Lecture 5

Switching Techniques

Learning Objectives

- After studying this topic you should be able to describe the following switching techniques:
  - Circuit switching
  - Message switching
  - Packet switching

Introduction

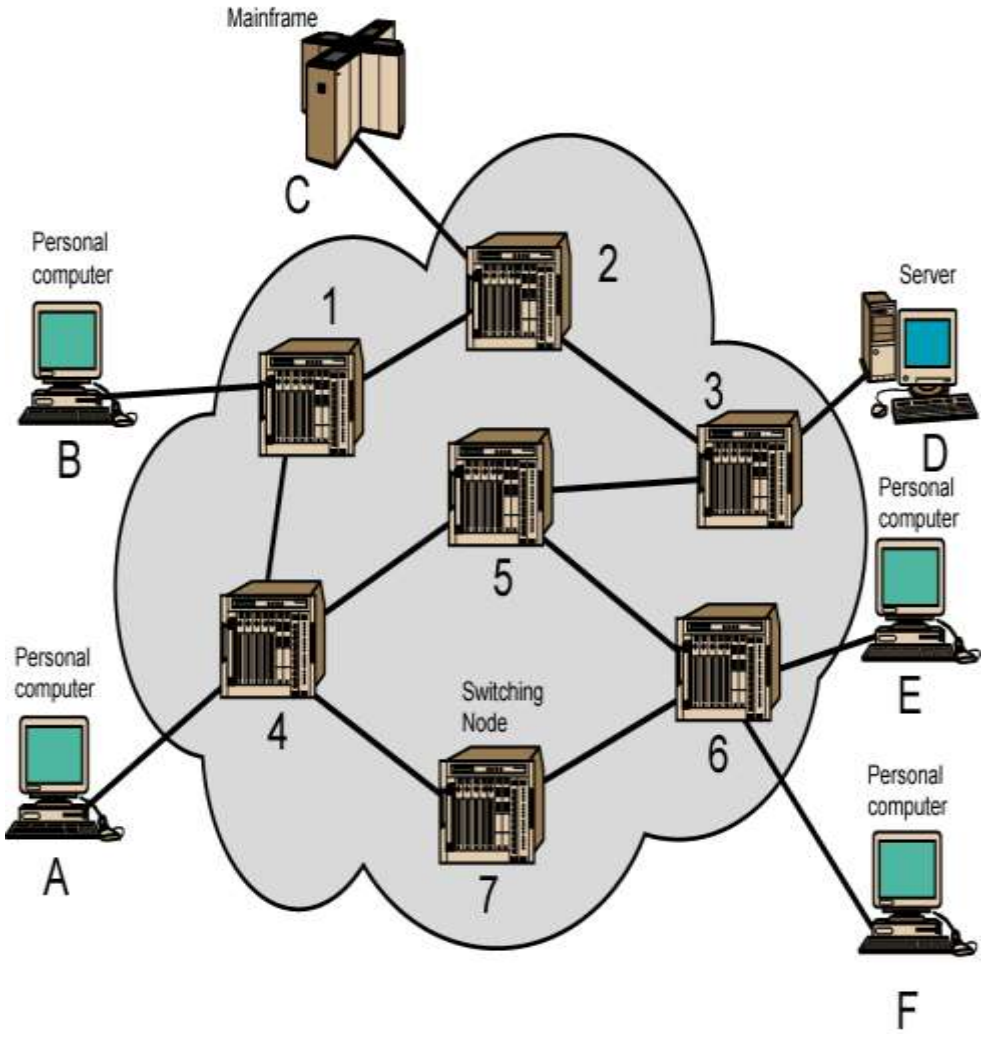
- In large networks where we have multiple devices, there is a problem of how to connect them to make one-to-one connection possible.
- In LANs this is achieved using one of three methods:
  - Direct point-to-point connection between each pair of devices (mesh)
  - a point-to-point connection between a central device and every other device (a star topology)
  - Connection to common bus in a multipoint configuration (bus)
    - However, none of these methods works in larger networks with large physical separation or consisting of a large number of computers

Introduction (cont'd)

- For transmission of data beyond a LAN, communication is typically achieved by transmitting data from source to destination via a network of intermediate switching nodes.
- This technique is called **switching**
  - **Switching** techniques are mechanisms for moving data from one network segment to another

Simple Switching Network

- In a *switched communication network, data entering the network from a* station are routed to the destination by being switched from node to node.
- Switching nodes do not concern with content of data.
  - Their purpose is to provide a switching facility that will move the data from node to node until they reach their destination.



