PERFORMANCE METRICS FOR EVALUATION OF MULTICAST ROUTING PROTOCOLS

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ABSTRACT

With the ever increasing demand of multimedia traffic on the Internet, the interest in deploying multicast for distribution of these contents have increased. One hurdle however in this regard is quantifying the multicast protocol performance. Many efforts have been put into defining multicast metrics for evaluating protocol performance. This paper defines the performance metric for evaluation of multicast protocols like DVMRP,MOSPF,PIM-SM,PIM-DM and CBT and also outlines the simulation parameters and different methods to evaluate the performance of protocol.

***Keywords**: Multicast, Performance Evaluation, Network Topology, Node Density, Link Capacity, End To End Delay, Re Link Usage, Bandwidth Consumption*.

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I. INTRODUCTION

Demand for multimedia content like audio and video has increased many folds in last few years. With this increase in demand, the need to deliver such media through multicast rather than unicast has also increased. Multicast not only provides efficient communication but also optimizes performance especially for distributed/multi-user applications. Messages are duplicated only when paths diverges. The optimal multicast path is computed from already computed unicast path. The quality of the multicast tree depends upon many factors. Low end to end delay, reduce link usage, low bandwidth consumption etc. With the advent of multicasting, many applications such as video conferencing, real time multimedia applications, multiplayer games and distributed interactive simulations have emerged that are designed to derive maximum benefit from multicasting of data. These applications are focused on utilizing certain inherited characteristics of a multicast protocol to deliver the desired QoS.

Before deploying multicast protocols to deliver multimedia traffic, a thorough evaluation of the protocol is necessary. For evaluating the performance of multicast protocols, some additional metrics other than those used for evaluating unicast protocols are required. Each multicast protocol performs a similar task i.e. constructing a multicast tree to propagate multicast traffic to all members of a multicast group. However, they use different mechanisms for tree construction and management. Efficiency of each multicast protocol in particular network scenario depends upon many factors, like network topology, node density, link capacity etc. The metrics for multicast traffic can be developed from multiple perspectives. One is of a network provider, who is more interested in measuring network resource usage of a multicast protocol and load it incurs on a network. Another could be an end user perspective, who is concerned with the quality and availability of service. These two perspectives can be combined to construct multicast metrics to analyze a multicast protocol's strengths and weaknesses under a particular network conditions. With more devices supporting wide range of multicast protocols, such metrics could help us to establish which protocol to use in any given scenario.

Different scenarios can be used to evaluate the performance like to vary the no. of multicast senders or receivers etc. To check the performance of each protocol the results can be compared by using different combination of groups and network size.

II. RELATED WORK

One of the very first efforts to quantify multicast protocol's performance was by Chuang and Sirbu [1]. According to it a multicast tree cost (the ratio of the total length of the multicast tree to the average length of the unicast paths) was found to be a power-law

$$\frac{Lm}{Lu} = N^{K} \quad (1)$$

Where 'k' is a factor whose values ranges between 0 and 1.

Lm is the total length of the multicast distribution tree, which is the sum total of the edge costs of all links. Lu is the average length of the unicast routing paths, while N is the number of nodes that have multicast hosts attached to them (Leaf nodes).This considers the resource consumption in the provider's network only. The value of "k" was established to be around 0.8. This model focuses only on link utilization but ignores node cost such as the state storage cost at each node and bandwidth utilization. The above formulae was further analyzed in [14] for k-ary trees and general networks which are not k-ary. Chuang Sirbu's law for k-ary trees is as stated below

$$Lm \cong X \left(C - \frac{Ln\frac{X}{M}}{Ln\ K} \right) \quad (2)$$

Where

$$X = \frac{Ln\left(1-\left(\frac{m}{M}\right)\right)}{Ln\left(1-\frac{1}{M}\right)} \quad (3)$$

where 'm' is number of randomly chosen distinct network locations, 'M' is total number of possible receiver locations, k is the degree of the tree. Another effort in defining multicast metrics was by Chalmer et al [2]. It presented an approach of quantifying the multicast protocols performance with that of unicast service. Many assumptions were made before defining the metric. It was assumed that multicast and unicast paths are the same, no multicast tunnels are present and group distribution is fairly even. The multicast metric was defined as a function of ratio

of multicast hops to unicast hops [4].

