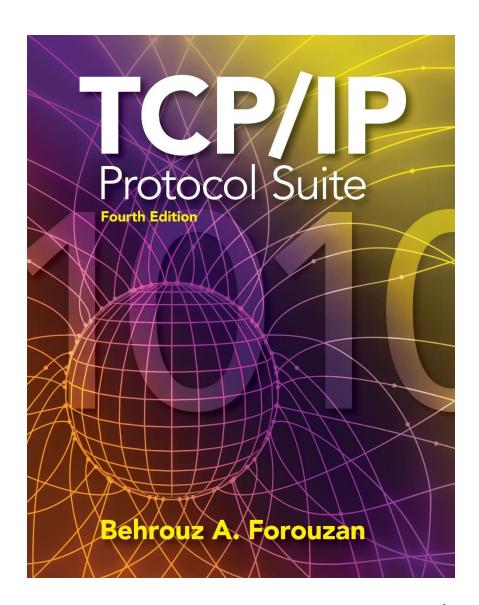
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Chapter 4

Introduction to Network Layer



OBJECTIVES:

- ☐ To introduce switching and in particular packet switching as the mechanism of data delivery in the network layer.
- ☐ To discuss two distinct types of services a packet-switch network can provide: connectionless service and connection-oriented service.
- ☐ To discuss how routers forward packets in a connectionless packet-switch network using the destination address of the packet and a routing table.
- ☐ To discuss how routers forward packets in a connection-oriented packet-switch network using the label on the packet and a routing table.
- ☐ To discuss services already provided in the network layer such as logical addressing and delivery at the source, at each router, and at the destination.
- ☐ To discuss issues or services that are not directly provided in the network layer protocol, but are sometimes provided by some auxiliary protocols or some protocols added later to the Internet.

Chapter Outline

4.1 Introduction

4.2 Switching

4.3 Packet Switching

4.4 Network Layer Services

4.5 Other Network Layer Issues

4-1 INTRODUCTION

At the conceptual level, we can think of the global Internet as a black box network that connects millions (if not billions) of computers in the world together. At this level, we are only concerned that a message from the application layer in one computer reaches the application layer in another computer.

Topics Discussed in the Section

✓ General Introduction



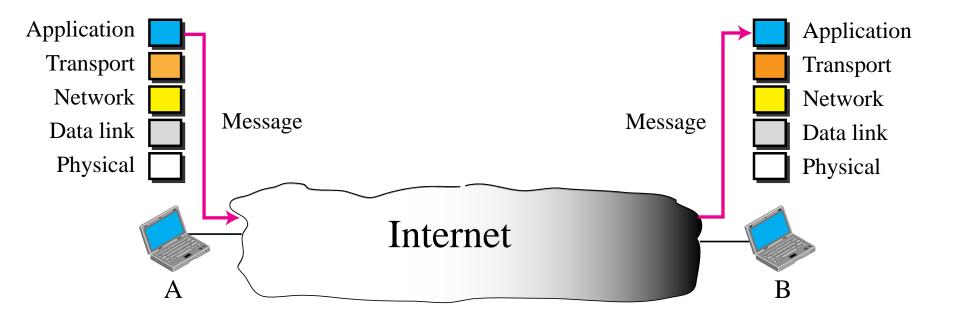
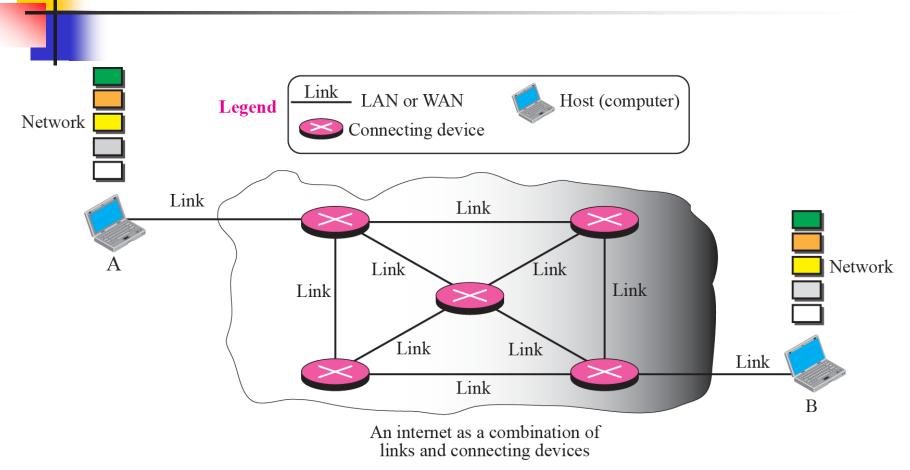


