster head node, then the cluster head node finds whether the destination node is in the region. If there is a route to the destination node in the same area, the source node then finds the route and send the data packet to the target node. If there is no route to the destination node, then skip to Step 2.
Step 2: Perform reactive inter-domain route discovery. The cluster head node of the cluster where the node resides sends the routing request information RREQ to the neighbor cluster head node through the gateway node. The cluster head node that receives the RREQ information determines whether the destination node is in the area maintained by finding its own route table. If there is routing information of the destination node, the destination node sends the RREP message to the source node; if it does not exist, the head node continue to send routing request information RREQ to its neighbor cluster head node. Repeat these steps until you find the path to the target node (Fig. 4).

4.2 Example

The network contains 15 nodes, which are divided into five clusters. Nodes A, C, G, I, K are the cluster head nodes of the cluster, nodes B, E, F, H, J are the gateway nodes of the cluster. The source node is S, the destination node is D1, D2.

(1) When the source node S is to communicate with the destination node D1, the node S firstly sends request data to the cluster head node C to find out whether there is routing information of node D1 in the route table. Since the node S and the node D1 are in the same cluster, the node S can communicate directly with the destination node D1 through the information in the route table.
(2) When the node S needs to communicate with destination node D2, there is no routing information for node D2 in cluster head node C. At this time, the cluster head node C sends the routing request information RREQ to the cluster A and the cluster G through the gateway nodes B. It is found that there is no information of D2 in the route table maintained by A and G, then the routing request information is forwarded through gateway node H. When node I receives the route request information RREQ sent by node C, node I checks to find the routing information of node D2 in the route table by checking it. At this time, node G sends a route reply information RREP to node C, then the cluster head node C forwards the information to the node S. So that the node S can receive the RREP information and communicate with the node D2.

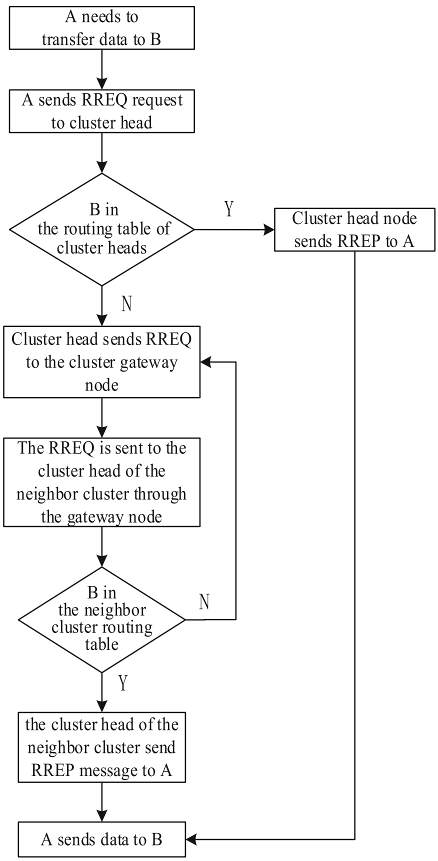

Fig. 4. Improved ZRP routing algorithm process

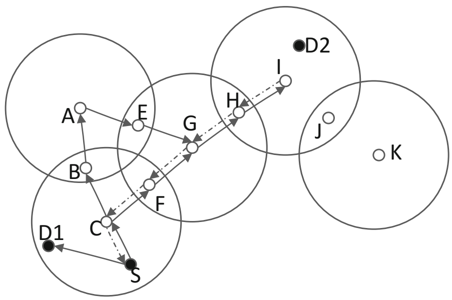

Fig. 5. Routing request process diagram

When the cluster head node broadcasts the routing request information to its neighbor nodes, the neighbor node may receive duplicate broadcast information and discard it for duplicate information. As shown in the Fig. 5, when the cluster head node C wants to find the routing information of the node D3, the gateway node broadcasts the routing request message RREQ to the neighbor cluster head nodes A and G. The node A does not have the routing information of node D2, then it will continue to forward routing request information RREQ to its neighbor cluster head node G. When node G receives the RREQ message, it finds that it is a duplicate routing request message and discards it.

The head node of the cluster where the source node resides may receive multiple routing reply information RREP after issuing the routing request information RREQ. When the repeated routing reply message is received, only the first received RREP message is selected as the routing information for the destination node, while other information is simply discarded. When the destination node is not present in the network or the existing network structure can't overwrite the destination node, the source node will receive a request error message RRER and notify the destination node that it is unreachable.

