Recent Trends in Networking Including ATM and Its Traffic Management and QoS

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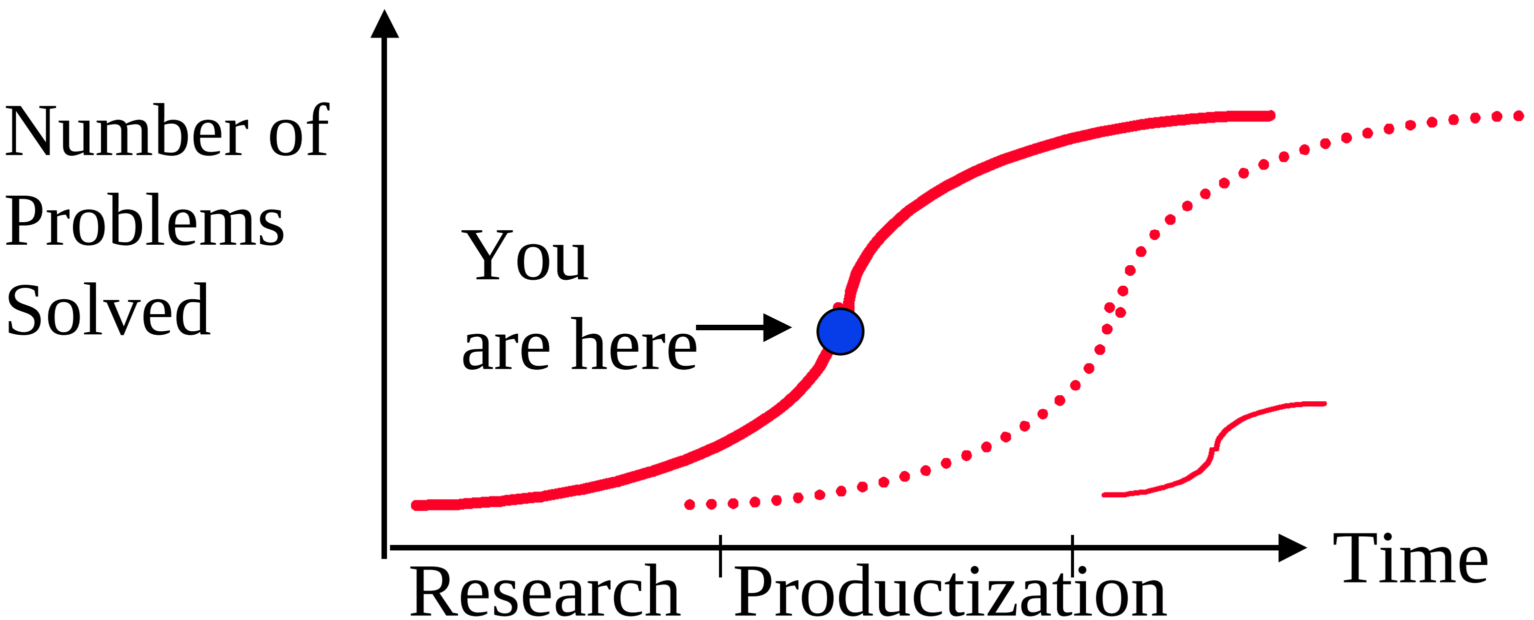
- Networking and Telecommunications Trends
- Why ATM?
- Traffic Management in ATM: ABR Vs UBR
- Quality of Service in IP:
  Integrated services/RSVP/Differentiated Services/MPLS

