Recent Advances in Networking Including ATM, Traffic Management, Switching, and QoS

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- ATM vs IP, ATM vs Gigabit Ethernet
- Traffic Management in ATM: ABR Vs UBR
- Switching vs Routing: LANE, NHRP, MPOA, MPLS
- Quality of Service in IP:
  Integrated services/RSVP/Differentiated Services

Computing vs Communication

- 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.
- Network is the bottleneck. Productivity of people, companies and countries depends upon the speed of their network.

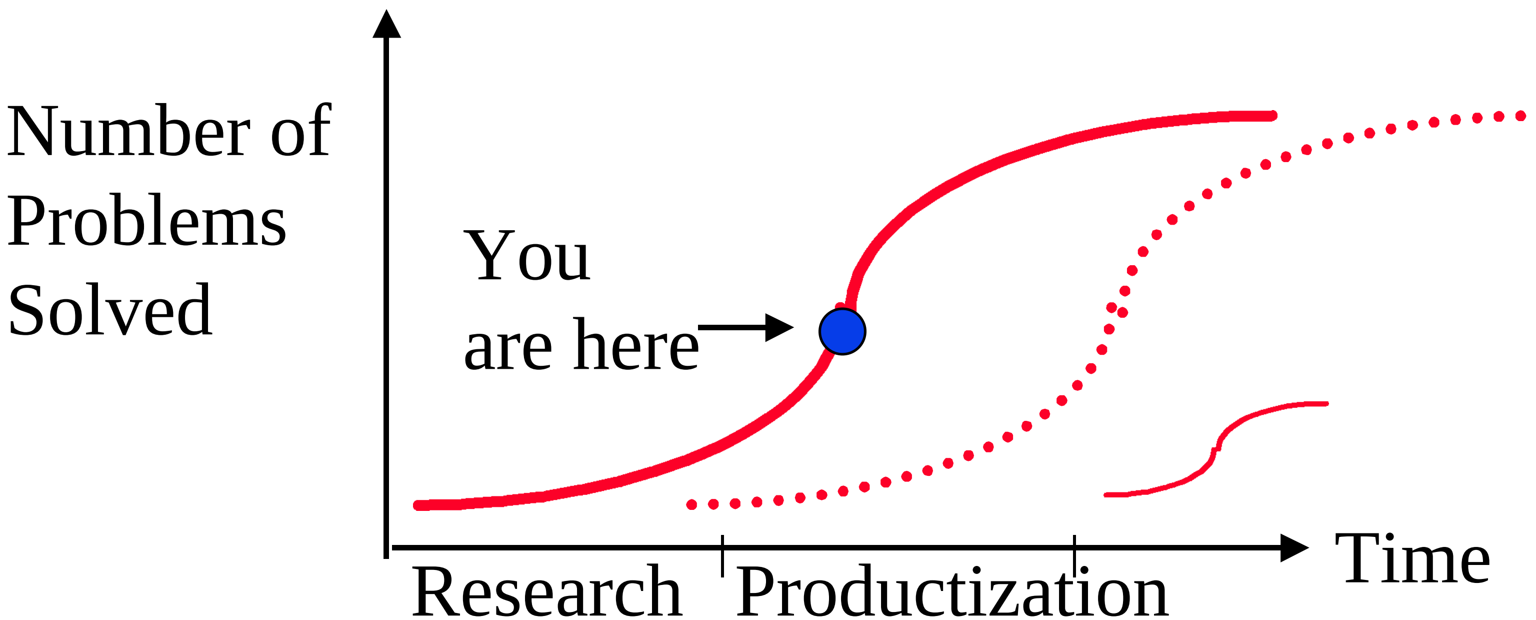
Social Impact of Networking

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

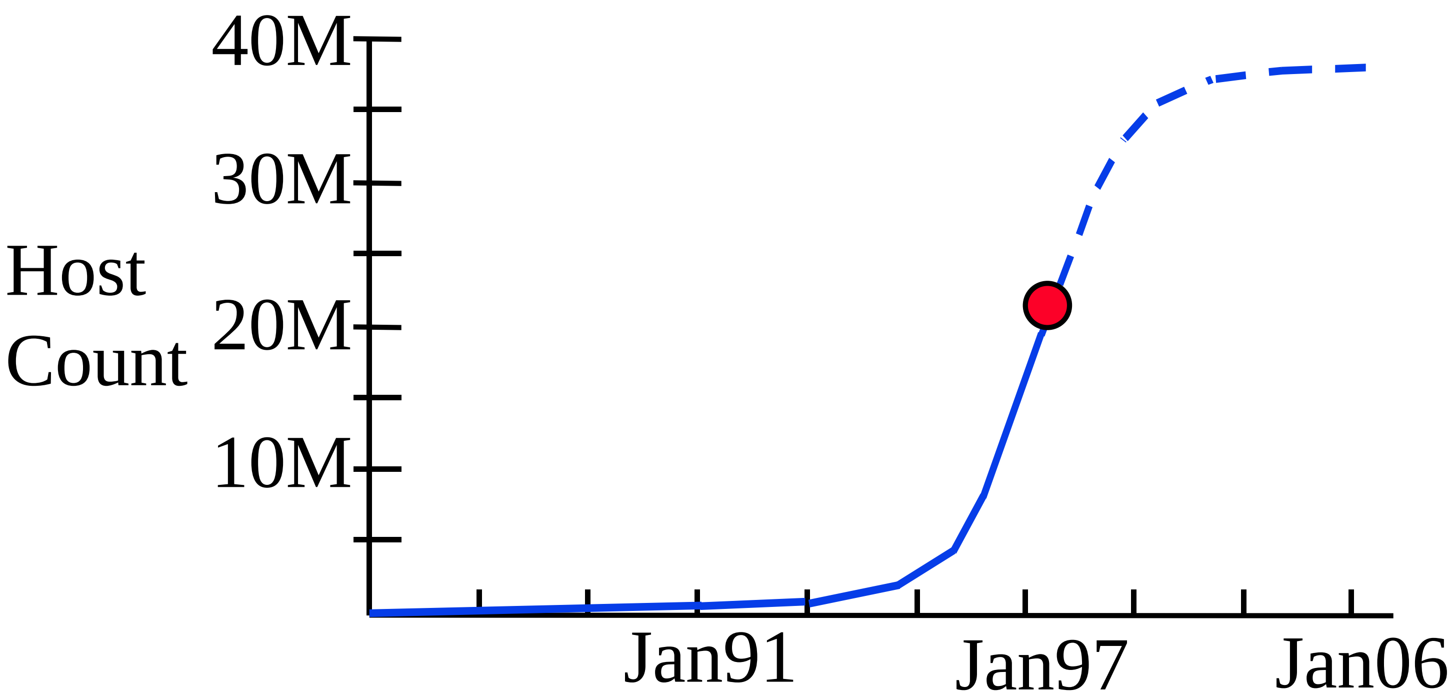
(55 Million US workers will work remotely by 2000)

Cave Persons of 2050

Life Cycles of Technologies



Internet Technology



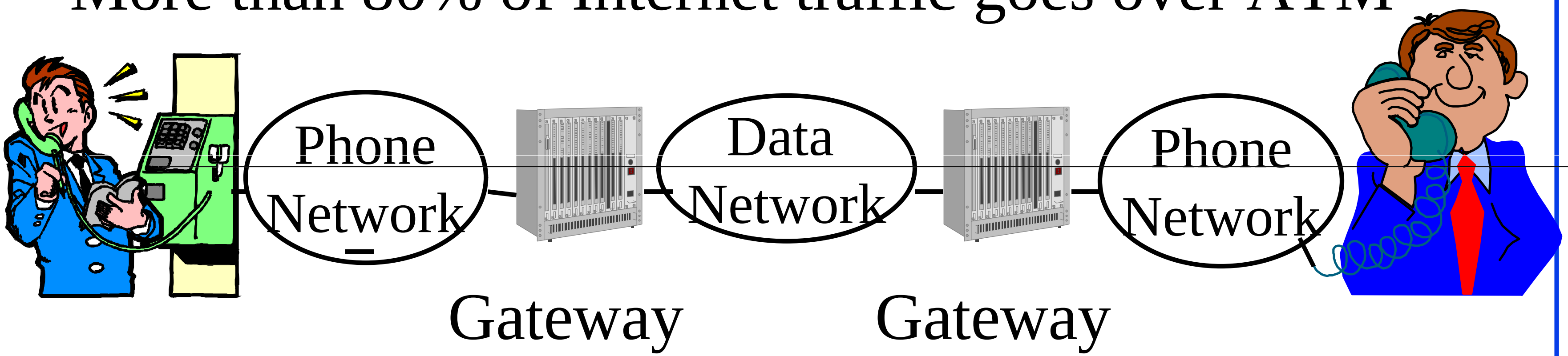
- **New Challenges**: Exponential growth in number of users. Exponential growth in bandwidth per user. Traffic management, Security, Usability, ...

