Solving QoS Multicast Routing Problem Using ACO Algorithm

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***Abstract*— In IP multicasting messages are sent from the source node to all destination nodes. In order to meet QoS requirements an optimizing algorithm is needed. We propose an Ant Colony Optimization algorithm to do so. Ants release a chemical called pheromone while searching for food. They are capable of finding shortest path to their target. This can give an effective optimal solution to our Multicast Routing Problem.**

1. INTRODUCTION

1.1 DEFINITION

Internet Protocol (IP) multicasting is delivering of message or information to the group of destination computers simultaneously in the single transmission from the source. It is the sending of a single datagram to multiple hosts on a network or internetwork.

Of the three delivery methods supported by IP, multicasting is the method that is most practical for one-to-many delivery. Unlike IP multicasting, IP unicasting sends a separate datagram to each recipient host. IP broadcasting sends a single datagram to all hosts on a single network segment (also known as subnet), even to those not interested in receiving it. Recent trends toward multimedia applications such as video conferencing necessitate the use of multicasting to efficiently send traffic to multiple hosts.

Before sending or receiving IP multicast data, a network must be enabled for multicasting, as follows:

- Hosts must be configured to send and receive multicast data.
- Routers must support the Internet Group Membership Protocol (IGMP), multicast forwarding, and multicast routing protocols.

1.2 WORKING

To support multicasting in an internetwork, the hosts and routers must be multicast-enabled. In an IP multicast-enabled intranet, any host can send IP multicast datagrams, and any host can receive IP multicast datagrams, including sending and receiving across the Internet.

The source host sends multicast datagrams to a single Class D IP address, known as the group address. Any host that is interested in receiving the datagrams contacts a local router to join the multicast group and then receives all subsequent datagrams sent to that address.

Routers use a multicast routing protocol to determine which subnets include at least one interested multicast group member and to forward multicast datagrams only to those subnets that have group members or a router that has downstream group members.

1.3 ARCHITECTURE

The following figure shows how multicasting components fit in an internetwork.

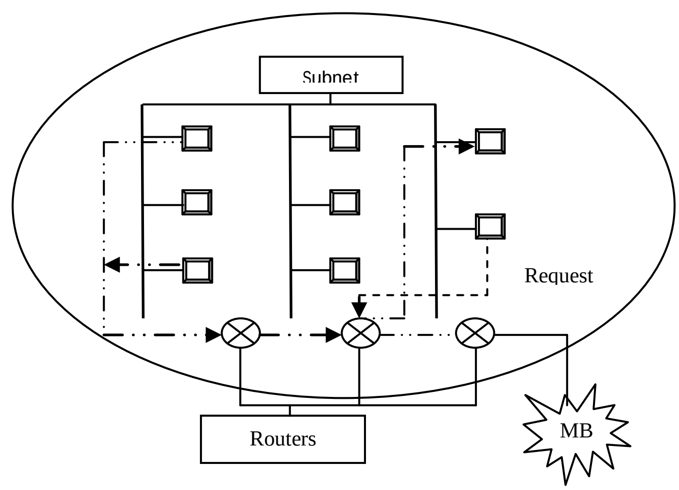

Fig.1: IP Multicasting Architecture

Component	Description
Host (source or receiver)	A host is any client or server on the network. A multicast-enabled host is configured to send and receive (or only send) multicast data.
Router	A multicast router is capable of handling host requests to join or leave a group and of forwarding multicast data to subnets that contain group members. A multicast router

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	can be either a non-Microsoft router that uses a multicast routing protocol or a Windows Server 2003-based server running the Routing and Remote Access service.
Multicast address	A Class D IP address used for sending IP multicast data. An IP multicast source sends the data to a single multicast address, as described later in this section. A specific IP multicast address is also known as group address.
Multicast group	A multicast group is the set of hosts that listen for a specific IP multicast address. A multicast group is also known as a host group.
MBone	The Internet multicast backbone, or the portion of the Internet that supports multicast routing.

Table 1: IP Multicasting Components

2. RELATED WORK

2.1 ANYCAST

Anycast is a communication technique between a single sender and nearest of several receivers of group. It exists in the contradistinction to multicast, communication between a single sender and multiple receivers, and unicast, communication between a single sender and a single receiver in a network.

An anycast packet is delivered to one of these nodes with the same anycast address. Like a multicast address, a single anycast address is assigned to multiple nodes (called anycast membership), but unlike multicasting, only one member of the assigned anycast address communicates with the originator at a time.

Only three connection types are commonly known and used in Internet Protocol version four (IPv4) networks: unicast, multicast and broadcast. A fourth connection type, Anycast, was unknown until IPv6 made it a standard connection type. Anycast is not standardized in IPv4 but can be emulated. IPv4 Anycast addressing is a good solution to provide localization for services and servers in order to obtain robustness, redundancy and resiliency.