Figure 4.2 Internet as a combination of LANs and WANs connected together



In this model, a connecting device such as a router acts as a switch. When a packet arrives from one of its ports (interface), the packet is forwarded through another port to the next switch (or final destination). In other words, a process called switching occurs at the connecting device.

4-2 SWITCHING

From the previous discussion, it is clear that the passage of a message from a source to a destination involves many decisions. When a message reaches a connecting device, a decision needs to be made to select one of the output ports through which the packet needs to be send out. In other words, the connecting device acts as a switch that connects one port to another port.

Topics Discussed in the Section

- **✓ Circuit Switching**
- **✓** Packet Switching

✓ Circuit Switching:

Circuit switching, in which a physical circuit (or channel) is established between the source and destination of the message before the delivery of the message. After the circuit is established, the entire message, is transformed from the source to the destination. The source can then inform the network that the transmission is complete, which allows the network to open all switches and use the links and connecting devices for another connection.

Note

In circuit switching, the whole message is sent from the source to the destination without being divided into packets.

Example 4.1

A good example of a circuit-switched network is the early telephone systems in which the path was established between a caller and a callee when the telephone number of the callee was dialed by the caller. When the callee responded to the call, the circuit was established. The voice message could now flow between the two parties, in both directions, while all of the connecting devices maintained the circuit. When the caller or callee hung up, the circuit was disconnected. The telephone network is not totally a circuit-switched network today.

Packet switching. The network layer in the Internet today is a packet-switched network. In this type of network, a message from the upper layer is divided into manageable packets and each packet is sent through the network. The source of the message sends the packets one by one; the destination of the message receives the packets one by one. The destination waits for all packets belonging to the same message to arrive before delivering the message to the upper layer. The connecting devices in a packet-switching network still need to decide how to route the packets to the final destination. Today, a packet-switched network can use two different

Note

In packet switching, the message is first divided into manageable packets at the source before being transmitted.

The packets are assembled at the destination.

4-3 PACKET SWITHING

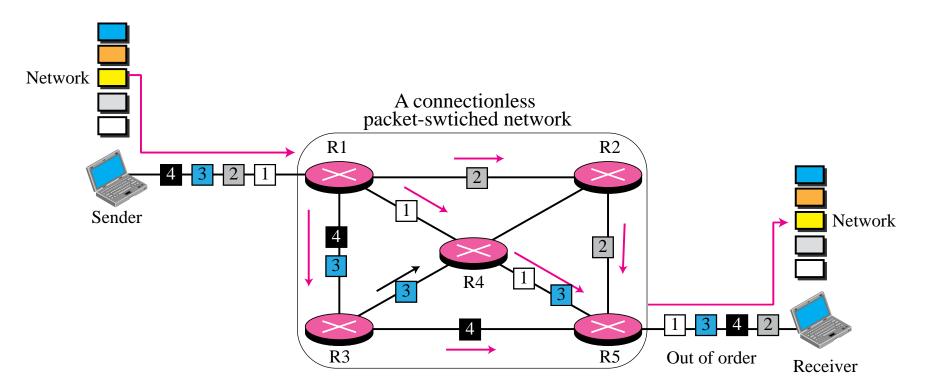
The network layer is designed as a packet-switched network. This means that the packet at the source is divided into manageable packets, normally called datagrams. Individual datagrams are then transferred from the source to the destination. The received datagrams are assembled at the destination before recreating the original message. The packet-switched network layer of the Internet was originally designed as a connectionless service, but recently there is a tendency to change this to a connection-oriented service.

