Quality of Service (QoS) in IP networks

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Quality of Service (QoS)

- QoS is the ability of network to support applications without limiting it's function or performance
- ITU-T E.800: Quality of Service is an overall result of service performance, which determines level of service user satisfaction

What influences QoS ?

What influences QoS ?

Every network component influences QoS:

- End stations (workstations, servers, …)
- Routers, switches
- Links
  - including links between routers and stub LANs

Parameters which constitute QoS

- bandwidth
- delay
- delay variation (jitter)
- packet loss

What contributes to delay ?

- Fixed part
  - serialization delay
  - propagation delay
- Variable part
  - buffering (queueing) in routers and switches

Reasons of delay variation

Non-uniform handling of individual packets of the same flow in individual switching devices

- variable delay caused by waiting in queues

Reasons of packet loss

- (physical transmission errors – receiver discards)
- Overload of switching element's CPU
  - (input drops)
- Output queue full
  - (output drops)

QoS Implementation Models

QoS implementation models

- Best Effort
- Integrated Services - Hard QoS
- Differentiated Services - Soft QoS

Best Effort Service

- Original Internet service
- Makes best effort to transfer packet, but provides no guarantees
- In case of congestion, any packet may be dropped
- No priorization

Integrated Services - Hard QoS (intserv)

- Explicit reservation of network resources for individual flows before communication starts
  - Link capacity, queue memory, CPU of switching elements
- Poor scalability
  - Many flows are passing through backbone devices
- Resource Reservation Protocol (RSVP)
  - reserves resources for individual flows along it's path

IntServ: Resource Reservation Protocol (RSVP)

- Signalling between flow receiver and switching devices along (reverse) flow path
  - also among switching devices
  - goes against flow direction
- Distinct and shared reservation
- Requires support of end-stations SW
- Natural in connection-oriented networks (like ATM), problematic in packet-switched networks

Differentiated Services - Soft QoS (diffserv)

- Traffic classification and marking
- Defined Per-Hop Behavior (PHB) of switching devices (routers, switches) for every traffic class
- Limited number of classes – better scalability
- Only prefers some data classes, no delivery time guarantee
  - only relative preferences

Traffic Classification

- Classification on the network (or QoS-domain) boundary
- Marking at layer 2: 802.1pq
  - 3-bit Class of Service (CoS) field
- Marking at layer 3: 8-bit TOS/DSCP field in IP header
  - Before: Type of Service (ToS), 8 IP precedence classes
  - Now: Differentiated Service Code Point (DSCP)
- Routers and L3 switches needs to map between L2 CoS and L3 ToS/DSCP
  - QoS has to be ensured end-to-end

Defined Diffserv Per-hop Behaviors

- Expedited Forwarding (EF)
  - “Virtual leased line”
  - Little loss, small but variable delay, guaranteed bandwidth
- Assured Forwarding (AF)
  - 4 classes specified by Class Selector (1-4)
  - 3 drop preferences in every class
    - (1=low, 2=medium,3=high).
  - Denoted as AFxy, x=class selector, y=drop preference
    - x,y coded in DSCP.
- Best Effort

QoS Implementation Mechanisms

Mechanisms of enforcing QoS

- Applied only when network congestion arises
  - If the network is not congested, QoS mechanisms only cause unnecessary overhead and commonly are not applied
- The goal is to guarantee minimal bandwidth, maximum delay and maximum jitter

Input filtering, classification and marking

Traffic Policing

- Limits input rate according to Commited Information Rate (CIR)
  - Sometimes takes EIR into account also
- Uses Token Bucket Algorithm

Input Traffic Classification

- Classification based on L1-L7 information
  - Incoming port, MAC address, protocol, IP addresses, TCP/UDP port, URL, MIME type, ...)
- Classified by sender or by network boundary device
  - NBAR: Network-Based Application Recognition
- Backbone devices trust classification performed on the network boundary

