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Research on Several Multicast Routing Algorithms

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Abstract

This paper first describes the dynamic multicast routing and routing optimization standard, then puts forward the RPL protocol based energy efficient DODAG multicast routing algorithm. Through simulation experiments, we can compare and analyze the advantages and disadvantages of several kinds of dynamic multicast routing algorithm. And according to the simulation results obtained conclusion, EE - DODAG multicast in the process of each packet sent after more a small amount of forwarding nodes, and consume less energy in survival time.

Keywords: *Multicast, dynamic multicast, delay constraint, On-line Steiner problem, Greedy Algorithm, DODAG, EE-DODAG multicast algorithm*

1. Introduction

Begin the Introduction two lines below the Keywords. The manuscript should not have headers, footers, or page numbers. It should be in a one-column format. References are often noted in the text1 and cited at the end of the paper.

With the great improvement of computer network transmission and processing capacity, more and more multimedia applications such as Video on demand, video conference, distance learning, computer collaborative work and so on are based on the network. In comparison with general network applications, these multimedia applications have the characteristics of large data volume, long duration, large demand for delay period, *etc.* Therefore, in order to solve the problems of large transmission bandwidth, strong real-time, *etc.,* it will be required to adopt forwarding technology and QoS safeguard mechanism, which are different from traditional unicast and broadcast mechanism. Multicast technology is precisely an ideal scheme to solve the problem.

Multicast is a kind of communication mode of point-to-multipoint. It can effectively use network bandwidth, and improve the utilization ratio of network resources. Multicast routing can be divided into two kinds: static multicast routing and dynamic multicast routing. The research of dynamic multicast routing is an important research direction in the field of multicast, and its algorithm is to deal with the update of the multicast tree after members joining and leaving.

2. Description of the Dynamic Multicast Routing Problem

The dynamic multicast problem that group members join and leave dynamically is called the On-Line Multicast Problem in the network, which can be formalized into the On-Line Steiner Problem in the network.

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Waxman first put forward the dynamic routing problem [1], made a research of dynamic Steiner tree problem [2], and divided it into two kinds: one is not to allow routing rearrangement, *i.e.*, the principle of optimizing route when members leave or new nodes join in communication group is that the communication paths of other members in the communication group are unchanged. The other one is to allow routing rearrangement, namely, when updating members, regulate communication paths of other members within the group can be changed, and communication routings of the whole group would be optimized.

Dynamic multicast routing algorithm is aimed at seeking for multicast tree T1, T2, …, Tm, and group member node of each tree Ti is the modified group member node after r1, r2, …, ri are requested. In all the possibilities of tree Ti, its cost (Weight of Edge) is the minimum one. There are two major kinds of dynamic multicast routing algorithms. One is not to allow the rearrangement of dynamic Stanley tree (DST, Dynamic Steiner Tree) algorithm, which Imase and Waxman have already proved [3]: when the request sequence is only composed of the increased nodes, the algorithm A is the solution for any dynamic Stanley Tree problem. The A (Si) is used to represent tree cost obtained through the basic node set Si after the algorithm A requests the ith node, OPT (Si) represents the optimal cost, ∀i (0<i≤k) can meet the requirements of Formula (1):

$$\frac{A(S_i)}{OPT(S_i)} \geq 1 + \frac{1}{2}\left\lfloor \log(|S_i| - 1) \right\rfloor \quad (1)$$

Another dynamic multicast routing problem that allows general rearrangement does not rearrange completely, but some parts of routing trees, *i.e.*, partial routing rearrangement. Based on the first two satisfactory conditions, another condition is added to the partial routing rearrangement problem: it is not necessary that there is an inclusion relationship between T and Ti-1, but in the process of routing rearrangement, the maximum degree of regulation from Ti-1 to Ti does not exceed the given upper bound B, namely, the maximum link numbers allowing regulation should be less than B.

