ATM Networking Research at OSU

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Overview

- Networking Faculty at OSU
- Networking Trends
- Our Research
- Our Research Facilities
- Courses

Networking Faculty

- Telecommunications Networks
  - Raj Jain and Gojko Babic
- Wireless Networks
  - Steve Lai and Raj Jain
- Multimedia Networking
  - Wu-Chi Feng and Raj Jain
- Protocol Engineering - Mike Liu
- Other Collaborators: D.K. Panda, Anish Arora, Mukesh Singhal, Jennifer Hou, and Stan Ahalt

ATM Research Group

- Faculty: Professor Raj Jain
- Instructors/Staff: Dr. Gojko Babic, Dr. Arjan Durresi
- PhD Students:
  - Rohit Goyal
  - Mukul Goyal
  - Sonia Fahmy
  - Sohail Munir
  - Bobby Vandalore
  - Chunlei Liu
- MS Students:
  - Murali Gandluru
  - Arvind Prabhudev
  - Wei Sun
  - Amit Anand
  - Padmini Misra

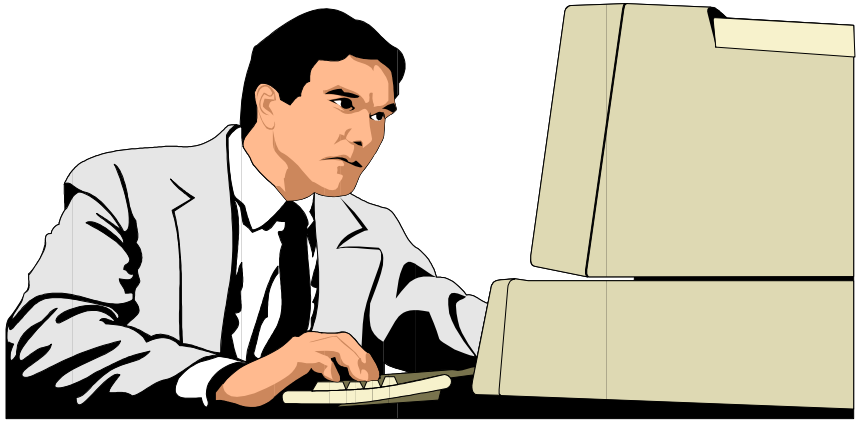
Trends

- Communication is more critical than computing
  - Greeting cards contain more computing power than all computers before 1950.
  - Genesis's game has more processing than 1976 Cray supercomputer.
- Internet: 0.3 M hosts in Jan 91 to 9.5 M by Jan 96
  $\Rightarrow$ More than 5 billion (world population) in 2003

Stone Age to Networking Age

- Microwave ovens, stereo, VCRs, had some effect. But, Stone, iron, …, automotive, electricity, telephone, jet plane,…, networks caused a fundamental change in our life style
- In 1994, 9% of households with PC had Internet link. By 1997, 26%. Soon 98% … like TV and telephone.
- URL is more important than a company's phone number. (54 URLs in first 20 pages of March'97 Good Housekeeping.)
- Better communication ⇒ Distance not important

