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A Distributed Simulator for Performance Analysis of Applications in the ATM Environment

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Abstract: In this paper, a distributed simulator for the performance analysis of various applications in the ATM environment is described. The simulator can be used to determine the way the quality of a synchronous service is affected when it is transmitted through an ATM network under various traffic conditions. The simulator has been implemented in a distributed Unix environment using network and operating system functions and simulates the supported service and the three lower layers of B-ISDN. It has been based on the time-driven approach, is modular and expandable and allows easy adaptation of various applications in this test-bed. Some experimental results on the analysis of constant and variable bit rate services in the ATM environment are presented and discussed.

I. INTRODUCTION

The Broadband Integrated Services Digital Network (B-ISDN) is probably the most promising communication system for supporting the large number of teleservices which are going to be developed in the near future. These services have different and sometimes yet unknown requirements, which must be supported by the same basic communication method. The B-ISDN uses the Asynchronous Transfer Mode (ATM), which is based on the transmission of constant length cells and provides the basic communication mechanism, while various adaptation functions must be used to adapt the ATM characteristics to the application requirements [1]. According to [2], the services which will be provided by B-ISDN, will diversify and will cover new sections in the residential and business environment. The Switched Multi-megabit Data Service (SMDS) will be used extensively for interconnection of high-speed Local Area Networks and it is considered as a necessity for B-ISDN. Video services will be introduced either as switched access television for residential customers or as video on demand for residential entertainment and business applications (medicine, education etc). Multimedia services will cover several different types of media (voice, video, text, graphics, etc) and their introduction in the B-ISDN will be successfully performed when the various technical problems, introduced by their wide range of traffic characteristics, will be solved. The analysis of the various components of a multimedia service in relation to the B-ISDN communication parameters is the main scope of this work. The analysis of such a system under various traffic conditions and especially the determination of its influence to the quality of

the supported services, is not a trivial task and requires the solution of complex models [3]. The simulation method is one of the methods used to analyze these systems, especially in cases where the probabilistic nature of the problem in combination with its complexity make the use of other modelling techniques rather impractical. The simulation is based on the development of a system model in a computing environment and the execution of experiments to analyze its performance or to evaluate alternative solutions [4]. The system under analysis can be described as continuous or discrete for the events' evolution and as deterministic or stochastic for the nature of its processes. The analysis of a communication system is based on its stochastic nature and discrete time events are used. The simulation can be performed in various timing levels depending on the system complexity, the nature of system execution, the required output statistics etc. Synchronous timing is performed in fixed, appropriately chosen time units while asynchronous timing is based on events. In this paper, a distributed simulator for the performance analysis of various applications in an ATM environment is described. The simulator has been built using discrete events, its timing has been based on the chronological events at the user side and the stochastic conditions have been taken into account for the resulting performance analysis.

The motivation of this work stems from the need to determine how the basic communication parameters affect the quality of a multimedia service when it is transmitted through an ATM-based network. The scope of the simulator besides providing the required performance analysis results, is mainly to simulate real test-sequences in order to observe visually the effect of the communication conditions to the service quality. Starting from this point, a complete, reliable and expandable distributed simulator has been developed.

In Section II the description of the communication environment is given and the structure of the developed simulator is highlighted. The characteristics of the B-ISDN services under analysis and of the used traffic conditions are described in section III. Finally, in section IV the performance analysis results are discussed and an example of how the quality of a video frame is affected when it is transmitted through an ATM network, is given. This work has been performed in the context of the DISTIMA (*Digital Stereoscopic Imaging and Applications*) project of RACE II (R2045).

II. THE SYSTEM MODEL

The B-ISDN architecture is based on the ATM method which uses fixed size cells for information transmission and a type of labeled multiplexing (virtual path / virtual channel - VP/VC) for information routing. The ATM is independent of the supported services and the adaptation of the service requirements to the ATM characteristics is performed by the ATM Adaptation Layer (AAL). AAL supports multiple protocols for different user requirements and these protocols are classified using the timing relation between source and destination, the constant or variable bit rate and the connection mode. AAL type 1 is used for supporting synchronous service of constant bit rate, type 2 is for variable bit rate synchronous services, type 3 is for connection oriented data transfer while connectionless data transfers are supported by type 4. The AAL is also divided in two sublayers, the Convergence Sublayer (CS) which is mainly used to satisfy the user interface requirements, while the Segmentation and Reassembly (SAR) sublayer is used for information transformation between Protocol Data Units (PDUs) and the ATM cells' information field. This layered architecture is used for service support in the developed simulator as it is shown in Figure 1.

