Performance management for a real full scale ATM network

BETEUS (M1010)

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ABSTRACT

This paper presents the Performance management platform of the BETEUS network. Beteus performs multimedia application trials in a testbed based on an ATM WAN interconnection of local ATM nodes. Sophia-Antipolis (F), Lausanne (CH), Zurich (CH), Geneva (CH), and Stockholm (SE) are interconnected over the European ATM Pilot. The BETEUS application platform allows geographically separated participants to actively take part in group discussions from their personal workstations equipped with audio and video capabilities. Therefore the Beteus application platform is a typical example of the future multimedia applications with its complexity with regard to numerous factors such as the information type, the distribution of users and their interactions, the information flow, and the stringent Quality of Service requirements. The multimedia high transfer rates place important constraints on networks and hosts at several levels.

Statistics are collected during the multimedia sessions and analysed off line in order to evaluate the Grade of Service. The management platform focuses more specifically on measurement and statistics of network utilisation in order to understand what Quality of Service means for end user applications in a real environment, how network management can be used to influence end to end application servicing, and in which respect the ATM technology fits the needs of end user applications.

The management activity permits a better understanding of the nature of the performance problems encountered by multimedia applications at different level during this earliest phase of ATM network deployment.

INTRODUCTION

Beteus, which is an acronym for Broadband Exchange for Trans European Usage is a European project aiming to build an early real usage of tele-collaboration services with the objectives to:

- give broadband access to tele-teaching organisations,
- develop and spread out the usage of remote education facilities,
- evaluate suitable multimedia applications.

Beteus will provide therefore experience in operating broadband systems from a user point of view. Focus is placed upon the utilisation of applications such as multi-connections (one to several remote sites), multi-channel handling (selection of various audio-video sources) and -set up a virtual working community in the same environment.

The application trial performs over the European ATM pilot which interconnects the local ATM equipment (Fore ASX 200). This real usage of multimedia applications over an ATM Network is a good opportunity to investigate whether or not ATM Networks satisfy the stringent performance requirements of multimedia applications. It should be noted that the performance depends also on the multimedia host systems.

This paper addresses the performance of the Beteus multimedia applications and presents the network management platform that has been deployed to monitor for performance at several levels (switches at local sites, workstations, applications).

The Beteus multimedia Application

The Beteus application uses multimedia workstations scattered over a wide area network[1]. Each workstation acts as a fundamental communication unit, it transmits, receives and processes multiple video, audio and data streams, independently from its geographical location.

In this setting, there is one participant per workstation. Participants have much freedom and flexibility, they may participate from any workstation convenient and available to them. They may join-in or drop-out of a session freely, so the size (in terms of users) of the teleseminar session varies dynamically[2].

