# Multicast as a traffic variance smoother for IP streaming service

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## Abstract

Live streaming service is expected to be popular in future IP networks. However, since the traffic generated by this service has a large bandwidth that varies unpredictably, it is very likely to bring about network congestion. This paper clarifies that the intractability of stream distribution traffic is effectively reduced by multicast techniques. The paper focuses on one multicast implementation technique and executes a computer simulation to verify its effectiveness. The simulation results show that the technique successfully decreases the traffic volume and variance for several traffic-change scenarios. It is also shown that traffic burstiness is, as measured by self-similarity, smoothed by multicast. All these characteristics confirm that the multicast technique effectively avoids the congestion possibilities associated with IP streaming services.

## 1. Introduction

The live streaming of contents, such as video broadcasting or Internet radio, will become the most promising service among the many interesting possibilities offered by the IP (Internet Protocol) network. It is anticipated that this service may provide telecommunication carriers or service/contents providers with a new income source. Unfortunately, the traffic of this service is intractable from the viewpoint of congestion for the following reasons. First, the bandwidth required is large, particularly for video broadcasts. Next, the bandwidth is likely to increase as the service becomes more popular. Moreover, the traffic will be bursty because data recipients randomly join and leave the data stream. Additionally, the geographic traffic patterns will vary unpredictably over time since traffic may concentrate on a particular area due to the release of a popular content. The asymmetry of the traffic is another problem in providing the service.

The live streaming service is expected to become more popular and dominate the IP network traffic. This means that the above traffic difficulties will become more critical. Among these difficulties, traffic asymmetry was treated in [2] and [3]. Thus, the remaining problems to be solved are large bandwidth requirements, increases in these requirements, and traffic burstiness. Considering the nature of the service, the employment of multicast techniques is a powerful solution to these remaining problems.

The key feature of live streaming traffic is the simultaneous distribution of the same information to many recipients. Therefore, transmission may become redundant which wastes network resources. It is known that multicast techniques can effectively reduce the volume of such traffic [4]. With a view to easing implementation concerns, we can employ the standardized IP multicast protocol [5] or other multicast techniques [1,6]. While these multicasting techniques are now widely available, it becomes important to determine how effectively multicast can decrease the traffic intractability caused by live streaming service.

This study uses computer simulations to examine the effectiveness of multicast in decreasing the traffic intractability. This study employs the multicast technique proposed in [1], because it can be introduced to the existing IP network more easily than the alternatives. To clarify its effectiveness in terms of traffic characteristics, several simulation scenarios are examined. These scenarios include traffic volume increases, geographic traffic pattern change/concentration and the partial placement of copy nodes. Traffic load characteristics were measured under these scenarios, and compared to the performance of unicast. The results show that the multicast technique minimizes the volume and variance of traffic load against demand variations. In particular, multicast dramatically reduces the burstiness of the traffic as well as its volume compared to unicast. The burstiness reduction is verified by checking the self-similarity of the traffic on a link. These characteristics prove that multicast effectively reduces the possibility of congestion when providing live streaming service. It is also shown that a significant reduction in traffic volume and variance can be obtained by introducing just a few copy nodes into the network. These results suggest that multicast is a promising technique with to solve the traffic problems expected in the future IP network that supports live streaming as the dominant service.

This paper is constructed as follows. Section 2 describes the multicast technique considered. The network model and scenarios used in the simulations are presented in Section 3. Finally, the simulation results are given in Section 4.