5 Analysis of Protocol Performance

In order to analyze the changes made and compare the performance between improved cluster-based ZRP and traditional ZRP, we evaluated both routing protocols in a simulation environment. Our simulations were conducted by OMNET Simulator. In the simulations, mobile nodes move around a square region of size 2000 m × 2000 m according to random waypoint mobility model. The node's speed is between 0 m/s to 10 m/s. The data packets are sent after 30 s the simulation starts. The packet size is 512 Bytes. The simulation time is 300 s. We analyze the performance between the two protocols from three aspects: end-to-end delay, packet delivery ratio and routing overhead.

Figure 6 shows the comparison of the end to end delay of the two route protocols. End-to-end delay refers to the time taken for a packet to be transmitted across a network from source to destination.

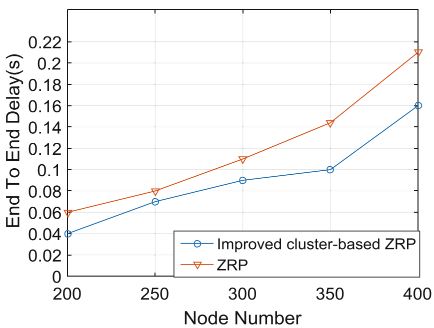

Fig. 6. End to end delay

As shown in Fig. 6, the improved cluster-based ZRP performs better than ZRP in end to end delay. It can be seen that the average end-to-end delay of the two protocols increases with the number of nodes increases. However, at the same number of nodes, the end-to-end delay of the improved ZRP protocol is always smaller than the delay of the ZRP routing protocol, and more obvious when the number of nodes is more. The improved protocol adopts a clustering-based partitioning method. It performs better for less overlapping zones and less request packets than ZRP. So it shows a smaller end-to-end delay than the ZRP protocol.

Figure 7 reflects the change of the packet delivery ratio of the two routing protocols with the increase of the number of nodes in the simulation scenario. Packet delivery ratio is the fraction of packets sent by the application that are received by the receivers and is calculated by dividing the number of packets received by the number of packets originated from the source.

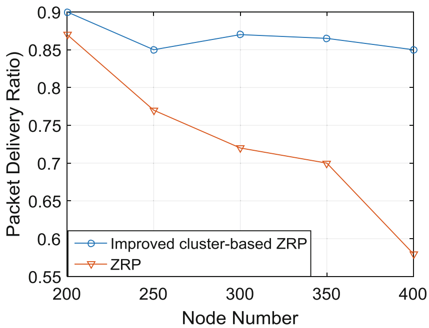

Fig. 7. Packet delivery ratio

As shown in the Fig. 7, with the increase of the number of nodes, packet delivery rate gradually reduces. Because the network topology changes more frequently, there are more route request packets in the network, which makes the network load heavier and influences the transmission of the data packets. So partial packet data may fail to send. But packet delivery ratio of the improved routing protocol is still higher than the original protocol.

Figure 8 compares the routing overhead of networks by using the two route protocols. Routing overhead is an important indicator of the efficiency of routing protocols. It is the total number of routing groups to be sent. In ZRP protocol, the nodes in the area adopt proactive route, regardless of whether you need to reach the routing of other nodes, these routes will be maintained in advance and regularly updated. As shown in the Fig. 8, as the size of the network continues to expand, the routing overhead increased significantly. Improved routing protocols can be used to cluster nodes in the network, so the number of messages that need to be sent for proactive routing maintenance in the region is reduced. Therefore, it can reduce the routing overhead and shows a lower routing load than the ZRP protocol.

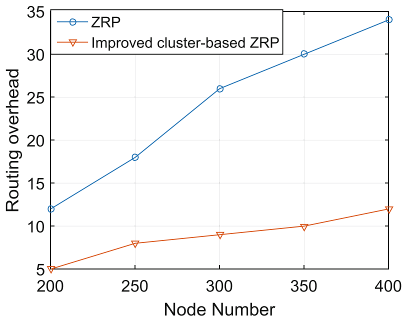

Fig. 8. Routing overhead

6 Conclusions

ZRP is a typical hybrid routing protocol which combines two completely different routing methods into one protocol. This paper proposes an improved cluster-based ZRP routing protocol, which solves the problem of poor extensibility and high overlap of routing area in traditional ZRP routing protocol. The improved cluster-based ZRP presents a new generation algorithm for cluster in hierarchical network, and proposes a new domain routing method to avoid redundant or duplicate route requests. Using this method, the improved cluster-based performs better in ETE delay, routing overhead and packet delivery ratio than ZRP.

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