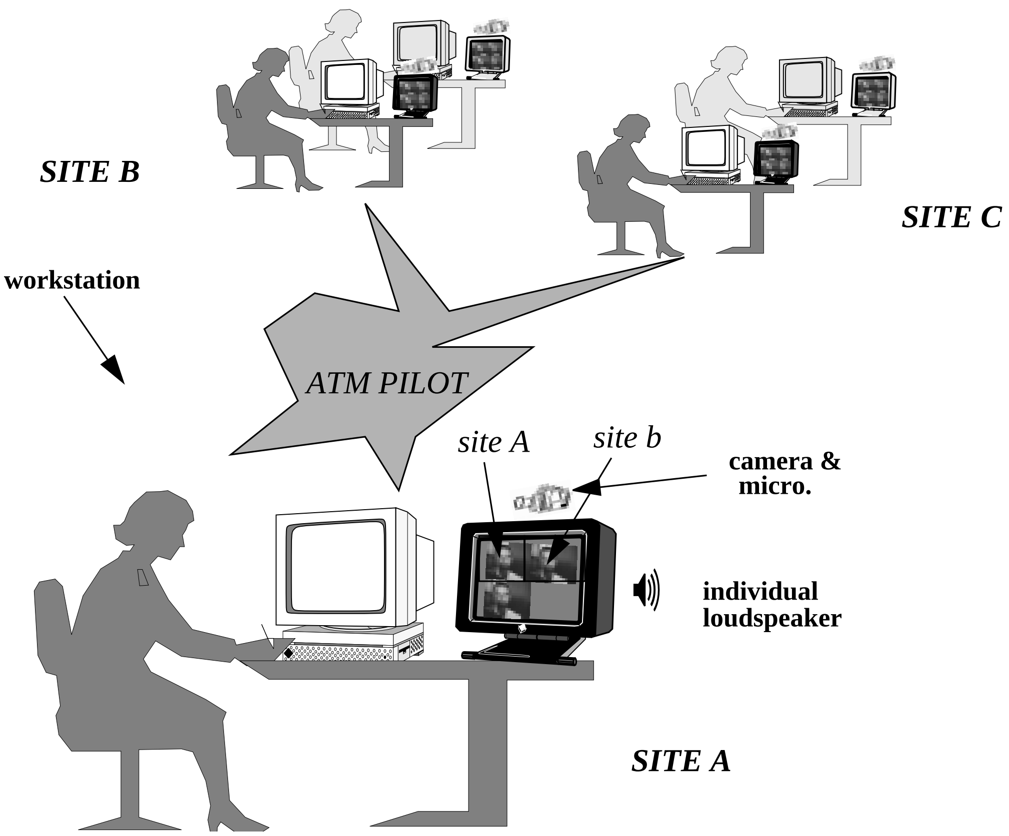


Figure 1: The BETEUS application

The multimedia facilities

Each participant receives the images and the sound of each colleague. His multimedia station has two screens, one computer screen dedicated to his working area and is able to display a shared application (X11 application shared between all the participants), and another for the video communications space. Only one participant per site can access to the full communications facilities (audio/video) so there is only one active group in the same time.

The sound coming from the remote sites are mixed and displayed through a personal loudspeaker.

1. APPLICATION AND PERFORMANCE REQUIREMENTS

The Quality of Service (QoS) is, according to the CCITT, the collective effect of service performances which determines the degree of satisfaction of a user of the service. It is important to characterize the traffic and the performance requirements of the applications in order to foresee where the Grade of Service offered may have an impact on the QoS.

The requirements of the applications involve the video, audio and shared workspace service characteristics.

For conversational applications the important metrics for user's perception are the *latency*, the *skew*, and the *jitter*.

- The *latency* delay includes all delays such as sampling, compression, networking, decompression and presentation. Delays of more than 150 milliseconds cause a loss of natural reactions. In the intermediate node, large playout buffers may increase the end to end delay and the delay variation.
- The *skew* is the difference in presentation times between two related objects. For example in order to synchronize voice with the speaker's lip motion the audio advance of video should be less than 40 milliseconds, and the delay following video less than 120 milliseconds.
- The *jitter* is the instantaneous variation in object presenting time. This metric is related to the packet loss probability. To maintain picture quality the requirements for uncompensated cell loss ratio are on the order of 10^{-7}.

The parameters that can affect these metrics should be identified and monitored.

The key feature of ATM networks is that both host capability and network performance should be considered in the context of end to end QoS.

1.1 The Video

The video images of 1/4 up to 1/2 PAL resolution are transmitted at a rate of 20-25 frames per second. Several video connections may be necessary at the same time. This results in a large amount of information to transfer and requires the use of CODEC to compress it. One of the important characteristics of a CODEC is the compression ratio. For a compressed video, the output rate is function of the amount of spatial detail and activity in scene. Thus, the display and camera of the multimedia terminal use the services provided by the CODEC. and it should be noted that Video CODEC are currently relatively slow devices. The compression algorithm used in BETEUS is JPEG.

The video bandwidth requirements is a derived function of the combination of all the points above. The two other stringent requirements are the end to end delay and the losses ratio of the video connections. By the way, it should be noted that the delay-bandwidth product defines the maximum number of bits in transit at any time and constitutes sometimes an important metric for the network complexity.

The video stream can be characterized by the following points:

- The number of bits per frame,
- The number of frames per second,
- The periodicity of the frames,
- The compression ratio,
- The end to end delay,

- The loss ratio (we can assume for example that an acceptable image quality can be maintained by the compression algorithm if more than 90% of each frame is delivered correctly),

1.2 The Audio

Collaborative work requires an excellent audio quality (sampling: 16bits, 16 Khz). the bandwidth required for the audio connection is about 256 Kbit/s. It is quite less than what video traffic ask for but it is much sensitive to losses. Any loss or distortion can be detected by ear. Voice packetization and depacketization can introduce additional delays and require echo compensation measures. Another important requirement relates to the latency period. It should be less than 250 msec. Users are very sensitive to the audio round trip delay.