Congestion Management

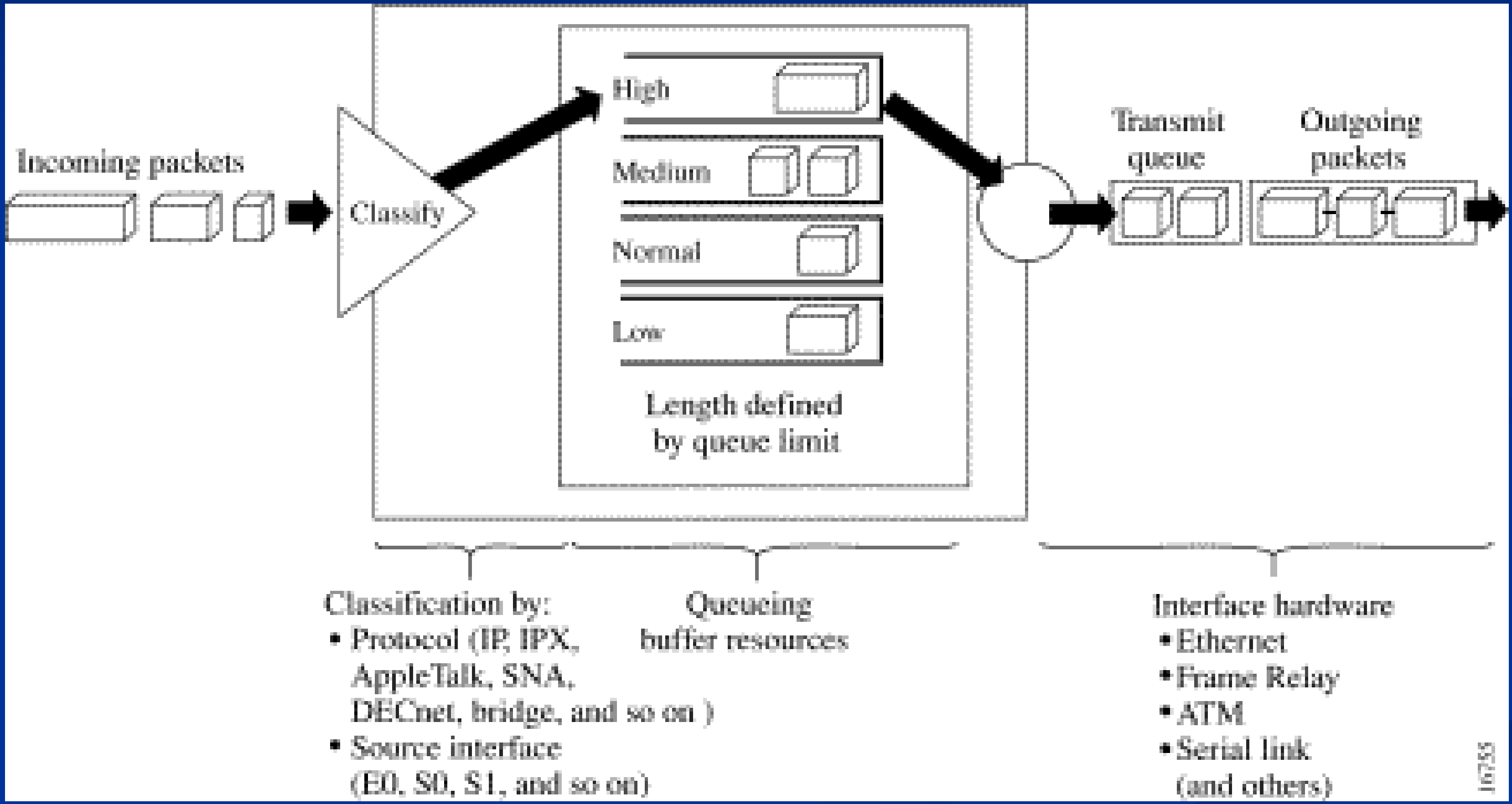
Congestion Management Principle

- Traffic classes sorted into queues
  - Explicit (marking-based) assignment to queue
  - Default queue
- Queues serviced by various algorithms
  - Selection of next packet to send out of output line