Networking Trends

1. Inter-Planetary Networks ⇒ Distances are increasing
2. WDM OC-768 Networks = 39.8 Gb/s
   ⇒ Bandwidth is increasing
   ⇒ Large Bandwidth-Delay Product Networks
3. Copper is still in. Fiber is being postponed.
   6-27 Mbps on phone wire.
   1999: Gigabit Ethernet on UTP-5 w 200m net dia.
4. Routing to Switching. Distinction is disappearing

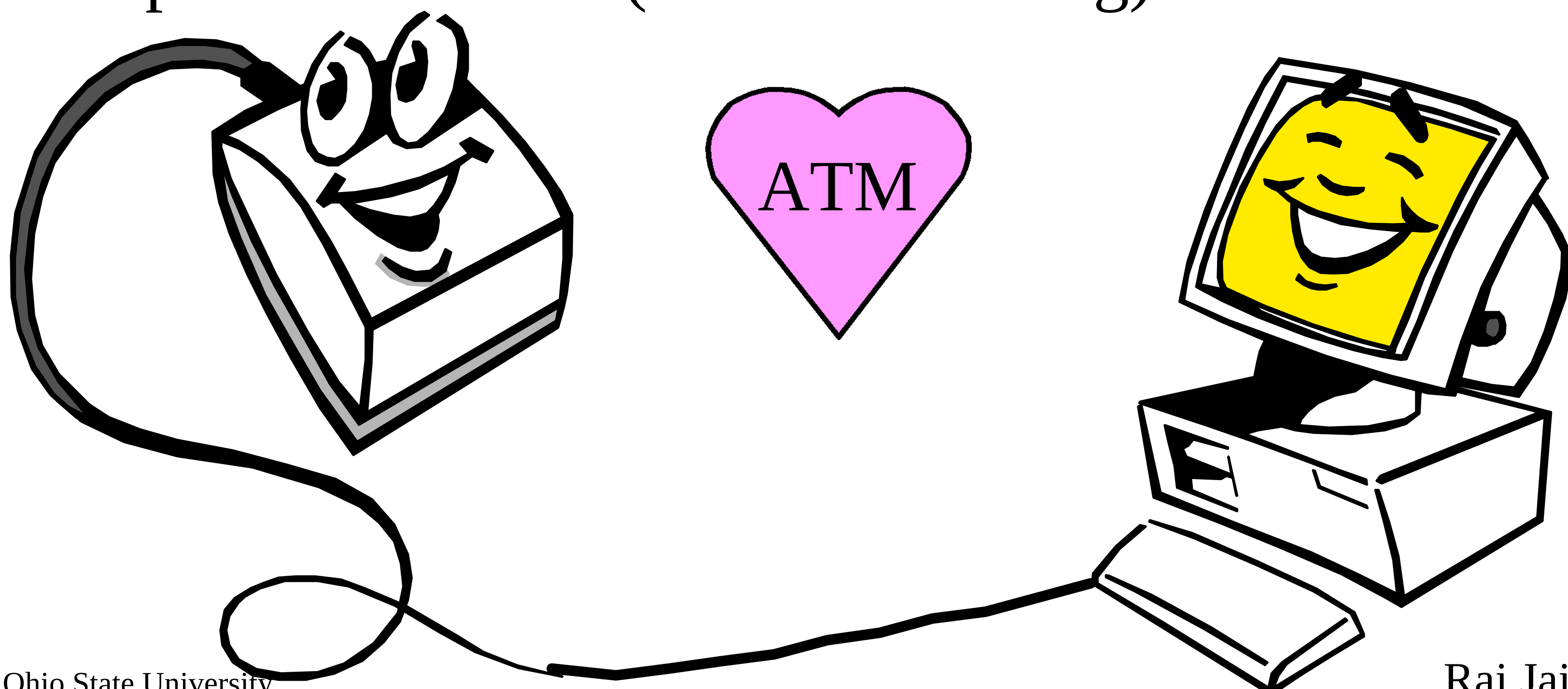
Telecommunication Trends

1. Voice traffic is growing linearly
   Data traffic is growing exponentially
   Bandwidth requirements are doubling every 4 months
   Data Volume > Voice Volume (1998)
2. Voice over data ⇒ Quality of Service issues
3. Carriers are converting to ATM
   More than 80% of Internet traffic goes over ATM

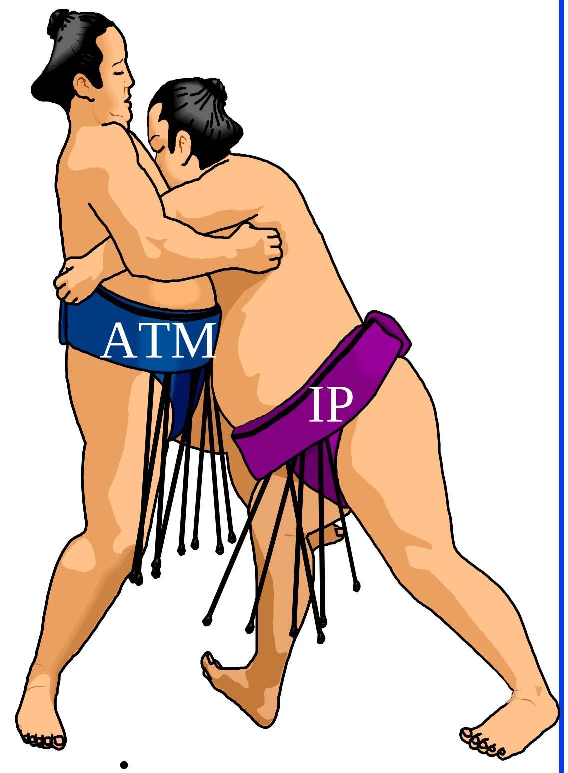


ATM

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



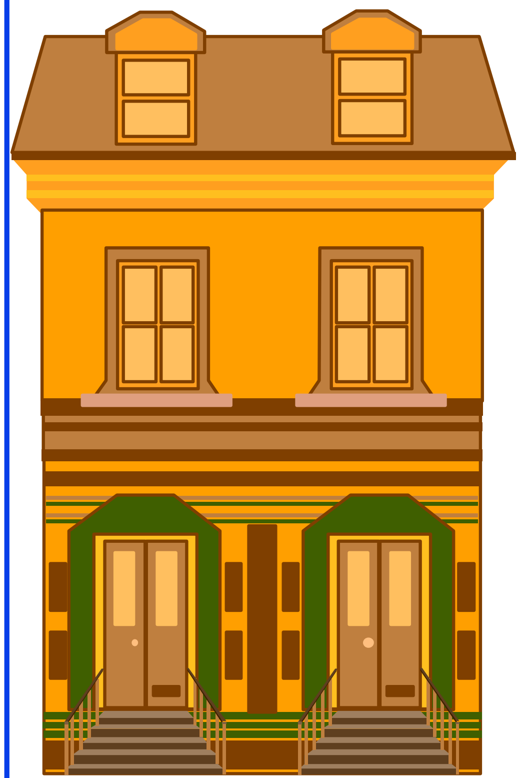
Why ATM?

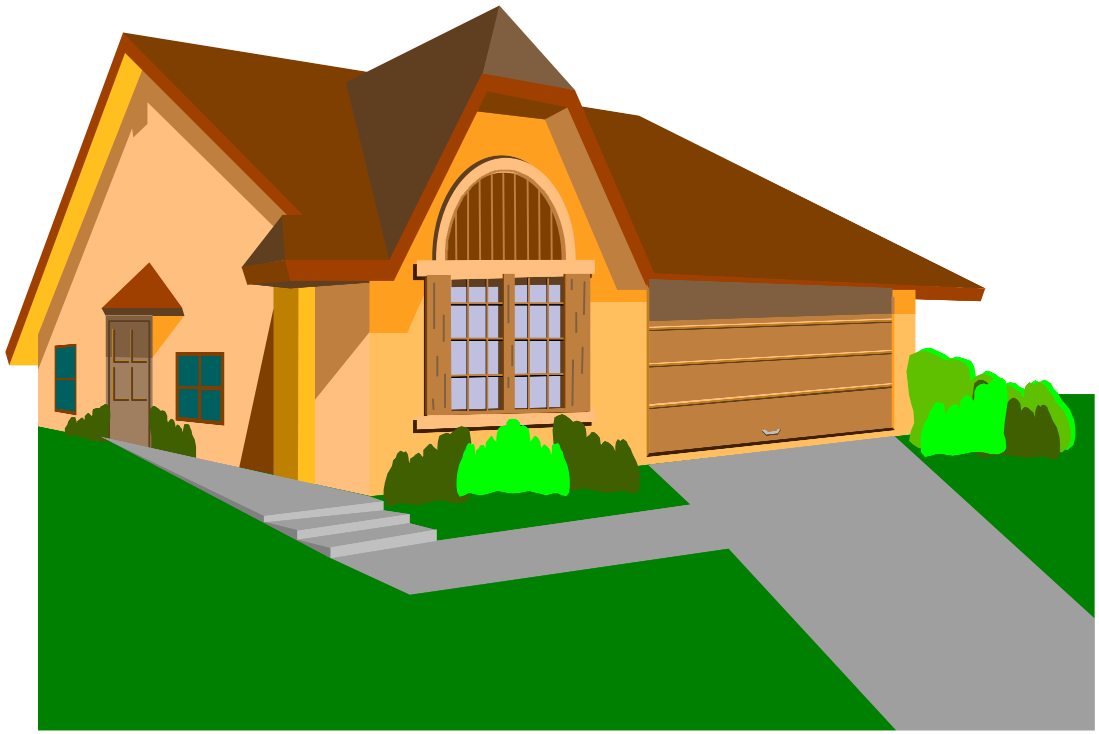


ATM vs IP: Key Distinctions

1. Traffic Management:
   Explicit Rate vs Loss based
2. Signaling: Coming to IP in the form of RSVP
3. QoS: PNNI routing, Service categories. Integrated/Differentiated services
4. Switching: Coming to IP as MPLS
5. Cells: Fixed size or small size is not important