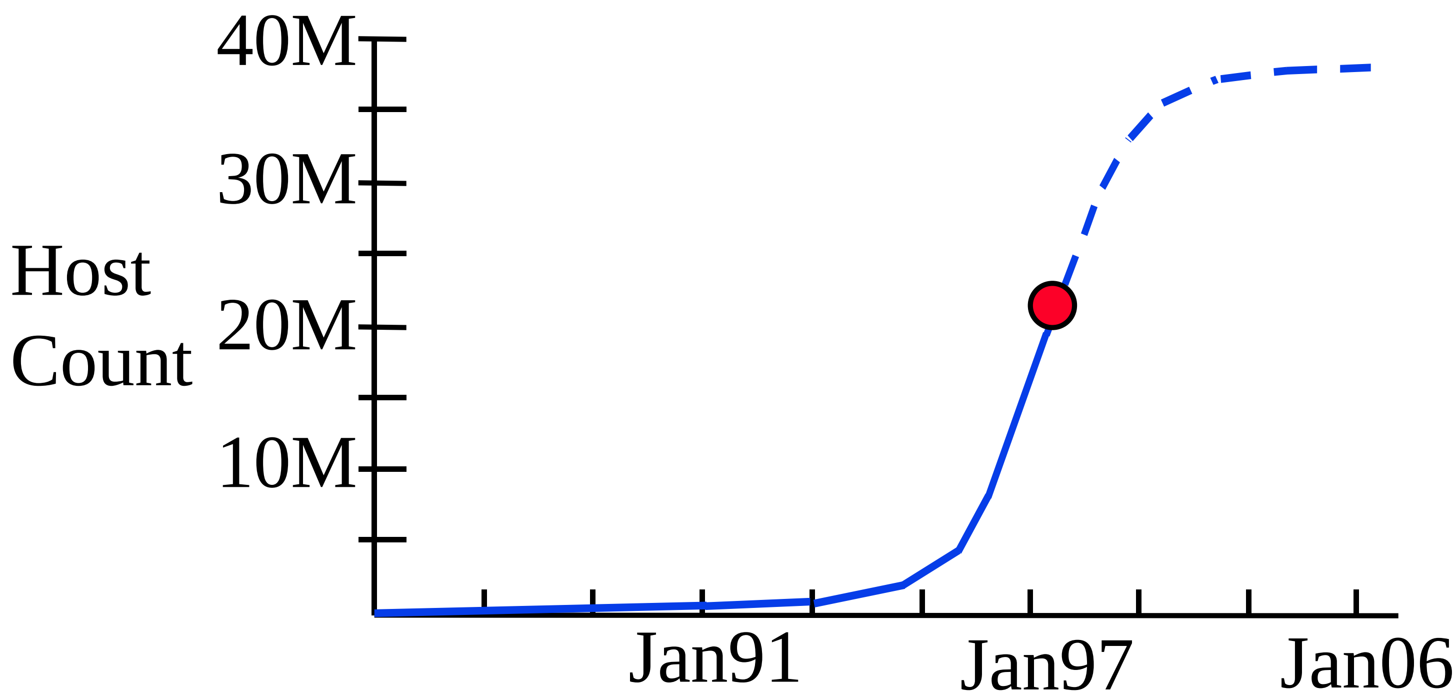
Computing vs Communication

- 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.

