Advanced Networks

(EENGM4211)

Rasheed Hussain

rasheed.hussain@bristol.ac.uk

Best contact : Microsoft Team

Slides courtesy: Dr. George Kanellos, Dr D. Kaleshi & Dr G. Oikonomou as well as Internet

Part 6:
Quality of Service

Unit Outline

- Introduction
- Internet Routing and Switching
- IP Multicast
- Networking for Realtime Applications
- Routing in Wireless Networks
- Quality of Service

Outline & Topics

- Motivation
- Some practical principles
- How do we apply the principles to make QoS work?
    - Queue Management
- Case study : IP Quality of Service
    - What? why?
    - Protocols

University of BRISTOL

ILOs

- Continues from previous lecture
- To be able to demonstrate the knowledge of the working principles of IntServ and DiffServ
- Knowledge of RSVP and different QoS primitives and working principles associated with those primitives

Recap

- What did we learn in the last lecture?
- QoS principles
- Queuing
- Fairness
- Methods?

Queue management

- Scheduling:
  - which output queue to visit
  - which packet to transmit from output queue
- Queue management:
  - ensuring buffers are available: memory management
  - organising packets within queue
  - **packet dropping when queue is full**
  - **congestion control**

University of BRISTOL

Queue management

- Congestion:
  - misbehaving sources
  - source synchronisation
  - routing instability
  - network failure causing re-routing
  - congestion could hurt many flows (case of aggregated traffic)
- Drop packets:
  - drop “new” packets until queue clears?
  - admit new packets, drop existing packets in queue?

