ATM VIRTUAL CHANNELS SIMULATION FOR A PACKET NETWORK SIMULATOR

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***ABSTRACT**: The step by step introduction of ATM technology will in the next decade result in heterogeneous networks of Ethernet LANs interconnected through the ATM WAN segments. The protocol and flow control architectures of heterogeneous networks are analyzed. End to end flow control with traffic shaping at the edge of the ATM network is assumed. In this work, the simulation of heterogeneous networks using the event driven simulation systems is based on a simple ATM SVC model which consist of traffic shaper and a conventional communication channel. The experimental implementation of the model is described, and the preliminary simulation results are presented.*

***KEY WORDS**: event driven simulation, ATM, Internet, end to end flow control*

1. INTRODUCTION

The broadband integrated services networks will probably be completed through the realization of the global public ATM network, which is to be used for the Ethernet LAN interconnections [2]. In the heterogeneous networks of such structure the conditions for the data traffic growth are to be achieved, where the flow control algorithms take the main role in the process of integration.

Experimental ATM and heterogeneous networks have been built in recent years to investigate the flow control dynamics and predict their operational characteristics. However, simulation of such networks is an unavoidable step in the performance analysis, which provides the possibility to control the every aspect of the experiment. Financial effects of the simulation experiments are significant as well.

Among several classes of the ATM and packet networks simulators, the event driven simulator systems are common because of their suitability to incorporate the sophisticated flow control algorithms [1]. More than that, those algorithms are implemented using the same code as in the real implementations, contributing to the experimental results reliability and to the quality of the software solutions tested.

Depending on the experiment's topics, event driven network simulators are build to simulate packet or ATM networks. Merging the two is not a trivial issue, because resulting simulation structure is complex, dependent on a large number of simulation parameters, and results are interpreted with significant difficulties.

Our approach to the problem is to implement the ATM network channels as an extension to the packet network simulator, based on the simple model of data traffic shaping on the edge of the ATM part of the heterogeneous packet network.

2. ATM AND HETEROGENEOUS NETWORKS FLOW CONTROL ARCHITECTURE

The ATM (Asynchronous Transfer Mode) technology has been developed in last ten years to provide the media for various traffic integration (voice, video, multimedia, real-time, data). Its perspective is based on the compatibility with the SDH/SONET optical transmission system. However, ATM technology lacks the application layer and will depend on other specifications. It is likely that the Internet application layer, and consequently transport and network layer specifications, will be temporarily adopted due to the existing Internet customers population.

Step by step realization of the global public ATM network will postpone expected changes of the customers installations. Taking into account the existing base of Ethernet (and other LAN) installations, it can be foreseen that the next decade will be dominated by the Ethernet LANs interconnected through ATM networks, possibly evolving to the global public ATM network. Such networks we call "heterogeneous". The protocol architecture of the heterogeneous network, based on the Internet paradigm, is shown on the Figure 1.

