WIDE AREA ATM NETWORK EXPERIMENTS USING EMULATED TRAFFIC SOURCES

Beng-Ong Lee

Master Thesis Defense

Department of Electrical Engineering and Computer Science
The University of Kansas

Committee Member :
Professor Victor Frost (Chair)
Professor Doug Niehaus
Professor Joseph Evans

January 16, 1998

Organization

- Motivation
- Introduction
- Emulated Traffic Sources
- NetSpec Implementation
- Validation Experiments
- WAN Experiments
  - Test Scenarios
  - Traffic Parameters
  - Performance Metrics
  - Traffic Shaping
    - TCP and UPD (Packet Pacing)
    - ATM (Cell Pacing)

Organization (Contd.)

- Experiment Results
  - No Cell Pacing
  - Cell Pacing on Target Flows
  - Cell Pacing on Background Traffic
- Comparison of Network Performance Before and After Network Upgrades
- Lesson Learned
  - ATM Network Performance
  - Doing WAN Experiments
- Conclusions
- Future Work

Motivation

- Many point-to-point maximum throughput measurements have been done.
- Multi-cross user traffic scenarios are more realistic to evaluate network performance from user prospective.

  WWW, FTP, Video, telnet, and etc.
- Evaluate Packet Level Performance

  Applications see packet performance, not ATM performance.

  One 53-byte ATM cell loss may cause the whole 9180-byte TCP packet useless.

  Measure packet level performance : Packet Delay Jitters, Packet Loss, and etc.

Introduction

- Future broadband WAN networks will carry the traffic from diverse applications, such as FTP, WWW, Video, Audio, Graphic, telnet.
- ATM is a perfect candidate to provide supports for these bandwidth-hungry multimedia applications.
- Several national wide large scale ATM testbeds, such as MAGIC, AAI, ATDnet, have been deployed to experimentally evaluate the ATM performance.
- KU is one of the AAI paticipants.
- All the experiments in this study were conducted on the AAI network.

Emulated Traffic Sources

- All the user traffic models were collected from various notes and papers.
- FTP (File Transfer Protocol)

  FTP Session Interarrival Time

  FTP Number of Item

  FTP Item Size
- WWW (World Wide Web)

  WWW Request Interarrival Time

  WWW Item Size
- MPEG (Motion Picture Experts Group)

  Video MPEG Frame Size
- Videoconference

  Video Teleconference Frame Size

- Telnet

  Telnet Session Interarrival Time

  Telnet Session Duration

  Telnet Packet Interarrival Time

  Telnet Packet Size

NetSpec Implementation

- The emulated traffic sources have been successfully implemented in NetSpec 3.0.
- Many generic random distribution are also included.

  Uniform

  Exponential

  Normal

  LogNormal

  Geometric

  Pareto

  Gamma
- By using any combination of random distributions, many differenct packet-level traffic types can be generated for experiments.
- Detailed Info can be found at
  http://www.ittc.ukans.edu/Projects/AAI/products/netspec/

Validation of Traffic Models

- Validation Experiments

  12-hour FTP Traffic

  12-hour WWW Traffic

  30-minute MPEG Stream

  30-minute Videoconference Stream

- The emulated traffic was captured by KU's ATM traffic data collector.