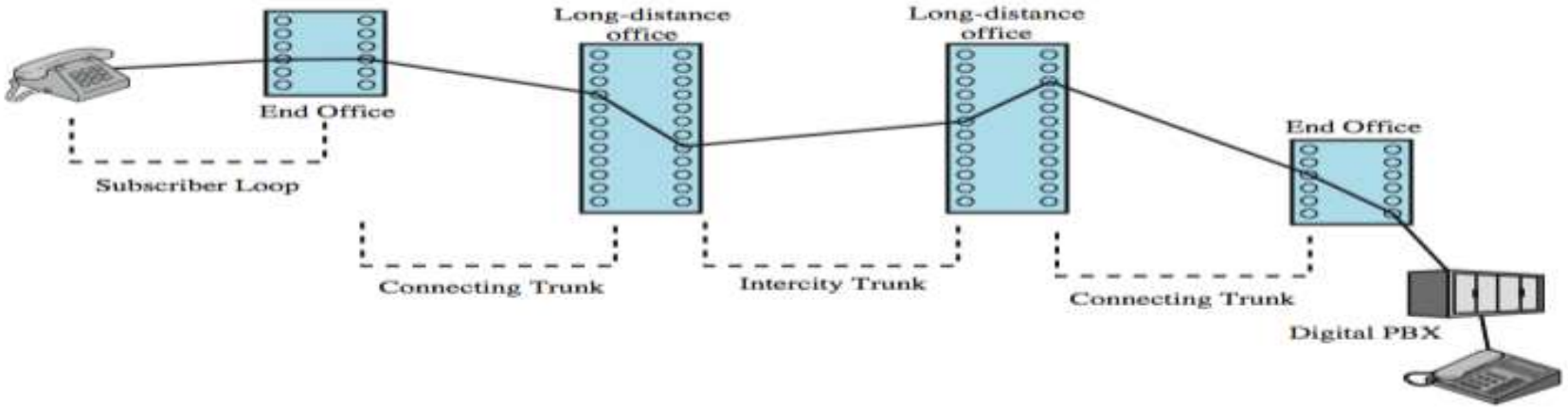
Switching Technologies

- There are three typical switching techniques available for digital traffic:
  - Circuit switching
  - Message switching
  - Packet switching

Circuit Switching

- Circuit switching:
  - There is a dedicated communication path between two stations (end-to-end)
  - The computer initiating the data transfer must ask for a connection to the destination.
  - Once the connection has been initiated and completed to the destination device, the destination device must acknowledge that it is ready and willing to carry on a transfer.
- Communication via circuit switching has three phases:
  - Circuit establishment (link by link)
    - A complete end-to-end path must exist before communication can take place.
  - Data transfer
    - Data can now be transmitted through the network between these two stations.
  - Circuit disconnect
    - Deallocate the dedicated resources

Public Circuit Switched Network



•The best-known example of a circuit-switching network is the public telephone network (see the figure above)

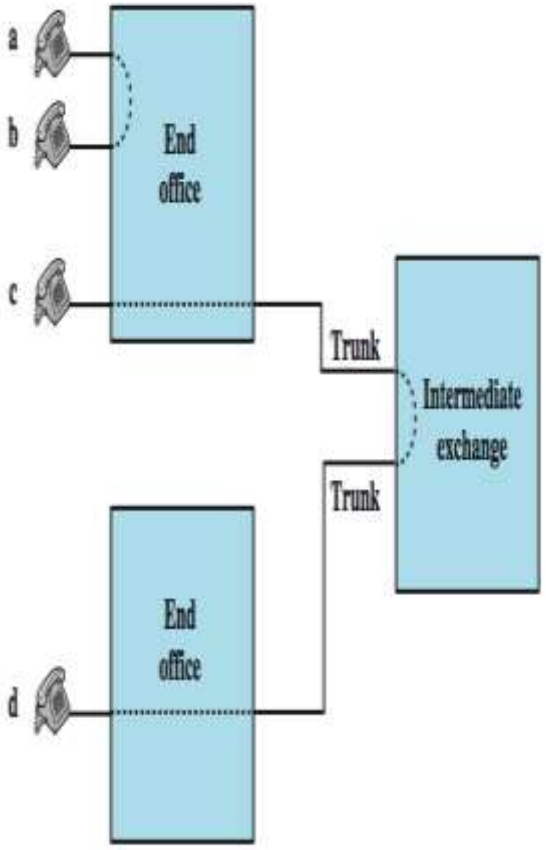
•This is actually a collection of national networks interconnected to form the international service. A public telecommunications network can be described using four generic architectural components:

- **Subscribers:** The devices that attach to the network, typically telephones, but the percentage of data traffic increases year by year.
- **Subscriber line:** The link between the subscriber and the network, also referred to as the *subscriber loop* or *local loop*, mostly using twisted-pair wire.
- **Exchanges:** The switching centers in the network. A switching center that directly supports subscribers is known as an end office.
- **Trunks:** The branches between exchanges. Trunks carry multiple voice-frequency circuits using either FDM or synchronous TDM

Public Circuit Switched Network (cont'd)

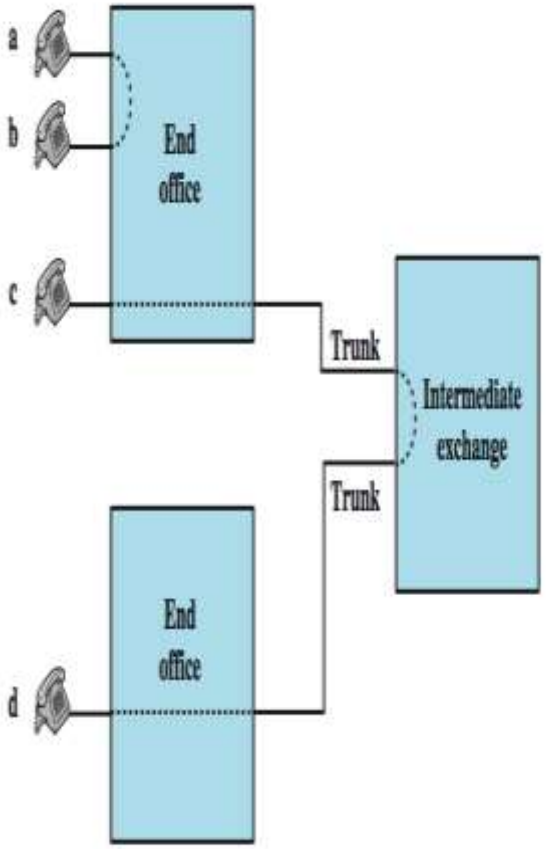
Circuit Establishment

- Subscribers connect directly to an end office, which switches traffic between subscribers and between a subscriber and other exchanges.
- The other exchanges are responsible for routing and switching traffic between end offices(see the figure on the right for this distinction)
- To connect two subscribers attached to the same end office, a circuit is set up between them
- If two subscribers connect to different end offices, a circuit between them consists of a chain of circuits through one or more intermediate offices



Public Circuit Switched Network (cont'd)

- In the figure, a connection is established between lines a and b by simply setting up the connection through the end office.
- The connection between c and d is more complex
- In c's end office, a connection is established between line c and one channel on a TDM trunk to the intermediate switch. In the intermediate switch, that channel is connected to a channel on a TDM trunk to d's end office
- In that end office, the channel is connected to line d.



A single Circuit-Switching Node

- The technology of circuit switching is best approached by examining the operation of a single circuit-switching node.
- A network built around a single circuit-switching node consists of a collection of stations attached to a central switching unit.
- The central switch establishes a dedicated path between any two devices that wish to communicate.
- Figure on the right depicts the major elements of such a one-node network.
- The dotted lines inside the switch symbolize the connections that are currently active.
- The heart of a modern system is a **digital switch**.
- The function of the digital switch is to provide a transparent signal path between any pair of attached devices.
- The path is transparent in that it appears to the attached pair of devices that there is a direct connection between them.
- Typically, the connection must allow full-duplex transmission.