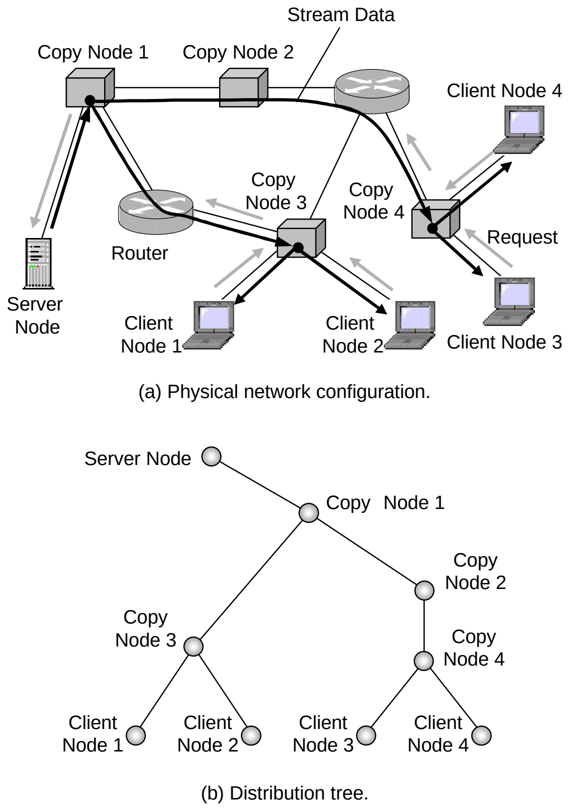
## 2. Multicast technique

The term multicast originally means a communication style, in which one source sends the same data to one or more recipients simultaneously [4]. This type of communication is possible by setting multiple one-to-one communication relationships between the source and recipients. However, it is more efficiently achieved through a distribution tree. This technique places a copy function at each transit node and thus eliminates duplicative transmission of the same data. This study calls such communication style "multicast"; the communication method that establishes multiple one-to-one communication relationships is referred to as "unicast". Several multicast methods have been proposed [1,5,6].

Among the multicast techniques suitable for IP networks, this study focuses on the multicast scheme proposed in [1]. This technique provides a more practical way of distributing the same data stream to many recipients simultaneously than the alternatives with regard to the following points:

- Simpler administration than standardised IP multicast.
- Load balancing and dynamic reconstruction of multicast trees.
- Addition of personalized information such as advertisements is possible.

The multicast technique proposed in [1] utilizes client nodes, server nodes, copy nodes (referred to as active nodes in [1]), and optional legacy routers. These nodes configure logical distribution trees, through which stream data are transmitted. Each distribution tree is associated with one particular data stream, for example, a video program. A server node is the root of the tree and acts as the source that sends original stream data. The leaves of the tree are client nodes, which send distribution requests and receive the stream data. Other nodes in the tree are copy nodes. The data passes from the server node to the copy nodes. A copy node makes as many copies of the data stream as its children, which may be other copy nodes or client nodes. The copied data are sent to the children. In this way, data is transmitted from one source to many clients simultaneously. This data transmission may involve some legacy routers between the server node, copy nodes and client nodes. This configuration is summarized in **Fig. 1**.



(a) Physical network configuration.

(b) Distribution tree.

**Fig. 1** Network configuration of the multicast technique of [1].

The distribution tree is constructed through a simple protocol. The main component of the protocol is the join (or keep alive) packets. The join packets are periodically sent from a client node or copy node to the server node. They are intercepted at its parent, which may be a copy node or a server node. The first role of the join packets is to notify the parent that a node has joined the tree. Second, they maintain the connection such that the stream continues to be sent from its parent. If a client node wants to receive data from a server, it starts sending join packets to the server. The join packets arrive at a copy node on the IP unicast routing path from the client to the server. The copy node picks up the join packets and extracts their sources and destinations. According to this information, the copy node puts the source of the packets into its distribution table. The copy node sends join packets to the server as long as it receives join packets from some other copy node or client node. Finally, the join packets reach the server. The server makes its distribution table in a similar way. The data stream is distributed from the server to the join packet sources written in the distribution table. A copy node then copies and distributes the data stream to its children indicated in its distribution table. In this way, stream data is transmitted from the server to clients along the distribution tree, which is constructed by sending join packets from the clients to the server.

A copy node deletes a distribution tree entry if it does not receive any join packet from the associated child node within a specified timeout period. Redundant data distribution is, therefore, avoided because the children that no longer need the distribution automatically leave the tree by this timeout mechanism. When a client node cease to receive data, it simply stops sending join packets.

The validity of the above protocol was confirmed using a prototype system, which was built on the basis of the active network technology [1]. Traffic load reduction may be obtained through other multicast schemes such as the standardized IP multicast etc [5, 6]. However, this paper focuses on the above protocol because it is more practical than the alternatives.

# 3. Network model and scenarios

To clarify the effectiveness of multicast, this study simulated the network model shown in **Fig. 2**. The model is composed of two connected hierarchical star networks. The network includes 90 client nodes, 8 copy nodes/routers, and 4 server nodes. Notice that copy nodes can be replaced with legacy routers when the unicast technique is evaluated or alternative copy node locations are compared. The server nodes are connected to the top-level copy nodes/routers as well as to the bottom-level copy nodes/routers. The latter configuration corresponds to peer type servers, such as personal IP broadcast stations. As seen in the figure, copy nodes/routers are labeled Center 0, Center 1, Edge 0, etc. according to their level while server nodes are labeled Server 0, 1, etc. The link capacity was set at 45 Mb/s.

