A Heuristic and Dynamic Multicast Router Algorithm based on QoS

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Summary
As the internet developing rapidly, new requirements, such as video on demand and video conference are emerging. QoS based Multicast router arouses widely attention. This paper proposes a Delay-constrained Dynamic Multicast Routing Heuristic Algorithm (DDMRH) with combining FLSPT algorithm and the greedy idea. The emulation test shows that DDMRH algorithm can meet the demand of multicast application that is limited end to end delay and has variable numbers.
Key words:
Multicast router, QoS, DDMRH algorithm

1. Introduction

With the fast development of internet and multimedia technology, some new requirements, such as stream media, video conference, network game, distance education come forth. Consuming minimal time and space to transfer, high network efficiency to achieve, transfer rate to expedite and real-time application to realize are new demands for present internet. From users' point of view, it is expected that QoS (Quality of Service) can be guaranteed, such as high bandwidth, low point to point delay, restricted delay jitter and etc. Current internet can only transmit data to the destination as soon as possible, which does not provide QoS to its users. Therefore, researchers pay the more attention to multicast router technique based QoS, as a key technology to support network multimedia service.

According to the different characters of QoS measuring parameter, QoS measuring parameter can be divided into three types: accumulation type such as point to point delay, multiplicative type such as datagram loss rate and concave type such as bottleneck bandwidth[1]. To the different type of QoS measurement and the different combinations of QoS measurements, the computation cost is also different. It has been proved that any two or more accumulations based or multiplicative based router selection problem under multi constraint conditions is a NP complete problem[2].

For a given network, it is not feasible to consider all measurement for designing router algorithm. The problems
should be simplified according as the actual instance and application requirements. For example, regarding the research of multicast tree in the real-time multimedia transmission, the delay and bandwidth must be prerequisite, and the cost is an important factor to evaluate network efficiency. To these services, the problem of delay jitter can be solved by the buffer technique and can be also without regard. The most of current multimedia applications in network are provided with the mechanism of the error correction and can allow the packet loss which is restricted below a definite rate. The delay, bandwidth and cost can be considered as the three main constraint measurements to research real time multimedia transmission. In other application environment such as the multimedia conference system, the data flow is real time and interactive, so delay jitter should be the important factor and obligatory constraint measurement.

Recently many researchers focus their attentions on the bandwidth restricted multicast router problem, delay restricted least cost multi routers, delay restricted multicast router and delay jitter restricted multicast router and etc.

2. Delay restricted dynamic multicast router algorithm in least cost

The set of source nodes and multi destination nodes can form a multicast group. According to the relationship of members in this set, the multicast group can be classified as a static multicast group and a dynamic multicast group. During a session period time, the relationship of members in the static multicast group remained unchanged. However in the dynamic multicast group, members can join or quit dynamically. The named dynamic router problem is caused with dynamic changing of the members and dynamic updating of the multicast tree. When members in the multicast group are changed, there are two approaches to update multicast tree. One is abandoning the existing multicast tree and then using the static algorithm to reconstruct a new multicast tree. Another is updating existing multicast tree by adopting dynamic algorithm. In

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any dynamic multicast application, it is very important to assure that members joining and quitting will not break the current session. The graft and pruning mechanism is usually adopted to alter the multicast tree gradually. The changing of the multicast tree topology will be minimized in order to make router stability, after the members are changed in each time.

There are many research papers about the study of the infrastructure of dynamic multicast tree. When new node added in a multicast tree, dynamic greedy algorithm[3] uses the shortest path of the multicast tree. Moreover source based shortest path algorithm uses the shortest path to the multicast node. Destination-Driven Shortest Path(DDSP) algorithm[4] uses the incremental path strategy from Dijkstra algorithm, and it can always choose the shortest path with the longest path shared by other nodes to decrease the reconstruct consumption of the shortest path tree. The time complex of DDSP algorithm is O(|E| log |V|). Fast Low-Cost Shortest Path Tree algorithm (FLSPT)[5] takes the approach that alters the way to find the given node's father node, so DDSP algorithm can preserve its optimized father node for the given node, when we calculate attainable shortest path for the given node. This method takes the search not over again and decreases the calculating. The multicast tree constructed in FLSPT algorithm has the same performance as the multicast tree constructed in DDSP algorithm, but time complex of FLSPT algorithm is less than time complex of DDSP algorithm.

This paper proposes a Delay-constrained Dynamic Multicast Routing Heuristic Algorithm (DDMRH) with combining FLSPT algorithm and the greedy idea.

