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A Comprehension Study of Distributed Qos Approach Based on Selective Probing

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Abstract: The emergence of many new real-time network applications has great influence on the network routing algorithms. The routing function in the current internet is limited to provide "best-effort" service, which means it will try its best to forward user's data packets, but can provide no guarantees regarding bandwidth and delay. While this kind of service is suitable for some traditional applications such as ftp & telnet but it is not adequate for upcoming high-speed and real-time services such as audio-video real-time transmission, virtual private networks which requires strict delay & bandwidth guarantee. There are many facets for the guarantee of the Quality of Service. However the one of the key technology is QoS routing. The basic problem of QoS routing is to find a path satisfying multiple constraints. It is concerned with identifying the path that will consider multiple parameters like bandwidth, delay, cost, hop count etc. instead of one. QoS routing can be implanted in both of the routing strategies - Source routing & distributed routing for the traffic flow. In source routing, the path computation is done at source node whereas in distributed routing, the path computation is distributed among intermediate routers between source and destination. Both Sources routing and distributed routing have important roles to play in QoS routing. Source routing is seen impractical in Internet as the complete explicit path would have to be included in the IP header. Source routing is used in today's Internet for special cases only, such as mapping the network with trace route, troubleshooting etc. Distributed routing is currently the dominant method in Internet. Many distributed QoS algorithms have been proposed in literature by varying the QoS metrics and protocols. An important contribution in these works is [9]. This paper portrays the work of distributed routing approach mentioned in [9] .

Keywords: Distributed routing, Quality of Service, Bandwidth, Delay, Local State.

I. INTRODUCTION

To provide Quality of Service (QoS) guarantee both of the routing schemes –source routing and distributed routing can be used.

In source routing, the source is required to be aware of the entire network topology. The route is predetermined and precisely specified by the source and is carried in a packet header. Source routing can be very flexible. Different packets with different QoS requirements can be sent on different routes. Because the routing decisions are done at a single place for each route, the routing algorithm can be very complex. It guarantees loop-free routes. Many source algorithms are conceptually simple and easy to implement, evaluate, debug, and upgrade. [1]

Source routing allows easier troubleshooting, improved traceroute, and enables a node to discover all the possible routes to a host. It also allows a source to directly manage network performance by forcing packets to travel over one path to prevent congestion on another.

Source routing has not been widely adopted in the Internet. It is impractical for any single node to have access to detailed state information about all nodes and all links in a large network. Also, since the source node computes the whole path on its own, the computational overhead in the source node could be very high if the network is large. Source routing is used in today's Internet for special cases only, such as mapping the network with trace route, troubleshooting, or forcing an alternate link to traffic flow to avoid congestion. Many QoS routing algorithms, however, are source routing algorithms .[10]

In distributed routing, the paths are computed by distributed computation. Each router along the path will decide for the next hop to be taken by the packet. Here the packet carries just the destination address and each router looks into its routing table for the next hop to be taken for this particular destination. In addition, there need not be any routing-overhead in the packet, since all routing decisions can be made from the destination address alone. Its advantage is that the size of the header is less as compared to source routing.[1]

Distributed routing is more scalable than source routing. Distributed routing is the common strategy for routing in the Internet today.Both routing models have important roles to play in QoS based routing. Distributed routing will be the default solution, but source routing will be needed to override the default behavior of the network . Distributed routing is currently the dominant method and source routing is used primarily for debugging the network. [1]

In order to support QoS routing, network nodes require accurate state information about the available resources.

State information can be local state or global state. Each node is assumed to maintain its local state information up-to-date e.g. Node delay, the residual bandwidth of the outgoing link, available buffer size etc. The union of all nodes' local states is called the global state.[12] The global state kept by a node is always an approximation of the current network due to the delay of propagating local states with the growing network size. This global state is maintained in every node by exchanging the local states between the nodes. There are two popular ways of doing this -Distance Vector Protocol and Link State Protocol. Link-state protocols broadcast the local state of every node to every other node so that each node knows the topology of the network and the state of every link. Distance-vector protocols periodically exchange distance vectors among adjacent nodes. [11]

In Source routing, each node maintains an image of the global state of the network, based on which a routing path is centrally computed at the source. Distributed routing can be implemented by either using local state or global state. However, in implementation, the global state information available for making the routing decisions at each node is often inaccurate in a lively environment. The routing algorithm does not provide satisfactory performance with imprecise state information. The effectiveness and performance of the routing algorithms can be degraded a lot by this outdated information. QoS routing is much more sensitive than non-QoS routing in terms of the accuracy of the global state. Inaccuracy can lead QoS to failure. Therefore, the design of routing algorithms for large networks should take the information imprecision into consideration.