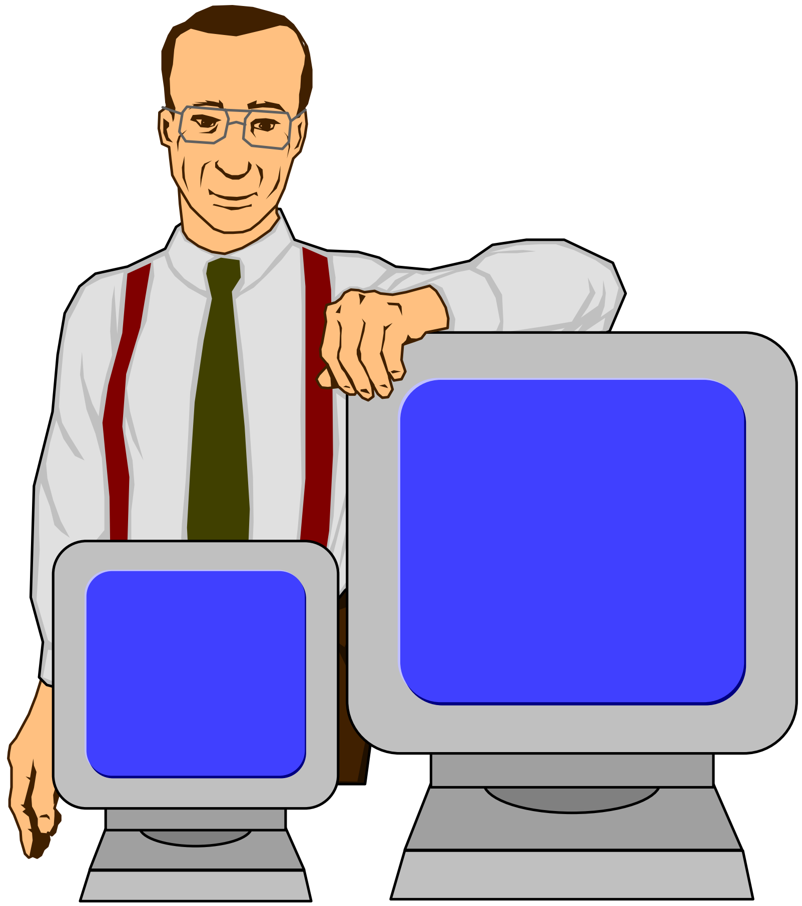
Old House vs New House





- New needs:
  Solution 1: Fix the old house (cheaper initially)
  Solution 2: Buy a new house (pays off over a long run)

Dime Sale



One Megabit memory, One Megabyte disk, One Mbps link, One MIP processor, 10 cents each.....

Future

Year

1980

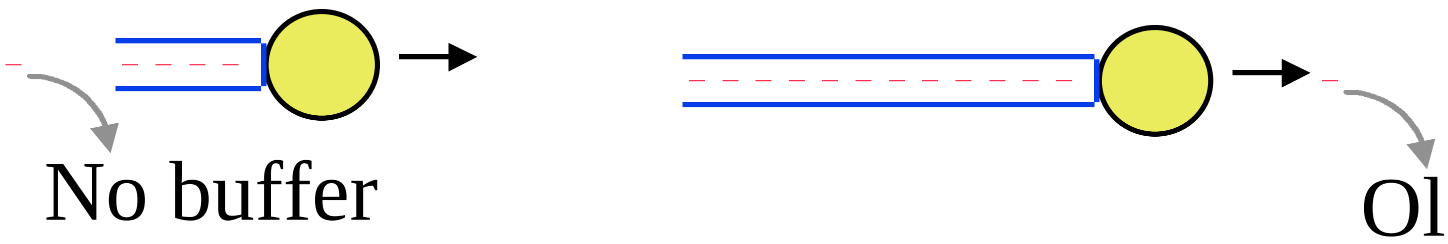
In 1990, the memory will be so cheap that you will not have to worry about paging, swapping, virtual memory, memory hierarchy, and....

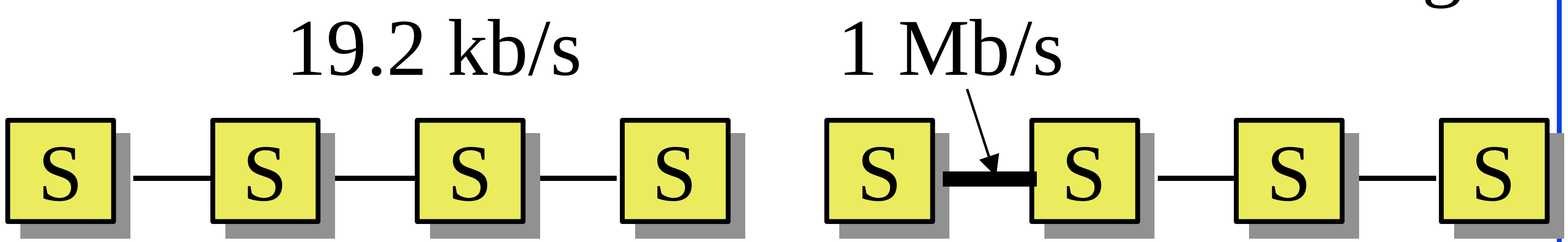
Why Worry About Congestion?

Q: Will the congestion problem be solved when:

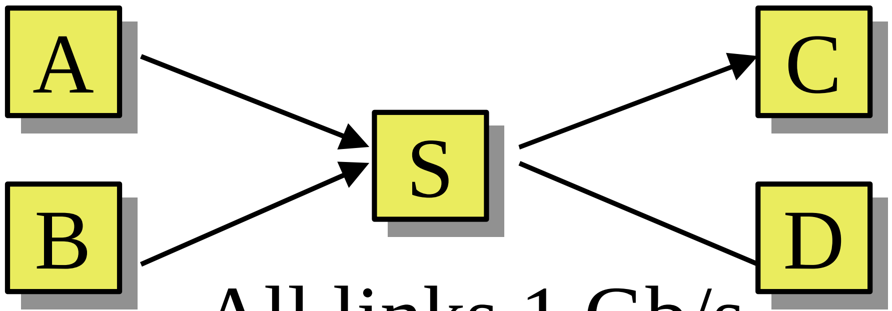
- Memory becomes cheap (infinite memory)?
- Links become cheap (very high speed links)?
- Processors become cheap?

A: None of the above.





File transfer time = 5 mins   Time = 7 hours

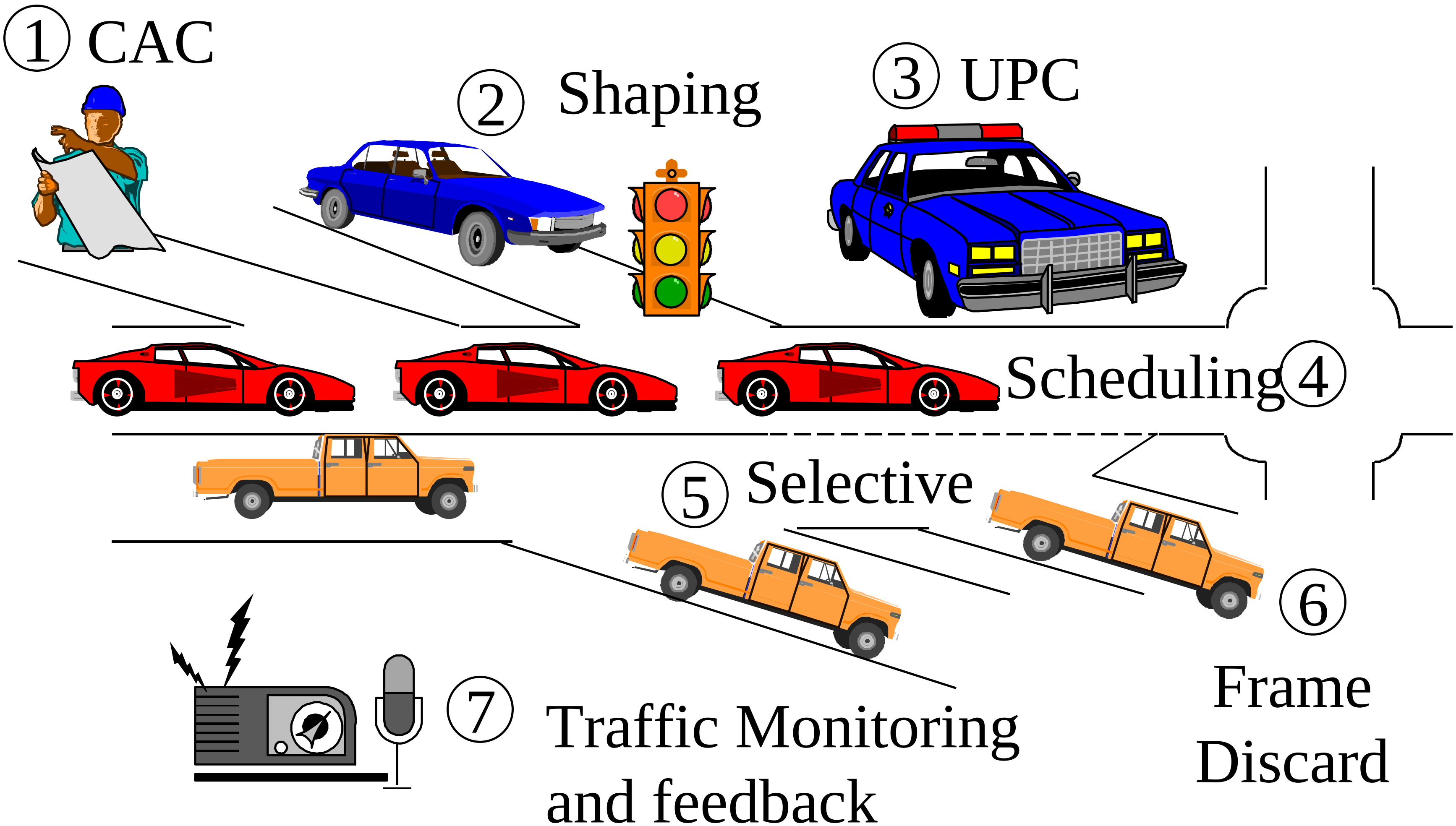


All links 1 Gb/s

Conclusions:

