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Implementation of QoS mechanisms in MPLS networks

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Agenda

- QoS background
- MPLS value addition to QoS
- Interaction of MPLS QoS with routing
- Procket QoS architecture and implementation
- Summary

QoS background

- Service provided by traditional network varies under congestion or during convergence
  - *Variable delay, jitter, loss, available bandwidth*
- Traffic has diverse service needs
  - *Voice requires low delay, jitter, loss*
- One approach: Avoid congestion by over provisioning
  - *Must guarantee no congestion at all times*
  - *May be wasteful to run network at low utilization*
- Alternative: Make network aware of service needs of traffic
  - *Most effective when there is congestion or you create congestion*
  - *Some packets have to lose for others to win*

QoS background: Granularity

- Fine grained
  - *QoS provided to individual applications or flows (Intserv approach)*
- Coarse grained
  - *Network aware of large classes of data or aggregated traffic (Diffserv approach)*
- Coarse grained approach scales better in the core

MPLS Value Addition to QoS

MPLS and QoS: Connection oriented

- Resource allocation
  - *Route flows (LSPs) through network with admission control*
  - *Police and/or monitor traffic at LSP ingress*
  - *Bandwidth constraints may be per link (TE) or different for different classes of traffic on a link (DS-TE)*
  - *For best results, apply admission control to all traffic that uses resources in a pool*
    - *Engineer all traffic*
    - *Or, use distinct PHB Scheduling Classes (queues) for engineered and other traffic*
  - *Controlled load => less probability of congestion => "better" service*

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MPLS and QoS: Connection oriented

- Easy identification of flow along LSP path (P2P LSPs)
  - *Enables flexible definition of flow (by ingress)*
  - *Allows for more classes -- a flow can be mapped to a traffic class at signaling time (as in L-LSPs)*
  - *Leaves open possibility of QoS guarantees on a finer grained level, as opposed to an aggregate basis*
- Interoperation with ATM / Frame Relay

MPLS and QoS: Source routing

- Fast Reroute
  - *Minimizes drops in the network due to slow IP convergence*
  - *Enables high availability of service*
  - *For traffic that requires low loss*
- Planned downtime
  - *Traffic can be seamlessly rerouted around an LSR box before bringing it out of operation*
  - *"Costing out" a link in IGP may not be good enough*

MPLS and QoS: Low overhead tunneling

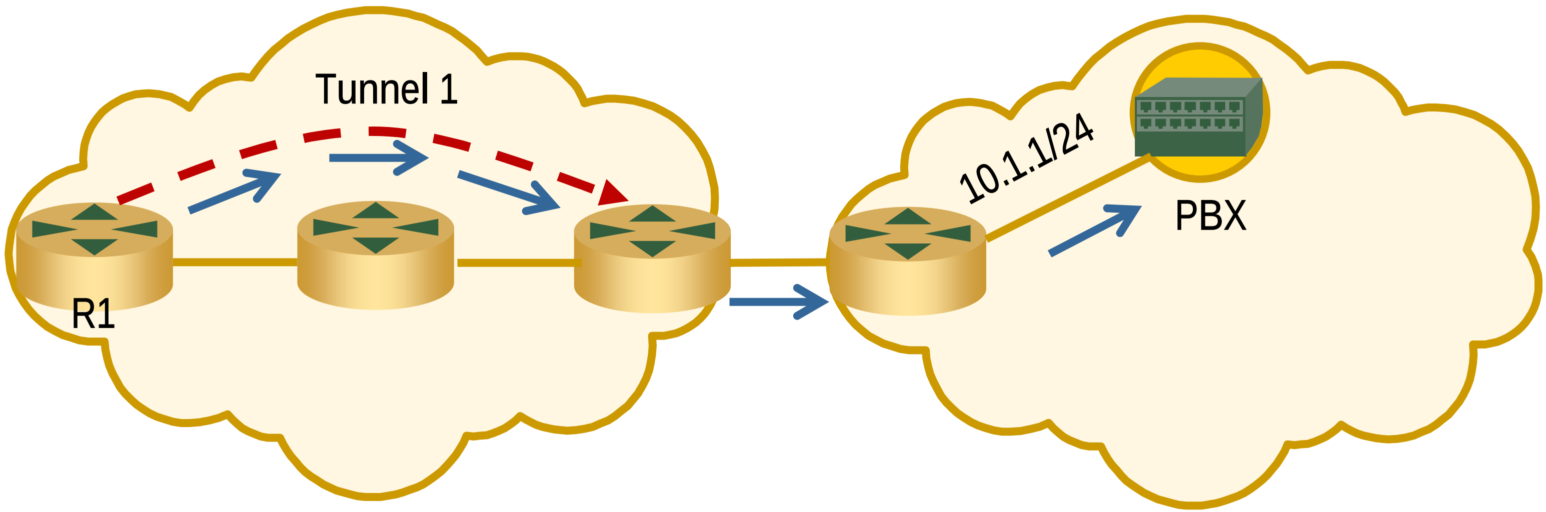
- Diffserv transparency
  - *Can use Pipe tunneling model to make transit Diffserv domain transparent to traffic*
- Routing table size on transit routers
  - *Allows routing decisions to be made at LSP ingress*
  - *QoS-aware routing may require larger routing tables*

