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Access Latency Model of Popularity Based QOS-Aware Replica Management Algorithms for Efficient Content Distribution in Distributed Computing Networks

[1]Dr. Anna Saro Vijendran, [2]S. Thavamani
[1]M.C.A., M.Phil., Ph.D., [2]M.Sc., M.Phil.

Abstract*— In this paper analyze the setting of methodological (analytic) models for distributed computing network performance analysis. This paper presents the basic of distributed computing network analyzes and discussions of distributed computing network design procedure. Finally, this paper presents some of the issues surrounding the design and behavior of distributed computing networks. In the heterogeneous peer's scenario, we propose the access latency model of popularity based QOS aware replica management algorithms for efficient content distribution in distributed computing network. This schedule gives the large data transmission of a reduced transmission delay, bandwidth utilization and increased throughput. The solution of proposed model based on the popularity of objects, peers weight values and cost model which could be considered into account several factors such as processor speed, access latency, and flow of bandwidth, storage capacity of peers. Routing is performed hierarchically by broadcasting the query to the clusters. From wide simulations using NS2 simulator, this proposed access latency model proves analysis of reduced delay.

Index Terms—**Distributed Computing, Content Distribution, Performance analysis, Simulation, Access Latency, Distributed Computing Networks.**

I. INTRODUCTION

Peer-to-peer(P2P) which is a distributed computer architecture are designed for sharing the computer resources such as storage, content, CPU cycles directly irrespective using a centralized server. P2P networks are classified based on their failure adaptation abilities, connectivity along with maintenance of suitable connectivity. Remarkable research attention has been pertained to content distribution which is a significant peer-to-peer application on the internet. Overlay networks are supple and easy to deploy which allows users to achieve distributed operations without changing or modifying the available underlying physical network. Peer-to-peer (P2P) architectures for file sharing among large distributed computing network, possibly dynamic, collection of peers are generating an increased fraction of the traffic on today's Internet and are reshaping the way new network applications are designed. The idea is to have the peers participate in an application level overlay networks enabling the signaling, routing, and searching among the participating peers. Once a peer locates the objects/ file(s) of interest, direct connections are established to mediate their transfer. The key principle is to allow, and in fact encourage, participating peers to play vital roles as servers or clients or routers. [1][2]

The fact is, there are a number of ways for doing network system performance analysis. They are as follows

1. Conduct a mathematical analysis which produces ex plicit performance expressions.
2. Conduct a mathematical analysis which produces an algorithmic or numerical evaluation procedure.
3. Write and run a simulation.
4. Build the system and measure its performance [11]

There is no explicit derivation enough to develop the first type of solution. That is, there is no explicit derivation to solve the mathematical model for our system. Because that the mathematical models *never* do an exact job in representing the actual network being analyzed. *Thus it always ends up with an approximation solution, even if our analysis is exact.* Sometimes, all we can do is to provide an approximate solution with the help of mathematical model; this often takes cleverness on the part of the analyst. So we analyze the actual measurements of the real network with simulation. Here we are analyzing and evaluating the performance of QOS matrices by using NS2 simulator. This document emphasizes the experimental performance evaluation of our proposed replica management algorithm through simulations. To simulate our proposed QOS aware dynamic replica management algorithms we used NS2 simulator. NS2 simulator is a general-purpose simulation tool that provides discrete event simulation of user defined networks. Based on the assumption that the overhead of the P2P network is at the access links of the users and not at the routers, we use a binomial topology in our simulations.

II. THE EARLY NETWORK ANALYSIS MODELS

The first models of computer networks were developed in the early 1960's [5] ,[6], However, it was not until the late 1960's when the United States Department of Defense Advanced Research Projects Agency (DARPA) funded the development of the ARPANET that serious effort began in this area. Indeed, it was the combination of a relatively small amount of government money and a large amount of vision in funding peer to peer network research that propelled the entire field of networking and packet switching forward and produced the extensive analytical work and physical networks in which the authors find themselves swimming today. One of the first general results was an *exact* expression for the mean delay experienced by a message as it passed through a network. The evaluation of this delay required the introduction of an assumption (the author's Independence Assumption) without which the analysis remains intractable, and with which the analysis becomes quite straightforward. Let us begin the author's journey through the analytical thread with the model [5]. Here the authors assumed in the peer to peer network that there are N peers corresponding to the network switches and in which y assume there are M links corresponding to data channels connecting the switches. They assumed that messages arrive from a poison process at origin peer j and headed for destination peer k at a rate $\gamma_j k$; that is, the variables $\gamma_j k$ correspond to the entries in the peer to peer network traffic matrix. In addition, the authors assume that the messages are exponentially distributed with mean length $1/\mu$ bits per message. Since each channel in the network is, in fact, a full-duplex channel, the authors choose to represent a channel as two simplex channels. Thus there are three ways incoming and outgoing of the peer for the moment. Now, when a message arrives to such a peer, a routing decision must be made which determines over which outgoing channel the message will travel next. Once this decision is made, the message is placed on the tail of a queue of other messages waiting to be transmitted out over this channel (say channel i). In the peer to peer network the authors have identified a queuing system consisting of such a queue and its corresponding channel. They denote by λ_i the traffic carried on this channel (in messages per second) and let C_i be the capacity of this channel (bits per second). In addition, let T_i be the mean response time of this **little queuing system.** Let us also define some global quantities. First, the authors define the total (external) traffic carried by the peer to peer network as

