



Data Communications and Networking

Fourth Edition

Forouzan

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

Figure 24.1 *Traffic descriptors*

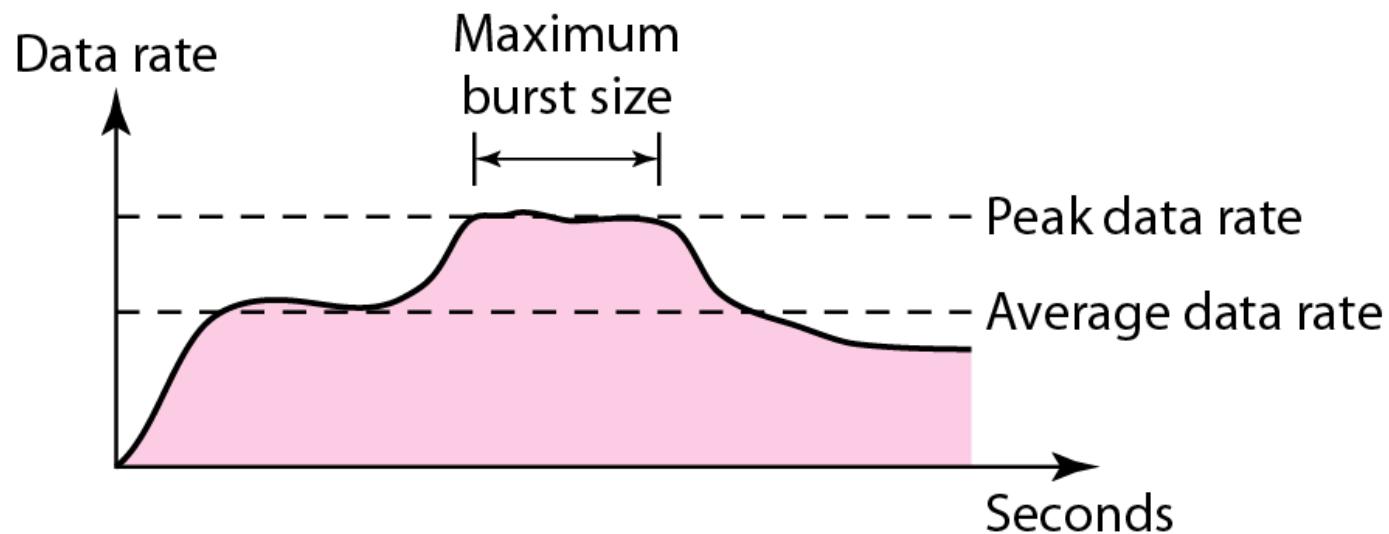
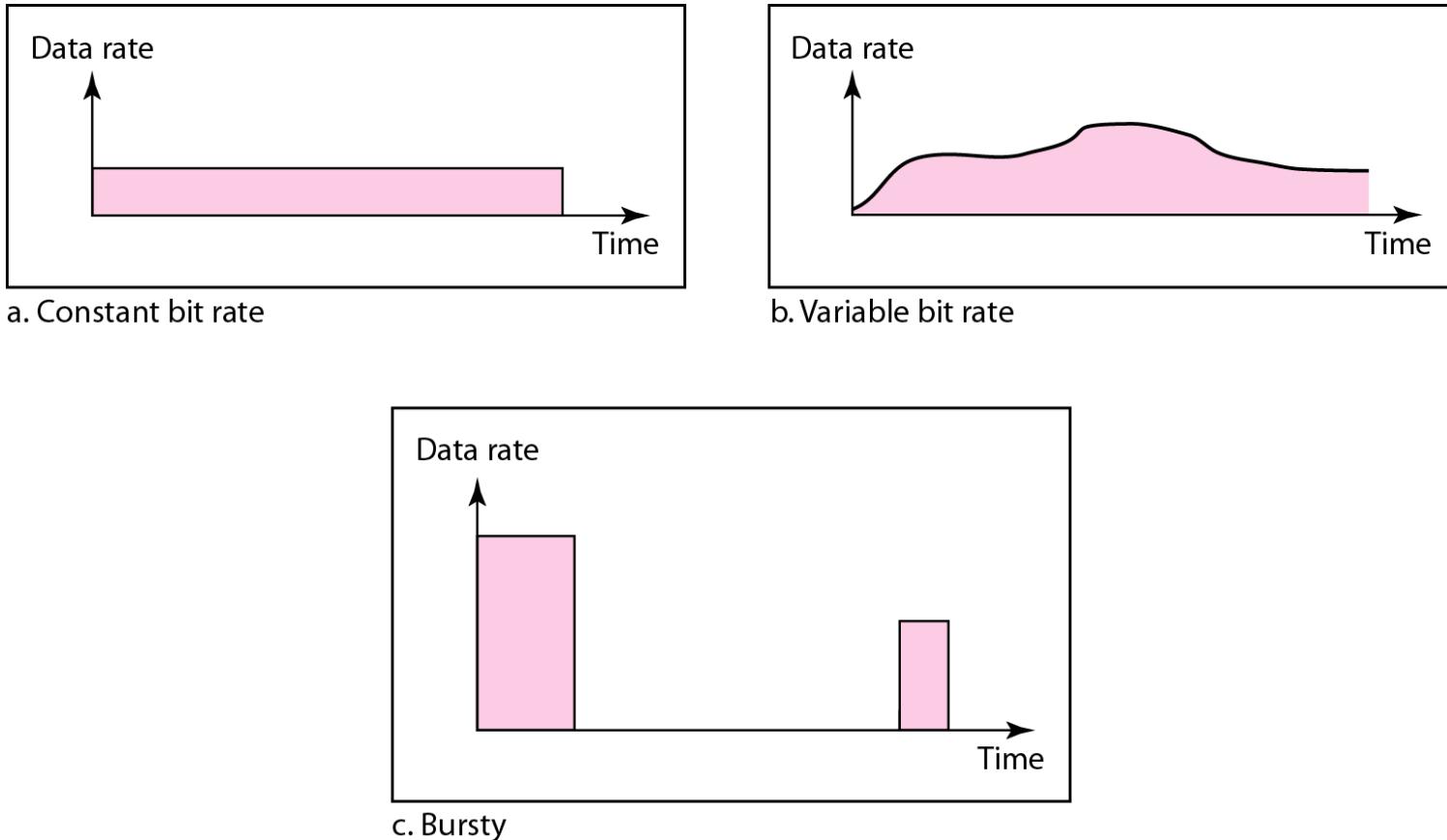


Figure 24.2 *Three traffic profiles*



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

Figure 24.3 *Queues in a router*

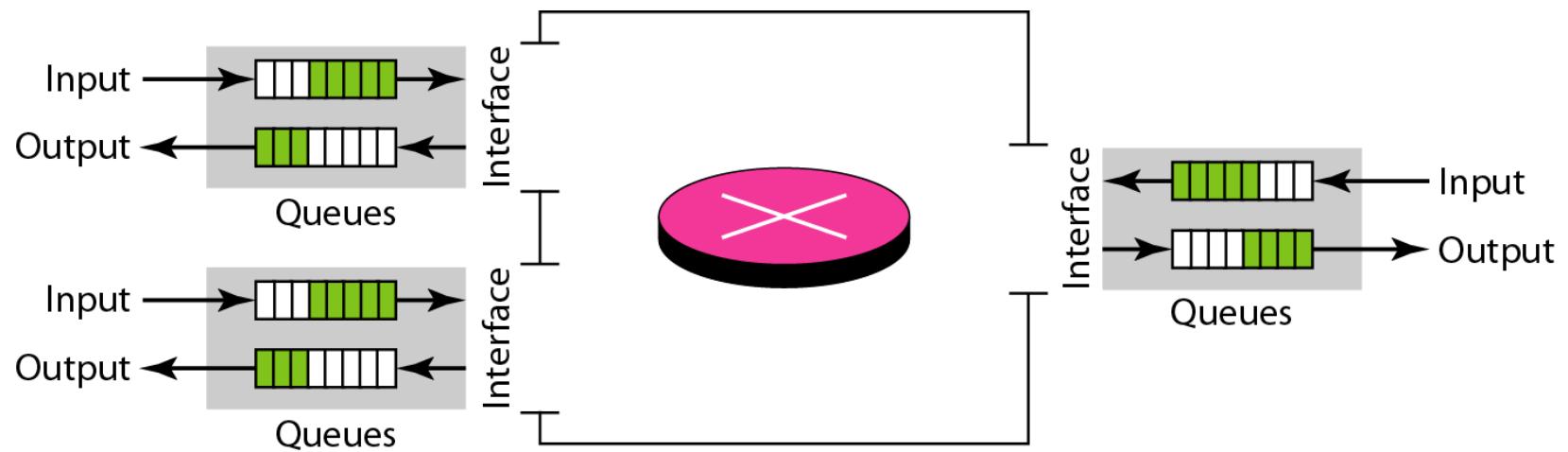
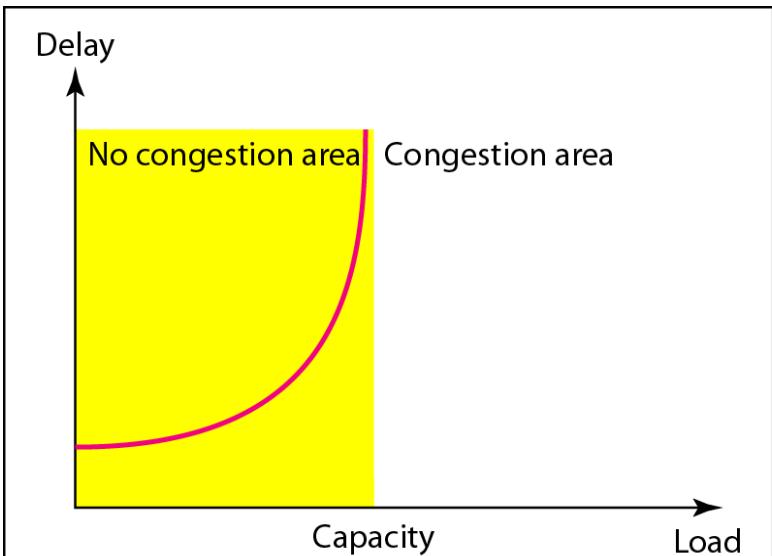
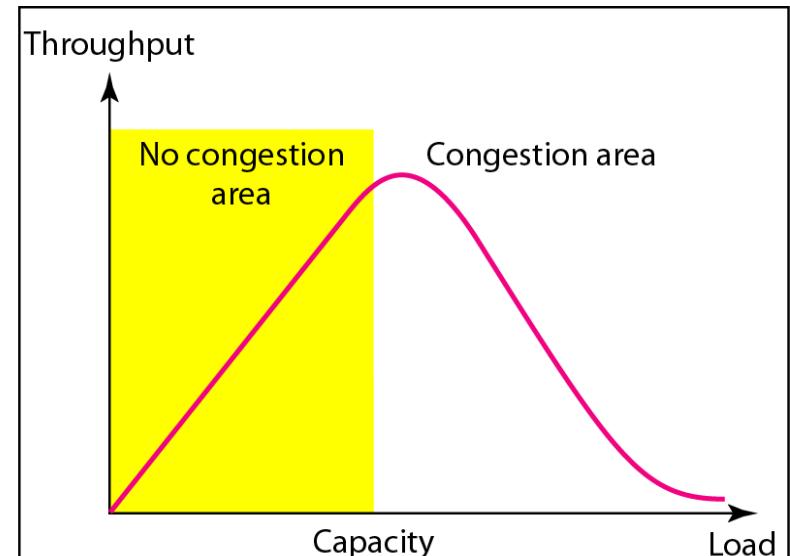