The basic idea of Anycast is very simple: multiple servers, which share the same IP address, host the same service. The routing infrastructure sends IP packets to the nearest server (according to the metric of the routing protocol used). The major benefits of employing Anycast in IPv4 are improved latency times, server load balancing, and improved security.

Anycast packets can be dropped like any other kind of traffic. Packets are not specifically marked or tagged. Preferably only anycast server receives a packet, but there is no guarantee. It is possible that the sequential packets from a client to anycast address are delivered to different servers. If servers are not synchronized incorrect data maybe sent back. The server that receives a specific packet is solely determined by the unicast routing protocol used in the domain. There is no special anycast routing table equivalent to a separate routing table for multicast traffic. Clients, servers, and routers require no special software/firmware. The only special configuration is needed on servers and routing infrastructure.

2.2 UNICAST

Unicast is the term used to describe communication where one piece of information is sent from one point to another having just one sender and one receiver. It defined as a point-to-point flow of packets between a source (client) and destination host (server). Unicast transmission in which a packet is sent from a single source to specified destination is the predominant form of transmission on LAN and within Internet. Unicast messaging is used for all network processes in which a private or unique resource is requested.

Certain network applications which are mass-distributed are too costly to be conducted with unicast transmission since each network connection consumes computing resources on the sending host and requires its own separate network bandwidth for transmission. Such applications include streaming media of many forms. Internet radio stations using unicast connections may have high bandwidth costs.

2.3 BROADCAST

` Broadcasting refers to a method of transferring a message to all recipients simultaneously. It can be performed in following ways:

- As a high level operation in a program, for example broadcasting Message Passing Interface.
- It may be a low level networking operation, for example broadcasting on Ethernet.

A piece of information is send from one point to many other points at the same time.

It is supported on most LANs and may be used to send the same message to all computers on the LAN. Network layer protocols (such as IPv4) also support a form of broadcast that allows the same packet to be sent to every system in a logical network.

Not all network technologies support broadcast addressing. For example, neither X.25 nor frame relay have broadcast capability, nor is there any form of Internet-wide broadcast. Broadcasting is largely confined to local are network (LAN) technologies, most notably Ethernet and token ring, where the performance impact of broadcasting is not as large as it would be in a wide area network.

3. ANT COLONY OPTIMIZATION ALGORITHM

Swarm intelligence is a relatively new approach to problem solving that takes inspiration from social behaviours to solve optimization problem. The attempt is to develop algorithm in computer technology to solve real life problems. Ant colony optimization is a heuristic algorithm which has been proven a successful technique and applied to a number of combinational optimization problem and taken as one of the high performance computing methods.

It has wide range of applications with very good search capabilities for optimization problems but it still remains a bottleneck due to high cost and time conversion. ACO inspired by the forging behaviour of real ants to find food from their nest. The algorithm is basically used to find shortest path from nest to food source and the path is then used by other ants this is all due to chemical name pheromone deposited by ants on ground while searching for food.

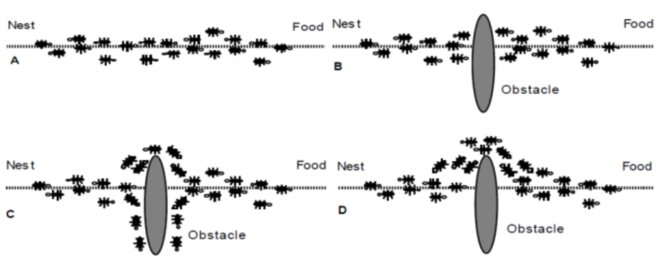

Fig.2: Ant chose the shortest path when the obstacle comes their way.

Ant Colony Optimization technique has emerged recently novel meta-heuristic for a hard combinational optimization problems. It is designed to stimulate the ability of ant colonies to determine the shortest paths to food. Although individual ant posses few capabilities, their operation as a colony is capable of complex behaviour. Real ants can indirectly can communicate though pheromone information without visual cues and capable of finding shortest path between food and their nests. The ants follow pheromone on trail while walking and the other ants follow the trail with some probability dependent on the density of pheromone deposited by the ants. The more the pheromone deposited the more ants will follow that trail. Through this mechanism ants ultimately find the shortest path.

Artificial ant can also imitate the behaviour of real ants how they forage the food but can also solve much more complicated problems than real ants can. A search algorithm with such concept is called Ant Colony Optimization Algorithm. ACO inspired by the forging behaviour of real ants to find food from their nest.