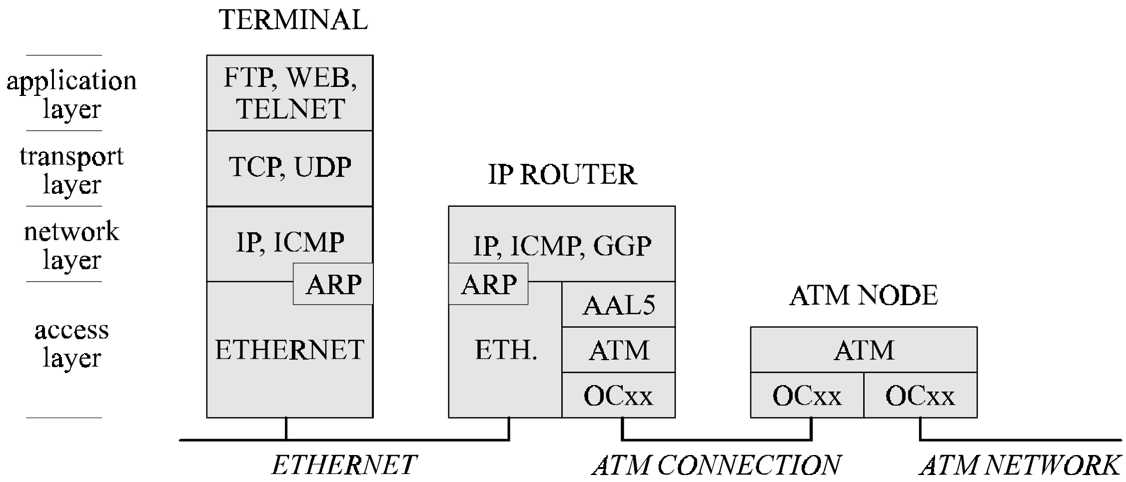


Figure 1 - The protocol architecture of the heterogeneous network

In such a network, using existing network (IP) and transport (TCP) protocols to maintain compatibility with the non-ATM parts of the global Internet, it is not possible to use the ATM flow control mechanisms to tune the sending rate of the terminal transmitter. The same difficulties occur in the simple case with a terminal using the Internet protocols directly connected to the ATM network. At the moment, only IP to ATM address transformation is solved, while the optimal ATM SVC (Switched Virtual Channel) parameter signalization is far from the final specification. However, using SVCs makes it possible for IP network to use the optimal routing of the underlying ATM network.

The ATM traffic management specification [5] provides four classes of service, the CBR (Constant Bit Rate), real and non real time VBR (Variable Bit Rate), ABR (Available Bit Rate) and UBR (Unspecified Bit Rate). CBR and VBR use forward flow control, appropriate for high capacity traffic flows when significant network delay prohibits the lost packet retransmission. Users negotiate the SVC parameters with the network, and later shape their traffic in accordance to these parameters. The network controls the user traffic conformance, marking excessive cells lower priority or dropping them altogether.

The ABR and UBR classes are provided for data communication users, interfacing through the AAL5 layer. ABR guarantees some QoS (Quality of Service) providing backward (feedback) flow control. The available rate is signaled to the AAL5 process, where traffic shaping takes place. Conformance tests are performed at the network side of the interface. UBR class of service provides no flow control. Low priority cells are buffered at the ATM nodes, while the excessive delays and possible cell losses can be used as the implicit congestion indication to the transport layer flow control algorithms.

The only possible flow control architecture at the current stage of protocol development is the end to end (transport layer) flow control, Figure 2. This approach is also the only appropriate one for the UBR class of service.

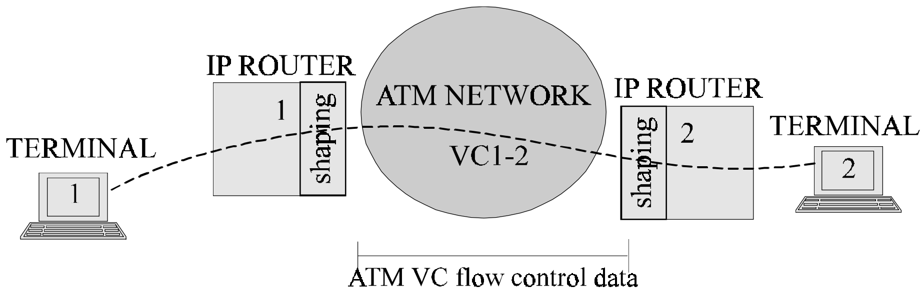


Figure 2 - The flow control architecture of the heterogeneous network

The interest of the user is to minimize cell losses, i.e. to shape his traffic to the SVC parameters negotiated. This function is performed at the IP-ATM interface (AAL), often far away from the terminal transmitter process. Other simulation studies have shown that the consequence of the shaping process is the cell buffering at the edge of the ATM network [4]. The main role of traffic shaping, to protect other ATM users from misbehaving ones, is achieved.

3. ATM VIRTUAL CHANNEL MODEL

The existence of the traffic shaping process at the edge of the ATM network makes it possible to simulate ATM SVCs in a simple way. Instead of simulating a whole, complex ATM network, one can simulate the dynamics of the traffic shaper at the edge of the ATM network. It can be assumed that the shaped traffic will be served with negotiated QoS, meaning with constant delay and low cell loss probability. Another advantage of this approach is that a complex model of ATM network with numerous simulation parameters (of the background traffic) is substituted with a simple model which needs managing only few simulation parameters. The ATM SVC is simulated using a traffic shaper and a conventional, constant delay duplex channel T_{pi}, C_i, Figure 3.

