Unit-1 Packet Switching Networks

Communication Networks:

- Communication Networks: "Sets of nodes that are interconnected to allow the exchange of information such as voice, sound, graphics, pictures, video, text, data, etc…"

Telephone Networks:

- "The first well established and most widely used communication networks which are used for voice transmission" – Telephone networks originally used analog transmission as a transmission technology for the information. However, digital transmission started to evolve replacing a lot of the analog transmission techniques used in telephone networks.

Computer Networks:

- "Collection of autonomous computers interconnected by a technology to allow exchange of information"

Computer Networks

A network is a series of connected devices. Whenever we have many devices, the interconnection between them becomes more difficult as the number of devices increases . Some of the conventional ways of interconnecting devices are

a. Point to point connection between devices as in mesh topology.
b. b. Connection between central device and every other device – as in star topology
c. c. Bus topology-not practical if the devices are at greater distances

- The solution to this interconnectivity problem is switching.
- A switched network consists of a series of interlinked nodes called switches. A switch is a device that creates temporary connections between two or more systems. Some of the switches are connected to end systems (computers and telephones) and others are used only for routing.

Taxonomy of Switched Networks

- Switched Networks
- 1.Circuit Switched
- 2.Packet Switched
- 3.Message Switched

Packet Switched networks

- 1.Data Gram Networks
- 2.Virtual Circuit Networks

Circuit switching

- Traditional telephone networks operate on the basis of circuit switching .In conventional telephone networks, a circuit between two users must be established for a communication to occur Circuit switched networks requires resources to be reserved for each pair of end users The resources allocated to a call cannot be used by others for the duration of the call .

  The reservation of the network resources for each user results in an inefficient use of bandwidth for applications in which information transfer is bursty or if the information is small

Packet Switching

- Packet switched networks are the building blocks of computer communication systems in which data units known as packets flow across the networks.
- It provides flexible communication in handling all kinds of connections for a wide range of applications e.g. telephone calls, video conferencing, distributed data processing etc…

- Packet switched networks with a unified, integrated data infrastructure known as the Internet can provide a variety of communication services requiring different bandwidths.
- To make efficient use of available resources, packet switched networks dynamically allocate resources only when required.
- The form of information in packet switched networks is always digital bits.(0/1)

Differences between Circuit & Packet Switching

- Circuit switching
- 1. Call set up is required.
- 2.Dedicated connection between two Hosts.
- 3. Connection/Communication is lost, if any link in the path between the Hosts is broken.
- 4. Information take the same route between the connected Hosts
- 5.Information always arrives in order.

- 6. Bandwidth available is fixed.
- 7. Congestion is call based.
- 8. Bandwidth utilization is partial.
- 9.It does not uses store-and forward transmission.
- 10. It is Transparent.
- 11.Charging is time based.

Packet switching

- 1. Call setup is not required.
- 2. No dedicated connection between two Hosts
- 3. Connection/Communication could continue between the Hosts since data have many routes between the Hosts.
- 4. Information could take different routes to reach the destination Host.
- 5. Information could arrive out of order to the destination

- 6. Bandwidth available is variable.
- 7. Congestion is packet based.
- 8. Bandwidth utilization is full.
- 9.It uses store-and forward transmission.
- 10. Not transparent.
- 11.Charging is packet based

- Packet networks can be viewed from two perspectives:
  External view of network :-

  It is Concerned with the services that the network provides to the transport layer
  - Need connection setup or not
  - What QoSs are provided
- Internal operation of the network.
- Physical Topology
  - datagram message transfer or virtual circuit information transfer,
  - *addressing and routing*, congestion control.

- Packet switching may be classified into connectionless packet switching, also known as datagram switching, and connection-oriented packet switching, also known as virtual circuit switching.
- Examples of connectionless protocols are
- Ethernet, Internet Protocol (IP), and the User Datagram Protocol (UDP).
- Connection-oriented protocols include X.25, Frame Relay, Multiprotocol Label Switching(MPLS), and the Transmission Control Protocol (TCP).

- Packets are composed of a header and payload. Information in the header is used by networking hardware to direct the packet to its destination where the payload is extracted and used by application software

- A large message may be divided into thousands of individual packets. The beginning of an packet is called the "header" and records the following information:
- Source. The IP address of the computer sending the packet.
- Destination. The IP address of the destination computer .
- Length. The length of the packet in bytes.
- Number. The total number of packets in the complete message.
- Sequence. The number of this packet in the whole list of packets making up this communication.
- This data provides the information an Internet *router* needs to get packets and messages to their destination. For example, a destination computer can request the retransmission of missing packets, since it knows the number of total packets and therefore can figure out which ones it doesn't have.

- For additional reliability, Internet packet headers also contain an error correction code, which is a number representing a mathematical combination of the rest of the packet data.
- If even a single bit of the packet is changed in transmission, then recalculation of the error correction code by a router won't match the code transmitted with the message, and the packet will be discarded and a request made for retransmission.

Network services and internal network operation

- Essential function of network: The essential function of network is to transfer information among the users that are attached to the network. • Transfer of information may be single block of information or sequence of blocks.

- In case of single block of information, we are interested in having the block delivered correctly to destination and also interested in delay experienced in traversing the network. In case of sequence of blocks, we are interested not only in receiving the blocks correctly and in right sequence.

Transfer of a block of info. VS. a sequence of blocks

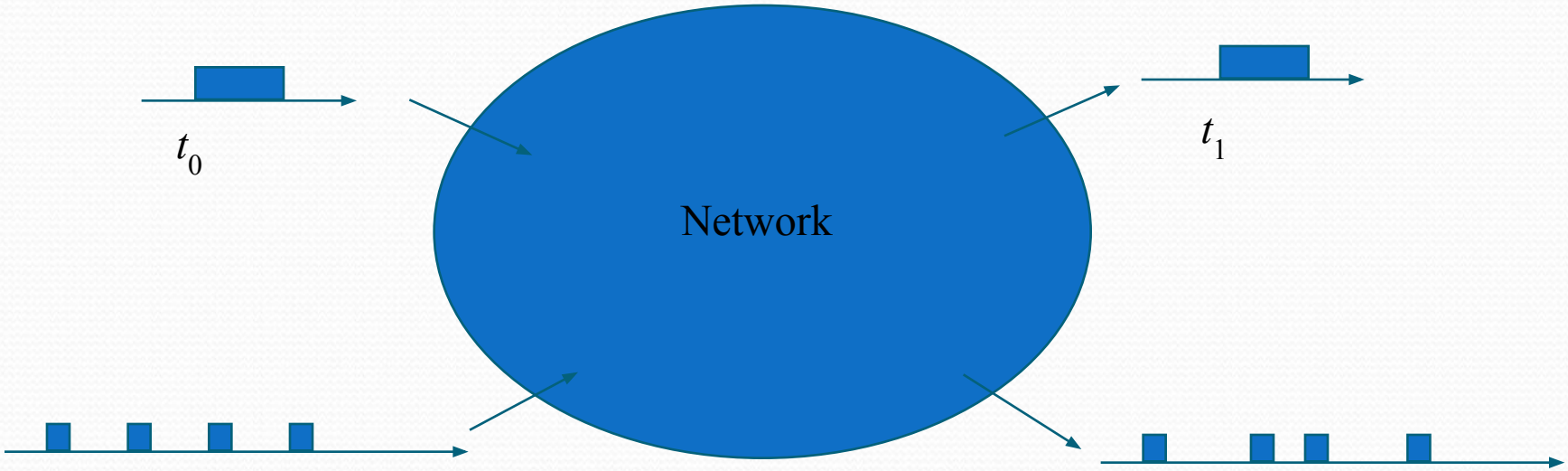
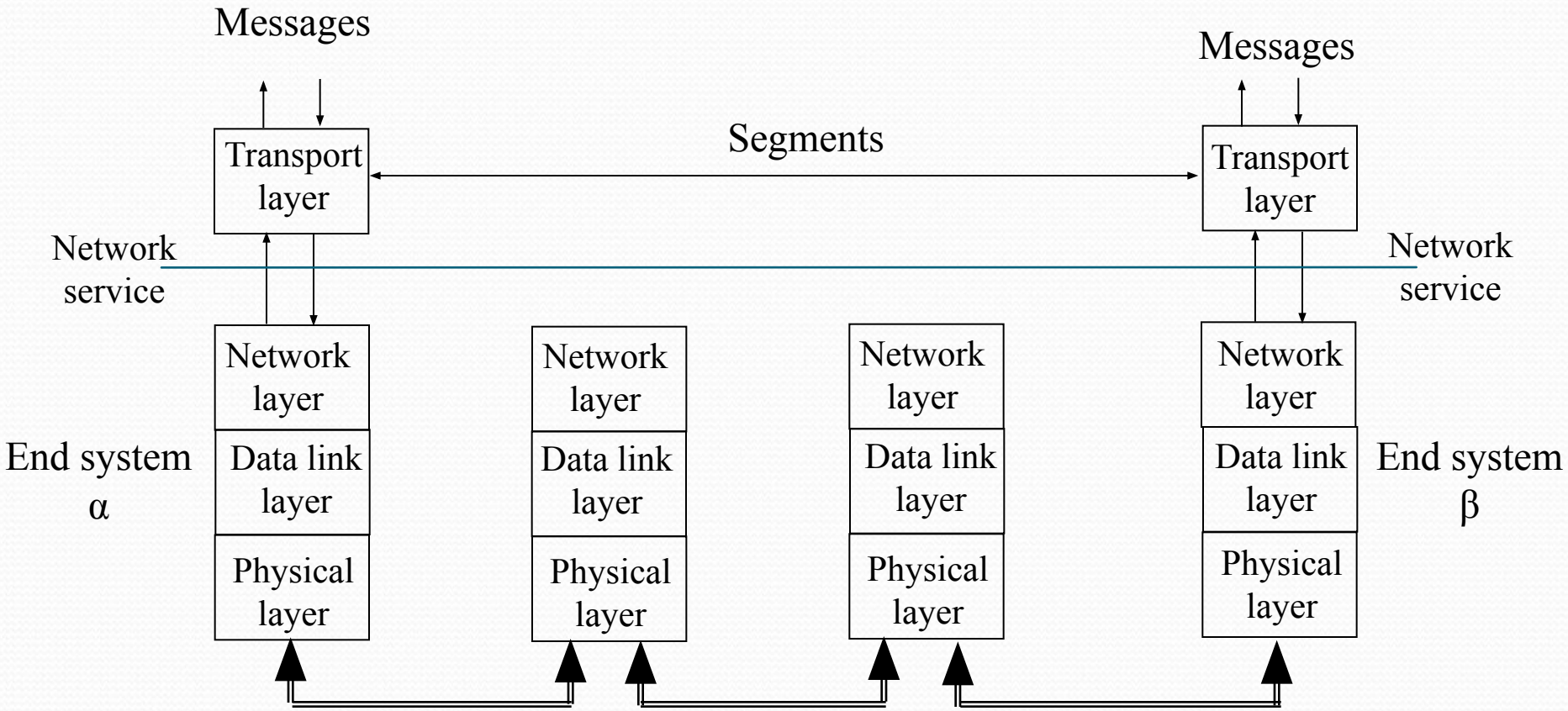