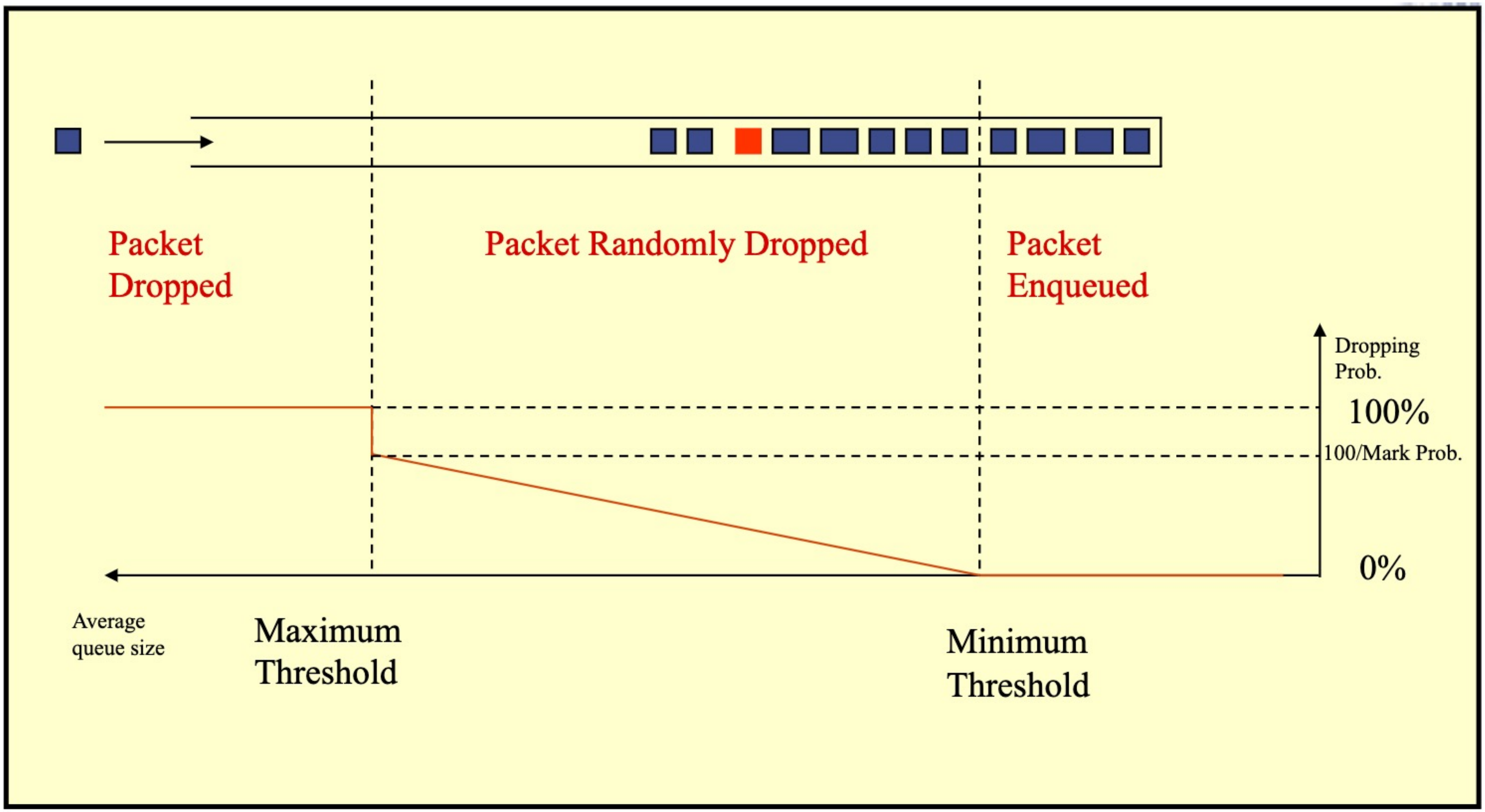
Packet dropping policies

- Drop-from-tail:
  - easy to implement
  - delayed packets at within queue may "expire"
- Drop-from-head:
  - old packets purged first
  - good for real time
  - better for TCP (detect early)
  - Usually more overhead
- Random drop:
  - fair if all sources behaving
  - misbehaving sources more heavily penalised
- Flush queue:
  - drop all packets in queue
  - simple
  - flows should back-off
    - *"punish" misbehaving flows*
  - Inefficient (bursts of re-transmission)
  - Unacceptable for real-time
- Intelligent drop:
  - based on level 4 information
  - may need a lot of state information
  - should be fairer

RED

- Random Early Detection:
  - spot congestion before it happens
  - drop packet → pre-emptive congestion signal
  - source slows down
  - prevents real congestion
- Which packets to drop?
  - monitor flows
  - cost in state and processing overhead vs. overall performance of the network

RED



Packet
Dropped
Packet Randomly Dropped
Packet
Enqueued
Dropping
Prob.
100%
100/Mark Prob.
0%
Average
queue size
Maximum
Threshold
Minimum
Threshold

RED

- Probability of packet drop $\propto$ queue length
- Queue length value – exponential average (EWMA):
  - smooths reaction to small bursts
  - punishes sustained heavy traffic
- Packets can be dropped or marked as "offending":
  - RED-aware routers more likely to drop offending packets
- Source must be adaptive:
  - OK for TCP
  - real-time traffic → UDP ?

TCP-like adaptation for real-time flows

- Mechanisms like RED require adaptive sources
- How to indicate congestion?
  - packet drop – OK for TCP
  - packet drop – NO for real-time (+hurts real-time flows)
- Adaptation mechanisms:
  - explicit congestion notification (ECN)
  - layered audio/video codecs
  - TCP is unicast: real-time can be multicast

End system reaction to packet drops

- Now we have to be specific about the Internet!
- Non-real-time – TCP:
  - packet drop → congestion → slow down transmission
  - slow start → congestion avoidance
  - network is happy!
- Real-time – UDP:
  - packet drop → fill-in at receiver → ??
  - application-level congestion control required
  - flow data rate adaptation not be suited to audio/video?
  - real-time flows may not adapt → hurts adaptive flows
- Queue management could protect adaptive flows:
  - smart queue management required

Section 3

QoS and the Internet: Protocol case studies

IP Quality of Service

- Performance Guarantees – delivery objectives
  - Throughput, Delay/Jitter, Packet Loss.
- Service Levels
  - Best Effort
    - fair to all
    - no guarantees
  - Qualitative
    - low delay, better than Best Effort
    - Olympic-like service class qualification - Gold/Silver/Bronze
    - relative guarantees
  - Quantified
    - One-way Delay < 100ms, Packet Loss Ratio < 1 * 10E-6
    - quantified guarantees

