Multimedia-Multiparty Service support in ATM Wide Area Networks

J.I.Moreno, A.Azcorra, D.Larrabeiti, T.de Miguel, M.Alvarez-Campana

Dpto Ing. Sistemas Telemáticos. ETSI Telecomunicación

Universidad Politécnica de Madrid. 28040 MADRID

{jmoreno,azcorra,dlarra,tomas,mac}@dit.upm.es

Abstract

Multicast Service support in today's networks will be crucial for the evolution of new Computer Supported Co-operative Work (CSCW) applications. In order to consolidate ATM as the future Wide Area Network technology it is required that it provides an efficient support for this service. In this article we are going to describe a new proposal of a network structure based on WAN-ATM that provides an efficient workgroup communication and which has been tested in real environments. We are going to focus on network structure, functional switching and resource allocation issues.

1 Introduction

New telematic applications based on CSCW require audio, video and data transfers among group members with very restrictive characteristics over delay, delay jitter and throughput. In order to support these demands, an appropriate network infrastructure must provide an efficient workgroup communication service that offers multipoint to multipoint communications. Unlike Wide Area Networks, in LAN environments the existence of a broadcast media and the implicit low cost of resources allow the provision of that service with a simple design and disregarding resource consumption. In WAN environments we need to analyse traffic pattern applications in detail and establish a network architecture that minimises transmission and switching resources.

In order to provide a workgroup communication service, ATM facilities only support point-to-multipoint connections, and therefore distribution of traffic is based on cell copies made by ATM switches in principle building a mesh of overlaid multipoint connections. However, in wide area environments we need to minimise resource waste through aggregation of traffic sources, which is not currently supported.

Main contributions to provide workgroup communications, based on ATM technology, are due to ATM Forum, through LAN Emulation specifications [1], and IETF through the definition of Multicast Address Resolution Service (MARS) [2] for Logical IP Subnetwork (LIS) [3,4]. Both solutions use the distribution capacity of the ATM network, point-to-multipoint-connections, for spreading group information among its members.

In LANE, multicast transfers are based on a central Broadcast and Unknown Server (BUS), which emulates the existence of a shared medium, broadcasting group information among all stations of the LANE and passing to them the problem of filtering this information. Multicast traffic is sent to the BUS, who forwards it to all LANE stations after serialisation of incoming AAL5 frames. This solution requires a connection from any group source to the BUS (Multicast Send VCC path), with enough bandwidth allocation to support the peak traffic injected by each source, and a point-to-multipoint connection (Multicast Fordward VCC path) from the BUS to all members of LANE, with enough bandwidth to support the peak traffic situation. Due to the centralised model and the resources needed, LANE is not scalable to WAN environments involving tens of sites.

In the case of IETF, workgroup communications have been defined around IP multicast support over ATM networks. For this purpose IETF has developed what is called Logical IP Subnetworks (LIS), made up of a set of systems that share the same IP network and mask. Connections between systems connected to different LIS must be made using classical methods (IP routers) and therefore in this case multicast communications are solved at IP level instead of ATM level. Inside a LIS, workgroup communication requires address resolution between IP and ATM addresses which is solved by means of Multicast Address Resolution Server (MARS). The resolution admits two modes: centralised or distributed. In centralised mode, MARS resolutions consist of a list of multicast servers, which broadcast workgroup information in the same way as BUS. In distributed mode, MARS resolutions consist of a complete list of sink members. Each source member of the group must establish a point-to-point connection with the sink members after address resolution for sending multicast traffic directly from sources to sink members.

The generalised use of this solution has two main problems. First, this solution is based on a specific protocol, the IP protocol. Second, this solution is not scalable, due to the great amount of circuits involved (order n^2) in the distributed mode, and due to the same problems of LANE in the centralised mode.

As a conclusion of current support of workgroup communications, we can say that both solutions described above can be applied to Local Area Networks, for which they were designed, because the cost of resources is not a critical aspect, but can not be used in a WAN environment where resources are limited and expensive. It is in WAN environments where workgroup applications are most interesting. If we think about videoconference, tele-teaching or tele-medicine applications we can conclude that the main interest of these applications is referred to interconnection of distant auditoriums, classrooms, hospitals, experts, etc, beyond the same building and even covering different countries. In these cases workgroup communication service must be supported by an efficient allocation of resources required according to traffic patterns injected by workgroup applications.

