Quality of Service In Data Networks: Problems, Solutions, and Issues

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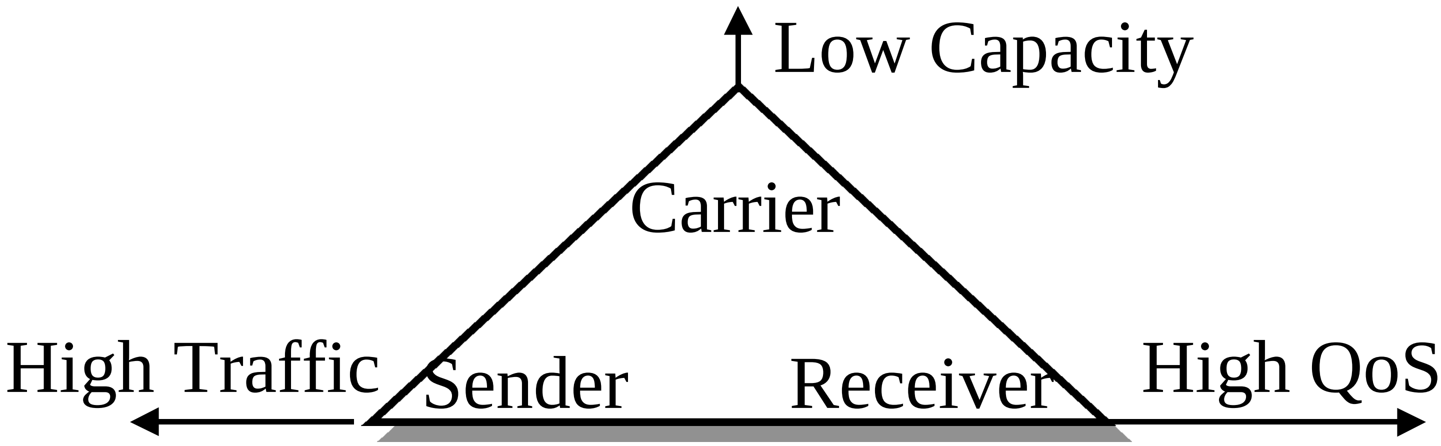
These slides are available at
http://www.cis.ohio-state.edu/~jain/talks/qos9906.ht

- ATM QoS and Issues
- Integrated services/RSVP and Issues
- Differentiated Services and Issues
- QoS using MPLS
- End-to-end QoS
- This is an update to the May'98 talk
http://www.cis.ohio-state.edu/~jain/talks/ipqos.htm

QoS Triangle



- Senders want to send traffic any time with high load, high burstiness
- Receivers expect low delay and high throughput
- Since links are expensive, providers want to minimiz the infrastructure
- If one of the three gives in ⇒ no problem

What is QoS?

Predictable Quality: Throughput, Delay, Loss, Delay jitter, Error rate

Opposite of best effort = Random quality

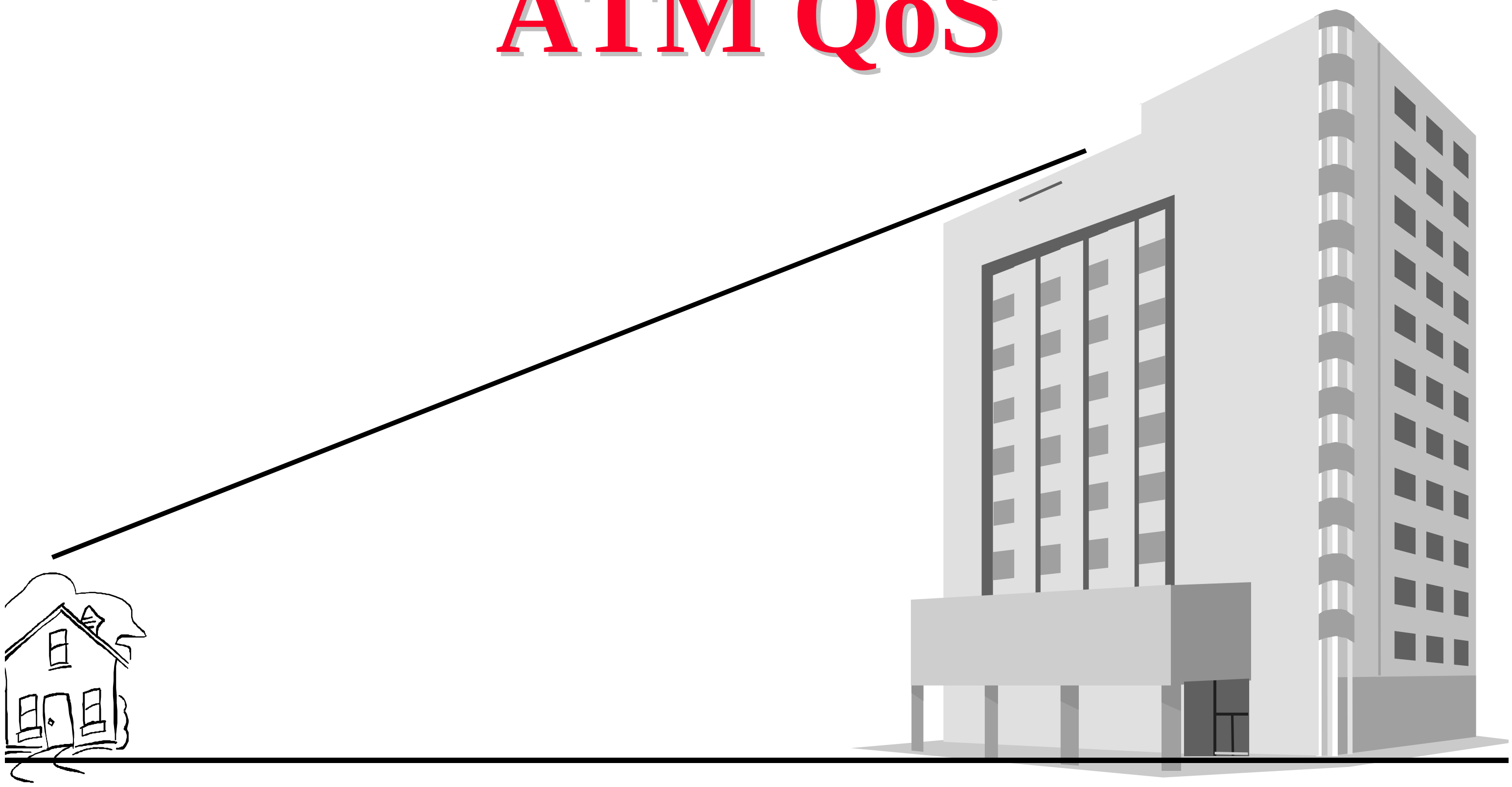
Mechanisms:

- Capacity Planning
- Classification, Queueing, Scheduling, buffer management
- QoS based path determination, Route pinning
- Shaping, policing, admission control
- Signaling

ATM Service Categories

- **CBR**: Throughput, delay, delay variation
- **rt-VBR**: Throughput, delay, delay variation
- **nrt-VBR**: Throughput
- **UBR**: No Guarantees
- **GFR**: Minimum Throughput
- **ABR**: Minimum Throughput. Very low loss. Feedback.
- ATM also has QoS-based routing (PNNI)

ATM QoS



Today ATM

Too much too soon

ATM QoS: Issues

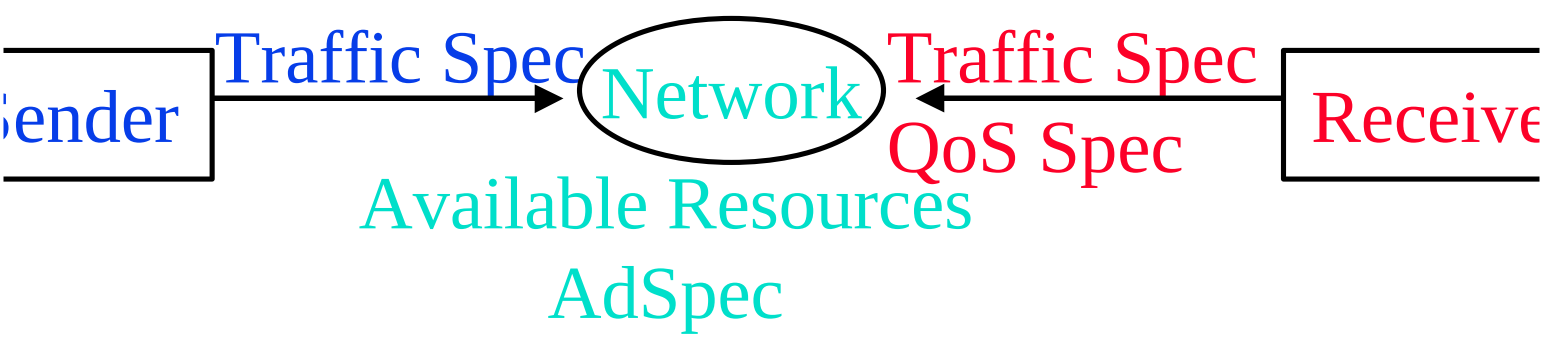
- Can’t easily aggregate QoS: VP = Σ VCs
- Can’t easily specifiy QoS: What is the CDV require for a movie?
- Signaling too complex ⇒ Need Lightweight Signali
- Need Heterogeneous Point-to-Multipoint: Variegated VCs
- Need QoS Renegotiation
- Need Group Address
- Need priority or weight among VCs to map DiffServ and 802.1D

Integrated Services

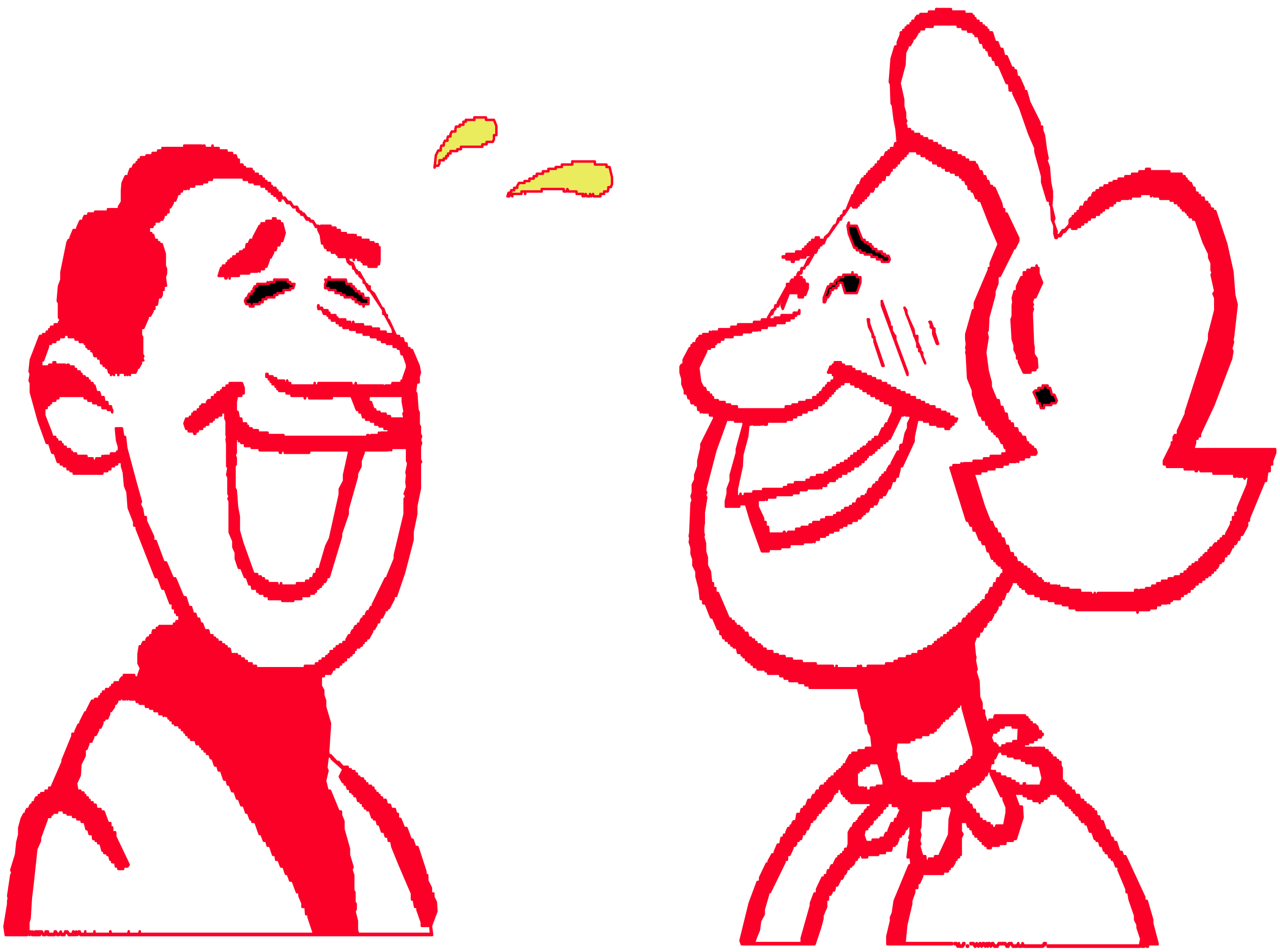
- Best Effort Service: Like UBR.
- Controlled-Load Service: Performance as good as in an unloaded datagram network. No quantitative assurances. Like nrt-VBR or UBR w MCR
- Guaranteed Service: rt-VBR
  - Firm bound on data throughput and delay.
  - Delay jitter or average delay not guaranteed or minimized.
  - Every element along the path must provide delay bound.
  - Is not always implementable, e.g., Shared Ethernet
  - Like CBR or rt-VBR