3. DDMRH algorithm

DDMRH algorithm is based on combination of the greedy idea and FLSPT algorithm. As each node joining a multicast tree T, by satisfying the delay constrain condition, DDMRH algorithm chooses the least cost path to the multicast tree and then join the multicast session. If this path does not satisfy the delay constrain, DDMRH algorithm will use the least delay path generated in initial phase.

Definition 1: a node in the generated tree is called the graft node. If a new node added to the graft node, the ramous will be generated by the graft node.

Definition 2: a graft path is the least cost path that satisfies delay constrain, when a member joins the multicast tree.
The process of DDMRH algorithm is described as follows:

(1) Regarding source node s as the root, we use FLSPT algorithm to calculate the least cost path (Pcost) and the least delay of each path (Pdelay) between the nodes. Then we can receive the cost and delay between each node pair. So there are two paths: One is the least price cost path (Pcost), and another is the least delay path (Pdelay). As a member joins the multicast session and try to choose a path, DDMRH algorithm will choose Pcost. if there are two or more paths with the same least cost, and DDMRH algorithm will choose Pdelay, if two or more paths are with the same least delay. If the delay and cost are the same, DDMRH algorithm will choose any one randomly. Pcost and Pdelay may or may not be the same path. According to their definition, the relationship between them is as follows:

$$\text{cost (Pcost)} \leq \text{cost (Pdelay)}$$
$$\text{delay (Pdelay)} \leq \text{delay (Pcost)}$$

(2) Regarding source node s as the initial tree T.

(3) Procedure of member joining. By the applying requisition operation ri = (vi, ρi = add), a host can join in a multicast session at any time. Initially, there is only one node s in the multicast tree. That is $T_0 = \{s\}$. Assuming the joining operation applied after k times, the multicast tree is called T_k. In this case a new node v is joining, the multicast tree will become T_{k+1}. Then there are two cases:

a) Node v is already in the multicast tree T_k. The multicast tree remains unchanged. $T_{k+1}=T_k$, $M_{k+1}=M_k \cup \{v\}$.
b) Node v is not in multicast tree T_k. Assuming there are N nodes in the multicast tree T_k. Since its least delay path and least cost path has been calculated from each node to node v, there are 2N paths that link v and T_k. DDMRH algorithm sorts these paths ascending, then searches these paths until finds a path that satisfies the delay constrain. If path P(k,v) is the result path, then DDMRH algorithm unites k into the multicast tree T_k and forms T_{k+1}.

As members join the multicast session, a loop may appear. Therefore, it is necessary to check the graft path and judge whether there is already a node in the multicast tree, before combing the graft path to the existing multicast tree. If there is already a node of the multicast group member in the existing multicast tree, this path must be pruned and then downward multicast paths must be also updated. The pseudo code for member joining is as follows:

```
//member joining
if v∈Tk
   Mk+1 = Mk + {v}
else
   mincost = ∞
   for each node k of Tk
```

```
    if delay(Pcost(k,v))+delay(P(s,k)) ≤ Δ
      if cost(Pcost(k,v))<∞
        mincost = cost(Pcost(k,v))
        Pcost(k,v) is graft path, k is graft node
    else if delay(Pdelay(k,v))+delay(P(s,k)) ≤ Δ
        if (cost(Pdelay(k,v))<∞
          mincost = cost(Pdelay(k,v))
          Pdelay(k,v) is graft path, k is graft node
  T_{k+1} = T_k ∪ graft path
 end if
```

(4) Procedure for member quitting. When a host quits from a multicast session, there are two cases:

a) If node v is not a leaf node, the node v will be deleted from multicast group M_k and will not receive multicast messages anymore, but still transmits messages.
b) If node v is a leaf node, the node v is deleted from multicast group M_k and stops receiving multicast messages. Then the upward node of v will be deleted, until the upward node has the ramous or is a multicast node.

The pseudo code for number quitting multicast group is as follows:

```
// member quitting
 T_{k+1} = T_k
 if v is leaf node
   m=v
   while US(m) ∉  and US(m) has only one subnode m
     T_{k+1}=T_{k+1}-P(m,US(m))
     m=US(m)
   T_{k+1}=T_{k+1}-P(m,US(m))
 end if
 M_{k+1}=M_k-v
```

The test in this paper uses the model proposed by Waxmam and modified by Salama[6,7]. It estimates the link whether exist or not based on the distance probability between the nodes. The function of the probability calculation is as follows:

$$\rho(u,v) = \beta e^{-\frac{d(u,v)}{\alpha L}}$$

Here, d(u,v) is Euler distance between node u and node v. L is the maximum Euler distance between a node pair. α and β are parameters of real type and α, β ∈ (0,1). By increasing β, the density of the links in the network can be increased. By increasing α, the number of the shorter links can be increased. Adjusting α and β can generate different random network topology. In this test we appoint α = 0.2 and β = 0.2. In each network, the link delay directs ratio to the link length, and the edge cost directs ratio to the edge length. The link cost is a random real number between 0 and 10, and the degree of each node is between 3 and 5.