Figure *Packet delay and throughput as functions of load*



a. Delay as a function of load



b. Throughput as a function of load

24-3 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

Figure 24.5 Congestion control categories

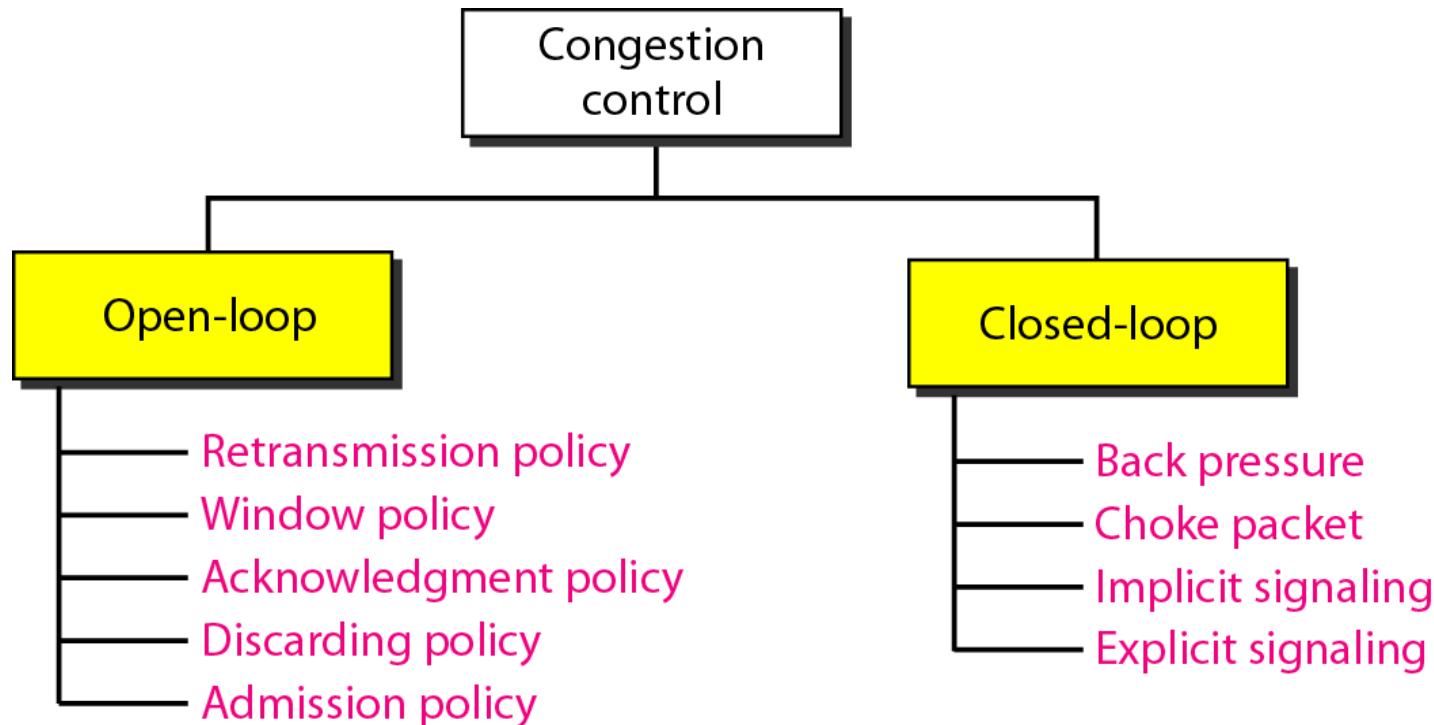


Figure 24.6 *Backpressure method for alleviating congestion*

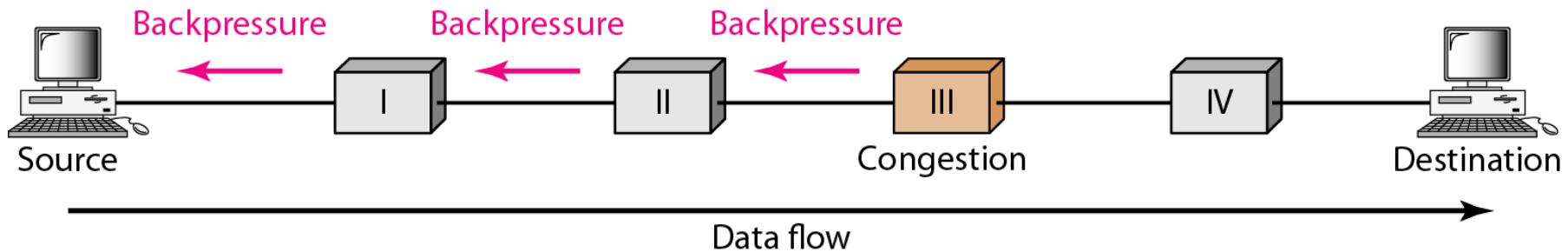
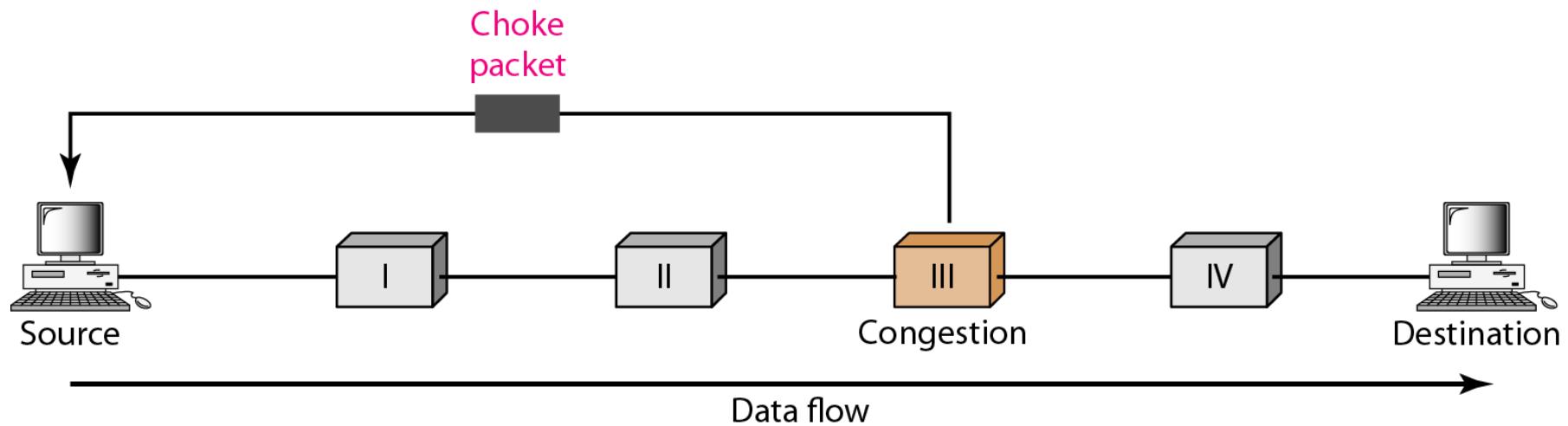


Figure 24.7 *Choke packet*



24-4 TWO EXAMPLES

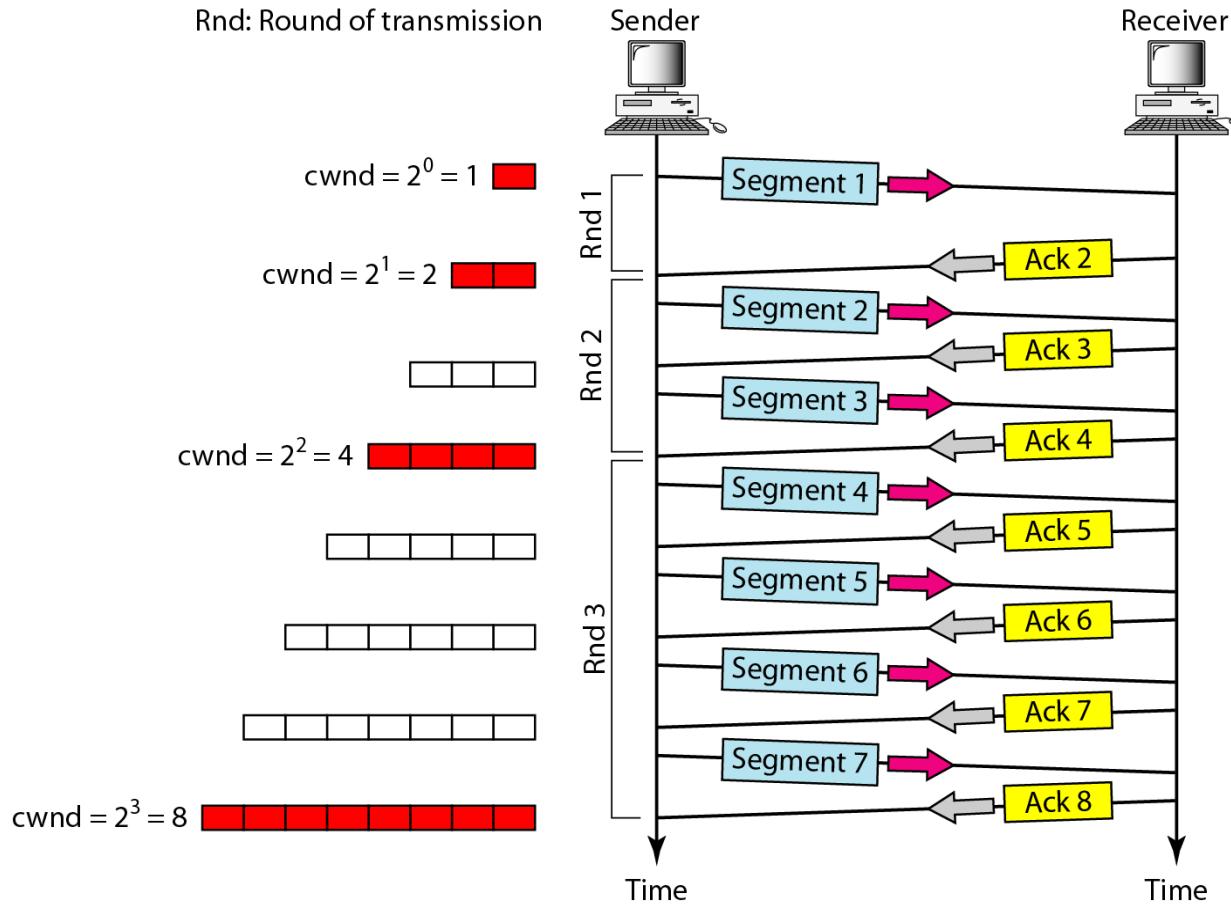
To better understand the concept of congestion control, let us give two examples: one in TCP and the other in Frame Relay.