Topics Discussed in the Section

- **✓** Connectionless Service
- **✓** Connection-Oriented Service

Connectionless Service, in which the network layer protocol treats each packet independently, with each packet having no relationship to any other packet. The packets in a message may or may not travel the same path to their destination. When the Internet started, it was decided to make the network layer a connectionless service to make it simple. The idea was that the network layer is only responsible for delivery of packets from the source to the destination.





Forwarding process in a connectionless network

in this case.

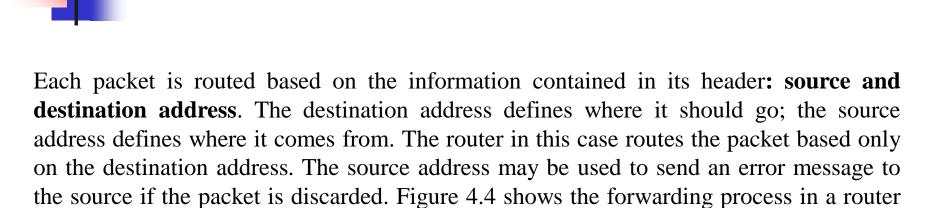
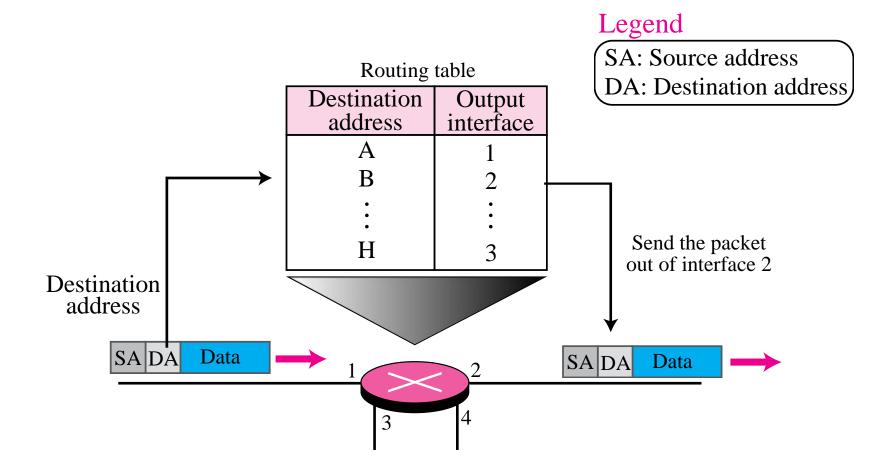


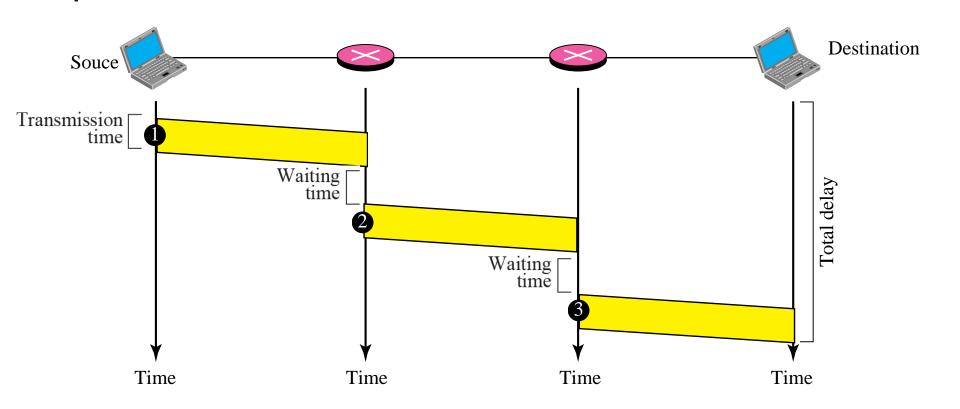
Figure 4.4 Forwarding process in a connectionless network



Note

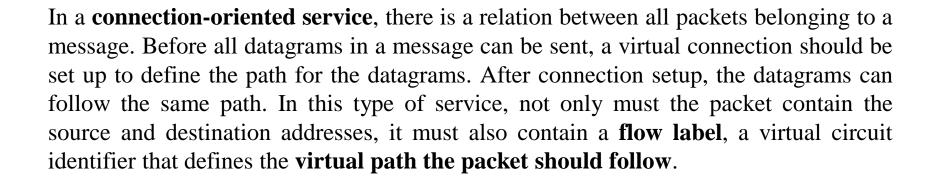
In a connectionless packet-switched network, the forwarding decision is based on the destination address of the packet.

