

LAN Addressing for Digital Video Data

1 Abstract

Multicast addressing was chosen over the broadcast address and unicast address mechanisms for the transmission of video data over the LAN. Dynamic allocation of multicast addresses enables such features as the continuous playback of full motion video over a network with multiple viewers. Design of this video data transmission system permits interested nodes on a LAN to dynamically allocate a single multicast address from a pool of multicast addresses. When the allocated address is no longer needed, it is returned to the pool. This mechanism permits nodes to use fewer multicast addresses than are required in a traditional scheme where a unique address is allocated for each possible function.

2 Introduction

The transmission of digital video data over a local area data network (LAN) poses some particular challenges when multiple stations are viewing the material simultaneously. This paper describes the available addressing mechanisms in popular LANs and how they alleviate problems associated with multiple viewing. It also describes a general mechanism by which nodes on a LAN can dynamically allocate a single multicast address from a pool of multicast addresses, and subsequently use that address for transmitting a digital video program to a set of interested viewers.

3 Project Goals

The objective of this project was to design a mechanism suitable for providing the equivalent of broadcast television using computers and a local area data network in place of broadcast stations, airwaves, and televisions. The resulting system had to provide access to broadcast, closed circuit, and on-demand video programs throughout an enterprise using its computers and data network. The use of computer equipment installed for data transmission would eliminate the need to invest in cable TV wiring throughout a building.

The basic system would consist of two primary components. One computer, or set of computers, would act as a video server by transmitting video program material, in digital form, onto the data network. Other computers, acting as clients, would receive the transmitted video program and present it on the computer's display. Figure 1 depicts such a configuration.

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The variety of video source material suggests that servers may be equipped in several ways. For example, accessory hardware can receive broadcast video programs; hardware and software can convert analog video into digital format; and hardware and software can compress the digital video for efficient use on a personal computer and data network.[1,2,3] Figure 2 shows a server equipped to handle different types of video program sources.

Video program material is categorized as live, e.g., the current program broadcasting on a television network, or stored and played on demand, e.g., a recorded training session. In both cases, it is desirable for more than one client to be able to monitor or view the transmitted video program.

To implement the client-server system described above, many technical hurdles had to be overcome. This paper, however, focuses on one narrow but critical aspect, the addressing method used on the LAN for delivery of the digital video data. The characteristics of digital video and the need for multiple stations to receive programs from a wide range of possible sources combined to create some interesting challenges in devising a suitable addressing method.

4 Choosing an Addressing Method

To transmit digital video over a data network, an effective addressing mechanism had to be chosen that would satisfy the project's goals. Most LANs support three basic data addressing mechanisms: broadcast, unicast, and multicast.[4,5,6,7] Each method of transmitting digital video over a LAN has characteristics that are both attractive and undesirable.

Broadcast addressing uses a special reserved destination address. By convention, data sent to this address is received by all nodes on the LAN. Transmitting digital video data to the broadcast address serves the purpose of permitting multiple clients to receive the same transmitted video program while permitting the server to transmit the data once to a single address. Viewed another way, this convention is a significant disadvantage because all stations receive the data whether they are interested or not. Compressed digital video represents from 1 to 2 megabits per second of data, therefore nodes not expecting to receive the video data are impacted by its unsolicited arrival.[1,3] As a further complication, when two or more video programs are playing simultaneously, stations receive 1 to 2 megabits per second or more of data for each video program. This renders many systems inoperative. Furthermore, LAN bridges pass broadcast messages between LAN segments and cannot confine digital video data to a LAN segment.[8] As a result of these drawbacks, use of the broadcast address is unsuitable for transmission of digital video data.

Unicast addressing sends data to one unique node. The use of unicast addressing eliminates the problems encountered with broadcast addressing by

confining receipt of the digital video data to a single node. This approach works quite well as long as only one node wishes to view the video program. If multiple clients wish to view the same program, then the server has to retransmit the data for each participating client. As the number of viewing

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clients increases, this approach quickly exhausts the server's capacity and congests the LAN. Because unicast addressing cannot practically support one server in conjunction with multiple clients, it too is unsuitable for transmission of digital video data.