$$\partial = 1 \frac{multicast\ hope}{unicast\ hope} \quad (4)$$

By combining it function with Chuang and Sirbu law a function was derived as follows

$$\frac{multicast\ hope}{unicast\ hope} = \frac{Lm}{(Lm)(N)} \cong \frac{N^{0.8}}{N} = N^{-2} \quad (5)$$

$$\partial = 1 - N^{-2}$$

This gives us a function where multicast protocol efficiency depends only upon the number of receivers and the distribution of the multicast receivers has no impact on theperformance of a multicast protocol. The study failed toanswer many issues. Many of these issues are critical. For example the presence of asymmetric links, multicast tunnels,and multiple receivers are some issues that can lead to flawed results if this model is to be employed. Another important factor is the group density which is neglected. Both dense and sparse mode protocols build a completely different tree. This study shows that it's the number of receivers which affects the multicast's protocols efficiency. So according to this model the dense and sparse mode protocols will have the same efficiency if numbers of receivers are same. This, however, is not the case and a protocol's efficiency depends upon many other factors including the density and distribution of the multicast group.

Deborah et al [3] evaluated the tradeoff between sparse and dense mode PIM operations. The metrics used in this study were state storage overhead, bandwidth consumption and the control bandwidth overhead. Topology that was used was designed to simulate the ARPANET. The study concluded that for a small group of receivers the amount of overhead traffic increases much faster than the sparse mode packets. Thus the advantage of sparse mode for small group was established in terms of control overhead. As PIM can switch from one mode to another, a study was also conducted to calculate the packet loss during the switching from one mode to another. As for state storage the overhead of dense mode was fairly constant but that for sparse mode varies directly with the density of the group.

Billahartz et al [4] compared the efficiency of PIM-SM and CBT and follow a much broader approach. Their analysis includes metrics such as link utilization, join time, overhead traffic percentage, traffic concentration, routing table size and end-to-end delay. Three different networks were designed and each protocol is simulated. Twelve scenarios were simulated on each topology. CBT performs well in case of end to end delay, join times and overhead traffic. While PIM-DM has more even distribution of traffic and have less implementation issues. The metrics were more comprehensive in this study.

Bilahartz et al work suffers from a major error. While calculating the storage overhead of a multicast protocol, it was assumed that each router maintains a list of every multicast group member. This is however not true. The routing table sizes they calculate therefore were not accurate. Another thing that lack in their study is the fact that they did not give an accumulative result of the multicast protocols performance. There analysis was comparative and efficiencies of multicast protocols are established relative to each other.

A Cost and Pricing model for multicast data delivery was discussed in [5]. The authors advocate a flat rate model for dense mode protocols and a rather dynamic pricing model for sparse mode protocols depending upon the group membership. According to them the bandwidth used by a multicast transmission is not consumed by a single receiver. Hence the cost of the bandwidth must be distributed among all the receivers.

Mieghem et al [6] conducted a study to show the relationship between the number of links in a multicast tree and changes in the multicast group membership. The study shown that the stability of a tree tends to a Poisson distribution for a very large multicast group. Another important conclusion was that the shortest path trees are not very stable when the group membership increases to a large value. Another work [7] was done to study the relationship between multicast tree shape and the efficiency of the multicast tree. It conclude that the efficiency of a particular tree depends upon tree height, breadth and number of receivers.

Robert et al [8] discusses the factors that determine the realism of a multicast tree and to quantify multicast bandwidth gain over unicast. They developed a characterization schemes to accurately model multicast tree for a wide range of group dynamics. The work involved collecting multicast data traces from MBONE and used that data to construct a characterization model independent of network distribution. Furthermore the metrics was then used to calculate a cost model. The paper emphasize that the shape and other characteristics of the multicast tree life like depth, degree average degree frequency and the receiver distribution directly influence the efficiency of the multicast tree. Unlike some previous works which consider all the nodes of the multicast tree as receivers, they differentiate between the actual receivers and transit nodes differently in their model. The tree properties identified in this work are very useful to model real multicast tree.

Kamil et al [9] developed Trace tree a mechanism to discover the multicast tree topology. The scheme uses multicast forwarding states in the router to construct a multicast forwarding tree. The scheme employs a query response mechanism in which an interested querier send a query to all multicast enable router in the network for the presence of multicast states. Each multicast node then constructs a response message and sends it back. Also each router forwards the query to downstream multicast routers. The drawback of this technique is that it needs to add extra functionality to each router in the network. Also issues arise when multicast protocol in use constructs a bidirectional tree because this could lead to duplicate response packet and a flawed multicast tree image.