The audio stream can be characterized as follow:

- the number of bit per sample (sample resolution),
- the number of sample per second,
- the end to end delay,
- the loss ratio.

1.3 The Shared Workspace

The shared workspace is an application, presents between the X-server and users' applications, which allows several users to share application interfaces (window displays, application inputs, etc.). The main requirement of a shared workspace application is related to the throughput.

2. INFRASTRUCTURE CHARACTERISTICS

2.1 The ATM switch

ATM networks promise to give a high performance level for multimedia applications. In theory VBR transmission offered by ATM networks is appropriate for multimedia services and it is pertinent to check exactly how it goes in practice and where the problems are. It seems that some problems such as cell loss can be serious obstacles and that careful management tasks should be taken within the network.

There are several problems, appearing at different levels of the ATM protocol, that can affect the QoS perceived by users:

- information errors that are caused by bit errors,
- cell losses that are generated by bit errors, buffer overflow at multiplexing or switching nodes,
- cell transfer delays due to the propagation, the buffering, the cell assemblies and the smoothing.

Information errors caused by bit errors happen only at the physical layer. Bit errors in the cell header result in the loss of cell delineation. A consequence of cell delineation is cell loss or cell insertion. It should be noticed that jitter is one of the sources of bit errors. The header CRC errors and the framing errors have to be monitored at the physical layer. There is no error control on the payload field. Thus, information errors can generate errors at the Adaptation Layer or the layers above.

ATM switches use buffering strategies at input/output ports or within the switch fabric to solve the possible resource contentions. Buffer overflows, and consequent cell losses, could occur due to the undeterministic variations of the traffic being queued. The buffer queue lengths and overflows should be monitored at this layer. Buffer queue lengths affect the delays while buffer overflows are concerned with cell losses.

Buffering is also needed at the AAL in order to accomplish the smoothing of the traffic. This layer performs also the segmentation/reassembly of information which is time consuming (e.g. a 48 octet information field carrying 64 kbits speech would take about 6 ms in cell assembling). Since at the ATM layer there is no error control (ATM layer carries cells without concern for their contents), errors in the payload field will appear only at the Adaptation Layer. These errors can result in SAR layer errors or in CS layer errors. These errors should be monitored at the AAL as well as pdu buffer queue lengths and overflows.

2.2 The Operating system characteristics

Multimedia applications place also some strong performance requirements on host systems. The performance factors can be the operating system design and implementation, the computer I/O architecture, the memory bandwidth, the application interface to name a few.

In order to evaluate the QoS perceived by users, consideration should be taken on host performance values such as the load, the memory usage, the number of device interrupts/sec, the CPU context switch rate, and the CPU usage. Multimedia applications require good process response time and system throughput.

2.3 The Protocol stacks

A major bottleneck for applications can be the overhead introduced by the different protocol stacks that may be used, such as TCP and IP multicast. TCP over ATM could experience poor performance because smaller switch buffers, larger TCP packets, and larger TCP windows cause cell dropping, consequently an increase of retransmission, and a decrease of the goodput (throughput without counting retransmission). On the other hand large switch buffers introduce latency problems. All these parameters should be considered when analysing the performance. The performance of X Windows also could limit the performance since the shared work space makes extensive use of it.

3. THE BETEUS DATA NETWORK CONFIGURATION

The ATM VP access to the ATM pilot is available in all BETEUS user sites[3]. The network is made of 6 nodes fully VP-interconnected (full mesh). In such configuration, if one of the sites cannot be reached it does not affect the other partners.

Each node is connected through the ATM pilot with the other five nodes by means of bi-directional VPs. The peak bandwidth allocated for each VP is 3 Mbit/s, except for the connection between EPFL and ETHZ which maximum bandwidth is 4 Mbit/s. To offer such topology, 30 VPs with a peak bandwidth ranging from 3 to 4 Mbit/s, have been ordered in the reserved (periodic) mode. The corresponding service is the semi-permanent virtual path service.