12-hour FTP Traffic

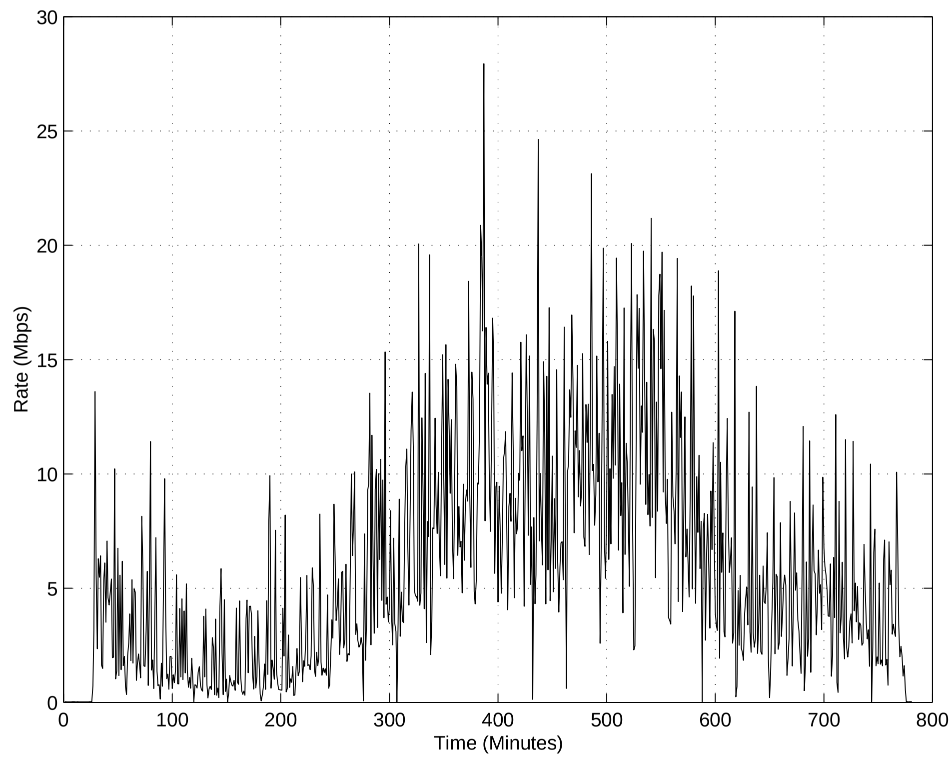


Figure 1: Emulated Daily FTP Traffic

12-hour WWW Traffic

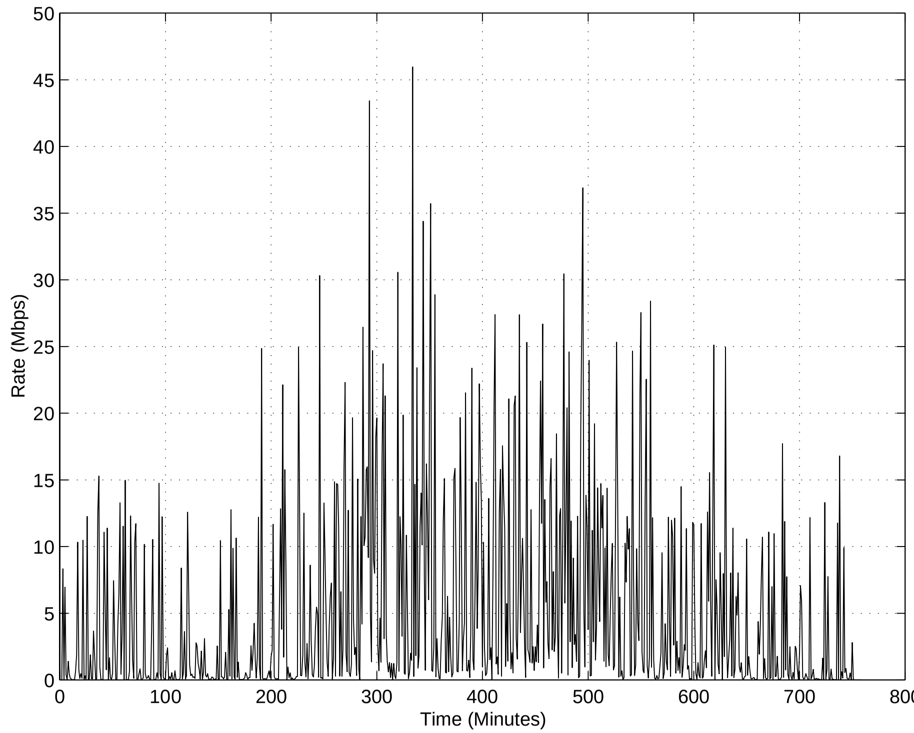


Figure 2: Emulated Daily WWW Traffic