In this article, we are going to describe a new network architecture based on WAN-ATM technology that offers an efficient workgroup communication service demanded by CSCW applications. This architecture is based on an efficient allocation of network resources and uses two complementary network models. First, what is called a double tree model, which establishes a shared hierarchy structure in a way that the workgroup traffic from the sources is aggregated at a central point, root node, and afterwards distributed to the sink members of the group. The second model is called distributed control model and is based on an acyclic graph, to exchange traffic among sources and sinks based on ATM point-to-multipoint connections.

In section 2 we are going to analyse the properties of traffic generated by CSCW applications. In section 3 the proposed network architecture is described, focusing on design issues and resource allocation. In section 4 we are going to explain the different switching techniques that can be used for the required aggregation and distribution functions. Section 5 presents some real case studies where this architecture has been partially applied. Finally, in section 6 we will summarise the main conclusions of our work.

2 Traffic Patterns

CSCW applications can be classified according to space and timing interactions among group members [5] into five types (Figure 11~~Figure 1~~).

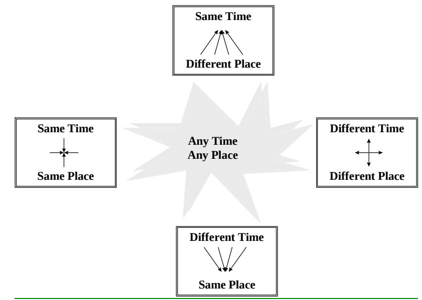

Figure 1~~1~~: Types of CSCW applications depending on time and place restrictions

Our main interest in the traffic analysis is centred on applications that require real-time interactions among distant members because they impose maximum restrictions on the telecommunication network.

Some previous works have studied CSCW traffic patterns [6], [7]. The main conclusions of these papers are:

- Traffic sources have different **states** in relation to the traffic injected to the network. These states depend on the nature of the signal (audio, video, data), of their quality (CD audio, telephone audio etc), code and compression methods used (H.261, MJPEG, MPEG). Thus, in a typical audio-conference only one source transmits audio signal while the others are listening, so that possible states of audio sources are active or passive. Figure 23~~Figure 3~~ shows an example of real traffic measurements produced by a workgroup application based on tele-teaching. In this application we can observe four typical states of a tele-teaching source: introduction of the class, where the source sends high quality audio and video signals; class development, where the source sends high quality audio, data (slides) and low quality video; listening, where the source sends low quality video and no audio; and panel where the source sends low quality audio and video. Different states of a source correspond to different levels of traffic injected to the network.

Figure 23: States in a CSCW Application

- Workgroup applications are developed under different **activity profiles**, which characterise operation mode of group members. Figure 35~~Figure 5~~ shows traffic injected by a co-operative workgroup in a distributed videoconference with an activity length of two and a half hours. This example shows the activity profiles of a real tele-teaching application involving 7 distributed classes through a European environment [8], with three profiles: one for teaching (profile 1), one for recess (profile 2) and one for panel (profile 3). In each activity profile different audio video and data signals with different qualities are exchanged, corresponding to different combinations of states between the sources.

- Activity profiles of a workgroup application characterise possible states of the members of the group. In the case of a video-conference we can establish different profiles such as: dialogue, speech and panel. In dialogue profile only two participants send traffic to the group at the same time. In speech profile only one participant injects traffic to the group while others are listening. In panel profile all participants send information to one another.

- There is a **strong correlation** among states related to the same activity profile. Consequently, aggregated traffic corresponding to an activity profile can be statistically modelled (assuming instantaneous independence) as a random variable with a mean rate equal to the sum of source mean rates and a peak rate equal to the sum of source peak rates (worst case modelling). Correlation among sources permits us to know the amount of aggregated traffic in relation to the least favourable activity profile, given by the expression:

$$\mathbf{C= x_1T_1+ x_2\ T_2+ x_3T_{3\ +\ ....+}+ x_n\ T_n}$$

Where C is the total bit rate injected by the group, x_i is the number of sources that are in state i injecting a bit rate equal to T_i.

Correlation property among source states allows us to save resources (bandwidth and virtual circuits) since the resources needed for supporting the workgroup service must not be allocated according to the sum of peak traffic injected by each system, but to the sum of peak traffic injected by each system in the least favourable activity profile. Current solutions (ATM Forum , IETF) make the allocation of resources by means of the sources instead of group activity and therefore resource consumption is not minimised. WAN-ATM support for workgroup communications must be based on a network design which minimises resources used, based on correlation property.

