Quality of Service

What is Quality of Service?

- QoS: Capability of a network to provide better service to selected network traffic over various underlying technologies like Frame Relay, ATM, IP and routed networks.
  - Traffic differentiation on classes and preferential treatment.

Need for QoS

- Support for multiple kinds of traffic requiring different treatments.
  - Traffic over single network links.
- Aircraft Analogy.
- Differentiation at active network elements: Have capability to Differentiate traffic flows. Example Routers.
QoS Metrics

1. Service Availability
2. Delay
3. Delay Jitter
4. Throughput
5. Packet loss rate

End to End QoS

• The aim of QoS enabled network architecture: To bring together end hosts closer by increasing performance and reducing delay of the underlying network.
• Network should implement service models.

Three service models
• Best Effort Service
• Integrated Services.
• Differentiated Services.

Best Effort Service

• Application sends data whenever it feels like, as much as it feels like and without requiring anyone's permission.
• Network elements try their level best to deliver the packets without any bounds on delay, latency, jitter etc
  – They give up if they cannot deliver.
  – Example: No Ack. after repeated attempts.
• Onus on end systems.
• Example: Current day IP networks.
Integrated Services (Intserv) Framework

- **Aim:** To provide individualised QoS guarantees to individual application sessions. RFC
- Applications know characteristics of their traffic beforehand
- It signals the intermediate network elements to reserve certain resources to meet its traffic properties.
- Resources available:
  - Yes: Reserve Resources.
  - No: Reject request.
- If "Yes": Application sends data according to contract.

Differentiated Services (Diffserv) Framework

- Network traffic is classified and conditioned at the entry to a network and assigned to a traffic class.
  - All packets of class treated in the same way.
- More scalable than Intserv Model.
  - No per flow resource reservation.
- **RFC 2475.**

Intserv Framework

- **Aim:** To provide individualised QoS guarantees to individual application sessions.
  
  Two Key features:
  - Reserved Resources: Current state of reservation at router.
  - Call Setup.
Intserv Classes of Service

Two major classes of service defined:

- **Guaranteed QoS**: This service guarantees
  - Bandwidth for the application traffic
  - Deterministic upper bound on delay.
- **Controlled Load Network Service**.
  - Average delay is guaranteed.
  - End-to-end delay experienced by some arbitrary packet cannot be determined deterministically.

Resource reSerVation Protocol - RSVP

- Signalling protocol: Allows applications to reserve bandwidth for their data flow.
- Carries host request.
  - Processed and forwarded by routers.
- Two Characteristics:
  - Provides Reservations for Bandwidth in multicast trees.
  - Is receiver oriented.
- Notion of Session.

Note:
- RSVP is not a routing protocol.
- Mechanisms for reservation not specified.

RSVP Protocol

- Special data packet sent by source: PATH
  - Specifies traffic characteristics of sender.
- Path state installed at each hop using PATH message.
- Thus a path from source to each destination is pinned down.
- PATH Error Message
RSVP Protocol

- Receiver issues RESV message.
  - Contains actual QoS characteristics expected by the receiver.
  - Different for each receiver.
- RESV traces back the path taken by PATH message.
- RESV Error message.

Figure 1: RSVP

Traffic Characterization/Specification

- Router must make a decision on resources available.
- Session must declare its QoS requirement and characterise its traffic.
  - Rspec: QoS Requirements
  - Tspec: Traffic characterization
- Rspec, Tspec vary depending on service requested.
Per Element Call Admission

- Sessions Tspec, Rspec carried to each router hop by hop.
- Router receives Request and Determines whether it can admit the call.
- Call Admission decision:
  - Traffic specification.
  - Requested type of service.

Principle of Soft State

- Each reservation for bandwidth in router has a lifetime.
- If lifetime expires, reservation is removed.
- To maintain reservation, receiver periodically refreshes reservation by sending RESV messages.

Figure 2: RSVP Network
**RSVP Example**

- Session has an assigned multicast address.
- Source stamps all outgoing packets with this multicast address.
- Each receiver sends reservation message upstream into multicast tree.
- Specifies rate at which receiver wishes to receive data.
- Amount of bandwidth reserved upstream from router depends on bandwidth reserved downstream.
- R1, R2, R3, and R4 reserve 20kbps, 100 kbps, 3 Mbps, and 3 Mbps respectively.

**RSVP Example**

- Max bandwidth request from D’s downstream: 3 Mbps.
- D’s request upstream to B to reserve 3Mbps.
  - Only 3Mbps: R3 and R4 watching the same event.
- Similarly C requests router B to reserve 10kbps. On link between B and C.
- Layered encoding ensures that receiver R1’s 20 kbps stream is included in 100 kbps stream.

**RSVP Reservation Types**

- **Wildcard Filter Style**: Receiver wants to receive all flows from all upstream senders in the session.
  - Bandwidth reservation to be shared among all senders.
- **Fixed Filter Style**: Receiver specifies a list of senders from which it wants to receive a data flow along with bandwidth reservation for each of these senders.
  - Reservations are distinct, not to be shared.
RSVP Reservation Types

• **Shared Explicit Style**: Receiver specifies a list of senders from which it wants to receive a data flow along with bandwidth reservation.
  – Reservation shared among all senders in the list.

Intserv Framework Limitations

• Intserv makes routing very complicated.
  – RSVP support
• Intserv is not scalable with number of flows.
  – Core router saturation.
• Intserv is purely receiver based.
• Involves maintenance overheads of soft states.