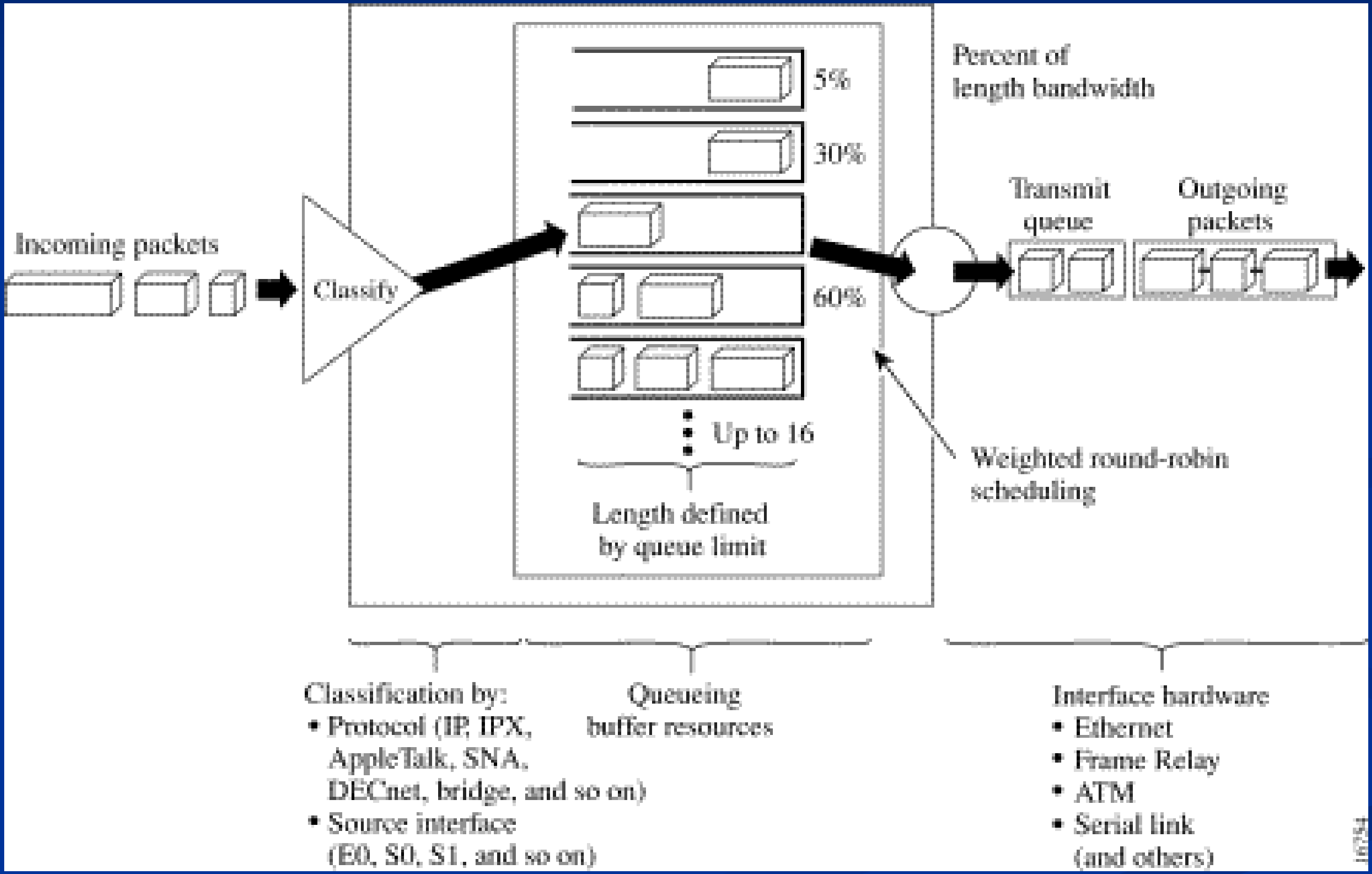
Basic Queueing Algorithms

- FIFO
- Priority Queuing (PQ)
  - absolute priorities
- Custom Queuing (CQ)
  - proportional queue processing
- Weighted Fair Queuing (WFQ)
  - automatic traffic classification into flows, fair handling of flows
- Class-Based Weighted Fair Queuing (CBWFQ)
  - Classification into classes, FIFO in every class, WFQ between classes
- Low-Latency Queuing (LLQ)
  - WFQ + absolute priority queue