Social Impact of Networking

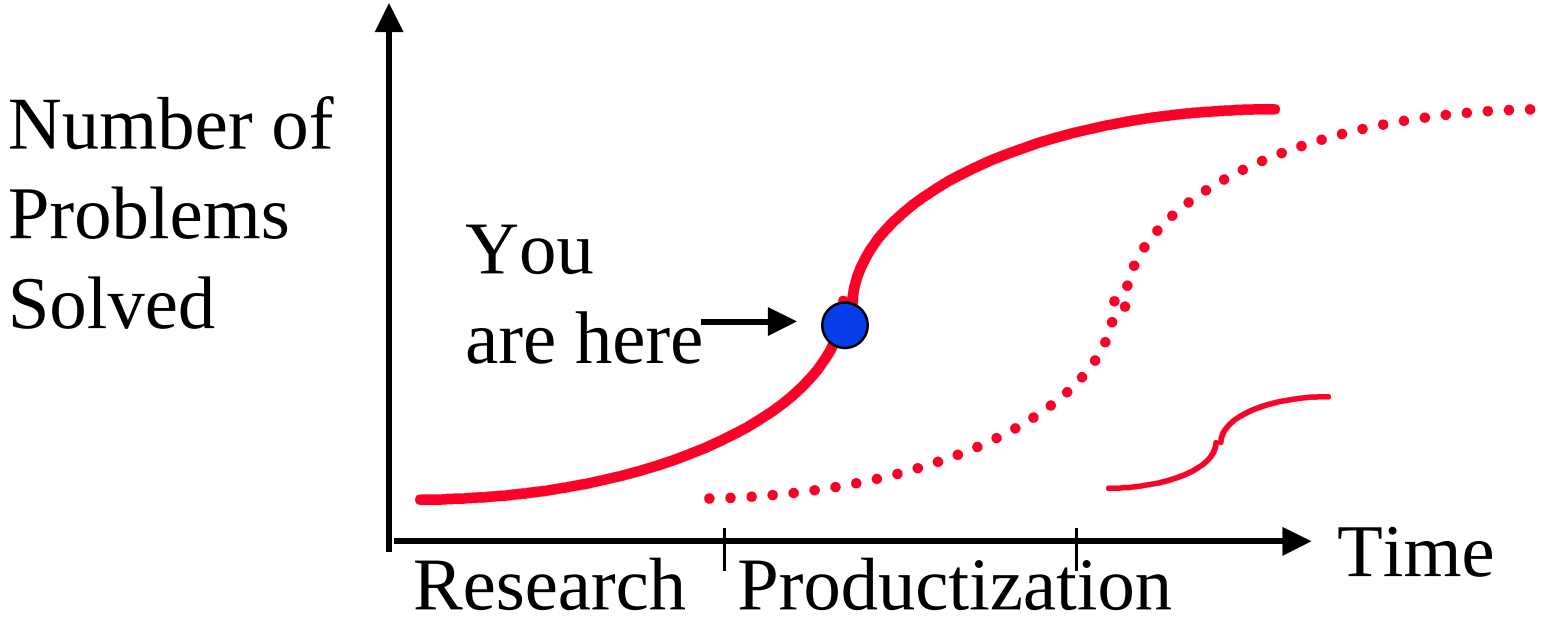


- No need to get out for
  - Office
  - Shopping
  - Entertainment
  - Education
- Virtual Schools
- Virtual Cash
- Virtual Workplace

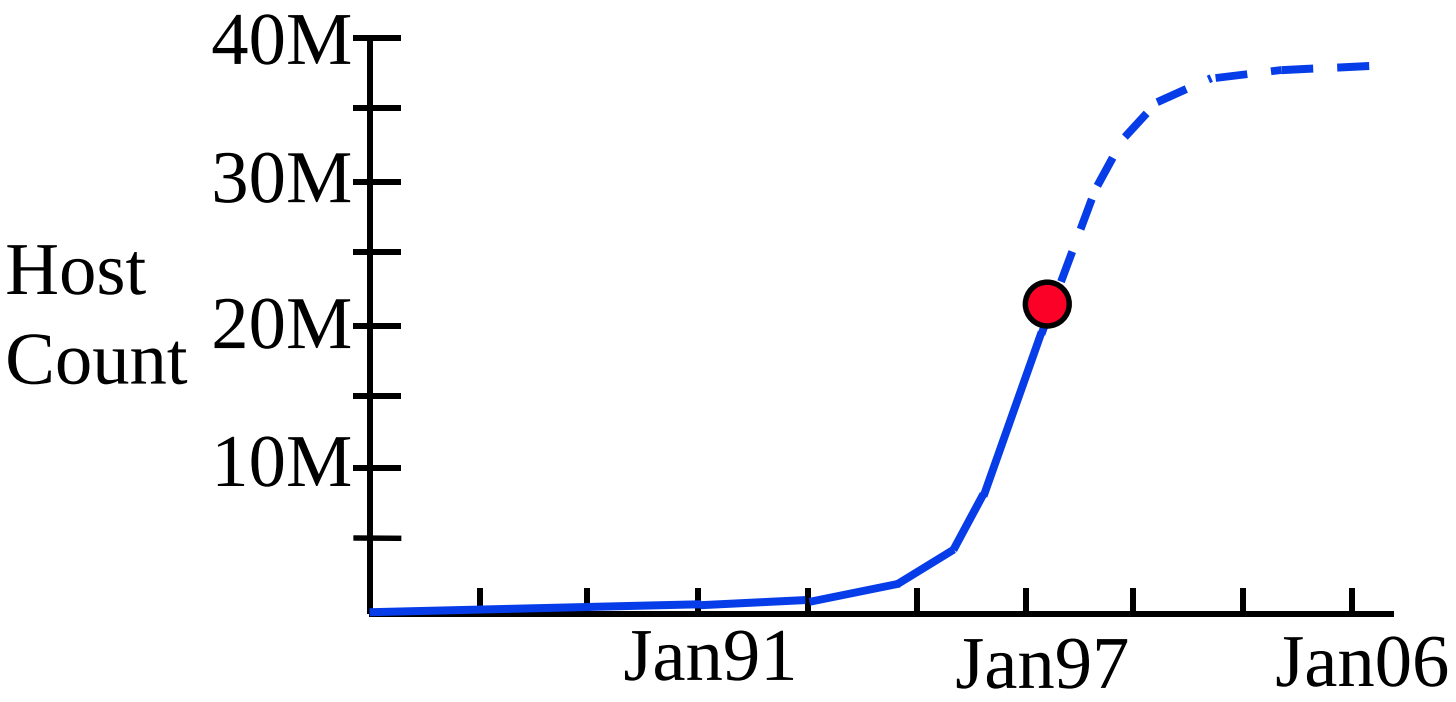
(55 Million US workers will work remotely by 2000)