Differentiated Services

• Network traffic is classified and conditioned at the entry to a network and assigned to a traffic class.
Consists of two sets of functional elements:
• **Edge Functions**: Packet Classification and conditioning.
• **Core Function**: Forwarding
Edge Functions

- Functions performed at the edge: Ingress of network.
- Involves Marking Function.
  - DS code point mapping for Traffic class.
- Different classes of traffic receive different service within core network.
- Class of traffic: Behaviour Aggregate.
- After marking Packet can be:
  - Forwarded Immediately.
  - Delayed.
  - Dropped.

Figure 3: Diffserv Network

Core Function

- Forwarding of marked packets in network core.
- Happens according to Per Hop Behavior (PHB) of traffic class.
- **PHB**: It influences how a router’s buffers and link bandwidth are shared among competing classes of traffic.
- Figure 2: Packets from H1 to H3 with same marking as packets from H2 to H4 then routers treat packets as aggregate.
- No Router state for individual source-destination pairs.

**Analogy: Passes for an event:**
DS Domain

- Organization's intranet or an ISP - i.e. networks controlled by a single entity.
- DiffServ is extended across domains by Service Level Agreement's (SLA) between them.
- **SLA**: Specifies rules such as for traffic remarking, actions to be taken for out-of-profile traffic etc.
- When a packet goes from one domain to another, the DS byte may be rewritten upon by the new network’s edge router.

Marking of Packets

- Packet’s mark carried in DS field.
  - Supercedes IP TOS field.

**DS field Structure**

- Differentiated Services Code Point (DSCP)
- Currently Unused (CU) Field.

Traffic Classification and Conditioning

**Classifier**

- Classification at the edge.
- Rules of Classification not explicitly defined.

**Marker**: DS field value set by the marker.

- Once packets are marked, they are forwarded along to destination.
- At each hop, packets receive service associated with their marks.
Traffic Shaping and Metering

- End user has a contract with ISP.
- Contract: declared traffic profile
  - Limit on peak traffic rate.
- If user traffic conforms to negotiated profile, it receives priority marking.
- If traffic profile violated, packets:
  - Receive different mark.
  - Traffic Shaped.
  - Packets dropped.

Traffic Shaping and Metering

**Metering Function:**
- Compare incoming traffic flow with negotiated traffic profile.
- To determine whether packet is within negotiated profile.

**Shaping Function:**
- To make a traffic stream compliant with a given profile.
  - Buffering, increasing delay.
- Packets might be discarded if there is crunch of buffer space.
Per Hop Behaviour (PHB)

- Implemented in the Network Core.
- PHB: Description of externally observable forwarding behaviour of a Diiffserv node applied to a particular behavioural aggregate.
- It influences how a router’s buffers and link bandwidth are shared among competing classes of traffic.

PHB

**Important characteristics of PHB:**
- Different classes of traffic receive difference performance.
- Mechanism Independent.
- Performance differences, observable, hence measurable.

**Examples**
- **Example 1:** A given class of marked packets receive at least X% of outgoing link bandwidth over some interval of time.
- **Example 2:** One class of traffic always receives strict priority over another class of traffic.
PHB
Two PHBs under discussion.
• **Expedited Forwarding**: Simple abstraction of a link with a minimum guaranteed link bandwidth.
  – Some form of isolation among traffic classes.
  – Guarantee independent of traffic intensity of other classes.
• **Assured Forwarding**: Divides traffic into four classes.
  – Each class provided with minimum bandwidth/buffering.
  – Within each class packets partitioned into 3 drop preference categories.
  – Result: Varying amount of resources allocated to each class.

Diffserv Framework Criticisms
• Sender oriented.
• Some sessions require per flow guarantees.
• No support for dynamic SLAs.
• Issue with ISP.

Queuing Methods
• Methods implemented in routers to support the various signaling protocols and actually provide different classes of service.
  – Usually implemented at core routers.
• Involve
  – Creation of different queues
  – Classification.
  – Scheduling packets
Queuing Methods

- Four types of queuing techniques commonly implemented
  - First in First Out (FIFO).
  - Weighted Fair Queuing
  - Custom Queuing
  - Priority Queuing
- **FIFO**: Packets are transmitted in the order in which they arrive.
  - Single Queue, Packet dropping

---

**Weighted Fair Queuing (WFQ)**

- Packets are classified into different "conversation messages"
- Each queue has some priority value or weight assigned to it.
  - Low volume traffic is given higher priority over high volume traffic
- After accounting for high priority traffic the remaining bandwidth is divided fairly among multiple queues (if any) of low priority traffic.

---

**WFQ**

- WFQ lays foundation for RSVP, setting up the packet classification and scheduling required for the reserved flows.
- Using WFQ, RSVP can deliver guaranteed service
### Queuing Methods

**Custom Queuing**
- Separate queues maintained for separate classes of traffic.
- The algorithm requires a byte count to be set per queue.
  - That many bytes rounded of to the nearest packet is scheduled for delivery.
- This ensures that the minimum bandwidth requirement by the various classes of traffic is met.
- CQ round robin through the queues, picking the required number of packets from each.
- If a queue is of length 0 then the next queue is serviced.

---

**Priority Queuing**
- 4 traffic priorities Defined:- high, medium, normal, and low.
- Incoming traffic is classified and enqueued in either of the 4 queues.
  - Classification criteria
- Unclassified packets are put in the normal queue.
- The queues are emptied in the order of - high, medium, normal, and low. In each queue, packets are in the FIFO order.