Figure 4.5 Delay in a connectionless network

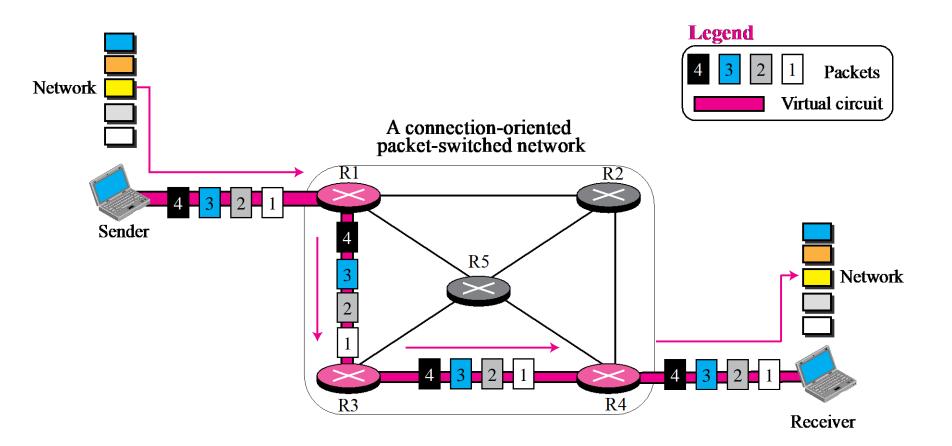


If we ignore the fact that the packet may be lost and resent and also the fact that the destination may be needed to wait to receive all packets, we can model the delay as shown **in the above Figure.**