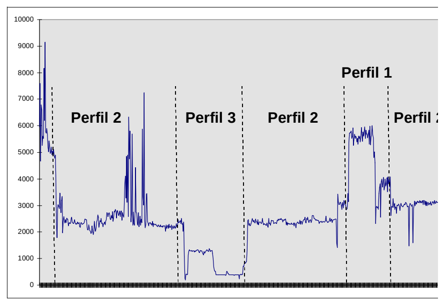

Figure 35: Activity profile of a videoconference application

As a conclusion of these properties, we have to analyse activity profiles of each application and possible states of sources in each profile in order to minimise the network resources required to support the workgroup communication service needed, and build the service based on the group activity instead of source activity.

3 Network Architecture for workgroup communications

The network architecture for workgroup communications proposed in this article is based on two network models: **double tree model** and **distributed control model**. Double Tree model tries to minimise the network resources while distributed control model tries to minimise transit delay. The combination of both models permits an efficient adaptation to any environment providing distributed management of the service. In both models, the allocation of resources needed for supporting group communications is based on traffic correlation property described in the section above.

3.1 Double tree model

The Double tree model is based on the construction of a single shared structure, which performs aggregation and distribution functions of information related to the group. Group information flows along two trees connected by its root: aggregation tree and distribution tree (Figure 47~~Figure 7~~). Aggregation tree has as leaves the multicast group's sources, whereas the distribution tree has the sink members as leaves. In this section, we are going to analyse the functionality to be provided by the network nodes for aggregation and distribution.

The construction of the shared structure depends on the number of group members, their topological location within the network, and the cost of involved resources. The elements of the model are:

- **Leaves**, formed by group members. Leaves can play 3 different roles:
  - ❑ Source of traffic, which only sends traffic to the group.
  - ❑ Sink of traffic, which is the destination of group traffic.
  - ❑ Source and sink which sends and receives traffic.
- **Nodes**, formed by intermediate systems (switch nodes) inside the network. We can distinguish three different roles for nodes, according to the functionality provided:
- **Aggregation node**, which adds traffic received from leaves/nodes of a lower level and sends the aggregated flow to its parent node towards the root. These nodes belong to the aggregation tree.
- **Distribution node**, which receives a traffic flow from its parent node and sends as many copies of this flow as children nodes/leaves are connected to it. These nodes belong to the distribution tree.
- **Root node**. This node connects aggregation and distribution tree and so, from a functional point of view, is composed of the serialisation of an aggregation node and a distribution node. The root node belongs to both trees, aggregation and distribution.
- **Transit node**, which makes regular switching functions between elements of the aggregation or distribution trees. From the point of view of workgroup communications service these nodes are transparent.

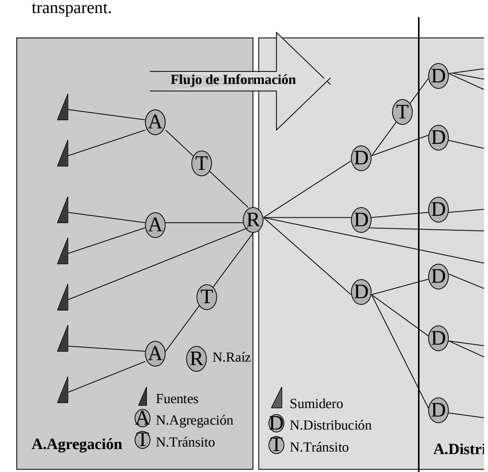

Figure 47: Double tree model

- **Transmission links**, which are the branches of the trees connecting nodes to leaves or to other nodes.

Group Sources inject traffic inside the network across the aggregation tree, through a single ATM connection. Sink members receive multicast traffic from one or more circuits depending on the adaptation protocol and the aggregation method used.

Multicast traffic travels the network following two directions: upstream to the root and downstream to the sink members.

- **Upstream Traffic**: it circulates through the aggregation tree. The flow of information sent by the sources goes towards the root node through the aggregation tree. Aggregation nodes must add traffic received from children leaves/nodes into a single flow and forward it towards the root through the aggregation path. Transmission resources required in the aggregation tree increase upwards as we approach the root.
- **Downstream Traffic**: it circulates through the distribution tree. This traffic corresponds to workgroup traffic aggregated in the root node through the aggregation tree and is distributed from the root to the sink members through the distribution tree. Transmission resources required must be the same for

all branches and equals to the amount of bandwidth consumed by the group.