Cave Persons of 2050

Life Cycles of Technologies



Internet Technology

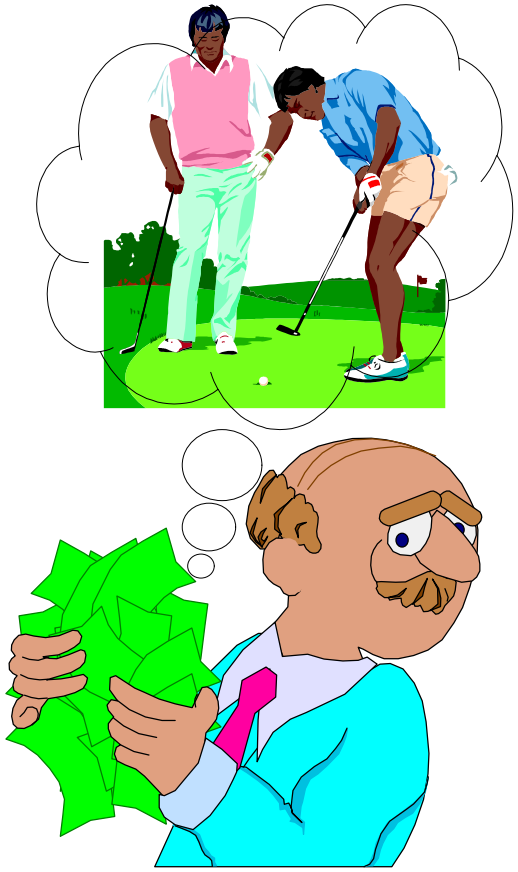


- **New Challenges**: Exponential growth in number of users. Exponential growth in bandwidth per user. Traffic management, Security, Usability, ...

Garden Path to I-Way

- Plain Old Telephone System (POTS)
  = 64 kbps = 3 ft garden path
- ISDN = 128 kbps = 6 ft sidewalk
- T1 Links to Businesses = 1.544 Mbps
  = 72 ft = 4 Lane roadway
- Cable Modem Service to Homes:
  = 10 Mbps = 470 ft = 26 Lane Driveway
- OC3 = 155 Mbps = 1 Mile wide superhighway
- OC48 = 2.4 Gbps = 16 Mile wide superhighway

High Technology ≠ More vacation



Impact on R&D

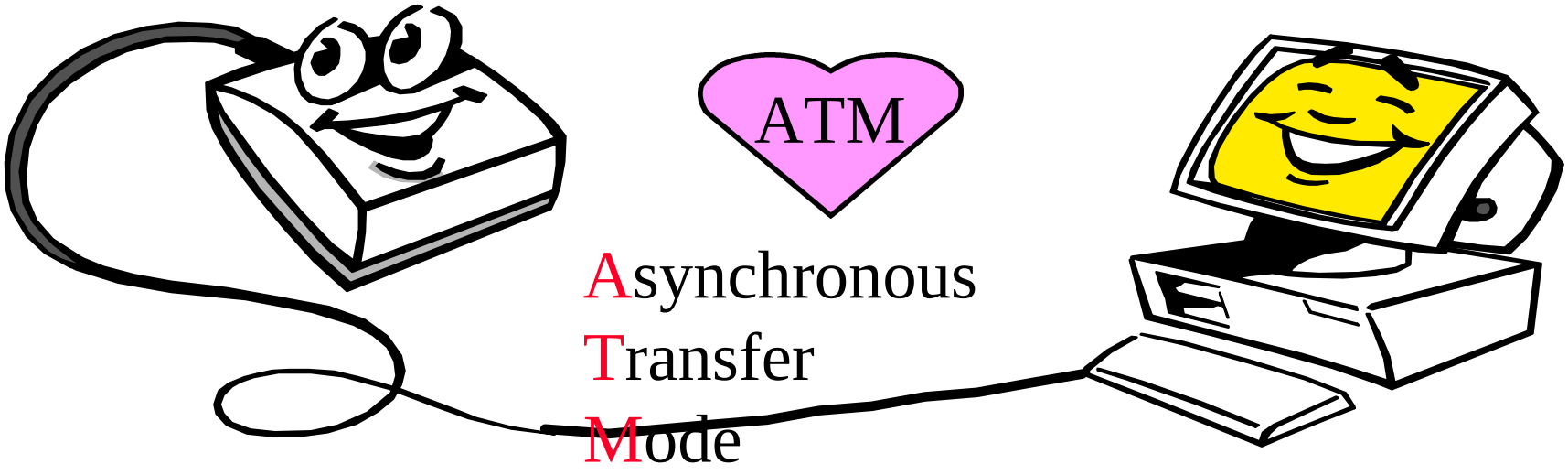
- Too much growth in one year
  $\Rightarrow$ Can't plan too much into long term
- Long term = 1_2 year or 10_2 years at most
- Products have life span of 1 year, 1 month, …
- Short product development cycles.
  Chrysler reduced new car design time
  from 6 years to 2.
- Distance between research and products has narrowed
  $\Rightarrow$ Collaboration between researchers and developers
  $\Rightarrow$ Academics need to participate in industry consortia