The physical configuration of the Beteus network is described as follow (figure 2):

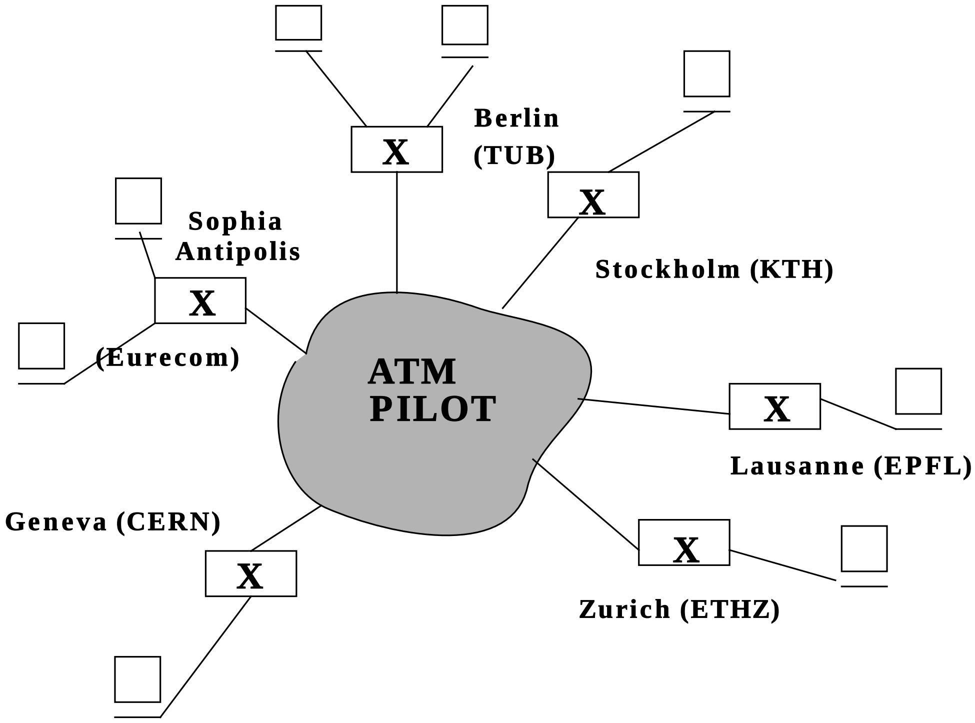


Figure 2: Physical configuration

The ATM configuration at each site consists of a single private ATM switch (FORE ASX 200). The multimedia applications run on Sun Sparc 10 Workstation(s) directly attached to the switch through an adapter card (SBA 200).

The service provided to the Beteus partners to the ATM Pilot is semi-permanent virtual path. Higher layers have end-to-end significance and can be chosen according to the needs of the application. The physical bit rate at the access is defined by the existing interfaces. For the purpose of the ATM pilot, two interfaces are defined at 34 Mbit/s (E3 interface) and 155 Mbit/s (STM-1 interface). ETHZ makes use of STM-1 interfaces while all other partners have E3 interfaces.

4. NETWORK MANAGEMENT

4.1 Networks Elements management capabilities

The local sites are composed of ASX 200 Switch and SUN workstations equipped with Fore SBA 200 adapter cards. Management agents are provided with the switch and the adapter cards in order to enable a remote monitoring via SNMP.

Multimedia applications place also some performance requirements on host systems (workstations). These latters may not preserve the throughput offered by the high speed networks. They are monitored in order to determine the performance they are providing. The performance factors could be the operating system design and implementation, the computer I/O architecture, the memory bandwidth, or the application interface. An SNMP agent has been developed in order to monitor the system performance statistics of the SUN workstations which are running the Beteus multimedia applications.

4.2 Network Management Architecture

A TMN architecture will be used to manage the local node of Beteus. In each node a mediation device (CMIP/SNMP gateway) will be used to request the local SNMP agents (switch, adapter cards, hosts-applications) on behalf of the Network Management Center (NMC) and then permits to exploit the power of OSI Management. This gateway will be directly managed by the NMC using CMIP protocol.

