Architectural Design and Bandwidth Demand Analysis for Multiparty Videoconferencing on SONET/ATM Rings

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***Abstract*—In this paper, we propose a scheme for implementing multiparty videoconferencing service on SONET/ATM rings. We focus on the architectural design and bandwidth demand analysis. Different multicasting methods on SONET/ATM rings are discussed and compared. A new multicast virtual path (VP) called "Multidrop VP" which is particularly suitable for SONET/ATM rings is proposed. An add-drop multiplexer (ADM) structure for rings capable of multidropping is also presented. Several VP assignment schemes are proposed and their bandwidth utilizations are compared.**

***Index Terms*—ATM/SONET rings, bandwidth demand, multicasting, videoconferencing.**

I. Introduction

VIDEOCONFERENCING is expected to be one of the most important services in broadband networks. Different kinds of videoconferences have different configurations, user-interactions, quality-of-service (QoS) requirements and network resource requirements [1]–[5]. Among the various videoconferencing methods, "speaker-video" conference, for which only the video and voice of the current speaker are broadcast to all other conferees, demands the least amount of equipment and bandwidth as compared with that of selectable media, common media [3], and virtual space conferences [2].

Multiparty videoconferences can be implemented on various kinds of networks. The ITU H.320 [15] is a recently adopted standard for videoconferencing on narrowband integrated service digital network (ISDN). Other implementations include those on Ethernet ring, token ring, Internet protocol (IP) networks, and asynchronous transfer mode (ATM)-based broadband integrated service digital network (BISDN) [16]–[18]. In [20], we studied the traffic engineering for multiparty videoconferencing in ATM networks. In this paper, we focus on the multicasting aspects and the virtual path (VP) assignment schemes for implementing multiparty videoconferencing on SONET/ATM type rings.

The increasingly popular SONET ring has the advantages of standard signal interfaces, economic adding and dropping of traffic streams, self-healing capability, and the support of operation, administration, and maintenance. Present SONET rings use synchronous transfer mode (STM) for signal multiplexing and switching and support nonswitched DS1 and DS3 services. VP-based ATM technology has been introduced into SONET rings as a means to reduce cost and to provide flexible bandwidth demand arrangement [8], [12]. This cost reduction is achieved by the use of nonhierarchical path multiplexing.

The ATM VP-based SONET ring architecture [8], [11] is essentially a combination of the SONET/STM architecture and ATM virtual channel (VC)-based network architecture. As a result, it keeps the simplicity of the SONET/STM network while retaining the flexibility of the ATM technology. In [8], a SONET/ATM ring using point-to-point virtual path (SARPVP) was proposed. It was assumed there that the ATM add-drop multiplexer(ADM) for the VP-based ATM rings can be built from the SONET ADM by replacing the STS-3 termination cards by the ATM STS-3c line cards. Other ATM ring architectures proposed can be found in [10]–[12] and topics such as bandwidth allocation [10], self-healing mechanism and VPI assignment [11] were studied.

Recently, some researchers studied multicasting issues on wavelength division multiplexing (WDM) rings. In [21], the authors derived the necessary and sufficient conditions on the minimum number of wavelengths required for WDM network to be wide-sense nonblocking for multicast communications. The network topologies under consideration include meshes, rings, etc. Wavelength assignment algorithms are proposed. The objective is to minimize the wavelength number. However, the mechanism to support multicasting was not discussed. In [2], the authors studied the multicast routing algorithm and analyzed the performance of the shortest path tree and minimum spanning tree methods in the tree of ring WDM networks, considering the performance criteria such as the delay, network cost, load balancing, and the number of wavelength required but the multicast mechanism was not considered. Only shortest path tree and minimum spanning tree were taken into account.

In this paper, we study the multicasting and VP assignment problems for multiparty videoconferencing on SONET/ATM rings. In Section II, we introduce the network configuration, the service characterization and the SONET/ATM ring architecture. In Section III, we discuss the use of various multicasting methods on SONET/ATM rings and a new method called multidrop VP multicasting is proposed. An ADM structure suitable for multidrop VP is presented in Section IV. In Section V,

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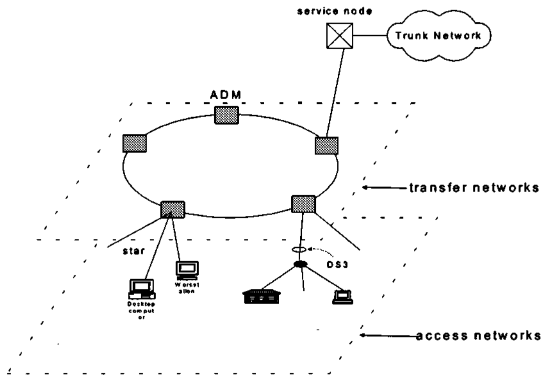


Fig. 1. A two-layer subscriber network architecture.