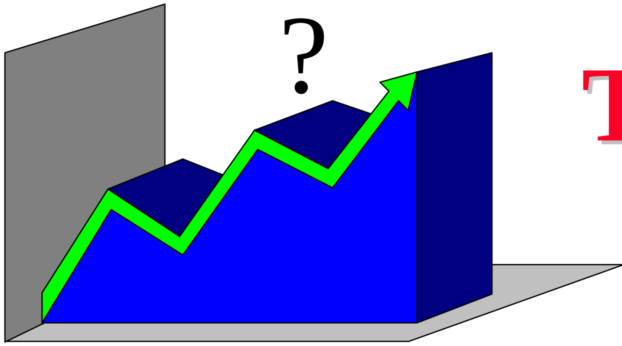
Life Cycles of Technologies



Internet Technology



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



Trend: Standards Based Networking

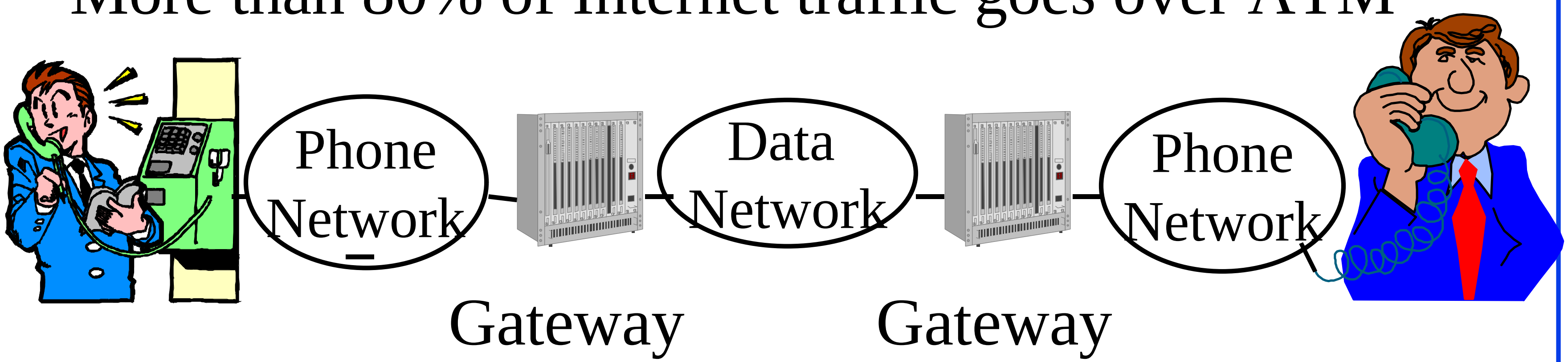
- Too much growth in one year
  $\Rightarrow$ Long term = 1_2 year or 10_2 years at most
- Distance between research and products has narrowed
  $\Rightarrow$ Collaboration between researchers and developers
  $\Rightarrow$ Academics need to participate in industry consortia
- Standards based networking for reduced cost
  $\Rightarrow$ Important to participate in standardization forums
  ATM Forum, Frame Relay Forum, ITU …
  Internet Engineering Task Force (IETF),
  Institute of Electrical and Electronic Engineers (IEEE)

Networking Trends

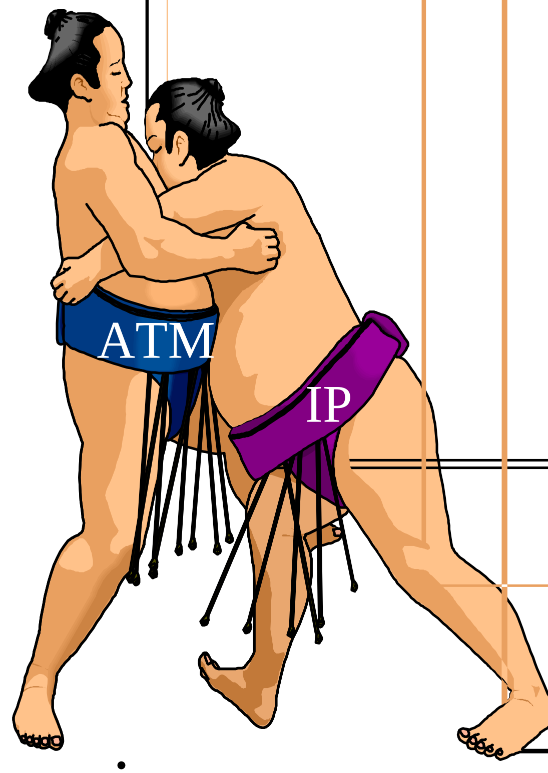
1. Inter-Planetary Networks $\Rightarrow$ Distances are increasing
2. WDM OC-768 Networks = 39.8 Gb/s
   $\Rightarrow$ Bandwidth is increasing
   $\Rightarrow$ Large Bandwidth-Delay Product Networks
3. Copper is still in. Fiber is being postponed.
   6-27 Mbps on phone wire.
   1999: Gigabit Ethernet 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



Why ATM?