$$A.\quad \gamma = \sum_{j,k=1}^{N} \gamma \quad \_\_\_\_\_\_\_\_\_\_(1)$$

and the total (internal) network traffic carried by the channels as

$$\lambda = \sum_{i=1}^{M} \lambda_i \quad \_\_\_\_\_\_\_\_\_\_(2)$$

Furthermore if the author let π be the average number of hops that a message must take in its journey through the network (averaged over all origin-destination pairs), then it is easy to show that the following is true [5]:

$$\pi = \lambda/\gamma \quad \_\_\_\_\_\_\_\_\_\_ (3)$$

Finally, and most importantly, we define T to be the mean delay of all messages (again, averaged over all origin-destination pairs). T is the mean response time of the peer to peer network and is one of the most important performance variables for a peer to peer network. It can easily be seen (by two applications of **Little's result** [7]) that [5]

$$T = \sum_{i=1}^{M} \frac{\lambda_i}{\gamma} T_i \quad \_\_\_\_\_\_\_\_\_\_ (4)$$

This is an exact equation and is an important general result for peer to peer networks of all sorts. The only difficulty with this last equation is that the authors have not given an explicit expression for T_i. In general, this turns out to be an unsolvable problem. It is probably true that the author will *never* be able to give a tractable expression for Ti! This may come as a surprise to those familiar with **queuing networks**; indeed, it appears that they have been set up a perfect Jackson open queuing network whose solution is simple and well-known [8]. It turns out that if the authors change the model to one which is, in fact, more representative of object/data traffic, and then the authors gave an exact solution for a restricted topology. The modification is to assume that the message lengths are all the same (rather than the exponential assumption above) and that the topology is a tandem network; in this case, Rubin [10] was able to give an exact solution for the response time when all traffic enters at one end of the tandem and exits at the other end. Unfortunately, the analysis does not extend to the case of non-tandem networks. Let us now return to the author's original model using exponentially distributed message lengths. As mentioned above, extreme analytical difficulty comes from the dependence among message service and inter-arrival times. The Independence Assumption assumes that the length of a message is chosen independently from the exponential distribution each time it enters a switching node in the computer network! This is clearly a sweeping assumption which is patently false; however, it turns out (from measurements and simulation) that this assumption has a negligible effect on the mean message delay. AND, if the authors do make the assumption, then their analysis becomes trivial since they will have then reduced the system to a Jackson open queueing network model. If the authors make the Independence Assumption, then the expression for Ti for the i^{th} queueing system reduces to an M/M/l queueing system [8] whose solution is simply.

$$Ti = \frac{1}{\mu C_i - \lambda_i} \quad \_\_\_\_\_\_\_\_\_\_(5)$$

Note that μCi is the capacity of the ith channel expressed in messages per second. When they substitute this into (4), they end up with an explicit and simple expression for the mean message delay T as follows:

$$T = \sum_{i=1}^{M} \frac{\lambda_i}{\gamma} \left(\frac{1}{\mu C_i - \lambda_i} \right) \quad \_\_\_\_\_\_\_\_\_\_ (6)$$

This equation is very effective for design calculations were below. However, it ignores certain realities which become important when one wishes to give a more precise prediction

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of network delay. For example, the authors have assumed K = 0 and Pi = 0 (where K = nodal processing time and Pi = propagation delay). When they came to apply this analysis to any realistic network, they must include these variables as well as other considerations. If the authors let *1/µ*i denote the average length of a data packet and if we let *1/µ*i represent the average length of all packets, then they have seen that a more accurate expression for Ti is

$$Ti = \frac{\lambda_i/\mu^1 C_i}{\mu^1 C_i - \lambda_i} + \frac{1}{\mu Ci} \qquad (7)$$