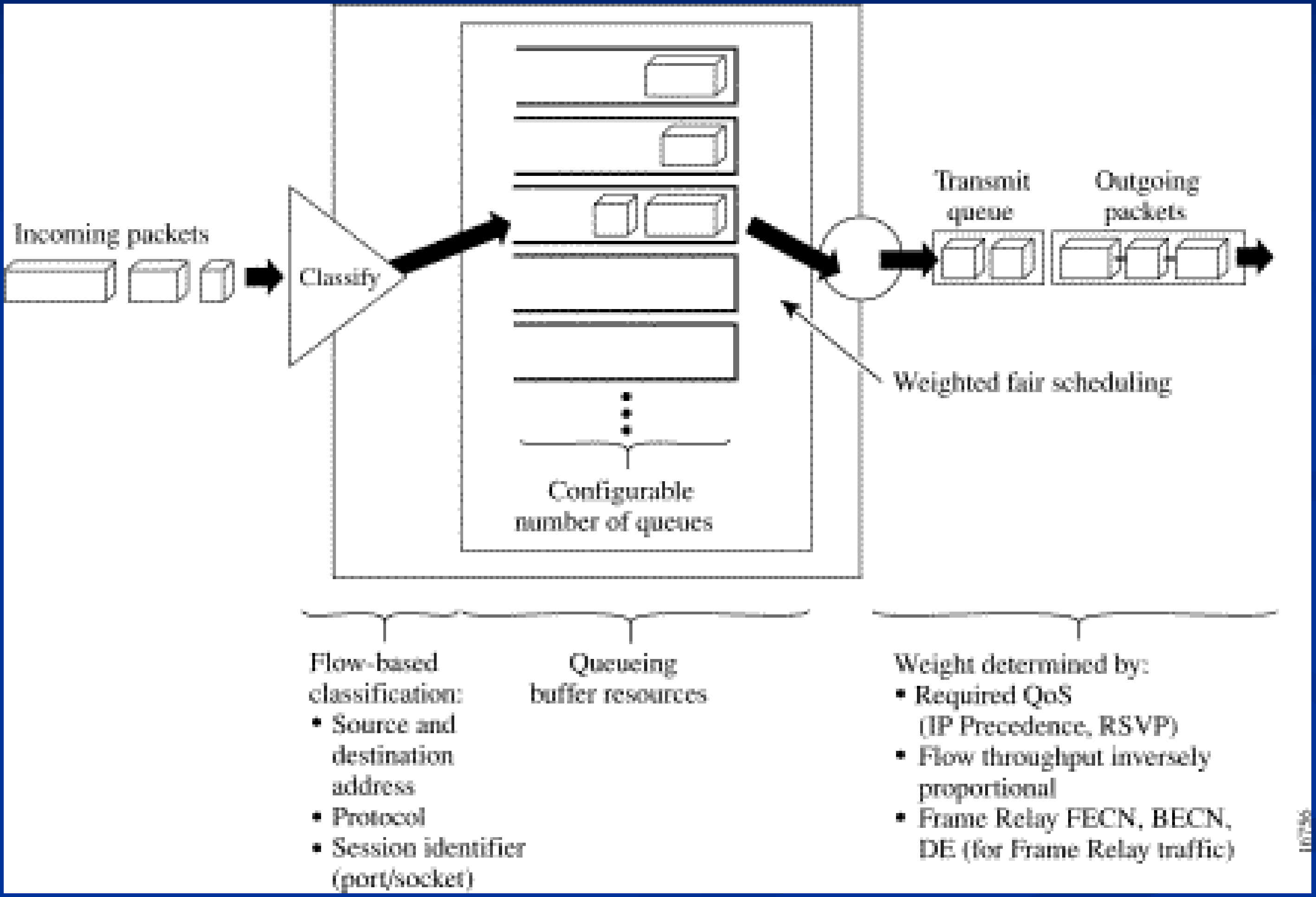
Priority Queueing



Custom Queueing



Weighted Fair Queueing



Congestion Avoidance

- When the queue fills-up, router starts to discards packet (tail drop)
  - Many TCP flows start to lose ACKs and perform slow start at the same time
  - The result is global TCP flow synchronization, causing network load oscillation
- Random Early Discard technique is used to combat against it

(Weighted) Random Early Discard

- As queue becomes full, router will start to randomly discard packets with increasing probability
- Slow start of some TCP connection(s) happens earlier comparing with standard tail-drop
  - Avoids global TCP flow synchronization
- Weighted RED – packet discard probability influenced also by packet's priority
- Note: RED can regulate only TCP flows (!)
  - There is no feedback in UDP protocol itself

WRED Configuration

For every traffic class we define

- Minimum queue length to begin random discard
- Constant to calculate drop probability based on current (averaged) queue length
  - Applies only when queue length reaches minimum length for random discard
- Maximum queue length
  - When a limit is reached, all packets of the class are dropped until queue length decreases
    - Some kind of hysteresis needed

Traffic Shaping

- Protects against sending of packets to ISP faster than ISP agrees to accept them
  - ISP applies traffic policing so sending more traffic only wastes bandwidth
  - The goal is to adapt traffic rate to the commited rate
- Important when physical line rate is higher than CIR of some virtual circuit

Mention the difference between Traffic Shaping and Traffic Policing

Fragmentation and Interleaving

- Mechanism used to ensure reasonable delay and jitter of interactive applications