As can be noted in the Figure 47~~Figure 7~~, aggregation and distribution trees are in general asymmetric, since the group could have members that only send traffic (and not receive) and members that only receive traffic (and not send) as could be in a videoconference application or television broadcasting. However, there are situations where all group members are sources and sinks of information at the same time (symmetric groups). In these cases aggregation and distribution trees should be symmetrical, that is to say, from a topological point of view there is only one tree, which performs aggregation and distribution function at the same points.

The double tree model has been proposed in different papers [7], [9] as a good balance between network delay and consumed resources, factors which are critical for WAN environments.

Some remarks:

Location of root node inside the network is a relevant issue of the network design due to its impact on required bandwidth and delay..The lesser the average distance from the root node to the sources, the lesser of transmission resources required.

In order to minimise average distribution delay from the root, it should be located minimising its average distance to the leaves. However, if the objective is to minimise the delay differences observed between leaves, the previous location might not in general be optimal.

Systems that are sources and sinks of the group will receive back their own traffic (self-traffic). Some applications would be disturbed by this self-traffic, and therefore a filtering function is required either at end-nodes or at the end-systems themselves.

3.2 Distributed control model

Double tree model supports workgroup communication in a WAN environment, minimising the consumption of network resources. However, there are certain cases (e.g.groups formed by different PNOs or groups where network delay is a critical factor) in which application of this model can not be appropriate due to different reasons: location of root node, transit delay and reflected traffic.

In these cases, a model in which information must travel through the network directly from sources to destinations could be more appropriate. This model, called distributed control model, due to the distribution of flow responsibilities in different systems, is based on the use of direct ATM point-to-multipoint connections from each source member to all the sink members.

Distributed control model is based on the construction of an acyclic graph as the logical topology of the network. An acyclic graph consists of a combination of ATM VPs that permits, through a single path, the interconnection of group members (sources and sinks). Connections among sources and sinks are established through point-to-multipoint VCs from each source to all the sinks (Figure 59~~Figure 9~~).

The distributed control model minimises transit delay in the network because workgroup traffic travels directly from source to destination. On the other hand, this reduction of delay is obtained by increasing the complexity in the management of the system, as well as the number of links.

The acyclic graph is used to allow sharing the VPs between sources in order to benefit from the correlation properties of these sources to minimise allocation of resources.

For each source, we have to establish a tree (point to multipoint VC) that connects it to the sink members following the VP acyclic graph.

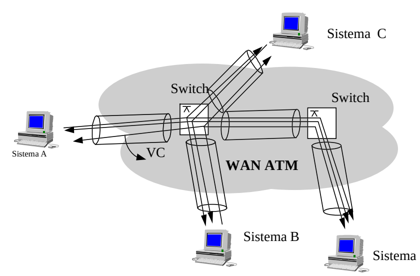

Figure 5~~9~~: Distributed control model

As in the double tree model, in the distributed control model we can distinguish several types of nodes:

- **Transit nodes**: make a regular switching function between elements inside the aggregation or distribution tree. From the point of view of workgroup communication service these nodes are transparent.
- **Distribution traffic nodes**: fork nodes of the graph. The distribution functionality consists of making from each flow of traffic received as many copies as output links belonging to the acyclic graph. This replication of traffic is based on ATM point-to-multipoint connections. The number of connections required depends on the network structure and in the worst case the number of connections are in the O(*n x m*), where *n* in the number of sources and m is the number of sinks (Figure 611~~Figure 11~~).
- **Aggregation nodes**: they are distributed along the network topology andtheir function consists of the aggregation of ATM virtual circuits, belonging to the same group and which travel across the acyclic graph in the same output virtual path in order to minimise resources needed.

This model improves transit delay since aggregation nodes can easily operate in cell-by-cell mode and do not require the reassembly of frames in transit. This operation at cell level could support the workgroup communication service independently of the adaptation protocol used and therefore could be a generic solution valid for any service.

However, because the complexity of management of the involved circuits increases according to the number of group members this model is not recommended for large groups. The development of tools, which simplify the management of these circuits, will permit the support of groups with more members.