One of the mechanisms to avoid information imprecision is relying on local state. When local state for path computation is being used, no link state updating is required, as each node can check for its local states along the path. So, the overhead problem and inaccuracy of state information are removed in this case. Many distributed QoS algorithms have been proposed in literature by varying the QoS metrics and protocols . A study of distributed algorithms has been done in [5]. Most of the published algorithms for distributed QoS approach use global state information.[1][4][6][7]. Some have also contributed in local state approach[8][9].

As far as path computation strategy is concerned in local state approach, techniques like flooding can be used to establish a path. Each node has to blindly flood the control messages in the network. This could again generate an overhead problem.

Selective flooding is a variation of flooding technique. In this; the router does not transmit the packets in every direction but selectively directs them to approximately right direction. Thus, it certainly reduces the overhead occurred in flooding.

An important contribution in this work is DRA algorithm proposed by Chen-Nahrstedt [9]. In [9] , family of distributed routing algorithms have been proposed which require every node to maintain local state. The algorithms use a distributed computation to collectively utilize the most up –to-date local information at each node to find a path. The found path is guaranteed to be loop free.

This paper describes the distributed QoS routing approach presented in [9] and illustrates this approach with an example network.

The layout of the paper is as follows-Section 2 gives brief description of QoS . Section 3 presents the illustration of the algorithm proposed in [9] and section 4 concludes the paper.

II. QUALITY OF SERVICE

The fundamental problem of routing in a network that provides QoS guarantee is to find a path between specified source and destination node pair that simultaneously satisfies multiple QoS parameters.

Quality of Service(QoS) puts some restrictions in the form of certain constraints on the path. These constraints may be desired bandwidth, delay, variation in delay experienced by receiver(jitter),packet loss that can be tolerated, number of hops, cost of links etc.

These parameters are represented in the form of metrics. One metric for each constraint is to be specified like bandwidth metric, jitter (variation in delay) metric, delay metric, number of hops metric, packet loss ratio etc. from one node to all other nodes in the network. Metric for a complete path with respect to each parameter is determined by the composition rules of metrics. The three basic rules are [13].-

- ***a.*** ***Additive Metric:*** The value of the constraint over the entire path is the addition of all links constituting path. For Example- delay, hop count, cost or jitter.
- ***b.*** ***Multiplicative Metric:*** Using this metric, the value for the complete path is multiplication of metric value of all its edges.
- ***c.*** ***Examples are –*** reliability (1-lossratio) and error free Transmission (probability)

Multiplicative metric can be converted into additive by taking logarithm.

- ***d.*** ***Concave Metric:*** In this metric, either min edge value or max edge value is taken as constraint value for a path among all the edges of that path. For Example- Bandwidth

For a complete path, the constraints may be required either as a constrained form or in a optimization form. In constrained form, some condition is put on constraint value e.g. Choose that path only which has delay less than or equal to 60 ms. The path obeying the condition is called feasible. On the other hand optimization refers to path having minimum or maximum value for a constraint e.g. Choose the path that has minimum delay among all the paths. This path is called optimal path .

The further QoS issues have been discussed in[2][3].

III. ILLUSTRATION OF DISTRIBUTED QOS ROUTING ALGORITHM

On the basis of characteristic evaluation of distributed QoS routing algorithms in [5], a fully distributed approach has been selected here for its exploration proposed by Chen and Nahrstedt[9]. Importance of information precision justifies the selection of the mentioned approach. A brief overview of this strategy with its illustration on an example network has been presented here.