A connection-oriented packet switched network



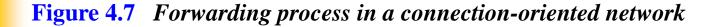


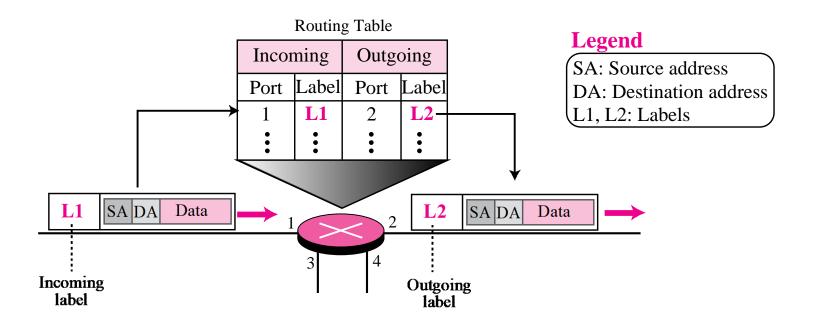


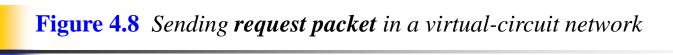


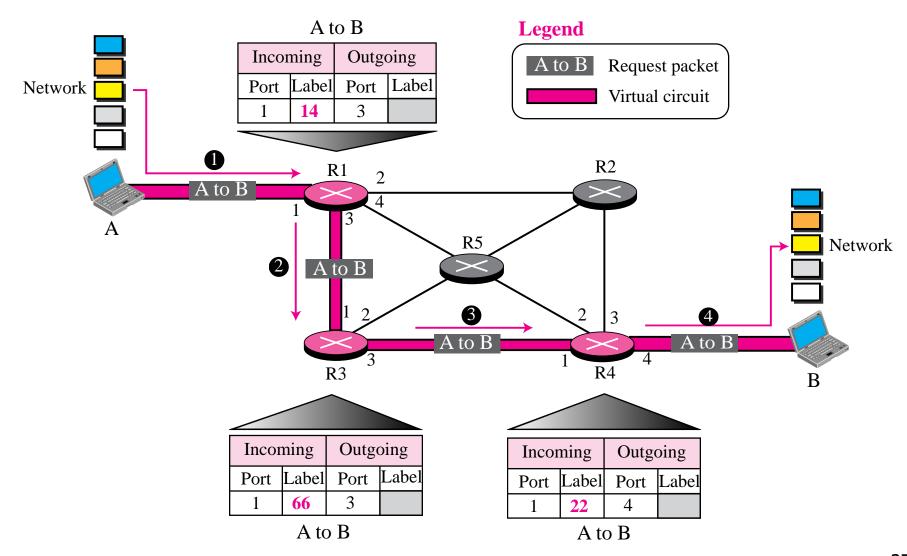
Note

In a connection-oriented packet switched network, the forwarding decision is based on the label of the packet.











