Quality of Service

Class 4: IntServ and Scheduling

Adaptive QoS Mechanisms

- Classification
- Marking
- Queue Management
- Policing
- Shaping
- Congestion Avoidance

Integrated Services

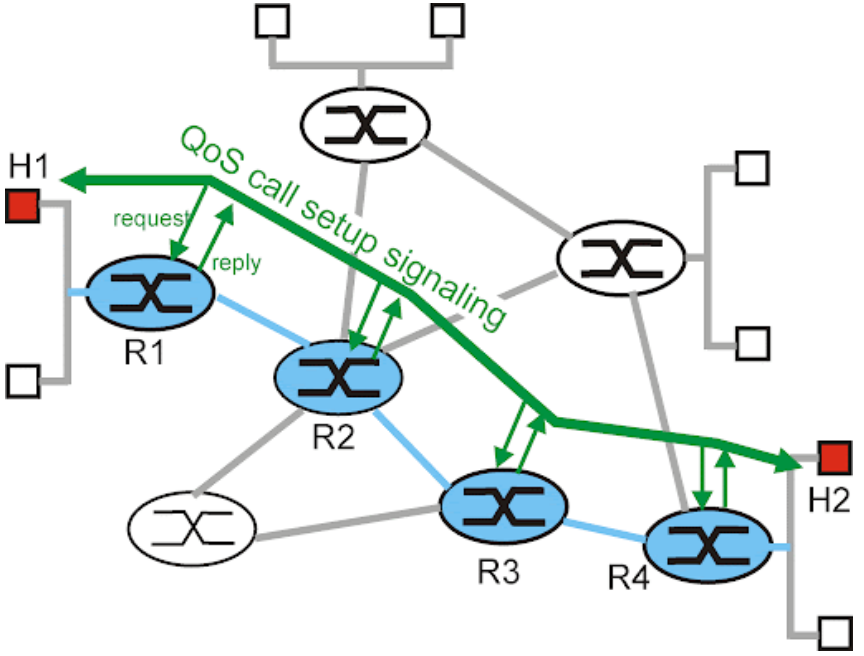
Circuit Switching vs Packet Switching

- Discussion on black board

Integrated Services (IntServ)

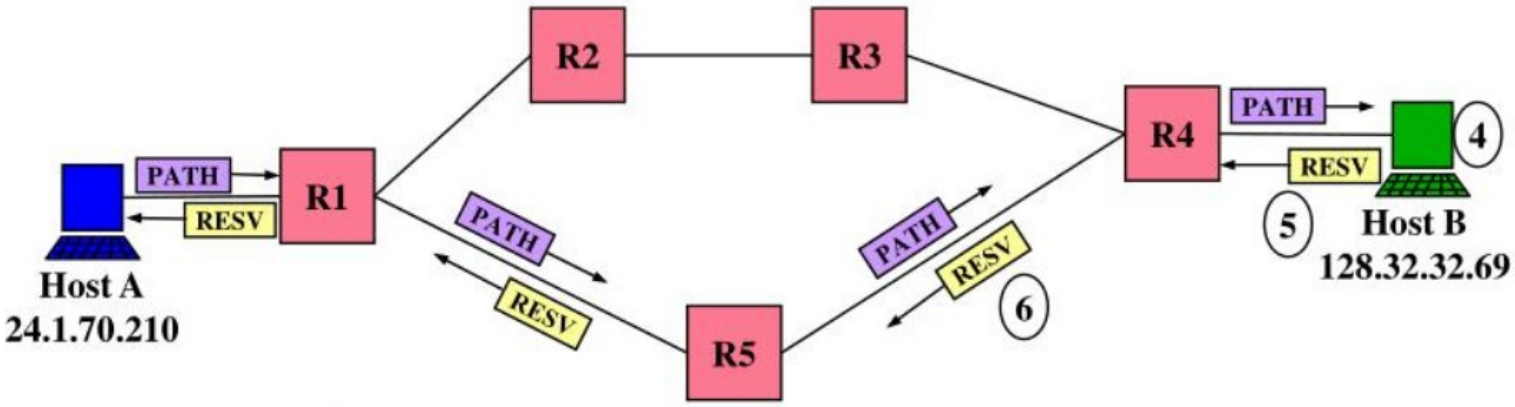
Definition: Integrated Services (IntServ) is a QoS mechanism that provides a more flexible provision of services by using reservation for each traffic flow.

The classic protocol used to implement IntServ is the Resource Reservation Protocol (RSVP).



