Data Communications and Networking

Chapter 10
Circuit Switching and Packet Switching

References:
Book Chapter 10.1 , 10.2, 10.5
Data and Computer Communications, 8th edition
By William Stallings

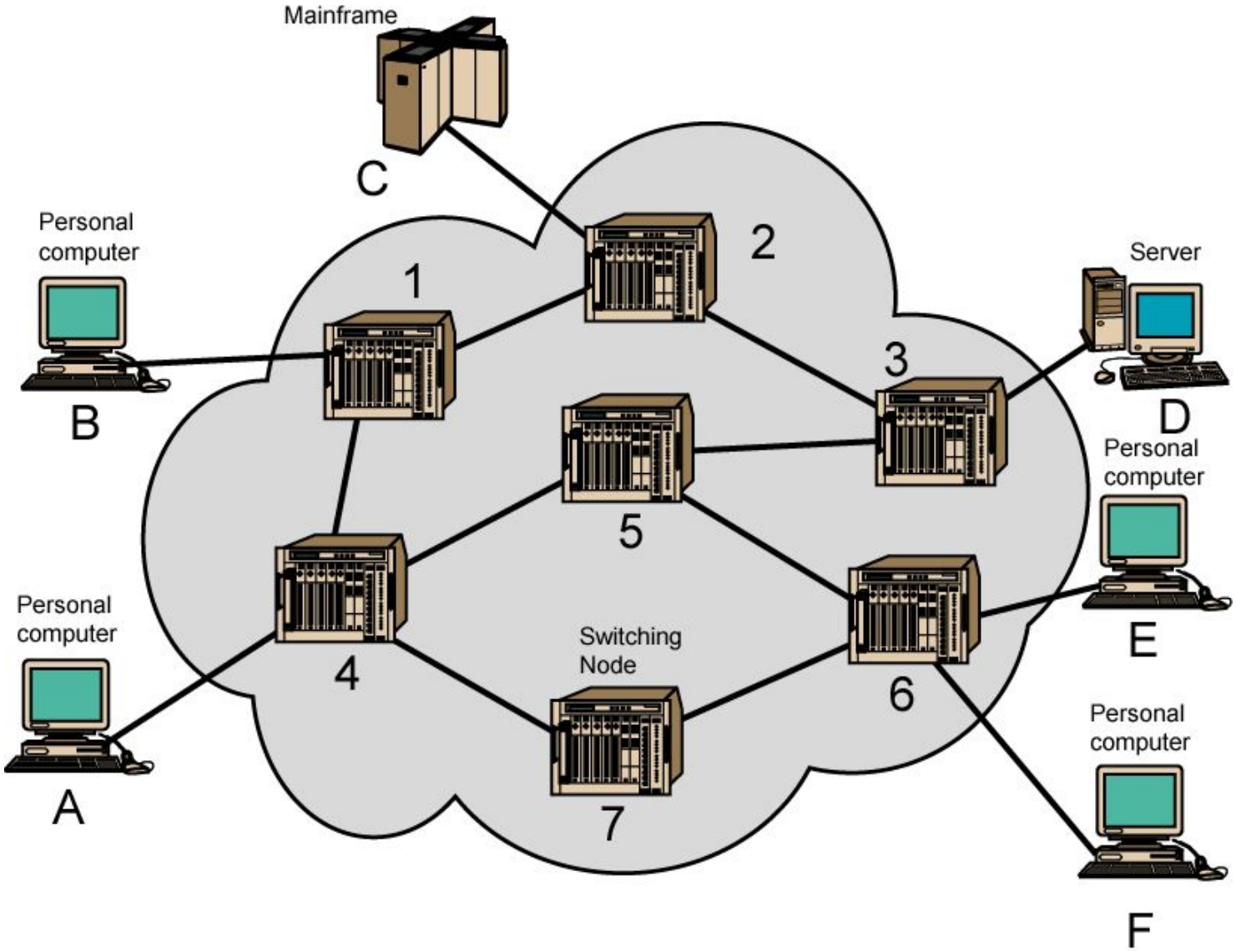
Overview

- Networks are used to interconnect many devices.
- We have checked with Local Area Networks.
- Now, wide area networks
  - Since the invention of the telephone, **circuit switching** has been the dominant technology for voice communications.
  - Since 1970, **packet switching** has evolved substantially for digital data communications. It was designed to provide a more efficient facility than circuit switching for bursty data traffic.
    - Two types of packet switching:
      - Datagram (such as today's Internet)
      - Virtual circuit (such as Frame Relay, ATM)

Switched Communications Networks

- Long distance transmission between stations (called "end devices") is typically done over a network of **switching nodes**.
- 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 (the end device).
- A collection of nodes and connections forms a communications network.
- In a switched communications network, data entering the network from a station are **routed** to the destination by being switched from node to node.