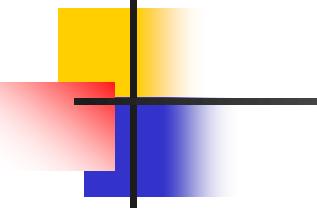
Topics discussed in this section:

Congestion Control in TCP

Congestion Control in Frame Relay

Figure 24.8 Slow start, exponential increase

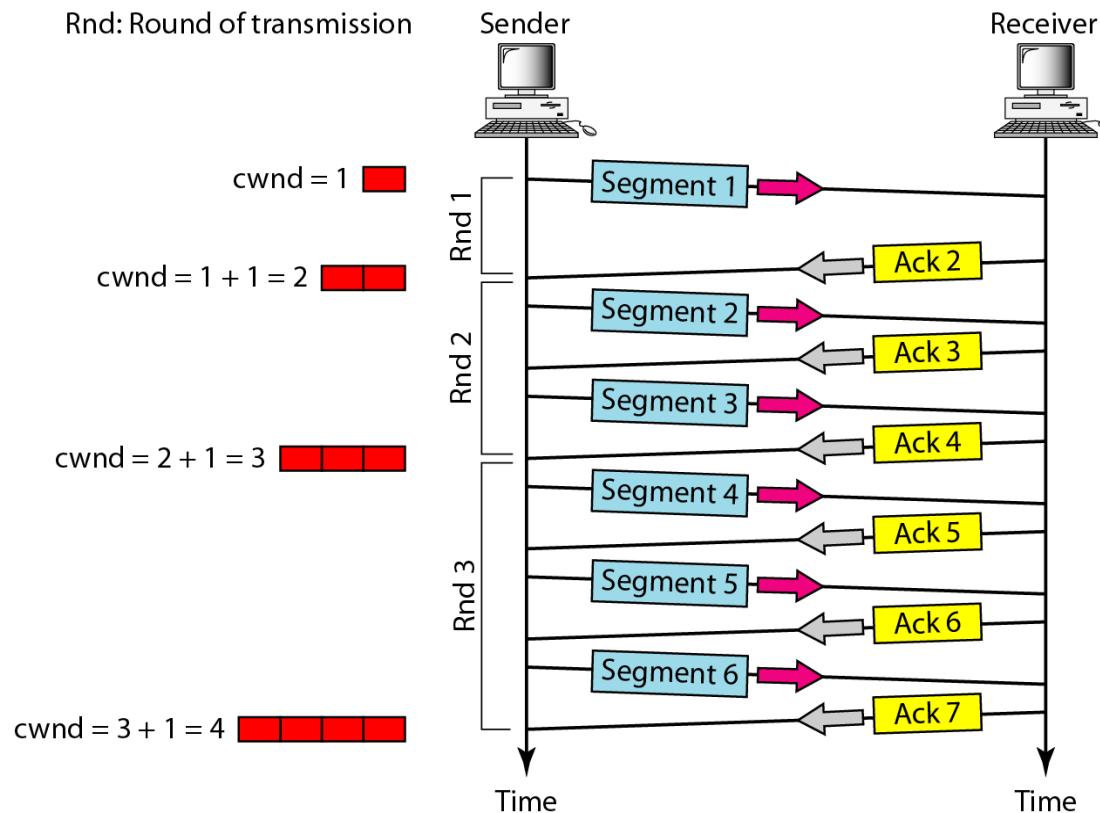


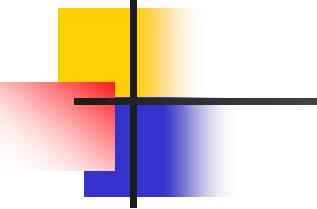


Note

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

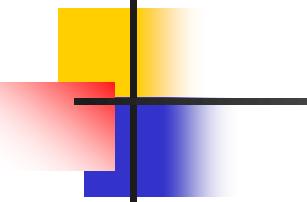
Figure 24.9 Congestion avoidance, additive increase