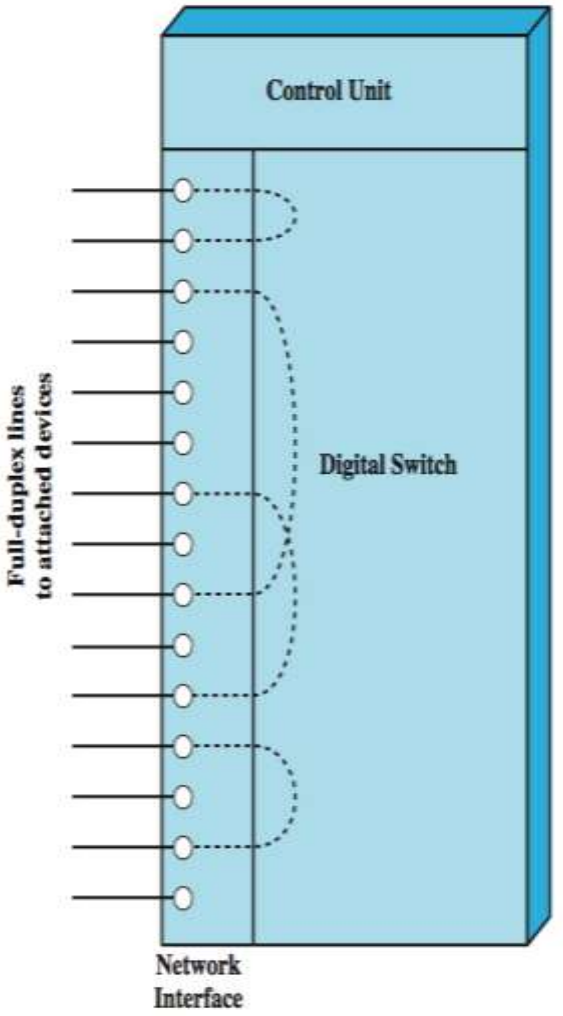


Fig: Elements of a Circuit-Switch Node

A single Circuit-Switching Node (cont'd)

- The **network interface** element represents the functions and hardware needed to connect digital devices, such as data processing devices and digital telephones, to the network.
- Analog telephones can also be attached if the network interface contains the logic for converting to digital signals. Trunks to other digital switches carry TDM signals and provide the links for constructing multiple-node networks.
- The **control unit** performs three general tasks.
  - First, it establishes connections. This is generally done on demand, that is, at the request of an attached device.
  - Second, the control unit must maintain the connection. Because the digital switch uses time division principles, this may require ongoing manipulation of the switching elements.
  - Third, the control unit must tear down the connection, either in response to a request from one of the parties or for its own reasons.

