Chapter 24

Congestion Control and Quality of Service

24-1   DATA TRAFFIC

The main focus of congestion control and quality of service is *data traffic*. *In congestion control we try to avoid traffic congestion. In quality of service, we try to create an appropriate environment for the traffic. So, before talking about congestion control and quality of service, we discuss the data traffic itself.*

Topics discussed in this section:

Traffic Descriptor
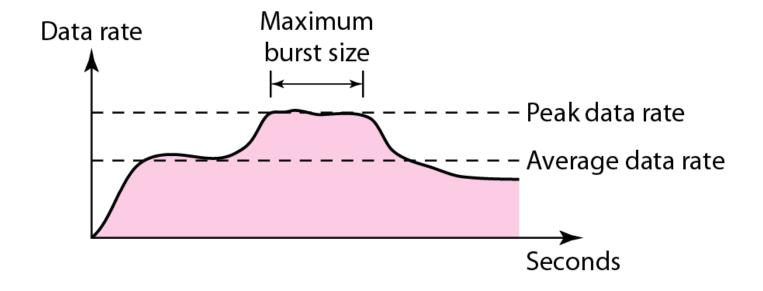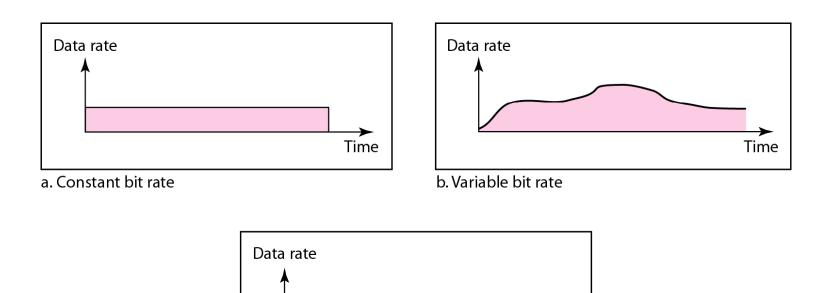**Traffic Profiles**

24.2

Figure 24.1 *Traffic descriptors*

Figure 24.2 *Three traffic profiles*

a. Constant bit rate

b. Variable bit rate

c. Bursty

24-2   CONGESTION

Congestion in a network may occur if the load on the network—the number of packets sent to the network—is greater than the capacity of the network—the number of packets a network can handle. Congestion control refers to the mechanisms and techniques to control the congestion and keep the load below the capacity.

Topics discussed in this section:
Network Performance

24.5

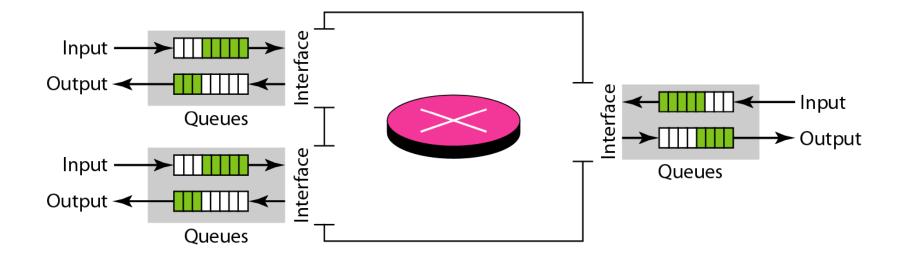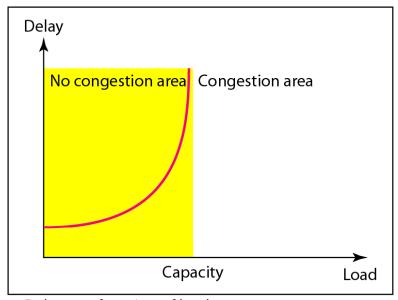# Figure 24.3 *Queues in a router*
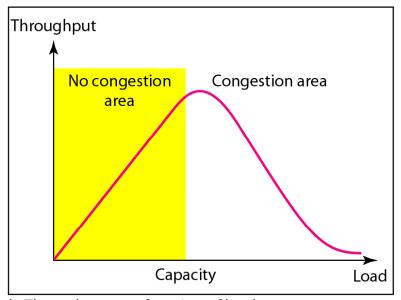
Figure *Packet delay and throughput as functions of load*

a. Delay as a function of load

b. Throughput as a function of load

24.7

24-3   CONGESTION CONTROL

Congestion control refers to techniques and mechanisms that can either prevent congestion, before it happens, or remove congestion, after it has happened. In general, we can divide congestion control mechanisms into two broad categories: open-loop congestion control (prevention) and closed-loop congestion control (removal).