Figure 7.1

Services provided by network layer

- Two basic kinds of services
  - One view: Transfer of a block of information VS. a sequence of blocks
  - Second view: connectionless VS. connection-oriented.
  - IP provides connectionless service VS. ATM provides connection-oriented service
- Other services such as:
  - Best-offer connectionless services
  - Low-delay connectionless service
  - Connection-oriented reliable stream service
  - Connection-oriented transfer of packets with delay and bandwidth guarantees
- End-to-end argument:
  - Functions should be placed as close as possible to the application since the application is in best position to determine whether a function is being carried out completely and correctly,
  - Therefore, network layer should provide *minimum functions* required to meet application requirements and performance. Leave more functions to upper layers such as transport layer.



protocol stack: network provides *minimum required* services to transport layer

Figure 7.2

Most basic functions of a network (layer)

Routing and forwarding.

Priority and scheduling (to provide QoS)

Congestion control (also in transport layer)

Segmentation (to deal with different frame sizes of underlying systems)
Alternatively, network (layer) sends error message to let edge system to do segmentation.

Addressing

1. to deal with different address formats when interconnecting networks.
2. Hierarchical address for scalability.

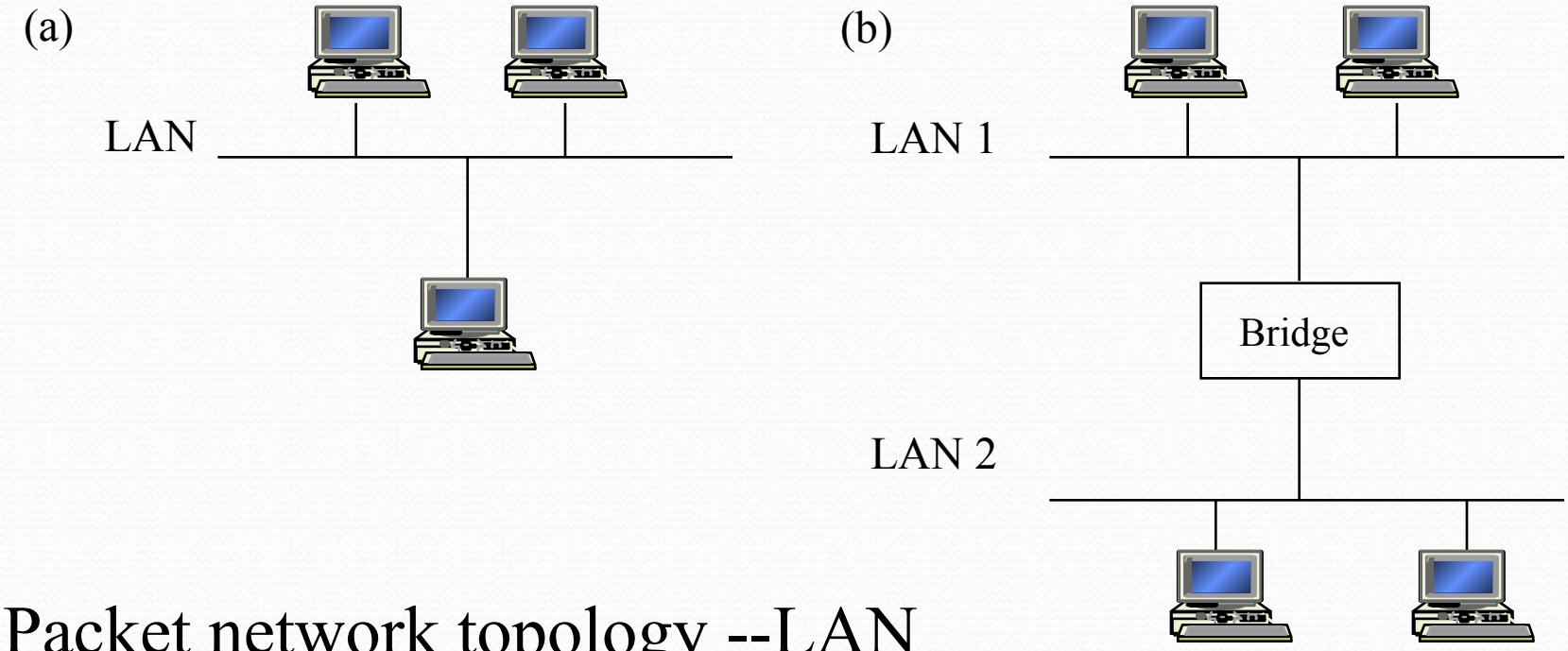
- Packet-switching networks for short messages, burst information, as well as real-time applications

Access node forwards packets into *backbone packet networks*.

Multiplexer combines multiple bursty flows into one aggregated flow.

Packet network topology --Access multiplexer

LANs were introduced for sharing of resources in a organization. They are basic building components for Wide Area Networks.



Packet network topology --LAN

Now nearly every LAN is connected to packet-switching network (the Internet) to share information globally and to make the Internet extremely large.