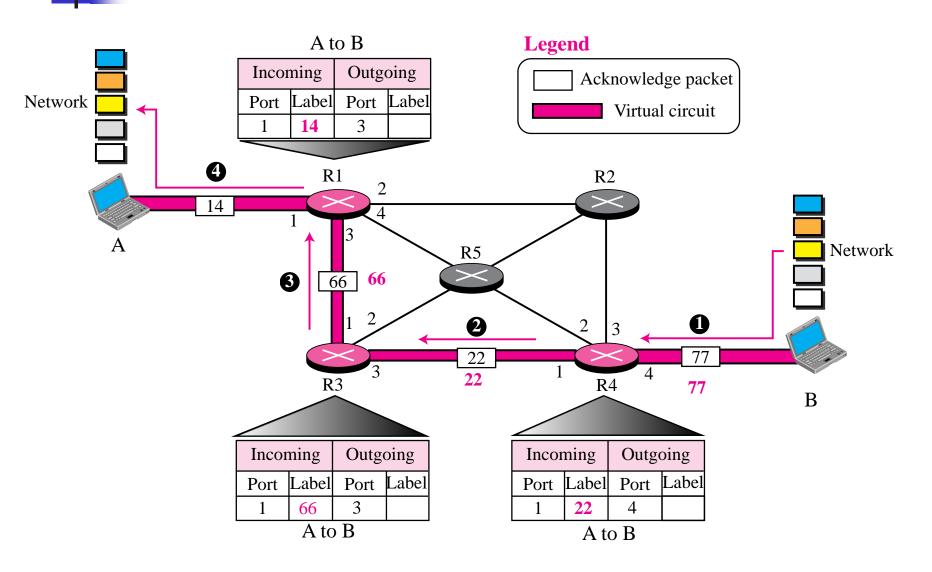


Figure 4.10 Flow of one packet in an established virtual circuit

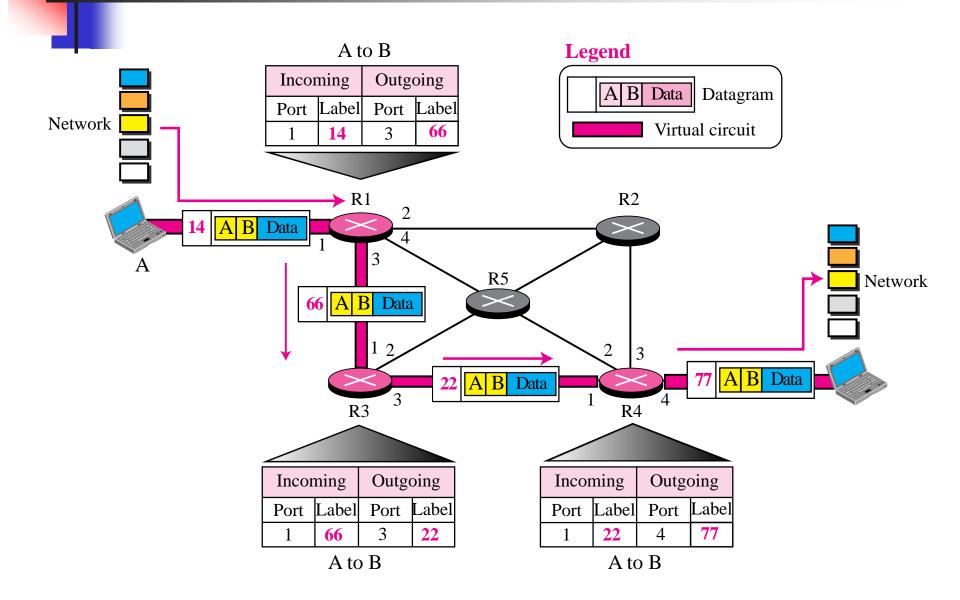
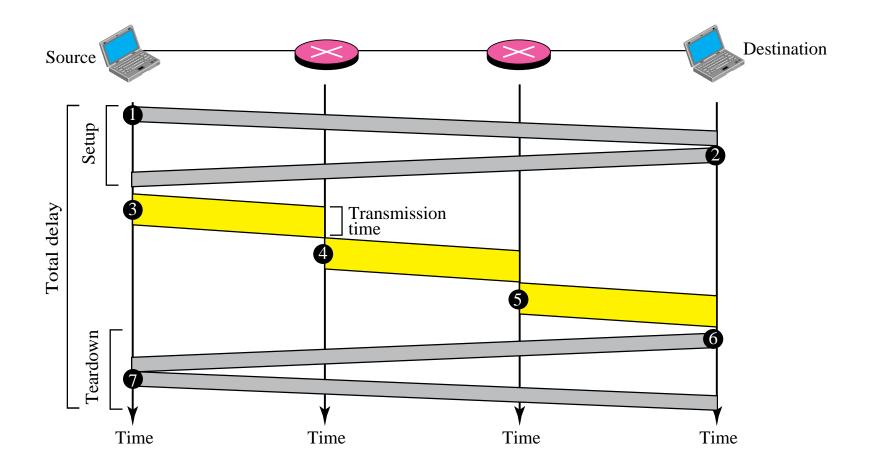


Figure 4.11 Delay in a connection-oriented network



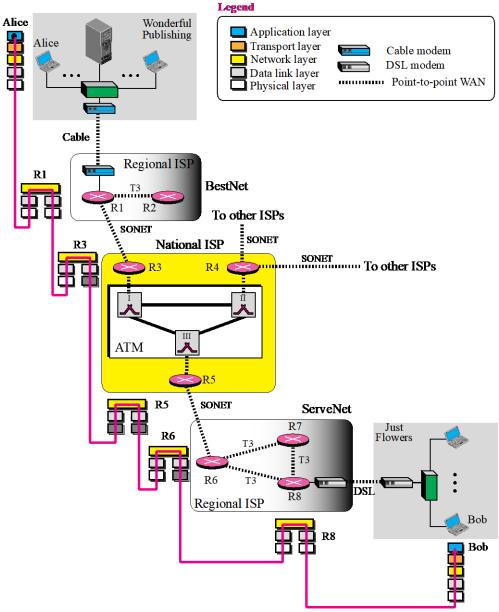
4-4 NETWORK LAYER SERVICES

In this section, we briefly discuss services provided by the network layer. Our discussion is mostly based on the connectionless service, the dominant service in today's Internet.

Topics Discussed in the Section

- **✓** Logical Addressing
- **✓ Services Provided at the Source Computer**
- **✓ Services Provides at the Each Router**
- **✓ Services Provided at the Destination Computer**

Figure 4.12 An imaginary part of the Internet



Services provided at the source computer



The network layer at the source computer provides four services: packetizing, finding the logical address of the next hop, finding the physical (MAC) address of the next hop, and fragmenting the datagram if necessary. Figure 4.13 shows these services.