RSVP

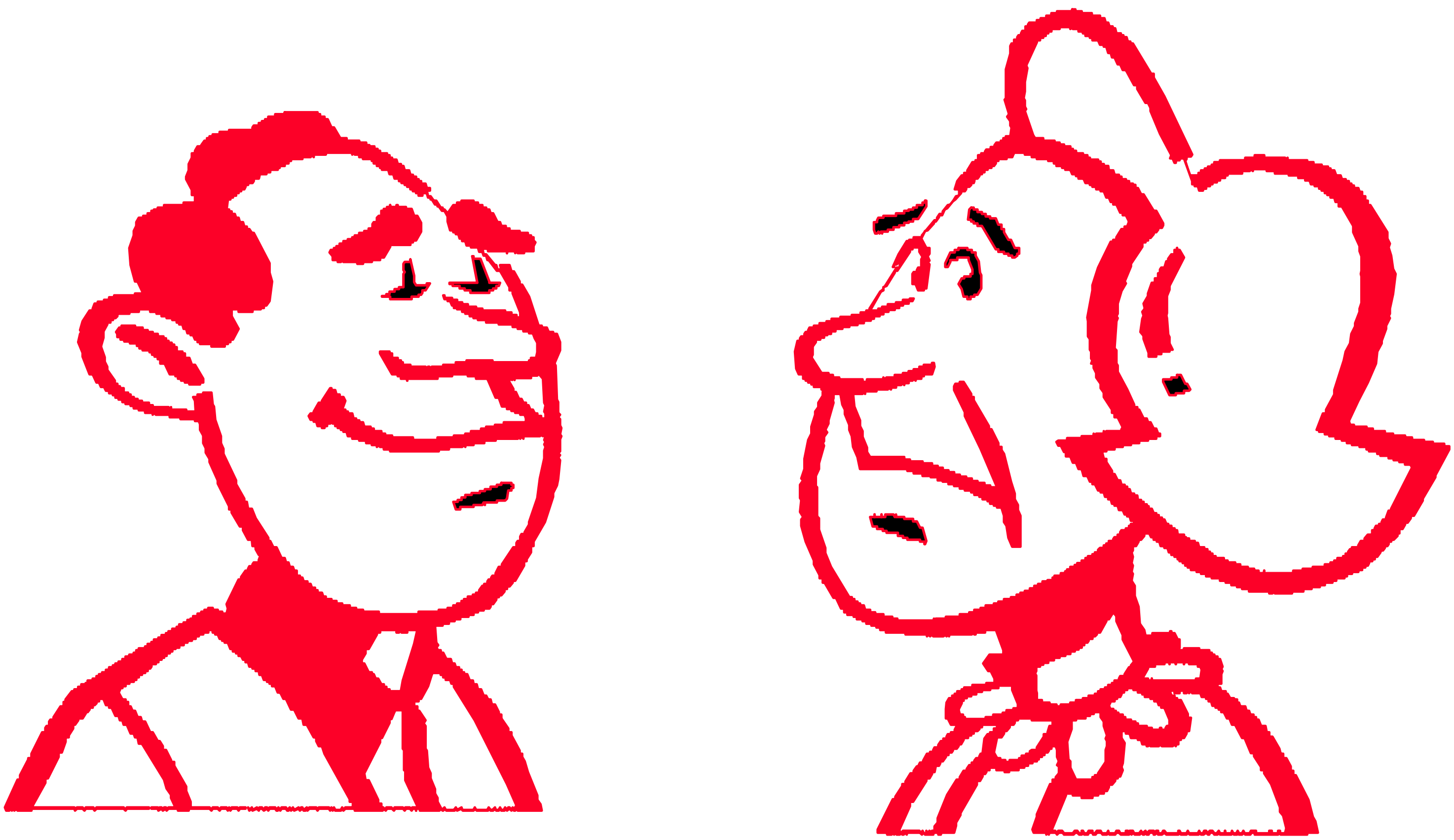
- Resource ReSerVation Protocol
- Internet signaling protocol
- Carries resource reservation requests through the network including traffic specs, QoS specs, network resource availability
- Sets up reservations at each hop



Before



After



roblems with RSVP and Integrated Services

Complexity in routers: packet classification, scheduling

Scalable in number of receivers per flow but

Per-Flow State: O(n) ⇒ Not scalable with # of flow

Number of flows in the backbone may be large.

⇒ Suitable for small private networks

Need a concept of “Virtual Paths” or aggregated flov groups for the backbone

Need policy controls: Who can make reservations?

Support for accounting and security.

⇒ RSVP admission policy (rap) working group.

Problems (Cont)

- Receiver Based:
  - Need sender control/notifications in some cases.
  - Which receiver pays for shared part of the tree?
- Soft State: Need route/path pinning (stability).
- Limit number of changes during a session.
- RSVP does not have negotiation and backtracking
- Throughput and delay guarantees require support of lower layers. Shared Ethernet ⇒ IP can't do GS or CLS. Need switched full-duplex LANs.
- Can't easily do RSVP on ATM either
- Most of these arguments also apply to integrated services.

