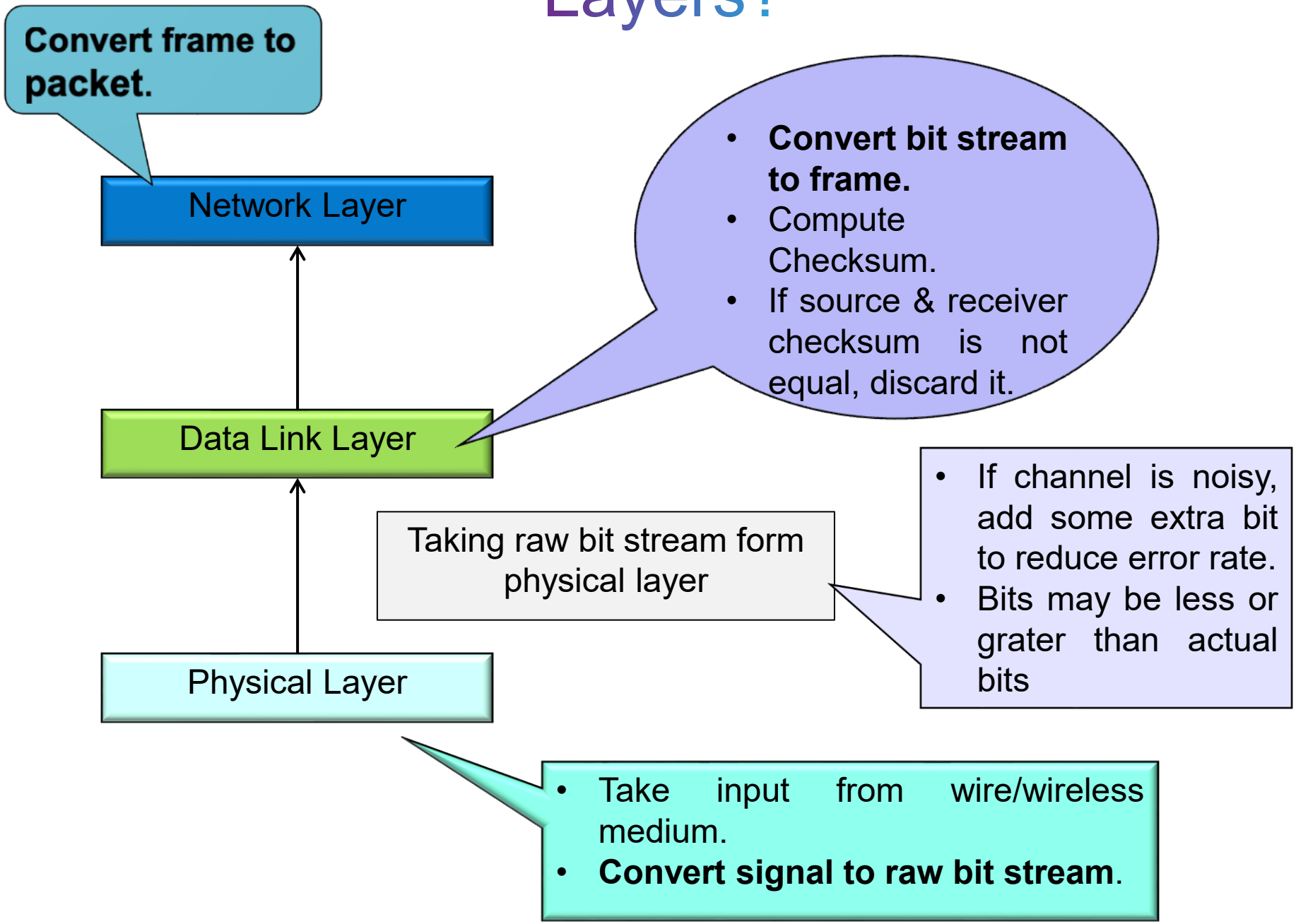
Chapter 5 (Tanenbaum)
Network Layer

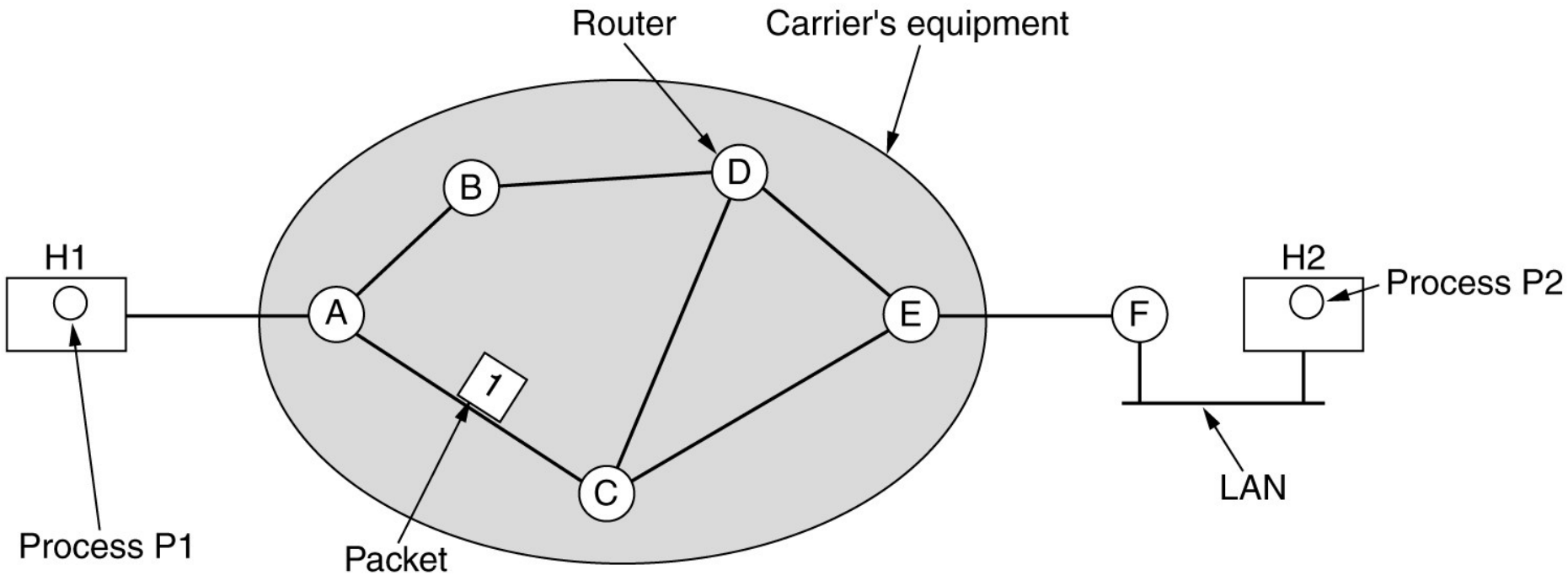
Layers?


Convert frame to packet.
Network Layer
Convert bit stream to frame.
Compute Checksum.
If source & receiver checksum is not equal, discard it.
Data Link Layer
Taking raw bit stream form physical layer
If channel is noisy, add some extra bit to reduce error rate.
Bits may be less or grater than actual bits
Physical Layer
Take input from wire/wireless medium.
Convert signal to raw bit stream.

Network Layer Design Issue

- Store-and-Forward Packet Switching
- *Services Provided to the Transport Layer*
- Implementation of Connectionless Service
- Implementation of Connection-Oriented Service
- Comparison of Virtual-Circuit and Datagram Subnets

Store-and-Forward Packet Switching



The environment of the network layer protocols.

Store-and-Forward Packet Switching (1)

- A host with a packet to send transmit it to the nearest router, either on it's own LAN or over a point-to-point link to the ISP.
- The packet is stored there until it has fully arrived and the link has finished its processing by verifying the checksum.
- Then it is forwarded to the next router along the path until it reaches the destination host, where it is delivered.