Of course, if the authors set $\mu 1 = \mu$, this would reduced to equation (5). If the authors now account for the nodel processing time K and the channel propagation time P_i they may then write down the following approximation for the average message delay:

$$Ti = K + \sum_{i=1}^{M} \frac{\lambda_i}{\gamma}\left(\frac{\frac{\lambda_i}{\mu 1 Ci}}{\mu 1 Ci - \lambda_i} + \frac{1}{\mu Ci} + Pi + K \right) \qquad (8)$$

The term in the brackets is just our new expression for ***Ti*** and the additional term ***K*** comes from the fact that messages pass through one more peer than they do channels in their travels through the peer to peer network.[6] From this delay analysis we may predict quantitative as well as phenomenological behavior of the average message delay in peer to peer networks. In particular, if we assume a relatively homogeneous set of Ci and A,, then as we increase the load on the network, no individual term in the sum for delay as given in equations (4,9) will dominate the summation until the flow in one channel (say channel ***i_0)*** approaches the capacity of that channel; this channel corresponds to the network *bottleneck.* At that point, the term Ti_o, and hence T, will grow rapidly. The expression for delay will then be dominated by this term and T will exhibit a threshold behavior; prior to this threshold, T remains relatively constant and as we approach the threshold, T will suddenly grow. Thus we expect an average delay in networks that has a much sharper behavior than the average M/M/l delay.

III. DESIGN ISSUES

A. System Model

Replication in Overlays network can be defined as graph G = (V, E), where V is the set of nodes and E ⊂V × V the set of links between the nodes in the overlay network. Each node is associated with a bandwidth Nb (node (i)). The system model is considered with a collection of N server nodes that form a peer to peer (P2P) overlay network. Along the part of the overlay, each node in the network functions as a server responding to queries which come from clients outside of the overlay network. As an example could be that each node is a web server with the overlay linking the servers and clients being web browsers on remote machines requesting content from the servers. It is assumed that each node always stores one copy of its own content item which it serves to clients and that it has additional storage space to store the replicated content items from other nodes which it can also serve. The object is associated with an authoritative origin server (OS) in the network where the content provider makes the updates to the object. The object copy located at the origin server is called the origin copy and an object copy at any remaining server is called a replica.

B. Assumptions

1. Each peer including the requesting peer can store replica copy.
2. Peer storage space is limited and additional replica if needed can only be placed by replica replacement.
3. Primary copy can reside only in one peer
4. Distributed list of replica information is stored across the overlay network in a peer in each cluster.
5. Cluster of peers is a set of nodes grouped physically. (e.g. nodes under a ISP, nodes in a university campus)

C. Replica Placement Matrix Representation of Replica Management Algorithms

Replica placement matrix is representing the requested object O_j which is in either Local peer or in Strong or medium or in weak cluster peer or in the origin server. A peer Pi knows the request rates (number of requests) r_{ij} , i=1,2,…m of all peers and j=1,…,n of its local users for all objects. The vector of request rates of the users at peer P_i is denoted by r_i=(r_{i1} , r_{i2} , r_{i3} ,…, r_{im}) the m X n of request rates of all objects at all peers. For the replica placement matrix PM and it is denoted by m X n matrix whose entries are represented as follows

$$PM_{ij} = \begin{cases} -1, if\ o_j in\ Localcatch \\ = 0, if\ o_j inStrongClusterPeer \\ = 1, if\ o_j inMediumClusterPeer \\ = 2, if\ o_j inWeakClusterPeer \\ > 2, if\ o_j inOriginServer \end{cases}$$

For i=1, 2,…,m and j=1,2,…,n. The system goal is to minimize the access cost each server overall objects.

IV. ACCESS LATENCY MODEL OF POPULARITY BASED QOS AWARE REPLICA MANAGEMENT ALGORITHMS

In distributed replication group a server peer needs to respond to the requests of various clients and also from other servers. At an instance a server consumes a request from the client, it quickly responds to the client if the requested object is available in its local storage. Else if, the requested object is fetched from other server peers within the group which will result in higher access cost. Else, the origin server access cost will be highest. A server needs to reduce its load through responding to the local client requests by replicas.

1. Let us define an N x M replication matrix with elements of PM= -1, 0, 1, 2, and >2. For i = 1,2, …, N number of

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peers and j = 1,2, …, M number of objects taken for replica creation and accessing in P2P network. An element PM_{ij} of this matrix will be equal to -1 if object O_j is replicated at local catch. The replica management problem and access latency may be formulated as follows

2. Find the assignment of -1, 0, 1, 2 , >2 values at the PM matrix ($PM_{ij} = -1$)that minimizes access latency.
3. Subject to the storage capacity constraints (ie. $PM_{ij} \le Ci$)

