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Improvement on Multicast Routing Protocol ODMRP Based on Path Stability

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Abstract. In mobile Ad Hoc networks, nodes' movement often makes the topology change frequently, which causes lots of routing interrupts and routing repair consuming limited network resources, while On-Demand Multicast Routing Protocol (ODMRP) can be more suitable for Ad Hoc. Based of above, NCR-ODMRP based on path stability is proposed, which uses the mechanism of Multipoint Relay (MPR) to limit flooding, and puts forward neighbor change ratio to choose three comparatively stable routes. As the result of the improvement, this protocol not only optimizes the multicast forwarding grid to reduce the overhead, but enhance the robustness. Through the comparison of simulation experiments, the results verify the improvement.

Keywords: Ad Hoc, multicast routing protocol, multipoint relay (MPR)

1. Introduction

Mobile Ad Hoc Networks (MANET), Ad Hoc for short, is a self-organizing collection of intercommunicating mobile nodes without a centralized coordinating entity or fixed infrastructure. Routing in mobile Ad Hoc networks because of frequent topology changes and dynamic group membership has special problems. Recent studies show that On-Demand Multicast Routing Protocol (ODMRP) has better comprehensive performance, which provides the anti-destroying ability through the redundant links, to reduce the unnecessary expense brought by routing searching for some link failures. Besides, it doesn't trigger the maintenance of routes when nodes move actively, which does not increase the network control expenses, as a result, it is more suitable to Ad Hoc[1]. However, ODMRP[2] floods JOIN-QUERY packets periodically to establish the forwarding grid. When load is larger, the control overhead of routing finding and updating increased rapidly, then the competition and conflict of the shared channel are intensified, which reduce the transmission efficiency. At present, improvements of ODMRP are focused on how to limit routing flooding, without taking the problem of path stability into account. For example, the method of motion prediction is commonly used to choose the backup path again when the previous path is expected to fail[3]. However, the nodes in redundant links can also move, which leads to the phenomenon of instability. Therefore, based on the flooding restriction, this paper introduces the factor of path stability to fully consider the stability of paths, and puts forward NCR-ODMRP.

2. NCR-ODMRP

The purpose of NCR-ODMRP is to make the network overhead as little as possible to transmit information, acquire more stable route when nodes constantly shift, to improve delivery ratio, and restore transmission route in short time when broken.

2.1. Restrict Flooding

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First of all, making use of Multipoint Relay (MPR) to restrict flooding in ODMRP, the purpose of which is to make node forward group selectively, as a result, we can use less forwarding expense, and gain the same effect as flooding. The two-hop neighbor of node N is defined the node which can be reached by two hops or more from node N[4]. Every node in network sends hello message periodically, which includes its neighbor lists. They can judge whether the link is two-way and gain their two-way neighbor lists and two-hop neighbors set. The information of MPR is also sent out in hello message, so the neighbor can identify itself MPR-Neighbor or NMPR-Neighbor. When receiving the flooding data, only the MPR-Neighbor can broadcast it. All the flooding data of node N can be received by its two-hop neighbors, through the forwarding of MPR-Neighbors[5].

Besides, nodes in Ad Hoc network are divided into two kinds: up-node and down-node, whose definitions are as follows: when node i forwards JOIN-QUERY package to node j, i is called up-node and j is called down-node. Only the up-node can forward JOIN-QUERY package, while down-node can not send it to up-node. Similarly, JOIN-REPLY packet only can be sent to down-node, which not only limit the forwarding of JOIN-QUERY package, but inhibit the flooding of JOIN-REPLY.

2.2. Predict Stability and Choose Stable Route

On the basis of flooding restriction, every node compares the differences between their neighbor set and calculates neighbor change rate by hello message received, to apperceive topological variation degree, then choose the nodes whose topological variation is less, to establish forwarding route. At last, according to the variation multiplicative value of every node in different routes, we can make the route which has the least topology change and less hops to be the primary route, and make another two node-disjoint routes whose topology change is less than others to be backup routes, which overwhelmingly enhance reliability of transmission and adaptability to movement.