Impact on Education

- Email is faster than telegram
  $\Rightarrow$ Fast pace of life
- Shorter product life cycles.
  Distance between research and products has narrowed
- Technology is changing faster than our ability to learn
  $\Rightarrow$ A person's value (salary) decreases with experience (years out of college)
- Recent graduates know C++, HTML, Java, TCP/IP, ...
- New Opportunities/Challenges for educators
- New challenges for learners

ATM

- ATM = Asynchronous Transfer Mode
- ATM Net = Data Net + Phone Net
- Combination of Internet method of communication (packet switching) and phone companies' method (circuit switching)



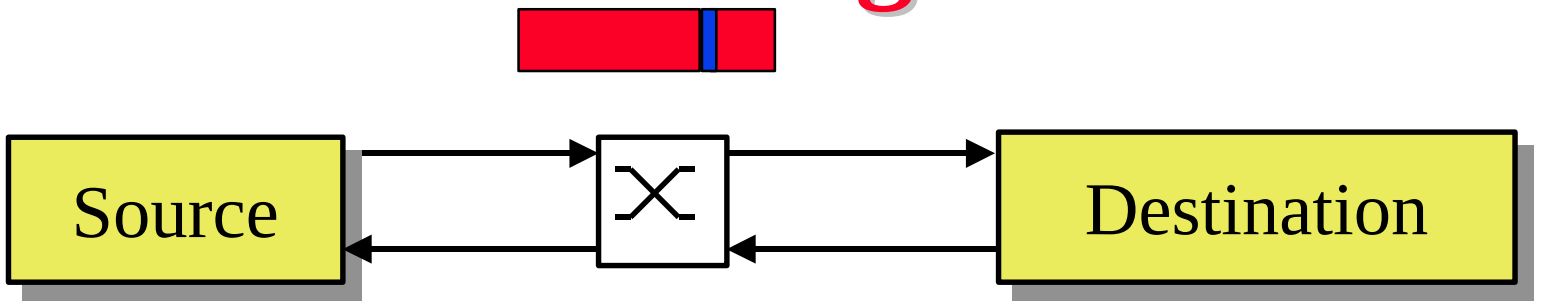
Why ATM?

- ATM allows voice, video, and data on the same network
- No need for separate phone network and data networks (T1 lines or frame relay)
- Signaling: You can dial a high-speed call. Bandwidth is available for the duration of the call.
- Routing based on quality of desired connection
- Traffic management: Someone's else's high load will not affect you
- Offers multiple classes of service

Our Research Projects

- ATM Traffic Management:
  - Multicasting
  - TCP/IP over ATM
  - Real-Time ABR
  - ATM over Satellite
- Voice over Data Networks
- Video over Data Networks
- Quality of Service over IP
- OCARnet: State-wide ATM testbed
- OSU National ATM Performance Testing Lab
- Wireless Networking

Traffic Management



- We invented DECbit scheme in 1986:
  One Bit in the header ⇒ Go up/Down
  - Used now in Frame Relay (FECN)
  - Used in ATM (EFCI)
- In July 1994, we proposed Explicit Rate Approach.
  Current standard.
- Two patents. Collaboration with industry.

ERICA Switch Algorithm

- ATM Forum traffic management standard allows each manufacturer to have its own switch algorithm
- We developed "Explicit Rate Indication for Congestion Avoidance (ERICA)." Included in TM4.0 as an example
- ERICA+ allows low delay even at 100% utilization and provides stability in the presence of high frequency VBR background traffic
- Being implemented by several vendors. Software implementation feasible.

Multicast ABR

- Available bit rate (ABR) service provides a feedback to the source about currently available bandwidth in the network.
- With one-source multicasting to multiple destinations, the feedback from branches has to be consolidated.
- We have developed/analyzed several consolidation and merge-point algorithms.

TCP/IP Over Satellite

- Satellite Links have associated with them long delay and bursty error characteristics.
- New TCP enhancements (SACK,FRR) have to be evaluated for high throughput on satellite links.
- Various switch drop policies (EPD, SD, FBA) have to be evaluated for high throughput and fairness on satellite links.
- Modeling of WWW traffic on satellite links using TCP/IP. (Based on WEBSPEC96 model)

Internet Protocols over ATM

- Available bit rate (ABR) service uses feedback to minimize congestion. The unspecified bit rate (UBR) service provides no feedback or guarantees.
- Internet Engineering Task Force (IETF) prefers UBR for TCP
- ABR pushes congestion to the edge of the network
- ABR recommended for large high-speed networks
- We have developed/analyzed ways to improve performance of UBR
- We have developed ways to implement Guaranteed Frame Rate (GFR) with a single FIFO Queue

