Internet QoS: IntServ and DiffServ

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- Per-Flow IntServ
- Per-Class DiffServ
- End-to-End Service Architecture I : DiffServ Customer and ISP
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- QoS Traffic Control for IntServ and DiffServ

IETF Working Groups on QoS

- Integrated Services (IntServ) Working Group

  per-flow state and processing
- RSVP Working Group

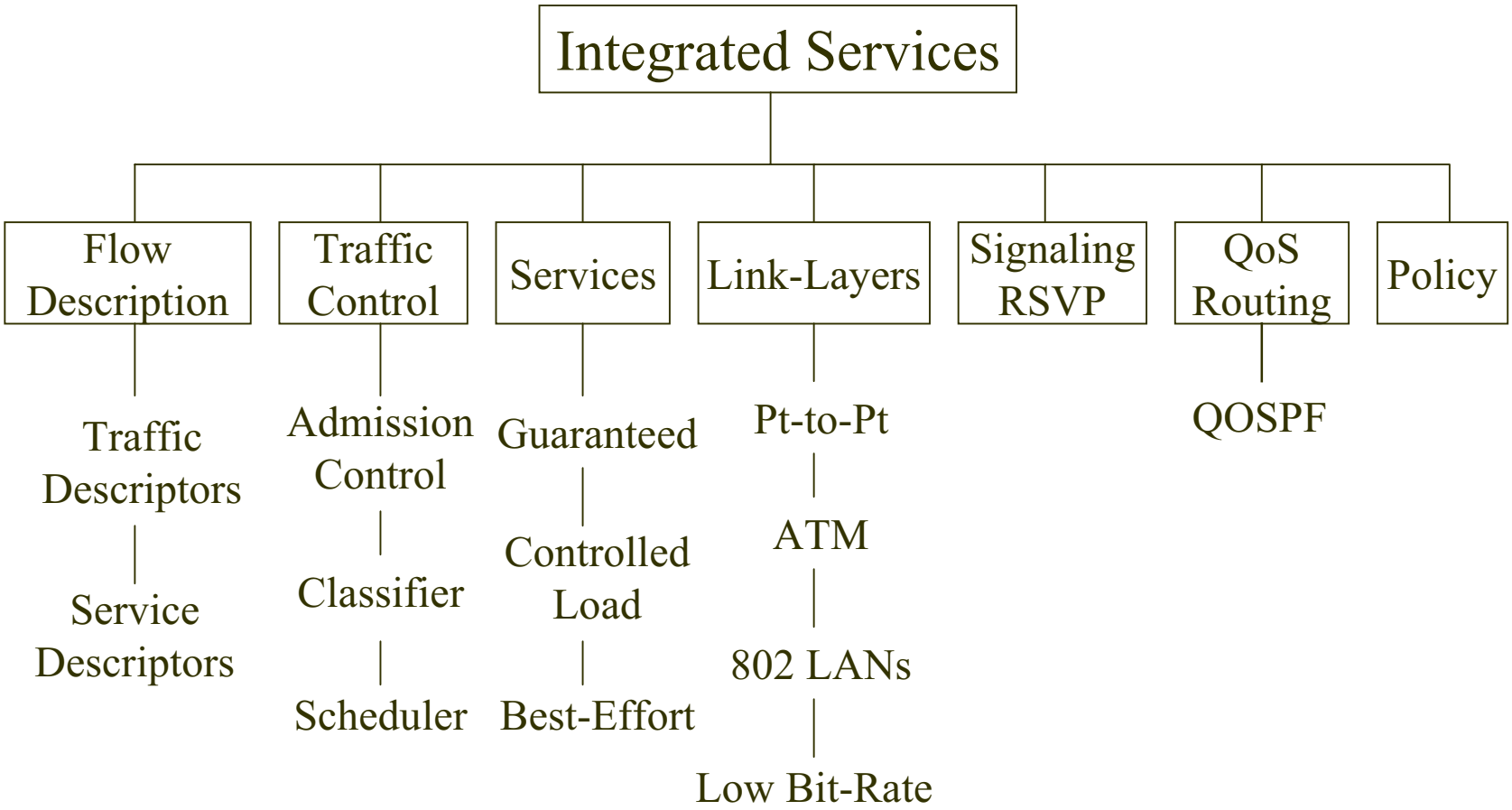
  signaling for resource reservation
- Differentiated Services (DiffServ) Working Group

  per-class state and processing

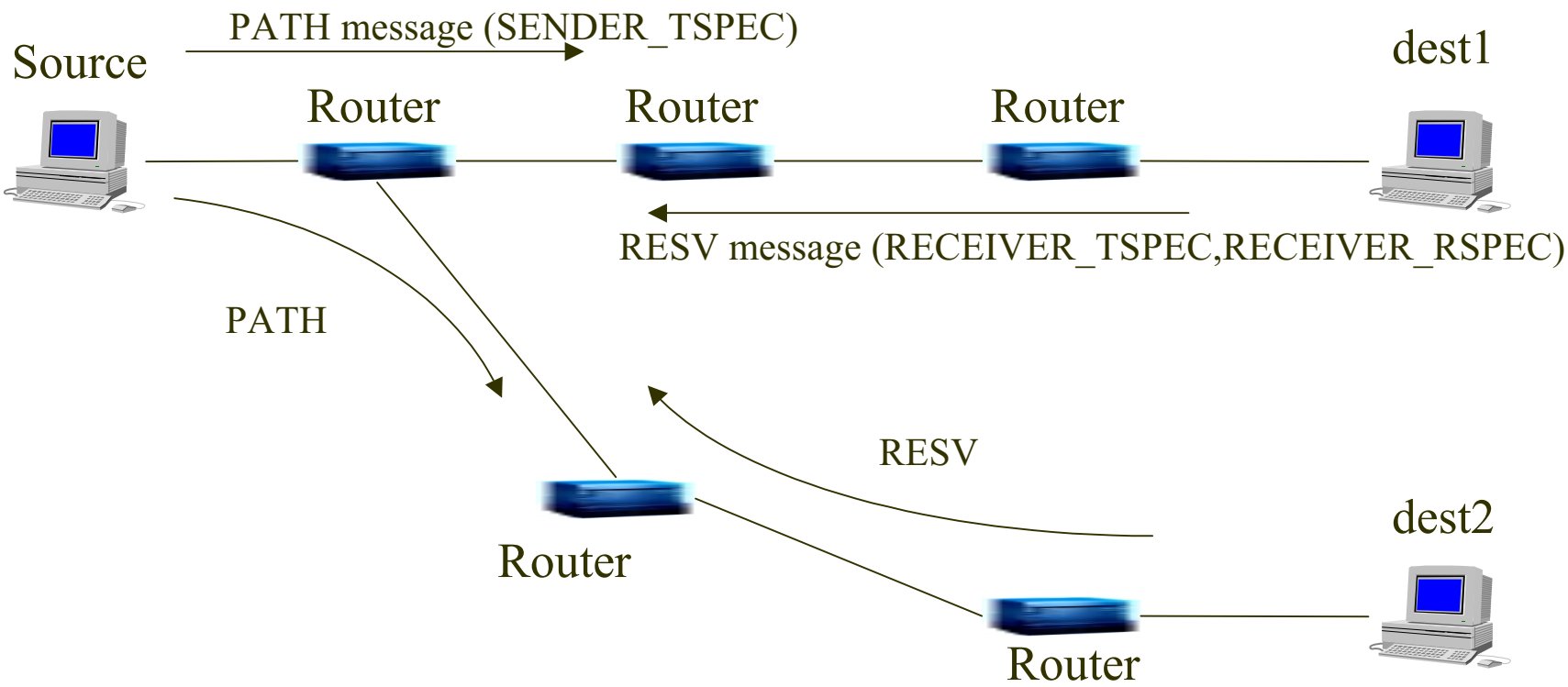
IntServ vs DiffServ

	IntServ	DiffServ	Best-Effort
Granularity of QoS	Per-flow	Per-class	None (fair to all)
Services	Guaranteed (quantitative) Controlled Load (qualitative)	Expedited Forwarding (quantitative) Assured Forwarding (qualitative)	"best-effort"
Resource Allocation	Dynamic	Static or Dynamic	None
Signaling	RSVP (for host/router)	RSVP (for host) RSVP/LDAP/COPS (for bandwidth broker) None for core router	None
Classification	Multi-field at host/router	Multi-field at the edge, DS-field at the core	None
Control	At host/router	Marking at the edge, queue mngt at the core	FIFO only
Complexity	High	Medium	Low

IntServ Elements



RSVP Signaling
(Resource Reservation Protocol)