Note

**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

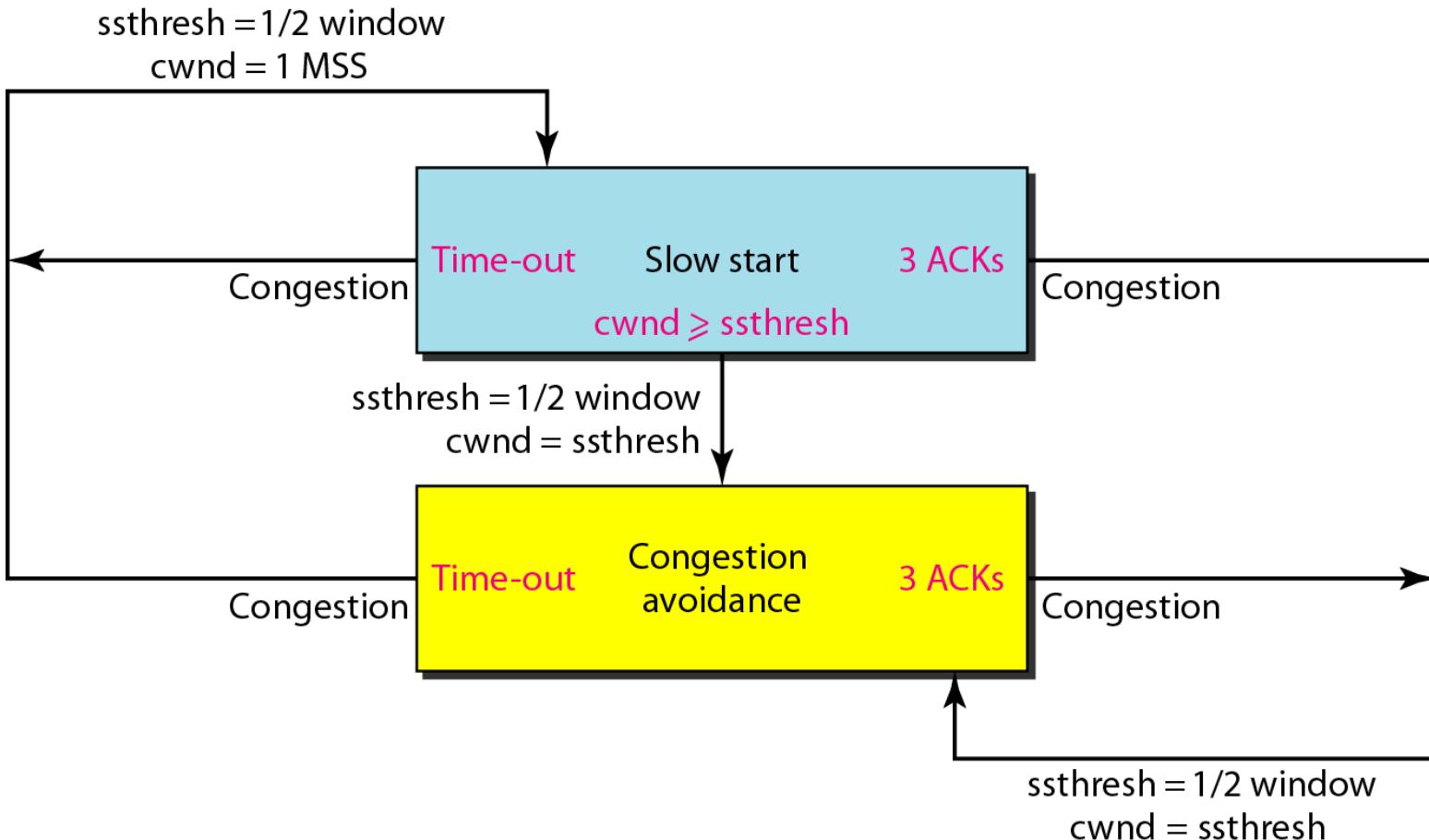


Figure 24.11 Congestion example

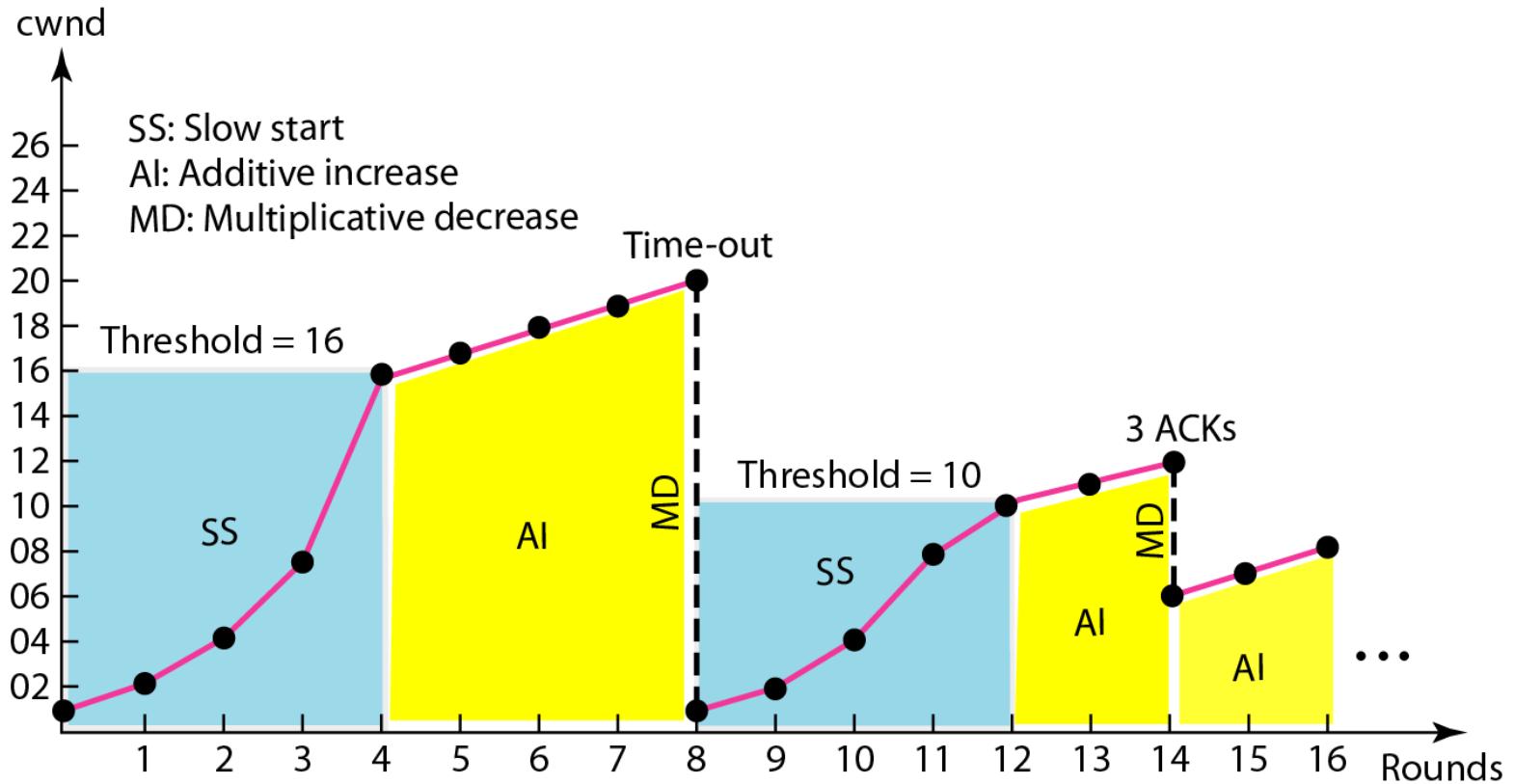


Figure 24.12 BECN

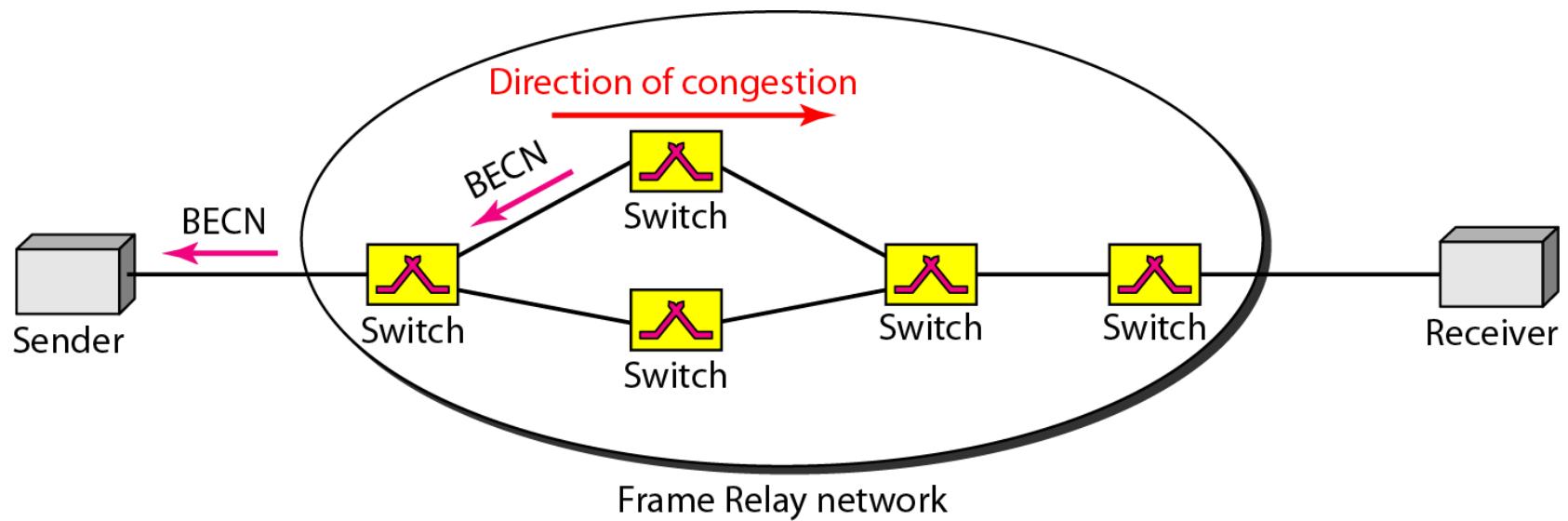


Figure 24.13 FECN

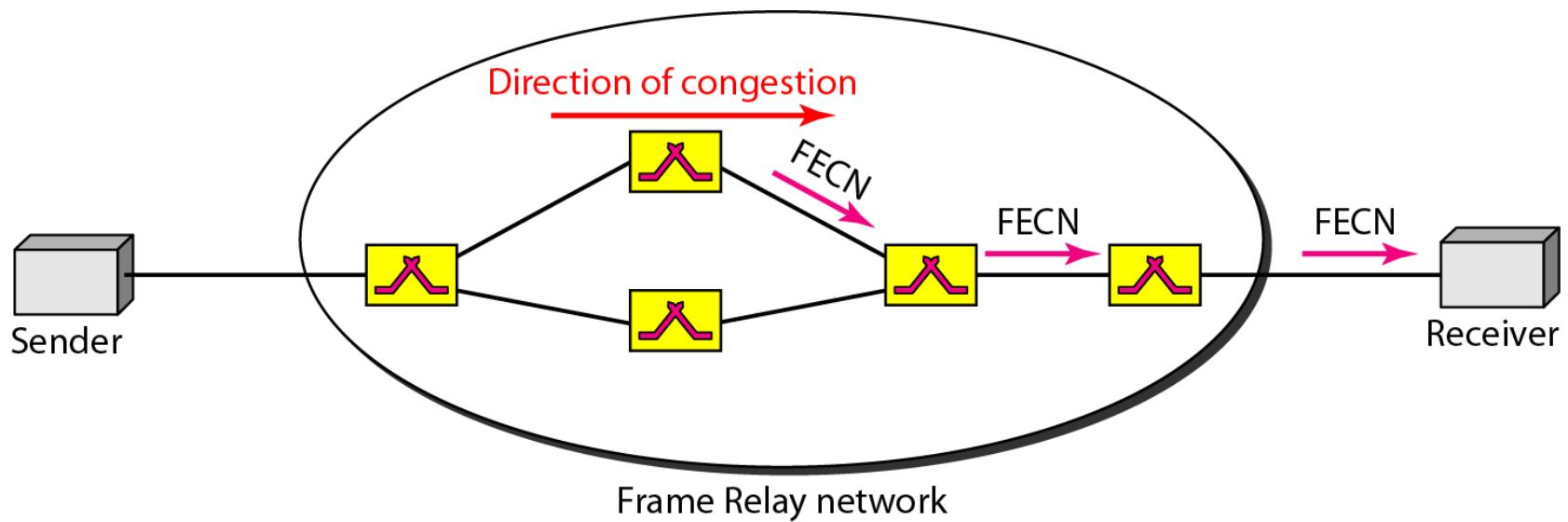
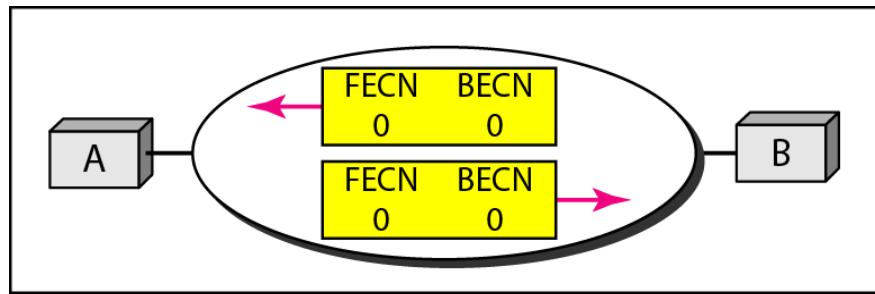
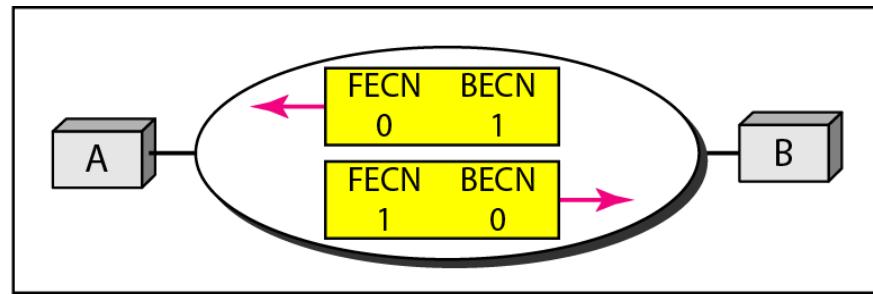