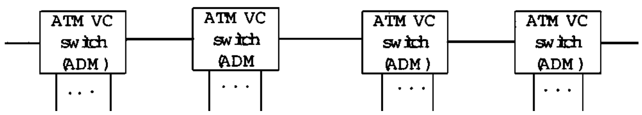


Fig. 2. A section of VC-based SONET/ATM ring.

we discuss the conference management issues on SONET/ATM rings. In Section VI, we propose several multidrop VP assignment schemes. After evaluating and comparing the bandwidth utilization of these schemes in Section VII and Section VIII, we conclude this paper in Section IX.

II. Videoconferencing on SONET/ATM Rings

SONET self-healing ring can be unidirectional or bidirectional at normal working state. In this paper, we assume the ADMs can support bidirectional transmissions. To carry conferencing traffic over SONET/ATM rings, a two-layer subscriber network architecture similar to that in [13] can be used. This architecture consists of a transfer network and an access network as shown in Fig. 1. The transfer network is a SONET/ATM ring with ADMs. The access network links up business and residential customers to the ADMs.

Video is the most troublesome traffic in videoconferencing. Fundamental issues regarding its transmission over ATM networks remain unresolved. For example, there is no general consensus on whether variable bit-rate (VBR) schemes are better than constant bit-rate schemes (CBR) for video services. ITU Recommendation H.320 [15] is a collection of standards for videoconferencing and videotelephony systems. It is intended for systems with channel capacity up to T1 or E1 rates and includes recommendations for audio coding, video coding, multiplexing, and system control. In this paper, we assume that the audio, video, and control data can all be multiplexed onto a fixed rate channel such as DS1 on SONET rings or equivalently a CBR channel on SONET/ATM rings and the H.320 conferences belong to this type.

ATM networks can be either VC or VP based. The VC-based ATM network, as depicted in Fig. 2, consists of ATM VC switches and manages VC connections on a VC-by-VC basis. It is sometimes referred to as the *full* ATM switched network and is characterized by its very flexible and efficient bandwidth management capability. On the other hand, it is also complex and expensive compared with the ATM VP switches [7], [19].

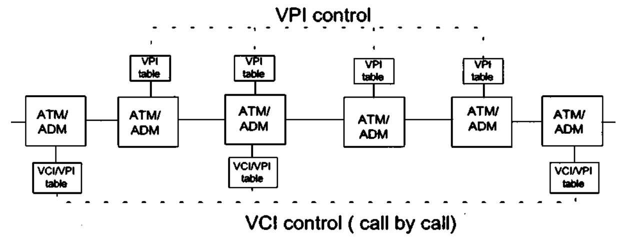


Fig. 3. A section of VP-based SONET/ATM ring with multipoint connection.

To reduce the signal transport complexity while preserving some flexibility of bandwidth management at intermediate nodes, the VP-based ring augmented with multicast function can be used (Fig. 3). Here the intermediate nodes perform the functions of cell routing by VPI, while the end nodes perform the functions of call setup, call admission control, VP assignment, routing, VP capacity allocation, and traffic control.

III. Multicasting on SONET/ATM Rings

Multicast connections can be set up in many kinds of networks. For example, according to Q.931 [14] and Q.93B [14], the ITU recommended call setup protocol for ISDN and B-ISDN, respectively, a multicast connection is set up by establishing multiple point-to-point connections. Efficient techniques for multicasting on ATM networks are still being intensively researched on. In this Section, we discuss the use of four multicasting methods on SONET/ATM rings. The first three are from [20] and the fourth called multidrop VP is new.

A. Multiple Point-to-Point VCs Scheme

This scheme makes use of the existing point-to-point communication and control protocols to set up a point-to-point connection for each destination [19]. It is simple but is also bandwidth wasteful as it requires identical cells to flow through the same physical links.

B. VP Augmented VC Multicasting Scheme

This is a VC multicasting method augmented by point-to-point VPs. On a ring using point-to-point VPs like SARVP [8], the intermediate nodes for a multicast connection are also the junction nodes between the point-to-point VPs. At these switching nodes (in this case, VC switches), the cells are passed from the VP processing layer to the VC processing layer. After copying at the VC processing layer and translating the VPI numbers, the copied cells are returned to the VP processing layer for onward transmission in the next VP. Here, multicasting is performed at the VC layer but the same VP route is used by different VC connections. Multicasting is realized through this kind of VP-VC-VP switching operation. This method can save VPI numbers because a VP route can be shared by different connection request with the same source and destination nodes. Since cells are copied at the switching nodes, identical cells are not transmitted through the same physical link. But the tradeoff is a much more complicated VC switching and the added delay due to VP-VC-VP processing. Its bandwidth management is also less flexible. Fig. 4 illustrates this kind of multicasting.