Figure 7.5

Campus network

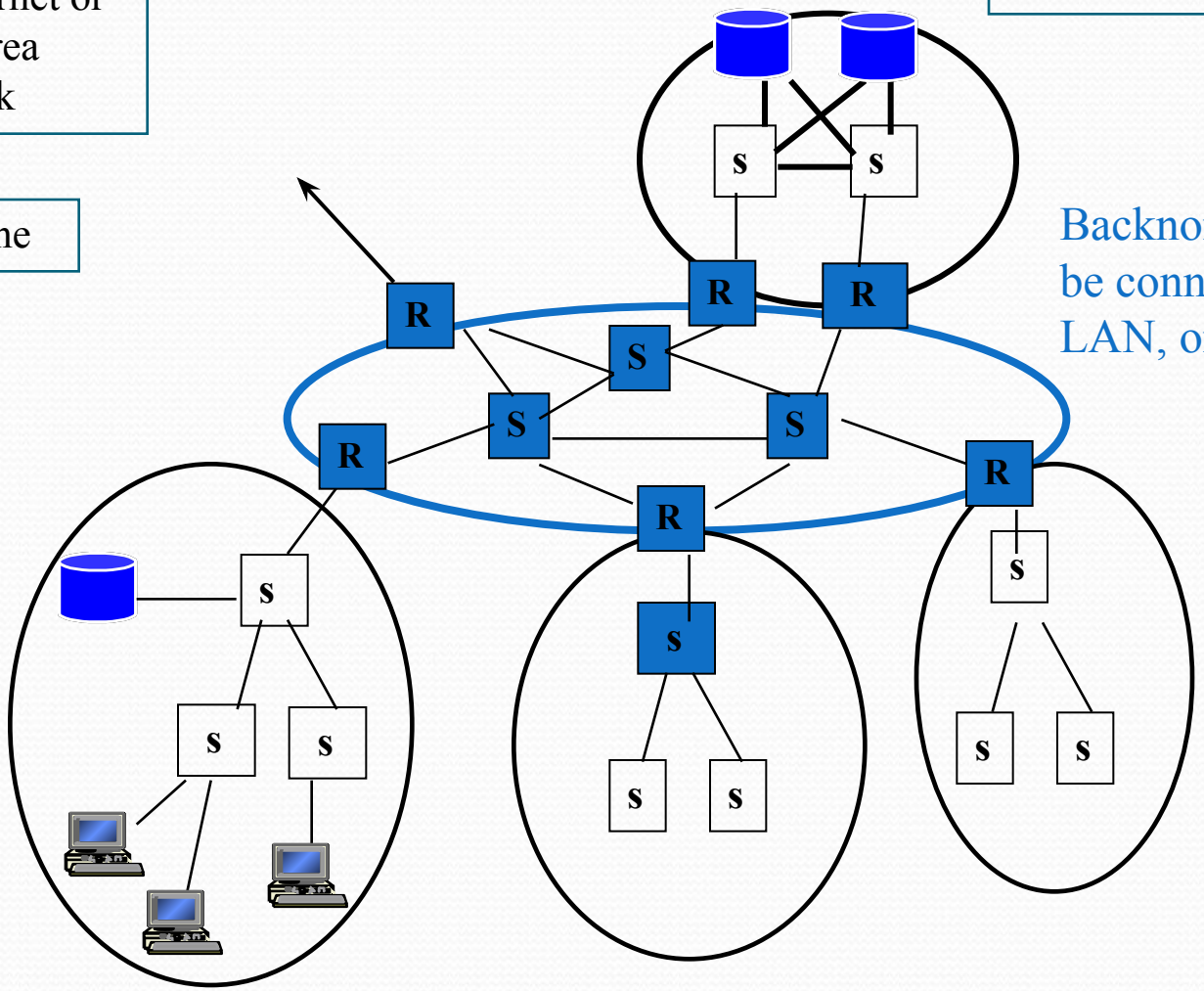
Gateway

Organization Servers

To internet or wide area network

Backbone

Departmental Server



Backnone network may be connected by links, LAN, or ATMs.

LANs extended LANs subnetworks (by backbone networks) campus network university network, finally connect to Internet, Servers provide various services. bridges, routers and gateway,… play key-role in networks

Figure 7.6

Bridge and Gateway

- A bridge joins two similar types of networks joins two similar types of networks so that they look like one network. The word transparent is often used with bridges because network clients do not know the bridge is even in place.
- A gateway joins two dissimilar networks. There can be a lot of protocol conversion work to do. Often the gateway needs to be configured on client systems where communications are directed to the gateway and then some address mapping is provided to get the message to the recipient on the other side.

Router ,Switch

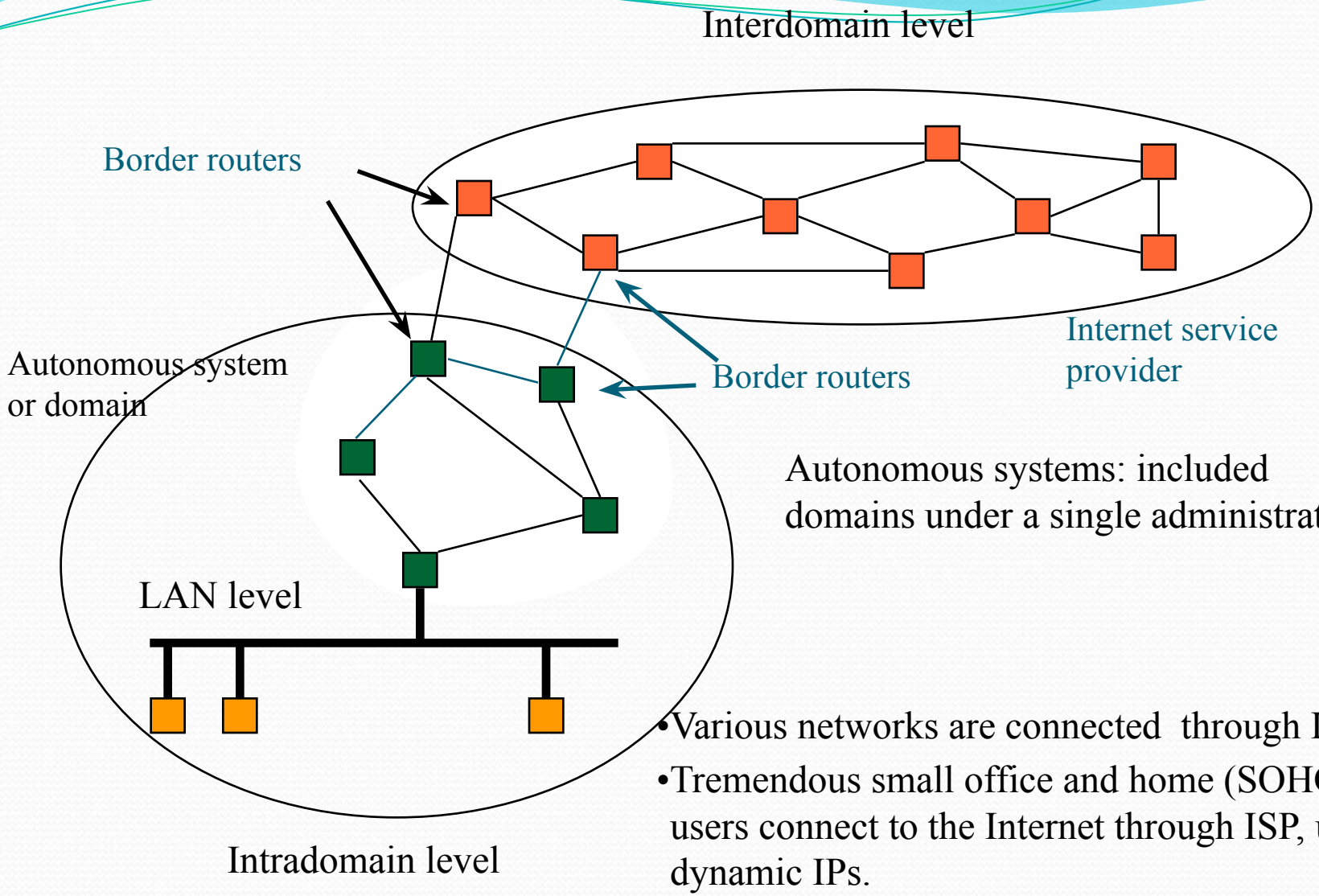
- A router connects two SIMILAR but different IP SUBNETS on SIMILAR networks.

  A gateway connects two DISSIMILAR networks.

  A switch connects devices on the SAME SUBNET.

  A bridge logically divides a SUBNET

Domain: indicate the routers run the same routing protocols.