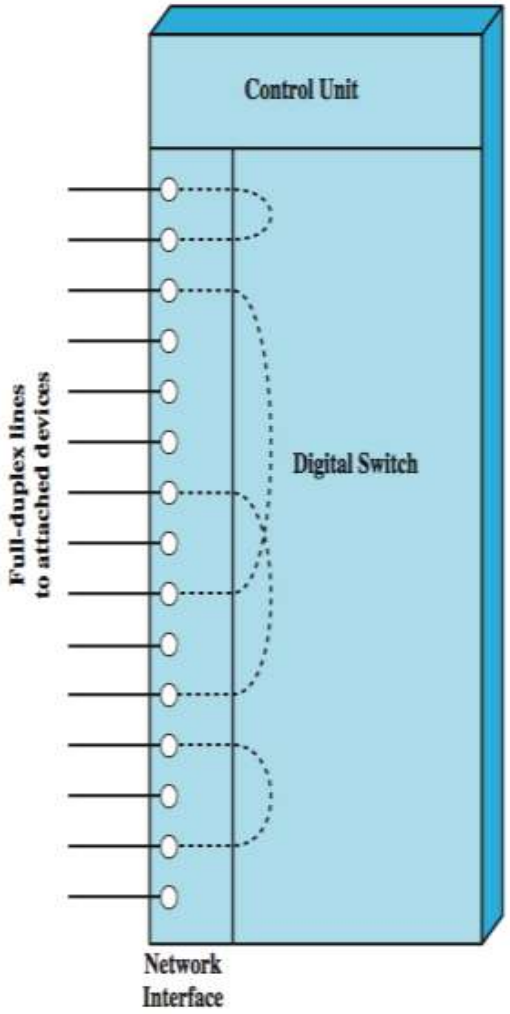


Fig: Elements of a Circuit-Switch Node

Circuit Switching Properties

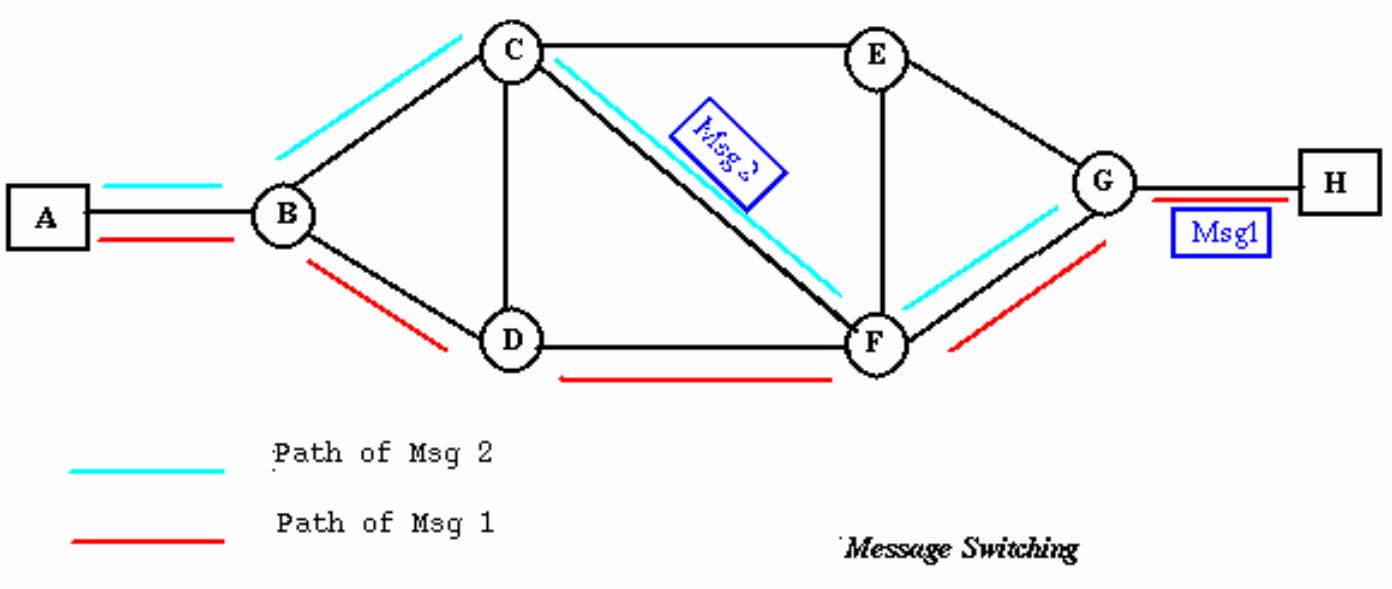
- Inefficiency
  - Channel capacity is dedicated for the whole duration of a connection
  - If no data, capacity is wasted
- Delay
  - Long initial delay: circuit establishment takes time
  - Low data delay: after the circuit establishment, information is transmitted at a fixed data rate with no delay other than the propagation delay.
  - The delay at each node is negligible.
- Cost
  - More expensive than any other switching techniques, because a dedicated path is required for each connection.
- Developed for voice traffic (public telephone network) but can also applied to data traffic.
  - For voice connections, the resulting circuit will enjoy a high percentage of utilization because most of the time one party or the other is talking.

Message Switching

- With message switching there is no need to establish a dedicated path between two stations.
- When a station sends a message, the destination address is appended to the message.
- The message is then transmitted through the network, in its entirety, from node to node.
- Each node receives the entire message, stores it in its entirety on disk, and then transmits the message to the next node.
- This type of network is called a store-and-forward network.