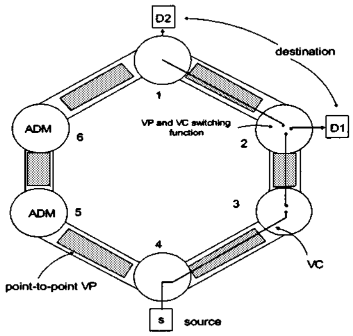


Fig. 4. VP augmented VC multicasting on an SONET/ATM ring.

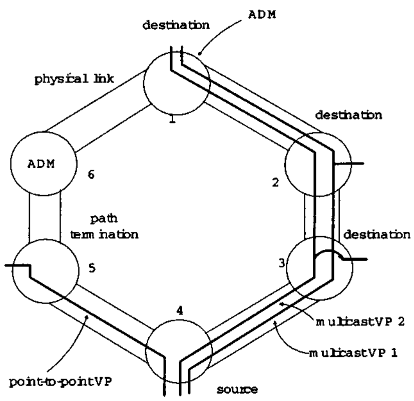


Fig. 5. VP multicast on a SONET/ATM ring.

C. VP Multicast Scheme

This method requires all possible point-to-multipoint VPs be established. A point-to-multipoint connection can then be established by reserving bandwidth on the corresponding point-to-multipoint VP for multicasting. Here, cells from the source node are copied at the intermediate ADMs on the SONET/ATM ring based on the VPIs. This method has the advantages of efficient bandwidth utilization, simple transport processing and flexible bandwidth management, but it has the problem of requiring a large number of VPI for all possible multicasting routes.

In the example showing in Fig. 5, VP 1 is for the multicast connection from node four to nodes two and one. VP 2 is for the multicast connection from node four to nodes three and one. Note that setting up and tearing down VPs "on the fly" are possible, but this is confusing with VC and contradicts the basic VP design philosophy of aggregating multiple VCs for better reliability and performance.

In VP multicasting, many VPs need to be set up for all combinations of source and destination groups. All together, $(i+1)\binom{N}{i+1}$ VPs are required for connections with i destinations on an N-node ring. Since the number of destination nodes can range from one to $N-1$, the total number of VPs needed is $\sum_{i=1}^{N-1}(i+1)\binom{N}{i+1}$. Even if we limit the maximum number of destination nodes allowed in a multicast to be M, $(M < N)$, the total number of VPs needed is still very large. Fig. 6 shows the number of VPs need versus network size N under several M values. It can be seen that the multicast VP scheme is impractical for the huge number of VPs needed.

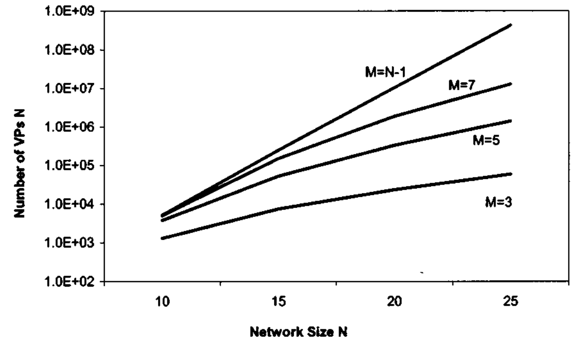


Fig. 6. Number of VPs needed for multicast VP scheme.

It is important to keep the number of VPs to be configured on the ring to small. A small number of VPs to be established improves network management. This, in turn, improves the fault tolerance of the network and further increases the scalability of the network [25]. In this paper, we do not consider the self-healing issue because of the limited space. However, if the VP restoration due to link or node failures is taken into account, the VP number becomes important. A large total VP number implies the average VP number on a link is also large. If VP restoration scheme is used, the overhead of the failure recovery process is clearly proportional to the number of VPs on the link [26]. Upon a link failure, the network reroutes VPs that use the faulty link to other paths on the ring. Low VP number can thereby achieve a low overhead of migration of all VCs that use the faulty link to alternative routes (and, thus, use the rerouted VPs).

D. Multidrop VP

Multicasting on SONET/ATM rings requires the dropping and forwarding functions at the nodal transceivers. Based on these requirements, we design the "multidrop VP" for multicasting on SONET/ATM rings. It has all the advantages of VP multicast without requiring VPs to be established for all multicast combinations. The traditional point-to-point VP [9] has only one exit point. A multidrop VP allows multiple drops or exits. To distinguish these two types of VPs, we use one bit in the GFC (Generic Flow Control) field of the cell header as the "multidrop VP Indicator"(MDI). Specifically, $MDI = 1$ means that the cell concerned has to be copied (or tapped out) at all intermediate ADMs and $MDI = 0$ means that the cell is on a point-to-point VP. Note that the GFC field is used for traffic control data on a multiaccess network. But on SONET/ATM rings, a VC connection corresponds to a DS1 channel and these is no statistical multiplexing among the VCs. Therefore, cell-level flow control is not needed at the user-network interface (UNI) and the GFC field can be used to indicate the multidrop nature of the VP.