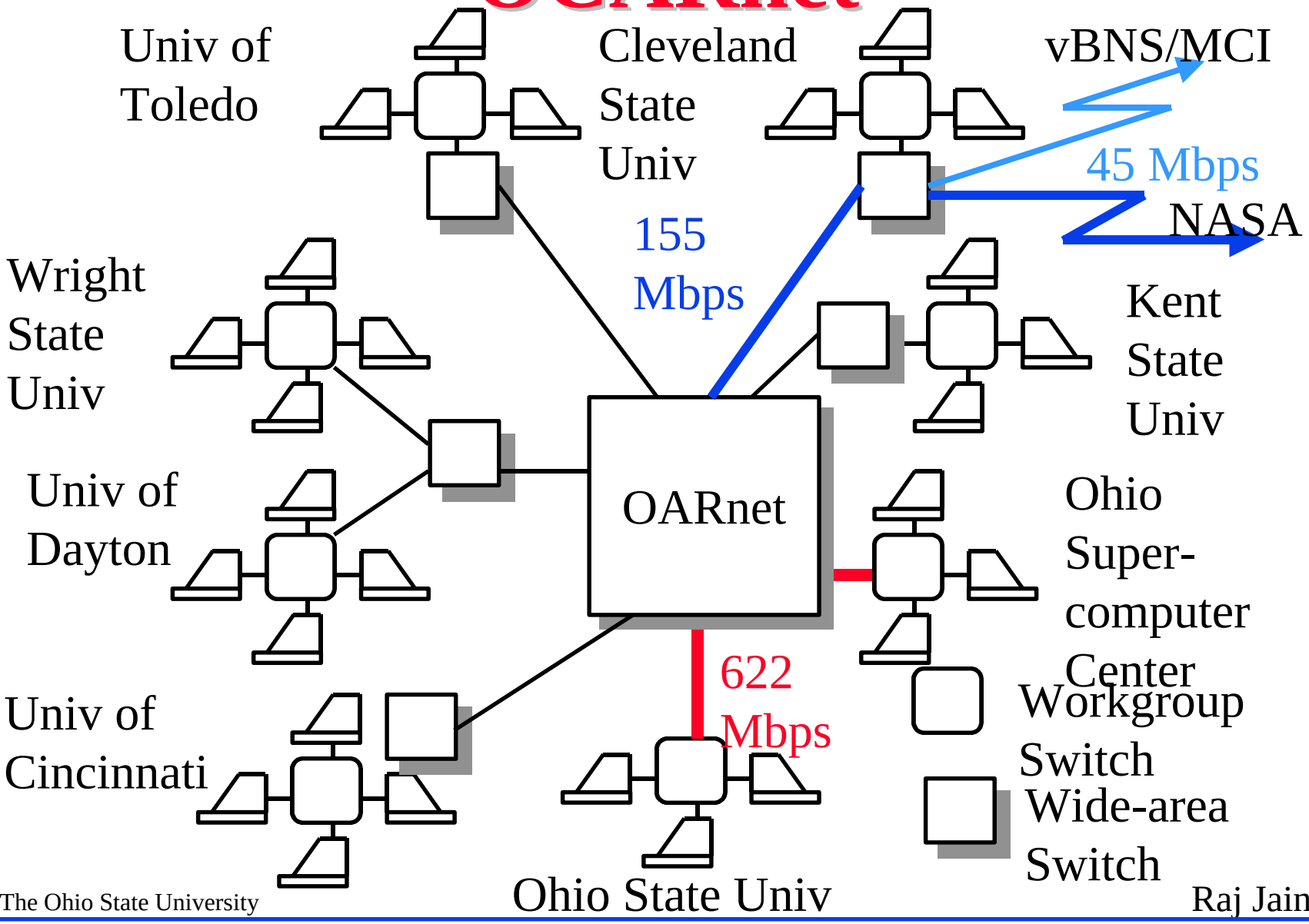
Real-Time ABR

- Compressed video produces variable bit rate (VBR) stream. VBR service is subject to connection denial.
- In situations where reduced service is preferable over connection denial, such as in tactical environments, Video over ABR is preferable over no Video.
- ABR divides the available bandwidth fairly among contending connections
- By proper control, ABR can be designed to reduce delay
- Compression parameters can be adjusted dynamically based on network feedback

OCARnet

- Ohio Computing and Communications ATM Research Network
- Nine-Institution consortium lead by OSU
  - Ohio State University
  - Ohio Super Computer Center
  - OARnet
  - Cleveland State University
  - Kent State University
  - University of Dayton
  - University of Cincinnati
  - Wright State University
  - University of Toledo

OCARnet


Univ of Toledo
Cleveland State Univ
vBNS/MCI
45 Mbps
NASA
155 Mbps
Wright State Univ
Kent State Univ
Univ of Dayton
OARnet
Ohio Super-computer Center
622 Mbps
Workgroup Switch
Univ of Cincinnati
Wide-area Switch
Ohio State Univ

