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An Efficient Fair Resource Allocation in Multicast Networks

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***Abstract*—A decentralized algorithm is presented that enables the different rate-adaptive receivers in different multicast sessions to adjust their rates to satisfy some fairness criterion. The problem of congestion control in networks, which supports both multirate multicast sessions and unicast sessions. A one-bit Explicit Congestion Notification (ECN) marking strategy to be used at the nodes is also proposed. The congestion control mechanism does not require any per-flow state information for unicast flows at the nodes. At the junction nodes of each multicast tree, some state information about the rates along the branches at the node may be required. This Paper calculates the throughput and rates of unicast and multicast packets for the given topology network receivers. The congestion control mechanism takes in to account the diverse user requirements when different receivers within a multicast session have different utility functions, but does not require the network to have any knowledge about the receiver utility functions. This paper compared the performance and fairness of unicast and multicast sessions.**

***Index Terms*— Congestion Control, Multicast, Explicit Congestion Notification (ECN), Unicast, traffic.**

I. INTRODUCTION

IN the modern Internet, there is a demand for multicast especially in applications where communication is required in a group. Multicast traffic can cause more congestion related damages than unicast traffic[8]. Due to the fact that a single multicast flows can be distributed along with a large multicast tree reaching throughout the entire internet. An important issue in the deployment of multicast is the impact of multicast traffic on the global Internet when there is congestion. This paper considers the problem of congestion control in networks, which support Multirate multicast sessions. This paper presents a decentralized algorithm which enables the different rate adaptive receivers in different multicast sessions to adjust their rates to satisfy some fairness criterion. A one-bit Explicit Congestion Notification (ECN) marking strategy to be used at the nodes is also proposed. This mechanism is highly desirable if we want the network to operate at low loss. This is a marking scheme to implement the congestion control algorithm[1]. The receivers adapt their rates accordingly based on the marks received. The congestion control mechanism does not require any per flow state information for unicast flows at the nodes. Widespread deployment of multicast communication in the Internet depends critically on the existence of practical congestion control mechanisms that allow multicast and unicast traffic to share network resources fairly[5]. Most service providers recognize multicast as an essential service to support a range of emerging network applications including audio and video broadcasting, bulk data delivery, and teleconferencing[15]. Nevertheless, network operators have been reluctant to enable multicast delivery in their networks, often citing concerns about the congestion. The basic conflict is, it is desirable to encourage use of multicast where appropriate to reduce the overall bandwidth demand of applications that transmit high-bandwidth data to many receivers, but the introduction of multicast sessions into the network must not deteriorate the performance of existing unicast traffic. There is a clear need for multicast congestion control algorithms that are provably fair to unicast traffic if this concern is to be addressed. Aim in this article is to provide insight into the problem of multicast congestion control by describing a promising new approach for congestion control of single-rate multicast traffic.

A. *Explicit Congestion Notification (ECN)*

For networks with mechanisms for the detection of incipient congestion, the use of ECN mechanisms for the notification of congestion to the end nodes prevents unnecessary packet drops. For bulk-data connections, the user is concerned only with the arrival time of the last packet of data, and delays of individual packets are of no concern. For some interactive traffic, however, such as telnet traffic, the user is sensitive to the delay of individual packets. For such low-bandwidth delay-sensitive TCP traffic, unnecessary packet drops and packet retransmissions can result in noticeable and unnecessary delays for the user. For some connections, these delays can be exacerbated by a coarse-granularity TCP timer that delays the source's retransmission of the packet. A second benefit of ECN mechanisms is that with ECN, sources can be informed of congestion quickly and unambiguously, without the source having to wait for either a retransmit timer or three duplicate ACKs to infer a dropped packet. For bulk-data TCP connections, the delay for the retransmission of an individual packet is not generally an issue. For bulk-data TCP connections in wide-area environments, the congestion window is generally sufficiently large that the dropped packet is detected fairly promptly by the Fast Retransmit procedure. Nevertheless, for those cases where a dropped packet is not detected by the Fast Retransmit procedure, the use of ECN mechanisms can improve a bulk-data connection's response to congestion. If the source is delayed in detecting a dropped packet, perhaps due to a small congestion control window and a coarse-grained TCP timer, the source can lie idle. This delay, when combined with the global synchronization, can result in substantial link idle time. An additional motivation for the exploration of ECN mechanisms in TCP/IP networks concerns the possibility of TCP/IP traffic traversing networks that have their own congestion control mechanisms (e.g., ATM networks). This use of ECN mechanisms to inform TCP sources of congestion would be independent of the congestion control mechanisms within the ATM networks. The simulations in this paper show that the use of ECN can reduce packet delay, but they do not quantify the expected reduction in packet delay in a particular network.