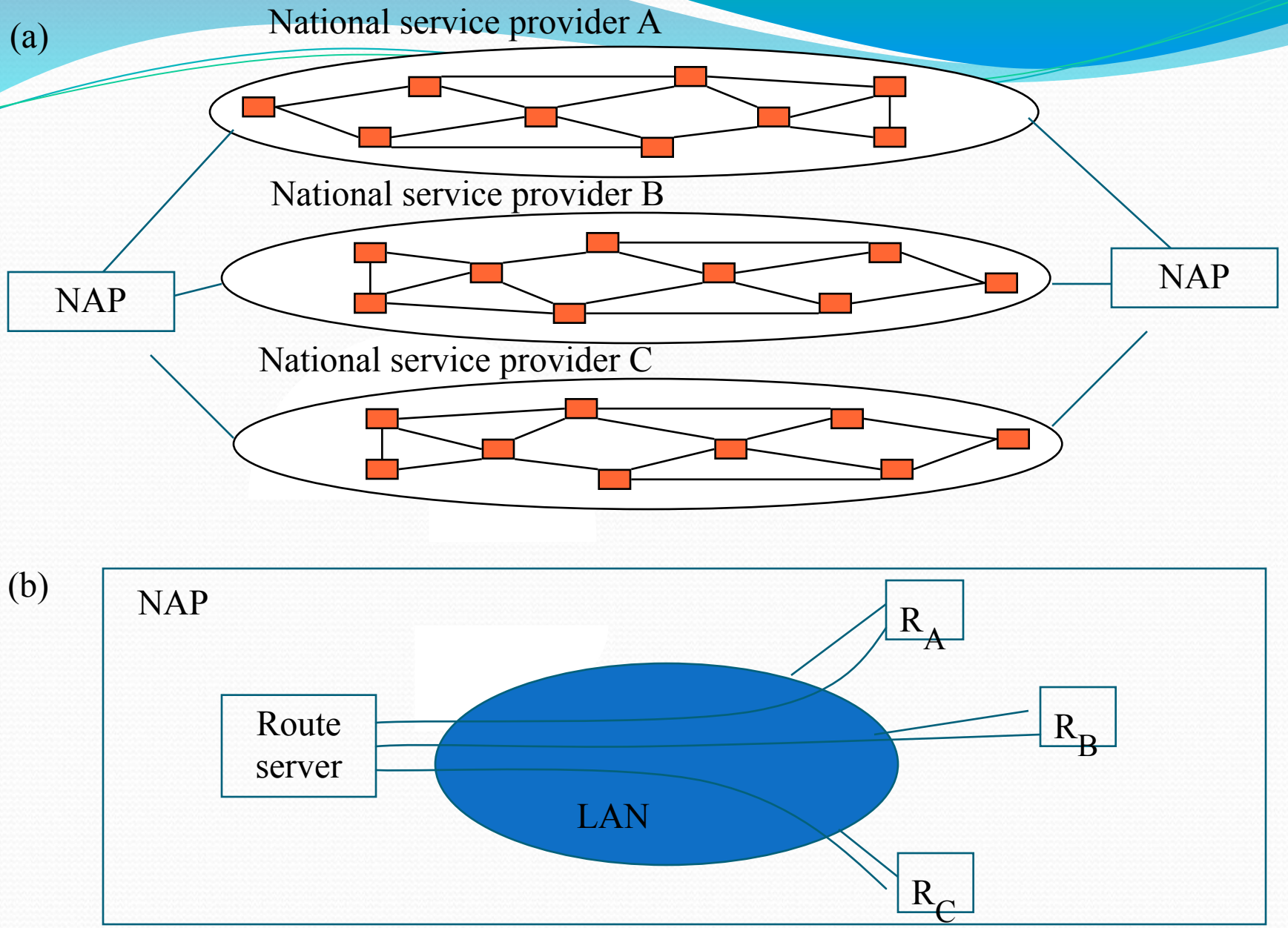


Autonomous systems: included domains under a single administrations

- Various networks are connected through ISP.
- Tremendous small office and home (SOHO) users connect to the Internet through ISP, using dynamic IPs.

Intradomain and interdomain levels

Figure 7.7



National service providers are connected by NAPs (national access point)

Route server distributes routing information to routers.

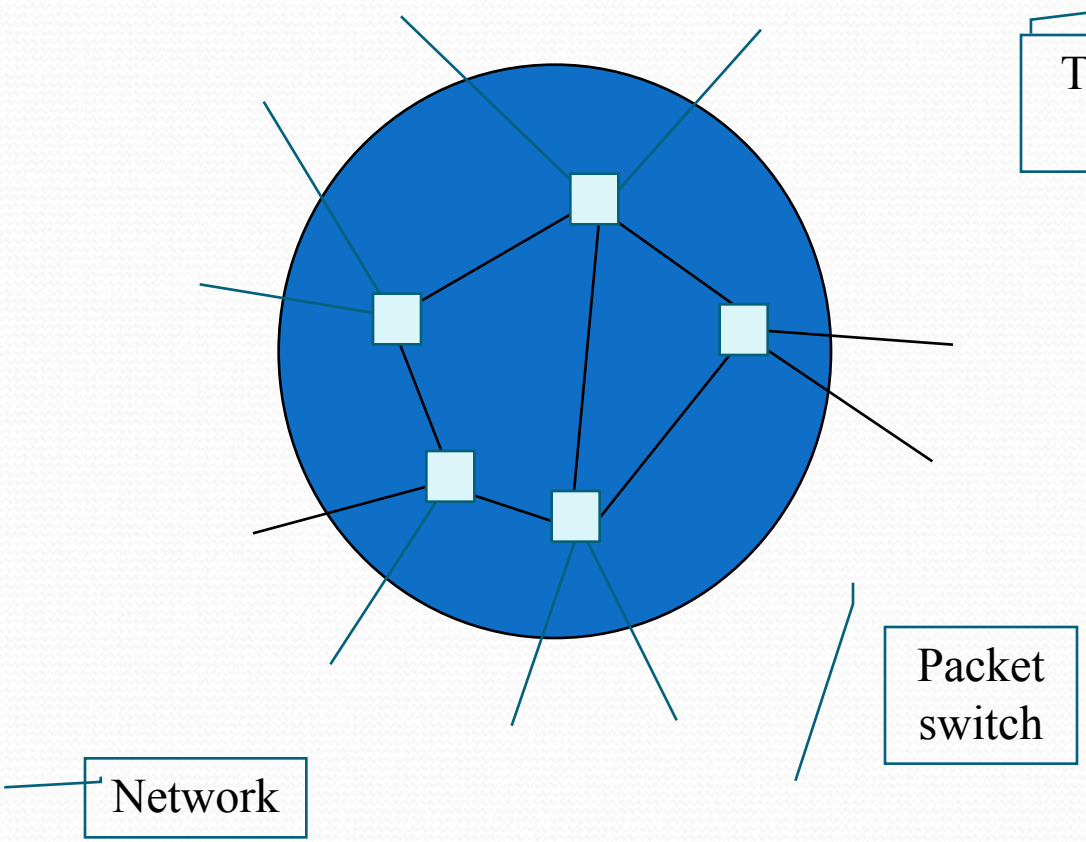
Figure 7.8

Packet-switching topology

- What a big picture of topology for packet-switching networks!!!
  - Hierarchical structure, from LANs campus, university and organization networks Internet
  - ISPs provide backbone networks to connect tremendous different networks and enormous home PCs
  - Switches (bridges, routers, gateways): key elements
  - Various servers provides rich services to users
  - Domain, intra domain, inter domain for easy administration and network management.

Simplified picture of switched networks

1. Transmission lines and packet switches
2. They provide connectivity between *any* source and destination *dynamically*



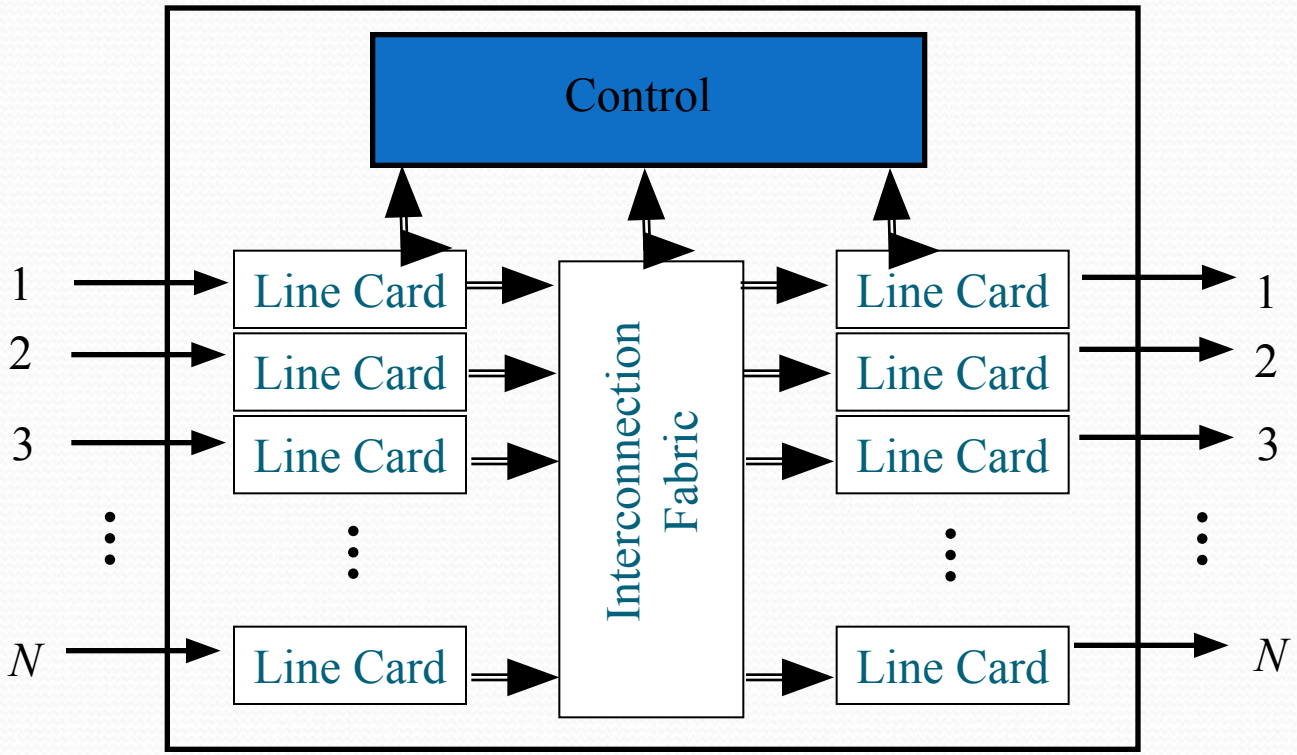
3. The resources are allocated when needed, so can be shared among multiple users
4. Information can be transferred in connection-oriented or connectionless manner.