Figure 4.13 Services provided at the source computer

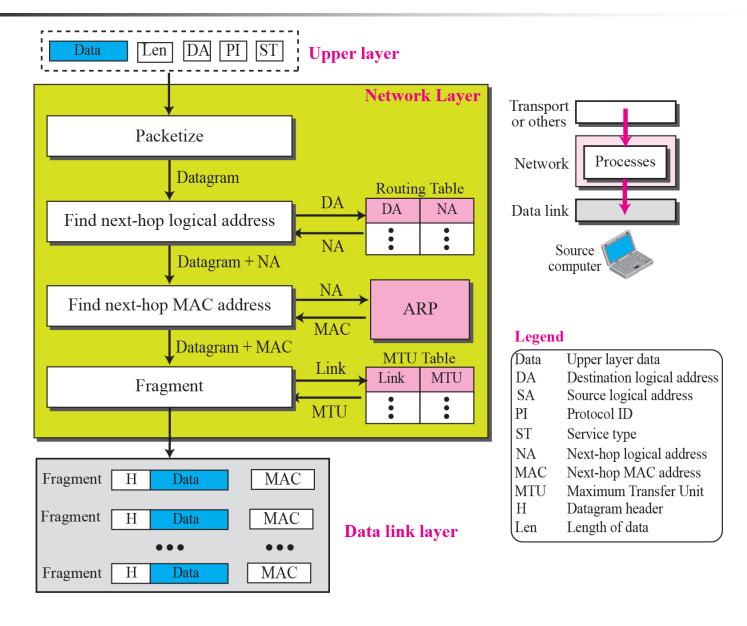
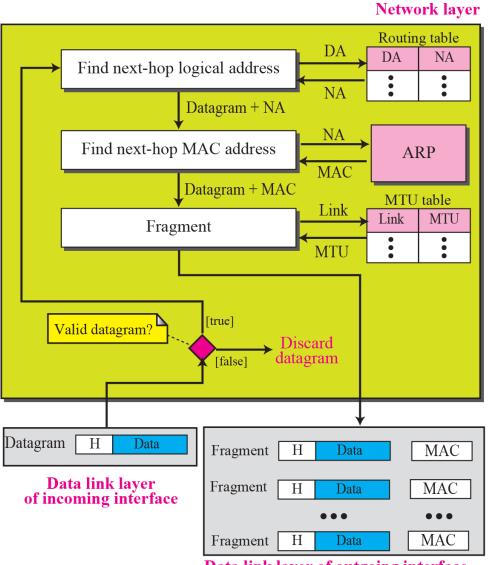
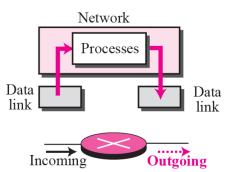


Figure 4.14 Processing at each router



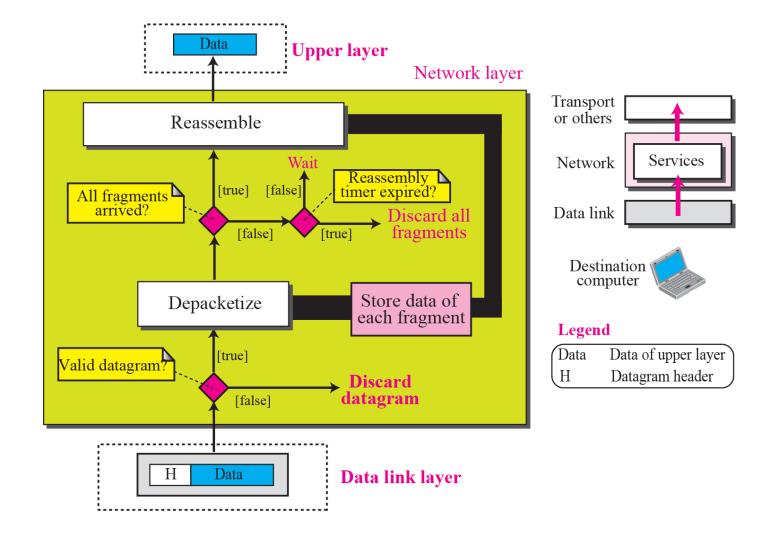


Legend

Data	Upper layer data
DA	Destination logical address
NA	Next-hop logical address
MAC	Next-hop MAC address
MTU	Maximum Transfer Unit
Н	Datagram header

Data link layer of outgoing interface

Figure 4.15 Processing at the destination computer



4-5 OTHER SERVICES

In this section we introduce some issues related to the network layer. These issues actually represent services that are normally discussed for the network layer, but they are either partially implemented at the network layer or not implemented at all. Some services are provided by some auxiliary protocols or by protocols added to the Internet later. Most of these issues resurface in future chapters.