Multicast addressing uses addresses designated to simultaneously address a group of nodes on a LAN. Nodes wishing to be part of the addressed group enable receipt of data addressed to the multicast address. This characteristic makes multicast addressing the ideal match for the simultaneous transmission of digital video data to multiple client nodes without sending it to uninterested nodes. Furthermore, many network adapters provide hardware-based filtering of multicast addresses, which permits high-performance rejection/selection of data based on the destination multicast address.[9] Because of these advantages, multicast addressing was selected as the mechanism for transmission of digital video data.

5 Multicast Addressing Considerations

Together with its advantages, multicast addressing brought significant problems to be overcome. The problems were in the assignment of multicast addresses to groups of nodes, all of which are interested in the same video program. If a single multicast address were assigned for all stations interested in receiving any video program, then only interested stations would receive data. All participating stations, however, would receive all programs playing at any given time. If multiple programs were playing, each station would receive data for all programs even though it is interested in the data for only one of the programs. The obvious solution is to allocate a unique multicast address for each possible program. The following sections examine various allocation methods.

Traditional Address Allocation

Traditionally, a standards committee allocates multicast addresses, each of which serves a specific purpose or function. For example, a specific multicast address is allocated for Ethernet end-station hello messages, and another is allocated for fiber distributed data interface (FDDI) status reporting frames.[10,11,12] Each address serves one explicit function. This static allocation breaks down when a large number of uses for multicast addresses fall into one category.

It clearly is not possible to allocate a unique multicast address for all possible video programs for several reasons. At any given time, hundreds of broadcast programs are playing throughout the world, and thousands of video programs and clips are stored in video libraries. Countless more are being created every minute. Assigning a unique address to each possible video program would exhaust the number of available addresses and be

impossible to administer. Furthermore, it would waste multicast addresses since only those programs currently playing on a given LAN (or extended LAN) need an assigned address. A technique, therefore, is needed by which a block of multicast addresses is permanently allocated for the purpose of

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transmitting video programs on a computer network, and individual addresses are dynamically allocated from that block for the duration of a particular video program.

Dynamic Allocation Method

A dynamic allocation method should have several characteristics to transmit video programs on a LAN. These desired characteristics

1. Must be consistent with current allocation procedures used by standards bodies like the IEEE
2. Should be fully distributed and not require a central database (improves reliability)
3. Must support multiple clients and multiple servers
4. Must operate correctly in the face of LAN perturbations like segmentation, merging, server failure, and client failure

It is clearly desirable to use a dynamic allocation mechanism that does not require changes to the way addresses are allocated by standards committees. Changes to protocols only create another level of administrative complexity. Instead, a single set of addresses should be allocated on a permanent basis for use in the desired application. Drawn from a pool of addresses, these allocated addresses could be dynamically assigned to video programs as they are requested for playback. When playback was complete, the address would be returned to the pool.

Regardless of which allocation mechanism is adopted, it needs to support multiple servers and multiple clients. This implies that some form of cooperation exists between the servers to prevent multiple servers from allocating the same address for two different video programs. One node could act as a central clearinghouse for the allocation of addresses from the pool, but the overall operation of the system would then be susceptible to failure of that node. The preferred approach is a fully distributed mechanism that does not require a centralized database or clearinghouse.

LANs tend to be constantly changing their configurations, and nodes can enter and leave a network at any time. As a result, an allocation mechanism must be able to withstand common and uncommon perturbations in the LAN. It must accommodate events such as the segmentation of a LAN into two LANs when a bridge becomes inactive or disconnected, joining of two LANs into one when a bridge is installed or becomes reactivated, and failure or disconnection from the LAN at any time by both server and client nodes.

Other Multicast Allocation Methods

A variety of different group resource allocation mechanisms exist, and the one most nearly applicable to transmitting digital video over a LAN is used in the internet protocol (IP) suite. Deering discusses extensions to the internet protocols to support multicast delivery of internet data grams.[13] In his proposal, multicast address selection is algorithmically derived from the multicast IP address and yields a many-to-one mapping of multicast IP addresses to LAN multicast address. As a consequence, there is no assurance that any given multicast address will be allocated solely for the use of a single digital video transmission. This undermines the goal of using multicast addressing to direct the heavy flow of data to only those stations wishing to receive the data. Deering discusses the need for allocation of transient group address and alludes to the concepts presented in this paper.

6 Model for Dynamically Allocating Multicast Addresses

Given the overall goals of the project and the desired characteristics of the application, the following model was developed. It transmits digital video on a data network using dynamically allocated multicast addresses. First, simple operational cases on the LAN are described. Then complicated scenarios dealing with network misoperations are addressed.