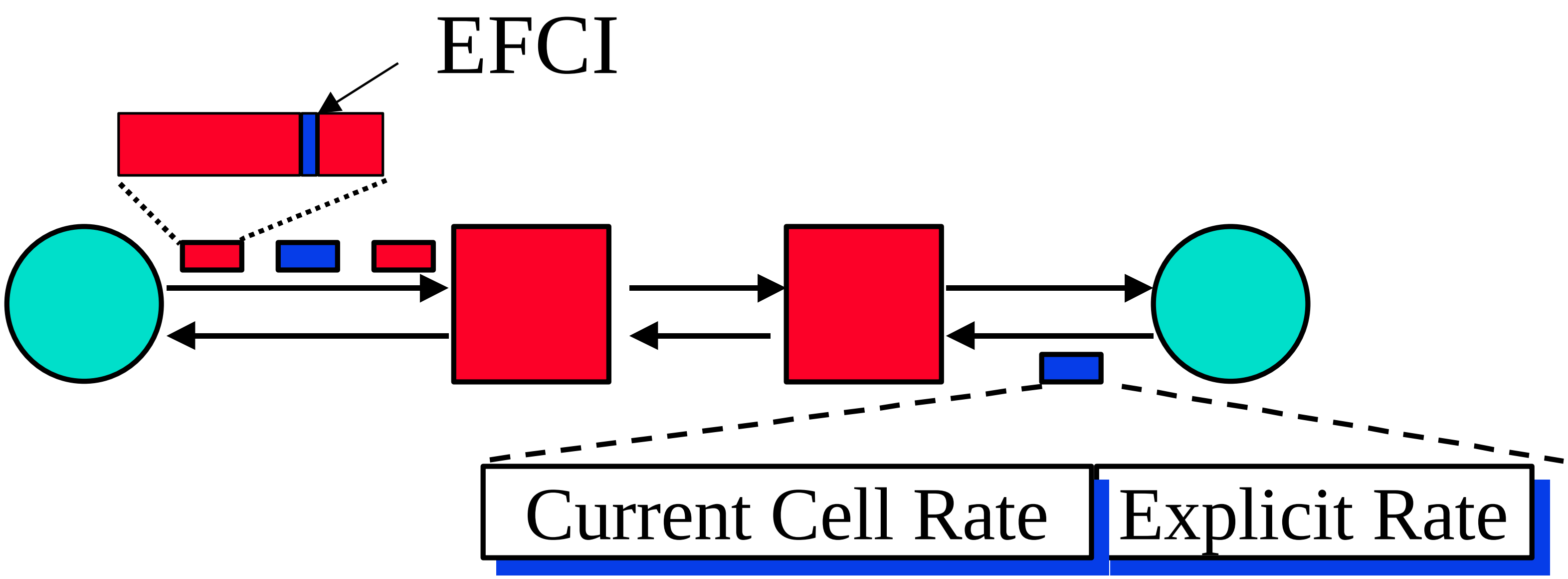
ATM vs IP: Key Distinctions

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

Service Categories

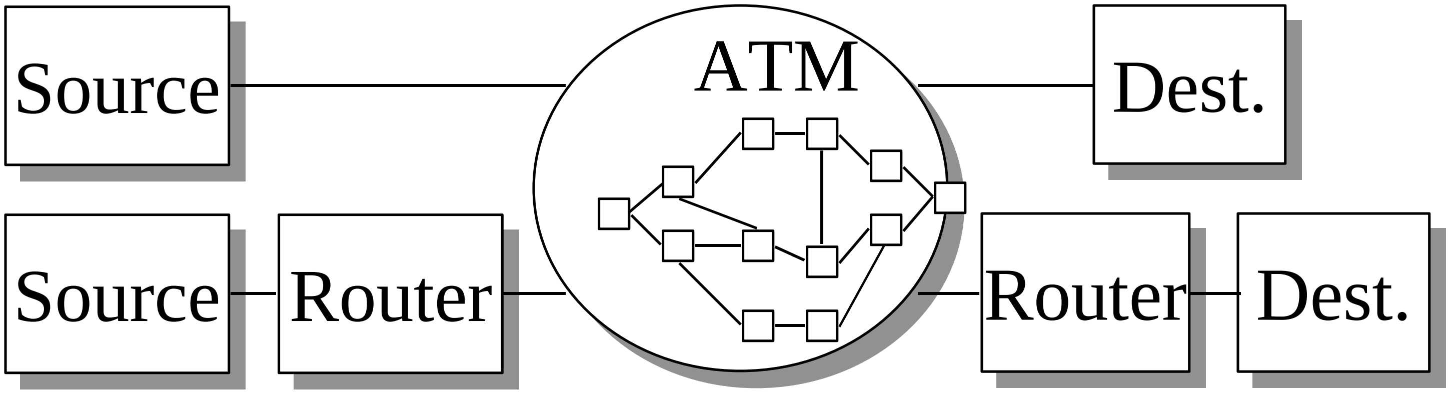
- ABR (Available bit rate):
  Source follows network feedback.
  Max throughput with minimum loss.
- UBR (Unspecified bit rate):
  User sends whenever it wants. No feedback. No guarantee. Cells may be dropped during congestion.
- CBR (Constant bit rate): User declares required rate. Throughput, delay 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.