Interaction of MPLS QoS with routing

Issue: QoS-aware routing

- Different paths in the network may be optimal for different services
- Control plane decision on path is easy when a predetermined service is required for some traffic
  - *Say, an L2 circuit, or all IP traffic matching a given prefix*
- Maintaining a routing table per class is expensive for control and forwarding plane

Control time selection of path



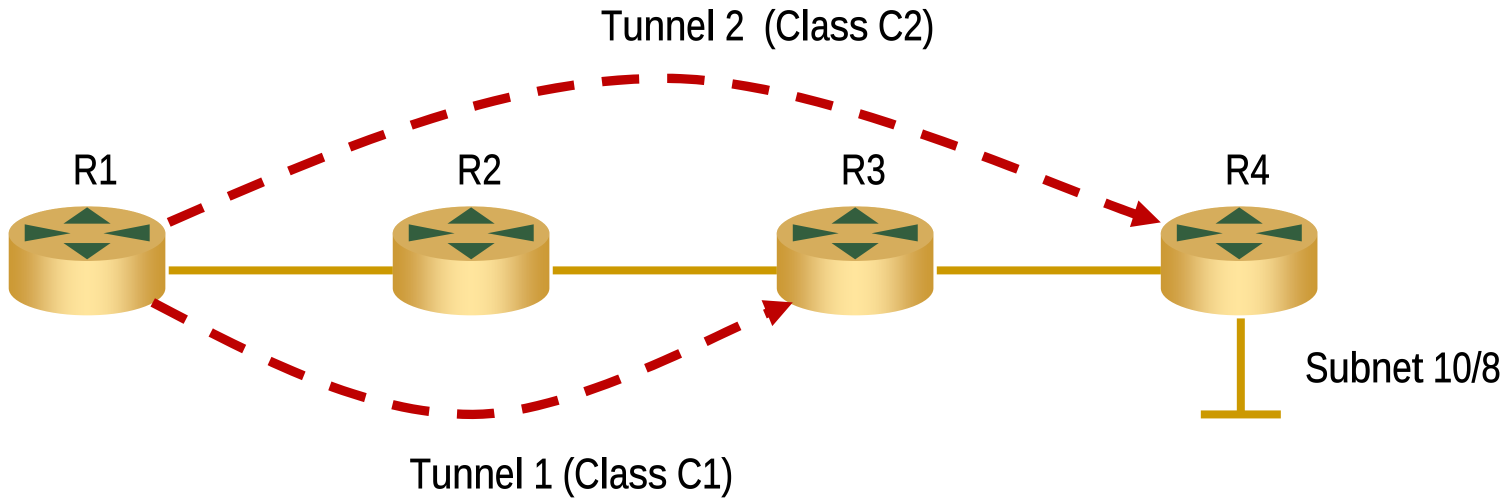
- Tunnel 1 is set up by R1 for carrying real time traffic
- Control plane on R1 treats traffic destined to PBX as real time

  10.1.1/24 -> Tunnel 1
- QoS applied by R1 based on matched prefix, not packet marking

Intra-domain IP routing

- Possible extension to IGP shortcuts
  - *Use single topology IGP as today with TE / DS-TE extensions*
  - *Run single SPF, modify IGP shortcuts to compute distinct tunnels as next hop(s) for desired classes*
  - *Don't need routing table per service or modification to longest match lookup*
  - *Next hop information more complex, requires sharing across prefixes for efficiency*
  - *Doesn't require upgrading boxes other than to run TE / DS-TE*

IGP shortcuts



- R1 signals Tunnel 1 for class C1 and Tunnel 2 for class C2.
- Paths to 10/8 on R1 are as follows

Prefix	C1 next hop	C2 next hop	Default next hop
10/8	Tunnel 1	Tunnel 2	R2

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Inter-domain routing considerations

- Routing per service in BGP would be expensive
- Existing BGP infrastructure should be okay if desired services are supported by selected paths
- Desirable for SPs to agree on standard service definitions for easy translation at border routers
- Domains that do not support QoS will increasingly not be used for transit
- Inter-AS TE could be used on a tactical basis to source route traffic