Figure 7.9

Brief discussion of switches

- Switches are generic term for switching devices in switched networks
  - Circuit-switches in telephony network
  - LAN switches in LAN connection, i.e. bridges, Ethernet switch,…
  - Packet switches in pack switching networks, i.e. routers and gateways.

Structure of a packet switch/router



Components: input ports, output ports, interconnection fabric, controller

A line card handles several pairs of input/output ports and implements physical layer and data link layer functions: symbol timing, line coding, framing, physical addressing, error checking, MAC protocol, data link protocol, and buffering (speed mismatch between lines and fabric).

Figure 7.10

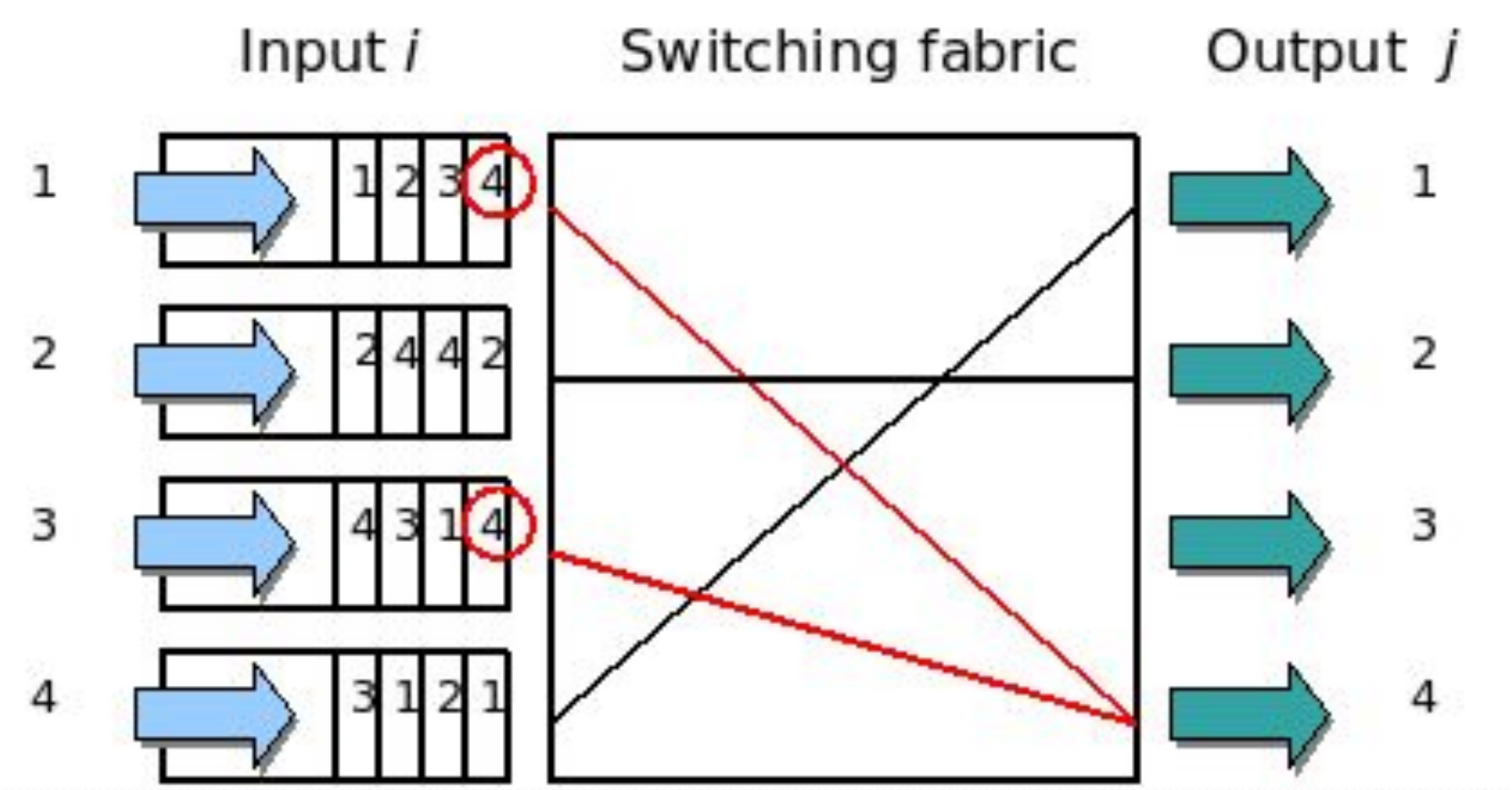
- A packet switch performs two functions
- 1) routing 2) forwarding.
- Routing functions uses algorithm to find a path to each destination and store the result in routing table.
- Forwarding function processes each incoming packet from an input port and forwards the packet to appropriate output port based on the information stored in routing table.

shows a generic packet switch consisting of input ports, output ports, an interconnection fabric and switch controller.

- Input ports and output ports are normally paired.
- Line card contains several input, output ports so that the capacity of the link connecting the line card to the interconnection fabric , which is typically of high speed, and is fully utilized.
- Line card is concerned with symbol timing, line coding, framing, physical addressing and error checking.
- The line card is made up of various chipsets as shown in diagram .
- The programmable network processor performs packet-related tasks such as table lookup and packet scheduling.
- The Controller in a packet switch contains a general-purpose processor to carry out a number of control and management functions.

- The controller also communicates with line card and the interconnection fabric
- The function of the Interconnection fabric is to transfer packets between the line cards.
- If there are high speed line cards the interconnection fabric is likely to be the bottleneck, since all traffic go through it.
- A bus type interconnection structure (whereby packets are transmitted serially) does not scale to large size, since the speed of the bus has to be about N times faster than the port speed.
- A cross bar interconnection fabric can transfer packets in parallel between input ports and output ports.
- The buffers need to be added to the crossbar to accommodate packet contention.

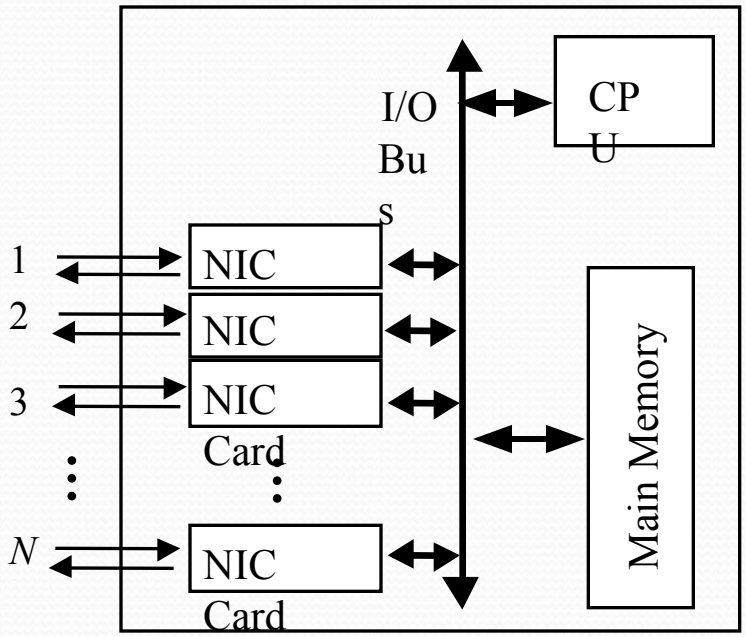
Head of line blocking



A PC or workstation can be configured to become a switch

1.Several NICs are inserted into expansion slots,

2. Install routing and other protocols in the computer



Operations:

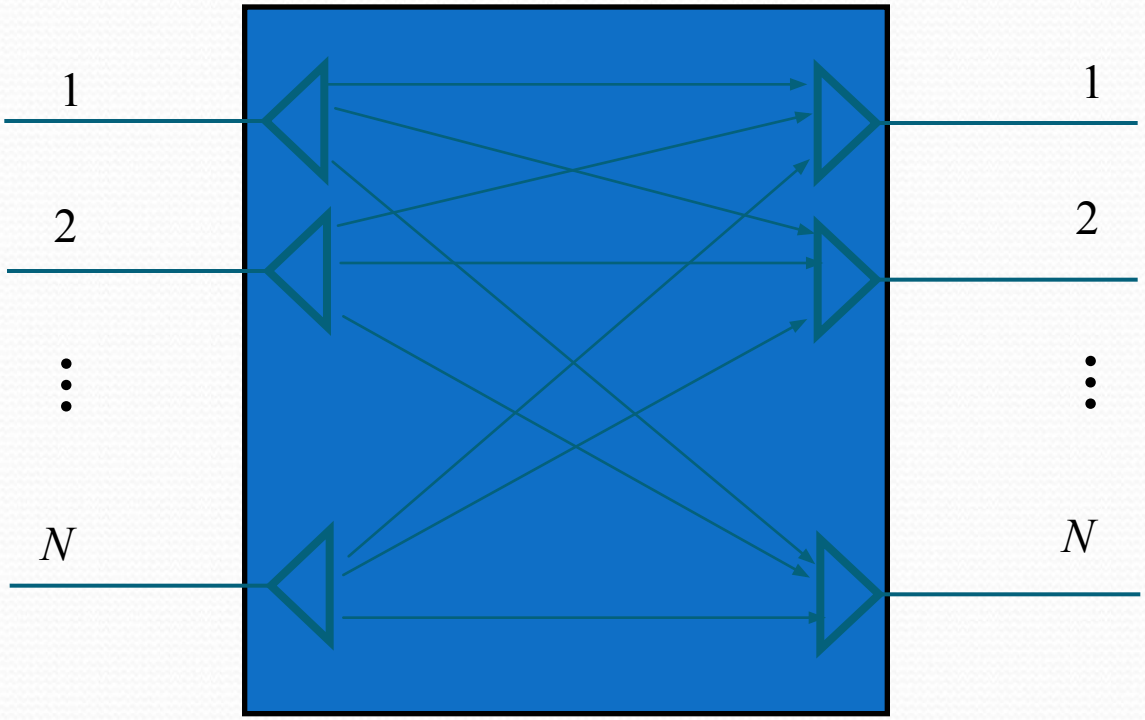
1. NIC gets frames from networks and de-encapsulate packets
2. Packets are transferred into memory using I/O bus
3. CPU performs required routing and protocol processing
4. Packets are transferred from memory to an appropriate NIC
5. The NIC forms new frame and sends out

Figure 7.11

Three basic resources and bottlenecks in switches

- Processing, memory and bus bandwidth
  - Processing implements protocols, hence processing capacity places a limit on maximum rate at which switch can operate
  - Memory stores packets, hence the amount of memory determines the rate at which packets are lost, placing another limit on switch load, moreover memory bandwidth also place limit on switch rate
  - I/O bus bandwidth places a limit on total rate at which information can be transferred between ports.

Input port demultiplexes incoming packet stream;
packets are routed to output port;
output port multiuplexes outgoing packet stream

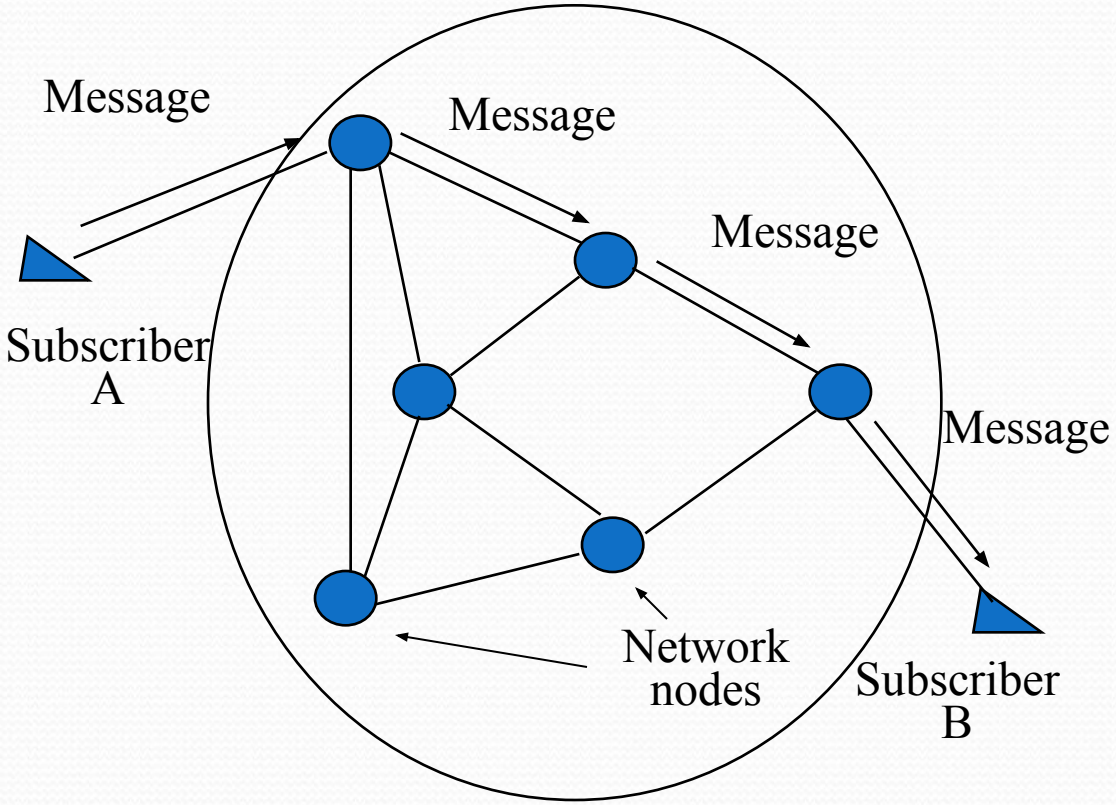


Switches/routers play a key role in controlling packet flows, thus efficiently using network bandwidth and optimizing performance.

Figure 7.12

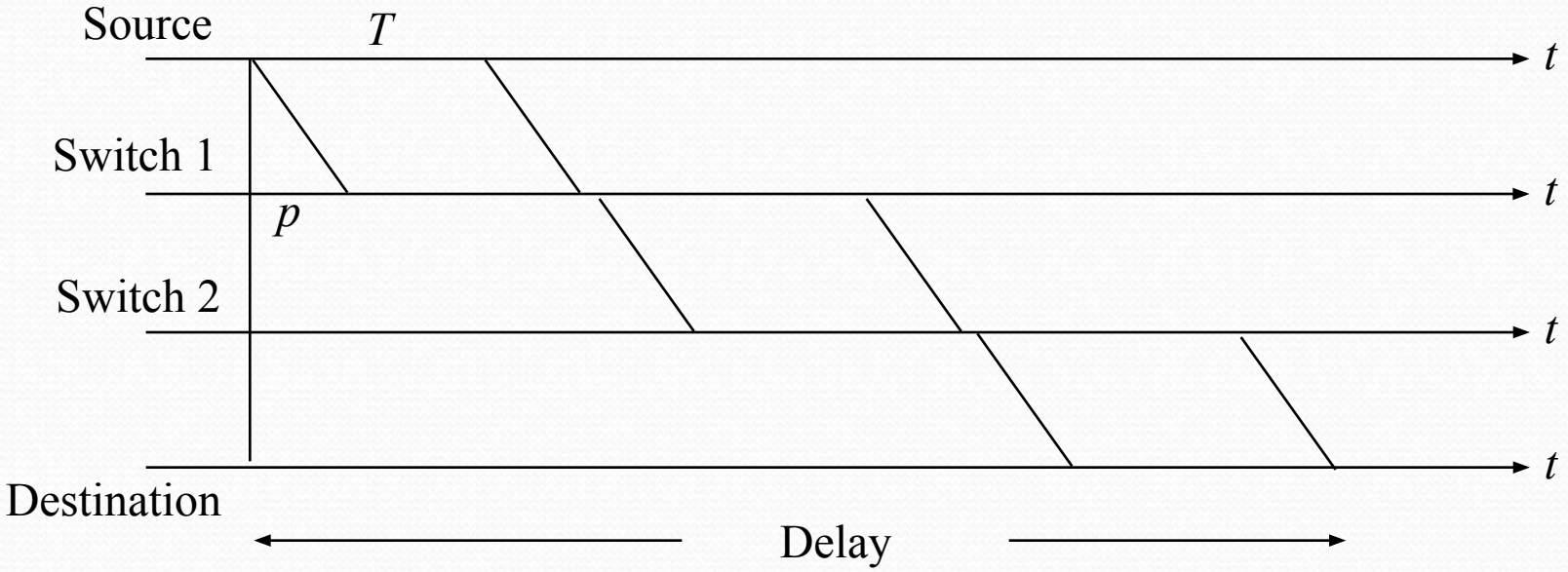
Connectionless packet switching——originated from *message switching*