The simulator has been implemented in a distributed environment of three workstations (HP9000/300 series) running under the Unix operating system. The communication between the various processes on the same or different workstation is achieved using network and operating system functions. The simulator is based on the time-driven approach [5], where the simulation clock is incremented at the end of each transmitted cell (fixed length time interval). The simulator is modular and expandable in order to allow easy adaptation of various applications in this test-bed. Its modular structure allows the use of workstations with various capabilities while the simulation load is balanced according to their performance.

The simulated system consists of four basic levels, which represent the three lower layers of the B-ISDN and the supported service. The simulator has been implemented by using various tasks in a pipeline structure for each information flow but the execution of tasks of parallel connections or in the same layer is performed using a time-sharing method since each layer is implemented using a single processing unit. The distribution of the processing power to the various modules of a layer is performed using a scheduler and its parameters can be easily adapted to the values of a real system. The tasks are organized in four basic modules having the following functionality:

- The *unassigned cells traffic generator* provides the required bandwidth to the supported service and is used to implement the variable traffic conditions of the network.
- The *network unit* simulates the performance of the part of the network which exists between the source and the destination nodes and generates variable delays on the cells of the same connection. This unit is also used to generate a specific cell error rate for each cell stream.
- The *transmitting unit* which receives the data from the supported service and implements the adaptation and ATM functions of a station. The AAL part of this unit depends on the type of the supported service. Its modular structure allows the easy alteration of its functionality in order to conform with the supported

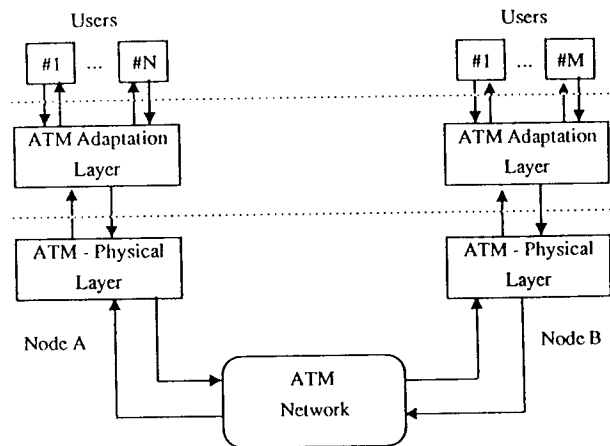


Fig. 1. The layered architecture for service support in the ATM environment.

The transmitting unit has one ATM and multiple AAL entities and can be configured to support multiple bit streams with different quality of service characteristics.

- The *receiving unit* collects the data from the network and regenerates the information transmitted through the network. Its structure is equivalent to the structure of the transmitting unit. Each network node can be emulated using various modules of the structure of the transmitting and receiving unit according to its functionality.

- The supported *service unit* is used to generate real traffic using various traffic models. The generated data can be either "dump" data or "real" data. "Dump" data are random data used only for collecting system statistics and measurements, while the "real" data (like video frames, audio sequences etc) can be used also for visual or acoustical perception of the communication system's influence.

The simulator performs all the functions (segmentation, assembly, cell header generation etc.) required by the network and its elaborate model description guarantees the correctness of the simulator. In Figure 2 the simulator's model architecture is shown. The specific functions used in its various submodules (like delay variation, available bandwidth etc) are described in the next section.

III. SERVICE AND TRAFFIC MODELS

Among the various services which can be supported by B-ISDN, the synchronous services (CBR and VBR) are of main interest in this work. A CBR service generates a constant bit rate traffic and various models have been proposed for describing such a service. The simplest model assumes that a byte is stored in the User - AAL buffer in constant time intervals while more realistic models assume that a burst is generated periodically and each burst contains a constant number of bytes. At the receiving node, the CBR service reads a number of bytes periodically from the output buffer. The system operates normally when no data are lost due to the network capacity limitations and traffic statistical multiplexing. In this case the relation between the traffic statistics, the service generation rate, AAL-PDU length and the AAL