A. Description of the Approach:

A distributed routing framework has been developed in [9] for the variety of QoS constraints based on selective probing. On the occurrence of routing request, probes are flooded selectively along those paths which assure the QoS requirements. Every node maintains its local state, based on which the routing decisions are prepared.

This algorithm has three phases: probing, acknowledgment and failure-handling.

The probing phase is the QoS routing phase that means it establishes a tentative path between the source and destination such that the path satisfies the QoS requirements of the connection . Source starts the process by sending the Probe message to all its neighbors which satisfy QoS demand. A router on receiving a probe, selectively floods on all outgoing links which are capable of supporting the QoS requirements, except the one on which the probe arrived. In basic algorithm, every router selectively floods the first probe for a given connection and rejects all duplicates. The probing phase ends once a probe reaches the destination and the path reaches the destination is called the tentative path.

The acknowledgement phase does the resource reservation. The destination sends an acknowledgment to the first probe it receives and it discards all the duplicate probes. This ensures that only one path is established. In the acknowledgment phase, the destination sends an acknowledgment along the tentative path and resources are reserved along the way. A connection is established when the source gets the acknowledgement.

As the network resources change rapidly, an intermediate node on the tentative path might not have the required resources when it gets an acknowledgment for the same connection. In such a case, the failure-handling phase is started. The node that was unable to reserve the resources sends a failure message to the rest of the routers to free their resources and the connection request is rejected. A connection request could be turned down in one other scenario. A router could receive a probe with certain QoS constraints which none of its outgoing links can support. The router will simply discard the probe without forwarding it. If such a condition occurs ,the connection will not be set up. In both the cases, the call is said to be blocked.

The algorithm successfully establishes a connection when the source receives an acknowledgment and reserves the required resources successfully. If the source does not receive an acknowledgment during a timeout period, the rejection of the connection is assumed.

A diversity of algorithms can be developed from the framework, to route connections with a variety of QoS constraints on bandwidth, delay, delay jitter, cost, and their combinations. Several techniques have been developed to reduce the communication overhead of flooding. First, probes are only allowed to be forwarded to a subset of outgoing links selected based on topological distance to the destination. Second, iterative probing is used to further reduce the overhead. At first iteration, the probes are sent only along the shortest paths. If the first iteration fails, probes are allowed to be sent along paths with increasing lengths in the following iterations.

The optimization aspect has also been suggested in this approach. The non-optimization algorithm i.e. the generic DRA algorithm will not surely find the best path as it will accept and forward only first message for one connection –id. Rest of the messages will be discarded by the node. But in optimization algorithm , every node will send the probe message received from its neighbor to all its adjacent edges which satisfy the QoS requirement after the waiting time of Δt . In this interval, every node may receive multiple messages for one connection- id. It will store all the messages and forward the best one. Here Δt varies according to QoS parameters and depends on the circumstances of network conditions. We have exemplified the optimization version of probe phase. We have just focused on the part of selection of the best path among all the received paths at each node assuming all the paths have been received in Δt time as its true value will depend upon the network environment.

B. Parameters of the Network:

A network is modeled as a set V of nodes that are interconnected by a set E of full-duplex ,directed communications links. Each node I keeps the up to date local state about all outgoing links .

The QoS parameters that are taken for example network are –delay and bandwidth. We are given bandwidth requirement and delay threshold.

As bandwidth is a concave metric and delay is an additive metric, paths satisfying QoS requirements are those paths whose bandwidth is greater than or equal to bandwidth requirement and whose delay is less than or equal to delay threshold.

The state information of link(i,j) includes the delay, bandwidth. The delay and bandwidth of a path p=i->j-> …. -> k->l are defined as follows

Delay(p)=delay(i,j)+…..+delay(k,l)

Bandwidth(p)=min{bandwidth(I,j)………………….bandwidth(k,l)}

Age(Hop count)- number of hops traversed in the path

The message will be forwarded to only those links whose bandwidth is equal or greater than required bandwidth and whose accumulated delay(delay of the link + delay of the path traversed so far) is less than the delay threshold.

We are also going to store its age i.e. the number of hops but no condition has been put on it.