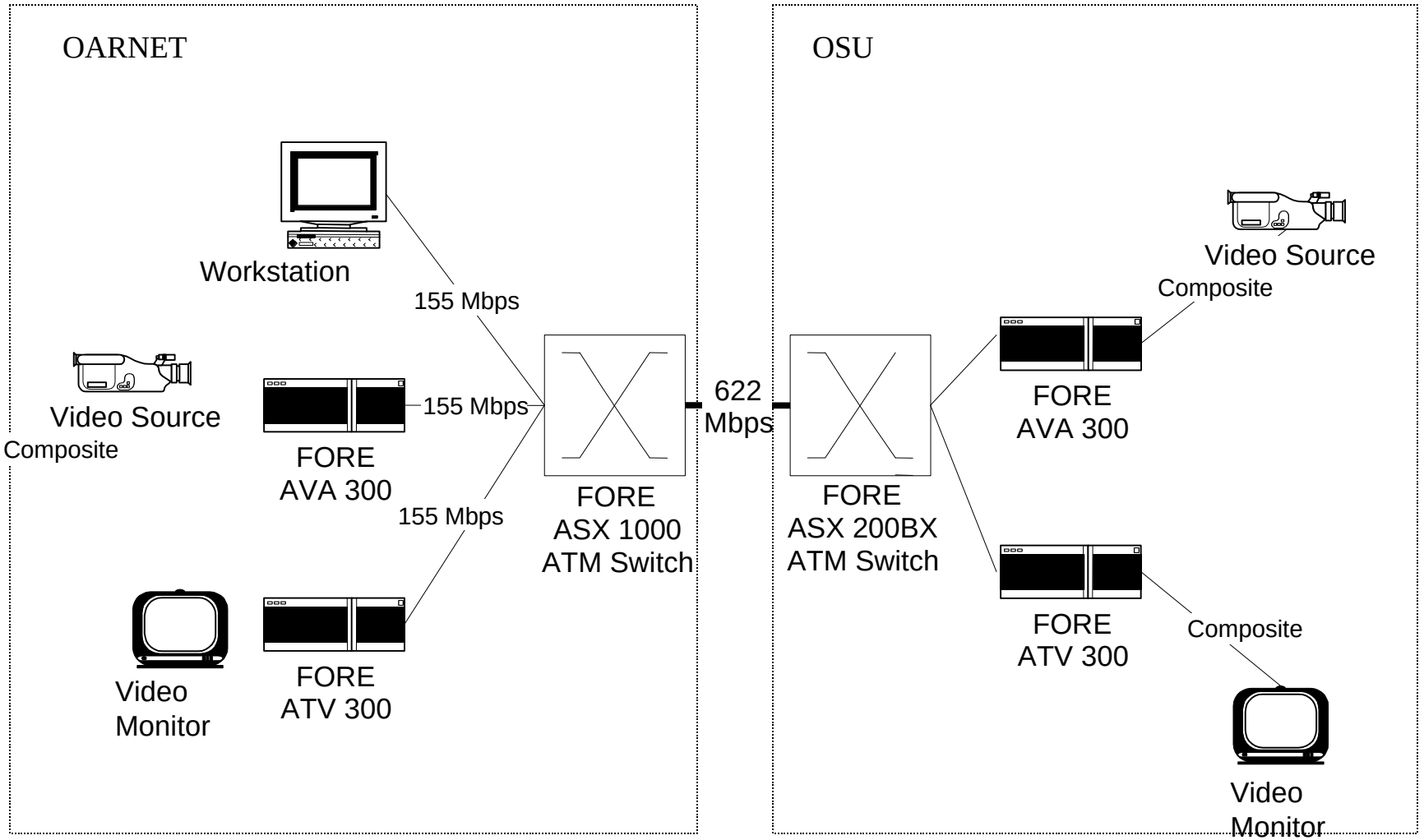
Voice over Data Networks

- Voice compression and silence suppression reduce the required bandwidth, but cause longer delay.
- Analysis of new ATM Adaptation Layer (AAL2):
  - allows multiplexing inside a cell,
  - shorter delay and higher utilization.
- Analysis of submultiplexing schemes in IP:
  - to allow multiple voice sources use the same packet,
  - to reduce delay and transmission overhead.

Video over Data Networks

- Hierarchical compression of video
  Different users can view the same compressed stream at different rates
- Network feedback to adjust levels of compression
- Forwarding adaptive to network feedback