Topics discussed in this section:
Open-Loop Congestion Control
Closed-Loop Congestion Control

24.8
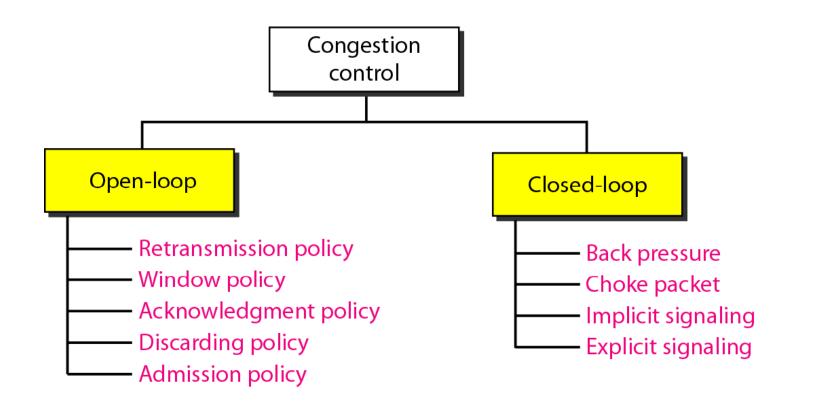
Figure 24.5 *Congestion control categories*

Figure 24.6 *Backpressure method for alleviating congestion*

Figure 24.7 *Choke packet*

Choke
packet

Source

Congestion

Destination

Data flow
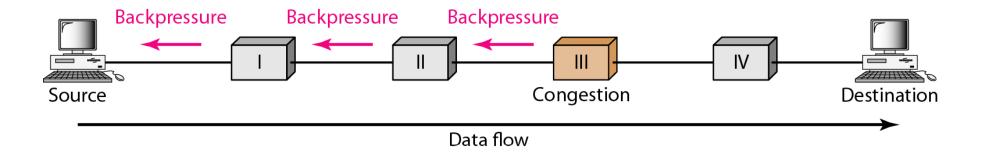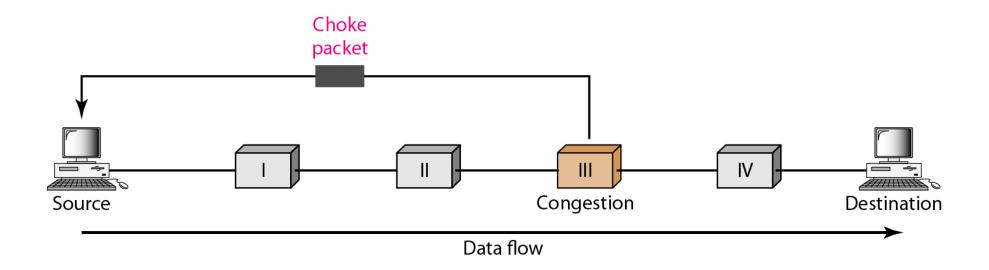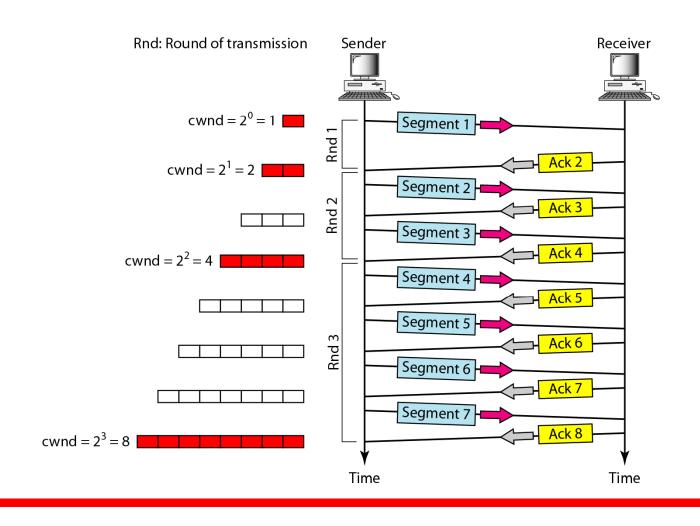
24-4   TWO EXAMPLES

To better understand the concept of congestion control, let us give two examples: one in TCP and the other in Frame Relay.