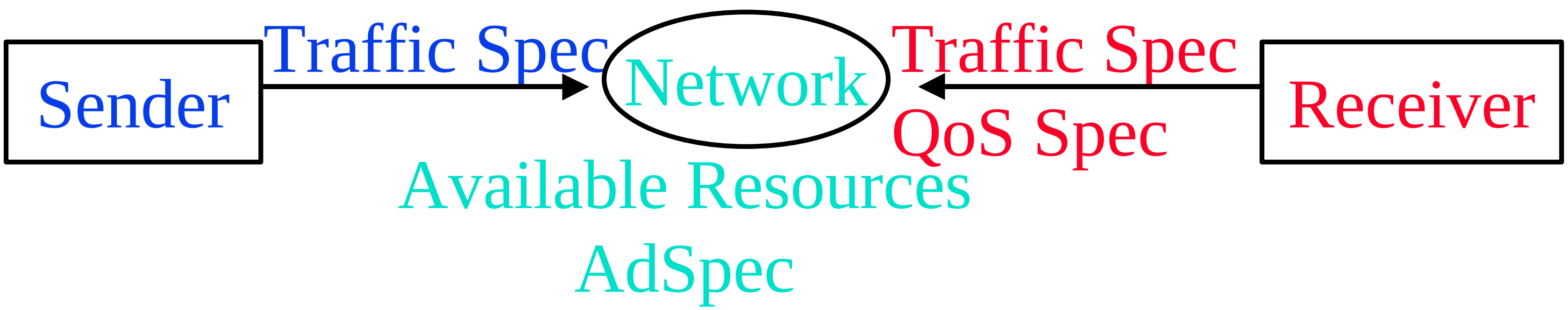
ABR vs UBR



ABR	**UBR**
Queue in the source	Queue in the network
Pushes congestion to edges	No backpressure
If ATM not end-to-end: intelligent Q mgmt in routers	Same end-to-end or backbone
Works for all protocols	Works with TCP

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



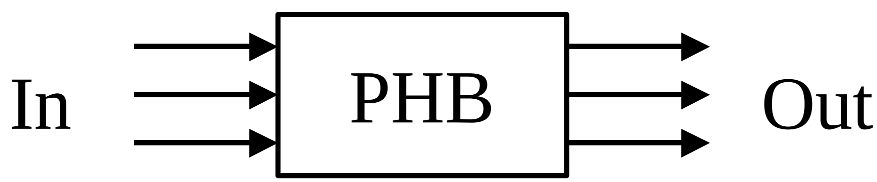
Problems with RSVP and Integrated Services

- Complexity: Packet classification, Scheduling
- Scalable in number of receivers per flow but
  Per-Flow State: O(n) $\Rightarrow$ Not scalable with # of flows.
  Number of flows in the backbone may be large.
  $\Rightarrow$ 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