Differentiated Services

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

Pv4: 3-bit precedence + 4-bit ToS

SPF and integrated IS-IS can compute paths for ea
oS

any vendors use IP precedence bits but the service
aries ⇒ Need a standard ⇒ Differentiated Service

S working group formed February 1998

harter: Define ds byte (IPv4 ToS field)

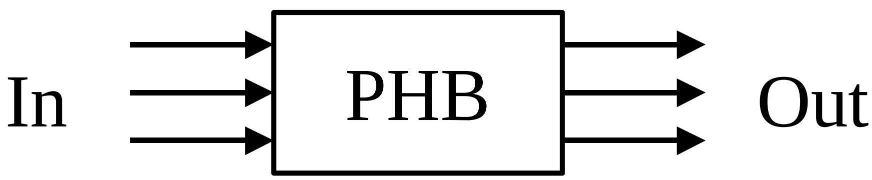
ail Archive: http://www-nrg.ee.lbl.gov/diff-serv-arch/

Service

Service: Offered by the protocol layer

- Application: Mail, FTP, WWW, Video,...
- Transport: Delivery, Express Delivery,...
  Best effort, controlled load, guaranteed service
- DS group will not develop services
  They will standardize "Per-Hop Behaviors"

Per-hop Behaviors

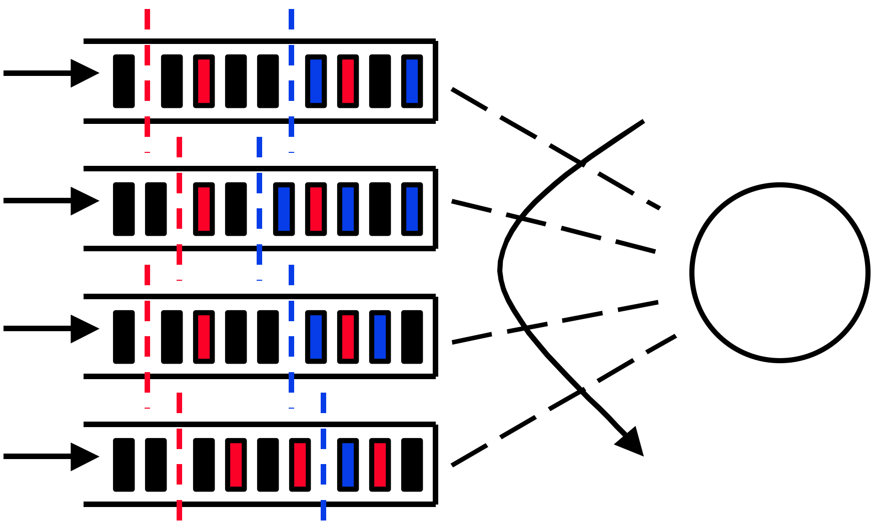


- Externally Observable Forwarding Behavior
- x% of link bandwidth
- Minimum x% and fair share of excess bandwidth
- Priority relative to other PHBs
- PHB Groups: Related PHBs. PHBs in the group sha
  common constraints, e.g., loss priority, relative dela

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
  ⇒ Highest data priority (if priority queueing)
- Code point: 101 110

Assured Forwarding



- PHB Group
- Four Classes: No particular ordering
- Three drop preference per class

Assured Forwarding (Cont)

-)S nodes SHOULD implement all 4 classes ınd MUST accept all 3 drop preferences. Can mplement 2 drop preferences.
- ;imilar to nrt-VBR/ABR/GFR
- :ode Points:

Drop Prec.	Class 1	Class 2	Class 3	Class 4
Low	010 000	011 000	100 000	101 00
Medium	010 010	011 010	100 010	101 01
High	010 100	011 100	100 100	101 10

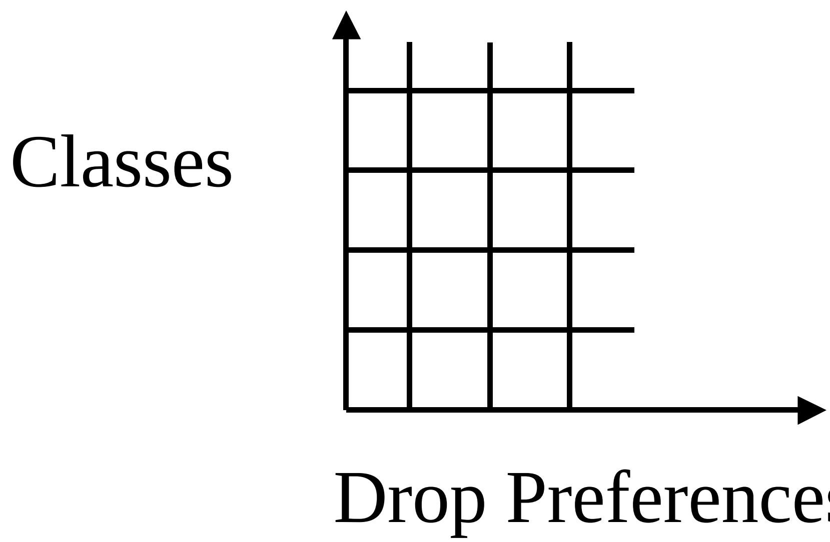
- Avoids 11x000 (used for network control)

AF Simulation Results

- W/O DPs, TCP is punished for good behaviour
- Fairness is also poor.
- Three DPs give better performance for TCP flows when there is considerable unused bandwidth.
- ason: TCP does not get any share of excess bandwic n presence of UDP.

erence: M. Goyal, et al, "Effect of Number of Drop Precedences in Assured Forwarding," IETF draft-goyal-dpstc liffserv-00.txt, March+July 1999, http://www.cis.ohio-tate.edu/~jain/ietf/dpstdy2.htm

On Drop Preferences



/Ve have two dimensions of control

- Classes = Queues
- Drop Preferences = Right to enter the queue

Classes ⇒ Directly controls bandwidth allocation

Drop Preferences (Cont)

DPs ⇒ Controls buffer allocation
⇒ Indirectly affects bandwidth allocation

- Depends upon the arrival pattern
  ⇒ Random ⇒ Not Reliable

Given a limited number of PHB's, it is better to have
more classes than more DPs

Problems with DiffServ

ɔer-hop ⇒ Need at every hop

Ↄne non-DiffServ hop can spoil all QoS

Ǝnd-to-end ≠ Σ per-Hop

Ↄesigning end-to-end services with weighted ɡuarantees at individual hops is difficult.

Ↄnly EF will work.