Message Switching (cont'd)

- A message-switching node is typically a general-purpose computer and needs sufficient secondary-storage capacity to store the incoming messages, which could be long.
- A time delay is introduced using this type of scheme due to store- and-forward time, plus the time required to find the next node in the transmission path.
- Examples include e-mail, telegraphy, group applications such as workflow, calendaring and groupware.



Message Switching (cont'd)

- Advantages
  - Channel efficiency can be greater compared to circuit-switched systems, because more devices are sharing the channel.
  - Traffic congestion can be reduced, because messages may be temporarily stored in route.
  - Message priorities can be established due to store-and-forward technique to manage network traffic.
  - Message broadcasting can be achieved with the use of broadcast address appended in the message.

Message Switching (cont'd)

- Disadvantages
  - Message switching is not suitable for real-time applications, including data communication, video and audio
  - Store-and-forward devices are expensive, because they must have large disks to hold potentially long messages.

Packet Switching

- Problem of circuit switching
  - Designed for voice service
  - Resources dedicated to a particular call
  - For data transmission, much of the time the connection is idle (say, web browsing)
  - Data rate is fixed
    - Both ends must operate at the same rate during the entire period of connection
- Packet switching is designed to address these problems.

Basic Operation

- Data are transmitted in short packets
  - Typically at the order of 1000 bytes
  - Longer messages are split into series of packets
  - Each packet contains a portion of user data plus some control info
- Control info contains at least
  - Routing (addressing) info, so as to be routed to the intended destination
  - Recall the content of an IP header!
- **Store and forward**
  - On each switching node, packets are received, stored briefly (buffered) and passed on to the next node.