3. Comparison of Several Non-Rearranged Dynamic Multicast Routing Algorithms Based on QoS

Routing is the bottleneck of multicasting. The design and choosing a suitable multicast routing algorithm and agreement is the key to develop and realize multicast technology. For people enhance the requirements for network service unceasingly, the routing problem with QoS (Quality of Service) constraints becomes a hot spot in the scientific research.

The algorithm that does not allow routing rearrangement means that when the group member set changes, *i.e.*, members leave or new members join in the multicast group, the original structure of multicast tree is not allowed to change; that is to say, when a node joins in, the tree edge cannot be deleted; when a node leave, edges cannot be added to tree. The advantage of this scheme is simplicity, and the sequence of information transfer would not be disrupted. Its disadvantage is performance instability, according to the Formula (1), we can see that the ratio of routing tree cost and optimal cost is unpredictable, even maybe worse.

This kind of algorithm includes “Greedy” Algorithm (GA) [4], Weighted “Greedy” Algorithm (WGA) [4], DPG Algorithm (Dynamic Prim-Based Greedy Multicast Algorithm) [5], DCDMR (Delay Constrained Dynamic Multicast Routing Algorithm) [6], *etc.*

3.1. Greedy” Algorithm and Weighted “Greedy” Algorithm

"Greedy" Algorithm is aimed at optimizing the network cost. The "Best" path is just the best path when a node joins in, with the update of members, the "best" might become the worst one; therefore, the performance of "Greedy" Routing Algorithm is seriously deteriorated sometime. In view of the randomness and unpredictability of member change, the performance of the proposed weighted "Greedy" Algorithm can be regulated by w under the worst condition. When W is equal to 0.5, the node u is connected to the connection host through the lowest cost path. Cost optimization has nothing to do with a node randomly joining and leaving. If the connection host is the source node, the weighted "Greedy" Algorithm means the destination cost optimization algorithm.

3.2. Dynamic Multicast Routing Algorithm Based on Minimum Spanning Tree

The dynamic multicast routing algorithm based on the minimum spanning tree is called DPG algorithm (Dynamic Prim-Based Greedy Multicast Algorithm), which belongs to the non-rearranged dynamic multicast routing algorithm. Because when all nodes are multicast nodes, the minimum spanning tree is the best one; therefore, the multicast tree performance generated by the algorithm should be within the reasonable scope. It turns out that the DPG algorithm is a dynamic routing algorithm, whose average invalid degree and maximum invalid degree are within the acceptable scope, especially, when the density of multicast node is high, its average invalid degree and maximum invalid degree are low; meanwhile, the average invalid degree of DPG algorithm is not sensitive to network scale and average node degree of network. Another advantage of DPG algorithm is low time complexity, and it is faster than "Greedy" Algorithm and weighted "Greedy" Algorithm.

3.2. Description of Delay Constrained Dynamic Multicast Routing Problem

Since the Delay Constrained Dynamic Multicast Routing Algorithm DCDMR means the destination cost optimization algorithm. It need not to regulate multicast tree, and can ensure the “Best” path when a node joins in; with the update of members, it is still the “Best” path.

Given a connected graph G = (V, E), G has n vertexes and m edges. V is the set of nodes, | V | = n, E is the set of edges, |E|=m, connected node u and V’s edge $e \in E$ is marked as (u, V). When each edge $e \in E$ has two nonnegative functions in contact with itself, cost C(e)： $E \rightarrow R+$ and delay D(e)： $E \rightarrow R+$. In the network path P= (v0, v1, v2, …, vn). D= {d1, d2, …, dm} represents the set of destination nodes, and all delay constrained destination nodes are stipulated asΔ. The set of initial basic nodes is $Q \subseteq V$. The dynamic change of nodes is represented by the node dynamic request vector R= {r0, r1, …, rk}, and each element in the “R” represents a node joining or requesting leave. Among them, ri is represented by a 2-tuple of (vi, ρi), $vi \in V$, $\rho i \in$ {add, remove}, the add means the request of that node vi requests to join in multicast group, and the remove means the requests that node vi requests to leave multicast group.