Inter-domain routing

- AS 300 has QoS enabled, AS 200 does not
- BGP policies avoid paths across AS 200

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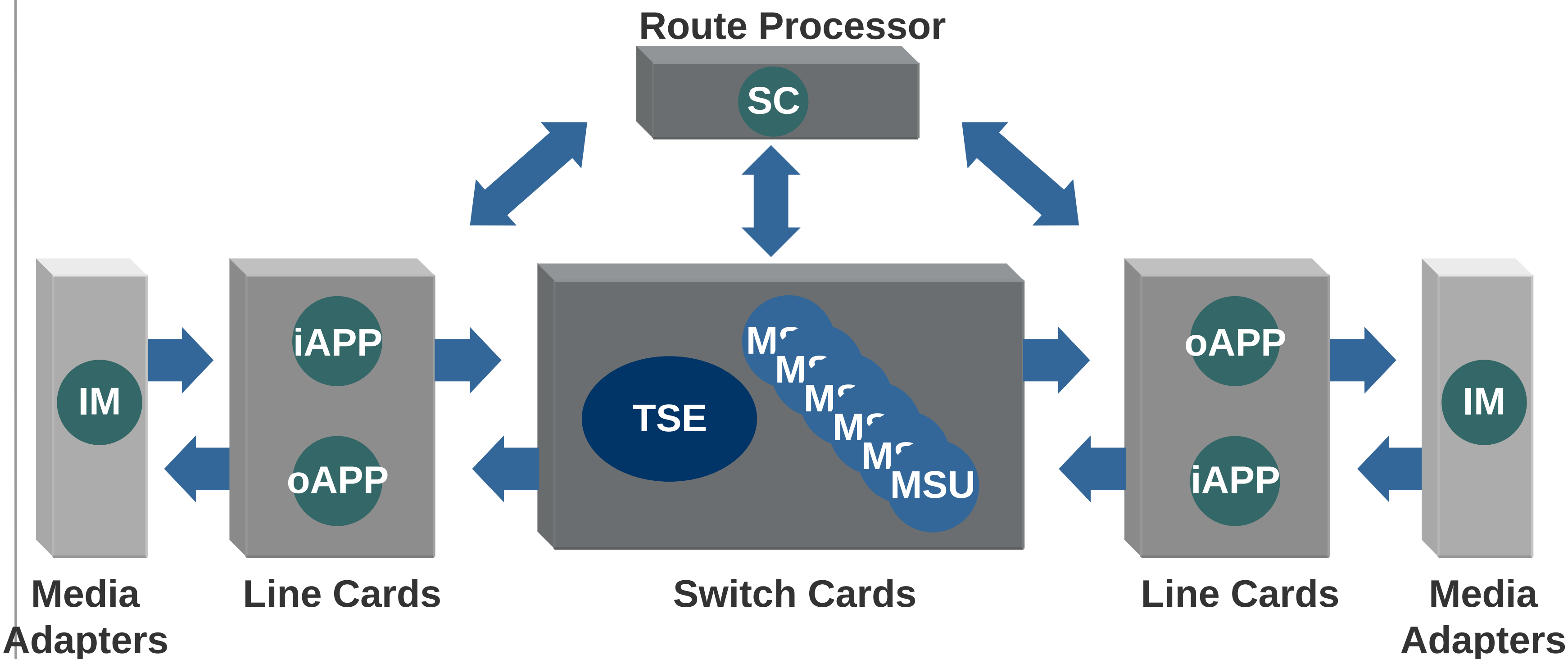
Procket QoS architecture and implementation