For this network model, several scenarios were examined to test various network congestion situations. Traffic congestion can be created by several factors. First, the network can become congested simply because the traffic load exceeds network resources. Traffic variance across regions and over time may congest particular links or nodes. Additionally, the burstiness of traffic is also a cause of congestion.

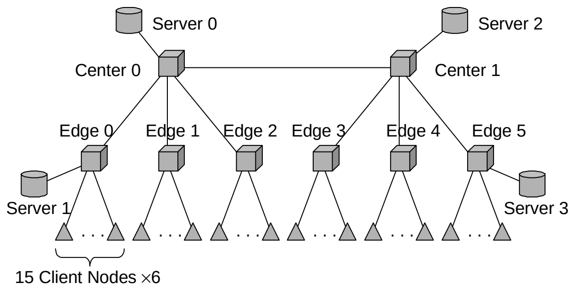



**Fig. 2** Network model for simulation.

This study examines the effectiveness of the multicast technique in decreasing the traffic congestion created by the above causes in the following simulation scenarios.

Scenario 1) Demand increases with simulation time *t*. This was simulated by increasing the number of client nodes that send requests. That is, only 30 of the 90 client nodes send requests at the simulation start time to $t$ = 1 (hour). The number of client nodes joining the distribution tree was increased by 30 every hour. The bit rate over one link was measured at regular intervals. This scenario approximates the customer increase according to the popularization of the service.

Scenario 2) Geographic traffic pattern changes at a specified time. Namely, the requests directed to Server 1 are switched to Server 3 at time $t$ = 1 (hour). The link bit rates were measured before and after this change. This scenario approximates the situation where server popularity changes at time *t*. Such a situation can occur if the content is changed or if the servers are mobile and move.

Scenario 3) Requests from a particular region increase during a specified time period. Specifically, 5 out of 15 client nodes supported by each edge node send requests to servers throughout simulation time. In addition to this basic demand, the remaining 10 client nodes connected to a specified edge node (Edge 1) also send requests from simulation time $t$ = 1 (hour) to $t$ = 2 (hour). We used the measure of the link bit rate. This scenario simulates a transient traffic concentration.

With the method of [1], some transit routers must be replaced with copy nodes. Since this replacement requires additional investment, it would be better if the effectiveness of multicast could be obtained by introducing as few copy nodes as possible. To clarify this point, the following scenario was examined as well.

Scenario 4) This scenario considers three schemes to locating copy nodes. Scheme A places the copy function at each transit node. Scheme B places the copy function only at the edge locations and not at the center. Scheme C places the copy function only at the center.

The payload size of each data stream packet was set at 1500 Bytes, while the interval between the packets was set at 0.1875 sec. These values lead to the stream bit rate of 64 kb/s. Although the bit rate looks low against the current values, it was selected to improve simulation efficiency. The request generation process from each client node was modeled as an on-off source. Namely, it repeats the *on* period in which join packets are transmitted periodically and the *off* period in which no join packets are transmitted. During the *on* period, one join packet was generated every second, and the packet size was set at 200 Bytes. The *on* and *off* periods were randomly determined according to the Pareto distribution of shape parameter $\alpha$ = 1.2 to obtain bursty traffic. The minimum values of *on* and *off* periods were 10 and 40 seconds, respectively.

The simulation program was built with using a telecommunication simulation tool (OPNET [7]). The program was executed on the Sun Ultra 60 computer.

## 4. Simulation result

**Figure 3** shows the simulation result for Scenario 1. The *x*-axis is the simulation time, while the *y*-axis is the bit rate over the link from Server 0 to Center 0. The figure compares the bit rates for multicast and unicast techniques.

As seen in Fig. 3, link utilization is strongly decreased with the multicast technique. This is because of the copy functions provided by multicast, and thus a server need send only one stream to a copy node. By contrast, since the server must send as many streams as there are clients in the distribution group with unicast, far greater bandwidth is required for unicast. This advantage of multicast is particularly significant for servers that have narrow bandwidth access lines, such as personal broadcast servers. Moreover, the required link bandwidth does not increase commensurate with the demand. This feature suggests that the multicast technique well supports the popularization of streaming service because additional demand requires little in the way of additional investment.