$$CostC(P) = \sum_{i=0}^{n-1} c(v_i, v_{i+1}) \tag{2}$$

$$DelayD(P) = \sum_{i=0}^{n-1} D(v_i, v_{i+1}) \tag{3}$$

The delay constrained dynamic multicast routing algorithm is aimed at seeking for Constrained Stanley Tree (CST) T1, T2, …, Tm, and group member node of each tree Ti is the modified group member node after requesting r1, r2, …, ri. In all the possibilities of tree Ti, its cost is the minimum one; meanwhile, the delay of each destination node in the tree should meet the delay constraintΔ; here the delay of destination node means the path of multicast tree from source node to destination node, marked as P(s, di) the aggregation of the time-delay on each edge. Namely, the following optimization problems are considered:

$$\min \sum_{(u,v)\in T} c(u,v)$$
$$s.t. \sum_{(u,v)\in P(s,d_i)} d(u,v) < \Delta, \forall d_i \in D \qquad (4)$$

This problem is still a NP-complete problem.

Link delay is composed of queuing delay, transmission delay and propagation delay [5]. Queuing delay is determined by the degree of network load, the emergency of information flow and business standardization in the network. Transmission delay is decided by link length, i.e. physical distance of nodes on both ends of link. Propagation delay is subject to the capacity of bottleneck link on the path.

3.4. Performance Analyses

We have constructed 20 random networks, the number of network nodes is 20, and average node degree is 4. α=0.1.β=0.2

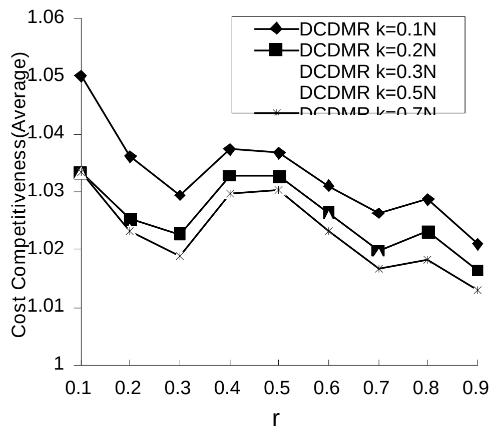


Figure 1. Relationship between DCDMR Algorithm's Effect Difference and k Value

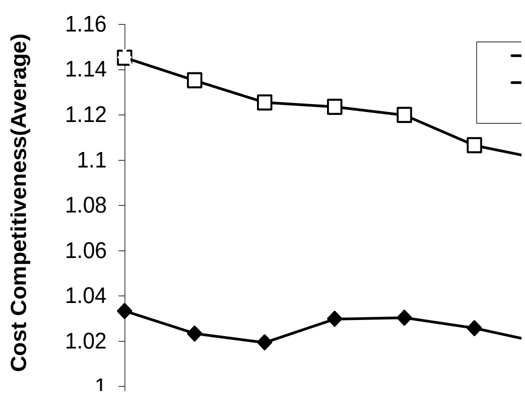


Figure 2. Average Effect Difference of Several Routing Algorithms

When γ is changed, make 20 times experiments in every random network, update members for 100 times in every experiment. Parameter k is the number of node in the priority list of the DCDMR algorithm, in the Figure 1.k is 0.1 *N*, 0.2 *N*, 0.3 *N*, 0.5 *N* and 0.7 *N* respectively, *N* is network node number. In the experiment, the number of network node is 200; therefore, the k is 20, 40, 60, 100 and 140 respectively. Investigate the influence of *k* values on average effect difference of DCDMR algorithm at different group scales. According to the simulation results in Figuer3-4, we can see that the greater the *k* value is, the smaller the average effect difference is, because the greater the k value is, the more nodes are in the priority list, the higher the possibility of nodes choosing low cost path for the access when joining. The DCDMR algorithm is tunable, use parameter k to regulate operation time for requesting joining, the results and average cost of multicast tree. If *k* is great, the considerable connection modes of new nodes and existing multicast tree will be increased. The *k* value increases the time of nodes requesting to establish the connections, moreover, it can increase the possibility of choosing low cost connection mode. From 0.1 *N* to 0.3 *N*, the performance of *k* value is improved much, but from 0.3 *N* to 0.7 *N*, the performance of cost is not improved much. In a given precision, curves basically coincide when k value takes 0.5 *N* and 0.7 *N*. This is because that after the number of nodes in the priority list reaches a certain extent, the optimal paths chosen by different nodes may be the same, and access nodes and connecting paths of new joining nodes and multicast tree are the same. And the increase of *k* value will increase execution time of algorithm, in the trade-off of cost and time, and *k* generally takes *k*=0.3 *N*. In the following simulation experiments, if no special instructions, *k* generally takes *k* =0.3 *N*.