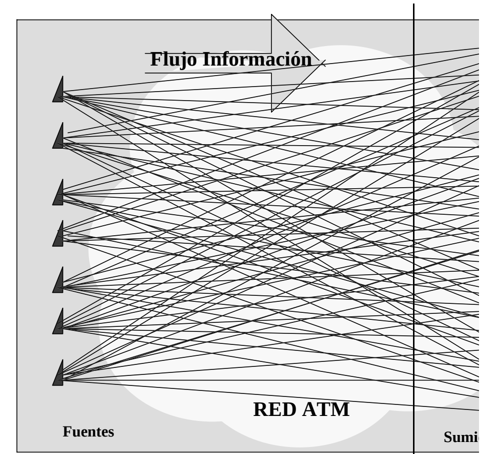

Figure 6~~11~~: Distributed control model

3.3 Combination of models

Distributed Control Model and Double Tree Model focus on different goals. The first of them focuses on minimising resource usage by sharing a common topology, while the second focuses on minimising transit delay by establishing a direct connection between each source and sink members while easing cell-by-cell operation.

Each of the models fits on different environments and the network architecture proposed in this paper uses the combination of both. In each of the description modes we have depicted some suggestion for using both. In a general environment both solutions could be combined.

As an example, a workgroup service which covers different public networks could be based on a double tree model as internal network model for each of the public networks involved, and distributed control model in order to interconnect all public networks (Figure 713~~Figure 13~~). As a benefit of this solution, self-traffic is not propagated between different networks and therefore it doesn't use long distance links, and finally each public network keeps control over its own resources.

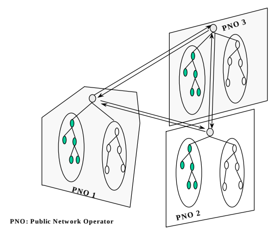

Figure 7~~13~~: Example of combination of Models

3.4 Resource Allocation

Bandwidth allocation for network architecture must be based on the correlation property of traffic sources described in section 2. This property permits saving a high amount of resources as the allocation must be based on the group activity instead of individual source traffic patterns.

Allocation of resources in network architecture proposed in this paper depends on the network model involved.

3.4.1 Double Tree Model

Resource allocation methodology depends on the tree involved. We must distinguish two types:

- **Aggregation tree**. In the aggregation tree, traffic increases as we move from the sources to the root node. For this reason, resource allocation is not fixed for each branch and increases as we are closer to the root node. Capacity of each link can be put as:

$$C = \sum_{i=1}^{n} x_i T_i$$

where:

T_i: amount of traffic injected by a source in state i.

n: number of different source states in the least favourable activity profile for this particular link.

x_i: number of sources which are in state i in the least favourable activity profile for this particular link. From this relation we can conclude that the capacity of the links of an aggregation tree increases as the link is closer to the root node, and is dependant on source members and activity profile of the group. For this reason the hierarchy (depth of the tree) must be made as short as possible by placing the root node at a place that minimises the average distance to the sources.

- **Distribution tree**. In the distribution tree traffic is already aggregated and therefore all branches must be allocated with fixed resources. The capacity of these links must be allocated to a fixed value that is equal to the traffic injected by group sources in the most unfavourable activity profile. Namely, given a group of N sources and being T_i the peak traffic injected in state i, the distribution circuits must be dimensioned to a value given by:

$$C = x_1T_1 + x_2T_2 + x_3T_3 + \ldots + x_nT_n$$

Where x_i is the number of sources which are in state i so that $\sum_{i=1}^{n} x_i = N$.

So, the capacity of the distribution tree is fixed and depends only on the number of group sources and on the activity profile that is least favourable.

3.4.2 Distributed Control Model

In distributed control model the aggregation and distribution functions are mixed in the same network structure and therefore bandwidth reservation depends on the number of source streams which cross each VP in the acyclic graph. Each VP and direction of the acyclic graph will be allocated with enough bandwidth, depending on the number of sources that cross it and correlation properties among sources, to a value given by the expression:

$$C = \sum_{i=1}^{n} x_i T_i$$

where:

T_i : amount of traffic injected by a source in state i

n : number of possible states inside the activity profile in the least favourable case for this particular VP and direction.

x_i: number of sources which are in state i and which send traffic through this VP in the least favourable case for this particular VP and direction.

4 Switching Functionality

Double Tree model and Distribution Control Model require new functionality in network nodes: aggregation and distribution functions. Both functions are required independently (aggregation and distribution nodes) or both in the same node (root node). In this section we are going to describe how aggregation and distribution functions could be supported focusing on each function separately. In case of root nodes both functions must be serialised in the node.