3.1 ALGORITHM

Assuming S is source code and U= {U_1, U_2……..U_m} donated a set of destination nodes.

1. Initialize network nodes.
2. Set LC=0 where LC is loop count.
3. Let L_k be the shortest path for the destination node U_i.
4. The initial value of τ_k=0 as no ant has traversed any path so ant can chose any path as probability of any path=0.
5. Ant chooses the path according to the probability of path.
6. Compute the pheromone update of the path and each edge selected by the ant using

   $\Delta\tau_k = \frac{R}{L_k}$

   Where

   R is any constant value.

   L_k is total path traversed by the ant.
7. Update the local pheromone τ_k

   $\tau_k = (1-\rho)\, \tau_{k+\Delta}\, \tau_k$

   Where

   ρ = (0 to 1) pheromone decay

8. Compute the probability P_k of each edge.

   $P_k = \frac{[\tau_k^\alpha] * [n_k^\beta]}{\sum_{j \in n}[\tau_k^\alpha] * [n_k^\beta]}$

   $n_k = \frac{1}{e_k}$

   Where k ϵ N

   α,β are meta values.

   n_k heuristic value.

   e_k edge value.
9. Set LC=LC+1.
10. Repeat from step 5 update the value of τ_k and probability of paths.
11. Collect best paths to get the multicast tree.

3.2 PROBLEM STATEMENT

We consider the multicast routing problem with bandwidth and delay constraints from one source node to muti-destination nodes.

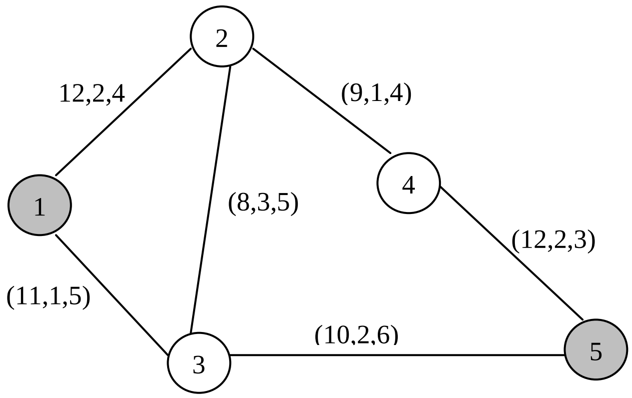

Fig.3 Network Topology Structure

Find the shortest path between 1 and 5.