All tapped-out cells are passed to the VC processing layer. Those belonging to the local destinations are passed there and the remaining ones are discarded. As an example, consider Fig. 7 where two multicast VCs are carried on a single multidrop VP (VP 2). VC 1 is set up for the connection from node four to nodes two and one. At the intermediate node (i.e., node three), the cells belonging to VC 1 are tapped out from the VP

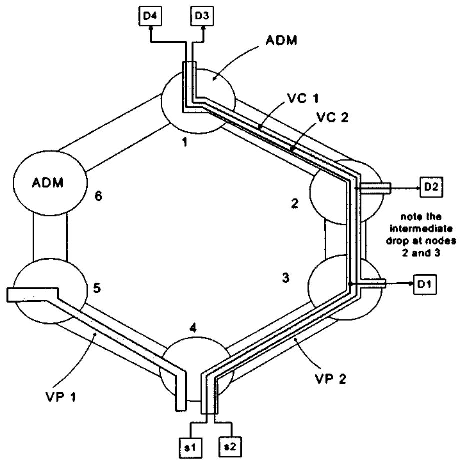


Fig. 7. Multidrop VP in the SONET/ATM ring.

processing layer but get discarded at the VC processing layer. In fact, VP 2 can carry all multicast traffic from node four to node one and any subset of nodes between them. In other words, multidrop VP keeps the advantages of multicast VP while being able to accommodate multicast connections with various destination combinations.

Multidrop VP is simpler than VP augmented VC multicasting because no VC switching function and, therefore, no VPI translations are needed at intermediate nodes. It requires a much smaller number of VPs than VP multicast. If the DS1 channels via circuit emulation on the SONET/ATM ring are used to support videoconferencing service, then each DS1 can be treated as a VC connection and assigned a VPI/VCI.

IV. ADM FOR SONET/ATM RING

ADMs for SONET/ATM rings can be implemented in different ways depending on the actual SONET STS-Nc terminations. A kind of ADM architecture for point-to-point SONET/ATM rings was introduced in [8]. In this section, we modify the hardware architecture in [8] to accommodate multidrop VPs. The most commonly proposed ATM STS-Nc terminations are STS-3C, STS-12c and STS-48c. Fig. 8 shows the ADM hardware architecture for STS-3c terminations. It consists of the SONET layer, ATM layer and the service mapping layer. As the SONET layer is identical to that in [8], we focus only on the latter two.

The ATM layer performs the following functions:

1) ATM/SONET interface—convert the STS-3c payload to ATM cell stream and vice versa;
2) Cell type classifying—check the MDI of individual cells and copy out those with $MDI = 1$;
3) Cell addressing—for cells with $MDI = 0$, check their VPIs to determine if they should be dropped (for local termination) or forwarded (for termination in the downstream nodes);
4) Idle cell identifying—identify the idle cell locations for cell stream insertion via a sequential access protocol.

The service mapping layer maps the input cells to their corresponding DS1 cards based on their VPI/VCI values. Cells from different STS-3c payloads are first multiplexed into a single cell stream. Their VPI/VCI are checked. Those correspond to the local terminations are passed there while the rest are discarded. According to [8], the bandwidth requirement for DS1 service is allocated on the peak rate basis and so no congestion will occur.

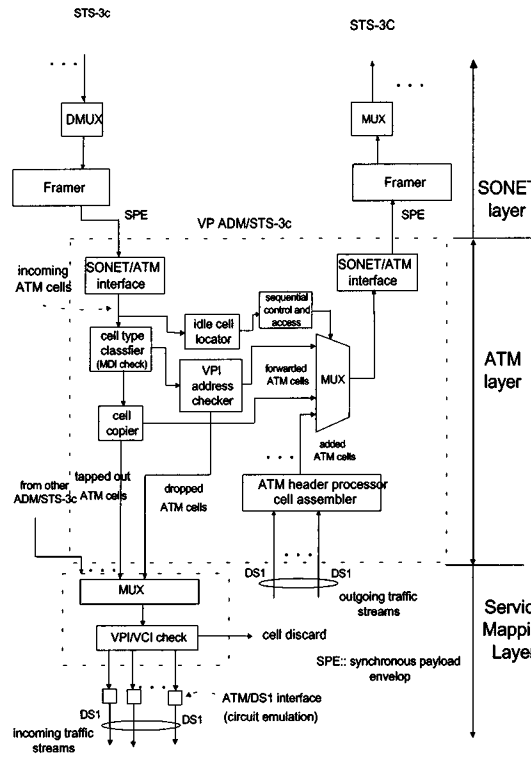


Fig. 8. A simple ADM hardware architecture suitable for multidrop VP.