Figure 24.8 *Slow start, exponential increase*

$$cwnd = 2^0 = 1$$

$$cwnd = 2^1 = 2$$

$$cwnd = 2^2 = 4$$

$$cwnd = 2^3 = 8$$

Rnd: Round of transmission

Sender

Receiver

Rnd 1

Rnd 2

Rnd 3

Segment 1
Ack 2
Segment 2
Ack 3
Segment 3
Ack 4
Segment 4
Ack 5
Segment 5
Ack 6
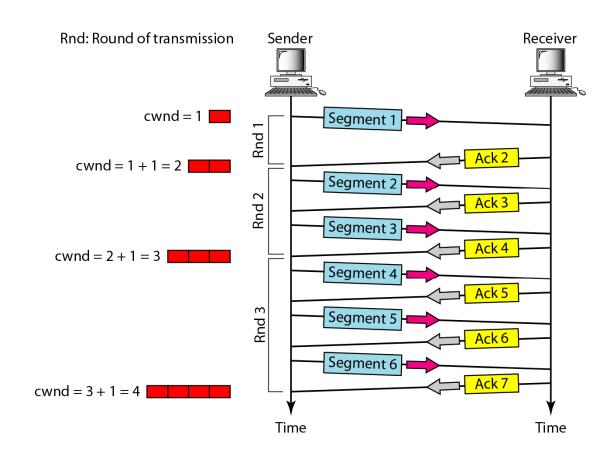Segment 6
Ack 7
Segment 7
Ack 8

Time

Time

24.13

Note

In the slow-start algorithm, the size of the congestion window increases exponentially until it reaches a threshold.

Figure 24.9 *Congestion avoidance, additive increase*

Rnd: Round of transmission

Sender

Receiver

cwnd = 1

cwnd = 1 + 1 = 2

cwnd = 2 + 1 = 3

cwnd = 3 + 1 = 4

Rnd 1

Rnd 2

Rnd 3

Segment 1

Ack 2

Segment 2

Ack 3

Segment 3

Ack 4

Segment 4

Ack 5

Segment 5

Ack 6

Segment 6

Ack 7

Time

Time

In the congestion avoidance algorithm, the size of the congestion window increases additively until congestion is detected.