To implement this, we have assumed a selected domain of the network where the algorithm will operate and all the links chosen from the source are the ones that lead to destination.

Every node is required to maintain the delay and residual bandwidth of its all outgoing links. Assumption has also been made that each node in the network is maintaining the topology of the network either by using distance vector or link-state protocol.

C. Data Structure:

a. Data Structure of the message-

There are three types of messages-

Probe, ack and failure

The data structure of a message is as follows.

The first field would be the type of message

The simplified structure of other fields in the message are-

{k, QoS, s, t, cid}

Here

k- sender of the message ,which can be the source or an intermediate node

cid- Id for connection request

s-Source ,t=destination

QoS- Quality of service requirement

For example, probe[k; QoS; s; t; cid] represents a probe sent by k for connection cid whose source, destination and QoS requirement are s, t and QoS, respectively .

b. Information Stored At Each Node-

Each node keeps the up to date local state of QoS values about all outgoing links. Other than the basic information of generic DRA, the following information is required to be stored at each node for its optimization achievement-

Predecessor node	Cid	Path	Bandwidth	Delay	Age

Here

a) Predecessor node- The node from where message has been received.
b) Cid- Connection Id
c) Path – Nodes constituting the path traversed so far.

d) Bandwidth –represents the bandwidth status that will contain minimum bandwidth among all the edges of path traversed so far.

e) Delay- represents the delay status that will contain the addition of delay of edges of path traversed .

f) Age- represents number of hops traversed so far.

The three fields bandwidth, delay and age have also been introduced in the probe message .The value for these fields will be updated during traversal.

D. Example Network:

Each node keeps the up to date local state of QoS values about all outgoing links. For illustration assumption of these values has been taken in the example network-

a. Example Network-

The following network of figure1 has been taken as example network

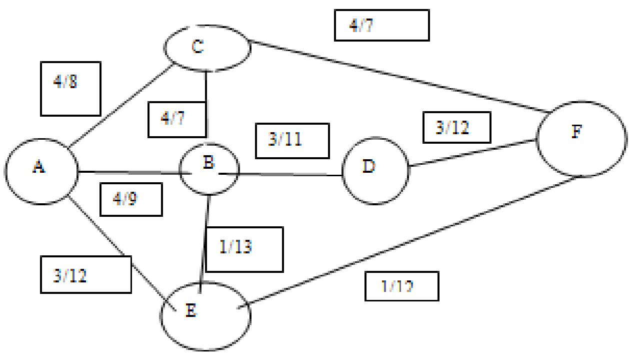

Figure 1- Network with edges depicting bandwidth/delay

Here the network is of 6 nodes. Each link is represented as bandwidth/delay. [For simplification, delay and bandwidth value from i to j and j to i has been taken identical.]

b. Supposition of the QoS request –

Connection id-101
A-Source
F- Destination
Bandwidth requirement-3
Delay threshold-40

So Those Paths will be considered whose bandwidth is greater than or equal to 3 and whose delay is less than or equal to 40

As , it is the optimization implementation, When one node receives multiple paths for the same connection Id ,it will keep/store all the paths but forwards the best one. Here we consider the path having minimum delay value will be forwarded.

The information to be maintained on every node is information of bandwidth and delay value of all its adjacent edges are as follows-

The Local information at node A

Table 1- Node A

Node	**Bandwidth**	**Delay**
B	4	9
C	4	8
E	3	12

The Local information at node B

Table 2- Node B

Node	**Bandwidth**	**Delay**
C	4	7
A	4	9
D	3	11
E	1	13

The Local information at node C

Table 3-Node C

Node	**Bandwidth**	**Delay**
B	4	7
A	4	8
F	4	7

The Local information at node D

Table 4- Node D

Node	**Bandwidth**	**Delay**
B	3	11
F	3	12

The Local information at node E

Table 5- Node E

Node	**Bandwidth**	**Delay**
B	1	13
A	3	12
F	1	12

The Local information at node F

Table 6- Node 6

Node	**Bandwidth**	**Delay**
C	4	7
D	3	12
E	1	12

Source A starts finding a path by sending a message to its neighbors which satisfy the bandwidth and delay requirements. Here B , C and E all fulfills the requirement. So it sends the message along the edges B , C and E .