- message has header with source & destination address
- CRC check bit are used to detect errors



- Each switch check error, if yes, ask retransmission, if not find next hop.
- Message enter into a QUEUE to wait for line free to transmit
- Increased utilization of line is at the expense of queuing delay
- Loss of message may occur because of insufficient buffer.
- End-to-end error recovery is needed

Delays in message switching



Minimum Delay = $3p + 3T$,

p: propagation delay

T: message transmission time

Figure 7.14

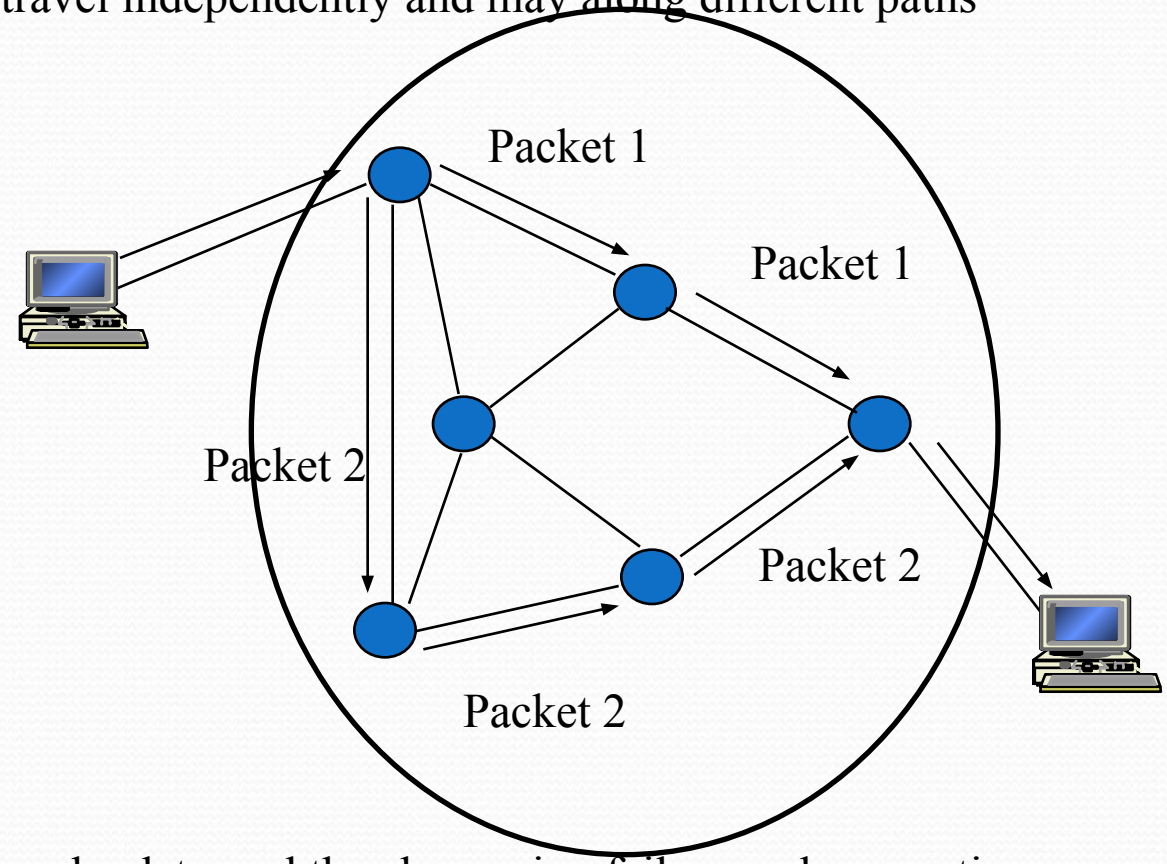
Operations: 1. Address information is included in header 2. CRC for error recovery

3. switches inspect destination address in header to determine next hop

4. Packets are put in QUEUE to wait for line becoming available

5. Sharing lines among multiple packets, high utilization is at the expense of queue delay

6. Packets travel independently and may along different paths



7. Route may be detoured,thus bypassing failure and congestion

8. Packets may arrive out of order, resequencing may be required

Datagram packet switching

Figure 7.15

Routing table in connectionless packet switching

Destination address	Next hop
0785	3245
1345	2343
1566	3784
2458	7612

Designing routing table is a key issue in packet-switching networks Which requires: knowledge of network topology and traffic levels. Moreover, size of table will become very large when network size increase.

Figure 7.16

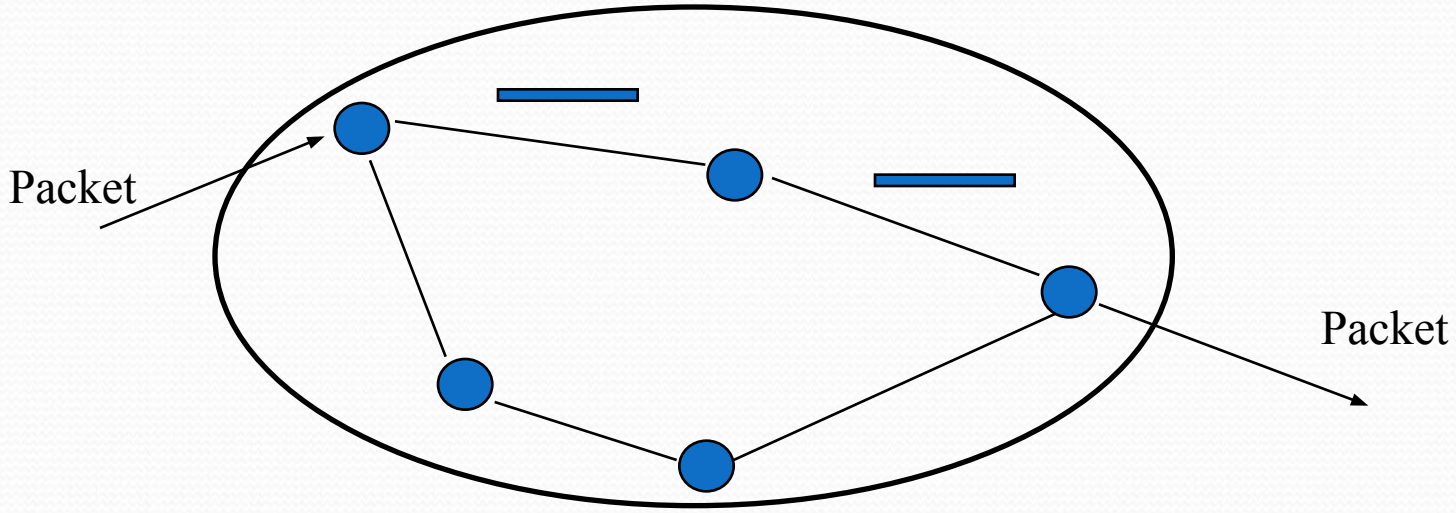
Example –IP internetworks

- Objective of IP is to provide connectionless transfer service across heterogeneous networks

Virtual-circuit packet switching

- Establishment of connection between source & destination prior to the transfer of packets
- Connect request is sent by source and connect confirm is replied by destination
- Signal exchanges is performed in virtual-circuit setup
- Admission control could be used to limit load on networks or specific links
- Routing is easier once connection was setup routing table