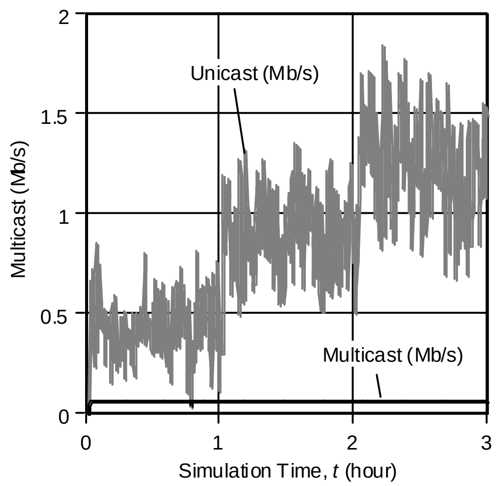



**Fig. 3** Bit rate comparison for demand increase (Scenario 1).

Figure 3 also shows that multicast greatly smoothes the burstiness in the bit rate. This smoothing effect is obvious from the figure because the bit rate is almost constant with multicast. We verified this effect by checking the self-similarity of the traffic. Self-similarity is a rational measure of burstiness because self-similar traffic is considered to be more bursty [8]. A simple method of checking self-similarity is the variance-time plot [8] shown in **Fig. 4**. The data represents a simulation period of 16 hours with 90 clients. The figure shows the relationship between the logarithms of *m*-aggregated bit rates and block size *m*. At a glance, the curve for unicast is a slowly falling line, which is a clear indication of self-similarity. This characteristic is brought by the Pareto distribution that determines the *off* and *on* period lengths. By contrast, the curve for multicast sharply falls against log(*m*). Thus, multicast traffic is not self-similar and so is less bursty. This characteristic of multicast is desirable because non-self-similar traffic will yield less congestion for the same level of network resources.

The result for Scenario 2 is shown in **Fig. 5**. The figure depicts the bit rate between Center 0 and Center 1 against simulation time. In both cases of multicast and unicast, the bit rate changes when the demand pattern changes ($t$ = 1). However, multicast minimizes the traffic load before and after the demand pattern change. This fact suggests that multicast ensures that the change does not seriously impact the total traffic load on the backbone link. Unicast, on the other hand, allows large sudden swings in traffic loads due to the demand pattern change. This may cause traffic congestion if resources are assigned without predicting such changes.

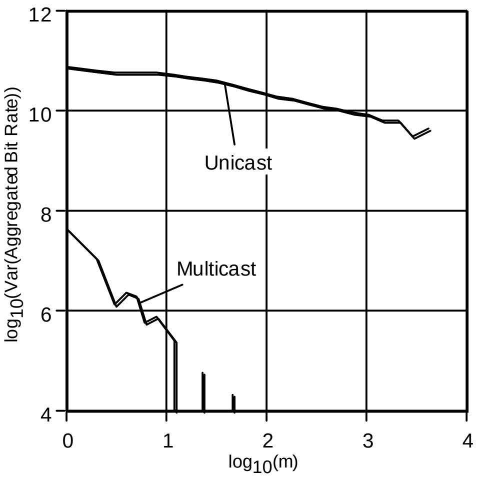



**Fig. 4** Variance-time plot of bit rate from Server 0 to Center 0.

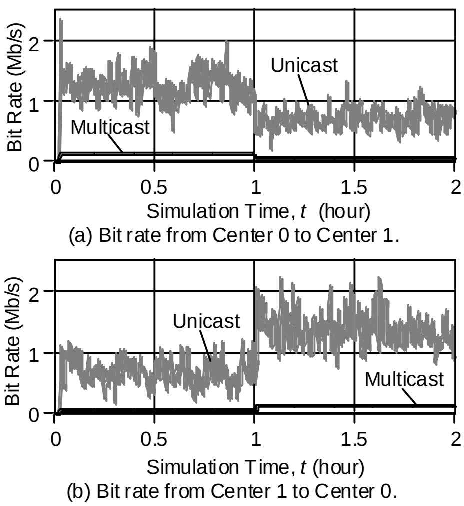



**Fig. 5** Bit rate comparison for the traffic pattern change (Scenario 2).

As mentioned above, the multicast technique decreases the traffic load as well as providing robustness against traffic changes. The latter characteristic is also confirmed through the results of Scenario 3 shown in **Fig. 6**. This figure shows the bit rate from Center 0 to Edge 1. Apparently, unicast makes the link utilization high when the traffic load concentrates at Edge 1. By contrast, the link utilization hardly changes with multicast during this period. Thus, the temporal demand concentration is successfully absorbed by the copy function in the nodes and does not affect the load on the backbone network. This result implies that multicast makes the backbone network free of congestion even for unpredictable traffic changes. However, edge node load is affected by the temporal traffic change. Thus, the capacity of a copy node must be sufficiently large if multicast is to realize its full potential in absorbing the effect of unpredictable and temporal traffic changes.