RSVP: Resource ReSerVation Protocol

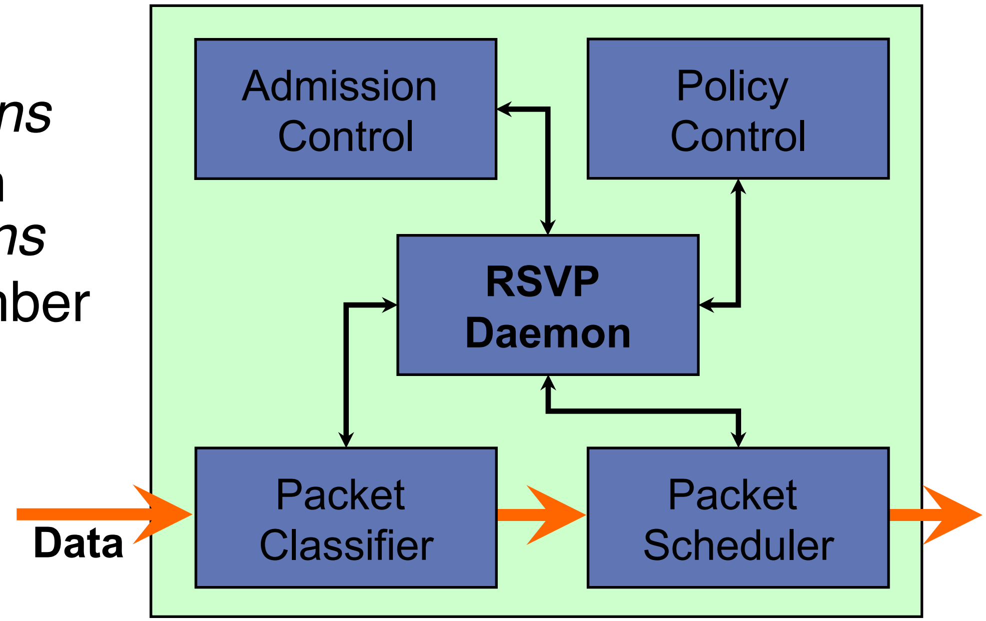
- Reservation allows
  - end-to-end guaranteed service
  - demand for bandwidth (unicast)
  - indication of bandwidth requirement (multicast)
- Why?
  - enable Quality of Service (QoS)
  - real-time applications need a guaranteed flow across networks
  - network-based filtering of flows

What is Reservation?

- Configure routers in a path (or multicast tree) to discriminate between packets for forwarding

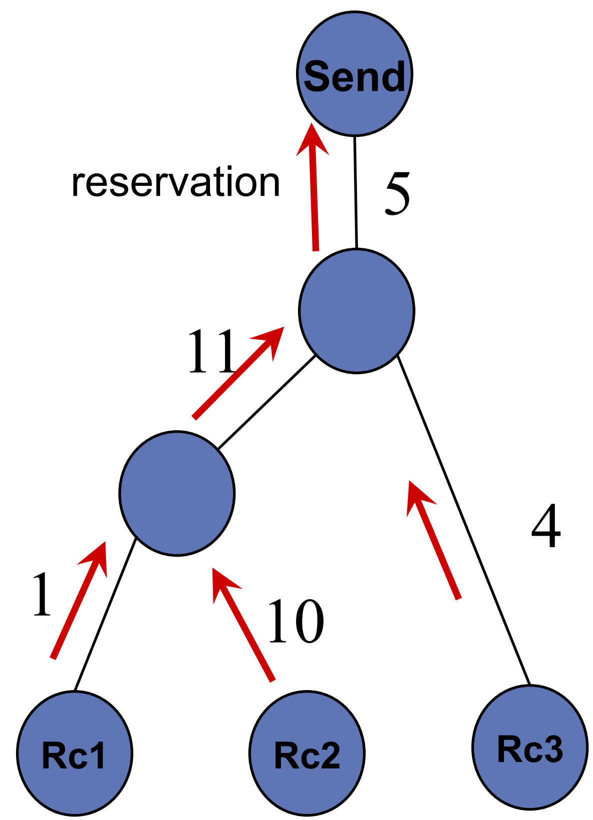
Functions

- classify arriving packets according to *filter specifications*
- schedule packet transmission according to *flow specifications*
- admission control to limit number of flows
- apply policies to prioritise admission