Video Testbed



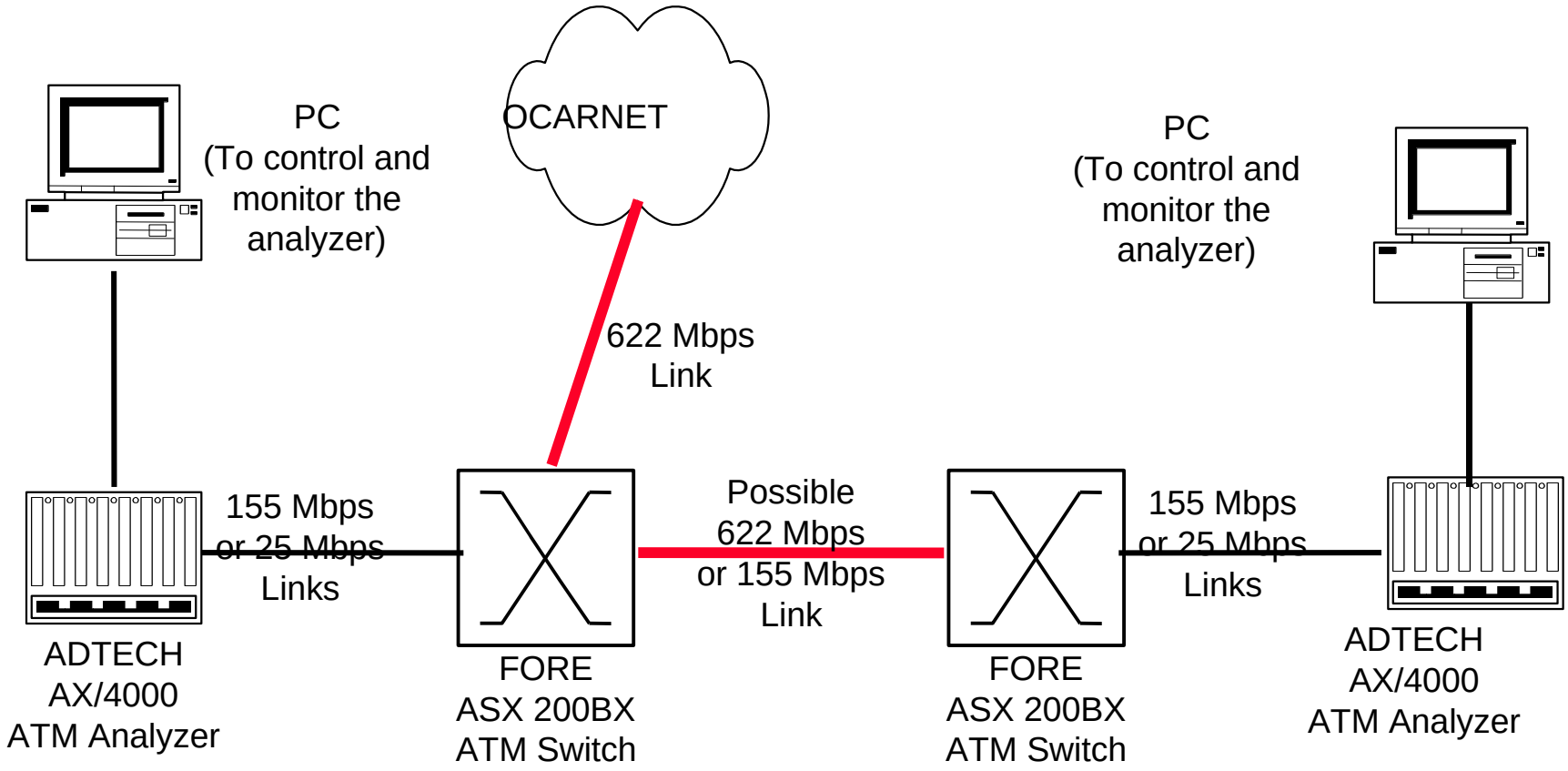
Wireless Networking

- In collaboration with Electro-science laboratory of EE Dept (Experts in Antenna design and wireless modem communications)
- Dynamically adapt to measured error characterstics:
  - Media Access Protocol
  - Transport protocol (retransmissions)
  - Hand-off strategies
- Modem design for optimal higher-layer performance

OSU National ATM Benchmarking Lab

- Started a new effort at ATM Forum in October 1995
- Defining a new standard for frame based performance metrics and measurement methodologies
- OSU benchmarking lab has the latest ATM testing equipment. Funded by NSF and State of Ohio.
- The benchmark scripts can be run by any manufacturer/user in our lab or theirs.
- Modeled after Harvard benchmarking lab for routers