2.2.1. Defination of neighbor change rate:

Supposing there is random distribution of N nodes in a mobile area, each node has its only sign. At t moment, the topology of Ad Hoc can be considered as a digraph G(t)=<V,E(t)>, where V={1, 2, …,N} is the set of all nodes at t moment and E(t) = {e1, e2, …, em} is the set of all edges. If node i can pick up signals sent by node j, there is a directed edge e(i, j), and node j is the neighbor of node i. All the neighbors constitute the neighbor set of node i. The computing formula of node i's neighbor change rate is as follows:

$$NCR_i = \frac{|S_i\_t_1 \cap S_i\_t_2|}{|S_i\_t_1 \cup S_i\_t_2|} \tag{1}$$

Among this formula, respectively, $S_i\_t_1$ and $S_i\_t_2$ is the neighbor set of node i at t_1 and t_2 moment, and t_2-t_1=T, which is the interval of sending hello message. NCR_i reflects the on-off state of links related to node i, which is the greater, the more stable of the local topology and the smaller, the more intensely local topology changed. At the extreme cases of that node i moves while surrounding nodes is static, or node i is static while surrounding nodes move, NCR_i is very small. The stability of route is defined as follow

$$SP_{path} = \prod_{i \in path} NCR_i \tag{2}$$

SP_{path} , the stability of route, is equal to the product of neighbor change rate of all nodes in route. Because there are maybe more than one route between source and destination, and the value range of NCR_i is [0, 1], using multiplicative processing intends to choose routes which are shorter and avoid nodes whose local topology changes intensely involving in data forwarding.

2.2.2. Calculation of NCRi:

- In this paper, the calculation cycle of NCR_i is set for $3\times T$[6]. Every T cycle, nodes exam that whether it has sent out broadcasting groups during last cycle. If not, broadcast a hello message, whose Time-To-Live (TTL) is equal to one. Local topology is detected and neighbor set is maintained according to received broadcasting groups sent out by neighbors. If nodes does not receive any broadcasting groups from certain neighbor (hello message included) at last $3\times T$ cycle, it is deemed that link to this neighbor is broken, and the node in neighbor set should be deleted.

- Supposing $S_{i}\_t_1$ and $S_{i}\_t_2$ are all neighbors appeared during the period of $[t_1-3\times T,t_1]$ and $[t_2-3\times T,t_2]$, and $t_2-t_1=T$. calculation of NCR_i is as (1).

2.2.3. Selection of node-disjoint route:

Node-disjoint route is also called completely unrelated route, which has no shared nodes with other routes, except for source and destination. As shown in Fig. 1, the route SAD, SBD and SCD between source node S and destination node D are all completely unrelated routes.

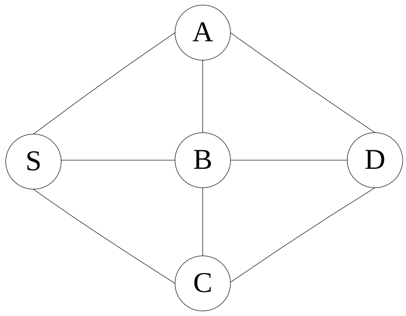

Fig. 1. schematic drawing of network structure

The node-disjoint route has the strongest fault tolerance, which won't cause a chain reaction for the independence of links. As DOMRP could produce more than one route, in order to choose relatively stable route and reduce the routing table overhead of each node, this paper selects only three node-disjoint routes when choosing multiple routes, even if getting more than three routes in the process of routing searching. Because the best compromise should be reached between efficiency and cost, when selecting three routes[7-8].

Based on the restriction of flooding, NCR-ODMRP amplifies ODMRP by using stable routes selecting method that neighbor change ratio based. The main differences between NCR-ODMRP and ODMRP are as follows:

- By reducing the overhead of the periodic flooding of JOIN-QUERY, NCR-ODMRP optimizes the multicast forwarding grid, and inhibits the JOIN-REPLY. It chooses the newest neighbors whose connection degree is the largest. Although overhead of hello messages is increased, it is so small, which depends on the intensive degree of network, and has nothing to do with the size of multicast group.
- The field of NCRpath is added in JOIN-QUERY packet, and it is updated according to (2) when forwarded by intermediate nodes. In addition, in order to choose the node-disjoint routes, the field of PathRecord is also added, which is used to record all nodes along route and judge the up-node and down-node.
- Conditions of updating routing table and forwarding packet are that serial number of packet is bigger, or serial number is the same while the value of NCRpath is bigger. The routing discovery and maintenance of NCR-ODMRP are as follows:

The source S is desiring to send packets to a multicast group but having no route to it. In this way, it will broadcast JOIN-QUERY control packets periodically to the entire network, which contains serial number, forwarding hops, NCR_{path} and PathRecord, respectively used to detect any duplicates, record transmitted hops, mark path stability and nodes along route. These JOIN-QUERY packets periodically broadcast to refresh the membership information and update routes. When an intermediate node receives the JOIN-QUERY packet, it stores the source ID, sequence number, up-node ID and NCR_{path} in its message cache to establish the reversed route. The routing table is updated with the upstream node ID (i.e, backward learning) from the message which was received for the reverse path back to the source. If the message is not a duplicate and the TTL is greater than zero or serial number is the same while the value of NCR_{path} is bigger, it is rebroadcast and the routing table is updated. In addition, if the value of NCR_{path} in JOIN-QUERY packet that firstly received is zero, and the subsequent value is zero too, the destination node will keep the existing route. Because, in this case, the end-to-end delay of route corresponding to JOIN-QUERY destination node received before is less than that of behind.

Destination node could receive multiple JOIN-QUERY packets from the same source, and instead of replying immediately when received, it waits for a period of time, and caching all routes from the same source, which constitute the routing set between source and destination. According to the request packets in current routing set, destination node selects route with the maximum NCRpath, namely the most stable routing as the first transmission path. From the field of PathRecord, destination node acquires all intermediate nodes in the route, then it sends JOIN-REPLY packet to source node, which contains nodes list of the whole route. Meanwhile, it compares NCRpath of routes in the current remaining routing packets with that of the first route. If some routes have the same value, it chooses the one which has the fewest hops. Then it detects the nodes in the route, if someone is the same with that in the first route, discards it, otherwise, replies to the source node with JOIN-REPLY packet. Repeat the process above, until it finds three node-disjoint routes.

At the stage of routing maintenance, NCR-ODMRP uses two ways of local recovery and routing reconstruction. When a link breaks down, using local recovery firstly, then doing routing reconstruction while it fails. As the intermediate node detects breakage, it cachings the data flow from source node firstly, then detects that whether there is backup routes in routing table, and it forwards data packet directly if there is, otherwise, sends routing request to neighbors. In a limited time, the destination node replies if it receives the request, which represents success of routing recovery and can be used to transmit data packets. Otherwise, the intermediate node sends routing reconstruction package to up-node, whose destination is the source node. After receiving the information, source node re-establishes routing according to the way routing established. If the source node receives routing reconstruction package and routing reply at the same time, it discards the routing reply and restarts routing discovery.

3. Simulation and Performance Evaluation

3.1. Settings of Simulation Scenes

NCR-ODMRP is simulated by NS2[9]and compares with ODMRP. The adopted scene is a 1200m×1200m square, in which the wireless coverage radius is 100m, and ten nodes are distributed at random, one of which is source node. The CBR Agent of NS2 produces the multicast data streams with jitter and fixed rate, the size of which is 512 bytes, and the sending rate is 10 packets/s. The moving speed of nodes is 0~20 m/s, whose moving direction is random and staying time is respectively 0~50 s. There is maybe some temporary breakdown in network. The average number of neighbor is 7.56. The propagation model is Two Ray Ground, and moving model is Random Way Point[10]. DCF of IEEE802.11 MAC protocol is applied in MAC layer. At the beginning of simulation, the multicast receivers join the group, and never exit in the whole stage. The process runs 400 seconds every time, then gets the averages from many results.

3.2. Performance Evaluation Index

Performance of NCR-ODMRP and ODMRP is compared according to following indicators:

- Packet Delivery Ratio: The ration of the number of data packets received by multicast receiver in fact to that sent by source node. This index is used to measure efficiency of data packets in the protocol, which indirectly reflects the stability of routes in the dynamic environment.
- Control Overhead: The various control overhead needed in every successful transmission of data packets on average, including JOIN-QUERY, JOIN-REPLY, hello and others. For the message transmitted in multiple hops is concerned, each hop is equivalent to a packet transmission. This index is used to evaluate performance of protocols in the respect of control overhead.
- Packet End-to-End Delay: The average differences between the time received by destination node and that sent by source node. This index is used to measure the efficiency of routing protocol.

