

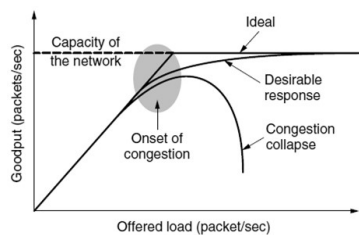
The Network Layer

Congestion Control Algorithms & Quality-of-Service

Congestion Control Algorithms

- Approaches to Congestion Control
- Traffic-Aware Routing
- Admission Control
- Traffic Throttling
- Load Shedding

Congestion



When too much traffic is offered, congestion sets in and performance degrades sharply.

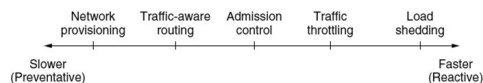
General Principles of Congestion Control

1. Monitor the system
 - detect when and where congestion occurs.
2. Pass information to where action can be taken.
3. Adjust system operation to correct the problem.
4. Difference between Congestion control and flow control – Elaborate
5. Problem of infinite buffer - Elaborate

Approaches to Congestion Control

Two solutions possible:

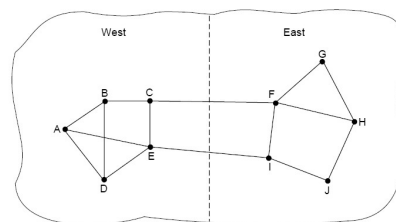
- 1) Increase resources
- 2) Decrease load



Timescales of approaches to congestion control.

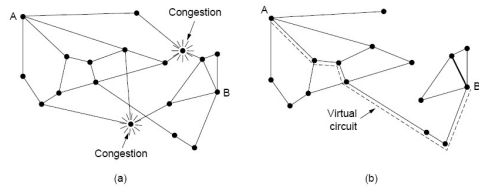
Admission control in virtual networks – no more provisioning

Traffic-Aware Routing



A network in which the East and West parts are connected by two links.

Admission Control



(a) A congested network. (b) The portion of the network that is not congested. A virtual circuit from A to B is also shown.

Problem is in virtual circuits – there may be provisioning but not real usage.

Traffic Throttling: Congestion Detection

- Routers must determine when congestion is approaching, ideally before it has arrived.
- Each router can continuously monitor the resources it is using.
- 3 possibilities:
 1. utilization of the output links
 2. buffering of queued packets inside the router (most useful)
 3. no. of packets that are lost due to insufficient buffering

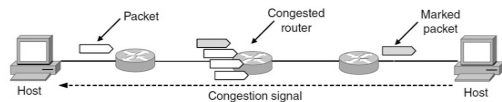
EWMA (Exponentially Weighted Moving Average)

- $d_{\text{new}} = \alpha d_{\text{old}} + (1 - \alpha)s$,
where, the constant α determines how fast the router forgets recent history.
- Whenever d moves above the threshold, the router notes the onset of congestion.

Traffic Throttling: Feedback

- Routers must deliver timely feedback to the senders that are causing the congestion.
- The router must identify the appropriate senders.
- It must then warn them carefully, without sending many more packets into the already congested network.
- Many feedback mechanisms:

Mechanism 1: Explicit Congestion Notification (ECN)

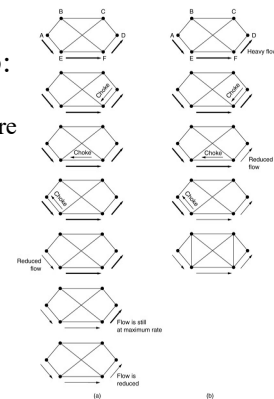


Mechanisms 2 & 3: Direct Choke Packets, Hop-by-Hop Backpressure

M-2: A choke packet that affects only the source.

M-3: A choke packet that affects each hop it passes through.

Sending choke packets to the source may be costly.



Mechanism 4: Load Shedding

- Performed when all other strategies fail.
- Cause blackout in some areas to save the entire network from failing.
- Intelligent packet drop policy desired.
- Which packets to discard may depend on application
 - Multimedia – old packets (full frame not to be discarded)
 - Text – Recent Packets
- Packet's importance can be marked in the beginning (application layer), then decision on which packets to discard can be taken.

Mechanism 5: Random Early Detection

- Discard packets before all the buffer space is really exhausted.
- To determine when to start discarding, routers maintain a running average of their queue lengths.
- When average queue length exceeds a threshold, the link is said to be congested – small fraction of packets dropped at random.
- The affected sender will notice the loss when there is no acknowledgement – transport protocol slowed down.