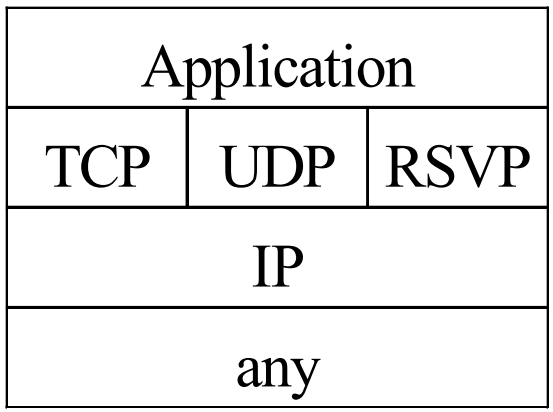


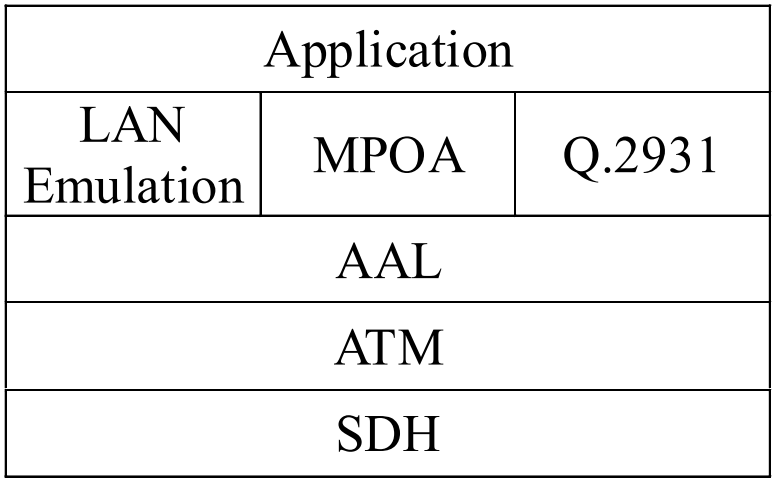
Characteristics of RSVP

- Source characterization using leaky bucket
  - Soft-state resource reservation from reverse direction
  - Separate routing and admission control (hop by hop)
- RSVP issues:
  - Per-flow state overhead and poor scalability
  - Not suitable for short-lived sessions
  - QoS routing support preferred

RSVP vs ATM Q.2931 (1/2)

- **Model:**





RSVP vs ATM Q.2931 (2/2)

- **Features**

RSVP	ATM Q.2931
Connectionless	Connection-oriented
Flow	Call
Soft state reservation	Hard state reservation
Receiver-initiated reservation	Sender-initiated reservation
Receiver-heterogeneity allowed (heterogeneous multicast possible)	Receiver heterogeneity not allowed (homogeneous multicast only)
No QoS routing so far (can work with RIP/OSPF, emerging QOSPF)	QoS PNNI/Phase 1 routing
Separate routing and admission control	Concurrent routing and admission control

- **Services**

RSVP	ATM Q.2931
Best-effort Guaranteed Controlled Load	**Constant Bit Rate Variable Bit Rate Unspecified Bit Rate Available Bit Rate**

Flow Description

Filterspec	Flowspec	
	Tspec	Rspec
•Identify which flow a packet belongs to (for classifier)	• Leaky Bucket para： p: peak rate r: token rate b: bucket size m: minimum policed packet size M: maximum packet size (for scheduler and policer)	• QoS para： R: bandwidth s : slack term (for admission control and scheduler)

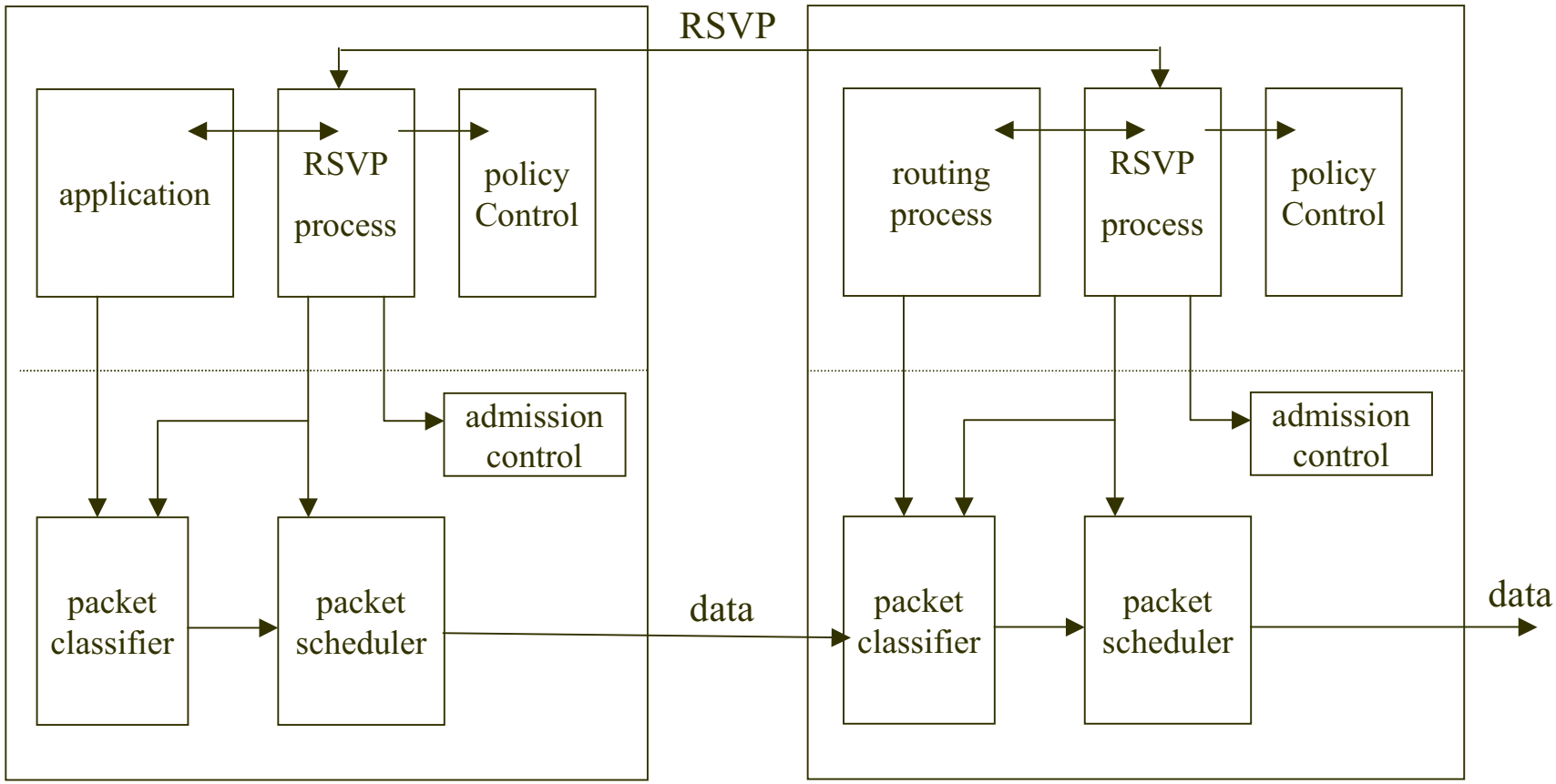
IntServ Services

	Guaranteed	Controlled Load	Best Effort
Parameters	Tspec Rspec	Tspec No Rspec	None
QoS	Delay bound No loss	Best-effort over uncongested network	None
Traffic control	Admission control Policing Scheduling	Admission control Policing Scheduling	FIFO scheduling
RFC	RFC 2212	RFC 2211	Many others

RSVP Traffic Control

- Admission control (Rspec, RSVP node state)
- Policing (Tspec)
- Classification (Tspec)
- Scheduling (Tspec, Rspec)
- QoS routing (Tspec, RSVP node state) (optional)
- Policy control (Tspec, Rspec, policy database) (optional)