II. Related Work

In the paper [2], the authors have extended the algorithm for the computation of max-min fair rates when discrete bandwidth layers are available as in the case of layered video[10][13]. In this paper, they introduce a new notion of fairness, maximal fairness. They propose a polynomial complexity algorithm for computation of maximally fair rates allocated to various source destination pairs. The disadvantage of this paper is, Max-min fair rate vector does not exist and also Fairness issues become vastly different. In this paper [3], Optimization based rate control mechanism is based on a utility maximizing framework. They have been proposed for multirate a multicast session, which tries to solve the dual of a convex program formulation of the problem[11]. This requires per flow state information at the nodes. It is not clear how this can co-exist with TCP-based unicast congestion control. The disadvantage of this paper is, it requires Per flow state information at the nodes and also it does not support with TCP-based unicast congestion control. In the paper [4], It enables a principled approach to the important problem of fairness between multicast and unicast traffic. They identified a fundamental trade-offs between the performance expectations of users and the stability concerns of network operators. This paper provide insight into problem of multicast congestion control by describing a promising new approach for congestion control of single rate multicast traffic. Therefore this mechanism is not strictly fair to unicast traffic, but can be tuned to provide an acceptable level of such controlled unfairness. The disadvantage is, Unfair to unicast traffic and also Strict Fairness. In this paper[9], Fairness in allocating bandwidth for loss-tolerant real-time multicast applications. Assume that the traffic is encoded in several layers so that the network can adapt to the available bandwidth and receiver processing capabilities by varying the number of layers delivered. In this case receivers cannot subscribe to fractional layers. Therefore, the network can allocate only a discrete set of bandwidth to a receiver, whereas a continuous set of rates can be allocated when receivers can subscribe to fractional layers. Furthermore, maxmin fair rate vector may not exist in this case. Even though maximal fairness is a weaker notion of fairness, it has many intuitively appealing fairness properties. The disadvantage is, Max-min fair rate does not exist and also not scalable. In this paper [6], A framework for designing end-to-end congestion control schemes in a network where each user may have a different utility function. There exists an additive increase multiplicative decrease scheme using only end-to-end measurable losses such that a socially optimal solution can be reached. The potential advantages of such networks would be the ability to offer even real time services with little or no interaction from the core network, i.e., without the need for a centralized admission control, resource reservation or complicated scheduling mechanisms. The disadvantage is, Low –delay service and also not scalable.

From the above papers, it considers virtual session as separate unicast sessions. This cannot be applying for a common congestion control mechanism. Unfair to the virtual sessions with rate less than multicast session rate. Source based

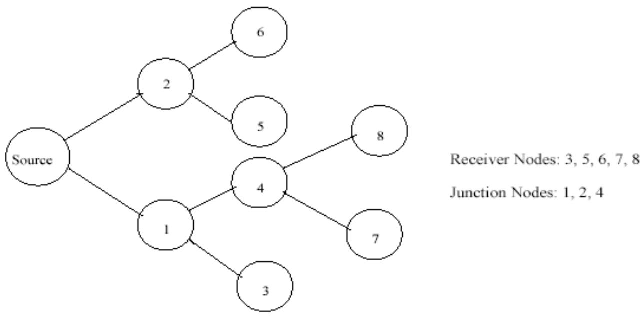

Fig. 1. A Multicast routing tree with 5 receivers and 3 intermediate junctions' nodes.

ECN congestion is also not appropriate.