Note

An implementation reacts to congestion detection in one of the following ways:
- ❏ If detection is by time-out, a new slow start phase starts.
- ❏ If detection is by three ACKs, a new congestion avoidance phase starts.
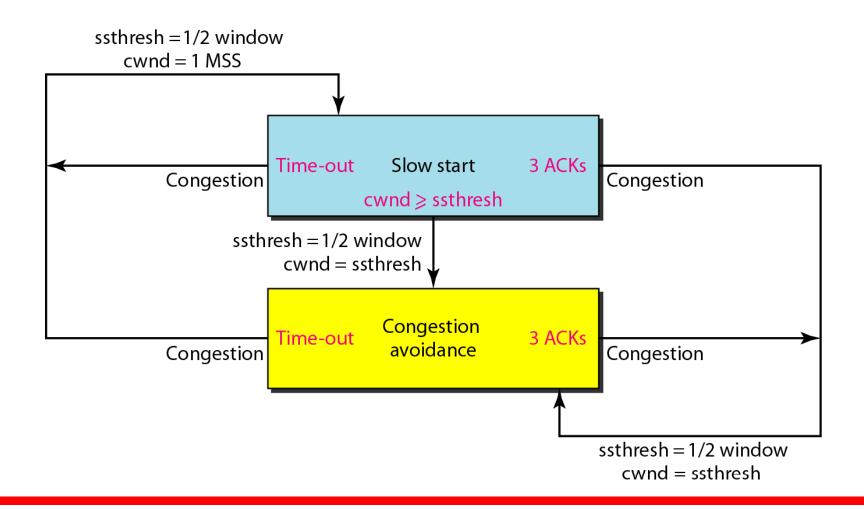
Figure 24.10 *TCP congestion policy summary*
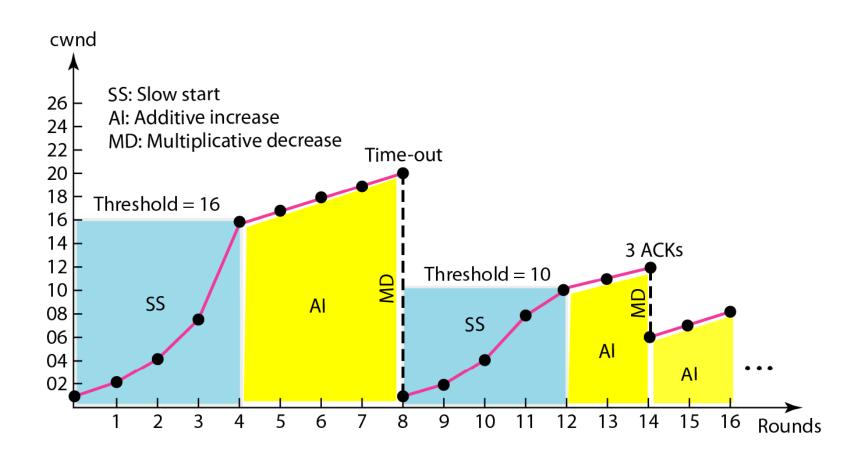
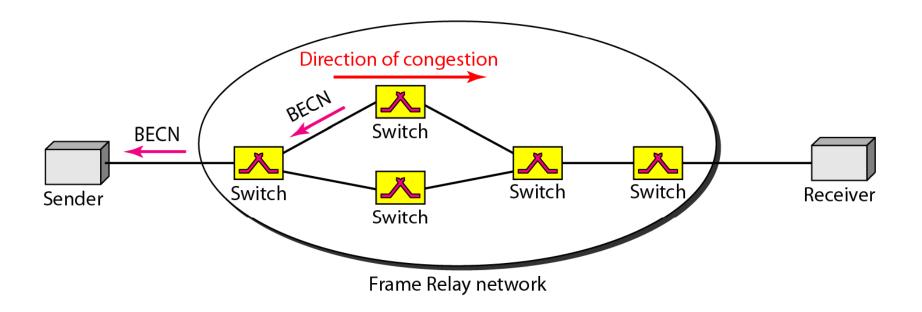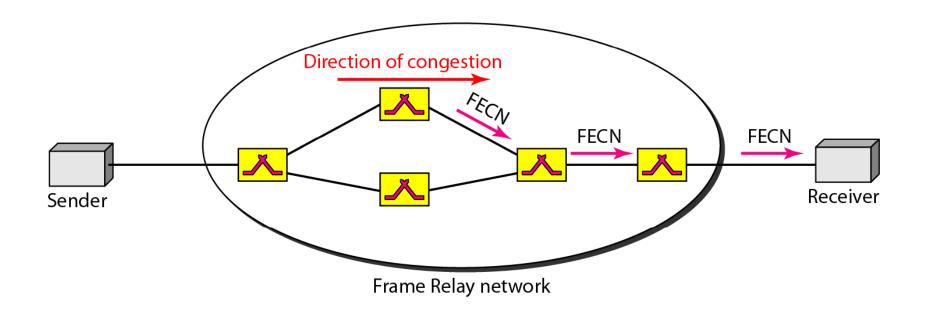# Figure 24.11 *Congestion example*

Figure 24.12 *BECN*
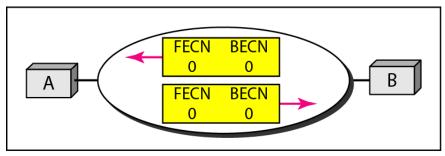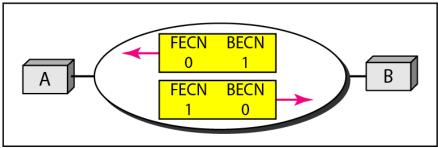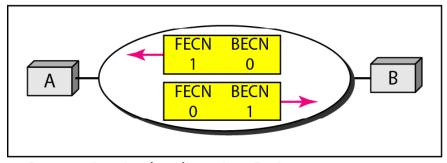
Figure 24.13 *FECN*

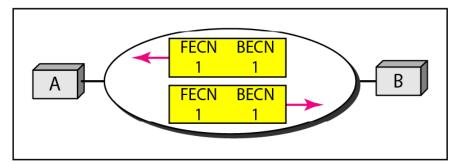# Figure 24.14 *Four cases of congestion*

a. No congestion

b. Congestion in the direction A–B

c. Congestion in the direction B–A
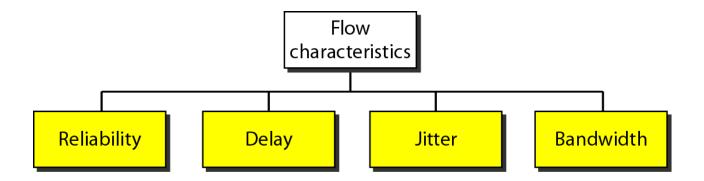
d. Congestion in both directions

24-5   QUALITY OF SERVICE

Quality of service (QoS) is an internetworking issue that has been discussed more than defined. We can informally define quality of service as something a flow seeks to attain.