RSVP-capable Host/Router



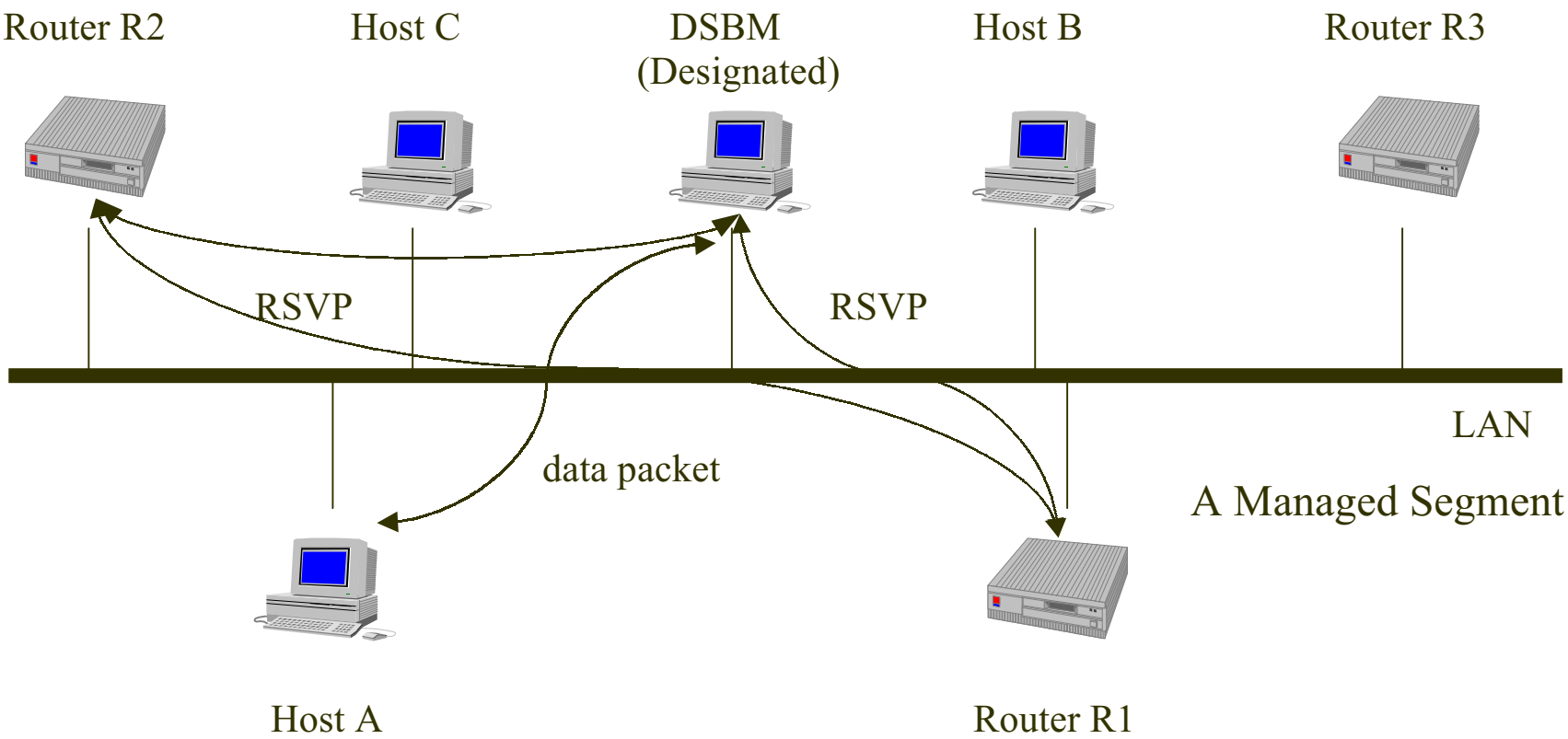
RSVP over Various Data Links

- RSVP over pt-to-pt (no extra problem)
- RSVP over ATM (parameter mapping, receiver heterogeneity, and VC management)
- RSVP over IEEE 802 LANs (SBM takes care of admission control and scheduling) (IEEE 802.1P VLAN Tag may be used)
- RSVP over low-bit rate links (Multi-class Multi-link PPP can fragment and queue packets)

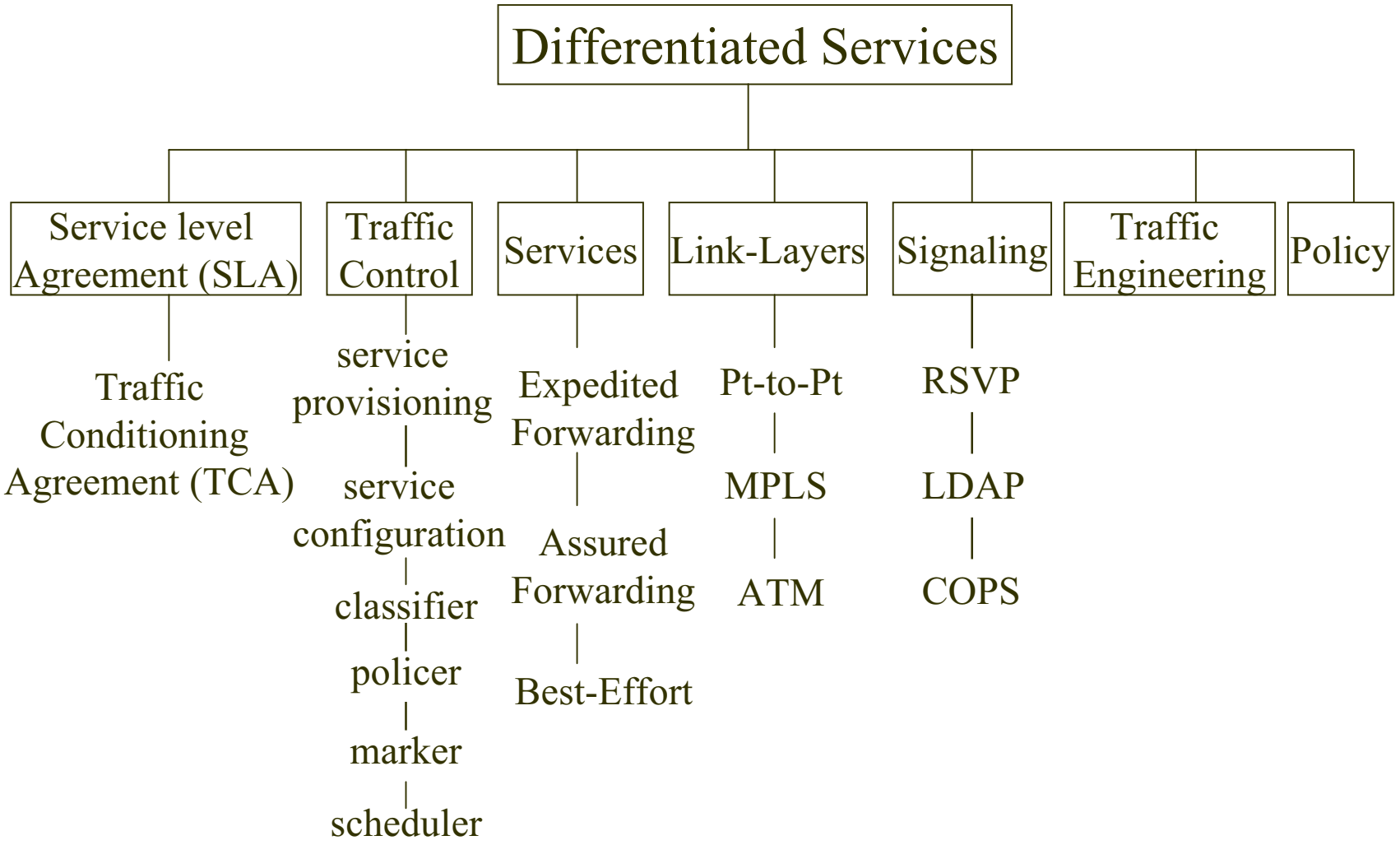
RSVP over ATM

- RSVP “rides on” ATM’s QoS
- RSVP RESV messages establish ATM switched path
  - ingress router establishes ATM SVC (upon RESV)
  - or “concatenated” SVCs to form a path
- Mapping from RSVP parameters to ATM Q.2931 parameters exists
- No heterogeneous multicast allowed
- VC management problems (soft/hard-state)