The system's goal is to minimize access time at each peer overall objects are as follows

$$Ti=\min\sum_{i=1}^{m}\left(\begin{array}{l}\sum_{j:PM_{ij}=-1} r_{ij}t_l+\sum_{j:PM_{ij}=0and(PW_i>\beta_{\max})} r_{ij}t_S \\ +\sum_{j:PM_{ij}=1and(PW_i\le\beta_{\max}andPW_i\ge\beta_{\min})} r_{ij}t_M \\ +\sum_{j:PM_{ij}=2\&\&(PWi<\beta_{\min})} r_{ij}t_W+\sum_{j:PM_{ij}>2\&\&(PWi<\beta_{\min})} r_{ij}t_{OS}\end{array}\right) \_\_\_\_9$$

The terms of the objective function represents the access time corresponding to the objects that are cached from local peer, from strong, medium, weak cluster peers, and from OS respectively.

V. EXPERIMENTAL PERFORMANCE EVALUATION OF ACCESS LATENCY MODEL

The performance is evaluated in terms of QOS metric such as end to end delay during content distribution for the proposed methods of SRMA [4] and PQSRMA [3]. The simulation will be conducted in two different scenarios to obtain an efficient result in terms of QOS performance metrics. Scenario 1 compares the proposed methods of PQSRMA [3] and SRMA [4] with the existing method QIRMA[14] in terms of QOS metrics such as throughput, packet drop, end to end delay, bandwidth utilization, query efficiency with load.

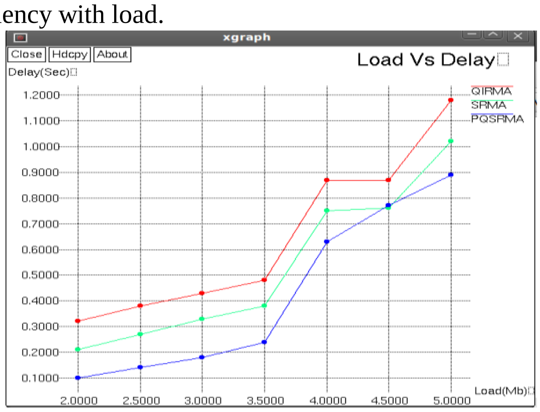

Fig.1 Load Vs Delay

i) Scenario 2 compares the proposed methods of PQSRMA and RRTIR with the existing method QIRMA in terms of QOS metrics such as throughput, packet drop, end to end delay, bandwidth utilization, query efficiency with data transfer rate.

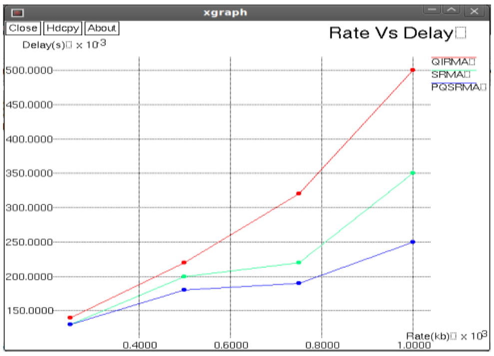

Fig .2 Rate Vs Delay

In this experiment, the rate of the requested content is varied from 2.0mb to 8.0 Mb. The response delay of packets is measured in seconds. From the Figure.2, it is evident that, when the rate increases, the delay also increases. Also it is shown that the delay of our proposed methods SRMA [4] and PQSRMA [3] is significantly less than the delay of QIRMA [14] since the proposed SRMA [4] and PQSRMA [3] utilizes the network less than that of QIRMA [14].

VI. CONCLUSION

In this paper, we have taken the analytic model of a peer to peer network for proposed methods. The purpose was to give the reader, the understanding as to the approximate state of the art in performance modeling and analysis of access latency. From the above two figures we came to know that the delay increases when increases the load. According to the little's law when the load increases that the delay increases automatically. PQSRMA [3] has reduced delay when comparing with QIRMA [14] and SRMA [4].

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AUTHOR BIOGRAPHY

Dr. Anna Saro Vijendran is the Director MCA in SNR Sons College, Coimbatore, India. She has a teaching experience of 21 years in the field of Computer science. Her area of Specialization is Digital Image Processing and Artificial Neural Networks .She has presented more than 40 Papers in various Conferences and her research works have been published in International Journals. She is currently a Supervisor for research works of various Universities and also Reviewer for reputed Journals.

S. Thavamani is an Assistant Professor in Department of Computer Applications, SNR Sons College, Coimbatore, India. She has a teaching experience of 14 years in the field of Computer science. Her area of Specialization is Distributed Computing and Networks. She has presented more than 15 Papers in various International and National Conferences. She is currently a supervisor for M.Phil research works of various Universities. She is currently pursuing Ph.D Degree in SNR Sons College, under Bharathiar University, Coimbatore.