24.23

Figure 24.15 *Flow characteristics*

24-6   TECHNIQUES TO IMPROVE QoS

In Section 24.5 we tried to define QoS in terms of its characteristics. In this section, we discuss some techniques that can be used to improve the quality of service. We briefly discuss four common methods: scheduling, traffic shaping, admission control, and resource reservation.

Topics discussed in this section:

Scheduling
Traffic Shaping
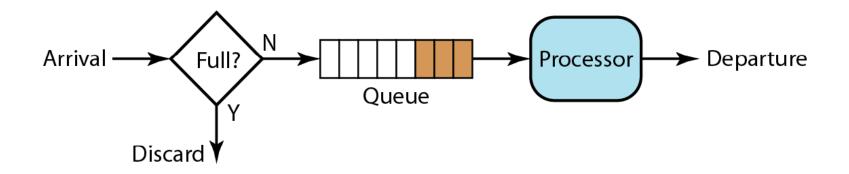**Resource Reservation**
Admission Control

24.25

Figure 24.16 *FIFO queue*

Figure 24.17 *Priority queuing*

The switch turns to the other queue when the current one is empty.

Arrival → Classifier

Full? N → Higher-priority queue
Y → Discard

Full? N → Lower-priority queue
Y → Discard

Processor → Departure
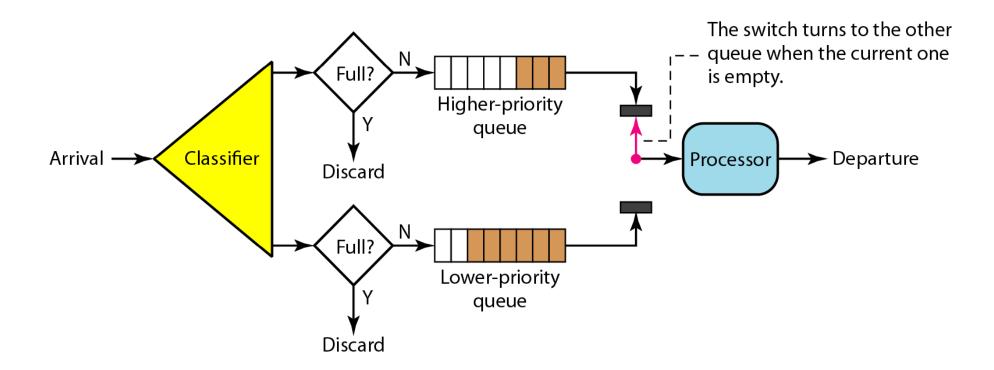
Figure 24.18 *Weighted fair queuing*

The turning switch selects 3 packets from first queue, then 2 packets from the second queue, then 1 packet from the third queue. The cycle repeats.