SBM (Subnet Bandwidth Manager): RSVP over IEEE 802 LANs



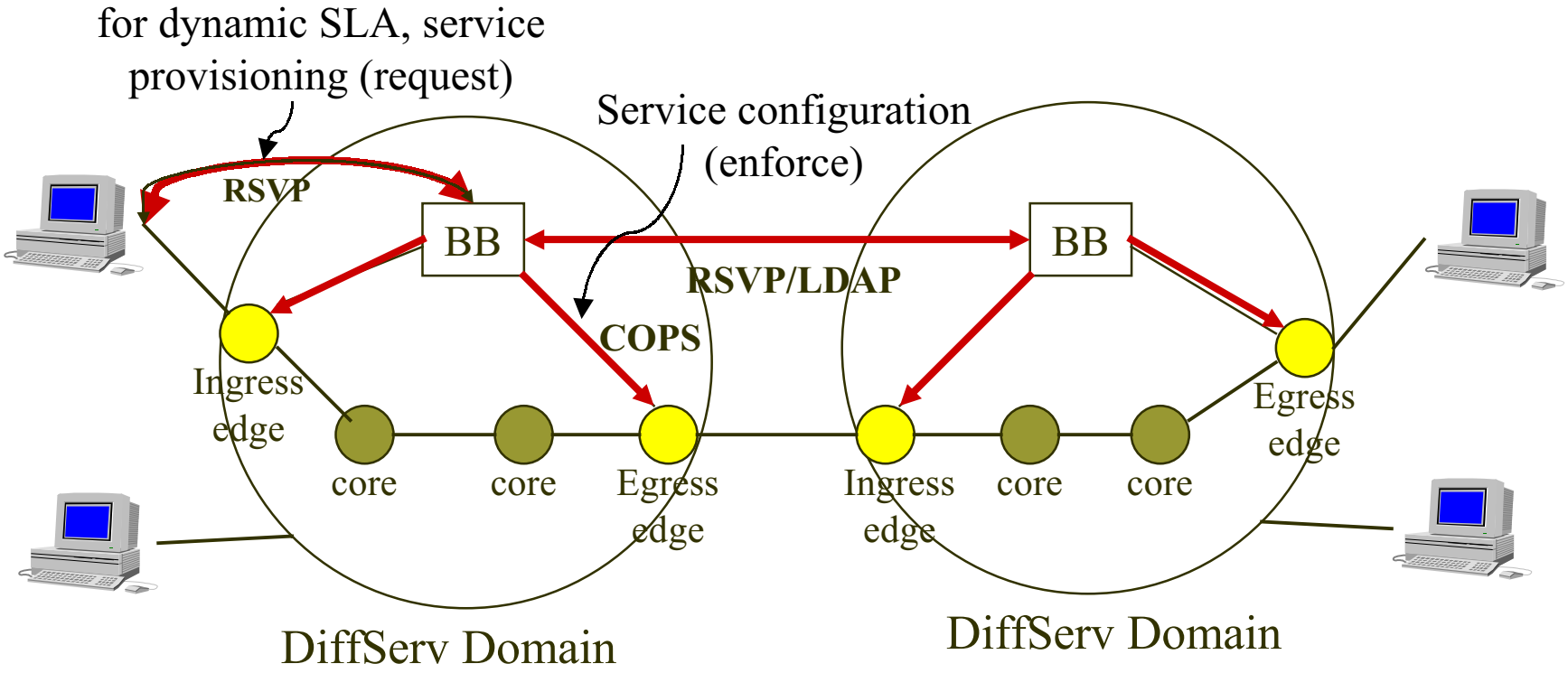
DiffServ Elements



DiffServ Overview

- No per-flow state and processing
- Provide a limited number of service classes
- Keep core routers simple
- Move control-plane mechanisms to bandwidth brokers
- Push complexity to the edges
- Exercise different user-plane mechanisms at edge and core
- Allow static and dynamic service provisioning

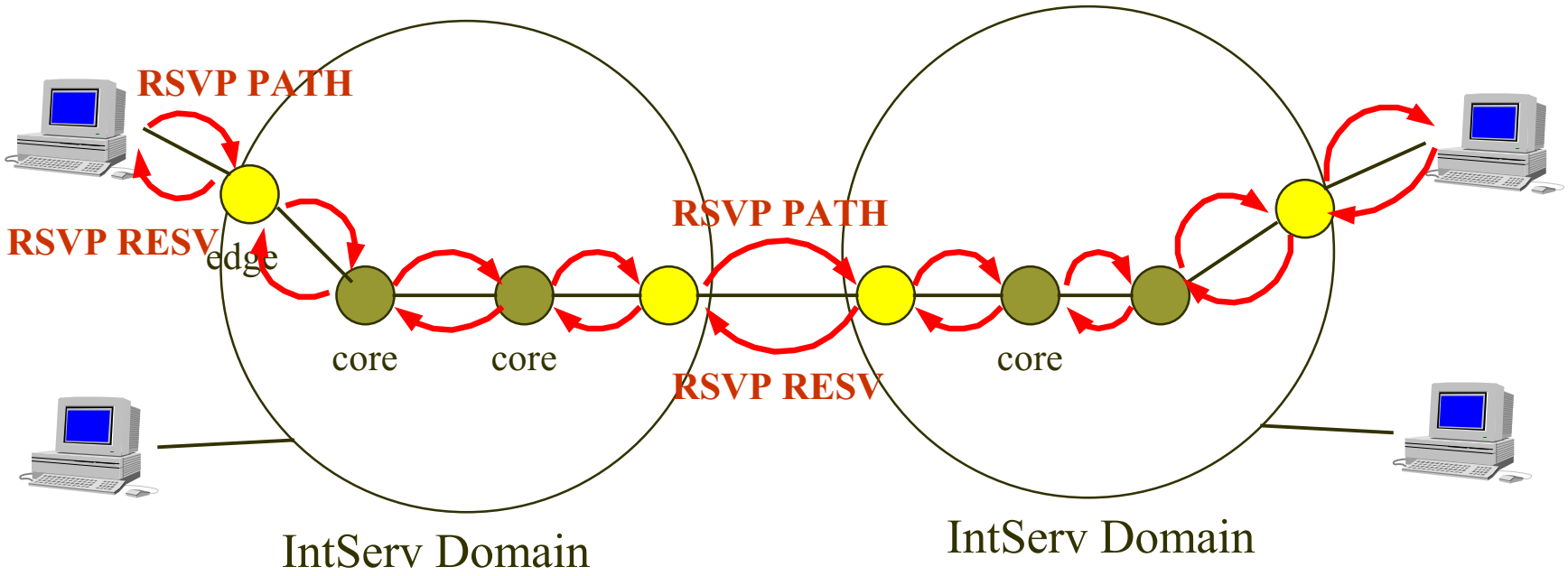
Generic DiffServ Operation Model



control-plane path
user-plane path
BB : bandwidth broker
SLA : service level agreement
MF : Multi-Field
BA : Behavior Aggregate

LDAP : Lightweight Directory Access Protocol
Ingress : MF classifier, policer, marker, scheduler
Core : BA classifier, scheduler
Egress : BA classifier, policer, shaper, remarker, scheduler
BB : provisioning, configuration

Generic IntServ Operation Model



: control-plane path

: user-plane path

edge, core : admission control, MF classifier, policer, scheduler

DiffServ Services

DSCP (DiffServ Code Point) and PHB (Per-Hop Behavior)

PHB Group	AF (Assured Forwarding)					EF (Expedited Forwarding)	Best-Effort
Features	Olymic service(an example) 4 delay priority classes, each with 3 drop precedence subclasses (quantitative service)					Premium/Virtual Leased Line Service (quantitative service)	none
Recommended DSCP in DS-field		AF1	AF2	AF3	AF4	101110	000000
	Low	010000	011000	100000	101000		
	Middle	010010	011010	100010	101010		
	High	010100	011100	100100	101100		
Traffic Control	Static SLA Policing, classification, marking RIO/WRED scheduling					Dynamic SLA Policing, classification, marking Priority/WFQ scheduling	FIFO scheduling
Non-conforming Traffic	Re-mark as Best-Effort					Drop	Forward