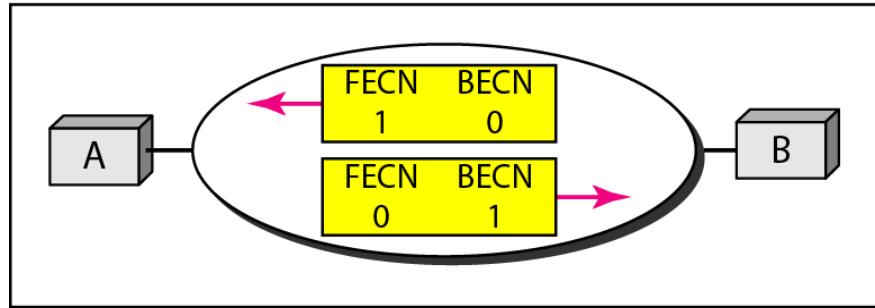
Figure 24.14 Four cases of congestion



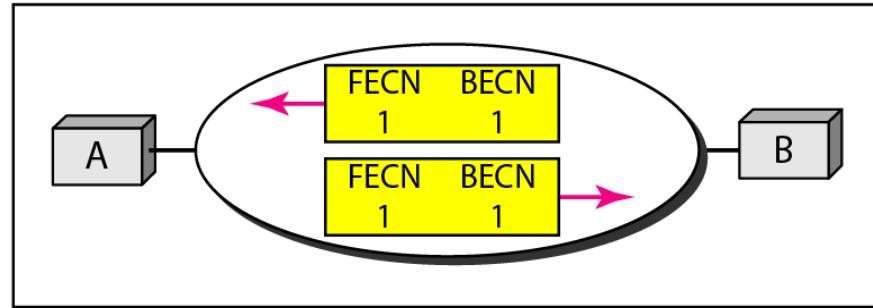
a. No congestion



b. Congestion in the direction A-B



c. Congestion in the direction B-A



d. Congestion in both directions

24-5 QUALITY OF SERVICE

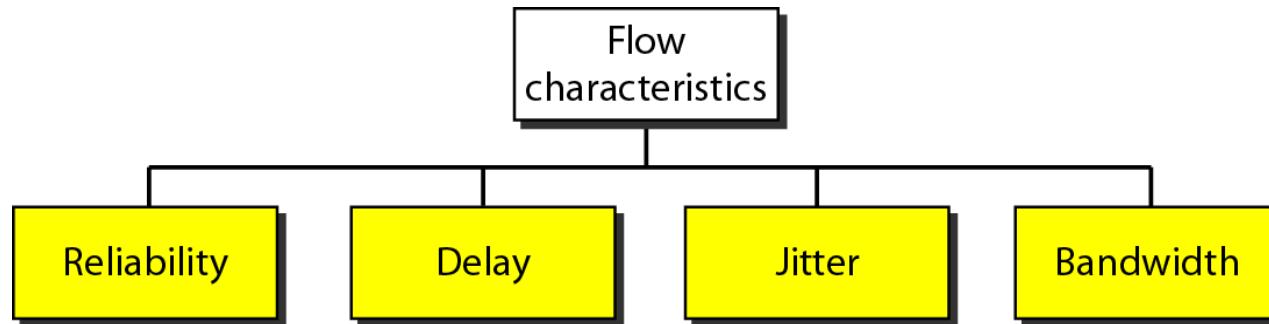
Quality of service (QoS) is an internetworking issue that has been discussed more than defined. We can informally define quality of service as something a flow seeks to attain.

Topics discussed in this section:

Flow Characteristics

Flow Classes

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

Figure 24.16 FIFO queue

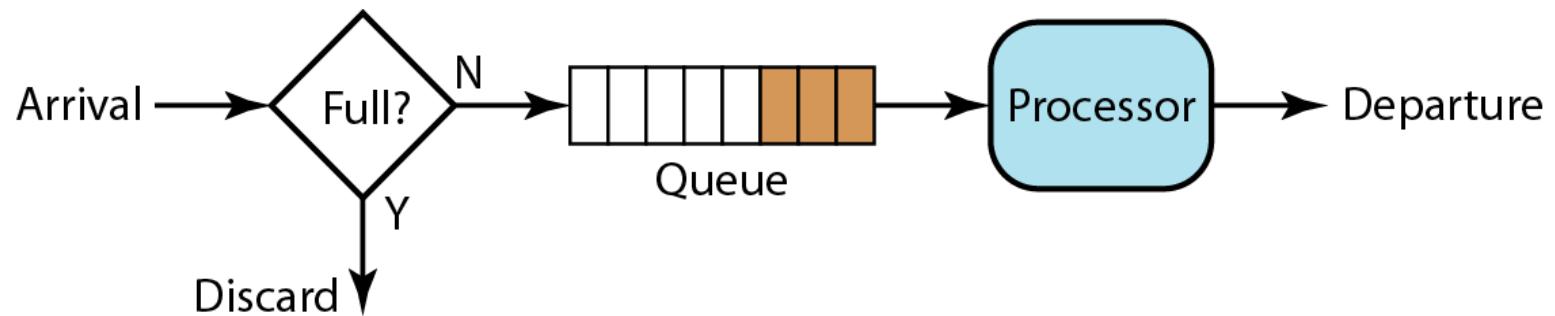


Figure 24.17 Priority queuing

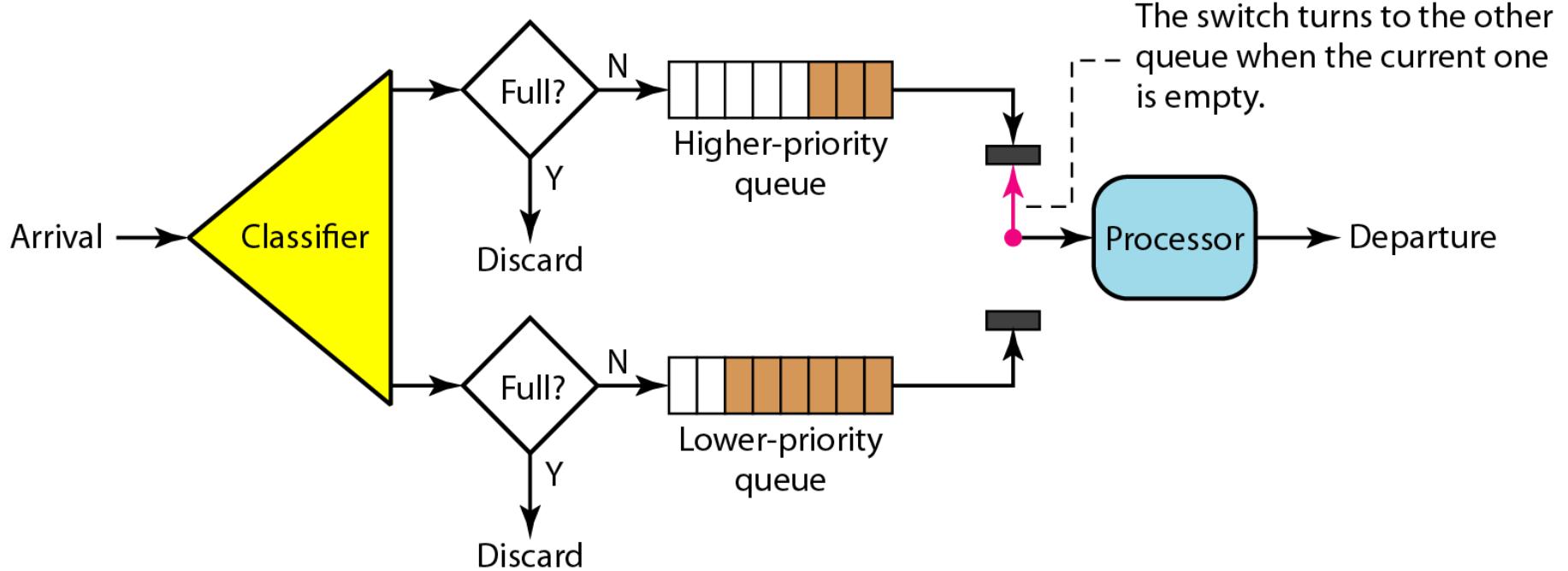


Figure 24.18 Weighted fair queuing

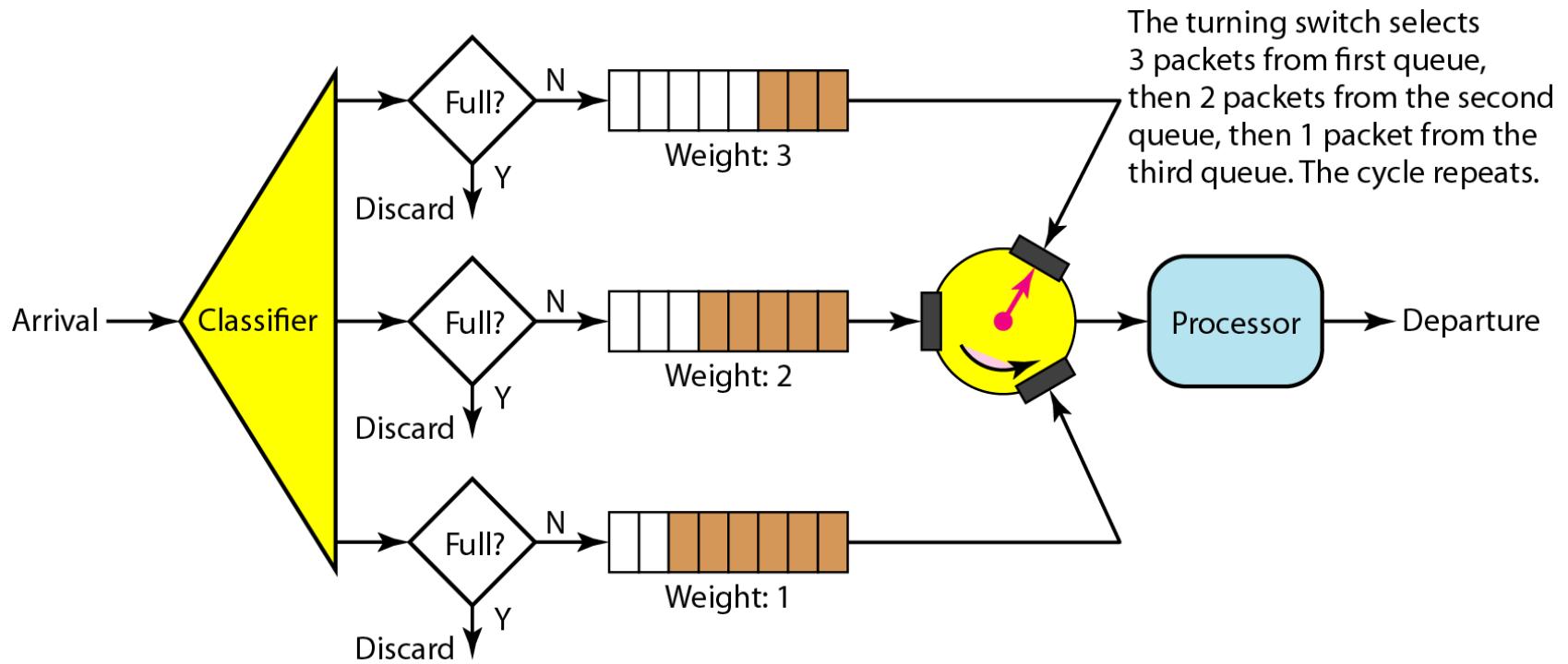


Figure 24.19 *Leaky bucket*

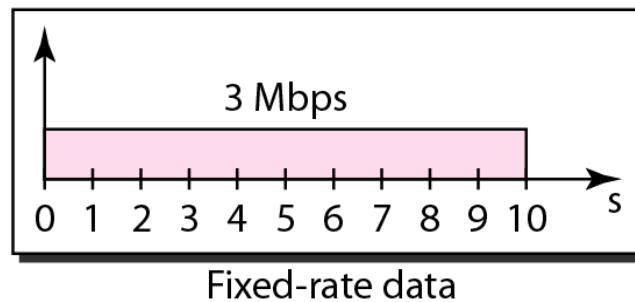
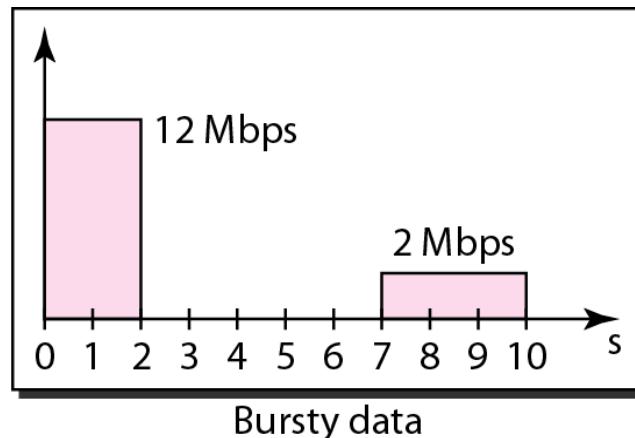
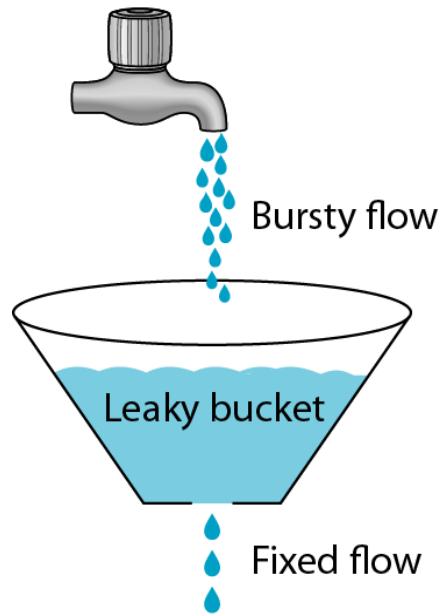
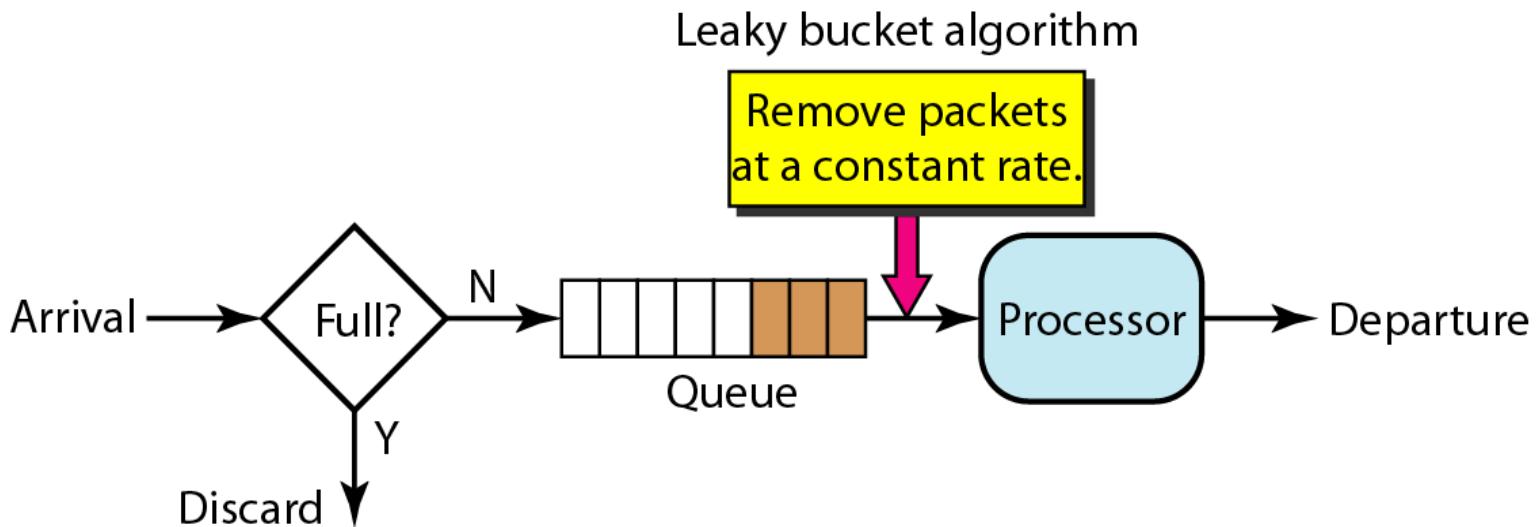
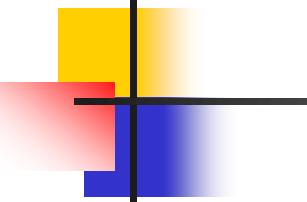


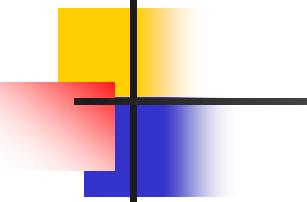
Figure 24.20 *Leaky bucket implementation*





Note

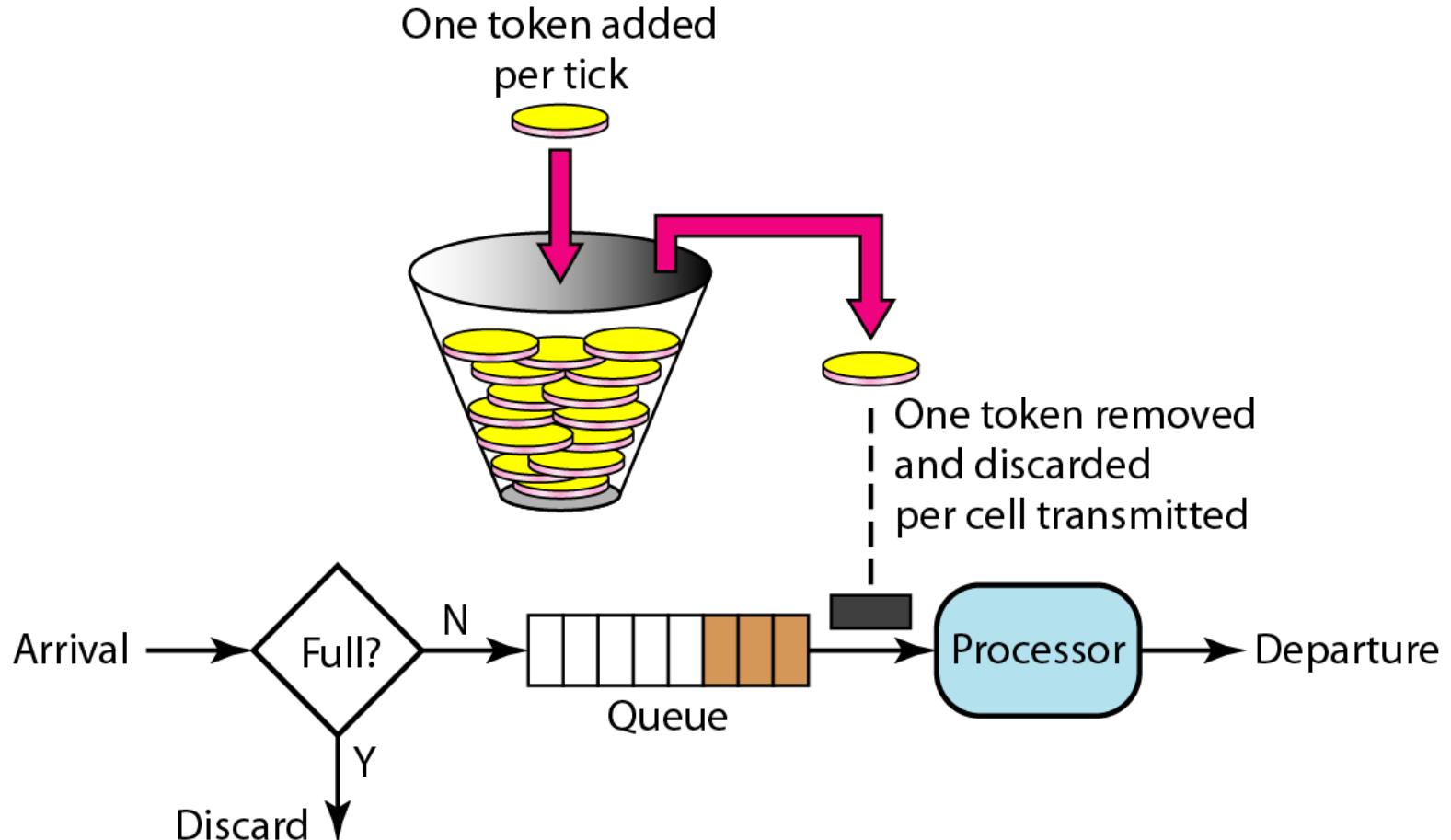
A leaky bucket algorithm shapes bursty traffic into fixed-rate traffic by averaging the data rate. It may drop the packets if the bucket is full.



Note

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

Figure 24.21 Token bucket



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.

Topics discussed in this section:

Signaling

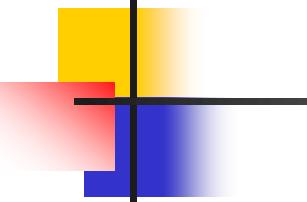
Flow Specification

Admission

Service Classes

RSVP

Problems with Integrated Services



Note

Integrated Services is a flow-based QoS model designed for IP.