Services Provided to the Transport Layer

- An important question is precisely what kind of services the network layer provides to the transport layer?
- Dealing with the following **goals** in mind:
  1. The services should be **independent** of the router technology.
  2. The transport layer should be shielded from the number, type, and topology of the routers present.
  3. The network addresses made available to the transport layer should use a uniform numbering plan, even across LANs and WANs.

Services Provided to the Transport Layer

- An important question is precisely what kind of services the network layer provides to the transport layer?
- **Service Kinds:**
  1. **Connectionless Service:** Internet Community.

     The hosts should accept the fact that the network is unreliable, so need to do error control (i.e., error detection and correction) and flow control themselves.
  2. **Connection-Oriented Service:** Telephone companies.

     Network should provide a reliable, connection-oriented service. (ATM)

Services Provided to the Transport Layer

❑ Service Kinds:

1. **Connectionless Service:** Internet Community.
   - Connection in unreliable.
   - Host does the error control (i.e., error detection and correction) and flow control themselves.
   - There is no packet ordering. Because host are going to do flow control already.
   - Furthermore, each packet must carry the full destination address, because each packet sent is carried independently of its predecessors, if any.

Services Provided to the Transport Layer

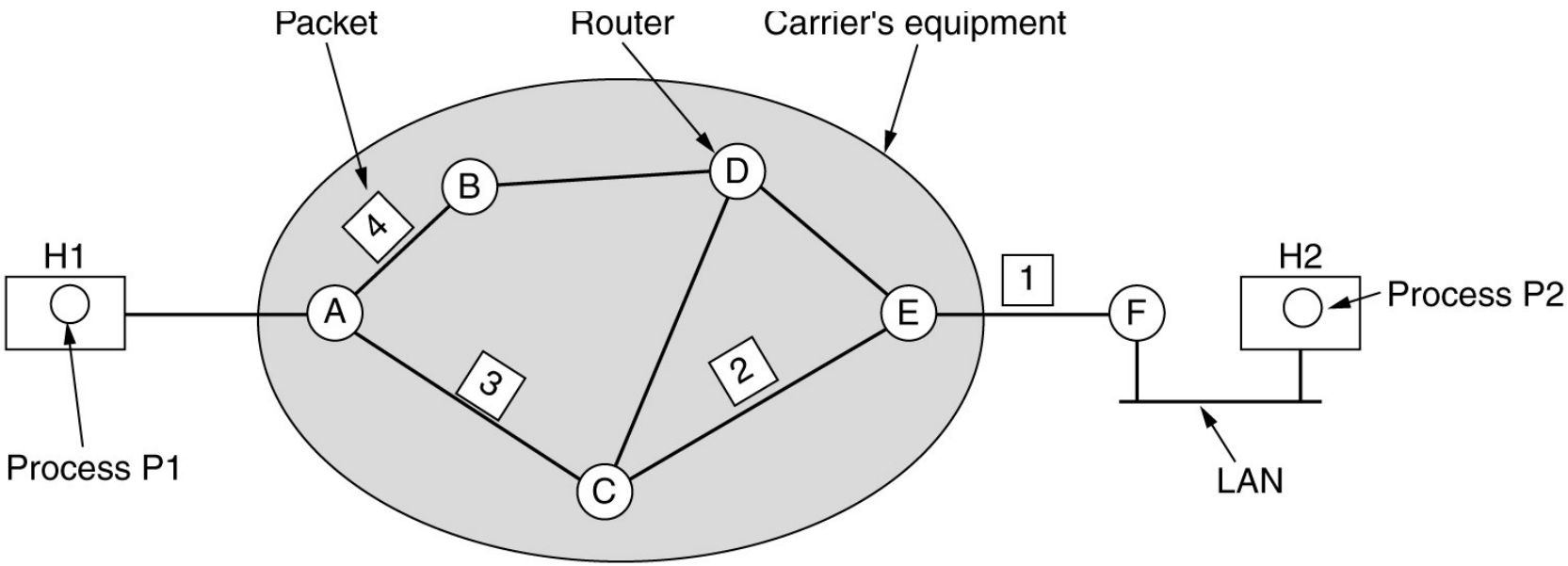
❑ Service Kinds:

2. **Connection-Oriented Service:** Telephone companies.
   - Network should provide a reliable, connection-oriented service. (ATM-Asynchronous Transfer Mode)
   - Quality of service is the dominant factor. Quality of service is very difficult to achieve, especially for real-time traffic such as voice and video.