ADM architecture for point-to-point SONET/ATM rings is analyzed in [8]. The ADM architecture for supporting multicasting proposed in this paper requires the adding of cell type classifier (MDI check) and cell copier. These two functional blocks can be embedded in a modified ADM chip.

V. CONFERENCE MANAGEMENT

A. Multicast Setup and Release Procedure

Let there be a *conference bridge* which performs the functions of routing, admission control and the management of changing active nodes. It is actually a program performing these functions at one of the network nodes. When a new conference is initiated or when there is a change of active node in an on-going conference, a conference management process is created. The conference bridge collects information such as the number of conferees, their location and their busy/idle status, etc. and tries to set up a multicast connection.

B. Call Admission

Call admission on a ring network is very simple. When a new call arrives, the conference bridge checks if there is a minimum hop multicast connection with all the links involved having enough bandwidth for the new call. If yes, accept the call, reject otherwise.

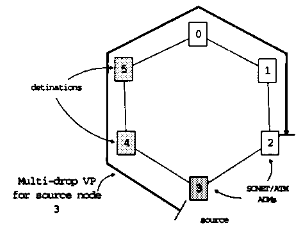
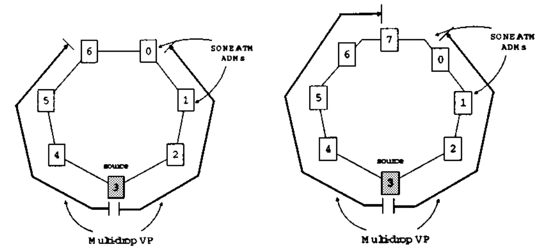


Fig. 9. Loop multidrop VP assignment scheme.



(a) N odd (b) N even

Fig. 10. Double half-loop multidrop VP assignment.

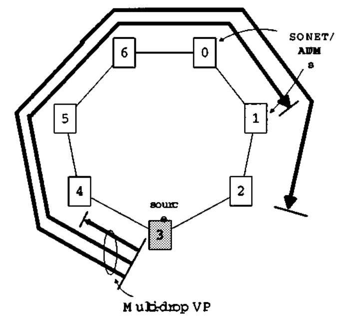


Fig. 11. Segmental minimum-hop multidrop VP assignment.

C. Speaker Change Management

In the speaker-video conference network, the network resources should be dynamically allocated and retrieved in response to the changes of speakers throughout the conference session. If the next speaker is attached to the same node, the *conference bridge* keeps the existing multicast connection. Otherwise, a new connection is identified and established according to the minimum hop routing rule and the channels in the former multicast connection are released.

D. Conferee Joining and Withdrawing

One conferee may request to withdraw from an ongoing conference while another conferee may wish to join. Upon receiving a withdrawal request, the conference bridge first checks the location of the node to which the withdrawing conferee is attached. If it is an intermediate node of a multidrop VP, the multicasting route is not changed. The tradeoff is between saving network resources and processing overhead of "hot" switching.

For joining, if the new conferee is attached to an intermediate or the termination node of a multidrop VP being used, the conference bridge only needs to inform the new conferee of the VC identifier used by the conference in that VP. The local node then outputs the cell stream of that conference to the new conferee. On the other hand, if the location of the new conferee is outside all multidrop VPs being used, a longer multicast route is set up for its inclusion.

VI. Multidrop VP Assignment Schemes

We propose five multidrop VP assignment schemes and compare their VPI numbers required in this section. Their bandwidth demands are derived and compared in the next section.

A. Loop Scheme

In this scheme, each source node sets up a loop multidrop VP that passes through all other nodes, as shown in Fig. 9. The total number of VPs required is, therefore, N. To balance the traffic on the clockwise and the counter-clockwise directions, the VPs for source nodes *1, 3, 5,…* can be assigned on one direction and the VPs for source nodes *2, 4, 6,…* on the other direction.

B. Double Half-Loop Scheme

In the double half-loop scheme, two multidrop VPs on the two sides of the source node are set up for embracing the rest of the nodes. Fig. 10 shows such an assignment for node three being the source node. The number of multidrop VPs required for encircling assignment is $2N$ and each VP has length of approximately $N/2$ hops.

Under this scheme, when all destination nodes are on one side of the source node, only one VP is needed. This results in a higher bandwidth efficiency than the Loop Assignment scheme.

C. Single Segmental Minimum-Hop Scheme

For each source node, we set up multidrop VPs to all other nodes on one direction, as shown in Fig. 11. Under this scheme, a minimum-hop route *within one segment* can be found for any multicast connection. Again, to balance the traffic on the two directions on a bidirectional ring, the VPs for nodes *1, 3, 5,…* can be assigned on one direction and the VPs for nodes *2, 4, 6,…* on the other direction. Obviously, the total number of VPs required is $N(N-1)$.