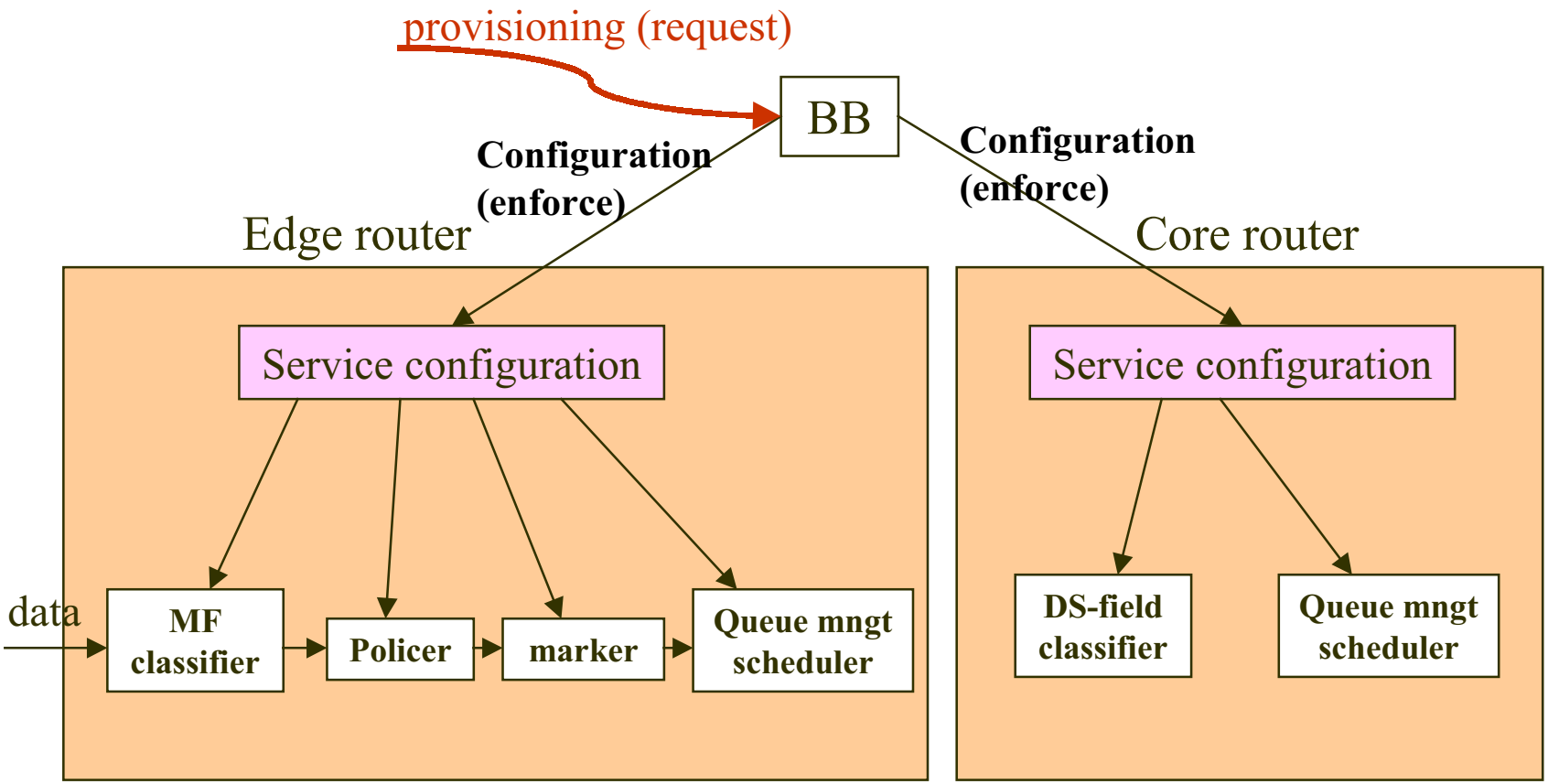
Service Level Agreement

- SLA: service contract between customer domain and DS ISP domain
- SLA may include TCA, classification rules, routing constraints, pricing and billing, authentication and encryption, etc.
- TCA (Traffic Conditioning Agreement) : subset of SLA
  - performance parameters
  - traffic profile
  - etc.
- Scope of SLA: unrestricted, one-to-one, one-to-many
  - governing transmitted traffic from ingress
  - but how about received traffic to egress?
- Static(pre-determined) and dynamic(on-demand) SLA

DiffServ Traffic Control

		Bandwidth Broker	Ingress Router	Core Router	Egress Router
Control-plane	Service Provisioning (request)	Intra-domain/inter domain (RSVP/LDAP)			
	Service Configuration (enforce)	Intra-domain (COPS)	Yes	Yes	Yes
User-plane	Classification		MF (multi-field) Classification	BA (Behavior Aggregate) (DS-field) classification	BA (DS-field) Classification
	Policing		Yes		Yes
	Marking		Yes		possibly remark
	Scheduling		Possibly drop/remark, Queue management (RIO/WFQ/priority over A-queue/P-queue)	Queue management (RIO/WFQ/priority over A-queue/P-queue)	Possibly drop/remark, Queue management (RIO/WFQ/priority over A-queue/P-queue)

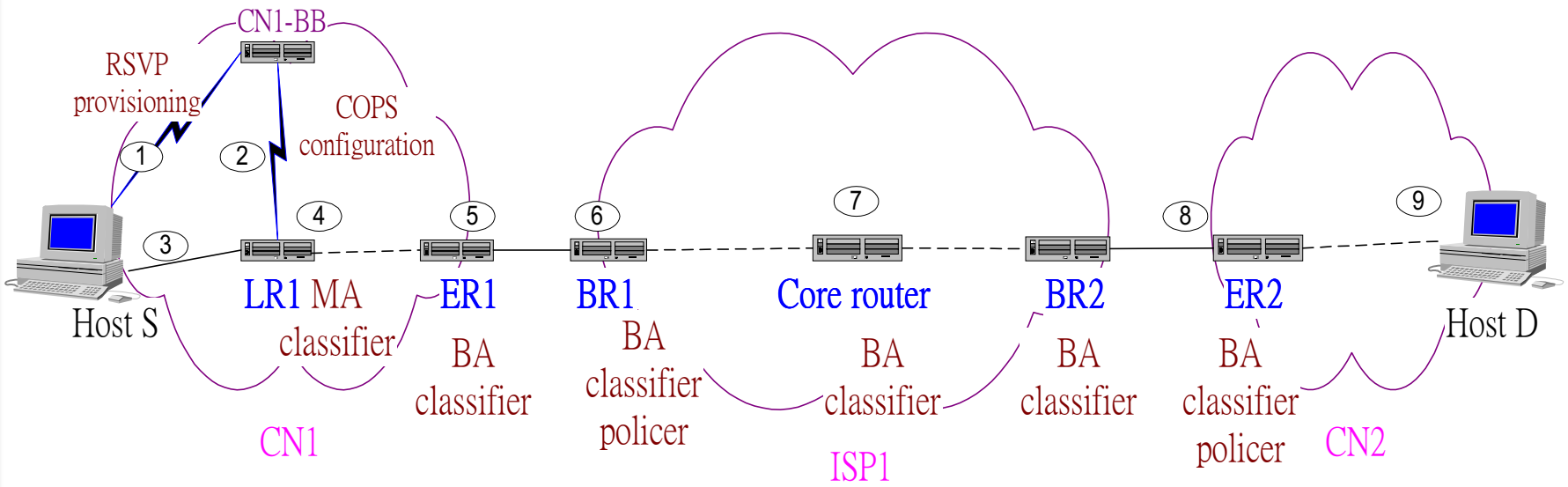
DS-capable Edge/Core Router



End-to-End Service Architecture I: DiffServ Customer/ISP

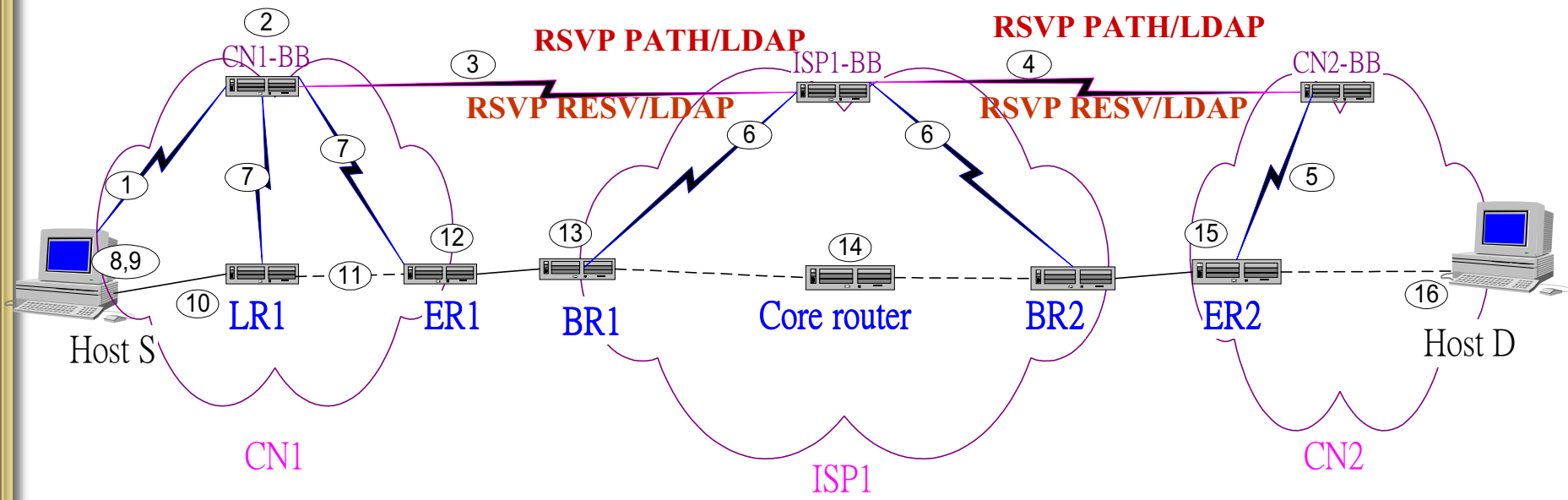
- AF with static SLA
- EF with dynamic SLA
- EF with dynamic SLA in MPLS-based DiffServ
- MPLS overview
- MPLS-based DiffServ ISP vs pure DiffServ ISP