RSVP: Operation Overview

- Packets PATH/RESV
- “Soft” states – Associated timer

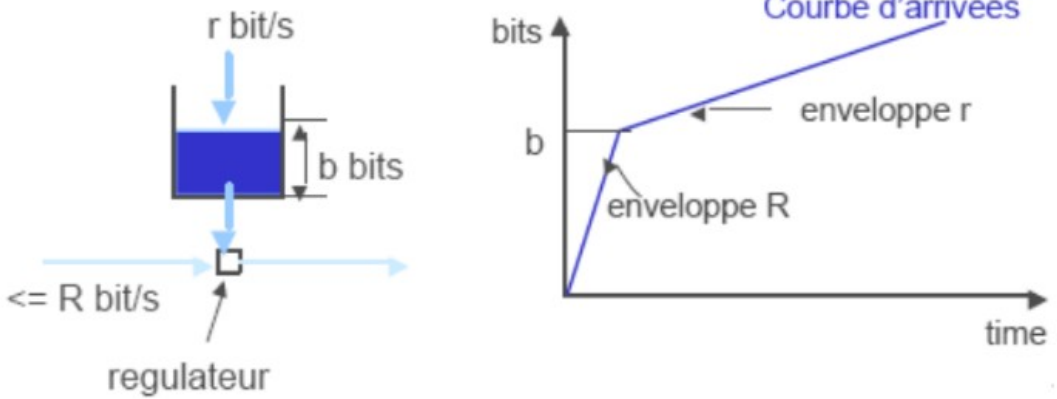


RSVP: Types of Packets

- PATH Packets
  - TSPEC: Traffic specification (How?)
  - Each router maintains:
    - Location information of previous node
    - Location of the transmitter
- RESV Packets
  - Follows reverse path of the PATH packets
  - RSPEC: TSPEC + Target QoS
  - Router proceeds by
    - Performing admission control
    - Updating reservation

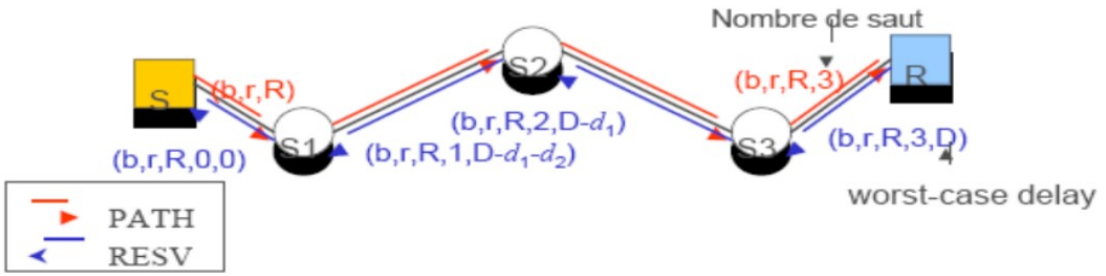
RSVP: Traffic Specification

- Parameters (r,b)
  - r: token arrival rate
  - b: size of the token buffer
- Remember that r <= R, where R is the link capacity
- Token Bucket: 1 transmitted bit consumes 1 token
- Arrival curve:



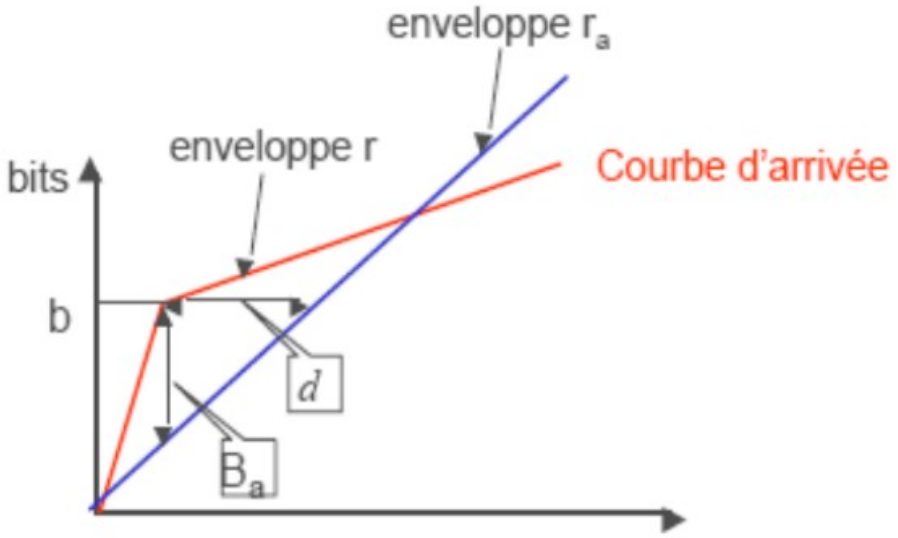
RSVP: End-to-End Reservation

- PATH packet provides
  - Traffic specification (tspec): (r,b,R)
  - Number of hops
- RESV packet provides:
  - PATH info
  - Worst-case delay
  - Guaranteed delay at each node (per hop)



RSVP: Per-Node Reservation

- Given (b,r,R) and guaranteed delay d
- The goal is to provide an average rate r_a that is going to guarantee delay d by consuming buffer B_a



RSVP: Insufficient Resources

- Admission control – traffic is rejected
- QoS-based (re-)routing

RSVP: Recap.