Quality of Service

- Requirements
 - Minimum throughput and maximum latency
- Techniques for Achieving Good Quality of Service
- Integrated Services
- Differentiated Services
- Label Switching and MPLS

Requirements

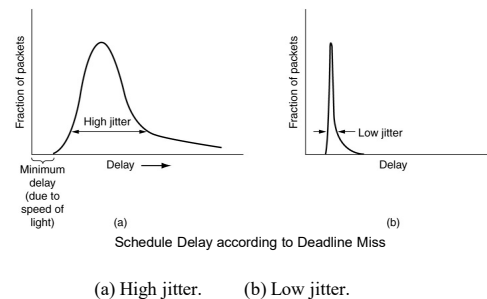
Application	Reliability	Delay	Jitter	Bandwidth
E-mail	High	Low	Low	Low
File transfer	High	Low	Low	Medium
Web access	High	Medium	Low	Medium
Remote login	High	Medium	Medium	Low
Audio on demand	Low	Low	High	Medium
Video on demand	Low	Low	High	High
Telephony	Low	High	High	Low
Videoconferencing	Low	High	High	High

How stringent the quality-of-service requirements are.

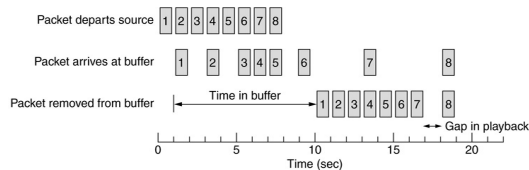
Categories of QoS and Examples

1. Constant bit rate
 - Telephony
2. Real-time variable bit rate
 - Compressed videoconferencing
3. Non-real-time variable bit rate
 - Watching a movie on demand
4. Available bit rate
 - File transfer

Jitter Control



Buffering

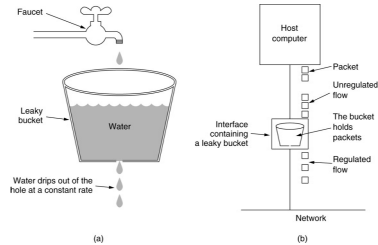


Smoothing the output stream by buffering packets.

Traffic Shaping

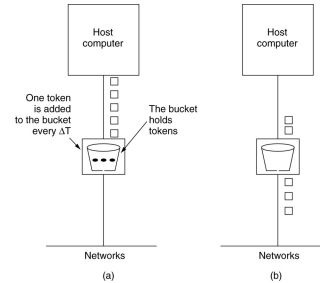
- Traffic in data networks is **bursty** – typically arrives at non-uniform rates as the traffic rate varies.
- **Traffic shaping** is a technique for regulating the average rate and burstiness of a flow of data that enters the network.
- When a flow is set up, the user and the network agree on a certain traffic pattern (shape).
- Sometimes this agreement is called an **SLA (Service Level Agreement)**.

The Leaky Bucket Algorithm



(a) A leaky bucket with water. (b) a leaky bucket with packets.

The Token Bucket Algorithm

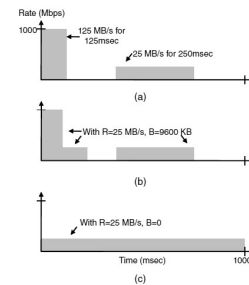


(a) Before. (b) After.

Token Bucket Algorithm (2)

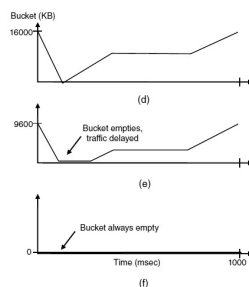
- Burst length – S sec.
- Maximum output rate – M bytes/sec
- Token bucket capacity – B bytes
- Token arrival rate – R bytes/sec
- An output burst contains a maximum of $(B + RS)$ bytes.
- The number of bytes in a maximum speed burst of length S seconds is MS .
- Hence, we have: $B + RS = MS$
- This equation can be solved to get $S = B / (M - R)$

Traffic Shaping (2)



(a) Traffic from a host. Output shaped by a token bucket of rate 200 Mbps and capacity (b) 9600 KB, (c) 0 KB.