If a multicast tree exists and satisfies the delay constrain, there should be at least one path form source node s to multicast number node m, and its delay is less than Δ (time delay constrain). Pdelay (s,m) is the least delay path from s to m and its delay must be less than Δ. That means, To any multicast member m, delay of Pdelay (s,m) is always less than Δ, and then the tree containing there paths is a tree that satisfies the delay constrain. DDMRH algorithm can always find a multicast tree which satisfying the delay constrain.

Pcost and Pdelay between a node pair are calculated by FLSPT algorithm beforehand. The most of calculating time which DDMRH algorithm takes is spent over processing node request. If a node quits from a multicast session, the worst pruning time is O(|T|). If a node requests to join to a multicast session, DDMRH algorithm need to find a graft node, and then combines that path to the multicast tree. In this course, it is also necessary to delete the loop path. The time for searching graft node is O(|T|), meanwhile the longest graft path of is O(|V|). As a result, the combination time is O(|V|) at worst, and the time for deleting loop path is O(|T|) at worst.

4. Emulation results

We have compared DDMRH algorithm to KPP algorithm and SPT algorithm in the emulation. In the emulation test we take one hundred data on each test point and then get the average as the final result.

Figure 4.1 shows the comparison between calculation time and the member nodes. There are one hundred nodes in the network. The member nodes change themselves from 1 to 91. For DDMRH algorithm and SPT algorithm, the calculation time shows the linear variation along with the increase of the number nodes. The ratio of SPT algorithm is lower, for it only needs to find the least delay path to source node. DDMRH algorithm must find an appropriate graft node in the multicast tree, so it takes some time. KPP algorithm makes the highest increase ratio than SPT algorithm and DDMRH algorithm, because KPP algorithm must recalculate all the multicast tree if a new member joins the multicast session.

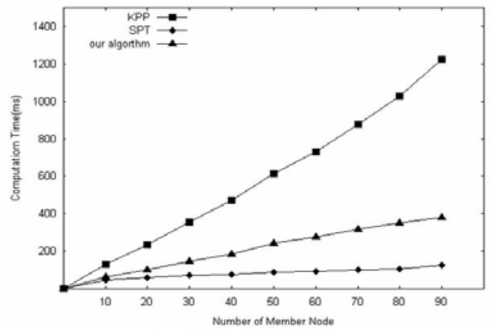

Figure 4.1 Calculation time with the change of multicast member nodes

Figure 4.2 shows the variation of the network cost with the change of member nodes. The member of network nodes is 200, and the member node increases from 20 to 180. The time delay constrain Δ is the maximal delay of from the source node to all other nodes. KPP algorithm has the lowest cost. SPT algorithm has the highest cost. DDMRH algorithm is in the middle. SPT algorithm only considers delay and is not optimized for the cost. In KPP algorithm the path of any joined member may not be the least cost path satisfied with the delay, but can be the least delay path.

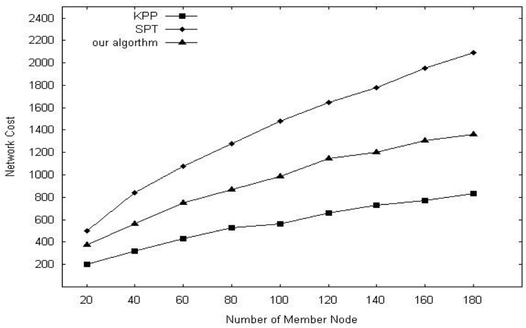

Figure 4.2 Network cost with the change of multicast member nodes

Thus it can be seen, the calculating cost of DDMRH algorithm is lower than that of SPT algorithm. The calculating cost of DDMRH algorithm is higher than that of KPP algorithm, but DDMRH algorithm takes the linear increasing speed, and whereas KPP algorithm has the greater increase ration than DDMRH algorithm as the member nodes increase. So DDMRH algorithm is an effectual algorithm.

5. Conclusions

This paper proposes DDMRH Algorithm with combining FLSPT Algorithm and the greedy idea. As a node joins a multicast tree T, this node chooses the least cost path to join to the multicast session, when it satisfies the delay constrain. The testing result shows DDMRH algorithm is suitable for the multicast application in the end to end delay constrain and members variable frequently.

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