The scale of multicast group is determined by the ratio γ of the member number and the network node number in the equilibrium state of multicast group. When γ is changed, 20 times experiments are conducted in every random network. And 80,000 data will be obtained every 100 times update of members. The Figure 2 how the relationship between average effect difference of DCDMR, "Greedy" algorithm and VTDM algorithm as well as the scale of multicast group, γ is changed from 0.1 to 0.9, in the VTDM algorithm, the number of virtual trunk nodes also takes n=0.3*N*. It can be seen from the simulation results that in the different group scales, from the angle of average performance, the cost performance of DCDMR routing optimization algorithm is better than that of other algorithms.

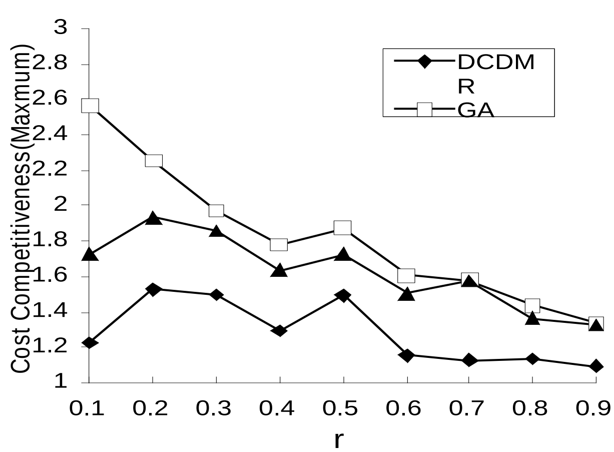


Figure 3. Maximum Effect Difference of Several Routing Algorithms

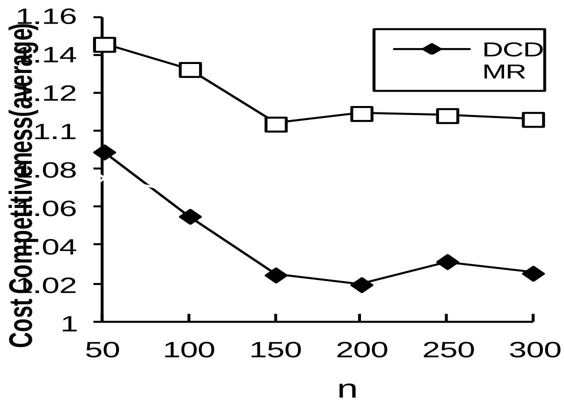


Figure 4. Relationship between Average Effect Difference of Routing Algorithms and Node Number

Figure 3 shows the relationship between the maximum effect differences of DCDMR, “Greedy” algorithm as well as weighted “Greedy” algorithm and the scale of multicast group. In the weighted “Greedy” algorithm, weighting coefficient takes w = 0.3 as recommended by Waxman. As seen from the Figure, with the scale of multicast group increases, the trend of maximum effect difference is in line with the change trend of average effect difference. But the maximum effect difference is greater than the average effect difference, especially when the scale of multicast group is relatively small. The maximum effect difference of “Greedy” routing algorithm is the largest one, which explains that the performance of “Greedy” algorithm would be seriously deteriorated sometimes. The maximum effect difference of weighted “Greedy” algorithm and DCDMR algorithm are not large, with the change of the scale of multicast group, their performance would keep stable, no serious deterioration. The maximum effect difference of DCDMR algorithm is smaller than that of weighted “Greedy” algorithm, because DCDMR algorithm is a destination cost optimization algorithm, which is uninfluenced by the dynamic change of multicast group, and the cost performance can keep stable.