The probe message to B will be of this form- Probe{A , 3,40 ,A , F, 101,4,9,1}

Here A is sender of the message, 3 is bandwidth requirement , 40 is delay threshold , A is source and F is destination and cid is 101.

4,9,1 are the status of bandwidth, delay and age(Number of hops) respectively of the path traversed so far that will be updated during traversal. Here the initial values are the values of link A-B representing bandwidth , delay and age as this is first link that has been traversed.

Similarly probe message to C and D are-

Probe{A , 3,40 ,A , F, 101, 4,8,1}

Probe{A , 3,40 ,A , F, 101,3,12,1}

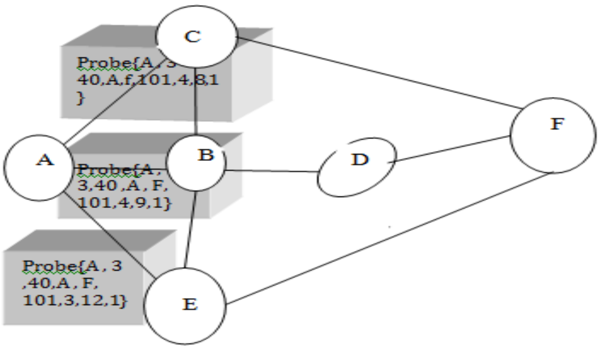

Figure 2: PROBE messages sent by Node A

Node B will store the following information after receiving this probe-

Table 7 : Status table of Node B

Predecessor node	Cid	Path	Bandwidth	Delay	Age
A	101	A	4	9	1

Node C will store the following information –

Table 8 : Status table of Node B

Predecessor node	Cid	Path	Bandwidth	Delay	Age
A	101	A	4	8	1

Node E will store the following information-

Table 9 : Status table of Node E

Predecessor node	Cid	Path	Bandwidth	Delay	Age
A	101	A	3	12	1

Now C has three adjacent edges A,B,F. C will update the fields in the messages and forward the following message to B and F as both are satisfying QoS requirements after the time Δt. It will not forward the message to A to avoid the loop as A has been included in the path.

Probe{C, 3 , 40, A , F, 101,4,15,2}

Probe{C, 3 , 40, A , F, 101,4,15,2}

Here delay status has been updated as sum of delay of two links and bandwidth has been updated as the minimum bandwidth of two links traversed.

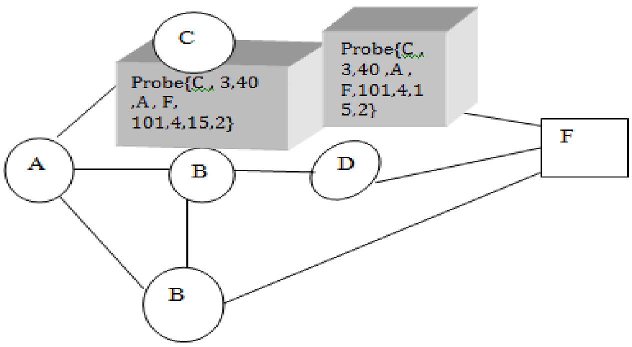

Figure 3: PROBE messages sent by Node C

B has received two message from A and C.

Probe{A , 3,40 ,A , F, cid,4, 9,1 }

Probe{C , 3,40 ,A , F, cid,4,15,2}

It will keep the following information in its tables but it will forward only the first message received from A to D because the message received from C may not be in Δt time ,suppose if it is in Δt time then also delay of first message is less than the delay of second message .So it will forward the message received from A as we are forwarding messages having lesser delay.