Simple Switching Network



Switching Nodes

- Nodes may connect to other nodes, or to some stations.
- Network is usually partially connected
  - However, some redundant connections are desirable for reliability
- Two different switching technologies
  - Circuit switching
  - Packet switching

Circuit Switching

- Circuit switching:
  - There is a dedicated communication path between two stations (end-to-end)
  - The path is a connected sequence of links between network nodes. On each physical link, a logical channel is dedicated to the connection.
- Communication via circuit switching has three phases:
  - Circuit establishment (link by link)
    - Routing & resource allocation (FDM or TDM)
  - Data transfer
  - Circuit disconnect
    - Deallocate the dedicated resources
- The switches must know how to find the route to the destination and how to allocate bandwidth (channel) to establish a connection.

Advantages and Disadvantages of Circuit Switching

Advantages

- It is suitable for long continuous transmission, since a continuous transmission route is established, that remains throughout the conversation.
- The dedicated path ensures a steady data rate of communication.
- No intermediate delays are found once the circuit is established. So, they are suitable for real time communication of both voice and data transmission.

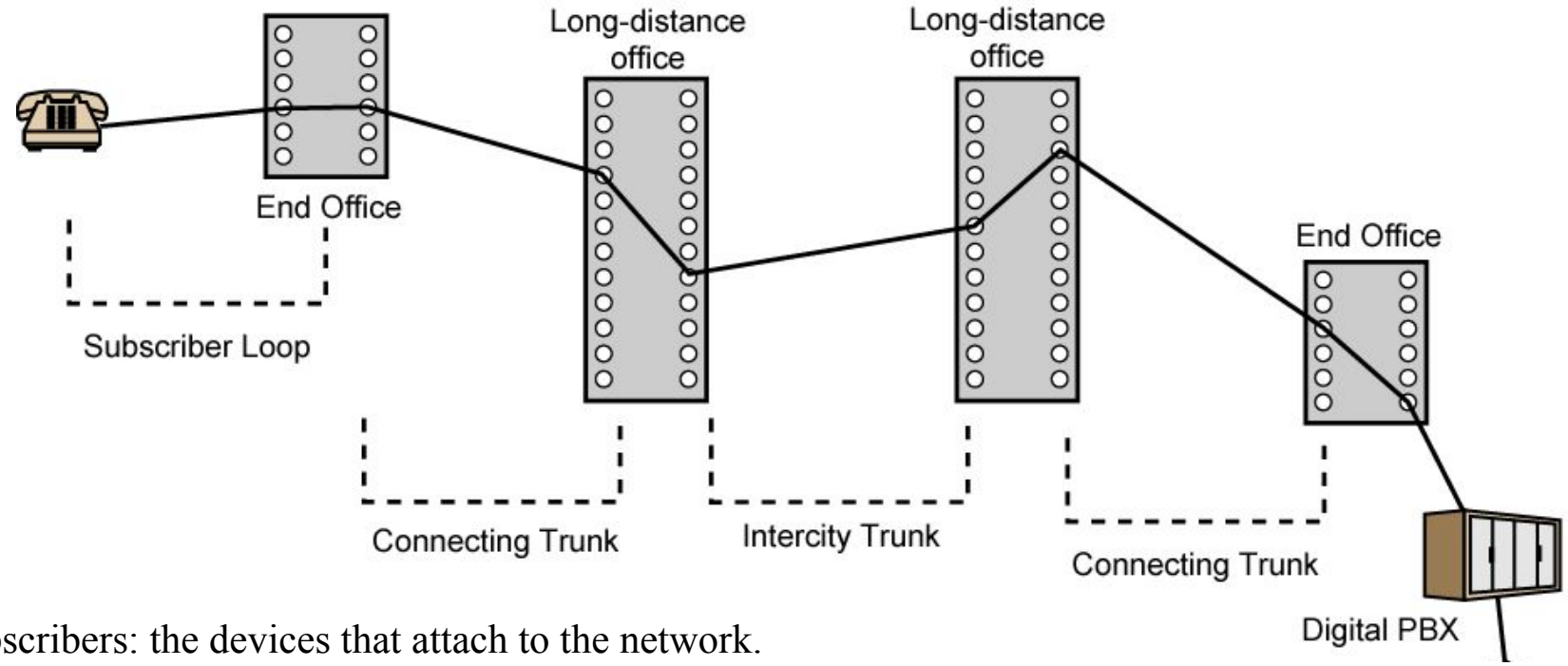
Disadvantages

- Circuit switching establishes a dedicated connection between the end parties. This dedicated connection cannot be used for transmitting any other data, even if the data load is very low.
- Bandwidth requirement is high even in cases of low data volume.
- There is underutilization of system resources. Once resources are allocated to a particular connection, they cannot be used for other connections.
- Time required to establish connection may be high.

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.
- 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.
  - But how about data connections?

Public Circuit Switched Network



Subscribers: the devices that attach to the network.

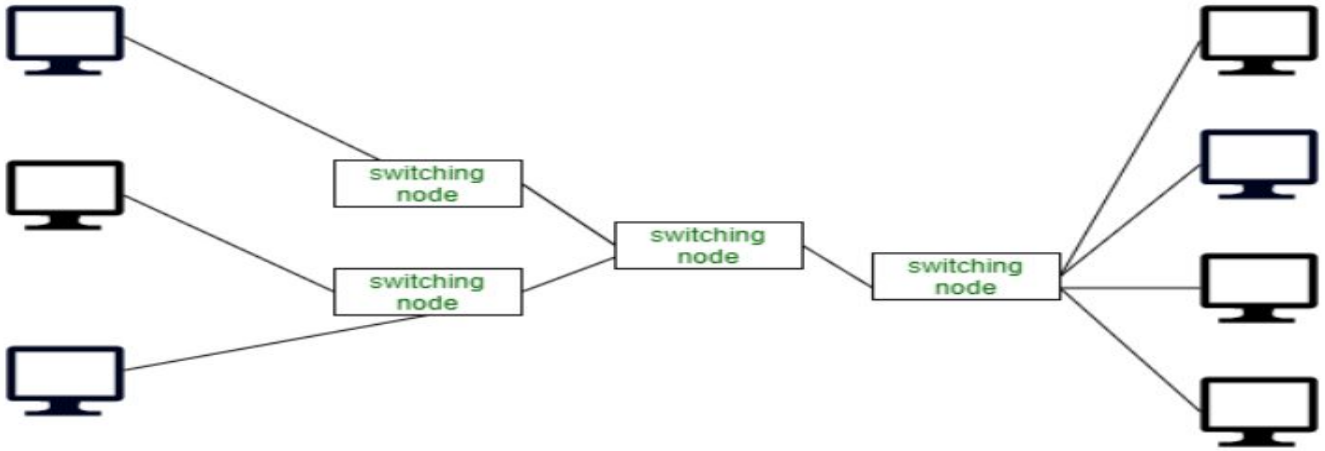
Subscriber loop: the link between the subscriber and the network.

Exchanges: the switching centers in the network.