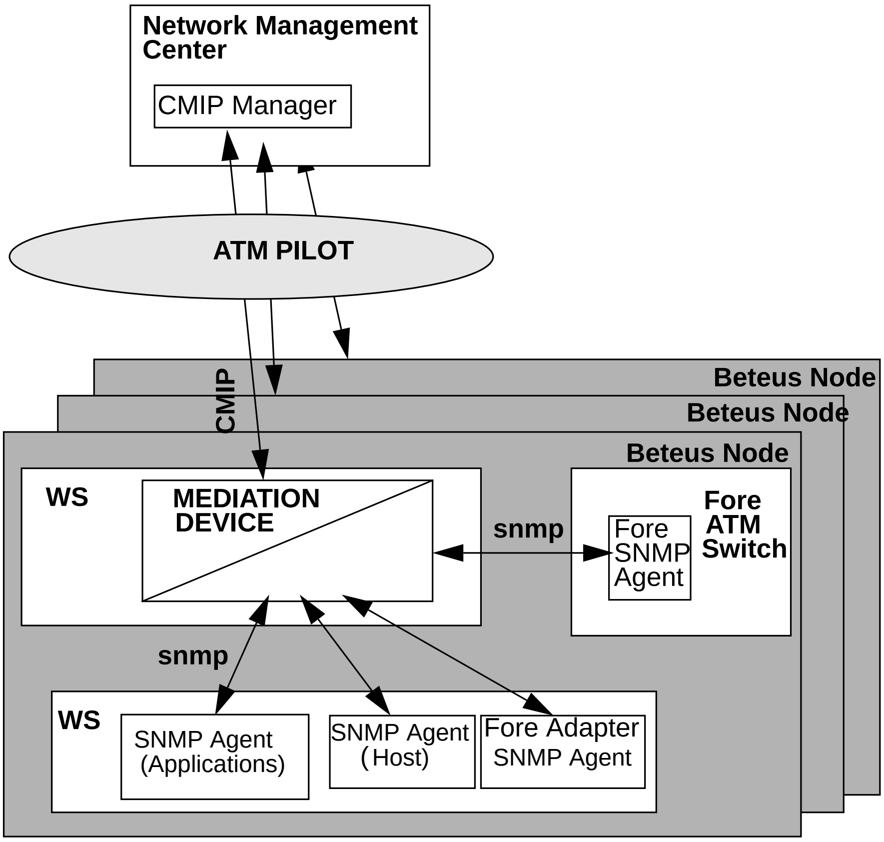


Figure 3: Network Management Platform

4.3 MIBs

The capabilities of the management platform must take into account the characteristics, limitations and constraints of the network infrastructure, hosts and applications. Managed objects are requested through a virtual information store called Management Information Base (MIB). The MIBs implemented by the agents contain the information of use to network management:

- The MIBs used on the ATM switches and ATM adapter cards are FORE proprietary. It is designed using the SNMPv1 Management Information Model. Most of the objects are accessible for reading only.
- The MIB used for information relative to the hosts (Workstations) contains the usual UNIX system statistics which include some objects of the RFC 1514 Host resources MIB. These object can only be read. An SNMP agent implementing this MIB for Sun OS 4.1.3-based hosts has been developed.

- Some specific information directly handled by the application software will be made available for Network Management purpose, for monitoring and control. These parameters are also modelled through a specific MIB.

4.4 Performance Management

According to ITU-T [4][5], Performance management provides functions to evaluate and report upon the behaviour of telecommunication equipment and the effectiveness of the network or network element. Its role is to collect statistical data for the purpose of monitoring and correcting the behaviour and effectiveness of the network, NE or equipment and to aid in planning and analysis.

In short, Performance management is performed mainly by monitoring the network and ensuring that the quality of service is satisfactory. It is also important to diagnose any changes that may modify the quality of service. ITU-T [4]identifies the following tasks for Performance Management:

- *Performance monitoring:*
  It consists in collecting continuously the Network Elements performance data. It requires the use of the following management functions:
- Performance management reporting functions,
- Performance information storage functions,
- Performance management thresholding functions.
- *Performance control:*
  It is mainly concerned with the performance data report schedule. The support functions of Performance control include application, modification and removal of manual and automatic network management traffic control.
- Performance analysis:
  Performance data may require additional processing and analysis in order to evaluate the performance level of the entities.

4.5 Performance monitoring

The methods used for the reporting of performance information are the event reporting and the polling.

With event reporting the agent takes the initiative to generate a report periodically to the manager. The reporting period may be set by the manager. This method could be used in SNMP by the mean of TRAP message. It should be noted that in SNMP v1 philosophy this method has been introduced mostly to notify the manager of significant or unusual events. Therefore this method is more Fault management oriented than Performance management. There is nothing provided to implement the report periods.

With polling, the manager queries the agent and requests the information of interest. This is the only way to perform information collection using SNMP. Polling, compared to event reporting, increases by the amount of management information generated. The resources in the local sites (switches, hosts) are monitored using SNMP v1. This polling could be isolated to the local sites and an event could be reported by the CMIP/SNMP Gateway when necessary. The Metric Objects of CMIP can take care of the polling of SNMP objects through the CMIP/SNMP gateway.