Assured Forwarding with static SLA



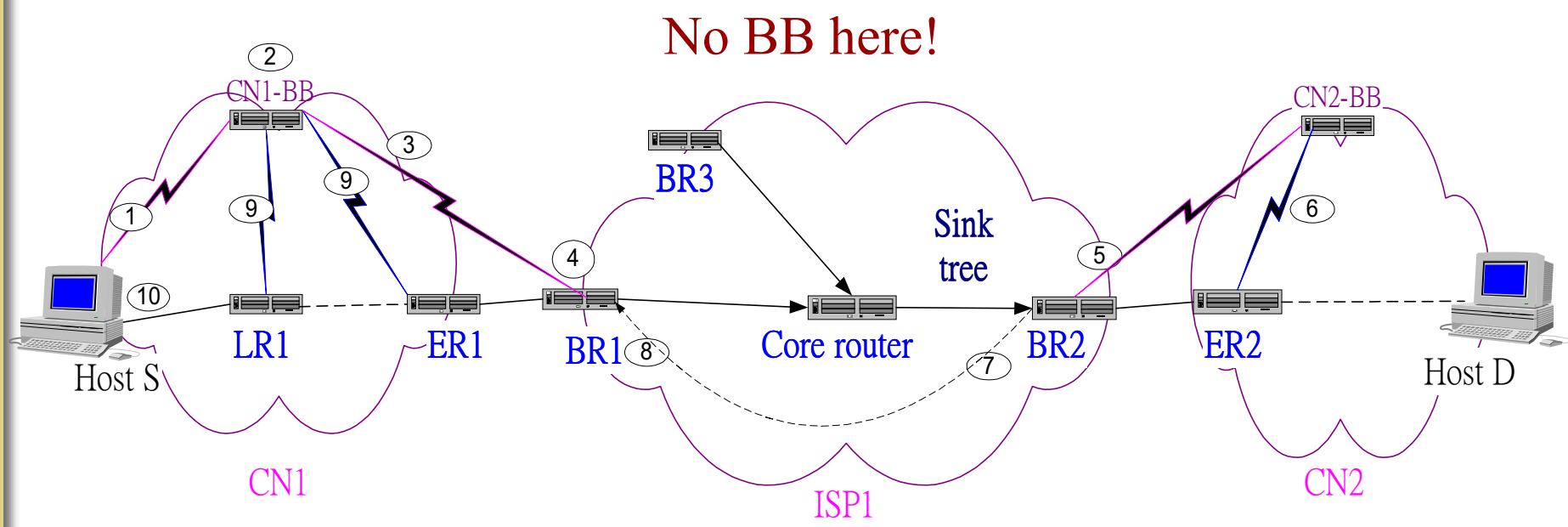
Source: IEEE Network, March/April 1999, Xiao and Ni

Expideted Forwarding with Dynamic SLA



Source: IEEE Network, March/April 1999, Xiao and Ni

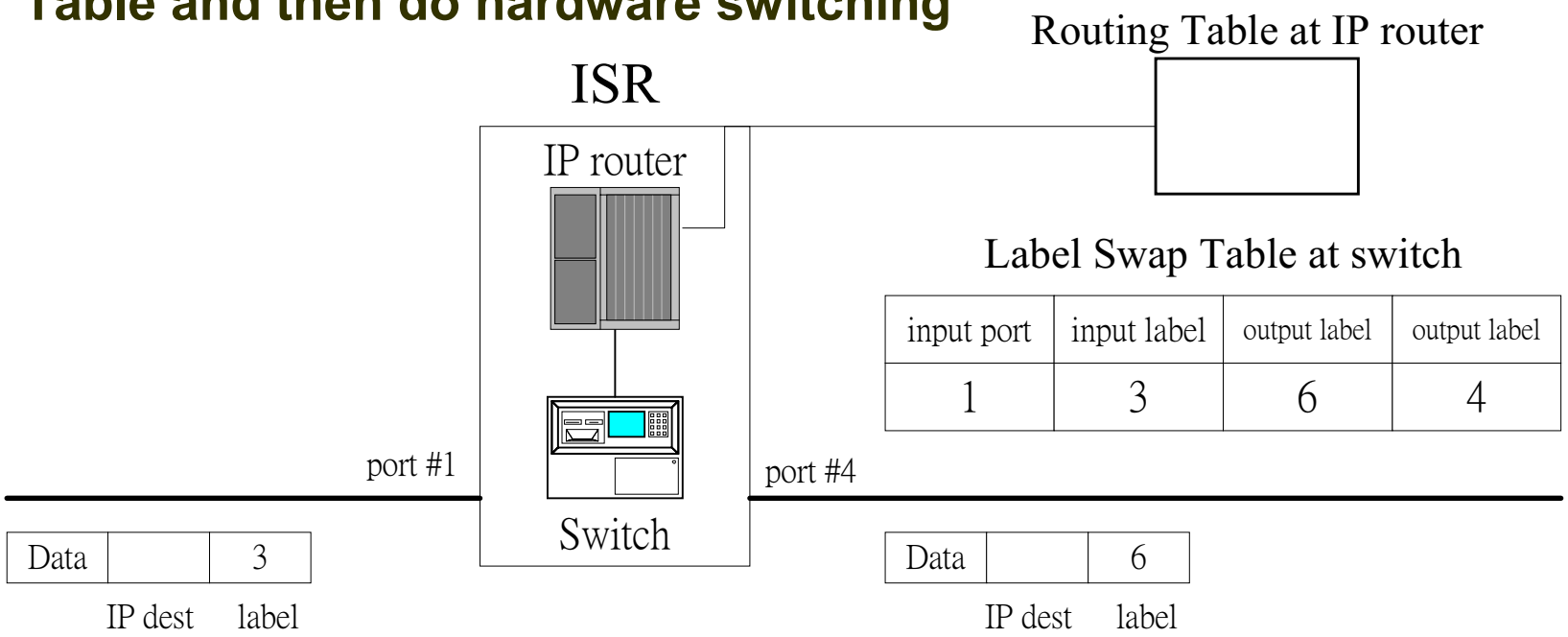
Expedited Forwarding with Dynamic SLA in MPLS-based DiffServ



Source: IEEE Network, March/April 1999, Xiao and Ni

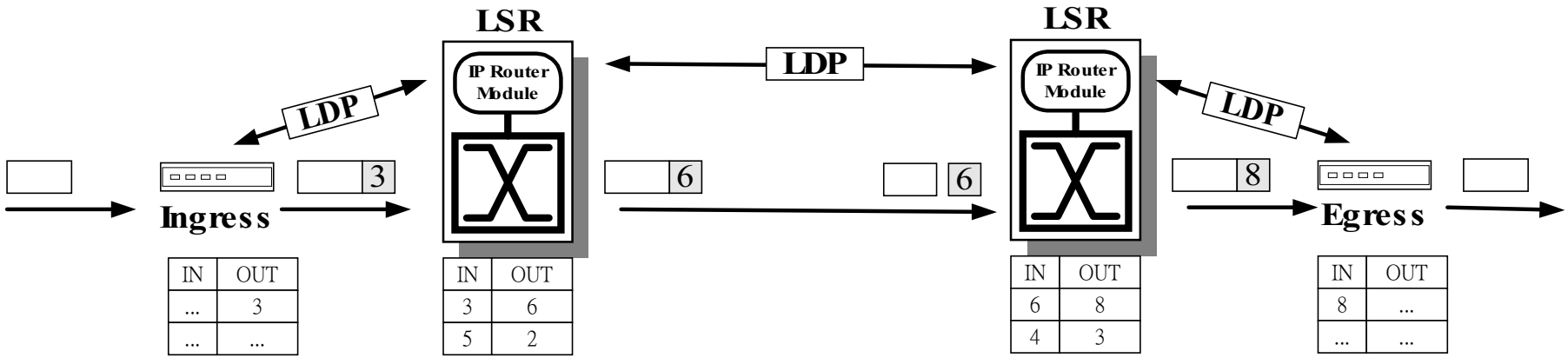
MPLS Overview

- ISR (Integrated Switch Router) includes IP router and layer-2 switch
- Packets are sent hop-by-hop by IP router in layer-3 or sent by switch in layer-2
- The data of IP routing or flow mapped into labels
- The label pasted on packets compare with Label Swap Table and then do hardware switching



Label Swapping

- Control protocol distributes route-to-label mappings
- Classify, label and forward at ingress
- Label swap over L2 path to egress
- Remove label and forward at the egress