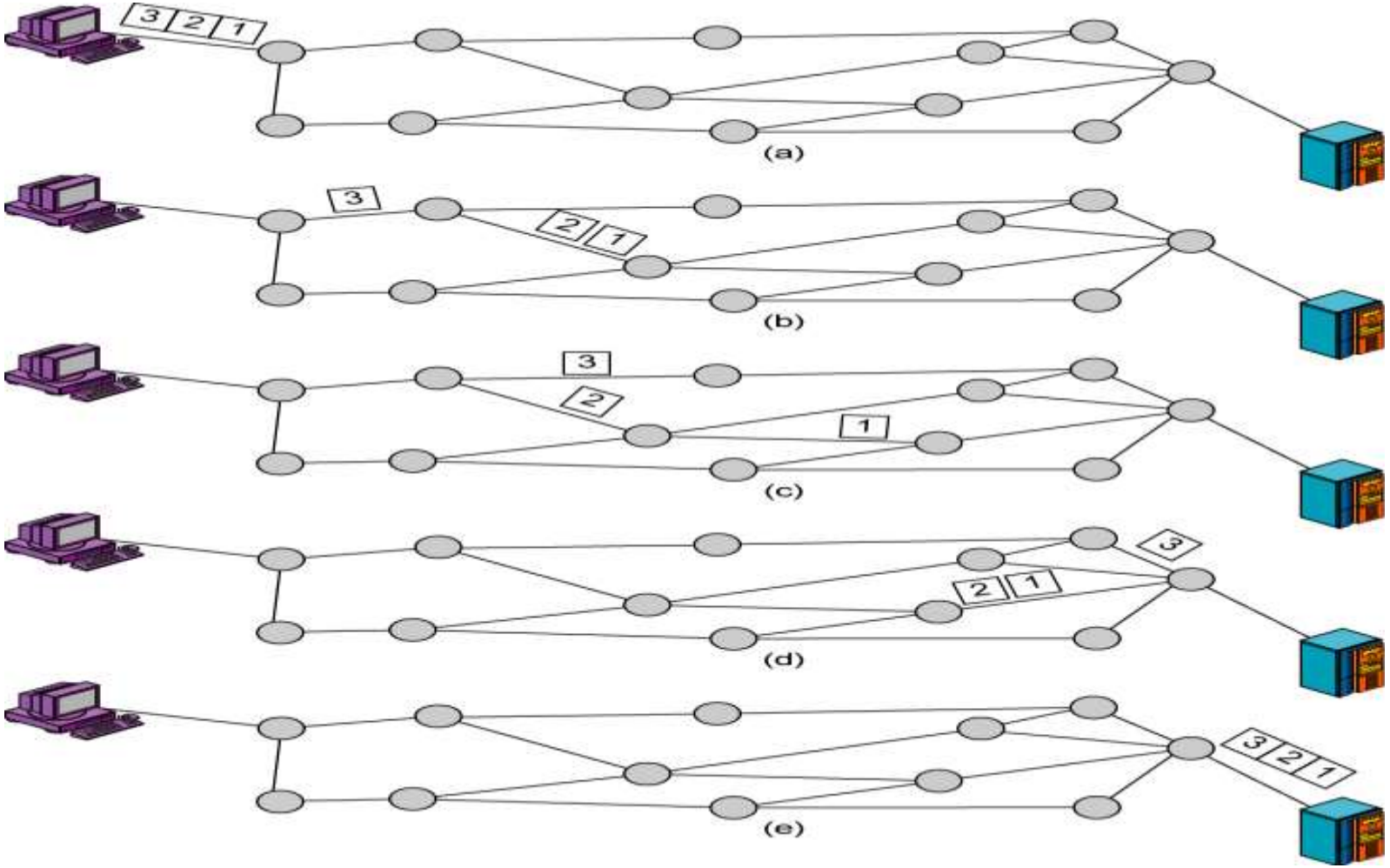
Packet Switching Technique

- A station breaks long message into packets
- Packets are sent out to the network sequentially, one at a time
- How will the network handle this stream of packets as it attempts to route them through the network and deliver them to the intended destination?
  - Two approaches
    - **Datagram** approach
    - **Virtual circuit** approach

Datagram

- Each packet is treated independently, with no reference to packets that have gone before.
  - Each node chooses the next node on a packet's path.
- Packets can take any possible route.
- Packets may arrive at the receiver out of order.
- Packets may go missing.
- It is up to the receiver to re-order packets and recover from missing packets.
- Example: Internet

Datagram



Virtual Circuit

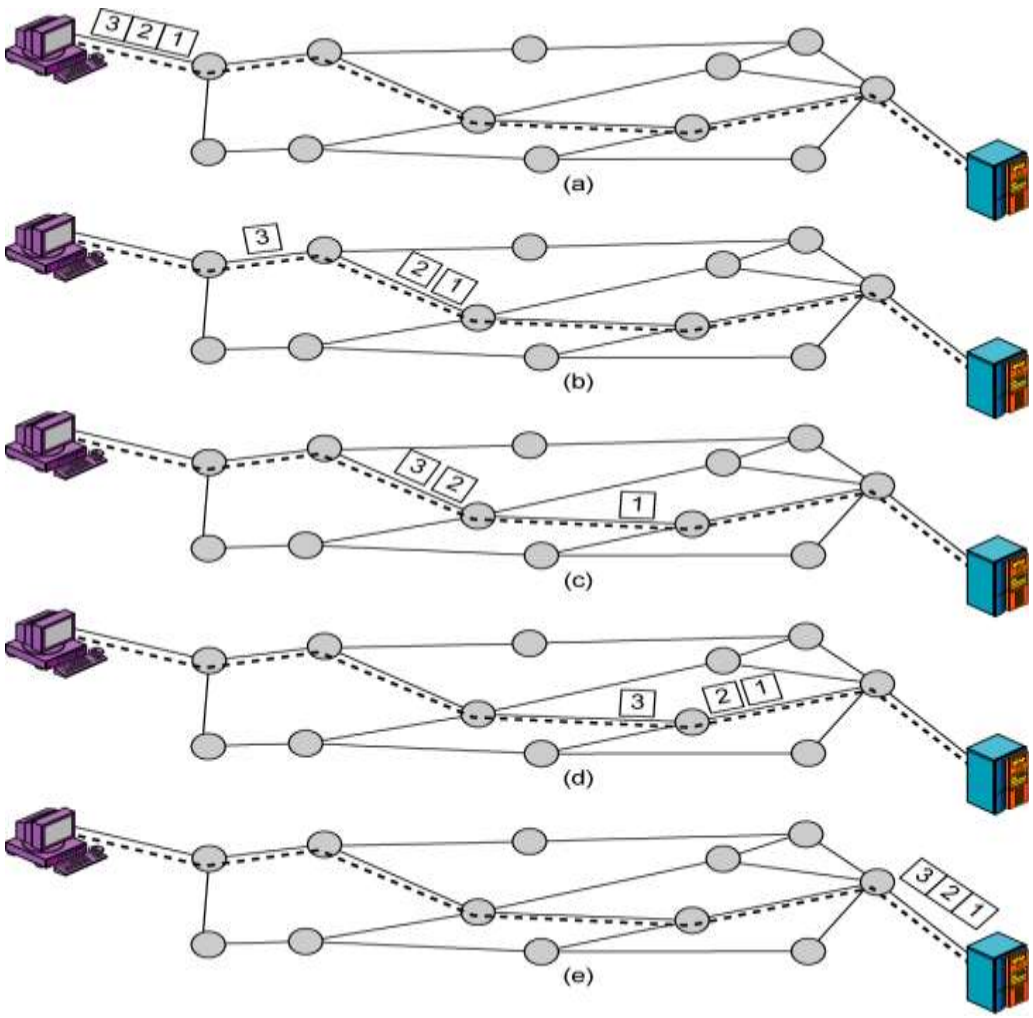
- In virtual circuit, a preplanned route is established before any packets are sent, then all packets follow the same route.
- Similar to circuit switching, but the circuit is not dedicated
- Each packet contains a **virtual circuit identifier** instead of destination address, and each node on the preestablished route knows where to forward such packets.
  - The node need not make a routing decision for each packet.
- Example: X.25, Frame Relay, ATM