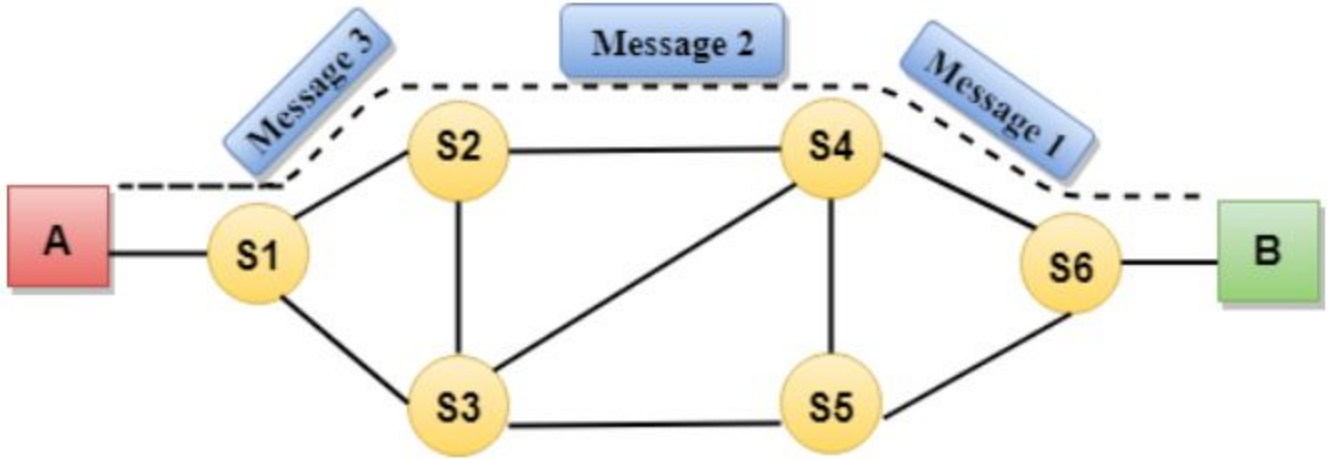
End office: the switching center that directly supports subscribers.

Trunks: the branches between exchanges. They carry multiple voice-frequency circuits using either FDM or synchronous TDM.

Examples



Circuit switching



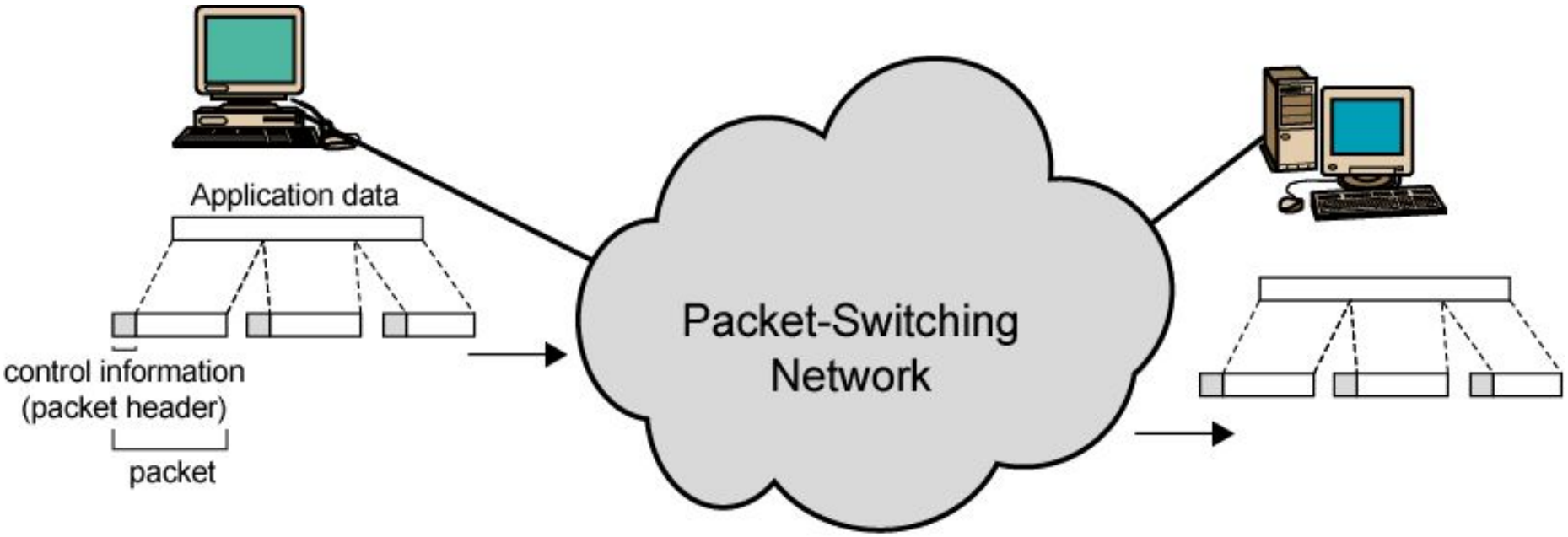
Packet Switching Principles

- 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.