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III. Math

A decentralized algorithm is presented that enables the different rate-adaptive receivers in different multicast sessions to adjust their rates to satisfy some fairness criterion. The algorithm used to control the congestion in the multicast

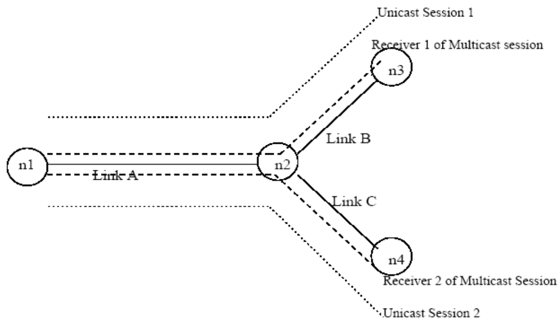

Fig. 2. The Y network with two unicast sessions and one multicast session with two virtual sessions.

network is the Multicast Congestion Control Algorithm. This algorithm gives a detailed explanation about the congestion control. A one-bit ECN marking strategy to be used at the nodes is also proposed[12]. The congestion control mechanism does not require any per-flow state information for unicast flows at the nodes. At the junction nodes of each multicast tree, some state information about the rates along the branches at the node may be required. The congestion control mechanism takes in to account the diverse user requirements when different receivers within a multicast session have different utility functions, but does not require the network to have any knowledge about the receiver utility functions.

A. Congestion Control Algorithm for Multicast Networks

A Class of congestion-control algorithm for rate adaptive Multirate multicast sessions, keeping in mind the heterogeneity of the multicast receivers. Algorithm require a packet marking capability by the network without keeping per-flow state information about the unicast sessions and requires minimal per flow information about the virtual sessions. An easy to implement one-bit ECN marking scheme to implement the congestion control algorithm. The receivers adapt their rates accordingly based on the marks received.

If the link has a marking function that depends on the total flow rate through the link, then it sets the ECN bit of a packet to1. If the ECN bit is 1, it is left as it is.

For packets of unicast sessions and packets of multicast sessions for which the node is not a junction node, it transmits

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each packet along the desired path. If the node happens to be a junction node of a multicast tree, then it sends the marks to any of the receivers whose rate is same as the multicast session rate. For all other receivers, the junction node unmarks any packet that is marked, before sending any copy of the packet. This effectively sets the ECN bit to 0 for all but one of the receivers for which it retains the mark. The receiver that receives the ECN bit chosen at random among the receivers with rate equal to the multicast session rate.

From the marked packets received, each virtual session estimates the rate at which marked packets are received. Specifically, let tk be the instant of the kth update and let m (tk) be the number of marked packets received in interval (tk,tk+1). Then m (tk)/(tk+1-tk) gives an estimate of the rate at which marked packets are received.

B. *Congestion Control Algorithm for Multicast Networks*

Consider the multicast tree with hierarchical organization of multicast nodes as shown in the figure 3.1. The source is at the top of the tree and there are five receivers, the nodes 3,5,6,7 and 8. The nodes 1,2 and 4 where the multicast tree splits are referred to as junction nodes. Any junction node can aggregate the feedback about the updated rates before passing it on the parent node.

For example, node 4 can calculate the maximum of the rates of receivers 7 and 8 and pass that to node 1. This is the rate at which node 1 sends data to node 4. Node 1 computes the maximum of the rate at which it sends data to node 4 and the rate at which it sends data to node 3 and forwards this information to the source. The source sends data to node1 with this rate (subscription level). Thus, every junction node consolidates the updates of the subscription level or the rates received from its children nodes, before providing a feedback to the parent node about the new desired rate or subscription level. In this implementation, every node in the network, which is a junction node of some multicast tree, has to keep track of the desired level of subscription or rates of every node it sends packets to[7]. However, the congestion control for the unicast sessions within the network can still be source-driven based on the feedback received from the receivers.

IV. Results with Packet-Level Simulation

The Simulation results using a packet model for transmission of data. The figure 1 shows a network with topology as the Y network to perform packet-level simulations. The network has four nodes, n1, n2, n3 and n4. Each of the nodes is connected by some rate and has a one-way propagation delay.