Ↄesigned for static Service Level Agreements (SLA

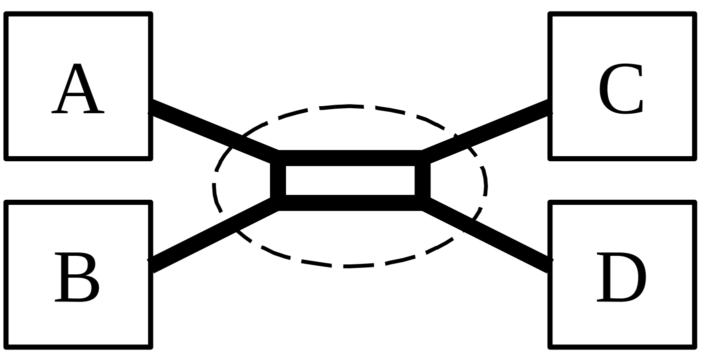
Ɜoth the network topology and traffic are highly ɭynamic.

Иulticast ⇒ Difficult to provision

Ↄynamic multicast membership ⇒ Dynamic SLAs?

DiffServ Problems (Cont)

-)iffServ is unidirectional ⇒ No receiver control
- Aodified DS field ⇒ Theft and Denial of service. ngress node should ensure.
- How to ensure resource availability inside the network?
- QoS is for the aggregate not per-destination. Multi-campus enterprises need inter-campus QoS.



DiffServ Problems (Cont)

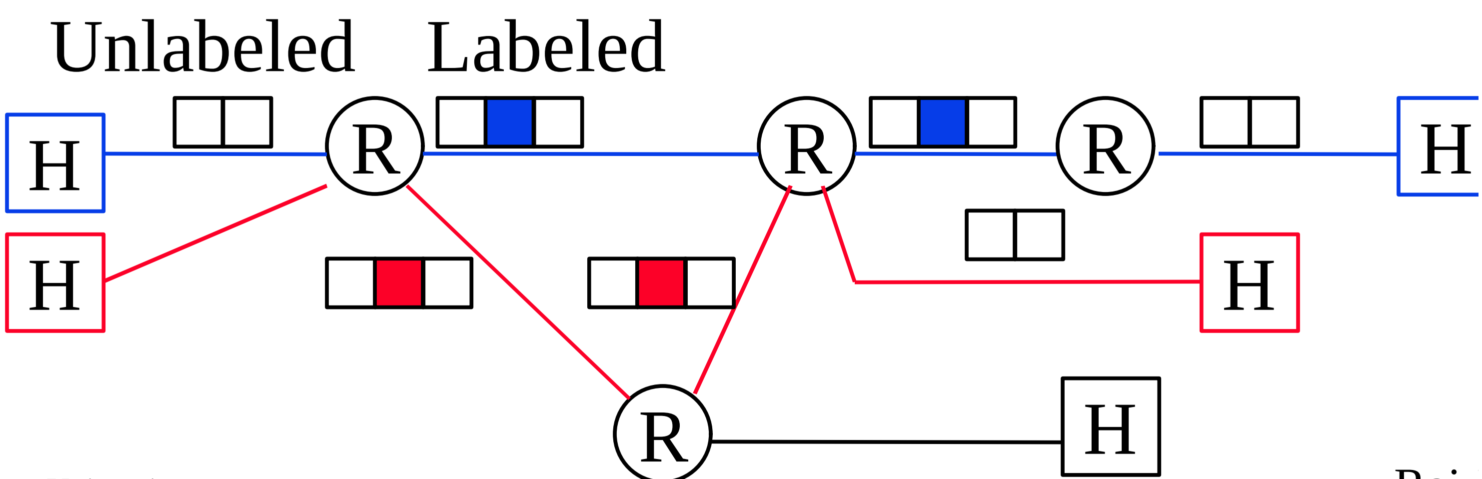
- QoS is for the aggregate not micro-flows.
- Not intended/useful for end users. Only ISPs.
  - Large number of short flows are better handled by aggregates.
  - Long flows (voice and video sessions) need per-flow guarantees.
  - High-bandwidth flows (1 Mbps video) need per-flow guarantees.
- All IETF approaches are open loop control ⇒ Drop
- Closed loop control ⇒ Wait at source
- Data prefers waiting ⇒ Feedback

DiffServ Problems (Cont)

- ℑuarantees $\Rightarrow$ Stability of paths
- $\Rightarrow$ Connections (hard or soft)
- Need route pinning or connections.

Multiprotocol Label Switching

- Label = Circuit number = VC Id
- Ingress router/host puts a label.
  Exit router strips it off.
- Switches switch packets based on labels.
  Do not need to look inside ⇒ Fast.



Traffic Engineering Objectives

Jser's Performance Optimization

⇒ Maximum throughput, Min delay, min loss, min lelay variation

Efficient resource allocation for the provider

⇒ Efficient Utilization of all links

⇒ Load Balancing on parallel paths

⇒ Minimize buffer utilization

- Current routing protocols (e.g., RIP and OSPF) find the shortest path (may be over-utilized).

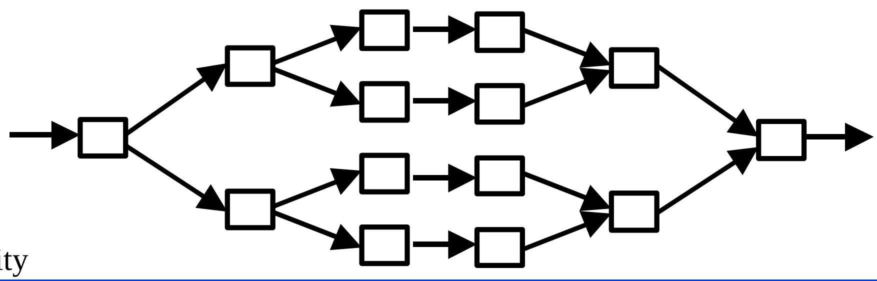
QoS Guarantee: Selecting paths that can meet QoS

Enforce Service Level agreements

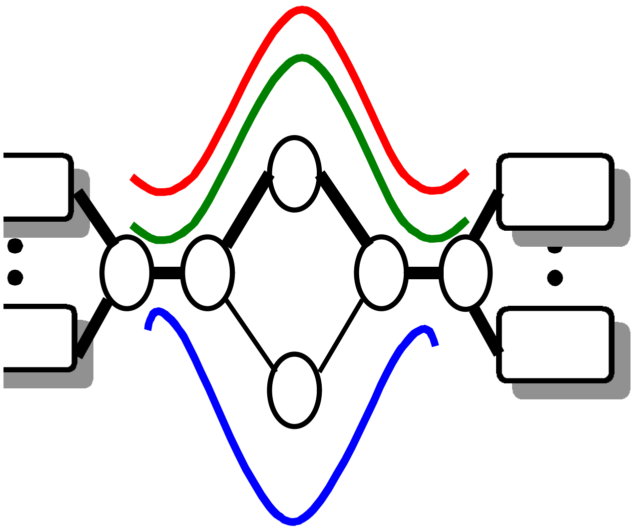
Enforce policies: Constraint based routing ⊇ QoSR