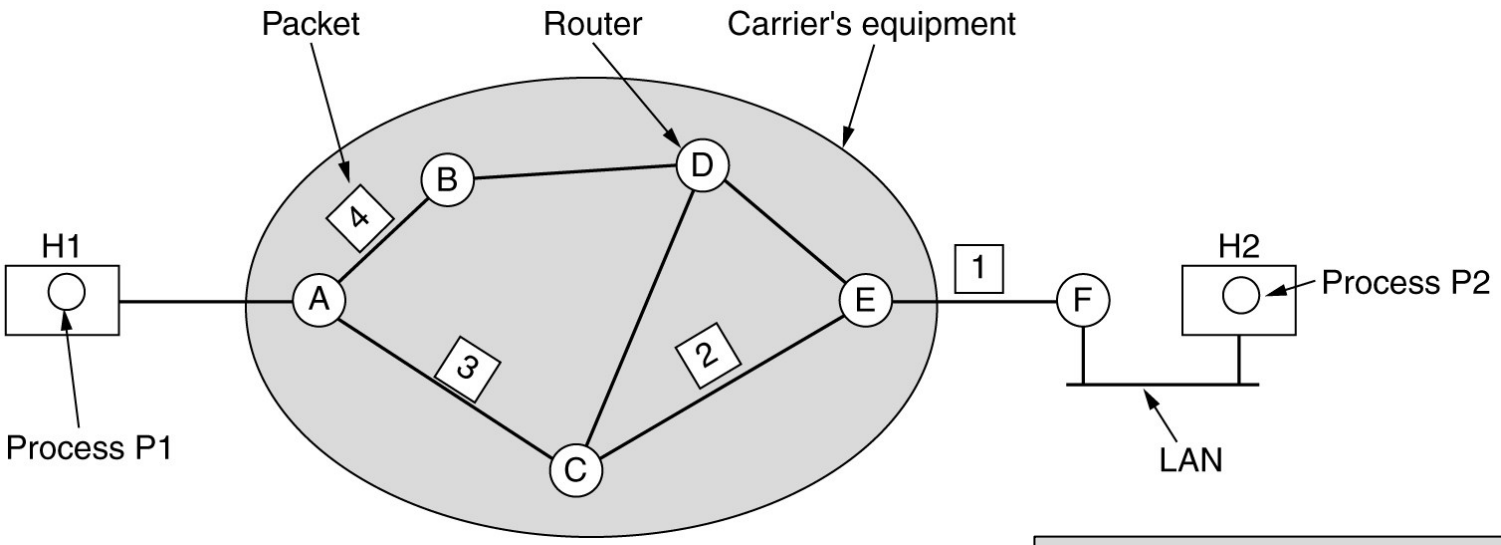
Implementation of Connectionless Service

a) Packets are injected into the network individually and routed independently of each other.

b) No advance setup is needed.