- Congestion is a dynamic problem.
  Static solutions are not sufficient
- Bandwidth explosion
  ⇒ More unbalanced networks
- Buffer shortage is a symptom not the cause.

Traffic Management on the Info Superhighway



ATM Traffic Mgmt Functions

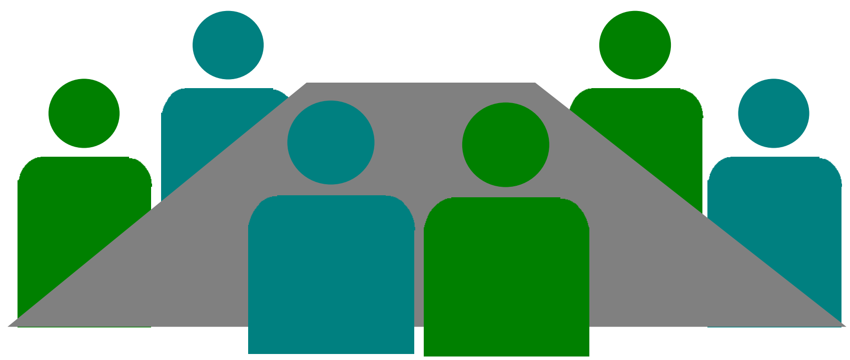
- Connection Admission Control (CAC):
  Can quality of service be supported?
- Traffic Shaping: Limit burst length. Space-out cells.
- Usage Parameter Control (UPC):
  Monitor and control traffic at the network entrance.
- Network Resource Management:
  Scheduling, Queueing, resource reservation
- Priority Control: Cell Loss Priority (CLP)
- Selective Cell Discarding: Frame Discard
- Feedback Controls: Network tells the source to increase or decrease its load.

ATM Service Categories

Standby

Guaranteed

Joy Riders

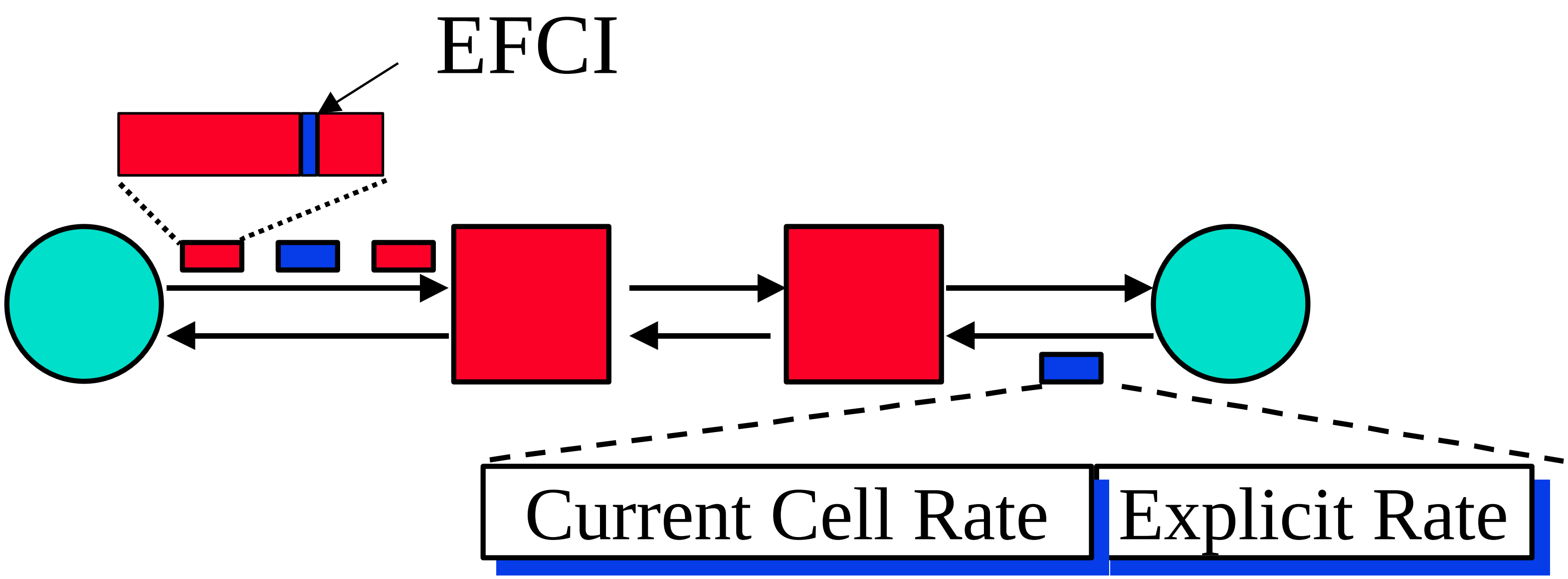


Confirmed

ATM Service Categories

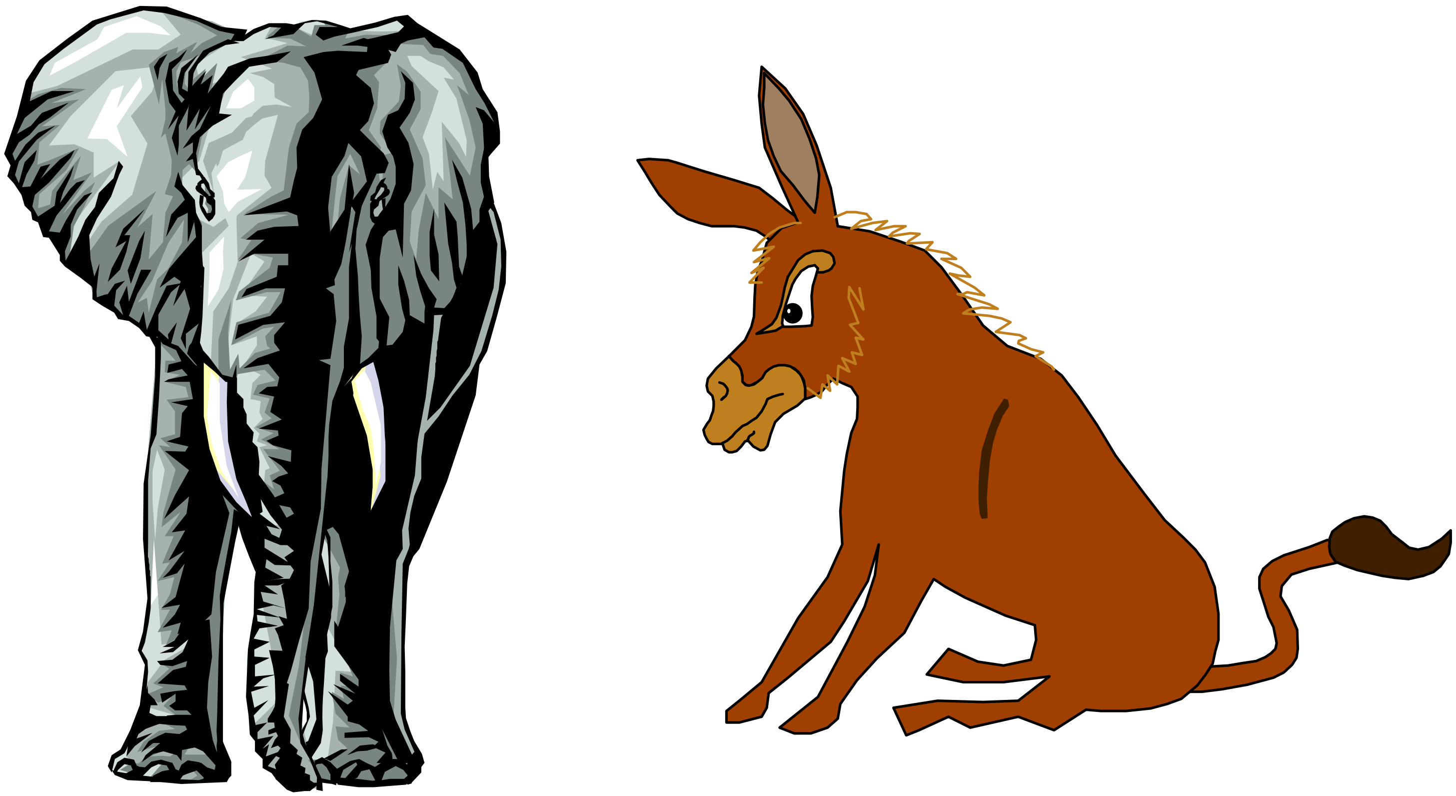
- ABR (Available bit rate): Source follows network feedback. Max throughput with minimum loss.
- UBR (Unspecified bit rate): User sends whenever it wants. No feedback. No guarantee. Cells may be dropped during congestion.
- CBR (Constant bit rate): User declares required rate. Throughput, delay and delay variation guaranteed.
- VBR (Variable bit rate): Declare avg and max rate.
  - rt-VBR (Real-time): Conferencing. Max delay guaranteed.
  - nrt-VBR (non-real time): Stored video.