4.1.1 Aggregation Function

The aggregation function consists of merging different input traffic streams into one output stream. In ATM networks, aggregation could be done using one virtual circuit (VC) per aggregated stream or one Virtual Path (VP).

- Multiplexing over a VC

Multiplexing over a VC consists of merging input traffic received from different sources into a single output flow and forwarding it over one VC (Figure 8~~15~~~~Figure 15~~). In this schema, sink members will receive all workgroup traffic in one VC. Depending on the adaptation protocol used by CSCW applications in the ATM stack this operation could be done in two ways: frame by frame or cell by cell.

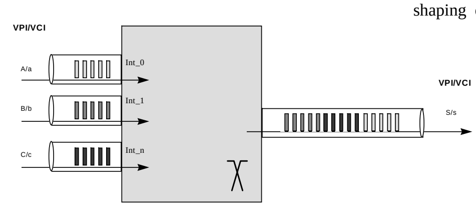

Figure 8~~15~~: Multiplexing over a VC.

In frame-by-frame operation, switch nodes must assemble frames received and forward the resulting stream in an output VC. Traffic shaping per output VC must be provided in order to avoid that aggregated traffic exceeds the guaranteed bandwidth. Frame-by-frame operation requires to mark the beginning and end of each frame in the node and therefore it requires enough memory to allocate adaptation frames in transit, operation which is carried out at present by ATM switches for congestion control ("Early Packet Discard") [10], [11], [12].

In cell-by-cell operation, switch nodes must aggregate cells received from different input streams into the output stream. In order to reassemble traffic by sink members, cells from different sources should be distinguished. Nowadays only AAL3/4 could be used as adaptation protocol since AAL5 does not support this functionality. Compared to frame by frame operation, cell by cell cuts down transit delay and buffers needed, but it limits the scope to the usage of AAL3/4, not quite common at present.

- Multiplexing over a VP.

Multiplexing over a VP consists of merging input traffic received from different sources and transmitting them over one VP (Figure 9~~17~~~~Figure 17~~). In this schema sink members will received one VP carrying all workgroup traffic. Traffic from each source member should be received in separate VCs all within the same VP.

This operation could be applied to any adaptation protocol but requires per VP shaping on output, in order to avoid that aggregated traffic exceeds the guaranteed bandwidth. At present this function is not quite common in ATM switches. Circuit management and per VP shaping on output are the main drawbacks of this schema.

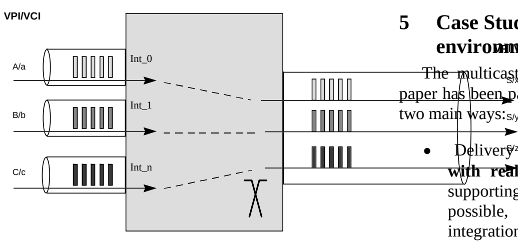

Figure 9~~17~~: Multiplexing over a VP

4.1.2 Distribution function

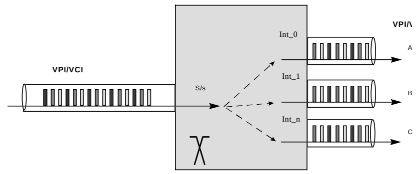

Figure 10~~19~~: Distribution function

Distribution function consists on generating from an input stream as many copies as output links belonging to the group path exist (Figure 10~~Figure 19~~). This operation could be done by means of usual point to multipoint ATM connections provided by commercial ATM switches.

5 Case Study: Application to real environments

The multicast network architecture described in this paper has been partially validated during the last years by two main ways:

- Delivery of **international distributed events with real users**, where an important goal was supporting as many fully interactive sites as possible, which required an important systems integration effort.
- Project **experiments** supporting a variety of application services making use of multicast functions, like tele-education (e.g. BONAPARTE [13]), tele-conferencing (e.g. BRAIN, NICE [14]) and tele-meeting (e.g. TECODIS [15]).

In the first group, the most relevant events have been the RACE/ACTS Summer Schools on Advanced Broadband Communications (ABC 1993-1996). In order to focus on a case study we will resume the network topology of last event: ABC'96.