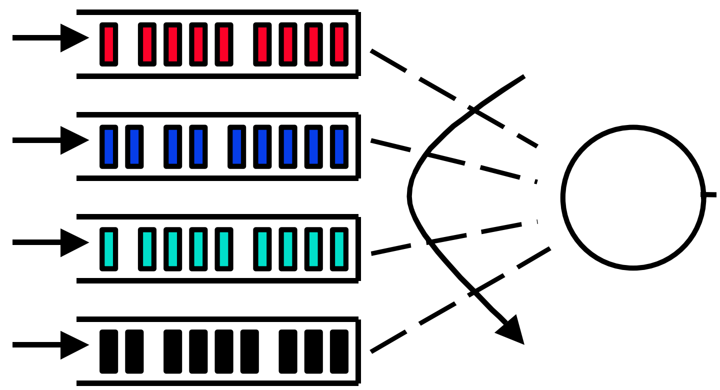
MPLS Mechanisms for TE

- ;ignaling, Admission Control, Routing
- :xplicit routing of LSPs
- :onstrained based routing of LSPs
  Allows both Traffic constraints and Resource :onstraints (Resource Attributes)
- Iierarchical division of the problem (Label Stacks)
- [raffic trunks allow aggregation and disaggregation Shortest path routing allows only aggregation)



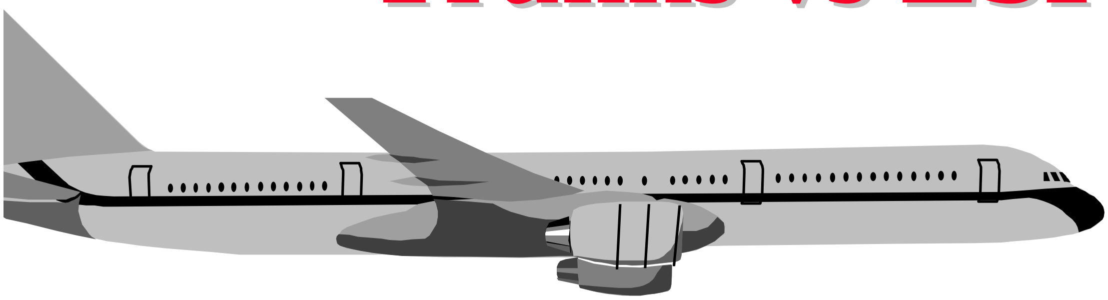
Traffic Trunks



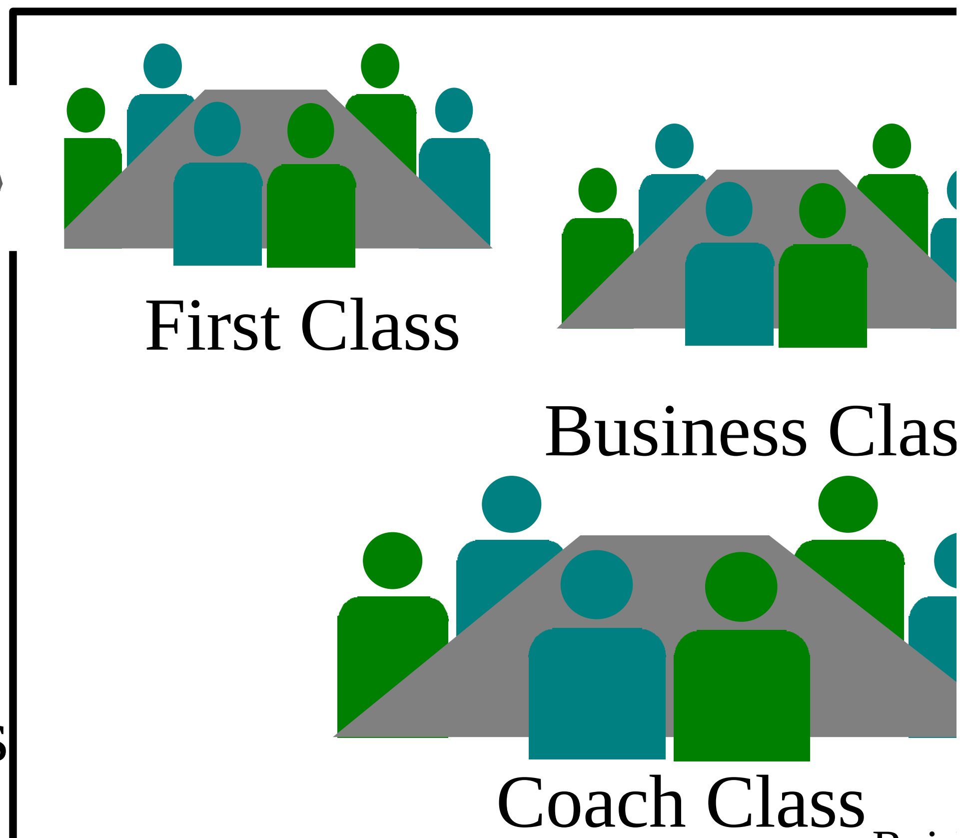


- Trunk: Aggregation of flows of same class on same
- Trunks are routable
- ⇒ LSP through which trunk passes can be changed
- Class ⇒ Queue, LSP ⇒ Next hop
- Class can be coded in Exp or Label field. Assume E