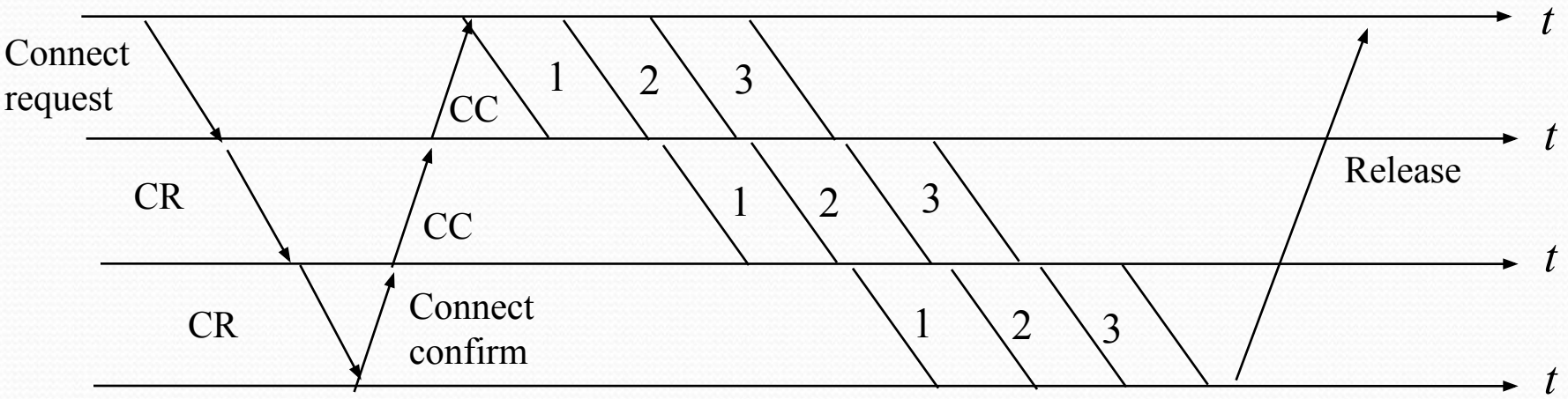
Virtual-circuit switching



Question: why called virtual-circuit?

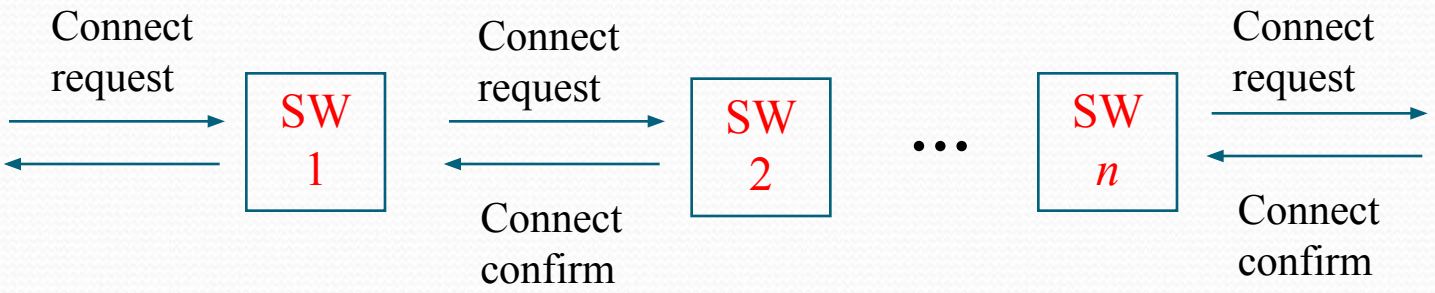
Because resources, e.g., switches, buffers and lines, are shared by packets from multiple connections, not dedicated to one specific connection.

Figure 7.17



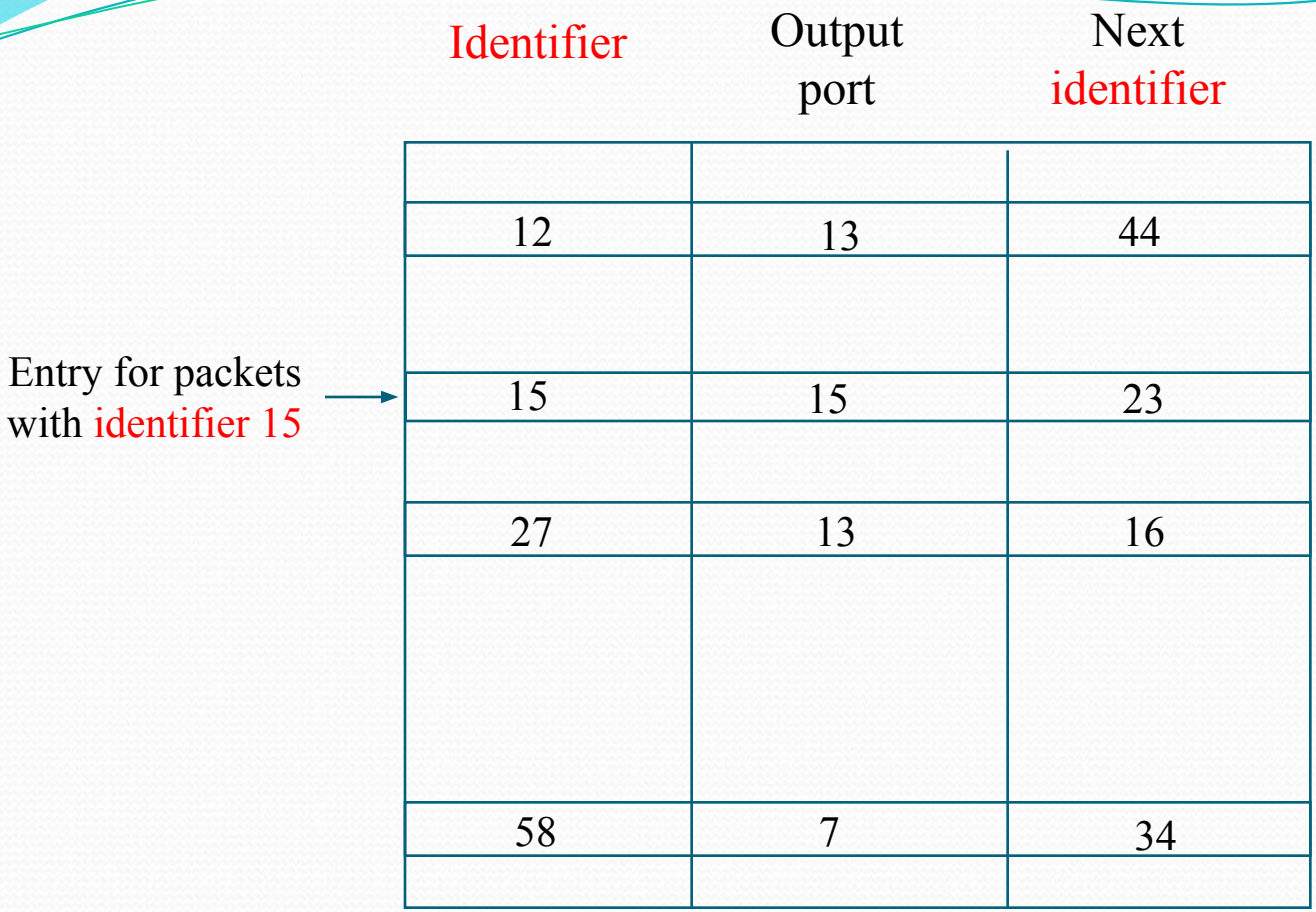
Beginning latency and delay of packets in virtual-circuit packet switching

Parameters such as buffer, bandwidth, delay requirements were set in every switch along the path during setup



Signaling message exchanges in virtual-circuit setup

Example of virtual-circuit routing table for an input port



Each connection is identified by VCI (virtual-circuit identifier).
VCI may be different along the path for the same connection: the input VCI in a switch is different from output VCI for the same connection, called local VCIs.
VCI is in the header of a packet, which is much smaller than IP address, as in IP protocol.
Table lookup will find the output port # and output VCI based on input VCI, which is faster.

Pro and con about virtual-circuit switching

- Pros:
  - Header is shorter, resources allocated during setup, admission and congestion are easier.
  - Minimum delay reduces further.
- Cons:
  - Every router needs to maintain state information about all connections
  - Once there is a failure, all affected connections must be set up again.

Network service can be Connection-oriented service / connectionless service

Connectionless service is simple with two basic interactions

(1) a request to network layer that it send a packet

(2) an indication from the network layer that a packet has arrived

It puts total responsibility of error control, sequencing and flow control on the end system transport layer

- It is also possible for a network layer to provide a choice of services to the user of network like:

- best-effort connectionless services
- Low delay connectionless services
- Connection oriented reliable stream services ,transfer of packets with guaranteed delay and bandwidth

- Revision
- Network layer essentials
- The Functions that need to be carried out at every node in the Network Layer are:-
- Routing
- Forwarding
- Priority & Scheduling

- Routing: mechanisms for determining the set of best paths for routing packets requires the collaboration of network elements.
- Forwarding: transfer of packets from inputs to outputs
- Priority & Scheduling: determining order of packet transmission in each Optional: congestion control, segmentation & reassembly, security

- Thank You