30-minute MPEG Stream

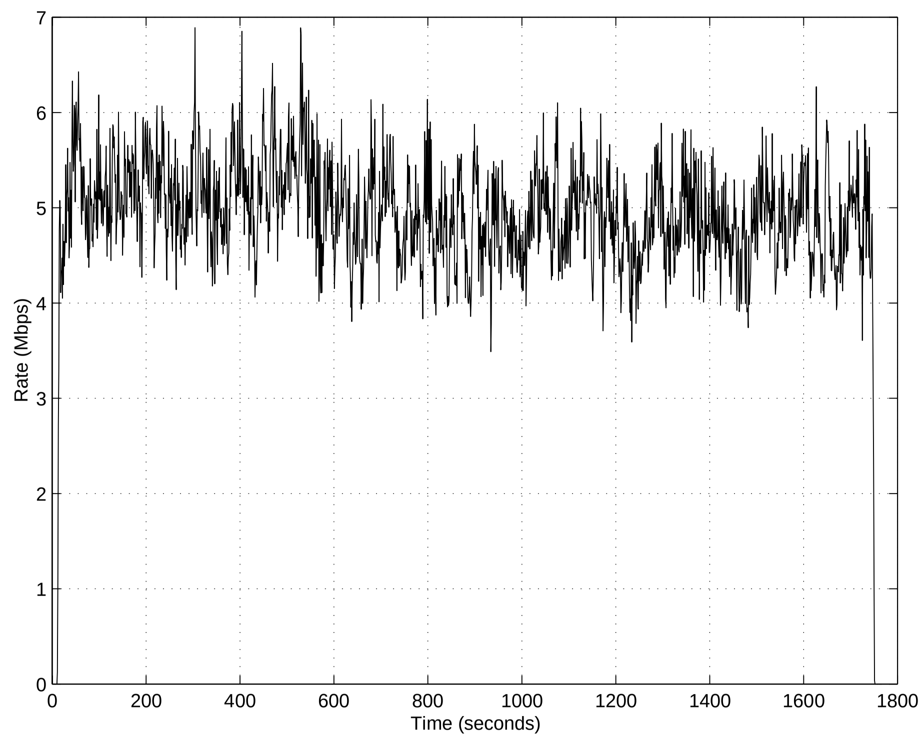


Figure 3: 30-minute MPEG Stream

30-minute Videoconference Stream

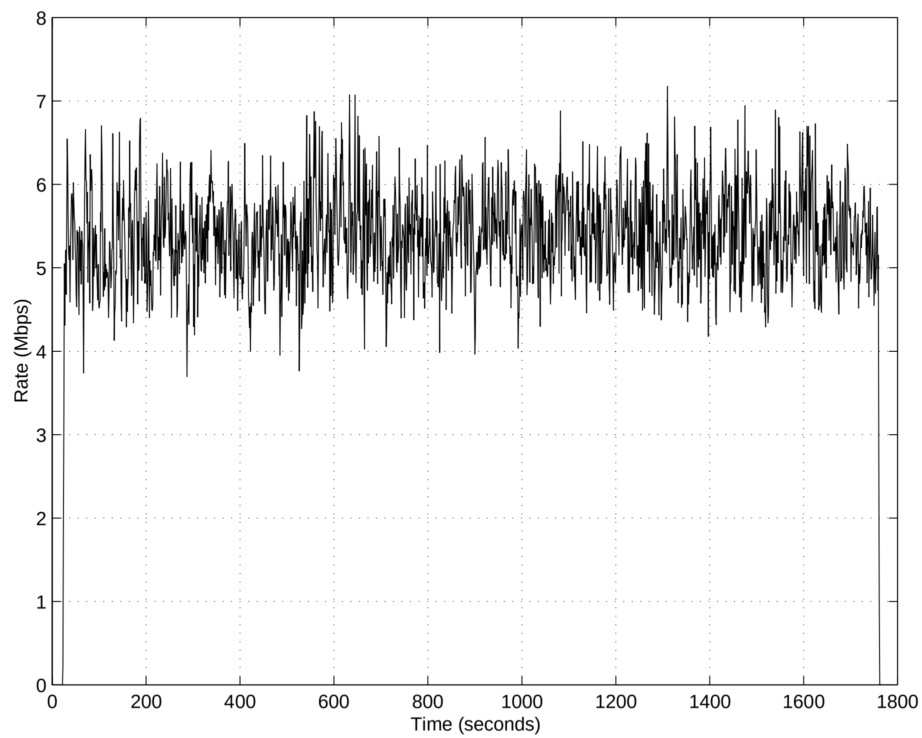
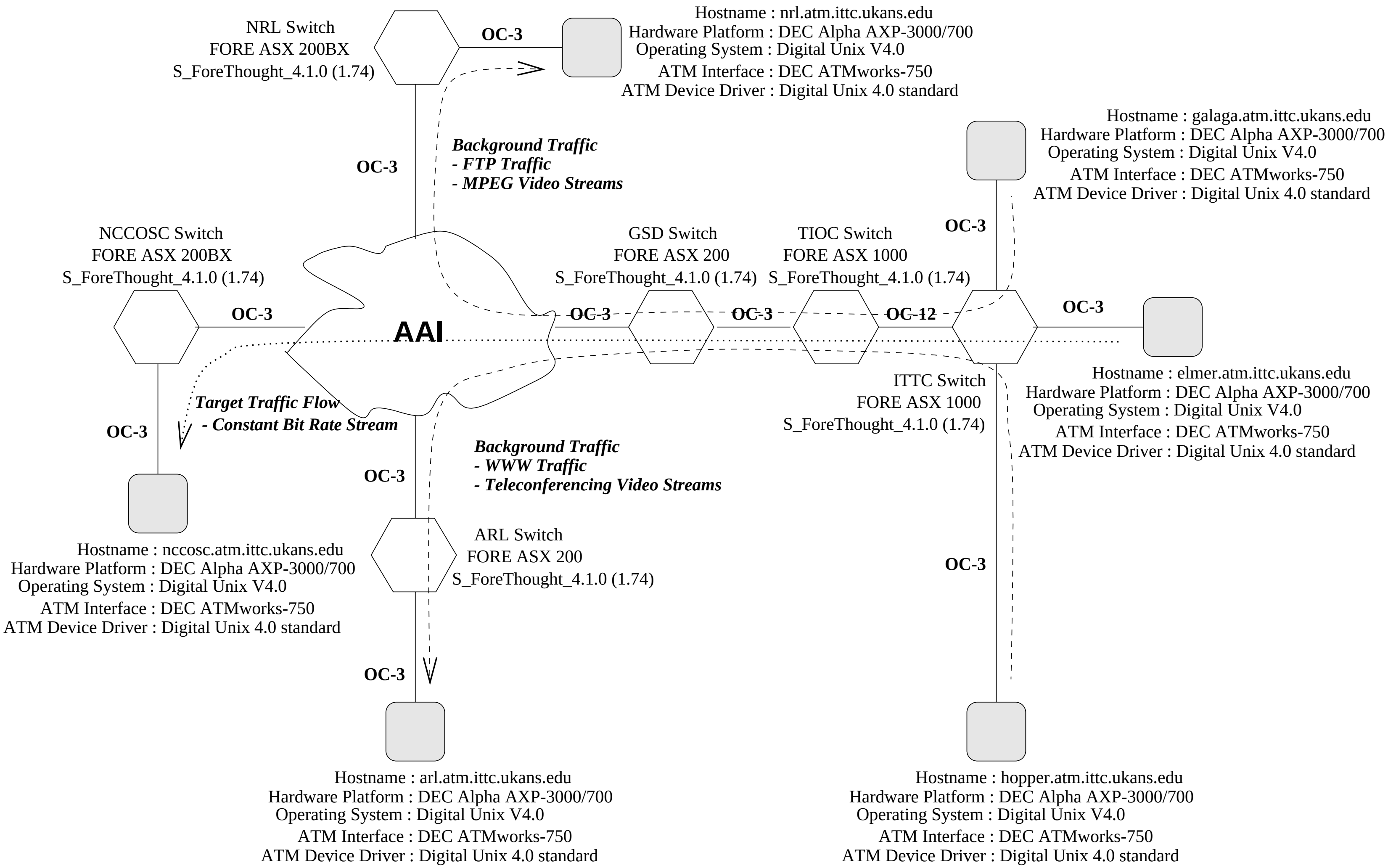