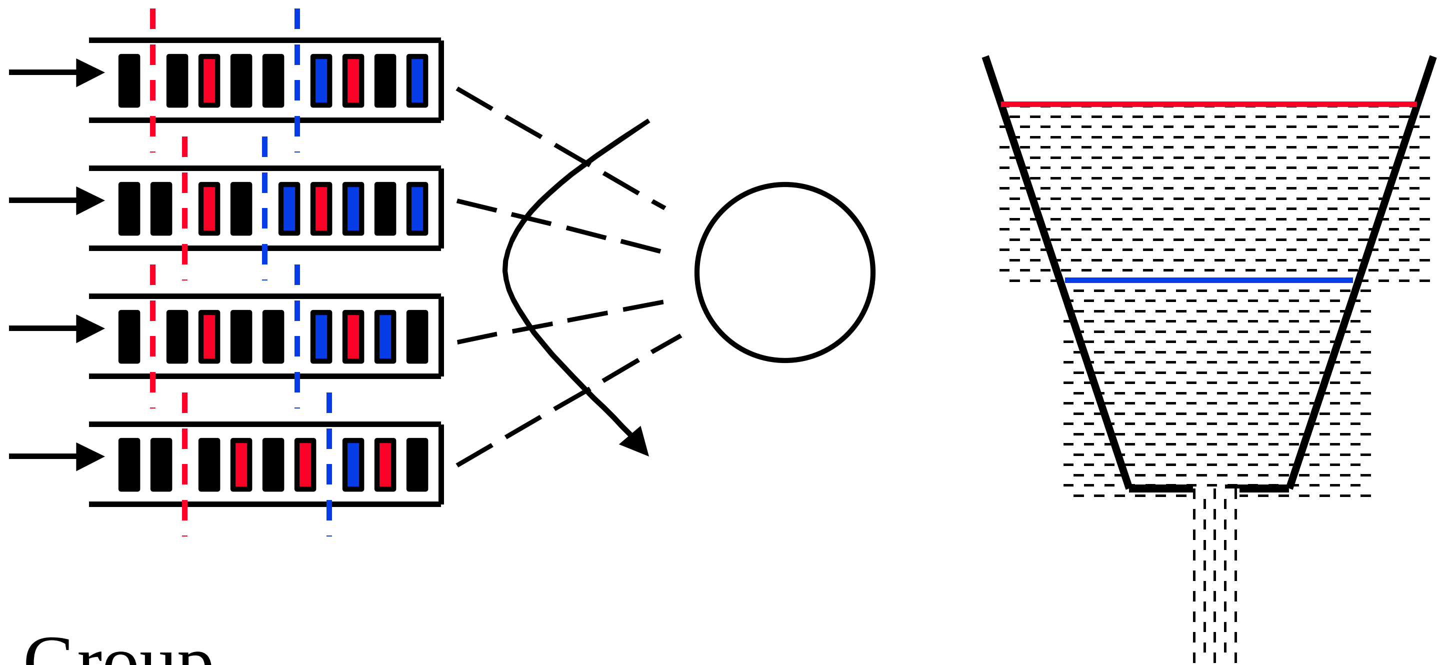
- IPv4: 3-bit precedence + 4-bit ToS
- Many vendors use IP precedence bits but the service varies ⇒ Need a standard ⇒ Differentiated Services
- DS working group formed February 1998
- Charter: Define ds byte (IPv4 ToS field)
- Per-Hop Behavior: Externally Observable Forwarding Behavior, e.g., x% of link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