Arrival

Classifier

Full? N Y Discard

Weight: 3

Full? N Y Discard

Weight: 2

Full? N Y Discard

Weight: 1

Processor → Departure

Figure 24.19 *Leaky bucket*

Bursty flow
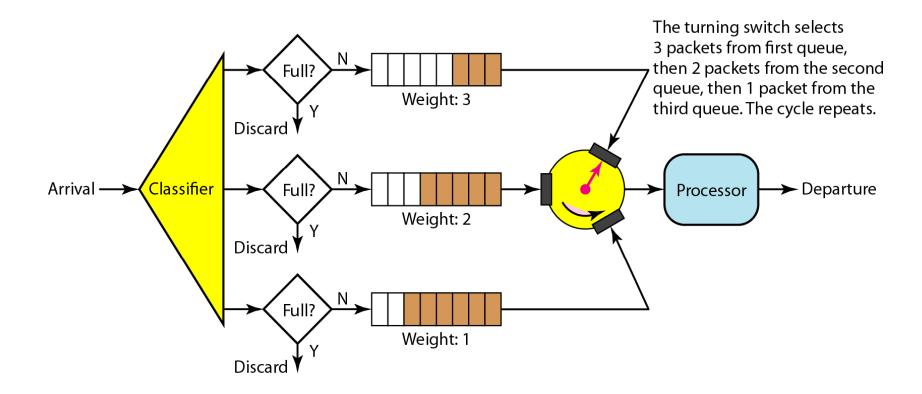
Leaky bucket

Fixed flow
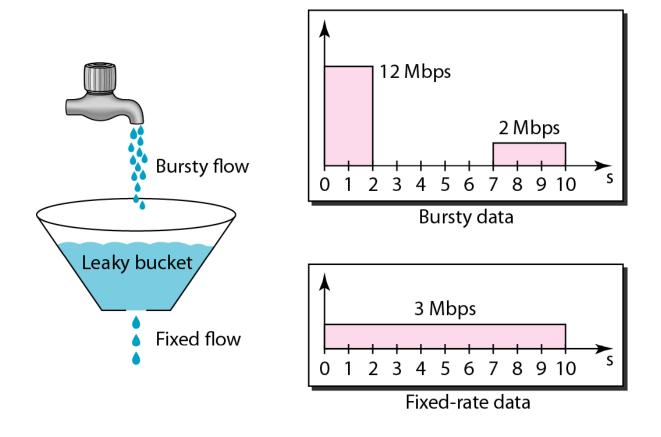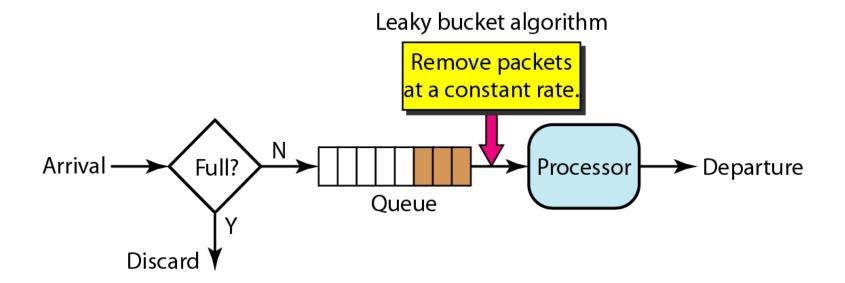
12 Mbps

2 Mbps

Bursty data

3 Mbps

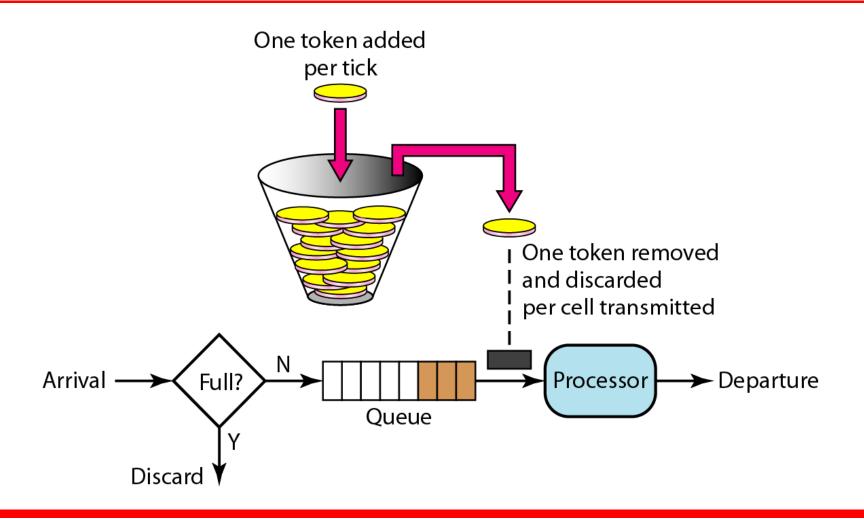Fixed-rate data

Figure 24.20 *Leaky bucket implementation*

A leaky bucket algorithm shapes bursty traffic into fixed-rate traffic by averaging the data rate. It may drop the packets if the bucket is full.

The token bucket allows bursty traffic at a regulated maximum rate.

Figure 24.21 *Token bucket*

One token added
per tick

One token removed
and discarded
per cell transmitted

Arrival → Full? — N → Queue → Processor → Departure

Y

Discard

24-7   INTEGRATED SERVICES

Two models have been designed to provide quality of service in the Internet: Integrated Services and Differentiated Services. We discuss the first model here.