Figure 4: 30-minute Videoconference Stream

WAN Experiments

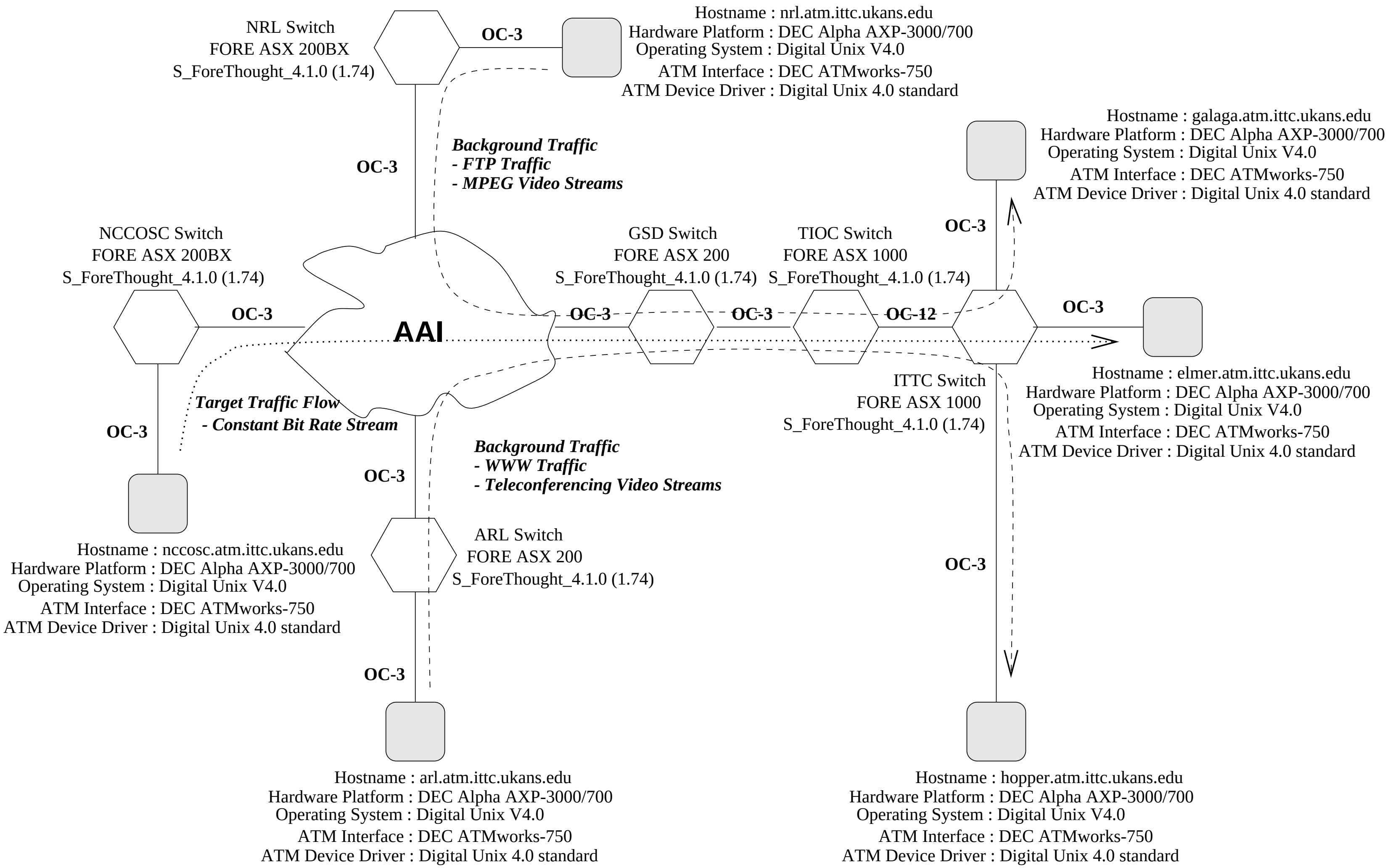
- Test Scenarios
- Traffic Parameters
- Performance Metrics
- Traffic Shaping