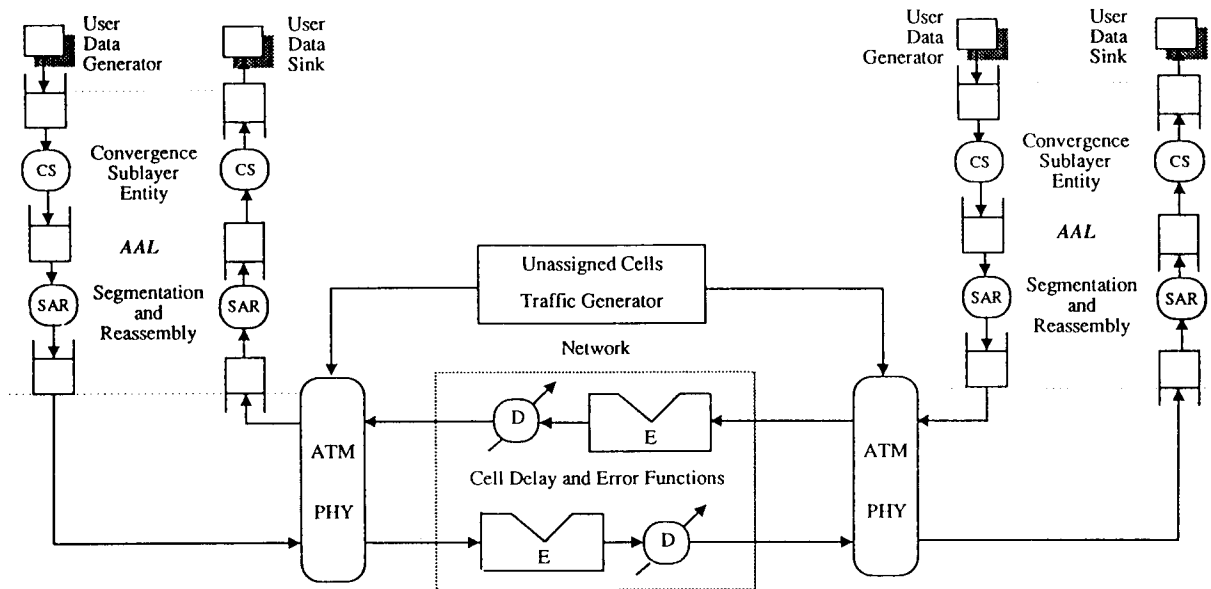


Fig. 2. The simulator model architecture

processing times must be analyzed.

When a VBR service is considered, new problems arise in the service modelling. Usually variable bit rate is generated when a constant image quality is pursued and the generated bit rate is adapted to the local and temporal image complexity. In [6] various results concerning source modelling for video teleconferencing services have been presented and they have been used as the basic information for our models. Each VBR service is characterized by its mean and peak bit rate and the data are stored in the user - AAL buffer using the peak rate. The VBR service generates bursts of data in constant time intervals (like the inter-frame period of the video system) but the burst length varies depending on the frame complexity. When a VBR service is analyzed in this simulator, the length of its bursts follows either a uniform distribution or a gamma distribution.

During the connection set-up procedure of a synchronous service, a part of the network bandwidth is allocated for use by the specific service and the unassigned cells are used in the ATM layer to denote to the AAL the bandwidth availability. Although this bandwidth allocation procedure is used, the available bandwidth varies depending on the statistical multiplexing performed at the network due to the variable bit rate nature of the total traffic. For these reasons a Poisson distribution with lower and upper limits has been used to describe the available cells for data transmission.

When the cells of a connection pass through the network, they are subject to errors (transmission errors, switching buffer overflow) and to different delays. The cells of a connection follow the same VP/VC routing and no reordering can be performed. The delay functions at the network unit have been also implemented using Poisson distribution, while for the cell error function a uniform distribution has been used.

IV. EXPERIMENTAL RESULTS

The developed simulator has been used to analyze primarily synchronous services in the ATM environment. In this section

some representative results are discussed.

Picture Quality: In this experiment a number of video frames has been transmitted through the network under various traffic conditions and various coding schemes have been used. In Figure 3a the original "Smiling Technician" frame is shown. This frame has been transmitted using either (i) uncompressed - no line synchronization format, or (ii) uncompressed -start of line control format. Figures 3b-c show how the cell error rate occurred due to the network statistical multiplexing affects the picture quality. When no line synchronization is used, a burst of errors makes the frame pixels to wrap around and the rest of the frame is destroyed even when there are no more transmission errors. When a line resynchronization method is used (Fig. 3c) the occurrence of a burst of errors affects only the specific line and re-synchronization is achieved in the next line.