Table 10: Status table of Node B

Predecessor node	Cid	Path	Bandwidth	Delay	Age
A	101	A	4	9	1
C	101	AC	4	15	2

Now B has four adjacent edges A,C,D,E.B will update the message (received from A) and forward the following message afterΔt time to C and D as E does not satisfy bandwidth requirement

probe{B,3,40,A , F ,101, 4,16, 1}

probe{B,3,40,A,F,101,3,20,2}

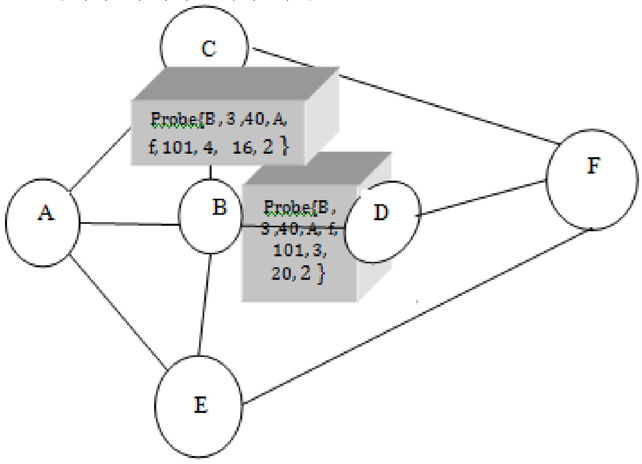

Figure 4: PROBE messages sent by Node B

C has got another message from the B but if it is after waiting time, it will not forward the message received from B as it has already forward one message for the same connection id.

E has got the message only from A

The information stored at E is-

Table 11: Status table of Node E

Predecessor node	Cid	Path	Bandwidth	Delay	Age
A	101	A	3	12	1

E has three adjacent edges A,B ,F. E will not forward the message to B and F as the edges do not satisfy the bandwidth requirement.

D has received a message from B. It will update its internal table as

Table 12: Status table of Node D

Predecessor node	Cid	Path	Bandwidth	Delay	Age
B	101	AB	3	20	2

D will forward the message to F as follows-probe{D,3,40,A , F ,101, 3, 32, 3}

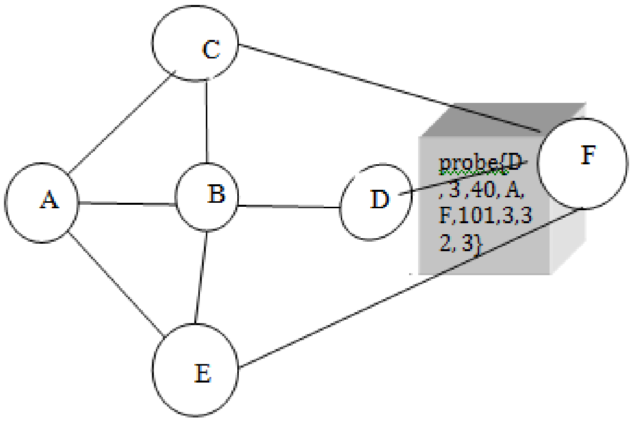

Figure 5: PROBE messages sent by Node D

F ,destination will get two messages from C,D and keep the following information in its table-

Table 13: Status table of Node F

Predecessor node	Cid	Path	Bandwidth	Delay	Age
C	101	AC	4	15	2
D	101	ABD	3	32	3

So the two paths calculated at destination are-
A-C-F
A-B-D-F

These two paths follow the bandwidth and delay requirement but the first path has delay less than the second path. So The algorithm finally selects the path –
A-C-F

It will send the acknowledgement message through this path to source.

We have considered minimum delay for path selection. It can be done either on bandwidth or age. If we make decision of path selection on bandwidth, then the path having higher bandwidth will be chosen and if age will be considered ,then the path having its lesser value will be the final path.

Thus the selection of path can be based on any metric i.e. bandwidth ,delay or age.

IV. CONCLUSION AND FUTURE WORK

Many distributed QoS algorithms have been proposed in literature by varying the QoS metrics and protocols .Most of the published algorithms use global information for finding the QoS path. That information is imprecise in the dynamic environment of network. An important contribution in these works is to find the QoS path with distributed approach using only local information[9].In this paper, we have described this approach by an example network . We have explored optimization version of the DRA algorithm . As we have seen in optimization algorithm, among all the paths satisfying QoS constraints, the best path has been chosen according to one QoS parameter. It would be better if multiple QoS parameters values can be considered for path selection. Our future work will focus to design such a strategy.

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