Test Scenario #1


NRL Switch
FORE ASX 200BX
S_ForeThought_4.1.0 (1.74)
OC-3
Hostname : nrl.atm.ittc.ukans.edu
Hardware Platform : DEC Alpha AXP-3000/700
Operating System : Digital Unix V4.0
ATM Interface : DEC ATMworks-750
ATM Device Driver : Digital Unix 4.0 standard
Hostname : galaga.atm.ittc.ukans.edu
Hardware Platform : DEC Alpha AXP-3000/700
Operating System : Digital Unix V4.0
ATM Interface : DEC ATMworks-750
ATM Device Driver : Digital Unix 4.0 standard
Background Traffic
- FTP Traffic
- MPEG Video Streams
OC-3
NCCOSC Switch
FORE ASX 200BX
S_ForeThought_4.1.0 (1.74)
GSD Switch
FORE ASX 200
S_ForeThought_4.1.0 (1.74)
TIOC Switch
FORE ASX 1000
S_ForeThought_4.1.0 (1.74)
OC-3
OC-3
AAI
OC-3
OC-3
OC-12
OC-3
Hostname : elmer.atm.ittc.ukans.edu
Hardware Platform : DEC Alpha AXP-3000/700
Operating System : Digital Unix V4.0
ATM Interface : DEC ATMworks-750
ATM Device Driver : Digital Unix 4.0 standard
ITTC Switch
FORE ASX 1000
S_ForeThought_4.1.0 (1.74)
Target Traffic Flow
- Constant Bit Rate Stream
OC-3
Background Traffic
- WWW Traffic
- Teleconferencing Video Streams
OC-3
ARL Switch
FORE ASX 200
S_ForeThought_4.1.0 (1.74)
Hostname : nccosc.atm.ittc.ukans.edu
Hardware Platform : DEC Alpha AXP-3000/700
Operating System : Digital Unix V4.0
ATM Interface : DEC ATMworks-750
ATM Device Driver : Digital Unix 4.0 standard
OC-3
OC-3
Hostname : arl.atm.ittc.ukans.edu
Hardware Platform : DEC Alpha AXP-3000/700
Operating System : Digital Unix V4.0
ATM Interface : DEC ATMworks-750
ATM Device Driver : Digital Unix 4.0 standard
Hostname : hopper.atm.ittc.ukans.edu
Hardware Platform : DEC Alpha AXP-3000/700
Operating System : Digital Unix V4.0
ATM Interface : DEC ATMworks-750
ATM Device Driver : Digital Unix 4.0 standard

Test Scenario #2

Wide Area ATM Network Experiments using Emulated Traffic Sources



Traffic Parameters

Target Flow	Blocksize (bytes)	Period (ms)	Rate (Mbps)
	9140	14	5.22
	18280	14	10.45
	27420	14	15.67
	36560	14	20.89
	45700	14	26.11
	54840	14	31.34

Background Traffic	Traffic Types	Mean Rate (Mbps)	Total (Mbps)
25Mbps	WWW	10	
	FTP	5	
	MPEG	5	
	Video Conference	5	25
60Mbps	WWW	30	
	FTP	10	
	MPEG	10	
	Video Conference	10	60

Performance Metrics

- Delay Jitter of Packets

$$J(n) = [T_R(n) - T_R(n-1)] - [T_T(n) - T_T(n-1)] \quad (1)$$

  J(n) is the delay jitter of n^{th} packet.

  T_R(n) is the received timestamp of n^{th} packet.

  T_T(n) is the transmitted timestamp of n^{th} packet.

  Standard deviation is used to represent the variation of delay jitters.