It should be noted that the protocols described address the location of video program material as well as the allocation of multicast addresses for delivery of that material. Because of the one-to-one correspondence between video material and address allocation, it is convenient to combine these two functions into a single protocol; however, the focus of this paper remains on the address allocation aspects of the protocol.

Multicast Address Pool

This model assumes a set of n multicast addresses permanently allocated and devoted to it. The addresses are obtained through the normal process for allocation of multicast addresses through the IEEE. All clients and servers participating in this protocol use the same set of addresses. For the sake of this discussion, these addresses are denoted as A_1, A_2, \dots, A_n . Address A_1 is always used by the participating stations for exchange of information necessary to control the allocation of the remaining addresses for use by the participating stations. The remaining addresses A_2 through A_n form the pool of available multicast addresses.

Server Announcements

All servers capable of transmitting digital video data continuously announce their presence and capabilities by transmitting a message at a

predetermined interval; for example, a message is addressed to A1 every second. In these announcements, the servers include information identifying their general capabilities, data streams they are currently transmitting, and data streams they are capable of transmitting.

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A server's general capabilities include its name and network address(es). Other useful information can also be announced, but it is not relevant to this discussion. To identify the data streams currently being transmitted, the server describes the data and the multicast address to which each data stream is being transmitted. In this way, it announces those multicast addresses that the station is currently using, along with a description of the associated video program. The data streams the server is capable of transmitting are identified by some form of a description of the data stream.

Identifying Servers and Available Programs

With each server continuously announcing the program material available for playback, clients wishing to receive a particular data stream can monitor the server announcements being sent to address A1. By receiving these announcements, a client can ascertain the address of each server active on the LAN, the data streams currently being transmitted by each server and the multicast address to which each is being transmitted, and the data streams available for transmission.

With a large repository of program material, it could easily become impractical to announce all available material. In this case, the announcements could be used only to locate available servers, and an inquiry protocol or database search mechanism could be used to locate available material more efficiently.

Once a client identifies a server that is offering the desired data stream, it can request that the server begin transmission. The client sends a message identifying the desired playback program material. In response, the server allocates a unique multicast address, includes the new material and multicast address in its announcement messages, and begins transmitting the program material.

Address Allocation and Tracking

Each server maintains a table containing the usage of each of the A2 to An addresses. Each address is tagged as either currently used or available for use. When a server receives a client's request for transmission of a new data stream, the server selects a currently unused multicast address and includes the address and data stream description in its announcements of data streams currently being transmitted. After sending two announcements, the server begins transmitting the data to the chosen multicast address. Sending two announcements before beginning transmission provides client nodes with ample time to ascertain the address to which the data will be sent and to enable reception of the video program.

In addition to sending announcement messages, the servers also listen

to the announcements from other servers to keep track of all multicast addresses currently in use on the LAN. Each time a server receives an announcement message from another server, it notes the addresses being used and marks them all as used in its table. This prevents a server from

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allocating an address already used by another server and eliminates the need for a central database or clearinghouse.

If a server observes that it is using the same address as another server, then the server moves its data transmission to another address if and only if its node address is numerically lower than the other server's node address. The new address is allocated exactly as it would be if the server were beginning to transmit the data stream for the first time. This algorithm resolves conflicts where two or more servers choose the same available multicast address at the same time. In addition, it resolves a similar conflict that occurs when two separate LAN segments become joined and two servers suddenly find they are using the same multicast address.

Clashing allocations of multicast addresses can be held to a minimum if servers allocate an address at random from the remaining pool of addresses rather than all servers allocating in the same fixed order.

Identifying and Stopping Playback

After a client requests playback of new material, it can then examine the server's announcements, and when the desired data stream appears as being transmitted by the server, the client can begin receiving data from the advertised multicast address. At this point, any other client stations on the LAN can also receive the same video program by enabling receipt of the same address.

When no more clients wish to view a particular program, a mechanism is needed to inform a server to stop transmission and return the associated address to the free pool. Two alternative approaches were considered to stop playback; one was chosen for several reasons.