Mikael et al [10] studied the impact of multicast state distribution upon the IPv6 network topology. They collected a map of the IPv6 network. The multicast tree was re-partitioned using their proposed function. The authors claims that by building multicast trees using this function, the number of multicast states of the top ten most loaded nodes can be reduced up to 83% at the cost of a 5% increase of the total number of multicast states in the IPv6 topology.

Simulations were done which proved the effectiveness of the function. There are however certain implementation issue with the function. Also the function has to be tested for real multicast data traces. Most of these works suffers from two major discrepancies.

First, user perspective is ignored and performance is measured only on the basis of protocol's performance in the core of the network and second, no base criteria are defined to compare the performance of a protocol. Some of these works provide good techniques to measure the efficiency of the tree constructed. But the efficient delivery of data on that tree was not evaluated. Some of these works define an evaluation model which can only be applied to a particular protocol and only for a particular network topology. These techniques are rendered useless when different multicast protocols are evaluated for some other network topology.

Usman Shaukat et al[11] work tries to overcome these two discrepancies, his model which not only provides a measure of the efficiency of a multicast protocol in the core of the network but also consider the user's perspective while evaluating a multicast protocol and also define base criteria of performance and evaluate the performance against these criteria. The results can then be compared with A very significant outcome of this model can be the approach in which multicast traffic is quantized and then subsequently

helps in cost estimation. The model can be enhanced by incorporating other network characteristics like throughput etc and by coming up with better techniques for data collection.

III. PERFFORMANCE METRICS AND EVALUATION METHODS

Performance Metrics to evaluate the performance of multicast routing protocols like DVMRP, MOSPF, PIM-DM, PIM-SM and CBT is as follows:

Metric	Description of Metric
End-to-End Delay	Time elapsed between the generation of a packet at a source and the reception of that packet by a group member
Network Resource Usage	Total number of hops that copies of a packet travel to reach all group members. Computed by dividing the total number of hops measured in a simulation (including overhead packets) by the number of packets received.

Overhead Traffic Percentage	The percentage of the total number of bits transmitted that are overhead bits.
Traffic Concentration	A measure of the distribution of the total network traffic on all links. Defined to be the ratio of the maximum throughput carried by any link to the mean throughput of all links.
Jitter	When a stream of packets traverses a network, each packet may experience different delay; this variation in delay is often called the jitter
Implementation Issues	(1) Size of the routing table and (2) the number of required timers. These issues impact memory requirements, speed, and operating system performance.
Join Time	The time elapsed between when a host requests to join a group and when that host receives its first message from another member of that group.

Table1. Network Performance Metric

1. Simulation Parameters

We can model delays due to the IP packet service rate; packet queueing at routers and hosts; propagation delays on all links; and transmission delays based on link data rate and packet size. We can also model the size of the data packets (size in bytes plus all appropriate header information for the application we are interested in modeling) and the size of the overhead packets defined by the protocol specifications. The parameters for simulation are as follows:

Parameter	Description of Parameter
Groups per Host	The maximum number of multicast groups to which each host can belong: Which can be 10, 20, or 30.
Group Distribution Type	The set of groups that hosts can join is according to modeling which may allow a host to join (a) groups with membership spread across the entire network or (b) groups with membership spread across the entire network AND groups with membership restricted to one quadrant of the network.
Join/Leave Dynamics	The maximum time between consecutive changes (join or leave) in group membership at a host: which can be specified as 5 or 10 seconds.
Traffic Generation Rate	Rate of packet transmission for each group at each host.Hosts can send packets to each group at intervals determined by a Poisson distribution with mean one packet per second per group.

Table2.Network Simulation Parameters

2. Results can be computed by following ways

To calculate and compare the performance of routing protocols following methods can be used

- Varying the Number of Multicast Receivers
- Varying the Number of Multicast Sources
- Single-Source vs. Multi-Source Groups
- Increasing Network Size
- Varying the send rate

To evaluate the performance the performance metric, simulation parameters and different ways can be used in meaningful combination.

CONCLUSIONS

In this paper we have defined performance metric to evaluate the performance of multicast protocols and also the methods which can be used for doing comparison of the performance of protocols. Many of the previous work done in this area are presented and issues related to these works are discussed. A possible extension of this work is to simulate and to evaluate the performance of each protocol using this metrics and to compare using defined simulation parameters and methods. The results can then be compared with A very significant outcome of this paper can be the approach in which multicast traffic is quantized and then subsequently helps in cost estimation.

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