ABR: Explicit Rate Feedback



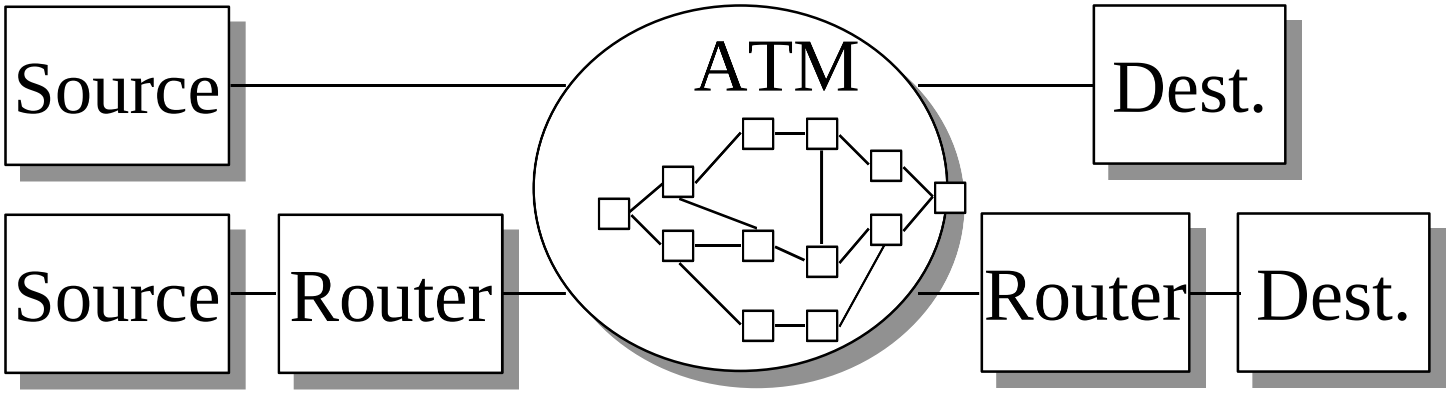
- DECbit scheme in 1986: Bit ⇒ Go up/Down
  - Used in Frame Relay (FECN) and ATM (EFCI)
- In July 1994, we proposed Explicit Rate Approach. Sources send one RM cell every n cells. The switches adjust the explicit rate field down.

ABR or UBR?



- Intelligent transport or not?