Trunks vs LSPs



our Group

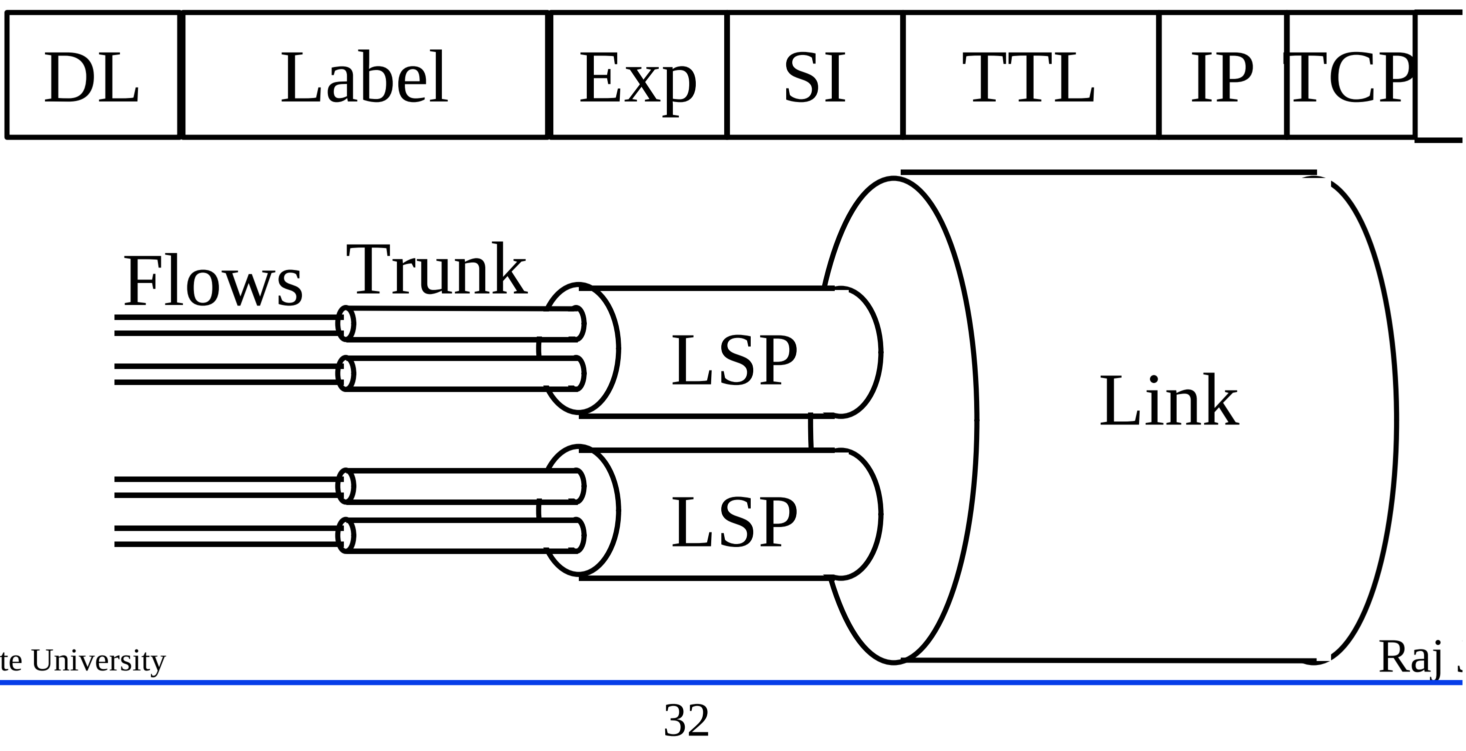


ghts = LSP

ur Groups = Trunks

lows, Trunks, LSPs, and Link

- abel Switched Path (LSP):
- ll packets with the same label
- runk: Same Label+Exp
- low: Same MPLS+IP+TCP headers



MPLS Simulation Results

Total network throughput improves significantly wit proper traffic engineering

Congestion-unresponsive flows affect congestion-responsive flows

- Separate trunks for different types of flows

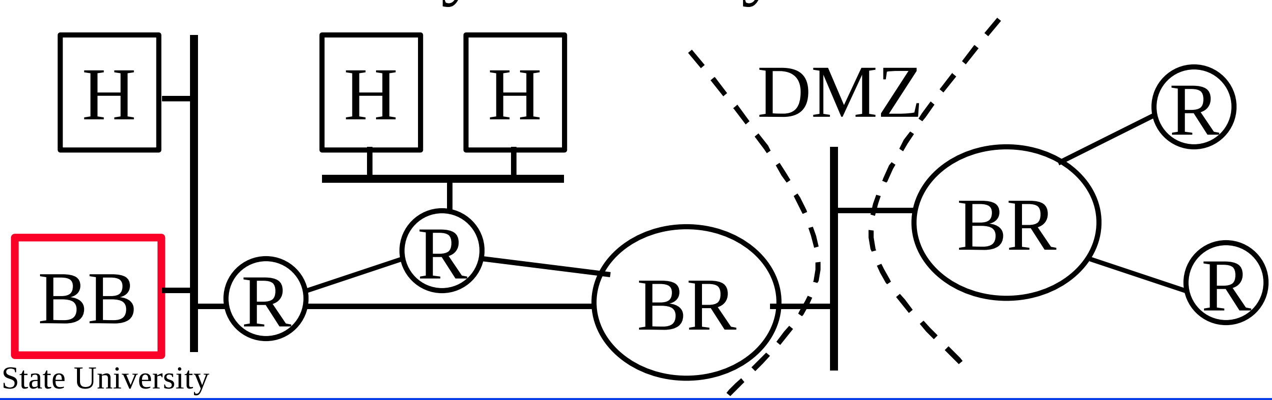
Trunks should be end-to-end

- Trunk + No Trunk = No Trunk

erence: P. Bhaniramka, et al, "*QoS using Traffic Engineerin over MPLS: An Analysis*," IETF draft-bhani-mpls-te-anal-00.txt, March 1999, http://www.cis.ohio-state.edu/~jain/teanal.htm

Bandwidth Broker

- Repository of policy database. Includes authenticatio
- Users request bandwidth from BB
- BB sends authorizations to leaf/border routers
  Tells what to mark.
- Ideally, need to account for bandwidth usage along t
  path
- BB allocates only boundary or bottleneck