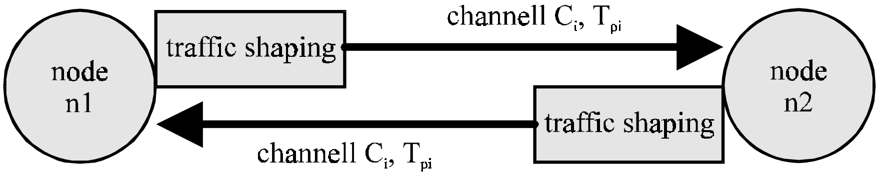


Figure 3 - The ATM SVC simulation model

The ATM traffic management specification defines the conformance testing procedure based on the leaky bucket model. To satisfy conformance tests, users can shape their traffic using the same leaky bucket algorithm. This approach is appropriate for the event driven simulation systems.

The leaky bucket shaper for the packet network consists of a cell buffer, where packets are segmented to cells, and a PCR (Peak Cell Rate) sender synchronized with the credit availability. Credits are generated with the appropriate process at SCR (Sustained Cell Rate) and accumulated at the credits buffer. The credit buffer depth is tuned to the MBS (Maximum Burst Size) value.

The CBR class of service emulates switched channel with constant cell rate and nearly constant delay appropriate for voice communications. The CBR channel simulation is achieved setting SCR=PCR and MBS=1, i.e. peak and sustained cell rates are the same and maximum burst size is one cell (no cell bursts), Figure 4.

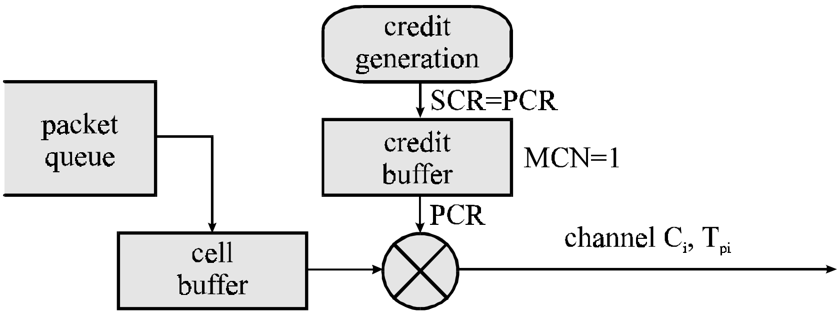


Figure 4 - The CBR simulation model

The VBR class of service is devoted to users which send their cells at variable rate (compressed voice and video, multimedia), which makes it possible to statistically multiplex their data flows. The network utilization is higher than with CBR service, and consequently more economical to the user. The VBR channel simulation is characterized with separate PCR and SCR settings together with the MBS greater than 1, meaning that cell bursts are allowable, Figure 5.

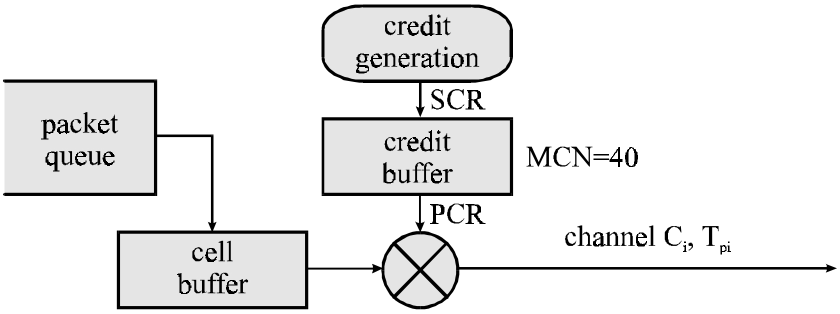


Figure 5 - The VBR simulation model

The residual network capacity is offered to data communications users after the CAC (Customer Admission Control) process has made necessary resource reservations for CBR and VBR channels. The ABR class of service is used for data communications with closed flow control feedback loop, to inform users about the average residual capacity available. The traffic management specification specifies explicit congestion notification mechanism and explicit rate signalization mechanism. Our model is based on the congestion indication mechanism. The sending process sends special forward RM (Resource Management) cells every 32nd data cell or at least every 100 ms. Forward RM cells collect the congestion information in the CI (Congestion Indication) and NI (No Increase) bits. The RM cell is sent back at the destination (backward cell). After reception of the backward RM cell, sender process either decreases its ACR (Actual Cell Rate, CI=1), increases ACR (CI=0, NI=0), or simply keeps its ACR constant (CI=0, NI=1). The ACR increase and decrease rates are set at the channel establishment phase (default to 1/16).