ABR vs UBR



ABR

Queue in the source

Pushes congestion to edges

If ATM not end-to-end: intelligent Q mgmt in routers

Works for all protocols

UBR

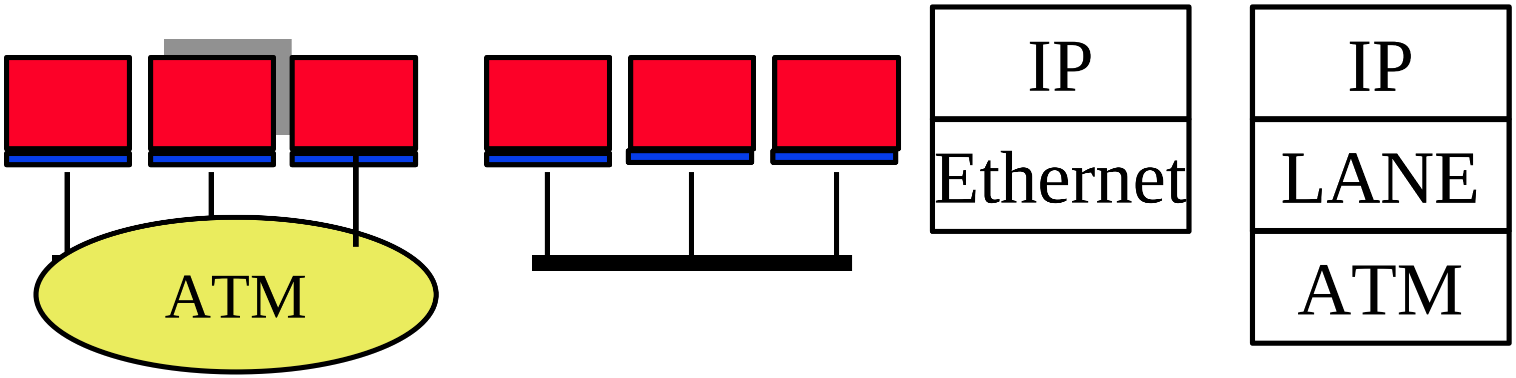
Queue in the network

No backpressure

Same end-to-end or backbone

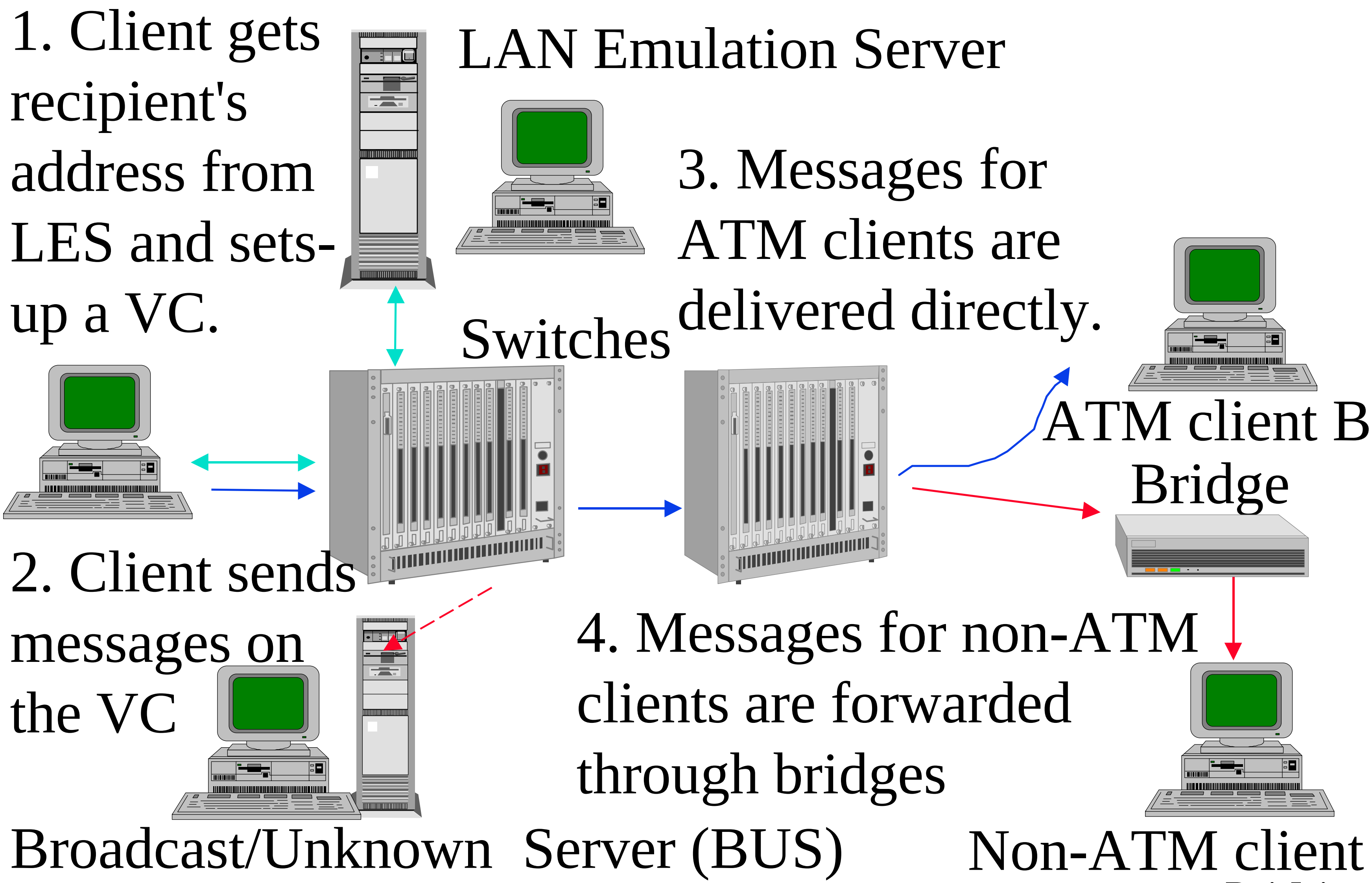
Works with TCP

LAN Emulation

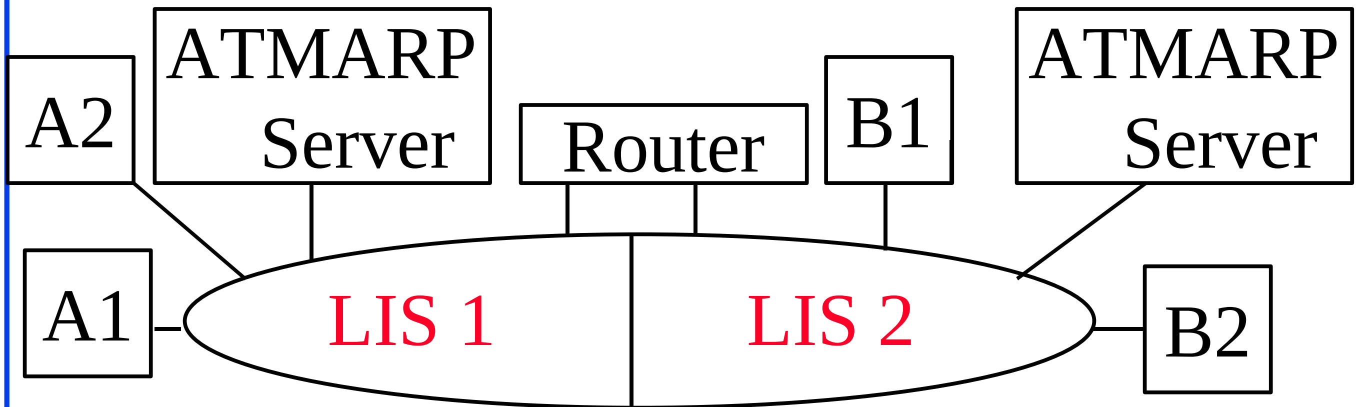


- LAN Emulation driver replaces Ethernet driver and passes the networking layer packets to ATM driver.
- Each ATM host is assigned an Ethernet address.
- LAN Emulation Server translates Ethernet addresses to ATM addresses
- Hosts set up a VC and exchange packets
- All software that runs of Ethernet can run on LANE

LAN Emulation



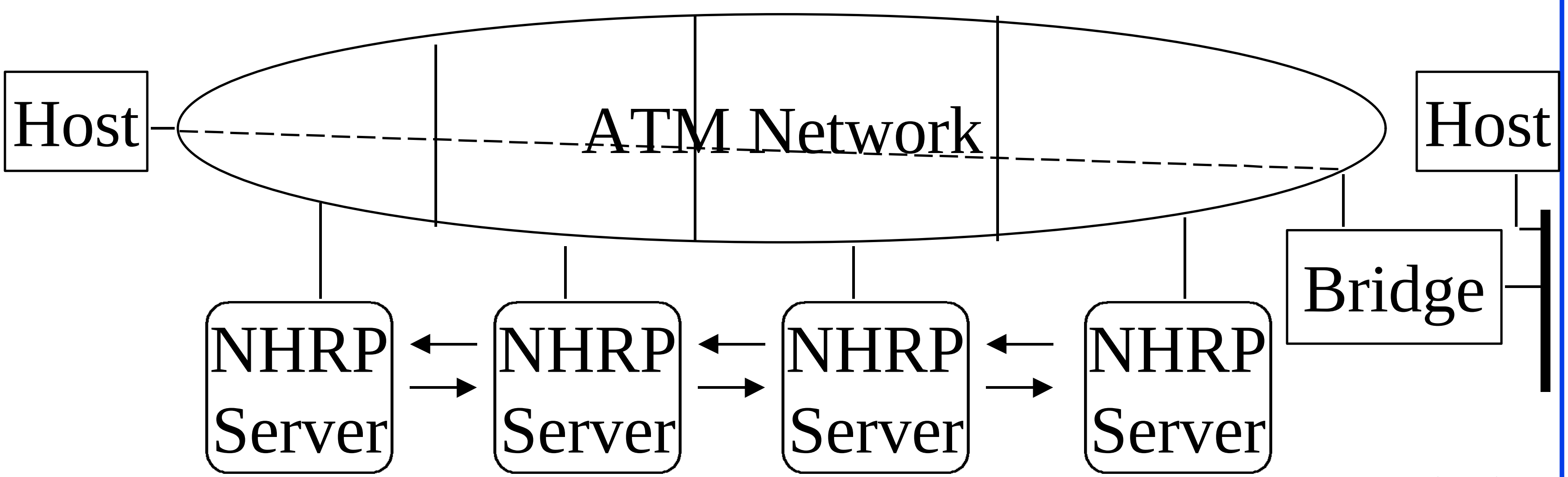
Classical IP Over ATM



- ATM stations are divided in to Logical IP Subnets (LIS)
- ATMARP server translates IP addresses to ATM addresses.
- Each LIS has an ATMARP server for resolution
- IP stations set up a direct VC with the destination or the router and exchange packets.

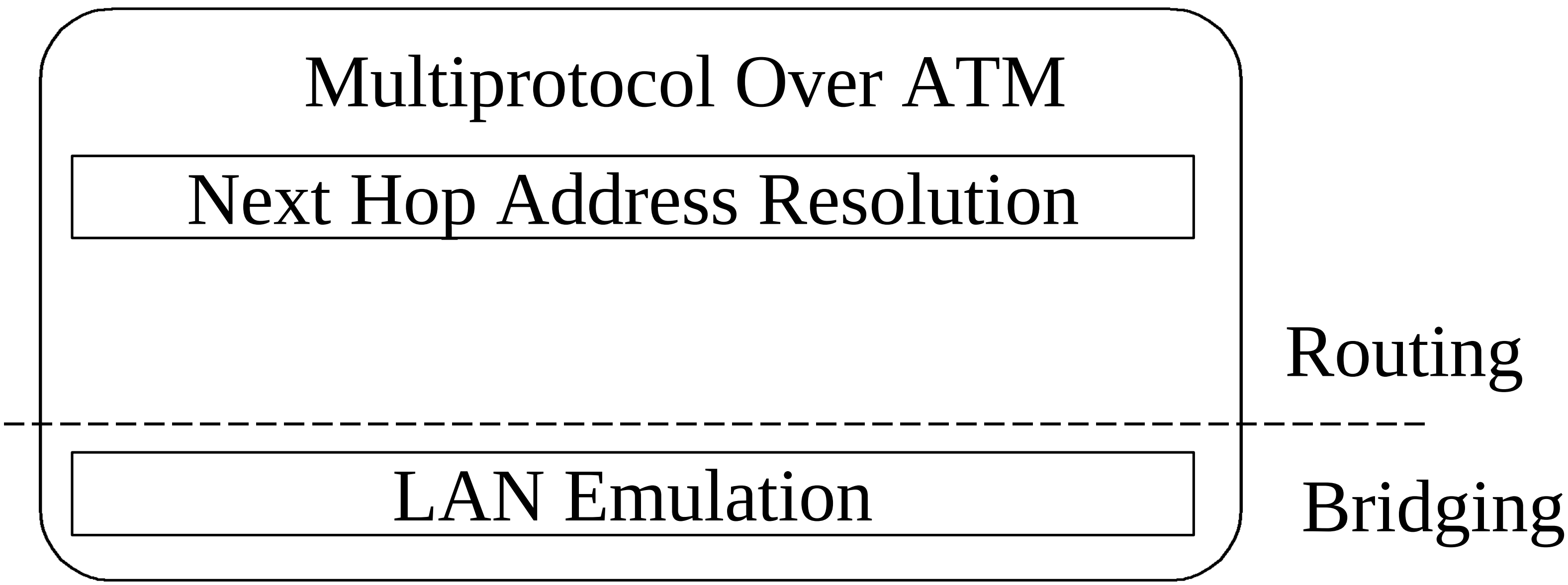
Next Hop Resolution Protocol

- Routers assemble packets ⇒ Slow
- NHRP servers can provide ATM address for the edge device to any IP host
- Can avoid routers if both source and destination are on the same ATM network.