In the first approach, each server tracks the number of clients that have requested a particular program by simply counting the number of requests for that program. In addition, clients are required to notify the server when they are finished viewing. The server then continues to transmit the material until all interested clients have indicated they are no longer interested in viewing. This approach has two problems. If a viewing client node is reset or disconnected, or if its message to end viewing is lost, the server could lose track of the number of viewing clients and never stop playing a particular program. The second problem, which is more of a nuisance, is that clients have to request playback of a program even if it is already playing to enable the servers to track the number of viewers.

In the preferred approach, interested clients periodically remind the server that they wish to continue viewing the program. Servers then simply keep playing the material until no client expresses interest for some period of time. For example, clients could reiterate their interest in a

program every second, and a server could continue transmitting a requested program until it did not receive a reminder for 3 seconds. This time lapse would accommodate lost reminder messages from clients, and client failure would result in transmission termination within 3 seconds. In addition, when all clients had finished viewing the material, the server, multicast

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address, and consumed network bandwidth would be released within 3 seconds, making them available for other uses. Selection of the actual timer value depends on the desired balance between ongoing consumption of network resources (bandwidth and multicast addresses) after all receiving parties have stopped viewing the data, and network, end system, and server resource consumption caused by more frequent reminder messages.

Changing Multicast Addresses

Aside from receiving and processing the data for a video program, client stations must also continue to examine the server announcement messages and remain alert to possible changes in the multicast address to which the received program is being transmitted. As noted above, address allocation can change at any time due to merging of LAN segments or duplicate allocation by two servers. Anytime a client notes a change in address, it must stop receiving data on the previous address and resume receiving with the new address. A momentary disruption in playback is likely to occur, but such disturbances are infrequent because only merging LANs cause duplicate allocations of addresses in the middle of playback.

Under the circumstances described earlier, a client can find itself receiving two data streams on the same multicast address for some finite time period until the servers resolve the allocation of that address. Clients can gain immunity to this situation by noting the source address of the server that originally provided the data stream, and discarding all data received on the multicast address that is not from the source address. With this improvement, clients can easily distinguish the data stream of interest from another which might momentarily appear addressed to the same multicast address.

The allocation and resolution of multicast address use can be improved if servers send their announcements at an increased rate for some time period after a new data stream begins transmitting or when a data stream changes address. Such accelerated announcements permit client stations to more quickly identify the address of a requested data stream, and more quickly identify when a data stream has moved from one address to another. They also permit servers to more quickly identify instances of clashing multicast addresses and resolve them. For example, the announcement interval could be increased from 1 second to one-quarter second for a 2-second duration and resumed at 1-second intervals.

Extension to Interconnected LANs

The described protocols and allocation methods function correctly across multiple LANs interconnected by bridges since bridges nominally forward multicast traffic. Many bridge implementations permit management control over the forwarding of multicast data. This can unintentionally interfere

with the desired operation of this protocol, but it can also as serve as a useful tool to confine data traffic to particular LAN segments. Another practical consideration in the particular application described here is the ability of a bridge to forward the large amounts of data traffic involved

in digital video without detrimentally impacting the time-dependent nature of the data.

Extending the protocols to a wide area network is a more difficult procedure. Routers do not forward multicast traffic, but they could be used as proxy nodes between LANs. Router forwarding performance tends to be even lower than bridge forwarding rates, which discourages the operation of this system over a router.

7 Conclusions

Dynamic allocation of multicast addresses is critical to enable features such as the continuous play of full motion video over a network with multiple viewers. It is not feasible (or at least is very difficult) for a server to transmit a data stream individually to all clients wishing to receive it. If, on the other hand, the desired data stream is transmitted to the broadcast address, all stations on the LAN have to receive an enormous volume of data whether they are interested or not. It is highly desirable not to inundate uninterested clients with video data streams, but to send them to clients that want to receive specific video data streams in which they are interested.

Multicast addresses are well suited (in fact designed) for transmission to some arbitrary group of stations. To prevent a client that is receiving one video stream from being inundated by other video streams, a unique multicast address is required for each unique data stream. Since there are infinite individual data streams to choose from, it is impossible to allocate a unique multicast address for every data stream. A mechanism to allocate a unique multicast address from a finite set of addresses for the duration of the data stream is the ideal choice. The described mechanism also has the attractive characteristic that it is completely distributed; there is no central agent for allocation of multicast addresses, therefore it is more reliable as servers join and leave the LAN.

Although transmission of digital video data has prompted this system design, the basic mechanism for dynamically allocating multicast addresses can be applied to any application with similar needs.

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10 Trademark

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11 Biography

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