D. Minimum-Hop Within Half-Loop Scheme

In the Double Half-loop scheme, if we add VPs for all the sub-segments of the half-loop VPs as shown in Fig. 12, the bandwidth utilization can be increased. We call this the *Minimum-hop within Half-loop Scheme*. Obviously, its bandwidth efficiency is higher than the first three schemes. The minimum number of VPs required is $N(N-1)$.

E. Unconstrained Minimum-Hop Scheme

A *minimum hop route* does not waste any bandwidth resources. Such route is always available if multicast VPs are set up for all combination of source and destinations. As discussed in Section III-C, the total number of VPs needed is huge. On the other hand, with the use of multidrop VPs, the same can be achieved when multidrop VPs are set up for all combinations of "source and farthest destination" pairs. To do so, for each node as source node, we assign $N-1$ multidrop VPs on the

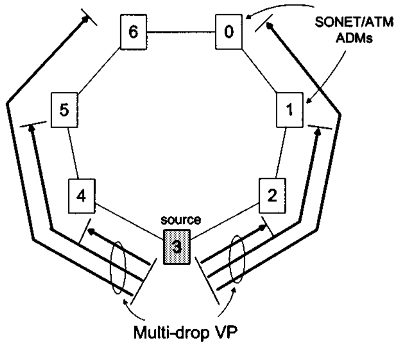


Fig. 12. Minimum-hop within half-loop multidrop VP assignment scheme.

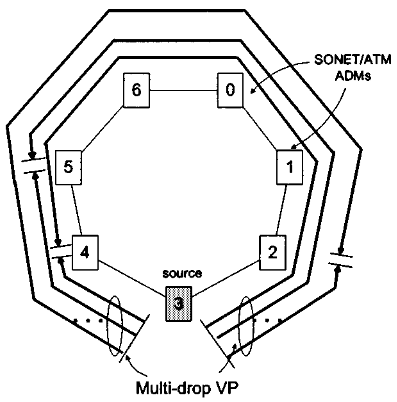


Fig. 13. Minimum hop assignment scheme.

clockwise direction around the ring to each of the other nodes and another $N-1$ multidrop VPs on the counter-clockwise direction to each of the other nodes as well (Fig. 13). The total number of VPs required is $2N(N-1)$. When all these VPs are available and used, we call this the *unconstrained minimum-hop* scheme.

Please note in the unconstrained minimum-hop scheme, all VPs including the ones that support unicast communications are treated as multidrop VP. If it is guaranteed that the farthest ADM along the VP also terminates the VP, there is no difference between a VP that supports multiple multicast destinations and a multicast VP that supports only one multicast destination (actually unicast VP). In this case, the MDI bit is not needed. This is true for all switched multicast and unicast connections. However, ATM networks usually also provide permanent virtual connections (PVCs) that are typically used by network operators to provision bandwidth between two endpoints. The PVCs act as "permanent" leased lines. For these PVCs, the multidrop VP is not suitable to be used. Therefore, the MDI bit is still needed if PVCs exist in the network.

Table I compares the VP numbers required for the five multidrop VP assignment schemes to that of the VP multicast scheme.

VII. Bandwidth Demand Analysis

In this section, we analyze the bandwidth demand of k party conferences for the five multidrop VP assignment schemes assuming that the source and $k-1$ destinations are randomly located on an N-node ring. For convenience, we refer the

TABLE I
Comparison of VP Number Required on an N-Node Ring

Loop Scheme	Double Half-Loop Scheme	Single Segment Minimum-hop Scheme
N	*2N*	*N(N-1)*
Minimum-hop within Half-loop Scheme	Unconstrained Minimum-hop Scheme	VP Multicast *Scheme*
N(N-1)	*2N(N-1)*	$\sum_{i=1}^{N-1}(i+1)\binom{N}{i+1}$

five schemes as Scheme A, B, C, D, and E according to their order of presentation in the last section. Without loss of generality, we can let node *0* be the source and let $\mathbf{A} = (A_1, A_2, \ldots, A_{N-1})$ be a random vector with $A_i = 1$ indicating that node i is a destination and $A_i = 0$ otherwise. In addition, let $\mathbf{a} = (a_1, a_2, \ldots, a_{N-1})$ be a binary vector and

$$\Omega_k = \left\{ \mathbf{a} \middle| \sum_{i=1}^{N-1} a_i = k-1 \right\}.$$

Due to the symmetry, the destination distribution takes any pattern in $\mathbf{a}$ with the same probability. Given N and k, the total number of patterns is simply $\binom{N-1}{k-1} = (N-1)!/((k-1)!(N-k)!)$. The probability that $\mathbf{A}$ will take on any specific pattern $\mathbf{a}$ is just one over that total number, specifically,

$$\Pr ob[\mathbf{A} = \mathbf{a}] = \begin{cases} \frac{(k-1)!(N-k)!}{(N-1)!}, & \text{for } \mathbf{a} \in \Omega_k \\ 0, & \text{otherwise.} \end{cases}$$