RSVP: major features

- Enables applications to signal their E2E QoS requirements for a **flow**
- Uses existing network routing protocol
- Simplex
  - Resource requests only for one flow direction
- Routers with 'soft state'
  - path & reservation needs to be refreshed periodically (typically 30 seconds)
- Uses IP multicast for message distribution
- Receiver-controlled reservation requests
  - Receivers decide when to join/leave groups
  - Receivers decide what QoS needed
- Flexible control over sharing of reservations

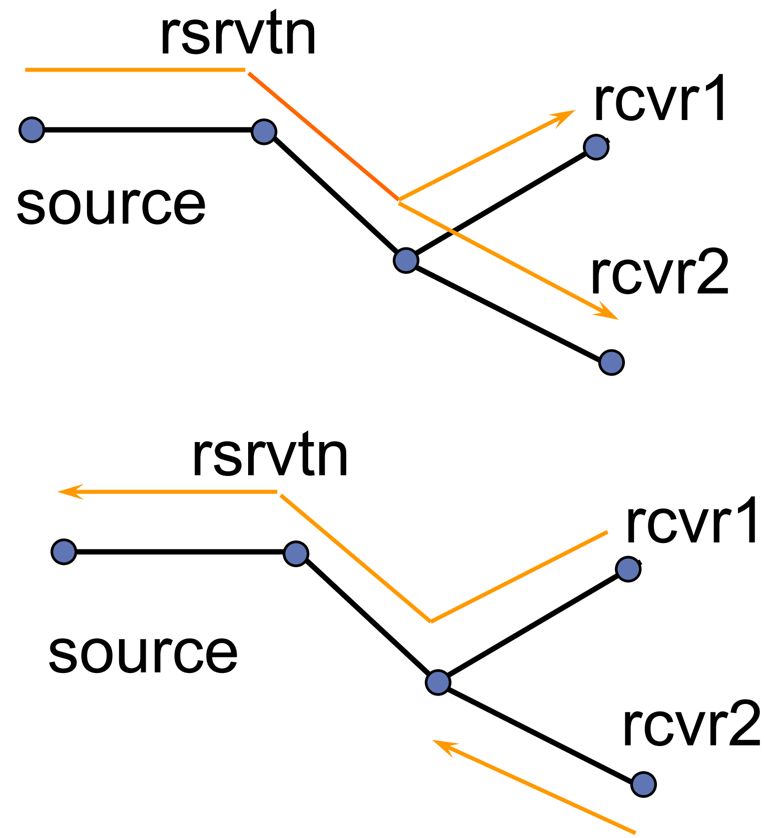


RSVP Concepts: Call Setup

- Contract between network and application
  - *both network and application should abide by rules*
  - network guarantees performance
  - application guarantees traffic behaviour
    - peak rate
    - average rate
    - burst size
- Approaches
  - one pass
  - two pass

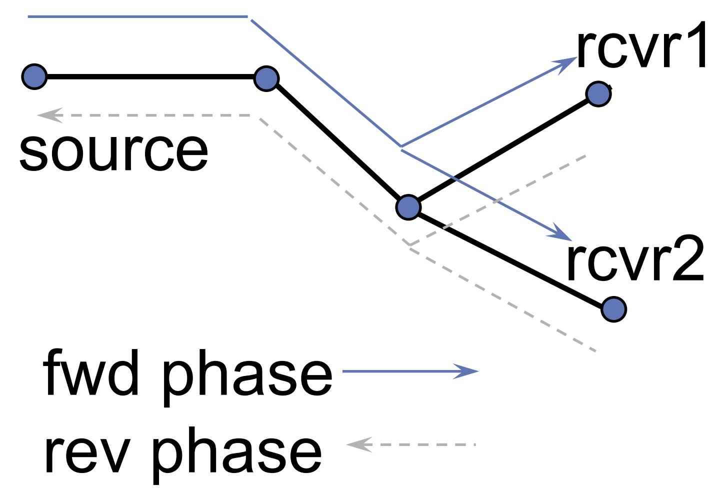
RSVP Operational Models: One Pass

- Sender or receiver oriented
- Source (or receiver) sends resource reservation to receivers (or source)
- Cannot specify / guarantee QoS
  - No confirmation / acceptance
- Periodic refreshes of state