Figure 24.22 *Path messages*

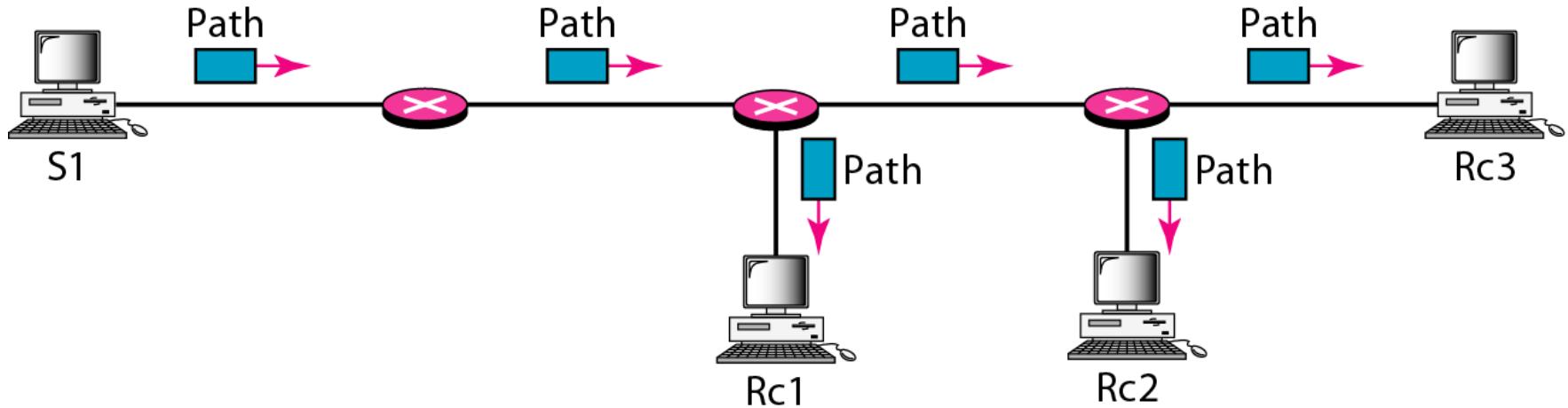


Figure 24.23 *Resv messages*

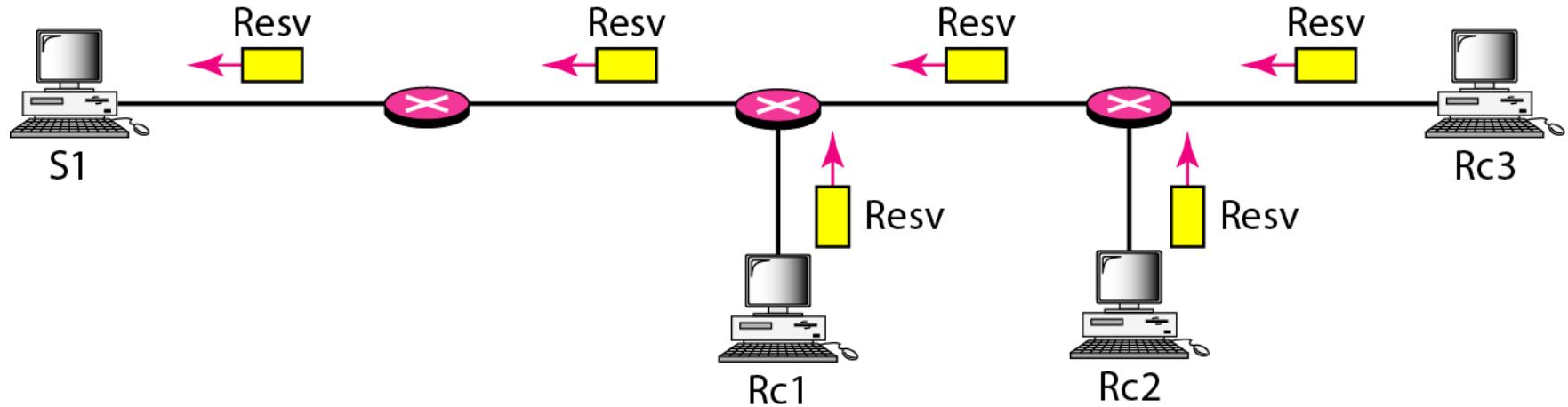


Figure 24.24 Reservation merging

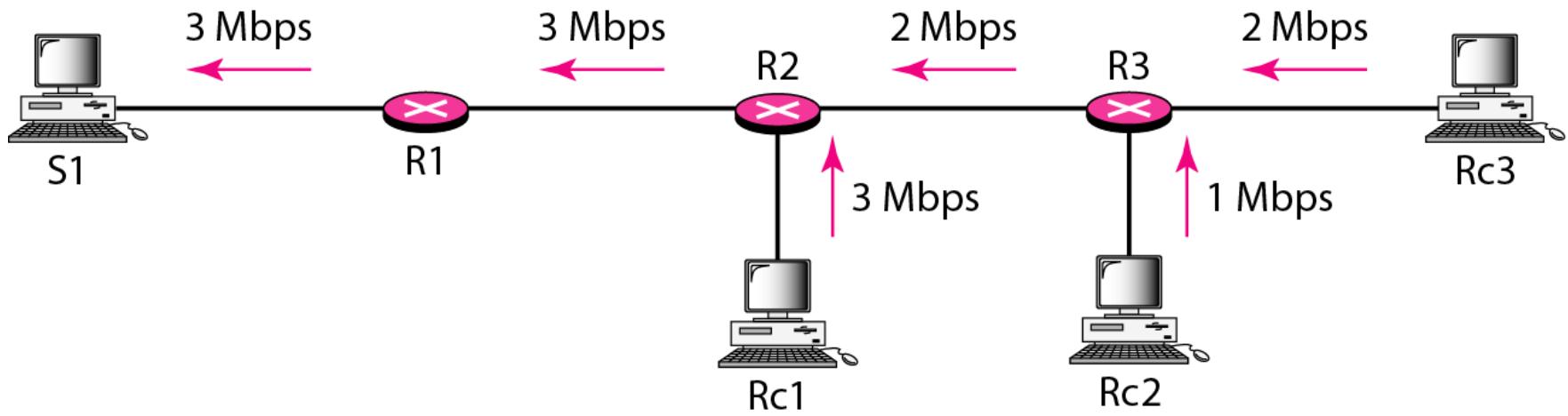
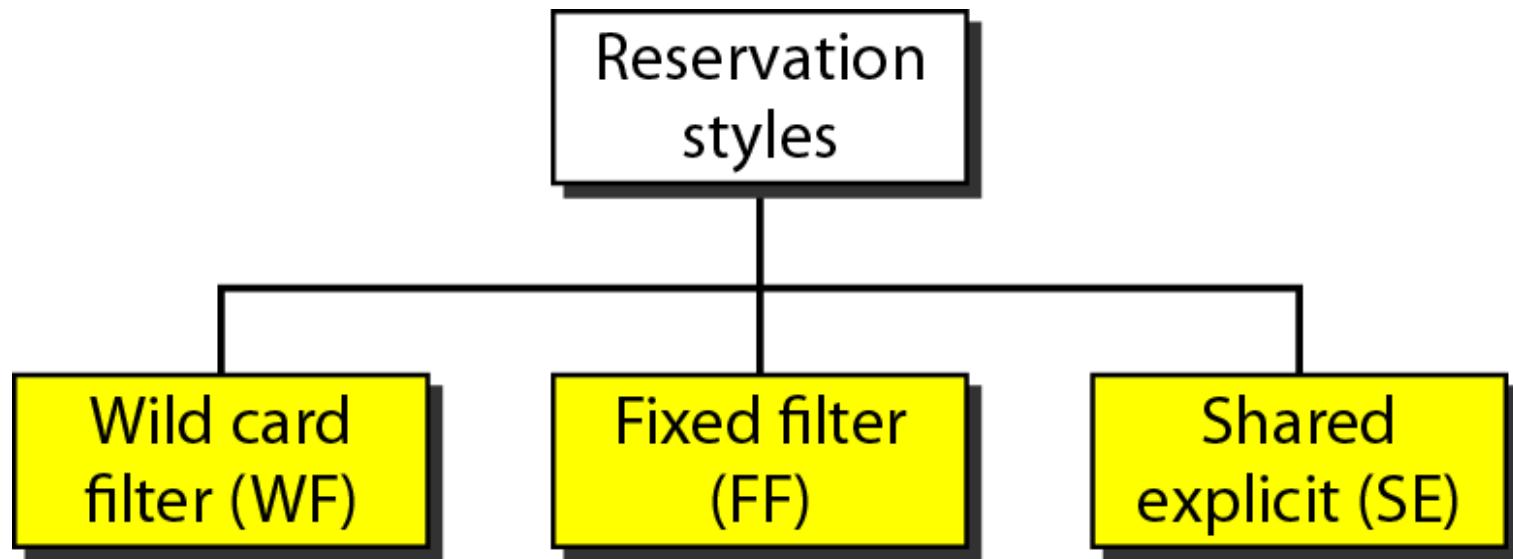