Traffic Shaping (3)



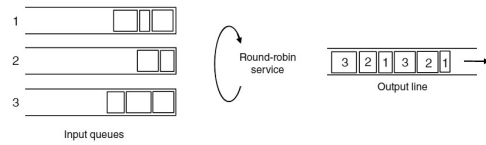
Token bucket level for shaping with rate 200 Mbps and capacity (d) 16000 KB, (e) 9600 KB, and (f) 0KB..

Packet Scheduling

Kinds of resources that can potentially be reserved for different flows:

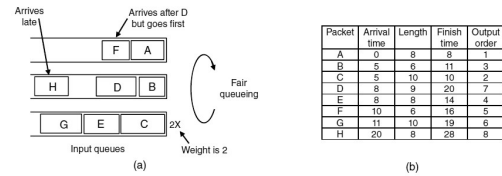
1. Bandwidth.
2. Buffer space.
3. CPU cycles.

Packet Scheduling (2)



Round-robin Fair Queuing

Packet Scheduling (3)



- (a) Weighted Fair Queuing.
(b) Finishing times for the packets.

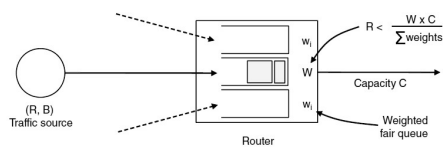
Admission Control (1)

Parameter	Unit
Token bucket rate	Bytes/sec
Token bucket size	Bytes
Peak data rate	Bytes/sec
Minimum packet size	Bytes
Maximum packet size	Bytes

An example flow specification

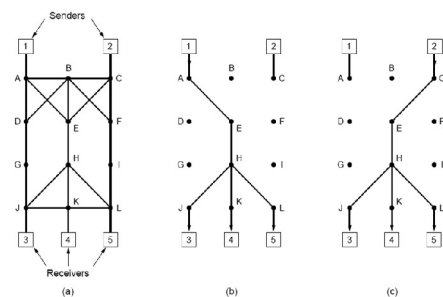
- a) $T = 1/\mu \times 1/(1-\lambda/\mu) \rightarrow \lambda = 0.95 \text{ Mpackets/sec}$
b) $\mu = 1 \text{ Mb packets/sec}$

Admission Control (2)



Bandwidth and delay guarantees with token buckets and WFQ.

Integrated Services: RSVP—The Resource reSerVation Protocol



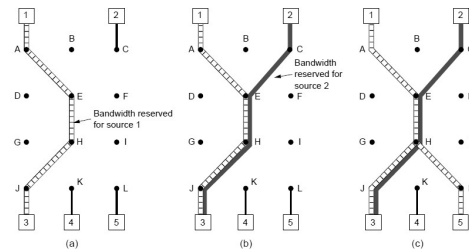
Hosts 1 and 2 are multicast sender

3,4, 5 are multicast receiver

Host 3 reserves for Host 1 and the Host 2

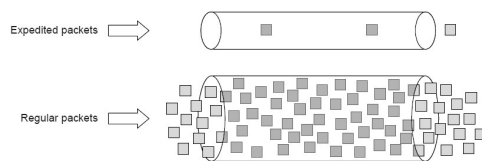
Host 5 reserves Host 1 (so the common path is utilized). However depending on need (Host 5 may be a bigger TV) – provision is made for the greediest part

RSVP (2)



(a) Host 3 requests a channel to host 1. (b) Host 3 then requests a second channel, to host 2.
(c) Host 5 requests a channel to host 1.

Differentiated Services: Expedited Forwarding



Expedited packets experience a traffic-free network

Class-Based Service

Per Hop Behaviors

Traffic within a class are given preferential treatment

Expedited Forwarding

Packets marked – Regular or Expedited

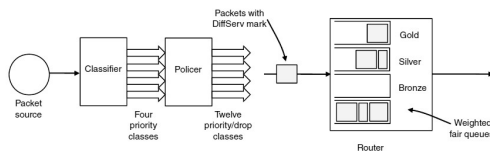
Assured Forwarding

Gold, Silver, Bronze, common

Packets that face congestion

low (short burst), medium and high _ this classes are determined by token bucket algorithm

Differentiated Services: Assured Forwarding



A possible implementation of assured forwarding, weighted fair scheduling, RED (random Early Detection discards packet according to the class).

The Leaky Bucket Algorithm

(a) Input to a leaky bucket.
(b) Output from a leaky bucket. Output from a token bucket with capacities of (c) 250 KB, (d) 500 KB, (e) 750 KB, (f) Output from a 500KB token bucket feeding a 10-MB/sec leaky bucket.