The actual ABR channel simulation is achieved performing the modulation of the credit generator with a random process, bounded to (0.1 - 1)*PCR. The random process changes its state every 100 ms. The effect of random process is synchronized to the credit generator with RM cell mechanism according to the traffic management specification, Figure 6.

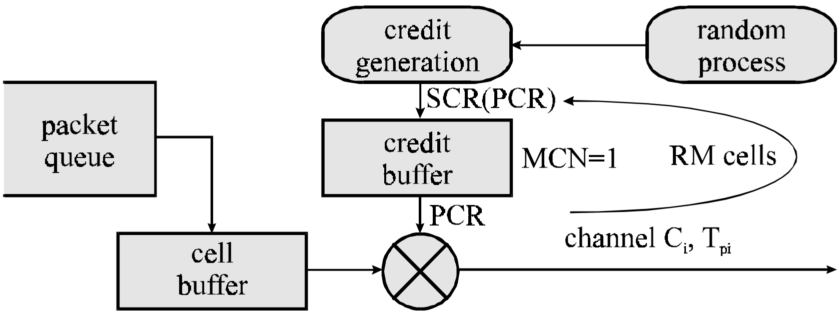


Figure 6 - The ABR simulation model

The UBR channels are used for data communications without any QoS guarantees. No flow control nor conformance testing are provided. The cells are set to low priority level and dropped if excess node buffer capacity is occupied. The cell buffering has the consequence of prolonged cell delays. In our UBR simulation model the credit generation is modulated with random process on every cell to induce cell delays. The cell loss process with loss probability proportional to the cell delay is included, Figure 7.

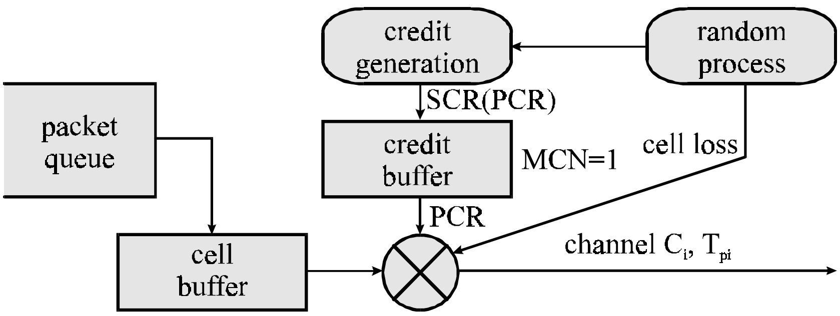


Figure 7 - The UBR simulation model

4. EXPERIMENTAL IMPLEMENTATION

The ATM channel simulation models are experimentally embedded in the Lawrence Berkeley Laboratory Network Simulator NS-1.1, an event driven packet network simulator designed for the research of the end to end flow control algorithms [6]. The object structure of the simulator is presented on the Figure 8.