RSVP Operational Models: Two Pass

- Sender or receiver initiated
- Forward phase
  - check for resources at each link
- Reverse phase
  - inform routers if call request is admitted
  - reserve resources
- Reserve maximum resources
- Resource reclamation phase can be added
  - Passive – originators tears down the requests
  - Active – routers do it as failures propagate



RSVP Problems

- Scalability
  - maintaining state per microflow & soft state refreshes
    - problem for backbones, not for campus/enterprise networks
- Does not work well with shared media networks
  - hence need for SBM (Subnetwork Bandwidth Manager), for example
  - …. but it works well with networks of point to point links.

IP QoS – Two Approaches

Integrated Services (IntServ)

- Reservation end-to-end
- Influenced by traditional telecom thinking about networks
- Fundamental unit is the flow

Differentiated Services (DiffServ)

- Architecture matches the IP architecture
  - No explicit resource reservation: each node provides mechanisms to implement the required QoS behaviour
- Fundamental unit is the aggregate (a collection of flows)
- Recognises that Internet is made up of independently administered domains
  - Domain (AS) boundaries are modelled explicitly
  - This is where policy and control are done

IntServ Architecture Components

- QoS Requirements
  - Expressed in terms of traffic (TSpec) and service requirement (RSpec) - Flow Specs
- A resource reservation protocol (RSVP)
  - The means by which the QoS requirements are exchanged between nodes in the IntServ transit path.
    - but IntServ is not the only QoS schema that uses RSVP; RSVP can be used with a variety of other QoS control schemas and architectures.
- Resource-sharing requirements
  - Allocation of resources is done on per-flow basis
  - *But several flows share the same link* – fairness must be ensured
    - Uses Weighted Fair Queuing (WFQ)
- Allowances for packet dropping
  - Provide for control of packet dropping policy - e.g., classifying packets as pre-emptable.

IntServ – Integrated Services

- IntServ supports two services
  - Guaranteed Service (RFC2212)
    - delay bounded & no loss
    - targeted at real-time intolerant applications
  - Controlled Load (RFC2211)
    - service is equivalent to lightly loaded best effort network
    - targeted at real-time tolerant applications
    - protects flows from one another up to a point
    - No RSpec!

Differentiated Services (DiffServ) Architecture

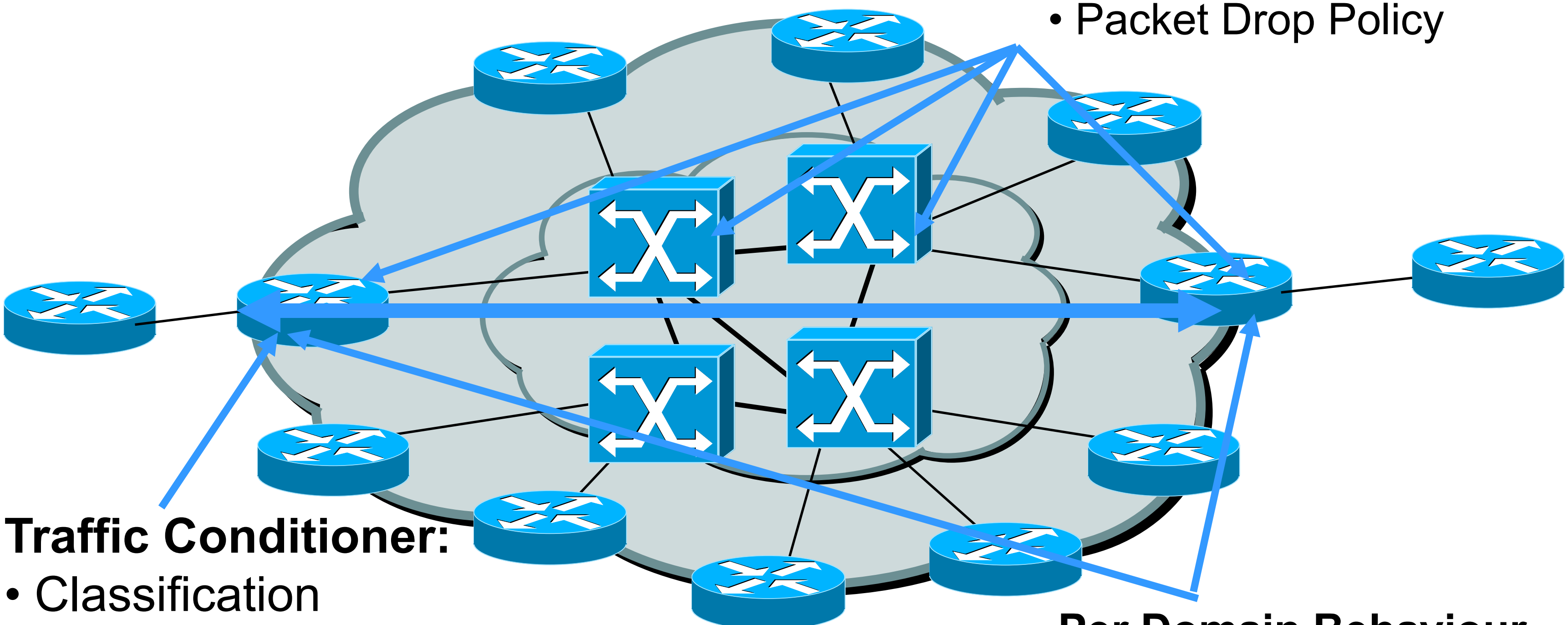
- DiffServ network supports a small number of service classes
- Service classes have relative priority
- Traffic entering DiffServ domain is classified into a service class
  - Service Classes are distinguished by *DiffServ Code Points (DSCPs) - 6 bit field in IPv4 header*
    - Most significant 6 bits of the TOS (Type of Service) field
- Each service class is given a particular forwarding treatment at each router
  - according to the Per Hop Behaviour (PHB) associated with the DSCP