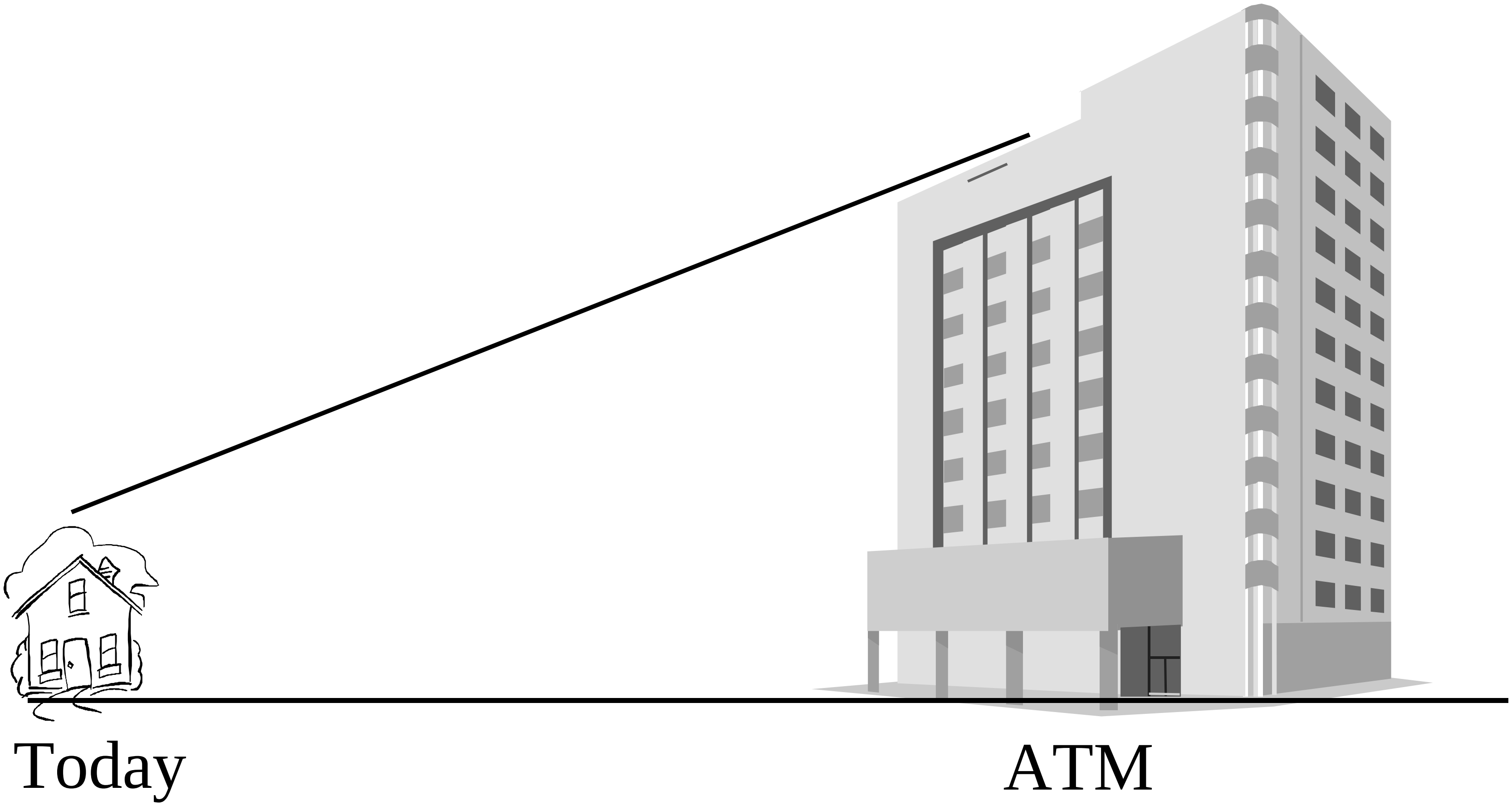


Multiprotocol Over ATM

- MPOA= LANE + “NHRP+”
- Extension of LANE
- Uses NHRP to find the shortcut to the next hop
- No routing (reassembly) in the ATM network

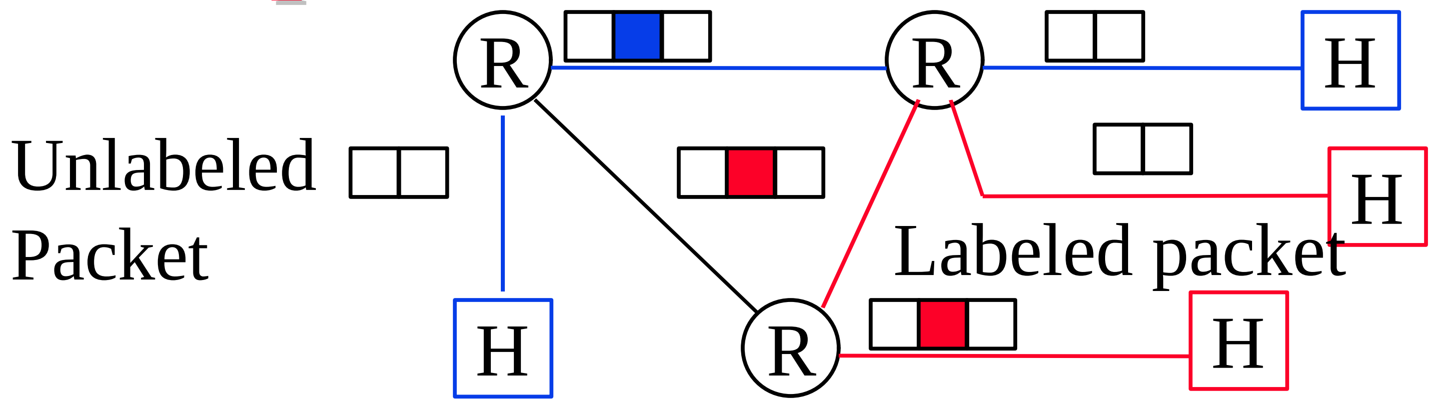


Quality of Service (QoS)



Too much too soon

Multiprotocol Label Switching



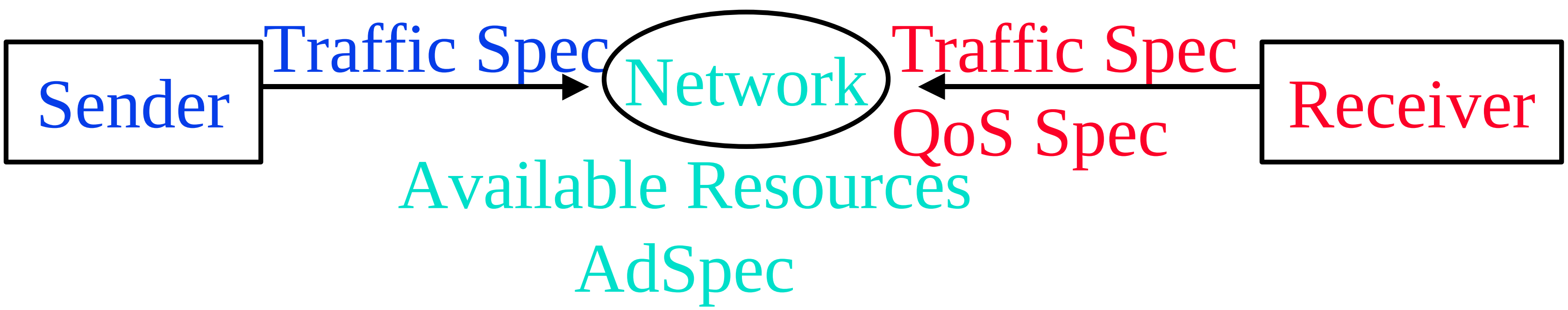
- Entry "label switch router (LSR)" attaches a label to the packet based on the route
- Other LSRs switch packets based on labels. Do not need to look inside ⇒ Fast.
- Labels have local significance ⇒ Different label at each hop (similar to VC #)
- Exit LSR strips off the label

ATM vs Gb Ethernet

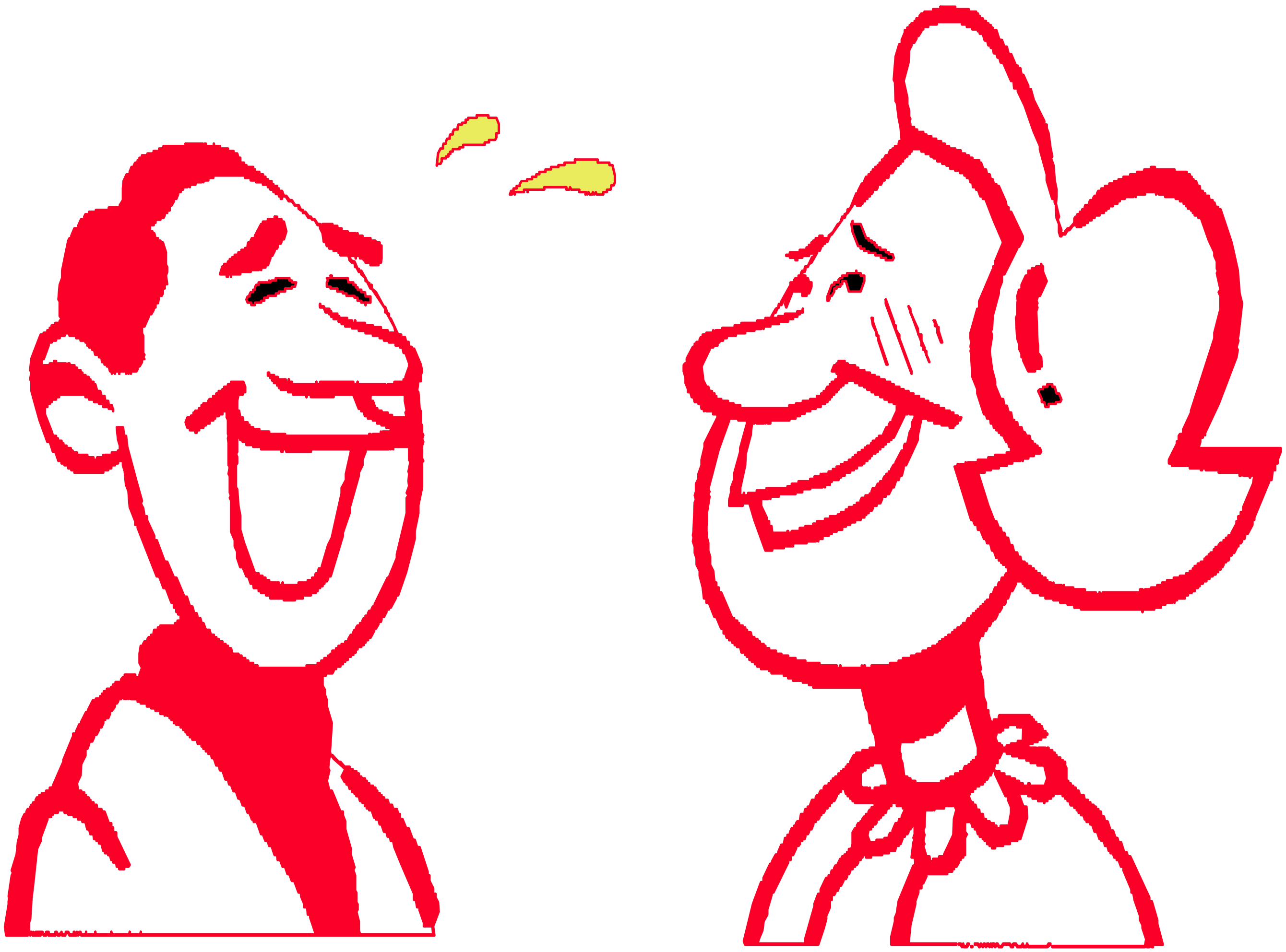
Issue	ATM	Gigabit Ethernet
Media	SM Fiber, MM Fiber, UTP5	Mostly fiber
Max Distance	Many miles using SONET	260-550 m Several km on SMF
Data Applications	Need LANE, IPOA	No changes needed
Interoperability	Good	Limited
Ease of Mgmt	LANE	802.1Q VLANs
QoS	PNNI	802.1p (Priority)
Signaling	UNI	Via Management
Traffic Mgmt	Sophisticated	802.3x Xon/Xoff