There are three classes of users. Class 1 consists of multicast sessions with source at node n1 and two receivers for each of the multicast sessions in this class at node n3 and n4. Class 2 has unicast sessions from node n1 to n3 and class 3 sessions is unicast sessions from node n1 to node n4.

A multicast network is comprised of nodes that replicate copies of each packet (depending on the rate requirement of the receiver) of a multicast session before sending to different receivers whose paths are different from that node onwards. These nodes are referred to as “junction nodes”. In the figure 4.1, the node common to the link A.B and C is a junction node for the multicast session. Clearly, the different multicast

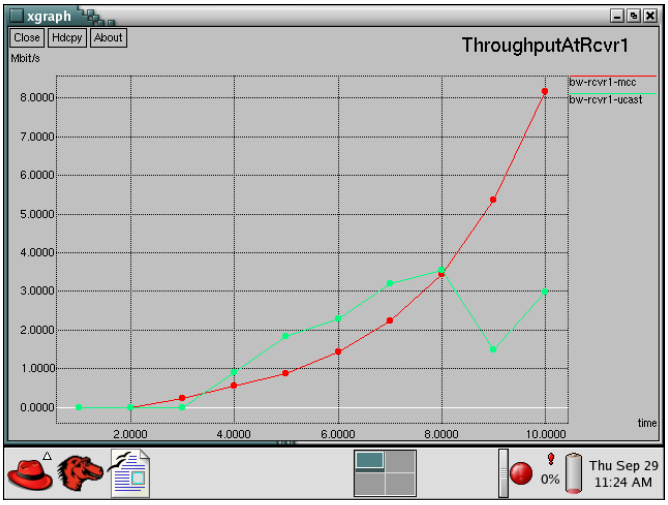

Fig. 4. The unicast and multicast Throughput at receiver1.

receivers of a multicast flow to receive ECN marks at different rates. However, the replication of copies of packets of a multicast flow will mean that if a packet is marked, the mark reaches all the receivers receiving a copy of the packet. To overcome this difficulty, introduce an unmarking scheme at the junction nodes. In reality, a diecretized version of the rate-control algorithm will be implemented, along with a minimum allowed rate. In this the updates of the rates of the different multicast sessions has to take in to account the sum of the marking probabilities in all the links along the path.

Consider a more complex network as shown in fig. 2 to illustrate the impact of discrete bandwidth layers being available. The different links are indexed and the corresponding capacities are given in the parenthesis next to the link. Simulation of this complex network is done with six multicast sessions and five unicast sessions. In this set of simulation, when the users (sources for unicast sessions and receivers for any multicast receiver) respond based on the ECN marks received have been chosen. Since the purpose of the simulation experiment is to demonstrate the effectiveness of the congestion-control algorithm when unicast and multicast

$$P(\lambda)=\frac{(\lambda_l - C_l)^+}{\lambda_l}$$

Where λl is an estimate of the total arrival rate in a link and Cl can be as a marking level of the link l and we have chosen Cl =0.98*C in the simulation. However, the observations in the simulation hold good for any other marking function used by the links[14].

The simulation results shows that the effect of throughput seen by each users, but they do not affect the relative fairness among the long flows. The simulation graphs show the compared results for the unicast and multicast session rates.

From the simulation of graphs, the multicast rate and throughput is better than the unicast rate and throughput. The reason is more number of packets is received at the multicast receivers. In the rate calculation of receiver 1 and receiver 2, only the unicast rate can be different from receiver1 and receiver 2. The multicast rate is same for both the receivers. Similarly the throughput calculation for the receiver 1 and receiver 2, the unicast throughput is different. The throughput for the multicast at receiver 1 and receiver 2 is same. So there is no change for the multicast rate and throughput for the both receivers as shown in the graphs.

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Multipliers can be especially confusing. Write "Magnetization (kA/m)" or "Magnetization (10^3 A/m)." Do not write "Magnetization (A/m) × 1000" because the reader would not know whether the top axis label in Fig. 1 meant 16000 A/m or 0.016 A/m. Figure labels should be legible, approximately 8 to 12 point type.