Virtual Circuit

A route between stations is set up prior to data transfer.

All the data packets then follow the same route.

But there is no dedicated resources reserved for the virtual circuit! Packets need to be stored-and-forwarded.



Virtual Circuits v Datagram

- Virtual circuits
  - Network can provide sequencing (packets arrive at the same order) and error control (retransmission between two nodes).
  - Packets are forwarded more quickly
    - Based on the virtual circuit identifier
    - No routing decisions to make
  - Less reliable
    - If a node fails, all virtual circuits that pass through that node fail.
- Datagram
  - No call setup phase
    - Good for bursty data, such as Web applications
  - More flexible
    - If a node fails, packets may find an alternate route
    - Routing can be used to avoid congested parts of the network

Advantages of Packet Switching

- Line efficiency
  - Single node-to-node link can be dynamically shared by many packets over time
  - Packets are queued up and transmitted as fast as possible
- Data rate conversion
  - Each station connects to the local node at its own speed
- In circuit-switching, a connection could be blocked if there lacks free resources. On a packet-switching network, even with heavy traffic, packets are still accepted, but delivery delay increases.
- Priorities can be used
  - On each node, packets with higher priority can be forwarded first.
  - They will experience less delay than lower-priority packets.

Comparison of communication switching techniques

Circuit Switching	Datagram Packet Switching	Virtual Circuit Packet Switching
Dedicated transmission path	No dedicated path	No dedicated path
Continuous transmission of data	Transmission of packets	Transmission of packets
Fast enough for interactive	Fast enough for interactive	Fast enough for interactive
Messages are not stored	Packets may be stored until delivered	Packets stored until delivered
The path is established for entire conversation	Route established for each packet	Route established for entire conversation
Call setup delay; negligible transmission delay	Packet transmission delay	Call setup delay; packet transmission delay
Busy signal if called party busy	Sender may be notified if packet not delivered	Sender notified of connection denial
Overload may block call setup; no delay for established calls	Overload increases packet delay	Overload may block call setup; increases packet delay
Electromechanical or computerized switching nodes	Small switching nodes	Small switching nodes
User responsible for message loss protection	Network may be responsible for individual packets	Network may be responsible for packet sequences
Usually no speed or code conversion	Speed and code conversion	Speed and code conversion
Fixed bandwidth	Dynamic use of bandwidth	Dynamic use of bandwidth
No overhead bits after call setup	Overhead bits in each packet	Overhead bits in each packet

End