Integrated Services and RSVP

- Best Effort Service: Like UBR.
- Controlled-Load Service: Performance as good as in an unloaded datagram network. No quantitative assurances. Like nrt-VBR or UBR w MCR
- Guaranteed Service: Like CBR or rt-VBR
  - Firm bound on data throughput and delay.
  - Is not always implementable, e.g., Shared Ethernet.
- Resource ReSerVation Protocol: Signaling protocol



Before



After

Problems with RSVP and Integrated Services

- Complexity: Packet classification, Scheduling
- Scalable in number of receivers per flow but
  Per-Flow State: O(n) ⇒ Not scalable with # of flows.
  Number of flows in the backbone may be large.
  ⇒ Suitable for small private networks
- Need a concept of "Virtual Paths" or aggregated flow groups for the backbone
- Need policy controls: Who can make reservations?
  Support for accounting and security.
- RSVP does not have negotiation and backtracking

Differentiated Services

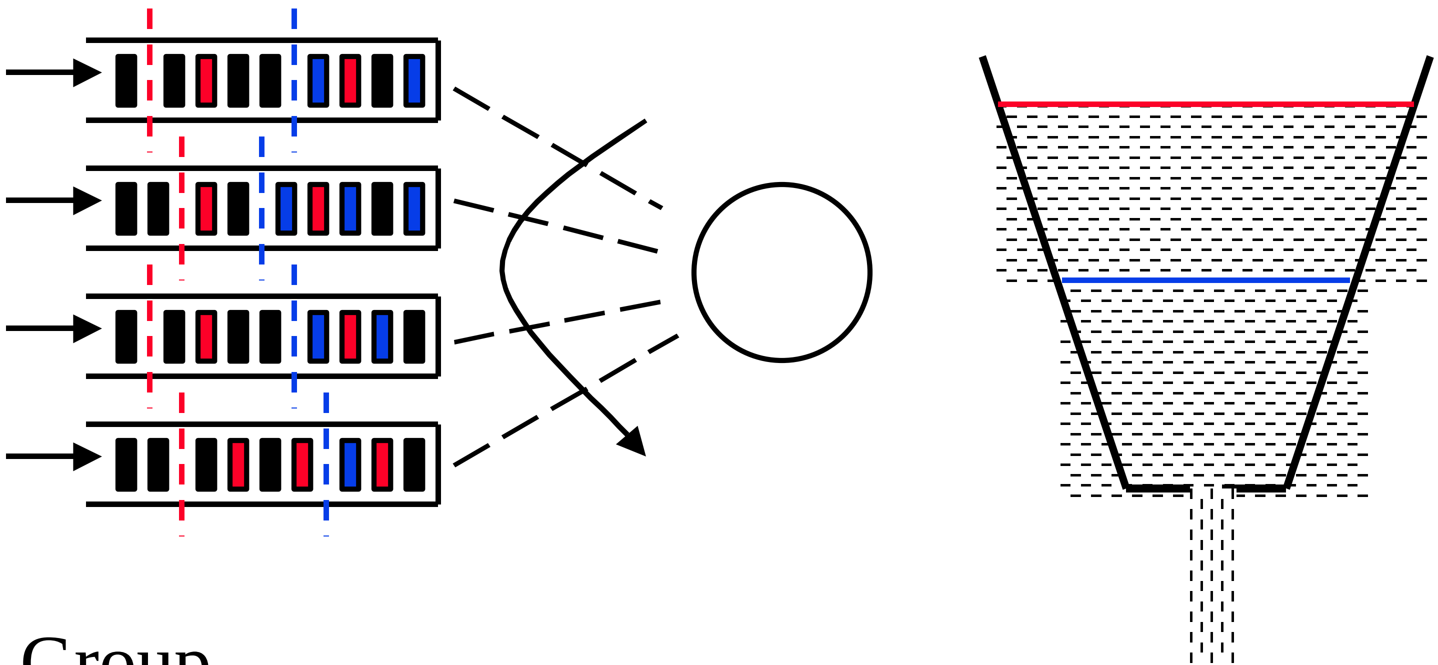
Ver	Hdr Len	Precedence	ToS	Unused	Tot Len
4b	4b	3b	4b	1b	16b

- IPv4: 3-bit precedence + 4-bit ToS
- Many vendors use IP precedence bits but the service varies ⇒ Need a standard ⇒ Differentiated Services
- DS working group formed February 1998
- Charter: Define ds byte (IPv4 ToS field)
- Per-Hop Behavior: Externally Observable Forwarding Behavior, e.g., x% of link bandwidth, or priority

Expedited Forwarding

- Also known as "Premium Service"
- Virtual leased line
- Similar to CBR
- Guaranteed minimum service rate
- Policed: Arrival rate < Minimum Service Rate
- Not affected by other data PHBs
  $\Rightarrow$ Highest data priority (if priority queueing)

Assured Forwarding



- PHB Group
- Four Classes: Decreasing weights in WFR/WFQ
- Three drop preference per class
  (one rate and two bucket sizes)

Problems with DiffServ

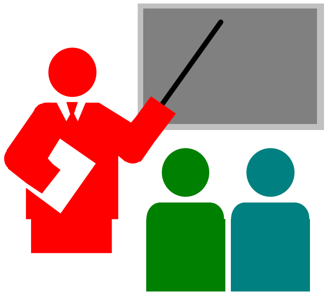
- per-hop $\Rightarrow$ Need at every hop
  One non-DiffServ hop can spoil all QoS
- End-to-end $\neq \Sigma$ per-Hop
  Designing end-to-end services with weighted guarantees at individual hops is difficult.
  Only EF will work.
- QoS is for the aggregate not micro-flows.
  Not intended/useful for end users. Only ISPs.
  - Large number of short flows are better handled by aggregates.

DiffServ Problems (Cont)

   - Long flows (voice and video sessions) need per-flow guarantees.
   - High-bandwidth flows (1 Mbps video) need per-flow guarantees.
- All IETF approaches are open loop control $\Rightarrow$ Drop.
  Closed loop control $\Rightarrow$ Wait at source
  Data prefers waiting $\Rightarrow$ Feedback
- Guarantees $\Rightarrow$ Stability of paths
  $\Rightarrow$ Connections (hard or soft)
  Need route pinning or connections.

Traffic Engineering Using MPLS

- Traffic Engineering = Performance Optimization
  = Efficient resource allocation, Path splitting
  ⇒ Maximum throughput, Min delay, min loss
  ⇒ Quality of service
- In MPLS networks: “Traffic Trunks” = SVCs
  Traffic trunks are routable entities like VCs
- Multiple trunks can be used in parallel to the same egress.
- Each traffic trunk can have a set of associated characteristics, e.g., priority, preemption, policing, overbooking



Summary

- Traffic management distinguishes ATM from its competition.
- ABR pushes congestion to edges. Good for wide area.
- MPOA combines LAN Emulation and NHRP and avoids the need for routers in ATM networks
- MPLS adds switching to IP packets and may be used for traffic engineering
- Integrated Services/RSVP have scalability problems
- Usefulness of Differentiated Services for QoS remains to be proven.
- References: See http://www.cis.ohio-state.edu/~jain/

Thank You!

References

- References on ATM: http://www.cis.ohio-state.edu/~jain/refs/atm_refs.htm
- ATM Standards: http://www.cis.ohio-state.edu/~jain/refs/atmf_ref.htm
- References on IP Switching: http://www.cis.ohio-state.edu/~jain/refs/ipsw_ref.htm
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