Implementation of Connectionless Service



A's table

Dest.	initially Line	later Line
A	–	–
B	B	B
C	C	C
D	B	B
E	C	B
F	C	B

C's table

Dest.	Line
A	A
B	A
C	–
D	D
E	E
F	E

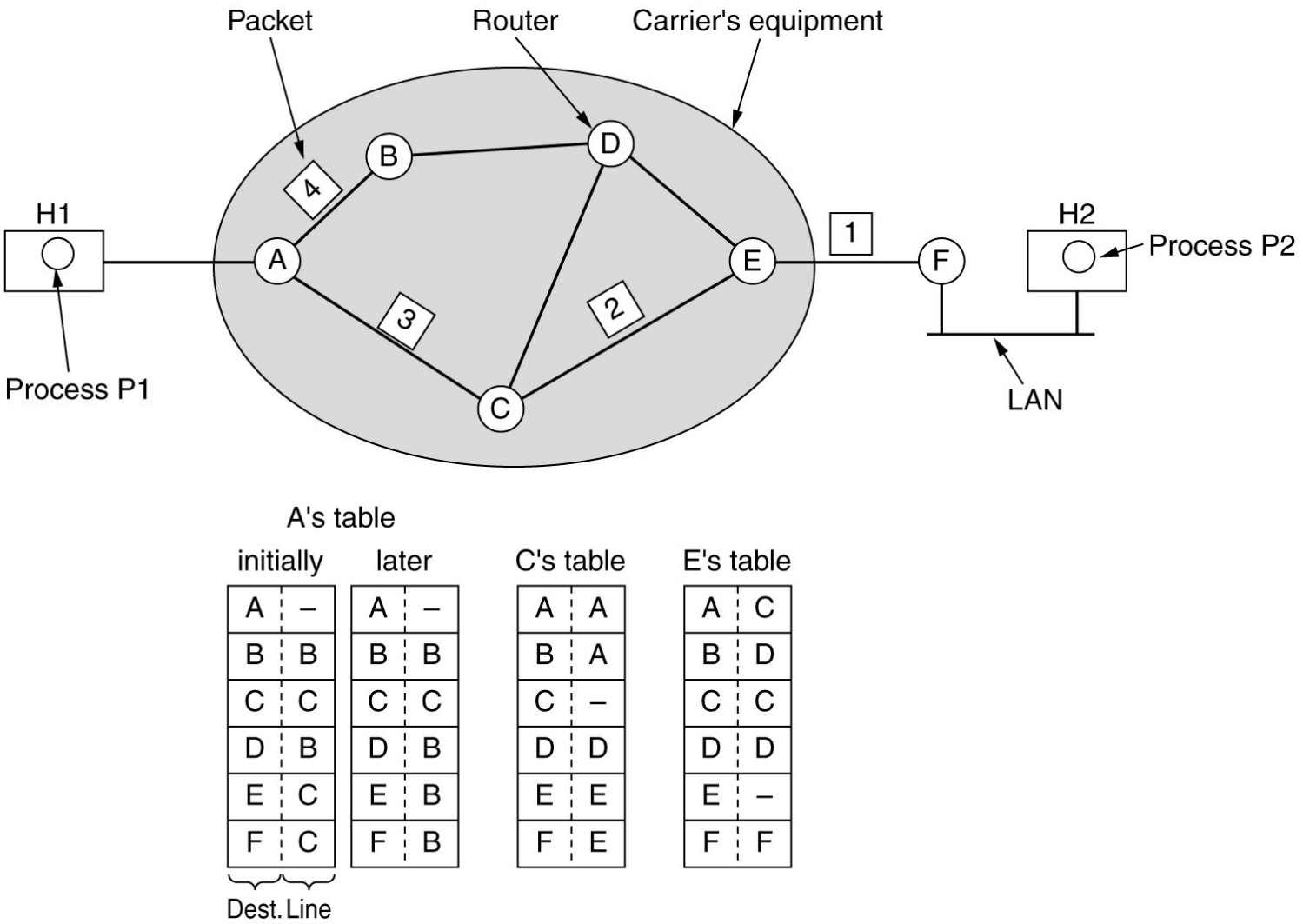
E's table

Dest.	Line
A	C
B	D
C	C
D	D
E	–
F	F

- Packet frequently called as **datagram.**
- The network is called a **datagram network.**

Routing within a diagram subnet.