Let $h_X(\mathbf{a})$ be the number of links used by a specific connection request of size k with destination distribution $\mathbf{a}$ under multidrop VP assignment scheme X. Averaging over all destination distributions $\mathbf{a}$ in Ω_k, we get the expected number of links required as

$$E[h_X(\mathbf{a})] = \sum_{\mathbf{a} \in \Omega_k} h_X(\mathbf{a}) \Pr ob(\mathbf{A} = \mathbf{a}).$$

The bandwidth demand factor under scheme X, denoted as $\boldsymbol{\eta}_x$, is defined as the average number of links used normalized by the ring size N. In other words

$$\eta_X = \frac{E[h_X(\mathbf{a})]}{N}.$$

In the following, we derive $h_X(\mathbf{a})$ under different multidrop VP assignment schemes.

A. Loop Scheme

Under this scheme, a route of $N-1$ hop counts is always used for any multicast connection request. Thus, we have

$$h_A(\mathbf{a}) = N - 1.$$

B. Double Half-Loop Scheme

Under this scheme, all VPs have length about $N/2$. If all destinations are clustered within one of the two half-loops, one VP is enough. Otherwise, two VPs are required. Specifically, if N is odd, we have the equation at the bottom of page. If N is an even number, we have

$$h_B(\mathbf{a}) = \begin{cases} \frac{N}{2}, & \text{if } \sum_{i=1}^{N/2} a_i = k-1 \\ \frac{N}{2}-1, & \text{if } \sum_{i=N/2+1}^{(N-1)} a_i = k-1 \\ N-1, & \text{otherwise.} \end{cases}$$

C. Single Segmental Minimum-Hop Scheme

Under this VP assignment scheme, the number of links used by the multidrop VP is numerically equal to the VP hop count from the source to the farthest destination. Specifically

$$h_C(\mathbf{a}) = \max\{j | a_j > 0, \forall j\}.$$

D. Minimum-Hop Within Half-Loop Scheme

Let u and v be the node numbers of the farthest destinations from the source within the two half loops. For a specific $\mathbf{a}$, they are given by

$$u = \begin{cases} \max\left\{j | a_j > 0,\ j \le \frac{(N-1)}{2}\right\}, & \text{for } N \text{ odd} \\ \max\left\{j | a_j > 0,\ j \le \frac{N}{2}\right\}, & \text{for } N \text{ even} \end{cases}$$
$$v = \begin{cases} \min\left\{j | a_j > 0,\ j \ge \frac{(N+1)}{2}\right\}, & \text{for } N \text{ odd} \\ \min\left\{j | a_j > 0,\ j > \frac{N}{2}\right\}, & \text{for } N \text{ even.} \end{cases}$$

With that, the number of links used is simply

$$h_D(\mathbf{a}) = u + (N - v).$$

E. Unconstrained Minimum-Hop Scheme

Under this scheme, a minimum hop route can always be used for any multicast connection request. On a ring, the minimum hop route can use either one VP in the clockwise direction or one VP in the counter-clockwise direction or two VPs fanning out from the source in both directions. Let $w_1, w_2, \ldots w_{k-1}$ be the node numbers of the destinations in ascending order, i.e., $w_1 < w_2 < \cdots w_{k-1}$. After using the minimum hop route for the multicast connection, there will be an idle segment left on the ring. The length y of the idle segment is just the number of links between the two adjacent connection nodes that are farthest apart. Enumerating all such segment lengths and finding the largest one, y is obtain as

$$y = \max\{(N - w_{k-1}), (w_{k-1} - w_{k-2}), \ldots, (w_2 - w_1), w_1\}.$$

The number of links used under the unconstrained minimum hop scheme is, therefore

$$h_E(\mathbf{a}) = N - y.$$

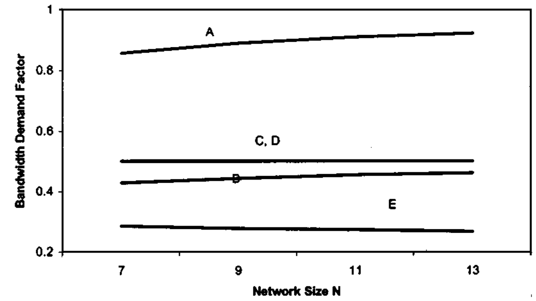


Fig. 14. Comparison of bandwidth demand factor $\boldsymbol{\eta}$ for call size $k = 2$.