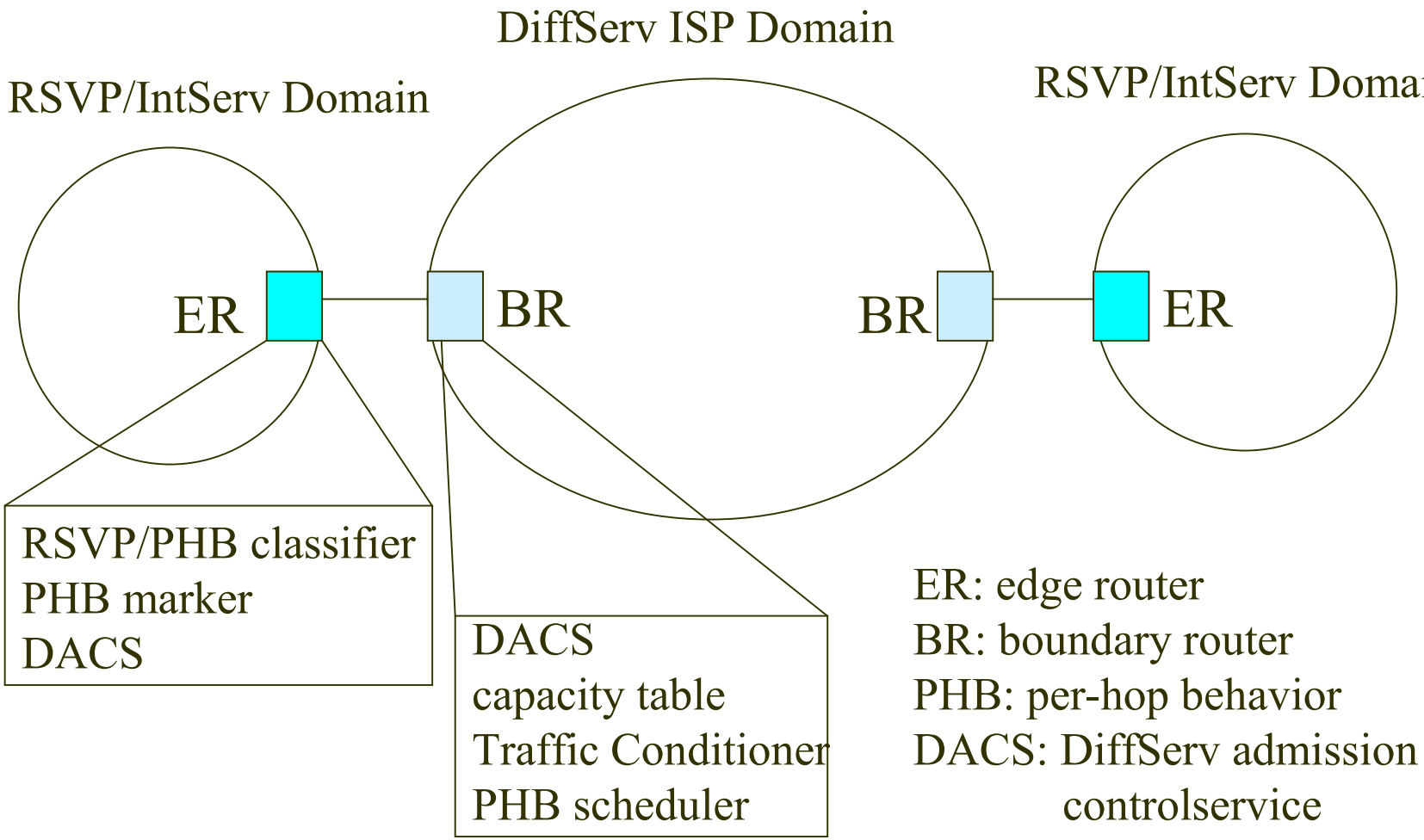


- LDP : Label Distribution Protocol
- LSR : Label Switch Router

MPLS-based DiffServ ISP vs Pure DiffServ ISP

- MPLS header:
  - label-for switching
  - COS-for class of service
- MPLS header inserted between layer 2 header and layer 3 (IP) header
- For pure DiffServ, routers check destination IP address and DS-field

End-to-End Service Architecture II:
IntServ Customer and DiffServ ISP



QoS Traffic Control

Admission Control
Policing
Classification
Scheduling

QoS Routing
Traffic Engineering
Policy Control

Admission Control for IntServ

- Main reference:
  - Tspec (Leaky Bucket parameter)
  - Rspec (B-bandwidth, S-slack term)
- Allocated bandwidth: R — between p (peak rate) and r (token rate).
- To satisfy Guaranteed Service:
  - low utilization(below 10%).
  - Controlled Load Service(no Rspec): flexible and higher utilization (50%~80%)
- Measurement-based(vs computation-based) admission control admit more flows subject to loss constraint.
- Adjusting the parameters of measurement is more important than what parameters to measure.

Admission Control for DiffServ

- Implicit: for static SLA
- Explicit: for dynamic SLA
- Capacity reconfiguration may be triggered when low-water mark is reached.

Classification

- How to distinguish the packets, according to some fields within packets

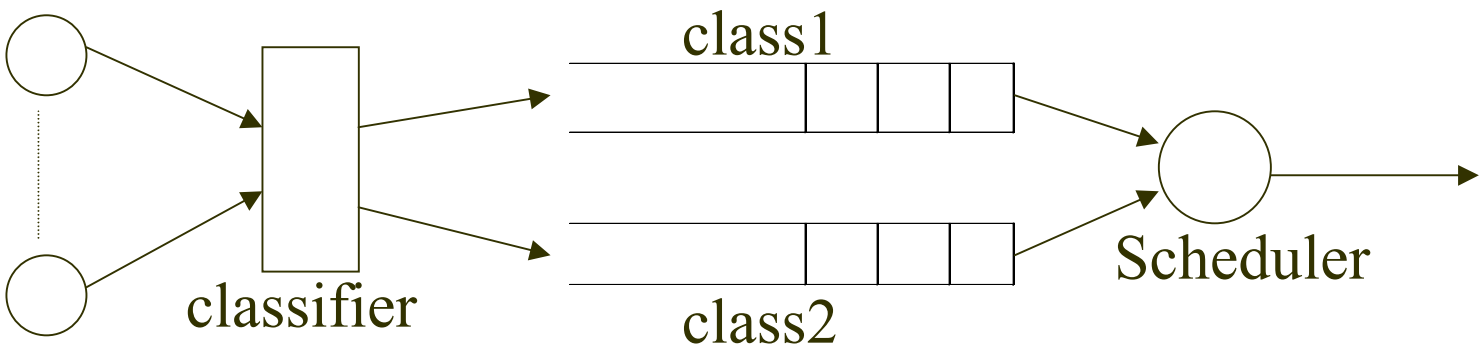
	MF (IntServ, DiffServ edge)	BA (DiffServ core)
Fields	eg. src/dest IP, proto id, src/dest port (flow id)	DS-byte
Decision	Send to per-flow or aggregated queue	Drop, mark or put at some location of a queue
Complexity	eg. 128 bits	6 bits

Scheduling for IntServ

- **Fair Queueing :**
  - **per-flow queues**
  - **bit-by-bit round robin (BR)**
  - **compute finish-time for each packet**
    (finish time: when packet would have left using BR)
  - **the one with smallest finish-time gets txed first**
- **Weighted Fair Queueing:**
  - **sum of weights = total bandwidth**
  - **each flow gets** $\frac{\text{its weight}}{\text{sum of wieghts}}$ **share**
  - **work-conserving**
  - **bounded delay**

Scheduling for IntServ (Cont.)