Implementation of Connectionless Service



Dest.	Line (initially)
A	–
B	B
C	C
D	B
E	C
F	C

Dest.	Line (later)
A	–
B	B
C	C
D	B
E	B
F	B

Dest.	Line (C's table)
A	A
B	A
C	–
D	D
E	E
F	E

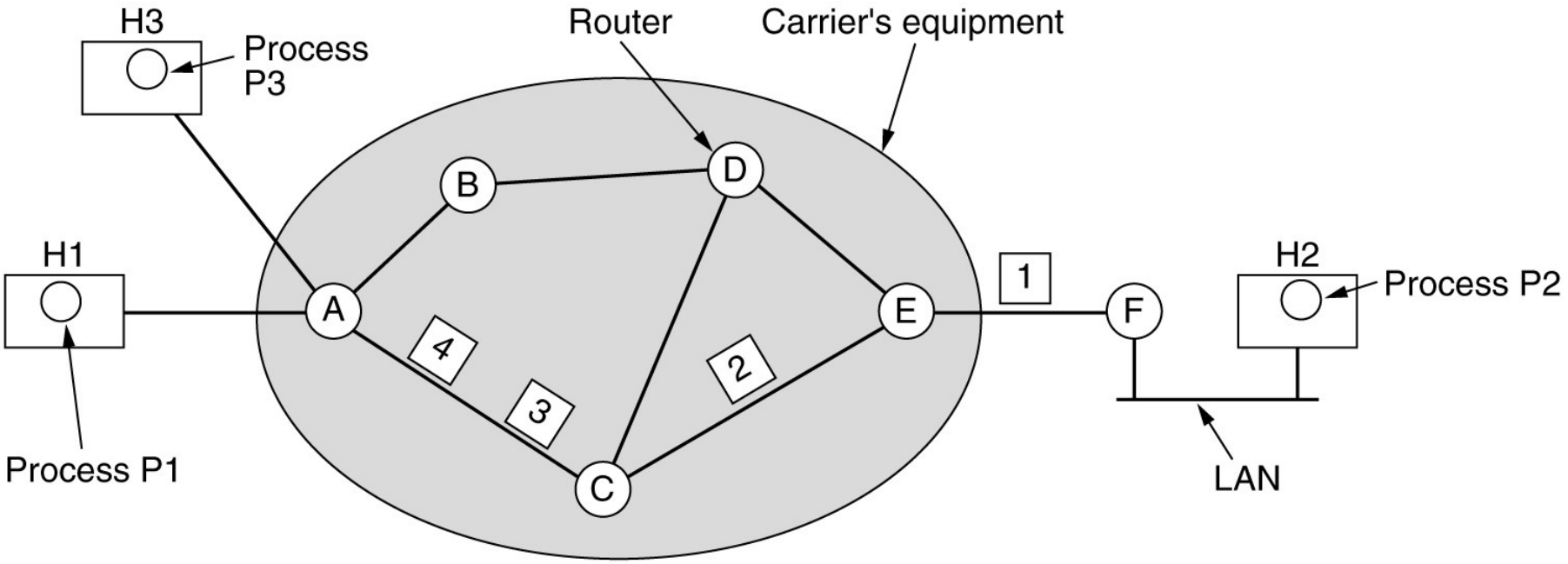
Dest.	Line (E's table)
A	C
B	D
C	C
D	D
E	–
F	F

Routing within a diagram subnet.

Implementation of Connection-Oriented Service

- In connection-oriented service a path from the source router all the way to the destination router must be established before any data packets can be sent.
- This connection is called a **VC (virtual circuit).**
- The network is called a **virtual-circuit network.**

Implementation of Connection-Oriented Service(1)



A's table

In		Out	
H1	1	C	1
H3	1	C	2

C's table

A	1	E	1
A	2	E	2

E's table

C	1	F	1
C	2	F	2

Routing within a virtual-circuit subnet.