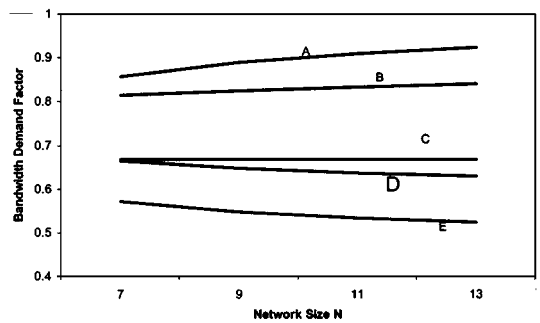


Fig. 15. Comparison of bandwidth demand factor $\boldsymbol{\eta}$ for call size $k = 4$.

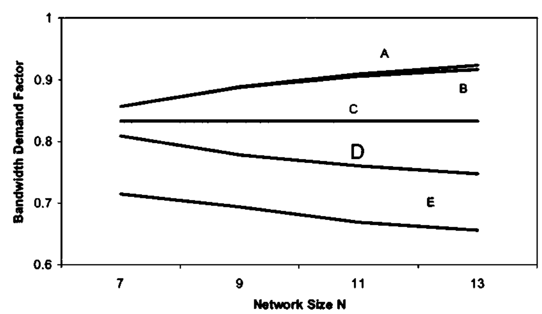


Fig. 16. Comparison of bandwidth demand factor $\boldsymbol{\eta}$ for call size $k = 6$.

VIII. NUMERICAL RESULTS

Figs. 14–17 show the bandwidth demand factors for some network sizes and call sizes under the various multidrop VP assignment schemes. Fig. 14 is for the call size $k = 2$, i.e., for point-to-point call. We can find that: 1) Bandwidth demand factor for Scheme E is significantly smaller than those for Schemes A, B, C, and D; 2) Schemes C and D have the same $\boldsymbol{\eta}$ values; and 3) $\boldsymbol{\eta}_C$ and $\boldsymbol{\eta}_D$ do not change with the call size. Fig. 15 shows the results for $k = 4$. Here, $\boldsymbol{\eta}_A$ and $\boldsymbol{\eta}_B$ increase with the network size while $\boldsymbol{\eta}_D$ and $\boldsymbol{\eta}_E$ behave the opposite. Figs. 16 and 17 show the results for $k = 6$ and 8, respectively. Here, we see that for $k \ge 6$, $\boldsymbol{\eta}_A$ and $\boldsymbol{\eta}_B$ become virtually indistinguishable. While $\boldsymbol{\eta}_C$ is always a constant, $\boldsymbol{\eta}_D$ and $\boldsymbol{\eta}_E$ both decrease slowly as N increases.

$$h_B(\mathbf{a}) = \begin{cases} \frac{(N-1)}{2}, & \text{if } \sum_{i=1}^{(N-1)/2} a_i = k-1 \text{ or } \sum_{i=(N+1)/2}^{N-1} a_i = k-1 \\ N-1, & \text{otherwise.} \end{cases}$$

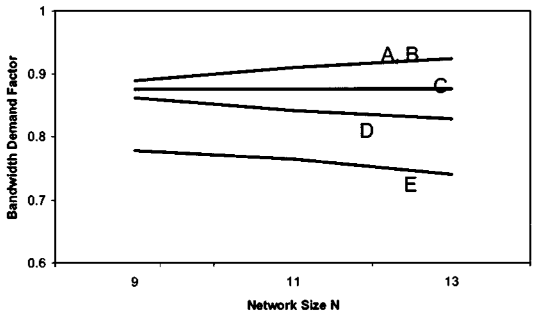


Fig. 17. Comparison of bandwidth demand factor η for call size $k = 8$.

Note that the bandwidth demand of Scheme E, i.e., the unconstrained minimum-hop multidrop scheme is the *same* as that of the multicast VP scheme. However, the number of VP needed is much smaller than that of the former.

IX. Summary

Current SONET rings cannot support multiparty videoconferencing efficiently. In this paper, we propose to use SONET/ ATM rings to support this service via switched DS1 service. Various multicasting methods are discussed and the new multidrop VP is found to be suitable for multicasting on SONET/ATM rings. Several VP assignment schemes are proposed and their bandwidth demand factors are compared. Among them, the Unconstrained Minimum-hop multidrop VP scheme has the smallest bandwidth demand factor which is identical to that of the multicast VP scheme. It, therefore, has the advantage of requiring much much smaller number of VPs to be set up and is, therefore, the preferred VP assignment scheme for multiparty video conferencing service on SONET/ATM rings.

Though the multidrop VP architecture proposed in this paper is only used in SONET/ATM rings, the idea of VP assignment is possibly applied to other network architectures, such as WDM/DWM rings. In addition, it is also possible to apply our idea of the multicasting mechanism to future MPLS/MPlS network based on ring topology and IEEE 802.17 resilient packet ring [23]. These are some interesting research topics in MPLS and RPR network paradigms in the future.

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