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Number citations consecutively in square brackets [1]. The sentence punctuation follows the brackets [2]. Multiple references [2], [3] are each numbered with separate brackets [1]–[3]. When citing a section in a book, please give the relevant page numbers [2]. In sentences, refer simply to the reference number, as in [3]. Do not use "Ref. [3]" or "reference [3]" except at the beginning of a sentence: "Reference [3] shows ... ." Unfortunately the IEEE document translator cannot handle automatic endnotes in *Word*; therefore, type the reference list at the end of the paper using the "References" style.

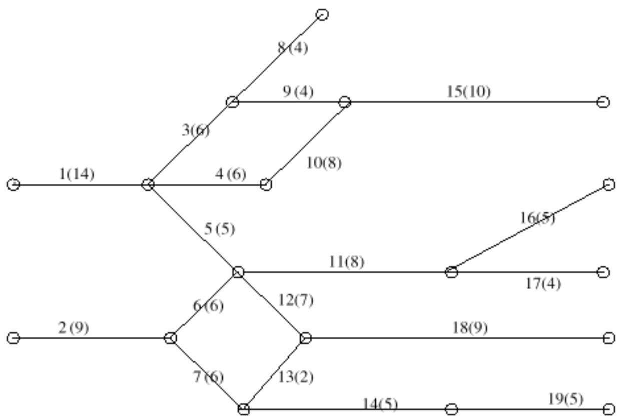

Fig. 3. Complex network with 19 links.

Number footnotes separately in superscripts (Insert | Footnote).[1] Place the actual footnote at the bottom of the column in which it is cited; do not put footnotes in the reference list (endnotes). Use letters for table footnotes (see Table I).

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$$\begin{aligned} \int_0^{r_2} & F(r,\varphi)\, dr\, d\varphi = [\sigma r_2/(2\mu_0)] \\ & \cdot \int_0^{\infty} \exp(-\lambda |z_j - z_i|)\, \lambda^{-1} J_1(\lambda r_2)\, J_0(\lambda r_i)\, d\lambda . \end{aligned} \tag{1}$$

Be sure that the symbols in your equation have been defined before the equation appears or immediately following. Italicize symbols (*T* might refer to temperature, but T is the unit tesla). Refer to "(1)," not "Eq. (1)" or "equation (1)," except at the beginning of a sentence: "Equation (1) is ... ."

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Use one space after periods and colons. Hyphenate complex modifiers: "zero-field-cooled magnetization." Avoid dangling participles, such as, "Using (1), the potential was calculated." [It is not clear who or what used (1).] Write instead, "The potential was calculated by using (1)," or "Using (1), we

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calculated the potential."

Use a zero before decimal points: "0.25," not ".25." Use "cm^3," not "cc." Indicate sample dimensions as "0.1 cm × 0.2 cm," not "0.1 × 0.2 cm^2." The abbreviation for "seconds" is "s," not "sec." Do not mix complete spellings and abbreviations of units: use "Wb/m^2" or "webers per square meter," not "webers/m^2." When expressing a range of values, write "7 to 9" or "7-9," not "7~9."

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IX. CONCLUSION

This paper proposed a class of congestion control algorithms for networks with unicast and multicast sessions. The congestion control mechanism can be implemented in a decentralized manner and with a simple one bit-marking scheme. The marking scheme is simple: among all receivers whose rate equals to the rate of the multicast session, randomly select a receiver to send the ECN marks. The congestion control mechanism takes in to account the diverse user requirements when different receivers within a multicast session have different utility functions, but does not require the network to have any knowledge about the receiver utility functions. From this simulation, the performance of multicast sessions is better than the unicast session. Also more number of packets is received in the 1multicast session than the unicast session.

In future, a new approach to multiple rate congestion control that leverages proven single rate congestion control methods by orchestrating an ensemble of independently controlled single rate sessions. A new scheme combines the benefits of single rate congestion control with the scalability and flexibility of multiple rates to provide a sound multiple rate multicast congestion control policy.

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