Service Classes

Service Class Name	DSCP Name	DSCP Value	Application Examples
Network Control	CS6	110000	Network routing
Telephony	EF	101110	IP Telephony bearer
Signaling	CS5	101000	IP Telephony signaling
Multimedia Conferencing	AF41,AF42 AF43	100010,100100 100110	H.323/V2 video conferencing (adaptive)
Real-Time Interactive	CS4	100000	Video conferencing and Interactive gaming
Multimedia Streaming	AF31,AF32 AF33	011010,0111000 011110	Streaming video and audio on demand
Broadcast Video	CS3	011000	Broadcast TV & live events
Low-Latency Data	AF21,AF22 AF23	010010,010100 010110	Client/server transactions Web-based ordering
OAM	CS2	010000	OAM&P
High-Throughput Data	AF11,AF12 AF13	001010,001100 001110	Store and forward applications
Standard	DF (CS0)	000000	Undifferentiated applications
Low-Priority Data	CS1	001000	Any flow that has now BW assurance

DiffServ Terminology

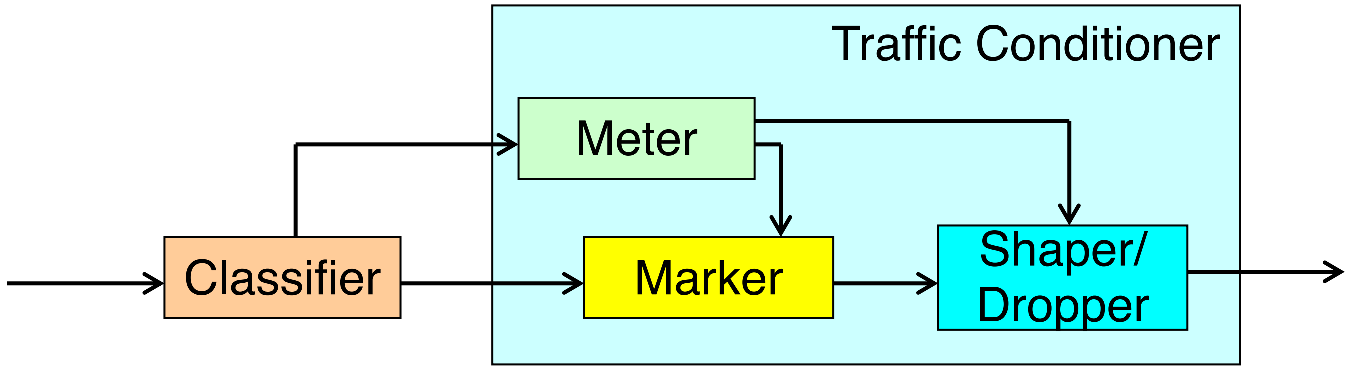
Per Hop Behaviour:
- Resource Allocation
- Packet Drop Policy