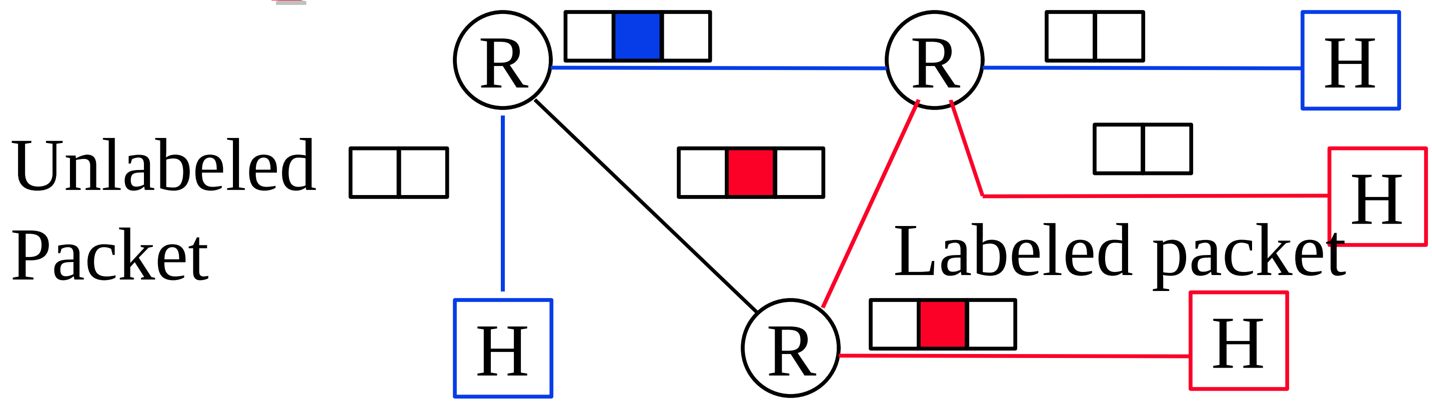
- per-hop $\Rightarrow$ Need at every hop
  One non-DiffServ hop can spoil all QoS
- End-to-end $\neq \Sigma$ per-Hop
  Designing end-to-end services with weighted guarantees at individual hops is difficult.
  Only EF will work.
- QoS is for the aggregate not micro-flows.
  Not intended/useful for end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

Multiprotocol Label Switching

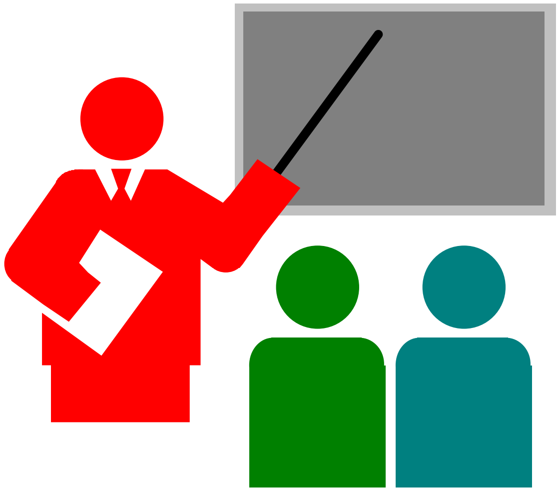


- Entry "label switch router (LSR)" attaches a label to the packet based on the route
- Other LSRs switch packets based on labels. Do not need to look inside $\Rightarrow$ Fast.
- Labels have local significance $\Rightarrow$ Different label at each hop (similar to VC #)
- Exit LSR strips off the label

Traffic Engineering Using MPLS

- Traffic Engineering = Performance Optimization
  = Efficient resource allocation, Path splitting
  $\Rightarrow$ Maximum throughput, Min delay, min loss
  $\Rightarrow$ 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



- Networking is the key to productivity
- Traffic management distinguishes ATM from its competition
- ABR pushes congestion to edges.
  UBR+ may be OK for LANs but need ABR for large bandwidth-delay paths.

Summary (Cont)

- Multiple drop preferences does not help data (TCP) or Voice/Video
- Voice/video need multiple leaky bucket rates for layered/scalable coding.
- Need additivity or mathematical aggregatability.
  CBR (EF) should be the first step for IP.
- Start with throughput guarantees.
  Fair allocation of excess throughput should be next.
  Delay is automatic with isolation.
- Excess allocation is useful with closed loop.
  Network/application dynamics $\Rightarrow$ Need closed loop

References

- References on Networking History and Trends: http://www.cis.ohio-state.edu/~jain/refs/ref_trnd.htm
- References on QoS over IP: http://www.cis.ohio-state.edu/~jain/refs/ipqs_ref.htm
- A tutorial talk on "QoS in IP Networks," May 1998, http://www.cis.ohio-state.edu/~jain/talks/ipqos.htm
- A follow up talk on "IP End-to-end Quality of Service: Recent Solutions and Issues," December 1998, http://www.cis.ohio-state.edu/~jain/talks/ipqos2.htm