Procket Logical Architecture



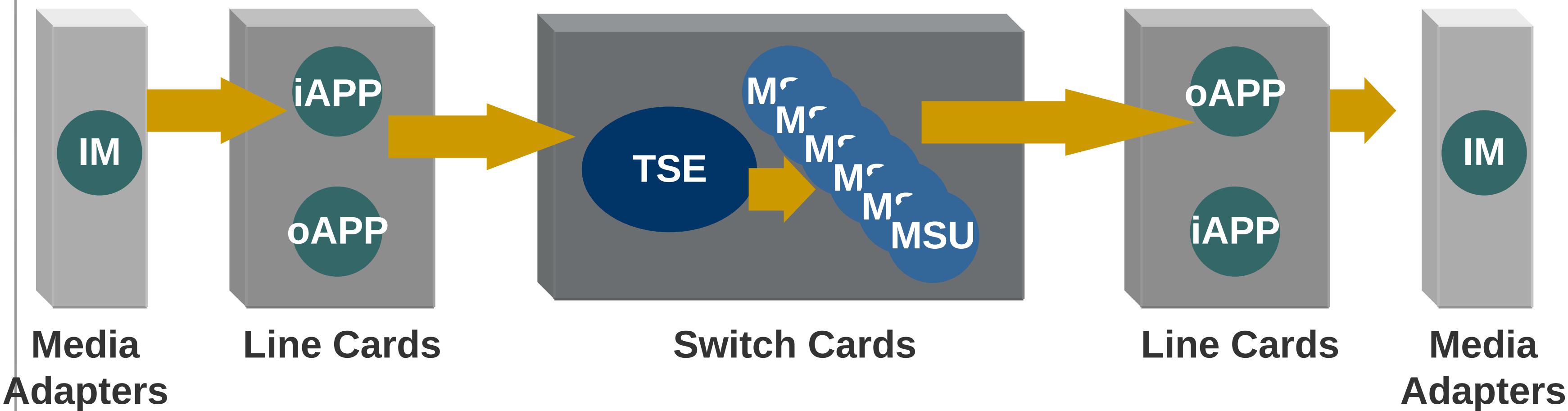
IM: Interface Multiplexer
iAPP: Input Adaptive Packet Processor
oAPP: Output Adaptive Packet Processor

TSE: Terabit Switch Engine
MSU: Memory Switch Units
SC: System Controller

Procket Architecture

- Distributed processing on line cards
  - *40 Gbps processors*
  - *Input Adaptive Packet Processor (iAPP): Fully programmable forwarding, accounting*
  - *Output Adaptive Packet Processor (oAPP): Fully programmable encapsulation, queuing discipline, accounting*
- Centralized shared memory switch fabric
  - *200 ms buffer*
  - *Up to 32 queues per physical interface. At least 4 queues per DS-3*
  - *36K queues per chassis*
  - *Packets read in and out of memory once. No separate input/output buffers*
- 480 Gbps full duplex line rate processing with 40 byte packets
- Fully non-blocking, any DS3 to any DS3

Procket Architecture/Packet Flow: QoS



- Packet Classification
- Modify DSCP/EXP/ Precedence
- Policing
- RED profile selection
- Queue selection

- RED, WRED
- Report queue fullness to TSE (RED)
- Queue lengths

- Programmable queuing discipline
- PQ, DWRR
- PQ(DWRR)
- DWRR(PQ)
- Rate shaping

Procket QoS Implementation

- Provides QoS in hardware without impact to system throughput
- UI designed so you can focus on delivering services and not on turning knobs.
  - *System intelligently maps service requirements to hardware*
- Classification on EXP, DSCP, Precedence
- Programmable RED, WRED
- Input policing, metering & marking
- Output marking
- Output rate shaping per queue

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Procket QoS Implementation

- Queuing algorithms implemented in microcode
  - *PQ and DWRR currently, set up in two levels of hierarchy*
  - *PQ for low latency, DWRR to distribute bandwidth*
- E-LSPs with uniform tunneling model
- Extensive statistics per interface
  - *Packet drops per class*
  - *Current and average queue depth*
  - *In-spec and out-of-spec packets per class*

Example: Service requirements

- Real time
  - *Small packets, delay and jitter sensitive. Low loss.*
  - *Interactive voice and video*
  - *Possibly Call signaling*
- Premium
  - *Low loss*
- Streaming media
  - *Less strict delay, jitter requirements*
- Best effort
  - *Everything else*

Example: Configuration

```
qos
    class premium
        exp internetwork-control
    class realtime
        exp critical
        dscp CS5
    class streaming-media
        exp flash-override
        dscp CS4
    output-behavior low-latency
        meter rate 3000 burst 100
        depth 50
    service-profile backbone
        class default
        class premium
        class realtime
            output-behavior low-latency
        class streaming-media
        queuing-discipline priority (realtime, dwrr (premium [45], default [20],
                                                          streaming-media [35]))
```

Procket QoS Futures

- Classification enhancements
  - *Based on policies*
  - *802.1p*
- More queuing disciplines
  - *WFQ*
  - *MDRR?*
- Interface rate shaping
- Remapping of traffic between services
- More MPLS support
  - *DS-TE*
  - *L-LSPs*

Summary

- QoS allows you to control treatment of packets by network
  - *Most useful when there is congestion*
- MPLS is a useful technology for QoS
  - *Enables better resource allocation, high availability, easier management, Diffserv transparency, smaller table sizes...*
- Incremental approach to intra-domain QoS-aware routing using TE and IGP shortcuts
- Common service definitions desirable for easier inter-domain operation
- Procket architecture and QoS implementation deliver easily manageable QoS without comprise on performance

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