- Percentage of Packet Loss.

$$PacketLosses(\%) = \frac{NumberofMissingPackets}{NumberofTransmittedPackets} * 100\% \quad (2)$$

Traffic Shaping

A total of six sets of experiments are defined to study the effect of TCP, UDP, and Cell Pacing :

- No Cell Level Pacing

  TCP-level CBR Target Flows + TCP-level Background Traffic
  UDP-level CBR Target Flows + TCP-level Background Traffic

- Cell Level Paced Target Flows

  Cell Level Paced TCP CBR Target Flows + TCP-level Background Traffic
  Cell Level Paced UDP CBR Target Flows + TCP-level Background Traffic

- Cell Level Paced Background Traffic

  TCP-level CBR Target Flows + Cell Level Paced TCP Background Traffic
  UDP-level CBR Target Flows + Cell Level Paced TCP Background Traffic

Delay Jitter of No Cell Pacing

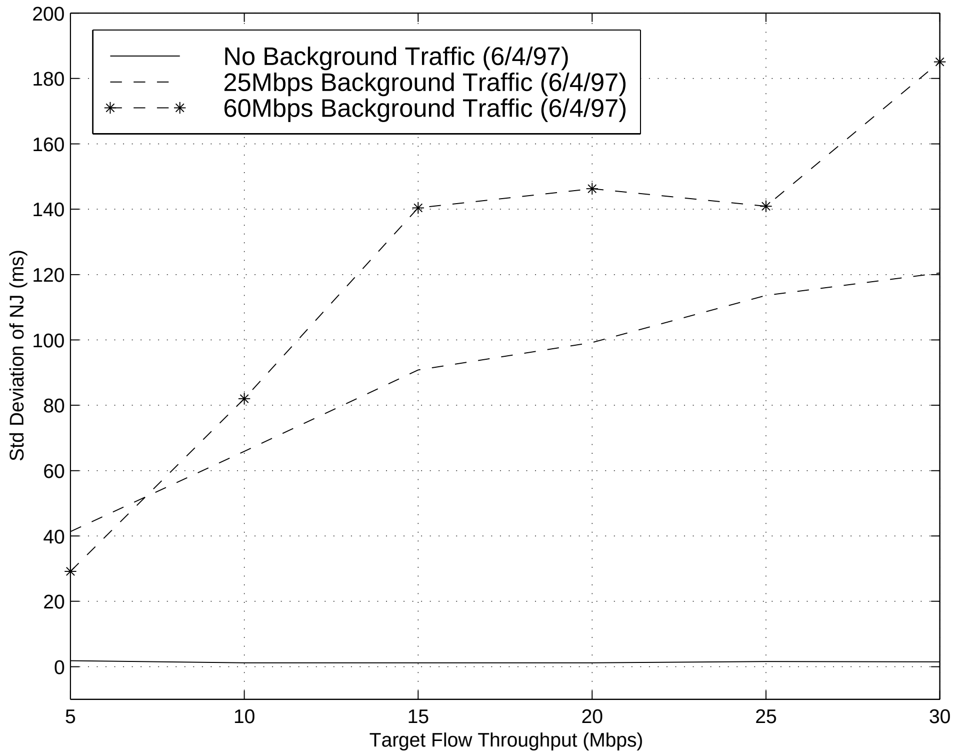


Figure 5: Standard Deviation of Network Jitter of TCP Target Flows

Network Performance After Upgrades

- Several network changes occurred after 10/1/97.
- The network changes are listed as follows :

  Edge switches are added.

  AAI network connections were changed from using VBR to UBR service.

  Early Packet Discard (EPD) was enabled where possible
- Two tests were selected to rerun.

  UDP Target Flows + TCP Background Traffic

  UDP Target Flows + Cell Paced TCP Background Traffic
- Experiments were conducted by Mike Linhart.