Solution-

a = 1, β = 1, ρ = 0.1

Initial $\tau_k = 0$, Q = 10

$$P_k = \frac{[\tau_k^a] * [\eta_k^b]}{\sum_{j \in n}[\tau_k^a] * [\eta_k^b]}$$

$k \in N$

Otherwise,

$\eta_k = \frac{1}{d_k}$

$\Delta\tau_k = \frac{Q}{c_k}$

$\tau_k = (1-\rho)\tau_k + \Delta\tau_k$

Initially f_k for every path = 0 as $\tau_k = 0$

Ant chose path 1 2 4 5

$C_{1,5} = d_{1,2} + d_{2,4} + d_{4,5}$

= 4+4+3

=11

Pheromone Value

$\Delta\tau_k = \frac{10}{11}$

= 0.90

As $\tau_k = 0 + \Delta\tau_k$

$\tau_k = 0.90$

2nd Ant chose path

$P_{1,2} = \frac{(.90)(1/4)}{(.90)(1/4) + 0}$

= 1

$P_{2,4} = 1$, $f_{4,5} = 1$

$P_{1,3} = 0$, $f_{2,3} = 0$, $f_{3,5} = 0$

$\Delta\tau_k = 0.90$

$\tau_k = (1-0.1).90 + .90$

= 1.71

3rd Ant chose same path

$c_k = 11$, $\Delta\tau_k = .90$

$\tau_k = (1-0.1)1.71 + .90$

= 2.43

For path

$\tau_{1,2} = 2.43$

$\tau_{2,4} = 2.43$

$\tau_{4,5} = 2.43$

4th Ant chose path 1 2 3 5

$C_k = d_{1,2} + d_{2,3} + d_{3,5}$

= 4 + 5 + 6

= 15

$\Delta\tau_k = \frac{10}{15} = 0.66$, $\tau_k = 0.66$

$\tau_{k\,1,2} = (.9)*2.43 + 0.66 = 2.84$

5th Ant on same path

$\tau_{k\,2,3} = (.9)*0.66 + 0.66 = 1.25 = \tau_{3,5}$

$\tau_{1,2} = (.9)*2.84 + 0.66 = 3.21$

6th Ant on same path

$\tau_{k\,2,3} = \tau_{3,5} = (.9)*1.25 + 0.66 = 1.78$

$\tau_{1,2} = (.9)*3.21 + 0.66 = 3.54$

Path 1 3 5

$c_k = d_{1,3} + d_{3,5} = 5 + 6 = 11$

$\Delta\ \tau_k = \frac{10}{11} = .90$

7th Ant

$\tau_{1,3} = .90$

$\tau_{3,5} = (.9)*1.78 + .90$

= 2.50

8th Ant

$\tau_{1,3} = (.9)*(.90) + .90 = 1.71$

$\tau_{3,5} = (.9)*2.50 + .90 = 3.15$

9th Ant

$\tau_{1,3} = (.9)*1.71 + .90 = 2.43$

$\tau_{3,5} = (.9)*3.15 + .90 = 3.75$

Destination Node	The shortest paths
	1 2 4 5

5	1 2 3 5
	1 3 5
	1 3 2 4 5

Table 2: The route set from source to destination.

The above table shows all the possible paths to the destination node.
Hence,
$\tau_{1,2} = 3.54$, $\tau_{1,3} = 2.43$, $\tau_{2,3} = 1.78$
$\tau_{2,4} = 2.43$, $\tau_{3,5} = 3.75$, $\tau_{4,5} = 2.43$

Finding shortest path

$$P_{1,2} = \frac{(3.54)(1/4)}{(3.54)(1/4) + (2.43)(1/5)} = 0.64$$

$$P_{1,3} = \frac{(2.43)(1/5)}{(3.54)(1/4) + (2.43)(1/5)} = 0.35$$

$$P_{2,3} = \frac{(1.78)(1/5)}{(1.78)(1/5) + (2.43)(1/4)} = 0.36$$

$$P_{2,4} = \frac{(2.43)(1/4)}{(1.78)(1/5) + (2.43)(1/4)} = 0.63$$

$$P_{3,5} = \frac{(3.75)(1/6)}{(3.75)(1/6) + (2.43)(1/3)} = 0.43$$

$$P_{4,5} = \frac{(2.43)(1/3)}{(3.75)(1/6) + (2.43)(1/3)} = 0.56$$

Ant 10th chose 1 2 4 5
$c_k = 11$
$\Delta\, \tau_k = .90$
$\tau_{1,2} = (.9)*3.54 + .90 = 4.086$
$\tau_{2,4} = (.9)*2.43 + .90 = 3.087$
$\tau_{4,5} = (.9)*2.43 + .90 = 3.087$

$$\tau_{1,2} = \frac{(4.08)(1/4)}{(4.08)(1/4) + (2.43)(1/5)} = 0.68$$

$$\tau_{2,4} = \frac{(3.08)(1/4)}{(1.78)(1/5) + (3.08)(1/4)} = 0.68$$

$$\tau_{4,5} = \frac{(3.08)(1/3)}{(3.75)(1/6) + (3.08)(1/3)} = 0.62$$

According to the above calculation path 1 2 4 5 has the highest probability. Initially paths 1-2-4-5 and 1-2-3-5 were chosen by the ants. But the pheromones on the path 1-2-4-5 were more, which lead to its higher probability to be chosen by the ants.
Thus, 1-2-4-5 is the optimum path chosen by the ants. Given below is the multicast tree obtained by the proposed Ant Algorithm.

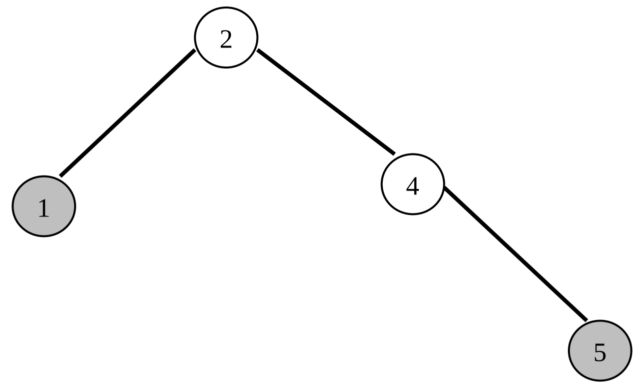

Fig.4 Multicast Tree

4. CONCLUSION

Hence by using the concept of ACO algorithm we found an optimum path to send message from a source node to a destination node. The first ant moves from the source to the destination leaving a trail of pheromones. The next ant calculates the probability of the path based on the presence of pheromones on that path. Higher the pheromone value on that path higher will be the probability. And ant tends to choose higher probability path. Results show that the proposed algorithm has features of well performances of cost, fast convergence and stable delay.

5. FUTURE WORK

ACO algorithm will be used in many applications like travelling salesman problem, data mining etc. ACO algorithm will be used in solving grid computing problems also.

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