Implementation of Connection-Oriented Service(2)

- Host H1 has established connection 1 with host H2.
- This connection is remembered as the first entry in each of the routing tables.
- What happens if H3 also wants to establish a connection to H2?
- Normally It chooses **connection identifier** 1 [but 1 is already used]. That's the problem!!!
- So have to choose different connection identifier I,e 2.
- This process is called **label switching.**

Comparison of Virtual-Circuit and Datagram Subnets

Issue	Datagram subnet	Virtual-circuit subnet
Circuit setup	Not needed	Required
Addressing	Each packet contains the full source and destination address	Each packet contains a short VC number
State information	Routers do not hold state information about connections	Each VC requires router table space per connection
Routing	Each packet is routed independently	Route chosen when VC is set up; all packets follow it
Effect of router failures	None, except for packets lost during the crash	All VCs that passed through the failed router are terminated
Quality of service	Difficult	Easy if enough resources can be allocated in advance for each VC
Congestion control	Difficult	Easy if enough resources can be allocated in advance for each VC

Routing Algorithms

- Main function of Network Layer:
  - ✓ The main function of the network layer is **routing packets** from the source machine to the destination machine.
- Process inside Router:
  - ✓ **Forwarding:** handles each packet as it arrives, looking up the outgoing line to use for it in the routing tables.
  - ✓ **Routing:** Determines route taken by packets form the source machine to the destination machine (Routing algorithm)
- **Routing Algorithms:**
  - ✓ The routing algorithm is that part of the network layer software responsible for deciding which output line an incoming packet should be transmitted on.

Routing Algorithms

Network Layer Software responsible for deciding which output line an incoming packed should be transmitted on. If the network layer use-

- ✓ **Datagrams:** require computation of decision making tables for every arriving data packet.
- ✓ **Virtual Circuit:** routing decision are made only when a new virtual circuit is being set up.
  - ✓ **Session Routing:** data packets follow the same routing for the entire session.

Routing Algorithms

- Desired properties of Routing Algorithm:
  - **Correctness** (Before we adopt any algorithm we need to make sure that it has been tested enough and it is functioning correctly)
  - **Simplicity** (Algorithm should be less complex)
  - **Robustness** (The routing algorithm should be able to cope with changes in the topology and traffic without requiring all jobs in all hosts to be aborted)
  - **Stability** (Converge to a fixed set of paths)
  - **Fairness** (No device or link has to be compromised)
  - **Optimality** (Converge to provide optimal throughput)

Network Performance Measures

- Two Performance Measures
  - ✓ Quantity of Service (Throughput)
    - **How much** data travels across the net?
    - How long does it take to transfer long files?
  - ✓ Quality of Service (Average packet delay)
    - How long does it take for a packet to arrive at its destination?
    - *How responsive* is the system to user commands?
    - Can the network support real-time delivery such as audio and video?

*Fairness versus Optimality

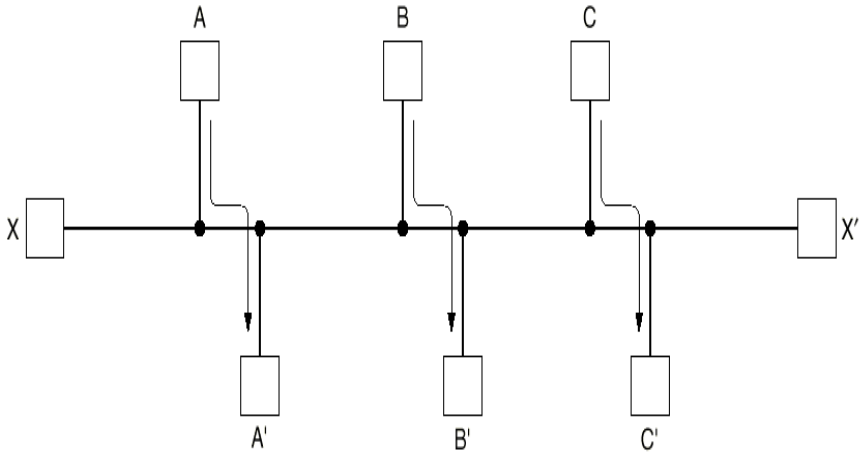


Fig. 5-4. Conflict between fairness and optimality.

a) Quantity of service (fairness) versus quality of service (optimality).

b) To optimize throughput, saturate paths between A and A', B and B', and C and C', but what happens to the response time from X to X'?