  - packets of interactive application have to be delivered on timely manner
  - Sending of long packet on the same line can take more time than is the maximum allowed between two interactive application’s packets
- Long packets are fragmented and fragments are interleaved with packets of interactive applications
- Used on slow links with large serialization delay

Policy routing and QoS

- Policy routing based on
  - TOS value
  - Packet size

QoS-based Routing

QoS-based Routing: Principles and Problems

- Many routing protocols can propagates current QoS parameters of individual links
  - Cisco (E)IGRP, OSPF v.3, …
- Problem with routing oscillation
  - and thus unwanted jitter of transferred packets
- Routing protocol may calculate multiple shortest paths optimized for various metric
  - Packet can be forwarded according to routing table selected based on it’s TOS field value
  - Consumes lot of resources (CPU, memory, bandwidth)

QoS support in operating systems

- Windows – suspicious
  - (commonly does nothing ;-))
- Linux – wide variety of QoS mechanisms for QoS-aware packet handling
- Specialized router and switch software
  - Not every vendor supports QoS today

QoS in networking technologies

QoS enforced by some media access control methods themselves

- Old technologies: Token Ring, 100VG-AnyLan
- WiFi: IEEE 802.11e (emerging standard)

Implementation of QoS mechanisms

1. Determine applications used in your network and their requirements
   - Monitor traffic for representative usage period
2. Suggest and implement QoS mechanisms
3. Verify behavior of your network
4. GOTO 1 ;-)

What to expect from QoS today

- Little strange and sometimes nonfunctional implementation
- Statistical behavior
- Works only in some domains
  - not implemented worldwide

References

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