Topics Discussed in the Section

- **✓ Error Control**
- **✓ Flow Control**
- **✓** Congestion Control
- **✓** Routing
- **✓** Security

Figure 4.16 Error checking at the network and data link layers

Error control means including a mechanism for detecting corrupted, lost, or duplicate datagrams. Error control also includes a mechanism for correcting errors after they have been detected. The network layer in the Internet does not provide a real error control mechanism. The designers of the network layer wanted to make this layer operate simply and fast.

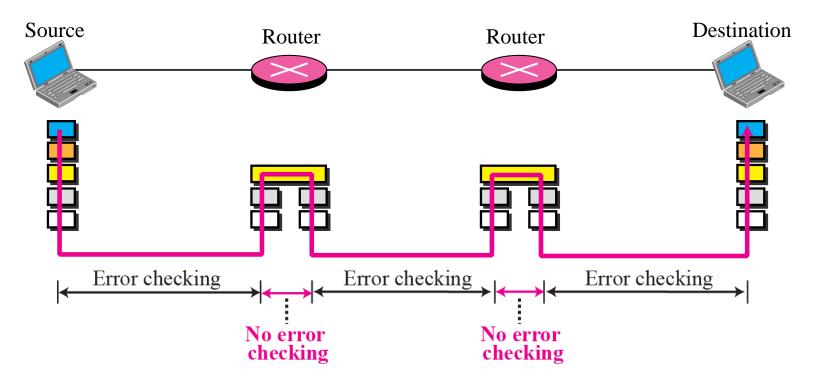
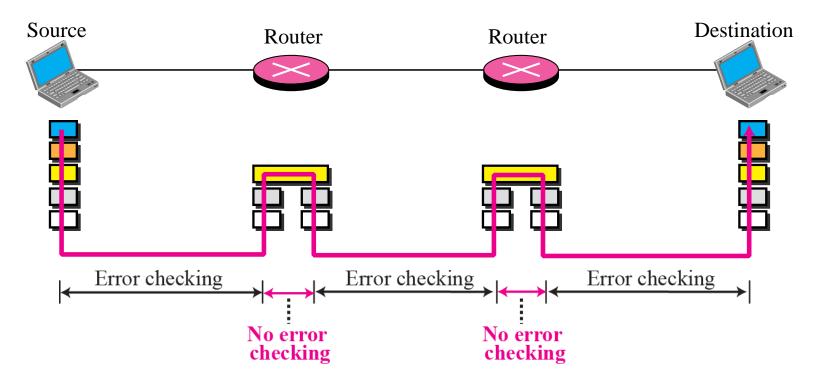


Figure 4.16 Erro

The **data link layer** that controls the behaviour of these networks (LANs or WANs) use error control.



Flow control at the Network layer

Flow control regulates the amount of data a source can send without overwhelming the receiver. If the upper layer at the source computer produces data faster than the upper layer at the destination computer can consume it, the receiver will be overwhelmed with data. To control the flow of data, the receiver needs to send some feedback to the sender to inform the latter it is overwhelmed with data.

Note

No flow control is provided for the current version of Internet network layer.

Congestion Control at the Network layer

Congestion may occur if the number of datagrams sent by source computers are beyond the capacity of the network or routers. In this situation, some routers may drop some of the datagrams.

Routing at the Network layer



A very important issue in the network layer is **routing**; how a router creates its routing table to help in forwarding a datagram in a connectionless service or helps in creating a virtual circuit, during setup phase, in a connection-oriented service.

Security at the Network layer



The network layer was designed with **no security provision**. To provide security for a connectionless network layer, we need to have another virtual level that changes the connectionless service to a connection-oriented service. This virtual layer, called **IPSec.**