Another target of the simulation was to clarify the effectiveness of partial copy node introduction. This is addressed in **Fig. 7**, which is the result for Scenario 4. Figure 7 (a) shows the bit rate from Server 0 to Center 0, while Fig. 7 (b) shows that from Center 0 to Edge 1. The figure confirms that the traffic reduction and smoothing effects can be obtained by introducing copy functions into just a few nodes. In Fig. 7 (a), the server traffic load with Scheme C is lighter than that with Scheme B. This is because the copy node is closer to the server in Scheme C than Scheme B so the server need support fewer streams. However, link utilization is lower with Scheme B than Scheme C in Fig. 7 (b). Therefore, the best location can not be unequivocally determined from these results. The location should be decided after considering the location of servers and bottleneck links in the operating network.

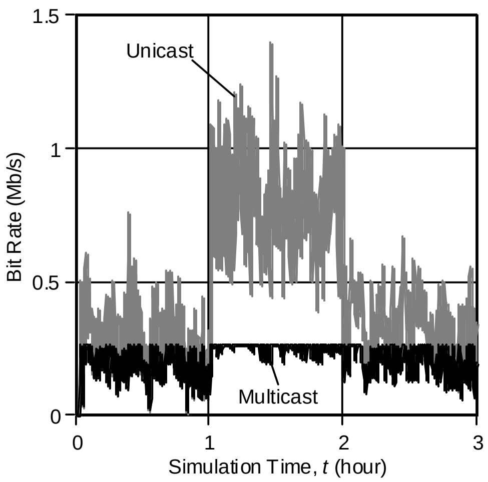
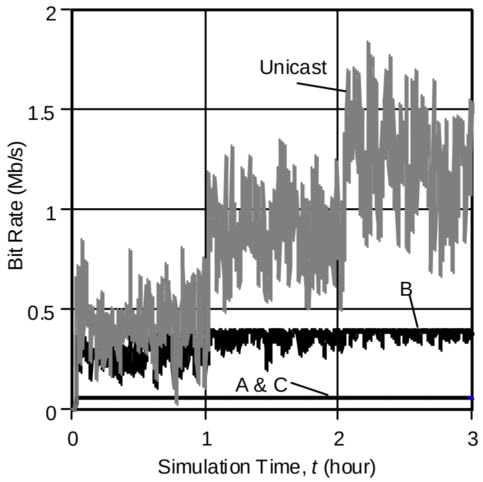
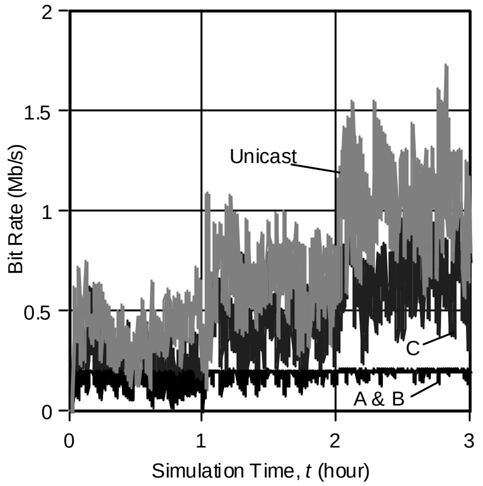



**Fig. 6** Bit rate comparison for the temporal traffic concentration (Scenario 3).




(a) Bit rate from Server 0 to Center 0.




(b) Bit rate from Center 0 to Edge 0.

**Fig. 7** Bit rate comparison for copy node location schemes A, B, and C (Scenario 4).

# 5. Conclusion

This paper presented the effectiveness of the multicast technique in avoiding the traffic congestion associated with live streaming service. The method proposed in [1] was evaluated as the multicast technique. A computer simulation was executed and several important results were obtained. Multicast greatly decreases the traffic volume as well as smoothing the traffic variance caused by several factors such as an increase in users, contents/server location changes, and local demand concentration. In particular, the variance-time plot revealed that multicast decreases the traffic burstiness as measured by self-similarity, which originates from the bursty requests of users. The simulation also showed that the copy function need be added to just a few network nodes to realize the traffic decrease and smoothing effects.

The avoidance of congestion is a serious challenge in introducing broadband IP streaming services. Multicast meets this challenge and allows these services to be cost effective.

# 6. References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