4. DODAG Energy Efficient Multicast Routing Algorithm Based RPL Protocol

4.1. Issues Raised

Literature suggested that the way to achieve broadcast multicast packet delivery, and use Trickle mechanism to suppress duplicate multicast packet transmission control multicast packet and control packet transmission frequency, this approach is called Trickle multicast. Since Trickle multicast does not depend on the network topology, it is universal; In addition, since all nodes in the network to receive and buffer the multicast packet, in most cases, the breakage of a link of the particular node does not affect the group received multicast packet, and therefore high reliability. However, Trickle multicast group members do not have the registration process, a multicast packet will be sent to many nodes do not need to receive the packet, which will bring a waste of energy and link bandwidth node.

Other literature suggests otherwise, proposes a scheme based DODAG multicast protocol standard in RPL support basis [7]. In this DODAG multicast, all nodes are within DODAG work in storage mode, the receiving node multicast announcement by DAO message to DODAG root node to join a multicast group. When a node receives a notice from its DODAG DAO child nodes, the nodes in the routing table, add an entry for the multicast address, thus forming a multicast mesh structure. Thus, when a node receives a multicast packet, which has been established only in the case where the multicast forwarding entry, it will continue the multicast packet to its child node forwards. This approach leverages the DODAG topology RPL protocol established, little overhead; meanwhile, only multicast group members will be registered nodes multicast packet is received, compared to Trickle Multicast, this program improves on node utilization of energy and network bandwidth. However, considering the topology of DODAG, DODAG multicast there may be multiple parent nodes to a child node transmits a multicast packet problem.

4.2. Algorithm Description

(1) Establish multicast routing Table entries

In EE-DODAG multicast algorithm, the multicast routing table entries are based on group membership registration process. The receiving node sends a multicast message to the root node through the link DAO broadcast mode. All messages need to carry on the DAO-hop node address information for all multicast receiving node can reach. Once a node receives a message from DODAG multiple DAO child node, then the receiving node from which to learn which multicast sub-nodes which can be reached through.

As shown, the receiving node as a multicast nodes 13, 14, 15; solid arrow points to the node's parent node priority; dashed arrow pointing to alternative parent. For a node 1, it receives a registration message from the sub-DAO nodes 3 and 4, DAO node 3 in message carrying the address information of multicast receiving nodes 13 and 14, the node 4, the DAO message carrying the multicast receiving node 13 , the address information 14 and 15, it can reach the node 1 of the current multicast receiving node is node 13, 14, which can be reached through the node 3 receives the multicast node set is {13, 14}, the node 4 may be by arriving multicast receiving node set is {13,14,15}. After the end of the group members to register and establish multicast routing table entries on node 1 to 6 and 8 to 11.

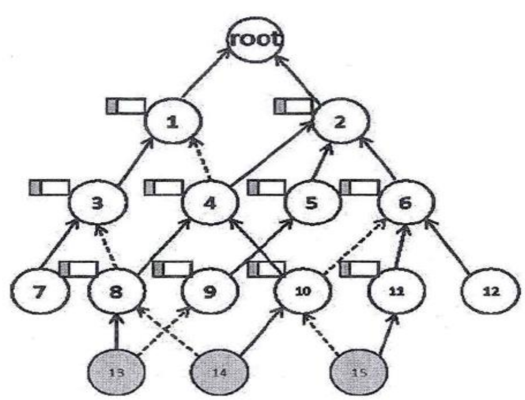


Figure 5. EE-DODAG Multicast Routing Structure

(2) Multicast routing rules

After the establishment of the multicast routing table entries EE-DODAG multicast routing rules, including the following five points [8].

Rule 1. After registration ends DAO, DODAG to multicast forwarding.

Rule 2. When a node i receives a multicast packet, node i first determine whether they have established multicast routing table entries, only the establishment of a viable child node set and forwarding node set of nodes fishes multicast packet forwarding.