24.34

Integrated Services is a flow-based QoS model designed for IP.
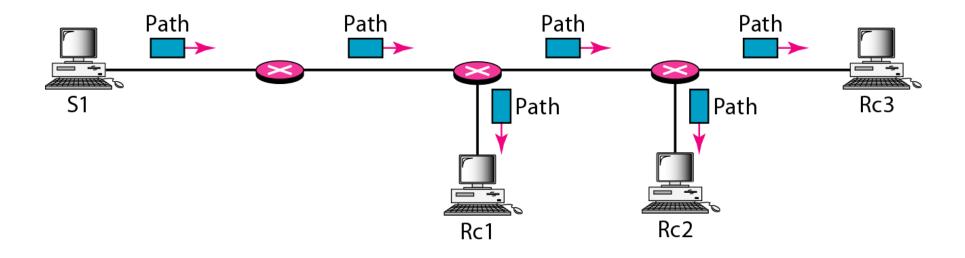
Figure 24.22 *Path messages*
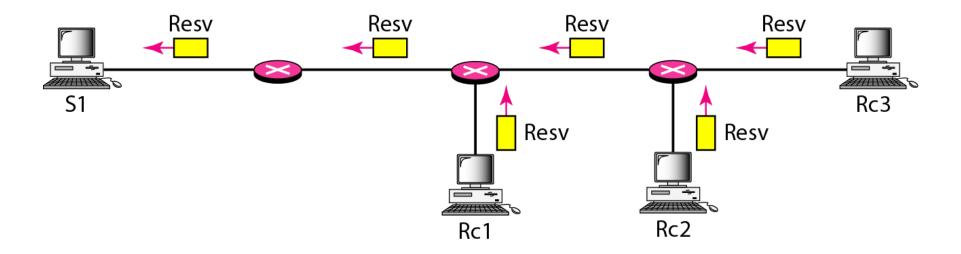
Figure 24.23 *Resv messages*

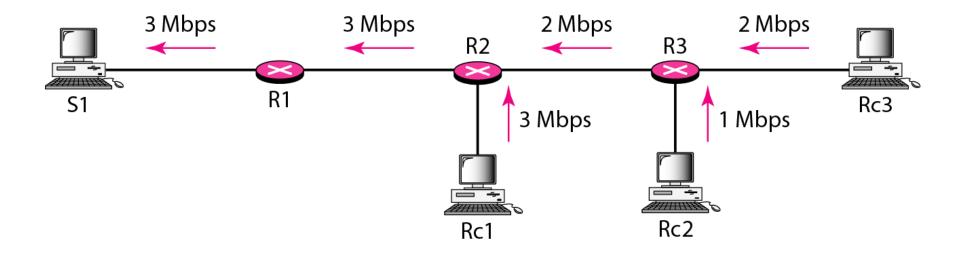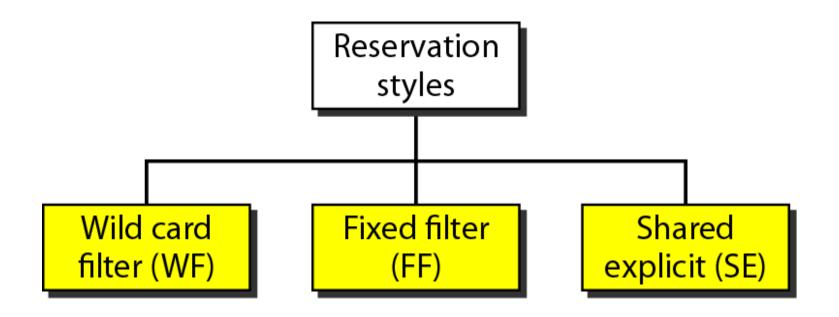# Figure 24.24 *Reservation merging*

Figure 24.25 *Reservation styles*

24-8 DIFFERENTIATED SERVICES

Differentiated Services (DS or Diffserv) was introduced by the IETF (Internet Engineering Task Force) to handle the shortcomings of Integrated Services.
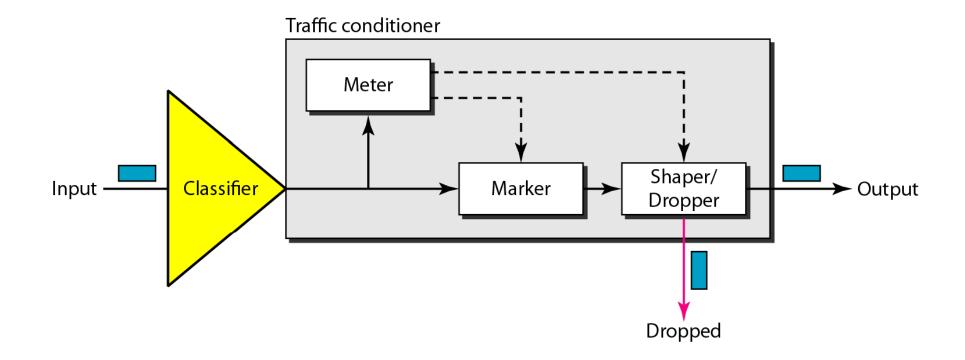
Topics discussed in this section:
DS Field

24.40

Differentiated Services is a class-based QoS model designed for IP.