Traffic Conditioner:
- Classification
- Meter
- Mark (DSCP)
- Police/Shaping

Per Domain Behaviour
- E2E Performance
- Basis for SLS

DiffServ Traffic Conditioner



- Traffic Conditioners are usually found at the edges of DiffServ Domains
  - Classifier - examines packet headers
  - Meter - checks rate conformance
  - Mark - set value for DSCP
  - Shaper - make non-conformant traffic into conformant traffic

DiffServ Code Points

IPv4 ToS (Type of Service) field evolution:

P2	**P1**	**P0**	**T3**	**T2**	**T1**	**T0**	**CU**	**RFC 1349**
Precedence			**Type of Service**					

DS5	**DS4**	**DS3**	**DS2**	**DS1**	**DS0**	**CU**	**CU**	**RFC 2474**
DiffServ Code Point						**ECN?**		

Per Hop Behaviour (PHB)

- Externally observable forwarding behaviour of node
- Implementation is not specified
- PHB is determined by three factors:
  - offered load
    - depends on Traffic Conditioning
  - resource allocation
    - depends on scheduler on output queue
  - packet discard policy
    - depends on congestion avoidance mechanisms
- Three PHBs have been standardized
  - Expedited Forwarding (EF)
  - Assured Forwarding (AF)
  - Class Selector (for backward compatibility with IP Precedence)

Per-Hop Behaviour (PHB)

- Expedited Forwarding
  - EF is designed to provide low loss, low delay, low jitter, assured bandwidth E2E service
    - Virtual Leased Line Service
  - EF requires that the maximum arrival rate is less than the minimum departure rate
    - arrival rate is controlled through Traffic Conditioner
    - departure rate is controlled by PHB scheduler
      - strict priority, WFQ,……

Per Hop Behaviour (PHB)

- Assured Forwarding
  - Provides forwarding assurance through controlling the drop probability
    - could use RED
    - Four Classes have been defined
    - Each Class has up to three drop probabilities
    - Each Class has an ordering constraint
  - Could be used to construct Olympic type services
    - Each colour relates to a Class
    - Use Traffic Conditioning to ensure less offered load for Gold than Silver, hence engineer lower average delay for Gold

University of BRISTOL

Conclusions

- IP Quality of Service – what is it?
- Integrated services
    - guaranteed service, controlled load
    - RSVP models and operation
- Differentiated services
    - per hop behaviours (Assured, Expedited)
    - packet marking using DSCPs

Reading and References

QoS in books

- Tanenbaum, A., “Computer Networks”, 3d Ed., pp.397-417.

or

- Peterson, L., “Computer Networks: A Systems Approach”
    - pp.457-464 for queuing, pp.488-512 for QoS.

RSVP

- RSVP: A New Resource ReSerVation Protocol,
  Zhang, L., Deering, S., Estrin, D., Shenker, S., and Zappala, D.,
  IEEE Network, September 1993.
- Resource ReSerVation Protocol (RSVP) -- Version 1 Functional Specification
  Braden, R., Zhang, L., Berson, S., Herzog, S., Jamin, S.,
  RFC 2205, September 1997, Proposed Standard.

Reading and References

IntServ

- Wroclawski, J., "Specification of the Controlled-Load Network Element Service", RFC 2211, September 1997.
- Partridge, C. and R. Guerin, "Specification of Guaranteed Quality of Service", RFC 2212, September 1997.

DiffServ

- Blake, S. et al., “An Architecture for Differentiated Services”, RFC2475, December 1998 (status: informational)
- Nichols, K., et al., "Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers", RFC 2474, December 1998.

Thanks and acknowledgements

- The slides have been previously used by Dr. George Kanellos
- The material in this notes is based on direct contribution by Dr Alistair Munro.
- The lectures have been influenced directly by Raj Jain and John Crowcroft