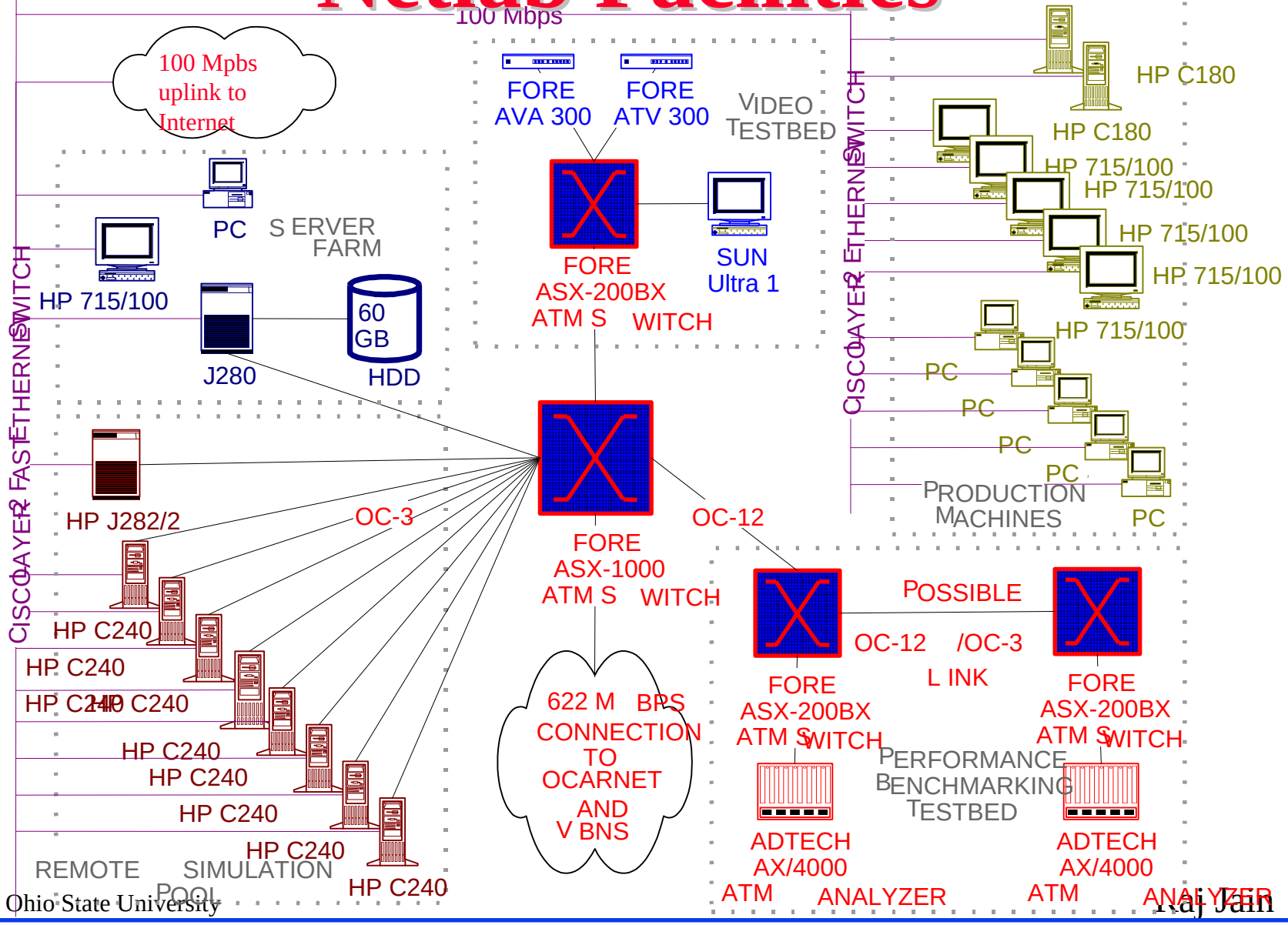
Performance Testing Facility



Computation Facilities

- 22 Workstations, 14 Desktop PCs, 9 Laptop PCs
- Several Printers, Fileservers. Over 100 GB storage.
  $\Rightarrow$ 10 times more compute power per research student than an average faculty member
- 100 Mbps Ethernet and 155 Mbps ATM Connections
- 622 Mbps Connection to OCARnet and vBNS/Internet 2
- Two 100 Mbps Ethernet Switches
  Three ATM switches with 25-622 Mbps links
- Two ATM test monitors with 25, 155, and 622 Mbps generator and analyzers

Netlab Facilities



Networking Lab Exercises

- NSF funding to develop networking lab exercises for students
- Multimedia oriented hands-on multi-player networking games-like exercises
- Ten labs covering: Ethernet, FDDI, IP, TCP, ATM, etc.
- Any university in the nation can download and use them in their networking courses

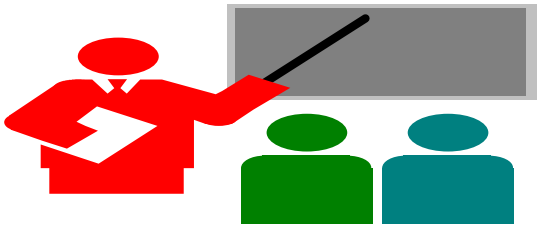
CIS Networking Courses

- CIS 677: Introduction to Networking
  - Offered every quarter
- CIS 678: Internetworking
  - Offered once a year - Winter quarter
- CIS 777: Telecommunication Networks
  - Offered once a year - Spring quarter
- CIS 788: Recent Advances in Networking (Raj Jain)
- CIS 788: Wireless Networking (Steve Lai)
- CIS788: Multimedia Networking (Wu-Chi Feng)
- CIS788: CDMA (Mike Liu)

Our Research Sponsors

- National Science Foundation
- Ohio Board of Regents
- NASA
- Nokia
- Nortel
- Past Sponsors:
  - Fore Systems
  - AT&T/Lucent
  - Cascade
  - Stratacom/Cisco
  - Intel

Summary



- OSU is a leader in ATM traffic management and Performance benchmarking
- Active collaboration with industry
  ⇒ Research on relevant topics |
  ⇒ Impact on products
- Leading regional ATM networks
  ⇒ Collaboration with other Ohio universities
- Collaboration with EE department on wireless and video research

Our Publications

- All our ATM Forum contributions and papers are available on-line at *http://www.cis.ohio-state.edu/~jain/*
  Specially see "Recent Hot Papers" and "References on Recent Advances in Networking"

Thank You!