Figure 24.25 *Reservation styles*

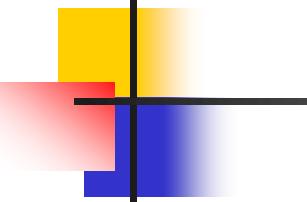


24-8 DIFFERENTIATED SERVICES

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



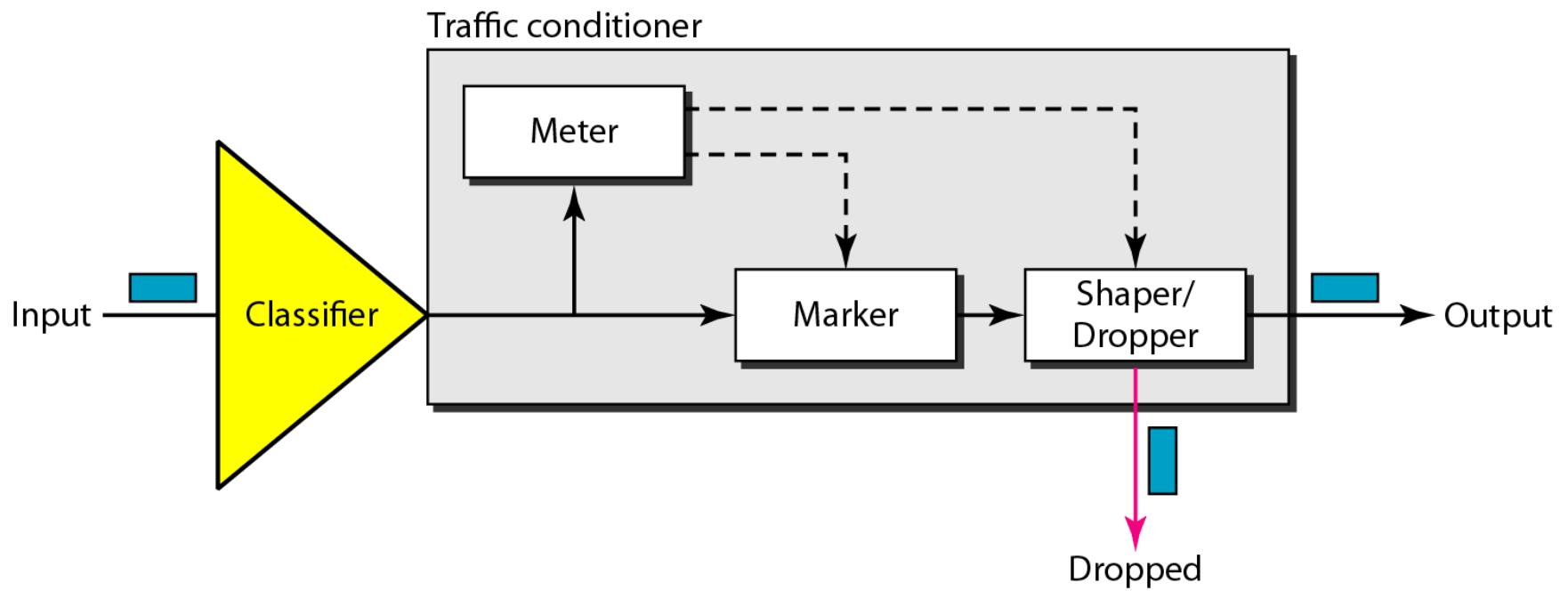
Note

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

Figure 24.26 *DS field*



Figure 24.27 *Traffic conditioner*



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*

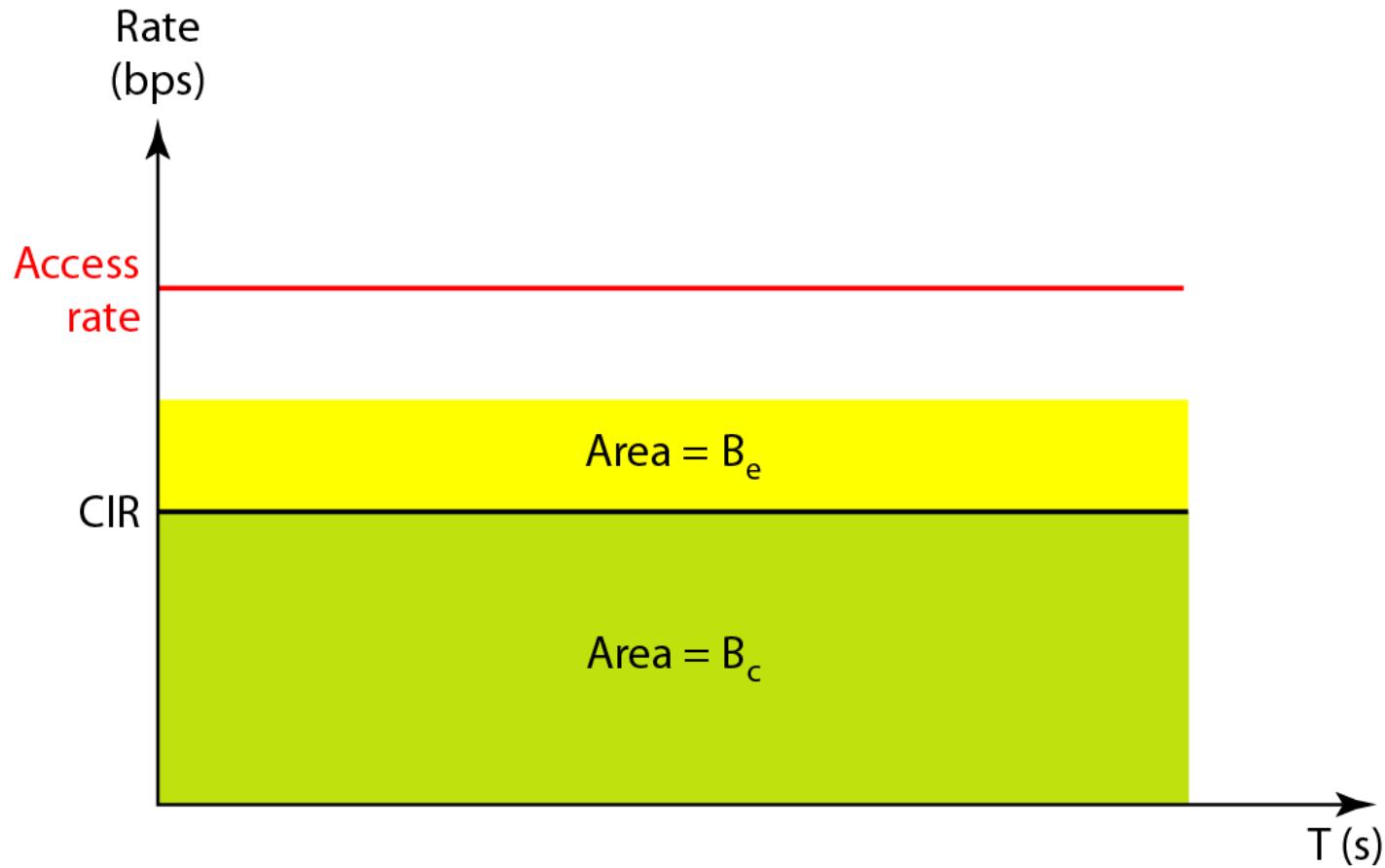


Figure 24.29 *User rate in relation to B_c and $B_c + B_e$*

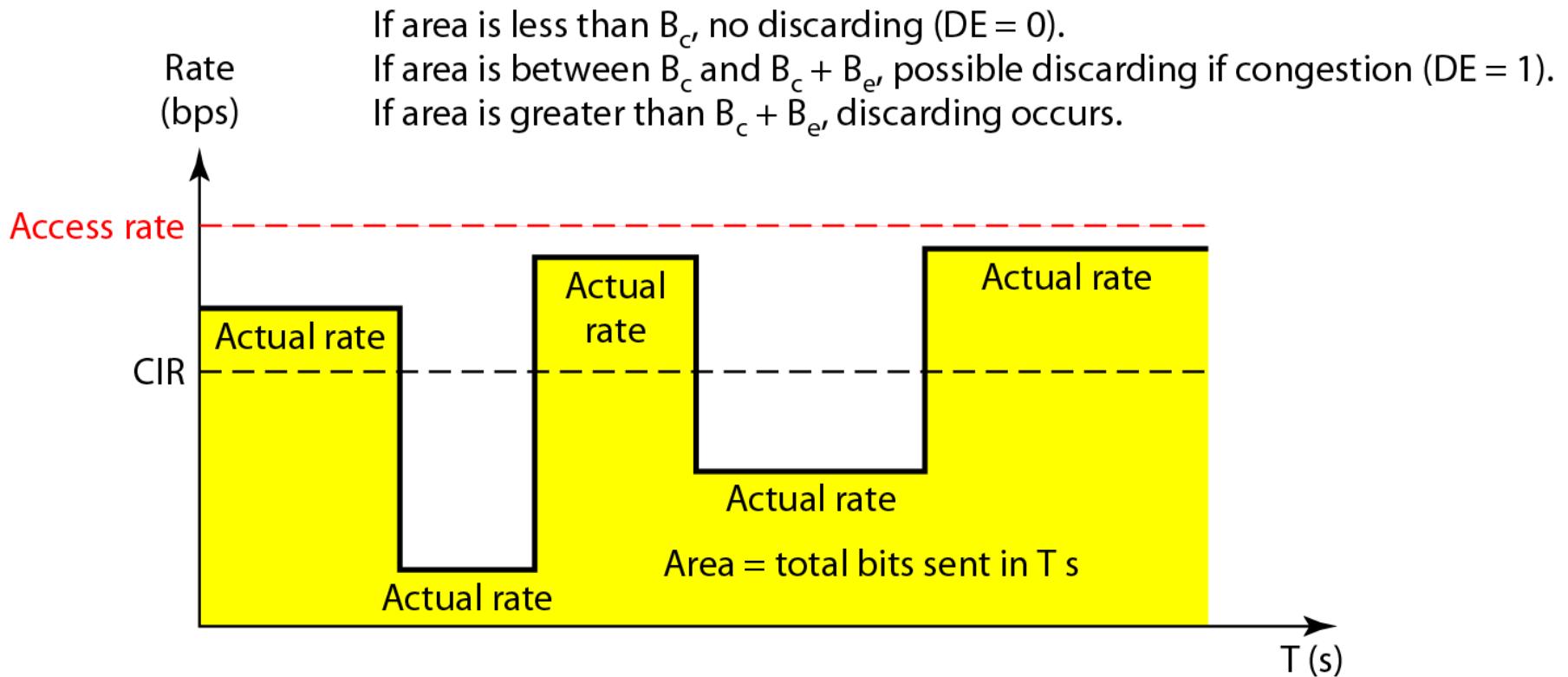


Figure 24.30 *Service classes*

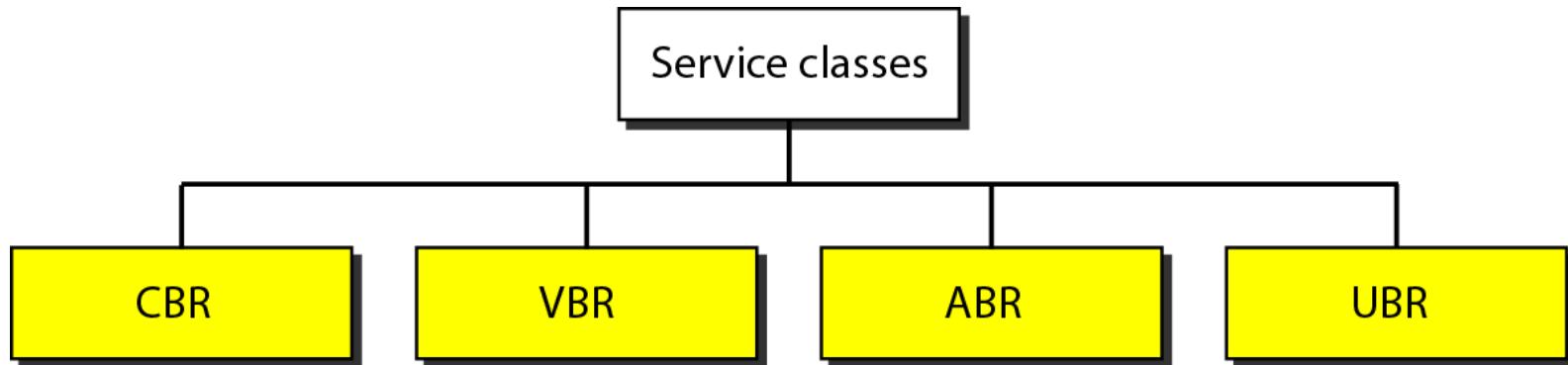


Figure 24.31 *Relationship of service classes to the total capacity of the network*