24.41

Figure 24.26 *DS field*

Figure 24.27 *Traffic conditioner*

24.43

24-9   QoS IN SWITCHED NETWORKS

Let us now discuss QoS as used in two switched networks: Frame Relay and ATM. These two networks are virtual-circuit networks that need a signaling protocol such as RSVP.

Topics discussed in this section:

QoS in Frame Relay
QoS in ATM

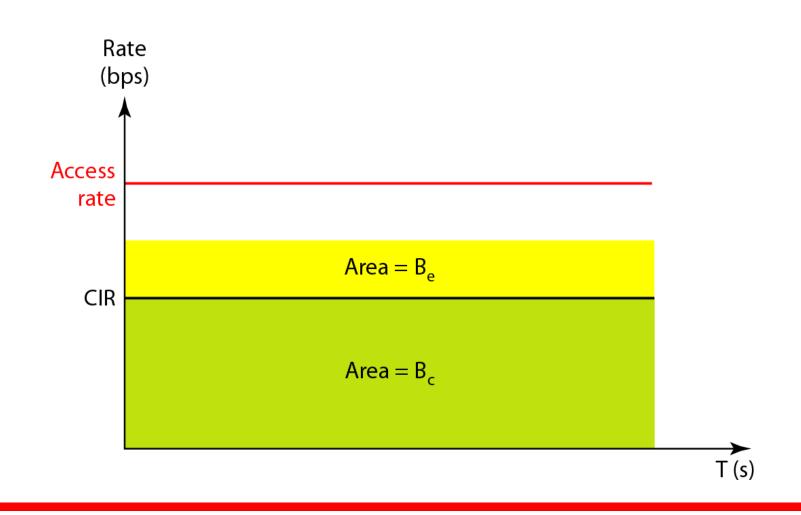# Figure 24.28 *Relationship between traffic control attributes*

24.45

Figure 24.29 *User rate in relation to Bc and Bc + Be*

If area is less than B_c, no discarding (DE $= 0$).
If area is between B_c and $B_c + B_e$, possible discarding if congestion (DE $= 1$).
If area is greater than $B_c + B_e$, discarding occurs.

Rate (bps)

Access rate

CIR

Actual rate

Actual rate

Actual rate

Actual rate

Actual rate
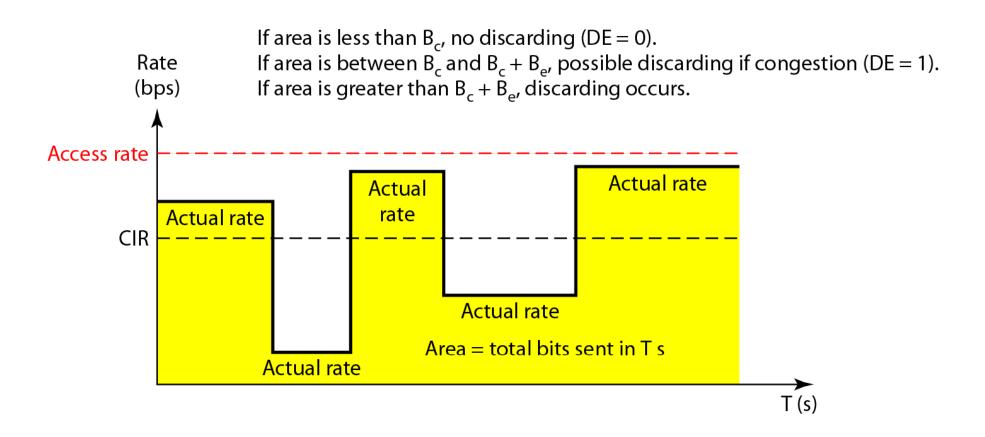
Area $=$ total bits sent in T s
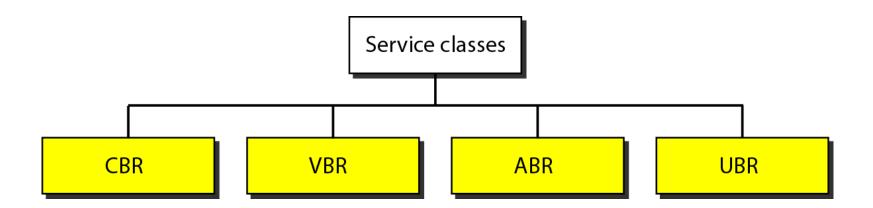
T (s)

Figure 24.30 *Service classes*

Figure 24.31 *Relationship of service classes to the total capacity of the network*