*Fairness versus Optimality/Efficiency

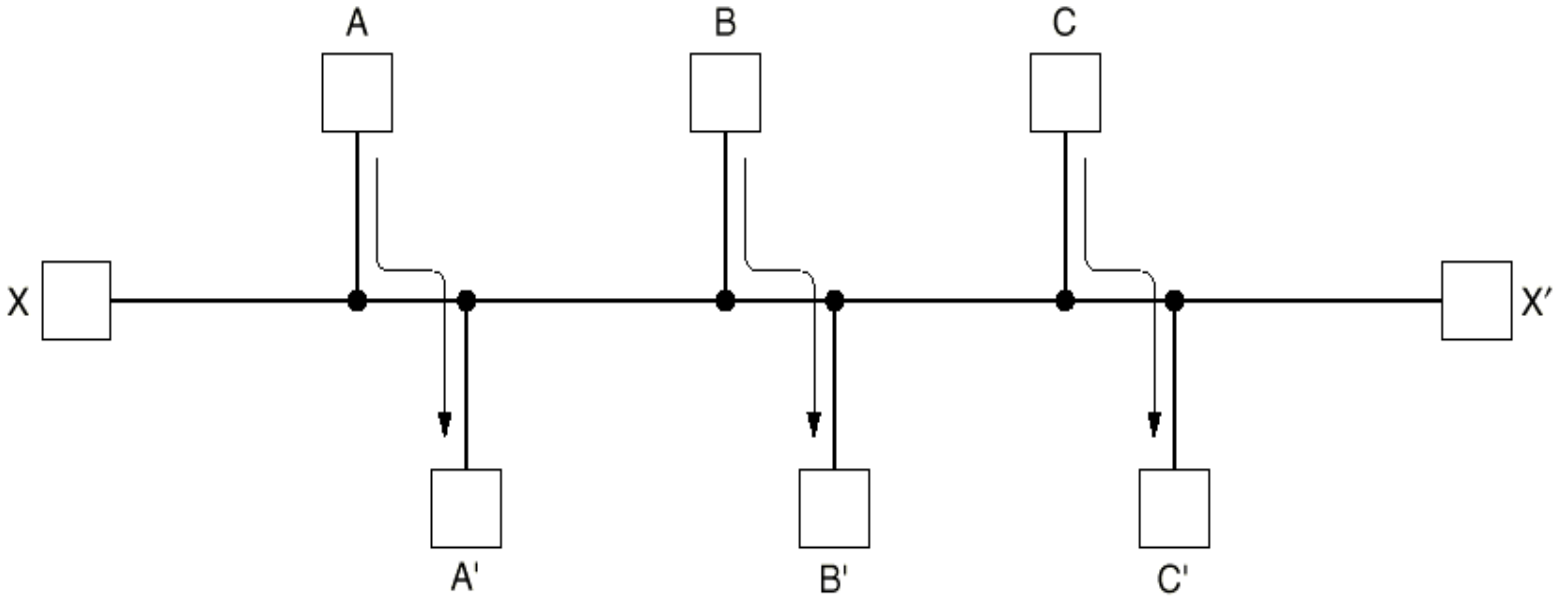


Fig. 5-4. Conflict between fairness and optimality.

There is enough traffic between *A* and *A'*, between *B* and *B'*, and between *C* and *C'* to saturate the horizontal links. To maximize the total flow, the X to X′ traffic should be shut off altogether. So it's not fair for X to X' link. So fairness drops but optimum output is achieved.

Routing Algorithms

- Routing algorithms can be grouped into two major classes:
  1. Nonadaptive and
  2. Adaptive.

a) **Nonadaptive algorithms** the choice of the route to use to get from source to destination is computed in *advance. Static*

b) **Adaptive algorithms**, in contrast, change their routing decisions to reflect changes in the topology, and sometimes changes in the traffic as well. Dynamic