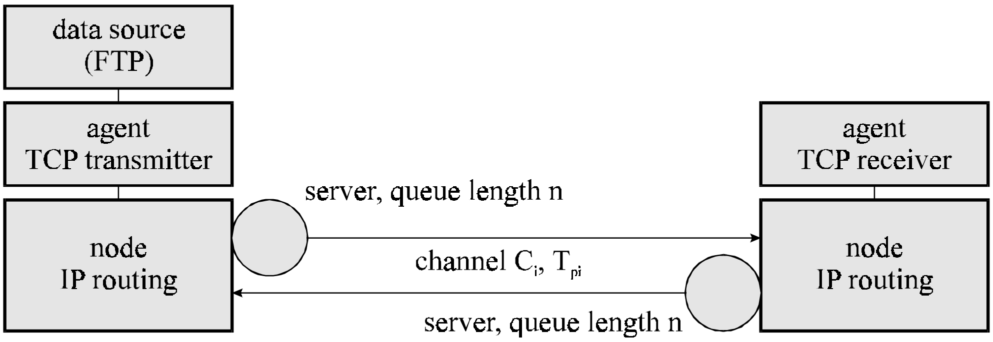


Figure 8 - The LBL NS-1.1 simulator object structure

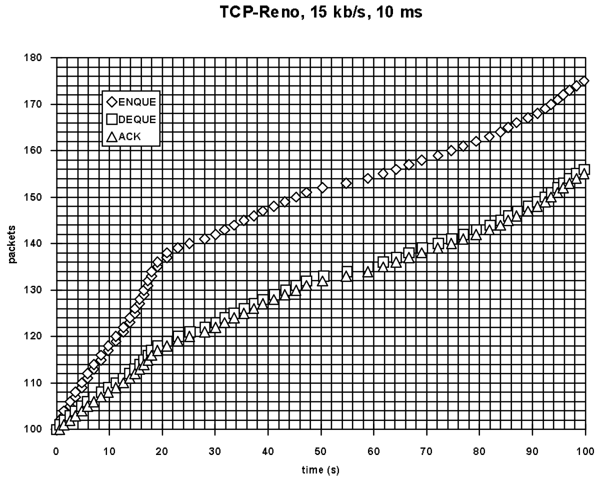
Central process of the simulator is the event scheduler working in the simulation time. The simulation topologies are built from the node objects, connected through the link objects (communication channels). Link objects perform server algorithms (FIFO, RED, class based queuing). TCP agents, which include flow control algorithms, reside above the appropriate nodes, and logical connections between transmitters and receivers are established. IP routing is accomplished automatically. Several data sources are available to simulate user behavior. Receiver agents just drop received "data".

ATM channels are embedded in the link object of the simulator, spreading its functionality with the four classes of ATM service. The simplified formal specification of the simulation algorithm using the pseudo language is shown in Figure 9.

```
object link
function handle (event from scheduler)
    if (event=send_interrupt)
        send(), exit;
    if (event=credit_interrupt)
        new_credit(), exit;
    if (event=random_credit_interrupt)
        random_credit_update(), exit;
    if (event=RM_minimum_imterrupt)
        send_RM_cell(), exit;
    // default (event=RM_receive_interrupt)
    update_ABR_rate(), exit;
function send()
    if (atm=NO)
        conventional_channel_send(), exit;
    if (credits=0)
        exit;
    if (cell_count=0)
        if (new_packet=0)
            exit;
        cell_count (new_packet);
    if (atm=UBR)
        random_time=f (random_function, PCR);
    credits--;
    schedule send_interrupt (PCR)
    if (atm=UBR)
        cell_lost(random_function, PCR);
    if (atm=ABR)
        RM_cell_count--;
        if (RM_cell_count=0)
            send_RM_cell();
    if (--cell_count=0) // last cell of packet
        if (atm=UBR & cell_lost=1)
            drop_packet();
        else
            ATM_packet_send();
function new_credit()
    credits++(max_credit_number);
    if (atm=ABR or atm=UBR)
        schedule credit_interrupt (random_credit);
    else (atm=CBR or ATM=VBR)
        schedule credit_interrupt (SCR);
function random_credit_update()
    random_credit=f (random_function, PCR);
    schedule random_credit_ interrupt (100 ms);
function send_RM_cell()
    RM_cell_count=32;
    schedule RM_receive_interrupt (2*delay);
    cancel RM_minimum_interrupt;
    schedule RM_minimum_interrupt (100 ms);
```

Figure 9 - The formal specification of the ATM channel simulation

The experimental results of the TCP-Reno flow control algorithm behavior on a simple one-channel network are presented on the Figure 10.