Delay Jitter of No Cell Pacing

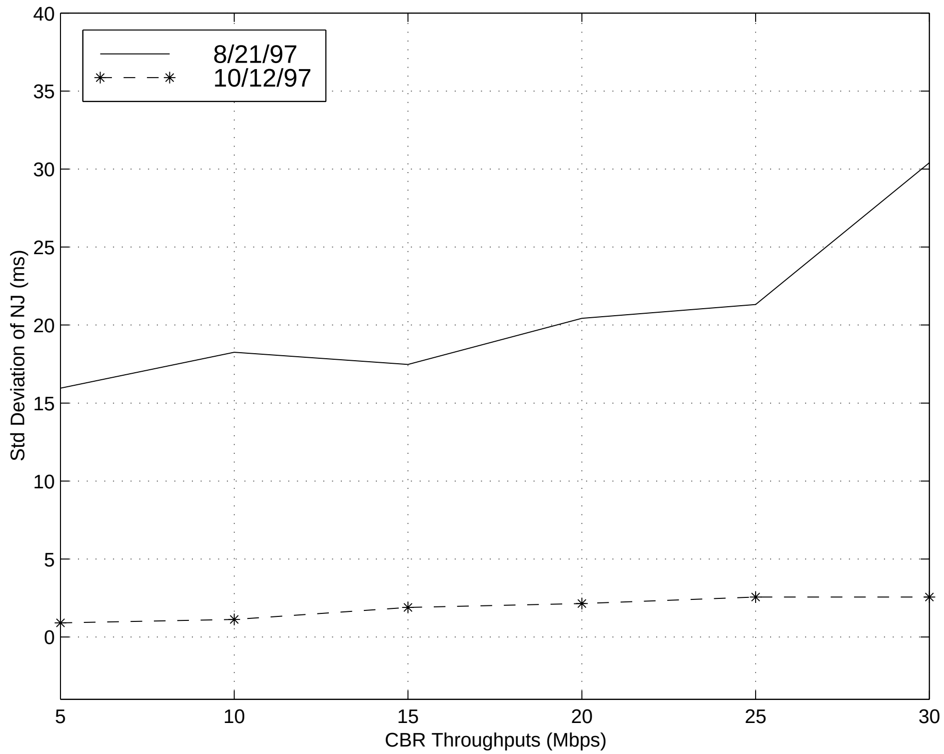


Figure 6: Standard Deviation of Network Jitter of UDP Target Flows

Packet Loss of No Cell Pacing

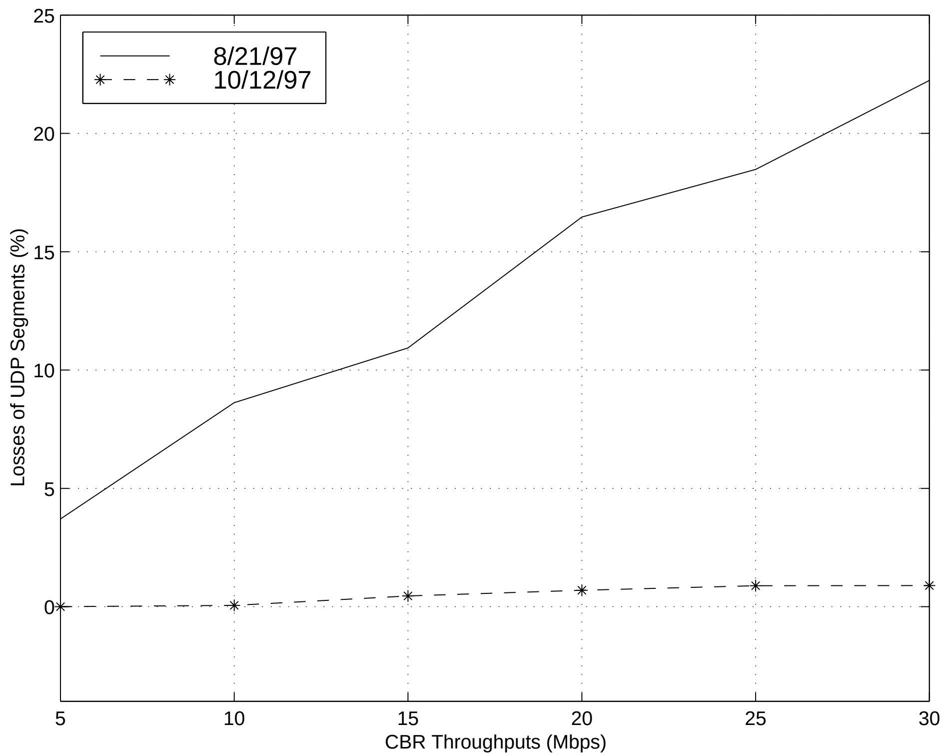


Figure 7: Percentage of Packet Loss of UDP Target Flows

Delay Jitter of Cell Pacing on Background Traffic

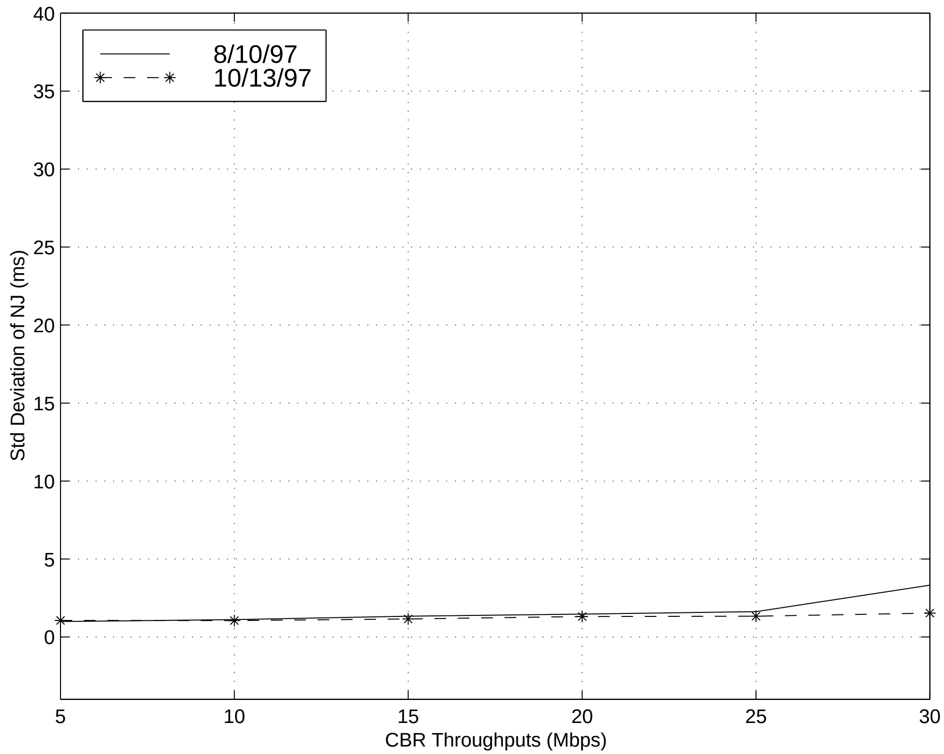


Figure 8: Standard Deviation of Packet Delay Jitter of UDP Target Flows with Cell Paced 60Mbps Background Traffic

Packet Loss of Cell Pacing on Background Traffic

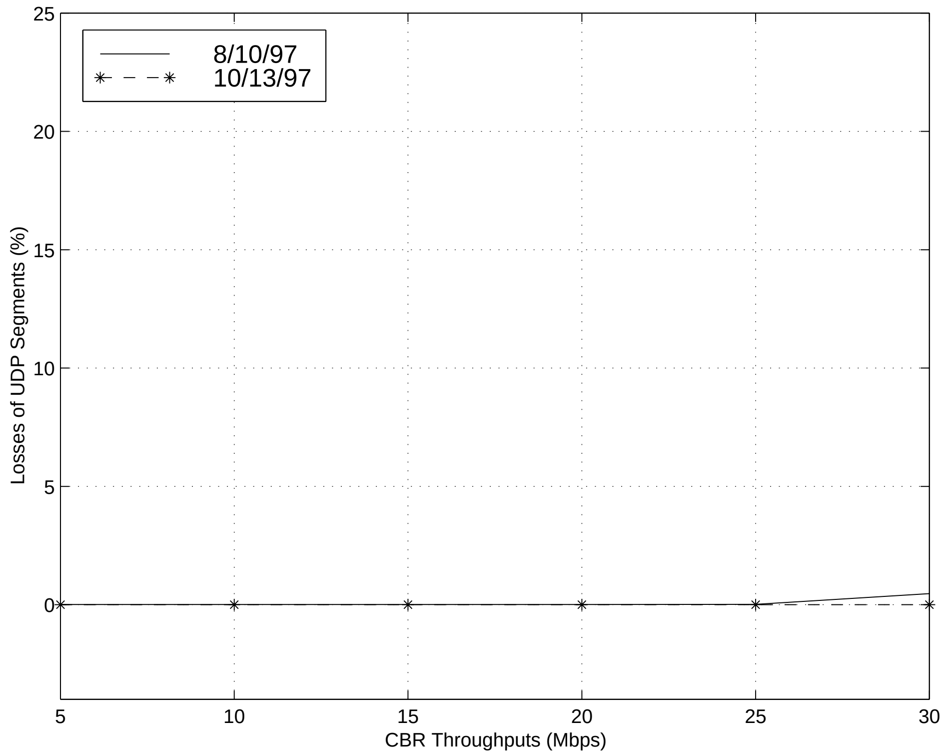


Figure 9: Percentage of Packet Loss of UDP Target Flows with Cell Paced 60Mbps Background Traffic

Lessons Learned

- ATM Network Performance

  Poor TCP and UDP protocol performance in an *uncontrolled* and *congested* environment.

  ATM traffic shaping significantly improves network performance.

  Asymmetrical network performance was observed.

  Early Packet Discard (EPD) technique significantly improves network performance of the target flows.

- Doing WAN Experiments (contd.)

Lessons Learned (contd.)

- Doing WAN Experiments

  Network Connectivity

  Host State

  Long Duration of Experiments

  A total of 772 successful experiments have been conducted from May 1997 to August 1997. 150 hours of experiment time are logged.

  Large Amount of Collected Data

  1Gbytes of uncompressed data have been collected and required 24 hours of processing time.

Conclusion

- Empirically-derived traffic models were collected and implemented in NetSpec 3.0.
- Congestion WAN experiments using these emulated traffic sources were successfully conducted.
- Packet level performance in terms of delay jitters, and packet loss, was evaluated.
- TCP alone does not provide efficient congestion control in this congested environment.
- ATM traffic shaping, cell pacing, significantly reduces network tention and improves network performance.
- EPD technique provides efficient congestion control for packet traffic.

Future Work

- More sophisticated traffic models to implement. For exmaple, WWW.

  More and more multimedia traffic appears on WANs.

  RealPlayer, QuickTime, ShockWave, IP Phone.
- In the experiments, WWW and FTP traffic were transmitted in a single TCP connection. Realistic scenarios that include multiple TCP connections transmitting WWW and FTP traffic may be considered.
- Analysis mainly focuses on the target flows. Further investigation on performance of background traffic may be done.