IEEE 802.1D Model

est Addr	Src Addr	Tag Prot ID	Pri	CFI	VLAN

← 802.1Q header →

Prot Type	Payload	FC

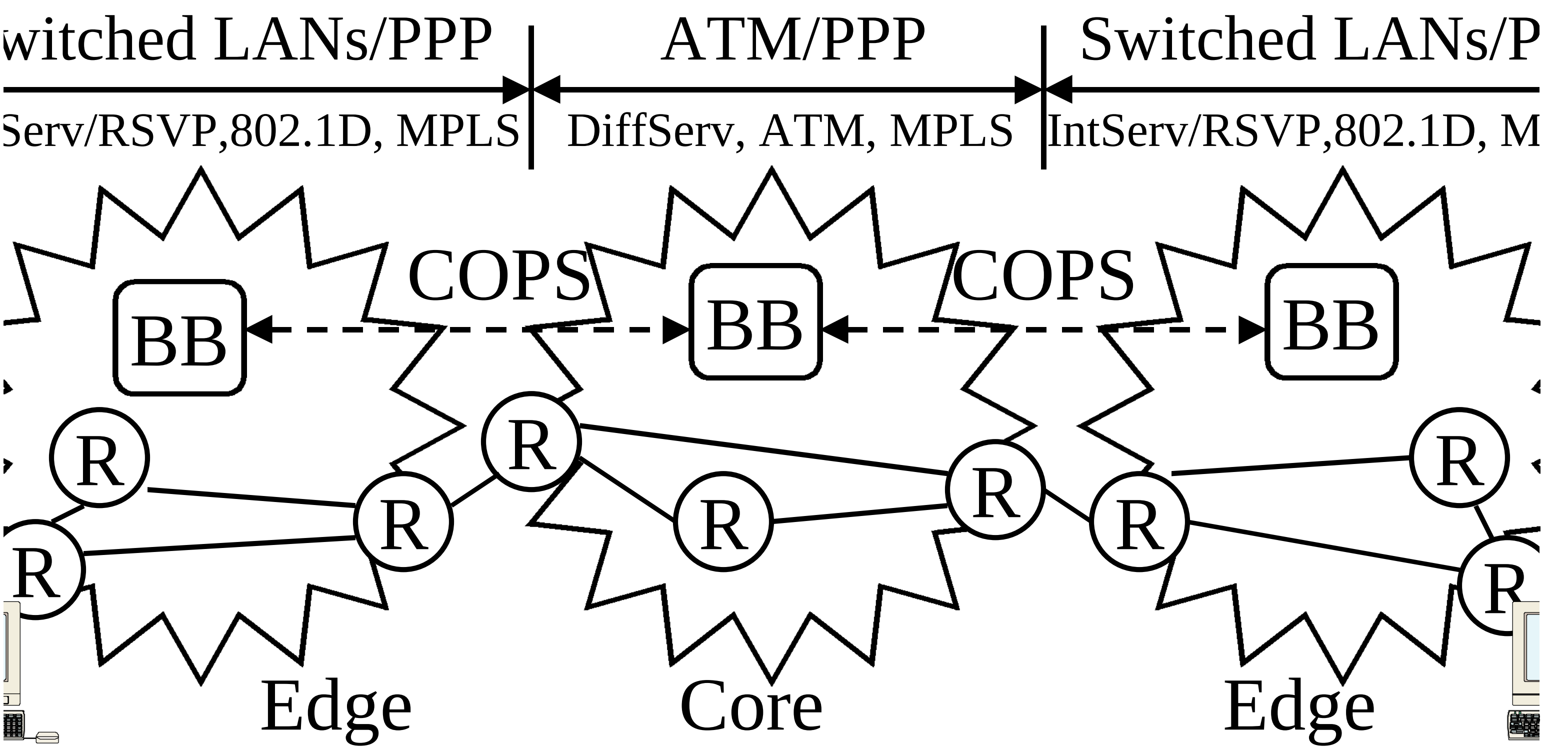
= Canonical Format
icator (Source Routing)

Jp to eight priorities: Strict.

1 Background
2 Spare
0 Best Effort
3 Excellent Effort
4 Control load
5 Video (Less than 100 ms latency and jitter)
6 Voice (Less than 10 ms latency and jitter)
7 Network Control

End-to-end View

- ATM/PPP backbone, Switched LANs/PPP in Stub
- IntServ/RSVP, 802.1D, MPLS in Stub networks
- DiffServ, ATM, MPLS in the core



QoS Debate Issues

- Massive Bandwidth vs Managed Bandwidth
- Per-Flow vs Aggregate
- Source-Controlled vs Receiver Controlled
- Soft State vs Hard State
- Path based vs Access based
- Quantitative vs Qualitative
- Absolute vs Relative
- End-to-end vs Per-hop
- Static vs Feedback-based
- One-way multicast vs n-way multicast
- Homogeneous multicast vs heterogeneous multicast
- Single vs multiple bottlenecks: Scheduling

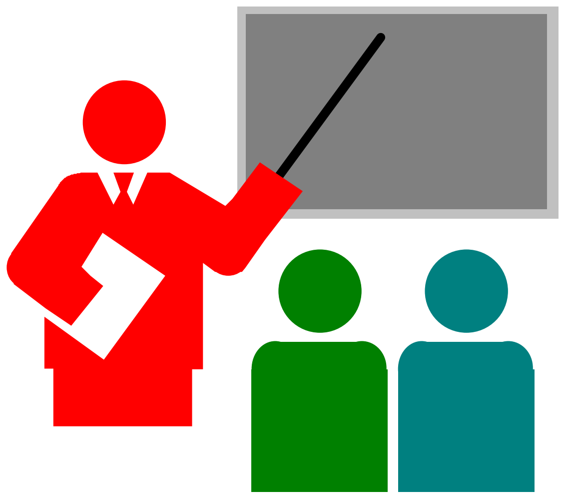
Comparison of QoS Approaches

ue	ATM	IntServ	DiffServ	MPLS	IEEE 802.3D
assive Bandwidth Managed ndwidth	Managed	Managed	Massive	Managed	Massive
r-Flow vs ggregate	Both	Per-flow	Aggregate	Both	Aggrega
urce-Controlled Receiver ontrolled	Unicast Source, Multicast both	Receiver	Ingress	Both	Source
ft State vs Hard ate	Hard	Soft	None	Hard	Hard
th based vs ccess based	Path	Path	Access	Path	Access
antitative vs alitative	Quantitativ e	Quantitativ e+Qualitati ve	Mostly qualitative	Both	Qualitati
solute vs Relative	Absolute	Absolute	Mostly Relative	Absolute plus relative	Relative

Comparison (Cont)

sue	ATM	IntServ	DiffServ	MPLS	IEEE 802.3D
d-to-end vs Per-p	e-e	e-e	Per-hop	e-e	Per-hop
atic vs Feedback-sed	Both	Static	Static	Static	Static
ne-way multicast n-way multicast	Only one-way				
omogeneous ulticast vs terogeneous ulticast	Homogeneous	Heterogeneous	N/A	Homogeneous	N/A
ngle vs multiple ttlenecks: heduling	Multiple bottleneck	Multiple		Multiple	

Summary



- ATM: CBR, VBR, ABR, UBR, GFR
- Integrated Services: GS = rtVBR, CLS = nrt-VBR
- Signaling protocol: RSVP
- Differentiated Services will use the DS byte
- MPLS allows traffic engineering and is most promis
- 802.1D allows priority

References

For a detailed list of references see:
refs/ipqs_ref.htm

Additional papers and presentations on QoS are at:
http://www.cis.ohio-state.edu/~jain/

Thank You!