ABC'96 stands for the fourth "*International Distributed Summer School on Advanced Broadband Communications*". ABC'96 was a large-scale distributed conference organised by the ACTS project NICE (AC110), supported by Directorate General XIII/B of the Commission of the European Union. The objectives of ABC'96 were to attract speakers who are world experts on broadband technologies , provide the participants with a state-of-the-art discussion forum on advanced communications, and serving as a real demonstration itself of advanced communications and ACTS results. Following the footsteps of the three previous Summer Schools, the number of sites has grown through the years. ABC'96 took place on 9th-12th July 1996 and was based on five main sites: Aveiro (Portugal), Berlin (Germany), Brussels (Belgium), Madrid (Spain), and Naples (Italy). Besides main sites, there were a number of subsidiary fully interactive sites and watch points (received only mode) in Austria, the Czech Republic, France, Greece, Iceland, the Netherlands, Norway, Sweden, Switzerland and Canada as first overseas node. Norway and Greece attended the summer school via satellite links through an earth station in Belgium as interactive site and receive-only mode respectively. ABC'96 run tutorials, lectures, panel discussions, interviews, debates and demonstrations. Lecture rooms at the different sites were joined into a single virtual lecture room using the multimedia application ISABEL [16]. Lecturers and participants interact and work together with full interaction despite their geographical separation.

The main requirement of the underlying network was the ability to support digital video from 18 sites on-screen simultaneously. There were two independent networks to support the application:

- *Unicast network:* it provided N to N bi-directional communications. The connection between the different machines was made with conventional IP routing.
- *Multicast Network (*Figure 11~~Figure 20~~): Based on double tree model and therefore including two streams
  - *Downstream network:* it carries the aggregated global multimedia output flow from the root network node to all the sites.
  - *Upstream network:* it carries the multicast IP traffic, originated at each Isabel workstation, towards the root flow adder.

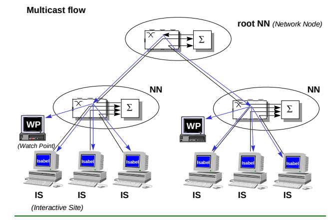

Figure 11~~20~~: Multicast Network

The distributed event described above is a real example of efficient usage of a WAN ATM network to support a multicast service. 7.Conclusions

Along the recent years the evolution of multimedia and workgroup communications service support in ATM networks have been focused on local environments. Nowadays there are different commercial solutions, which solve communications problems related to CSCW applications like videoconference or tele-teaching in an ATM local area environment where cost of resources is not a critical aspect. However, these applications are most interesting when focused on distant environments involving different buildings, cities or countries. In these cases, workgroup communication service must be supported with the constraint of an efficient allocation of resources.

In this article, after a review of current approaches to the problem and an analysis of traffic properties of CSCW applications, we have proposed a network architecture which minimises network consumption of resources providing a flexible support of workgroup communication in WAN-ATM networks. Our architecture is based on the combination of two network models: double tree model and distributed control model. The first of them tries to minimise network resources consumed while the second focuses on minimising transit delay. The combination of these models provides a flexible way for supporting the service required by workgroup applications.

The proposed network architecture has been partially tested in real ATM environments and we have described one of the latest experiments involving 18 interactive sites. In these environments, where different countries around Europe where interconnected and where the cost of resources (international links) was a critical point, other solutions were discarded due to the high amount of resources needed.

The network architecture proposed would be optimised with new functions in the switching nodes for aggregation and distribution operation, although it may also be implemented (as done in the case studies) using commercial equipment available now. In this paper we have presented different ways for supporting aggregation and distribution functionality depending on adaptation protocol used and operation mode: cell by cell or frame by frame.

In the near future, when user ATM signalling can be effectively transported by the ATM service provided by network operators, several protocols designed to build multicast trees at ATM level will be usable in such context. Next generation ATM switches are starting to implement new VP/VC aggregation features in order to share circuits with common destinations and thus save channels when setting up multicast networks. This trend is the best proof of the viability of this architecture in tomorrows' multiparty network service implementation over ATM.

- it fulfils the transport requirements of a typical multimedia application made up of a number of components with very different transport needs and traffic generation patterns.
- it is more scalable than other solutions like graphs made up of overlaid multipoint connections and full-mesh layouts.
- it is conceptually simple: the number of virtual paths required to set up the network is the minimum (tree structure), the functionality of nodes is homogeneous (management simplicity) and the network processes AAL5 frames, not application level data units (efficiency).

8. References

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