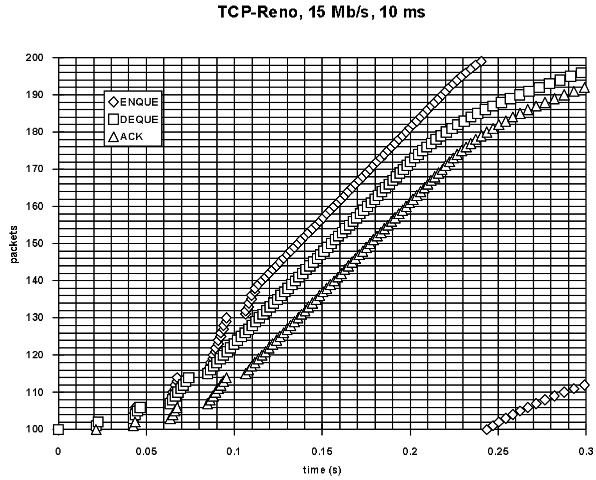
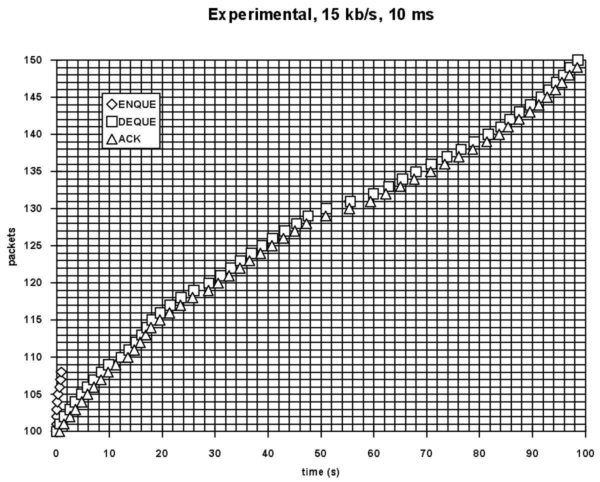


Figure 10 - The TCP-Reno behavior over the ABR channel

The behavior of an experimental flow control algorithm [3] is presented on the Figure 11.



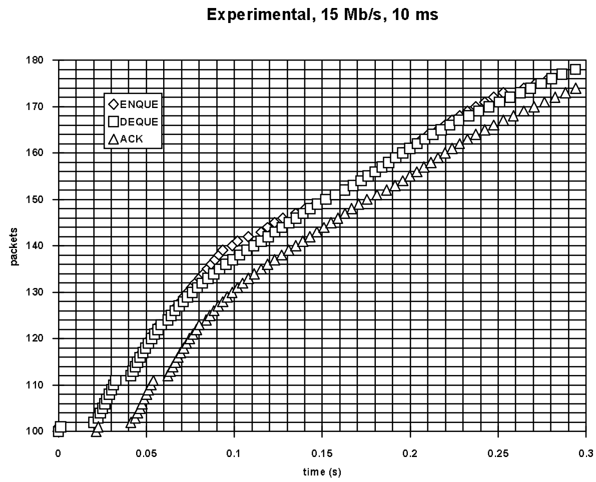


Figure 11 - The experimental flow control algorithm behavior over the ABR channel

It is evident that the experimental flow control algorithm estimates the available channel capacity.

5. CONCLUSIONS

The packet network simulator is extended with ATM SVCs based on the simple model consisting of the traffic shaper and the conventional channel. All relevant flow control algorithms of the ABR class of service are simulated. The experimental results show that the simulation model used is appropriate for at least unrefined simulations. The model makes it possible to compare flow control algorithms behavior, such as TCP-Reno and experimental ones used to obtain simulation results presented.

REFERENCES:
[1] Frost, V.S.: "MODELING AND SIMULATION IN NETWORK MANAGEMENT", McGraw-Hill, 1993.
[2] Ozegovic, J.: "FLOW CONTROL ARCHITECTURE IN HETEROGENEOUS PACKET NETWORKS", Proceedings SOFTCOM'97, Split 1997.
[3] Ozegovic, J.: "OPTIMAL FLOW CONTROL ALGORITHMS IN HETEROGENEOUS NETWORKS", Ph.D. Thesis, University of Split, Split 1997.
[4] Patel, B. V, Bisdikian C. C.: "End-Station Performance under Leaky Bucket Traffic Shaping", IEEE Network Magazine vol. 10, no. 5, pp. 40-47, Sep. 1996.
[5] xxx "ATM TRAFFIC MANAGEMENT SPECIFICATION VERSION 4.0", ATM-Forum 1996.
[6] xxx "NS MANUAL PAGES", LBL Berkeley 1993.