Rule 3. When selecting the next hop node, node i from the forwarding node set Fi randomly selected element Aiv, Aiv may contain one or more neighbor node i forwarding node.

Rule 4. The address of the selected node i neighbor nodes recorded in the packet header, and forwards the specified neighbor node multicast packets.

Rule 5. Before forwarding node i multicast packet, the packet needs to be stored, in exceptional circumstances in order to re-select the forwarding node.

These rules can guarantee the number of nodes in the multicast packet forwarding process through which as little as possible. Every multicast forwarding path through the interior is actually DODAG a tree, so there is no problem DODAG invalid parent node multicast transmission redundancy to minimize the energy consumption of nodes.

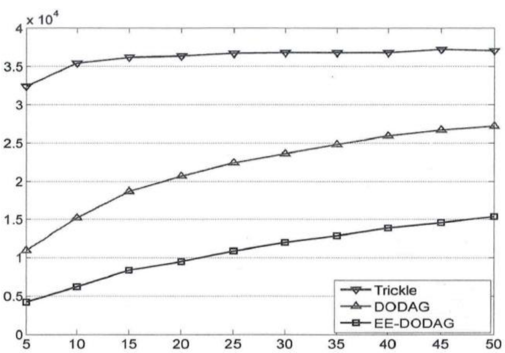
Due to a combination of the next-hop node to the multicast receiving nodes multiple reservations on each node, so this scheme has higher stability than the average multicast tree topology can adapt to the changing dynamics of low-power there loss network. Further, since the randomly selected set of nodes from the next hop node forwarding node, it can achieve the purpose of the energy balance to some extent.

4.3. Total Energy Simulation Analysis

In Figure 6, there are three multicast, Trickle multicast, DODAG multicast, and EE-DODAG multicast. When the network density $\rho = 10$ when their survival time, the total energy consumption of the network nodes with multicast destination nodes change curve.

Figure 7 show that when the multicast destination nodes is 30, the total energy consumption of network nodes within the network density changes over the lifetime of the curve.

The total energy



Multicast mesh nodes

Figure 6.The Total Energy Consumption of the Network Nodes with Multicast Destination Nodes Change Curve

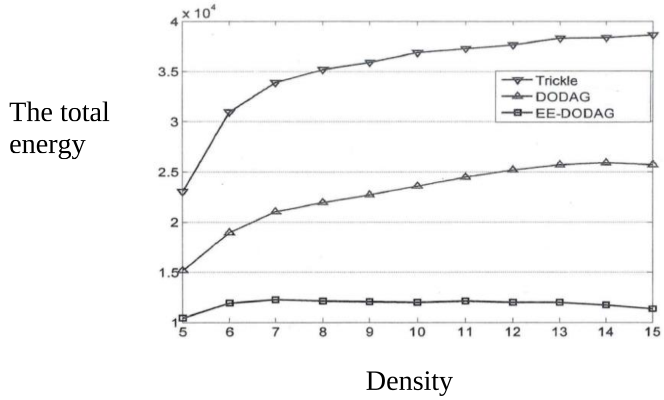


Figure 7. The Total Energy Consumption of Network Nodes within the Network Density Changes Over the Lifetime of the Curve

Seen from the above two Figures, the total EE-DODAG multicast energy in survival time was significantly less than the Trickle DODAG multicast and multicast.

5. Conclusions

Earlier in this article describes several of the more common dynamic multicast routing method, and compare their advantages and disadvantages. Later in the article, is based on previous research, we propose an effective amount of RPL protocol multicast routing algorithm (EE-DODAG Multicast) is based. DODAG topology of the algorithm, RPL protocol established in DODAG point reaches the root node multicast forwarding node receives multiple paths to establish multicast routing table entry, add a feasible set of child nodes and forwarding node set. Simulation results prove that, EE-DODAG multicast forwarding by a smaller amount in the process of each node in the packet transmission, and consumes less energy in the survival time.

Acknowledgements

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