3.3. Result and Analysis of Simulation

As can be seen from the Fig. 2, with the increasing speed of nodes’ movement, the number of disruption and reconstruction increased, as a result, the packet delivery rate of these two protocols tends to decline. Because NCR-ODMRP is based on the path stability, which choose routes with less topology change to forward data as far as possible, its packet delivery ration is always higher than ODMRP, and relatively balanced. As the speed increasing, the advantage is more and more obvious.

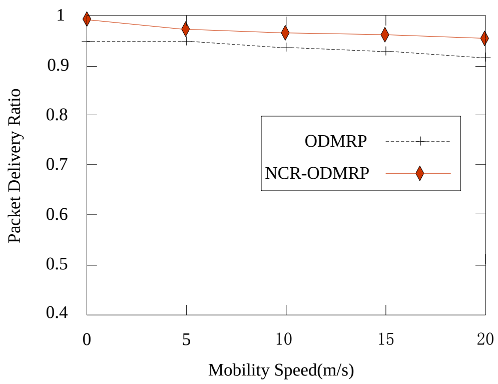

Fig. 2. the comparison of packet delivery ratio

Nodes need to send control packets to repair route, when the breakdown of links is appeared. As the moving speed is increasing, the times of repairing also increased, as a result, the number of control packets that sent increased significantly. NCR-ODMRP needs to send hello message to detect neighbors, so it has more overhead than ODMRP in the beginning. However, in the high-speed case, because the forwarding grid that established is more stable than ODMRP, and it only choose three routes, simulation shows its growth trend below ODMRP, which is shown in Fig. 3.

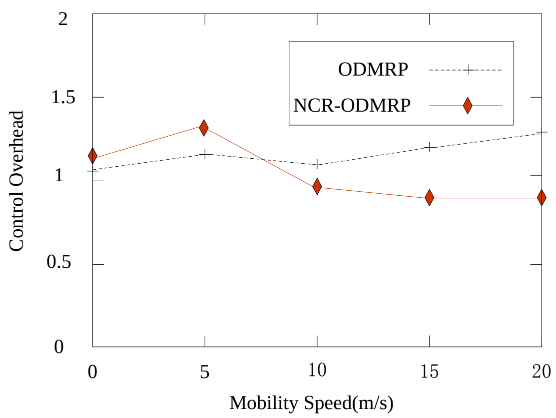

Fig. 3. the comparison of control overhead

As shown in Fig. 4, with the increasing speed of nodes' movement, ODMRP is influenced by the topology changes, and time of route establishing may be long, which causing the waiting time of packets that in node buffer queue is far higher than its transmitting time, so the average end-to-end delay change is greater. NCR-ODMRP takes path stability into count, which spend some time in calculating and waiting. So it has greater delay at the beginning, but owing to the stable routes, the delay that caused by routing recovery and reconstruction is reduced. Relatively speaking, NCR-ODMRP has smaller delay than ODMRP.

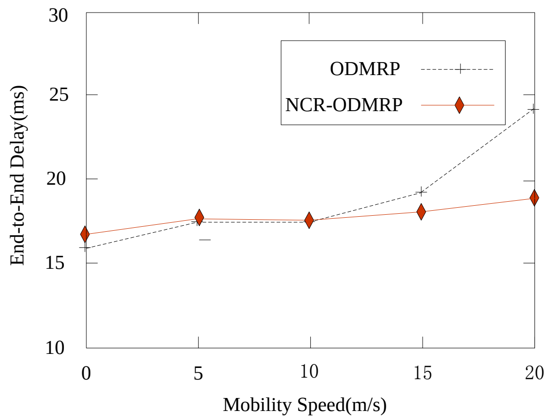

Fig. 4. the comparison of end-to-end delay

4. Conclusion

Based on the application of MPR to restrict flooding, NCR-ODMRP prefers to select stable routes from the respect of the stability of link, which have less topology change and less hops to forward data, and can recover in a short time at the stage of maintain. The simulation results show that, selecting route with this algorithm in the mobile scene can effectively reduce interrupt times and the end-to-end delay of data packets, and improve the transmission efficiency of the grid and robustness, and reduces the control overhead. In a word, it is greatly improved in the aspects of transmission performance, scalability and robustness.

In Ad Hoc networks, balancing nodes' energy consumption is a kind of new thoughts. As different special environments have different requirements for getting energy consumption minimization and energy consumption distribution balance are different, the future work should include: from the perspective of consumed energy balance, the strategy of saving energy consumption based on path stability is proposed, considering the characteristics of Ad Hoc networks.

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