- Advantages:
  - Fine-grained QoS
- Disadvantages:
  - Initial token budget configuration can be misleading
  - Complicated scheduling for multiple flows
- Conclusion:
  - Appropriate for small networks (it does not scale)
  - IntServ at the edge, DiffServ at the core

Scheduling (Revisited)

Scheduling

- **Definition**: In a system where multiple agents share resources, **Scheduling** is a set of strategies to guarantee performance levels by organizing resource access.
- All QoS mechanisms studied so far describe scheduling features used to ensure different QoS levels.
- **Scheduler**: Entity that organizes resource access via a scheduling algorithm.
- Scheduling packets:
  - Determine their transmission order
  - Control performance of each flow
  - Isolate and “fairly” share output link capacity

Classes of Schedulers

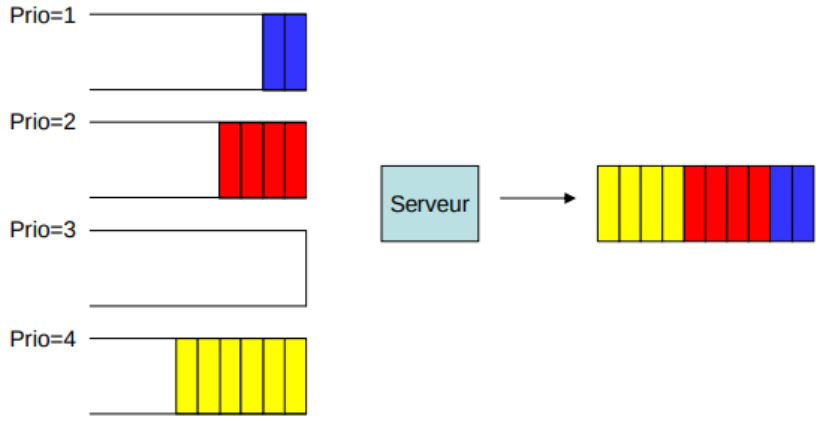
- Work-Conserving (WC) Scheduler: It keeps the shared resource busy as long as there are requests to access it.
  - Capacity utilization optimization
- Non-WC Scheduler: It may leave the shared resource idle even when there are requests to access it.
  - Traffic handling for QoS
- Scheduling packets:
  - Shared resource: Transmission medium
  - Requests to access: Packets

First-In, First-Out (FIFO)

- Packets are transmitted at the same order they arrive in the interface.
- Advantages:
  - Simple implementation
  - Fastest operation
- Disadvantages:
  - No traffic isolation or differentiation
- Suitable for: Best Effort traffic (no services)

Priority Queue (PQ)

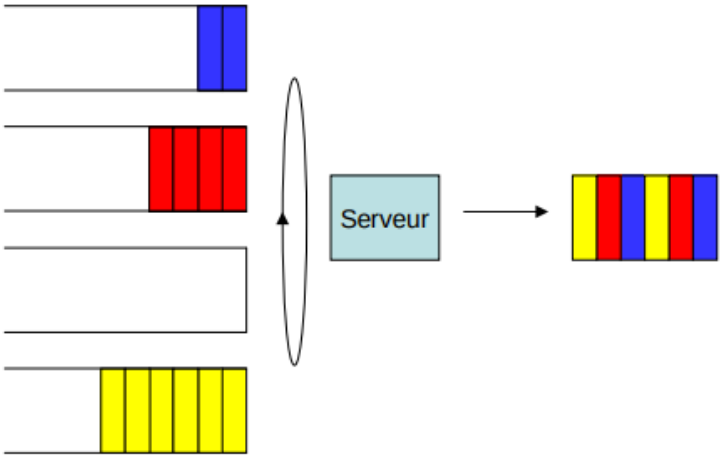
- Consider N priority levels
- Isolation: Flow at each priority level gets one queue
- In practice, it usually takes 3 levels (control, high, and low priority)
- Used for low-latency traffic differentiation
- Problem: Busy high-priority traffic causes starvation of lower priority queues



In a PQ system with 2 priorities, link capacity R and all packets of size B, what is the worst-case queuing delay of:
(i) a high-priority packet?
(ii) a low-priority packet?

Round Robin (RR)

- Consider N classes
- Isolation: Flow at each class gets one queue
- In practice, the difference classes depend on the used DiffServ technique
- No more starvation!
- Problems:
  - It does not guarantee throughput and delay required by high-priority traffic.
  - RR becomes “unfair” if packets have different sizes (different average throughput)



Consider an RR system with 4 classes, link capacity R and all packets of size B.
(i) What is the worst-case queuing delay of a packet of any given class?
(ii) What is the average throughput in 1 second?

Weighted Fair Queue (WFQ)

- Extension of RR designed to mitigate starvation while guarantee priority-based services
- Parameters:
  - Transmission time interval T for every queue at every cycle
  - Weight (also called quota) w_i of every flow i.

Deficit Round Robin (DRR)

- Extension of classic RR designed to handle scenarios with variable packet size.
- Parameters:
  - Max. number of bits for flow i every cycle, also called quantum: Q_i
  - Deficit of flow i for the next cycle:

    $Dc_i = Q_i$ – Service
  - Number of bits of packet k of flow f: L_i^k
- In the long run, it provides fair average throughput, i.e., for each flow i,

$$\frac{Q_i}{(Q_1 + Q_2 + \ldots + Q_N)} R$$