The monitored Network Elements can store history information (e.g. statistical information) on a preassigned time duration. This history information will lead to an off-line analysis. The information could be transferred later to the Network Management Center in order to not interfere with real-time communications.

A performance management thresholding allows the manager to be informed when thresholds are crossed. The manager set the threshold criteria (performance degradation basis) and the agent should detect when the threshold is crossed and then issue a event to the manager. SNMP v1 does not provide this capability which is available with CMIP using the Metric Objects and Attributes. Thresholds within the Metric Objects may be used to determine if a QoS Alarm Notification should be emitted when the observed attribute exceeds a boundary. These threshold boundaries can be set/changed, turns on/off by the manager at run-time.

4.6 Information Model

The Physical layer performance monitoring is the performance information that is monitored at the physical layer (adapter card, switch, E3 card).

The ATM layer performance monitoring is the performance information that is monitored at the ATM layer (adapter card). The cells coming from the physical layer and addressed to the adaptation layer could experience atmOutOfRangeVPIs, atmUnconnectedVPIs, atmOutOfRangeVCIs, atmUnconnectedVCIs errors. The error information is collected by the agent for the whole adapter instead of being by connection.

The following information on the ATM switch is available:

The ATM Adaptation layer performance monitoring which is the performance information that is monitored at the ATM Adaptation layer (adapter card). The error information is also collected by the agent for the whole adapter instead of being by connection.

The VP and VC connections monitoring is the performance information that is monitored for the VP (vs VC) passing through this ATM switch and originating at the switch.

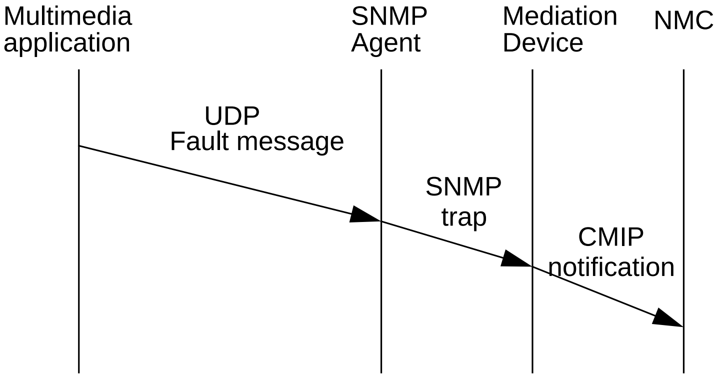
A Cell Delay Variation can be specified as a time window in which a cell may be received on a connection passing the switch and originating at this switch. It is possible to the number of cells outside this window: The number of cells over the path or channel that were rejected by the hardware due to traffic violation.

One of the most important part of the performance monitoring is the Application performance monitoring. Several parameters is made available by the applications to network management platform. They will be organized into a Application MIB.

One SNMP agent per workstation is responsible for monitoring the **receiving** multimedia applications activities. These activities include the video and audio performance information such as the number of frames and audio packets transmitted, received, and lost. Multimedia applications interact with the agent by sending and receiving UDP messages. In fact there are several types of applications according to the type of information (video, audio, data) they send and receive.

Two types of performance measurement are performed within the applications and send to the agent:

- on a periodic time basic a message is sent to the agent. The message includes the time at which, the images or n sound packets have been received or sent, the source or destination, the size of the image (the sound packet size is fixed), etc. The Mediation Device logs locally in a flat file the messages. This file is retrieved after the session by the Network Management Center in order to be analysed off-line.
- In case performance degradation (e.g. n consecutive images or sound packet lost) the video and audio applications send a UDP message to the agent that forwards this message to the mediation device. This latter converts the SNMP trap to a CMIP notification that is sent to the NMC.



CONCLUSION

ATM aims to provide a flexible mean of information transfer for the emerging multimedia applications which typically video, audio and data connections.

In the Beteus trial all these different types of information are transmitted over the network. If the QoS perceived by users is not satisfying, it is important to identify where the performance is degraded. The ATM pilot does not provide performance management support or QoS guarantees. It is however important to measure the level of performance achieved at the local sites within the ATM equipment, the multimedia workstation and the applications.

In this paper we presented the different performance issues raised by Beteus multimedia applications and the network management architecture used to monitor the different devices and applications.

Reference

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[2] "Detailed specifications", BETEUS deliverable, D6.

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