System Parameters: The simulator has also been used to measure how the network performance is affected due to some system parameters values and how this is related with the type of the supported service. We have considered a CBR and a VBR service with similar characteristics and the influence of the CS-PDU length to the cell rejection rate at the transmitter and the buffer overflow at the receiver have been studied. In the transmitting unit, a new burst is received at constant time intervals and its length is constant for the CBR service and variable for the VBR service depending on the line complexity. When a new burst is received, the CS buffer is cleared and its content is rejected since its playout time has expired. As it is shown in Figure 4, the longer the PDU, the smaller the cell rejection rate since the variations at the network traffic are better smoothed. At the receiving end as the PDU length increases, the buffer overflow probability increases when no flow control mechanism is used, due to the increased probability of the arrival of a long burst at the output buffer. The analysis of the same parameters for a VBR service has shown great variation to its mean values depending on the statistical relation between the burst length variations and the traffic multiplexing.

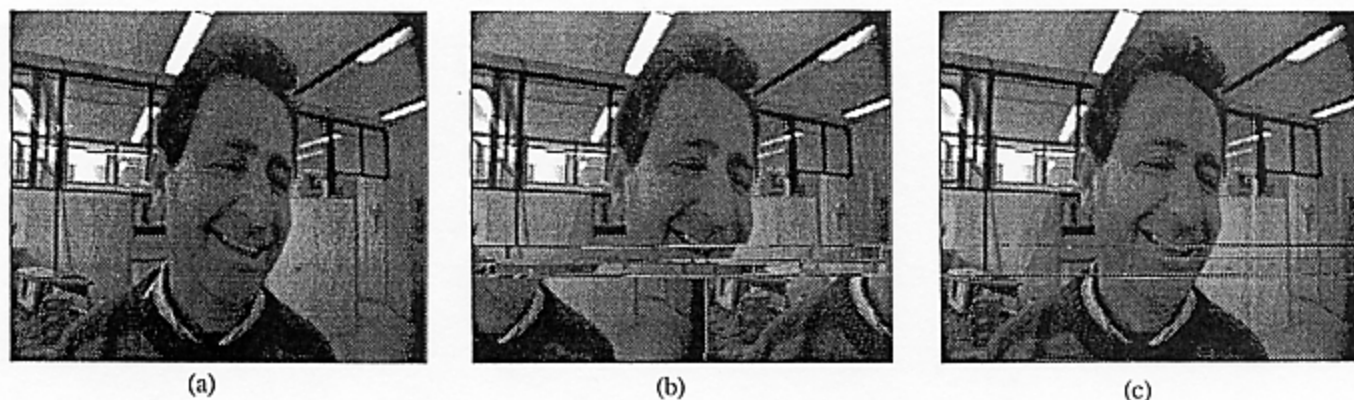


Fig. 3 Video frames transmitted through the ATM network: (a) the original frame, (b) uncompressed without synchronization and (c) uncompressed with synchronization characters.

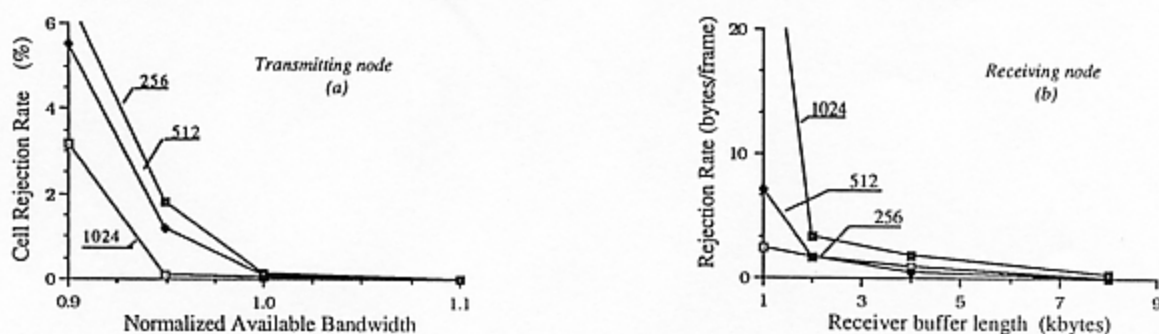


Fig. 4 The influence of the CS-PDU length (a) to the cell rejection rate at the transmitting node and (b) the buffer overflow at the receiving node.

V. CONCLUSIONS

A distributed simulator for analyzing various applications in the ATM environment was described in this paper. The simulator has been based on the time-driven approach and has been used to determine how the quality of a synchronous service is affected when it is transmitted through an ATM network under various traffic conditions. Experimental results on the analysis of constant and variable bit rate services in the ATM environment have been presented and the influence of various network parameters to the service quality has been examined.

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