- **Class-based Queueing:**
  - per-class queues
  - priority & bandwidth for each class
  - scheduled based on priority & bandwidth
  - regulated flows (dropped or moved to lower class for violating traffic)
  - less state required than WFQ

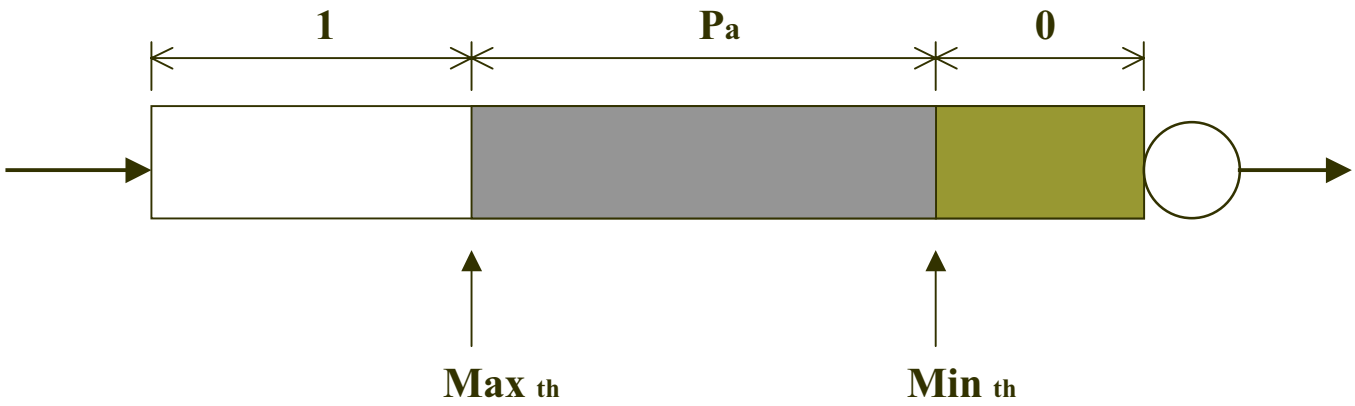


Scheduling for DiffServ

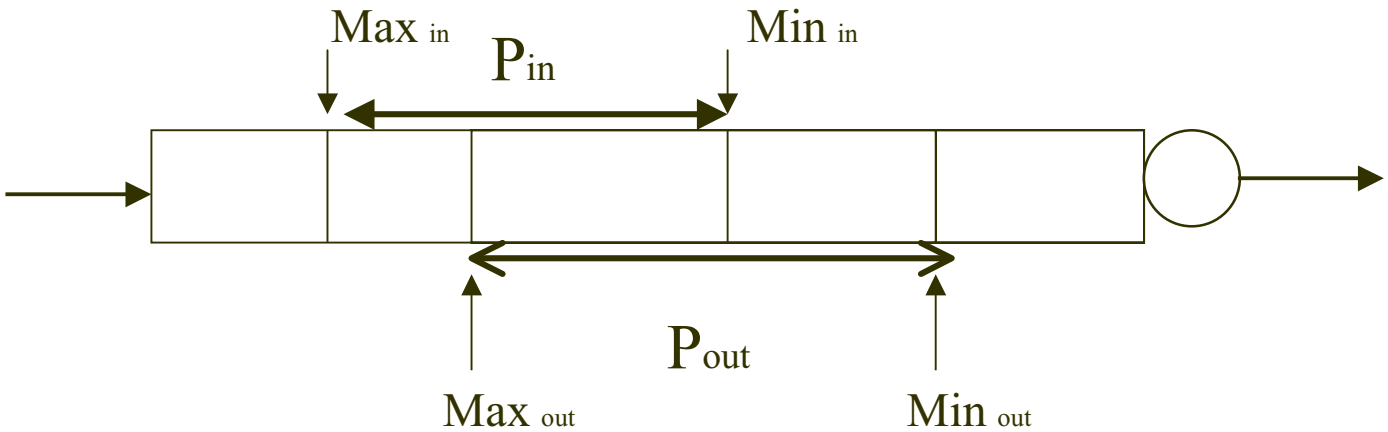
- **Mostly single queue management**
- **Common strategies:**
  - Threshold discard
  - Push out
  - Precedence
  - Weighted
- **Over a dozen of proposed schemes:**
  - RED,WRED,HOL,HLPO,RIO,PPP,etc.

RED and RIO

- **RED (Random Early Detection)**



- **RIO (RED with in and out)**

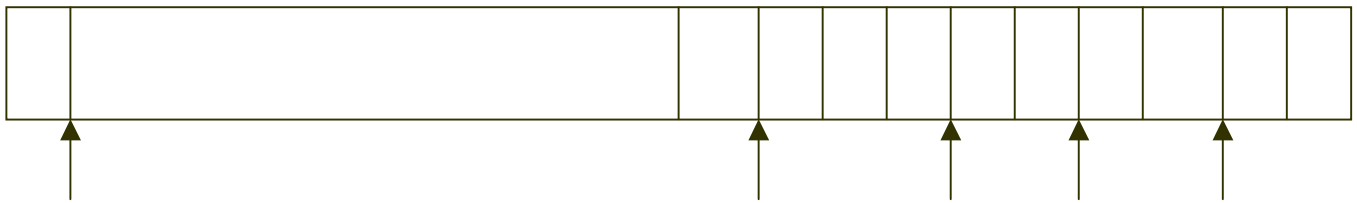


WRED (Weighted Random Early Detection) -- Cisco

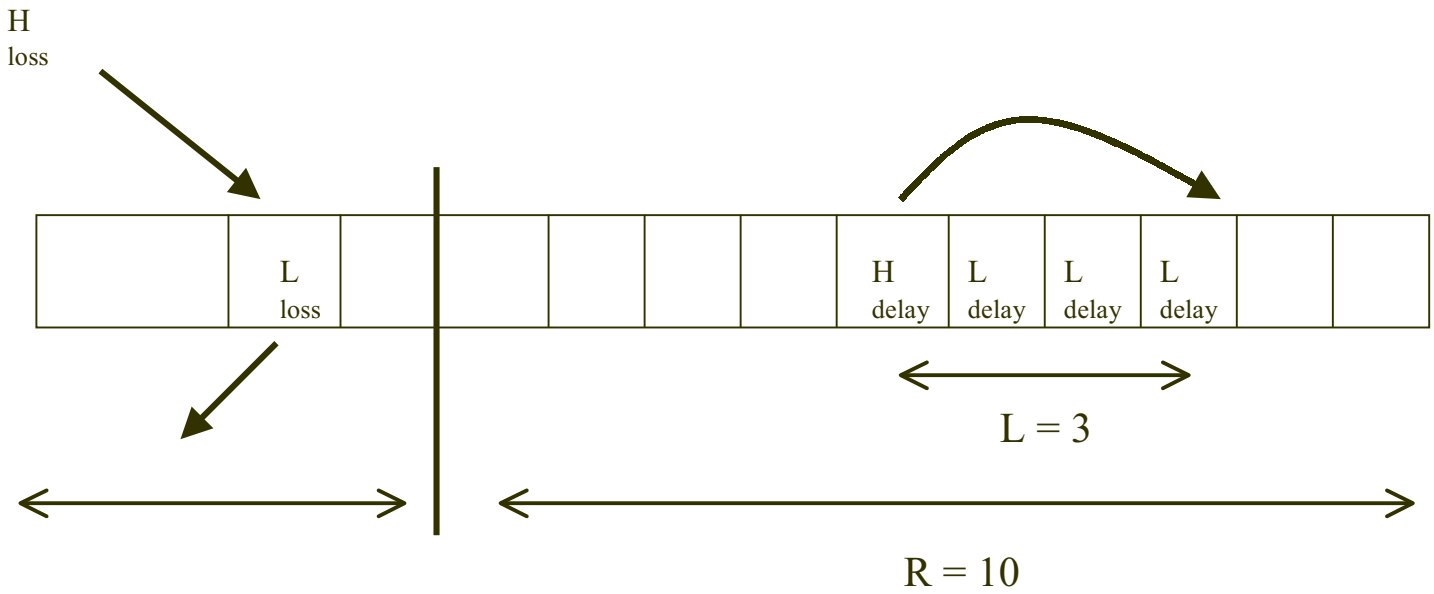
* Used in "**core routers**", rather than "**edge routers**"

* Edge routers assign IP precedence to packets

* WRED uses these precedence to determine weights and thresholds



PPP (Precedence with Partial Push out)



Current Internet Routing: RIP and OSPF

	RIP	OSPF
message exchanged	distance vector	link state
message propagation	between neighbors	flooding
state information	local	global
path computation algorithm	Bellman-Ford	Dijkstra

Problems as in Integrated Services RSVP Networks:

- not take link bandwidth into account ⇒ high blocking probability
- per-destination routing table⇒ routing table update(path change) ⇒ QoS interrupt

QoS Routing: Comparison of QOSPF

QoS Routing	QOSPF/Z	QOSPF/G
Criteria	constrained shortest path parameter:(residual_bw, delay)	constrained widest-shortest path (WSP) parameter: (residual_bw, #hops)
Triggering Path computation*	on-demand, topology change, or incoming LSA	pre-compute periodically, or threshold (number of updates)
Triggering Link-state update*	threshold	threshold or periodical
Algorithm	modified Dijkstra	modified Bellman-Ford
Routing	hop-by-hop or explicit (source) routing	hop-by-hop or explicit (source) routing
Forwarding Cache Granularity	per-pair	per-flow
Route pinned by	RESV message	RESV message

* Triggering rate can be limited by hold-down timer

Related IETF RFCs and Drafts (1/2)

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