Use of Packets



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, by 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.

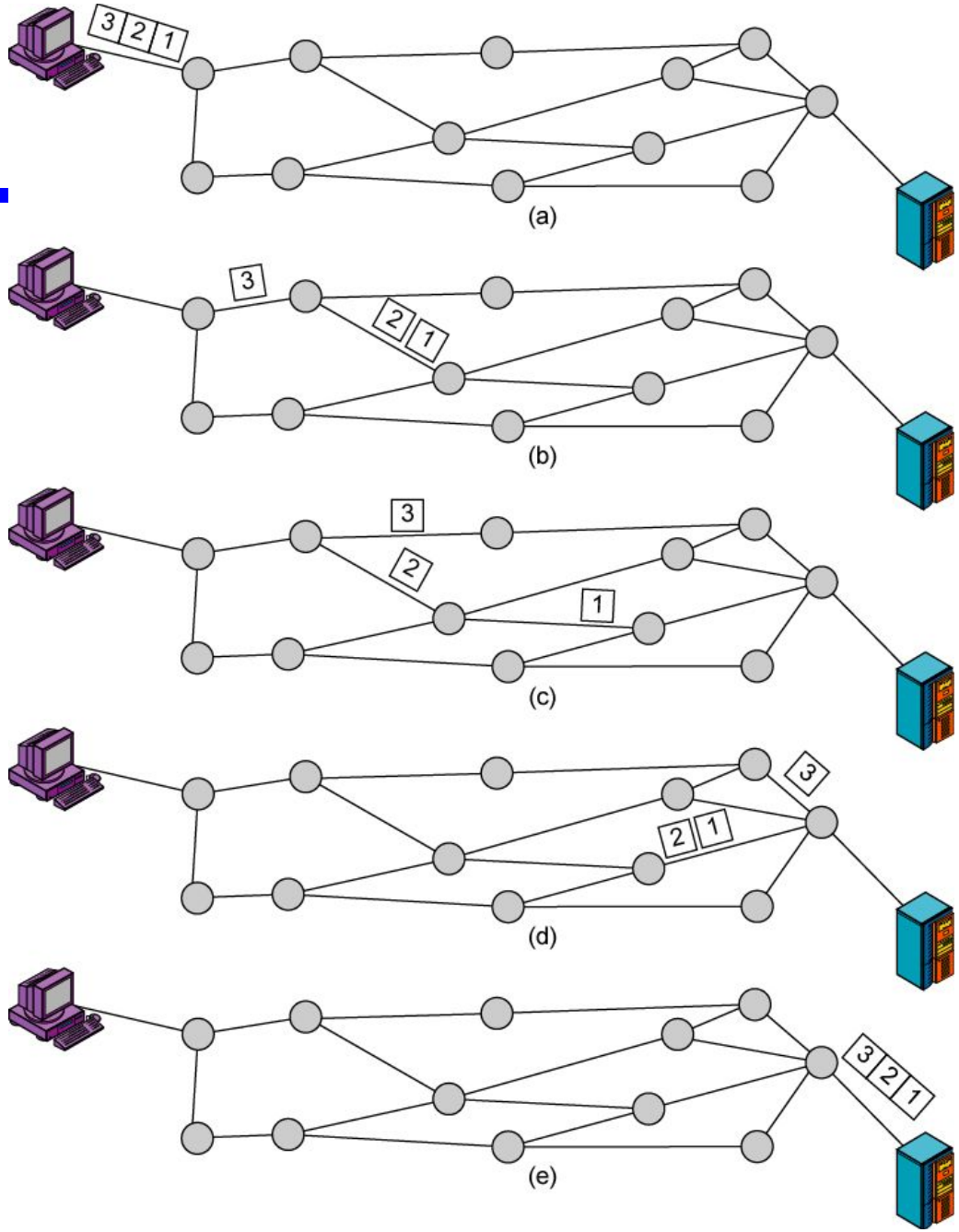
Packet Switching Technique

- 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

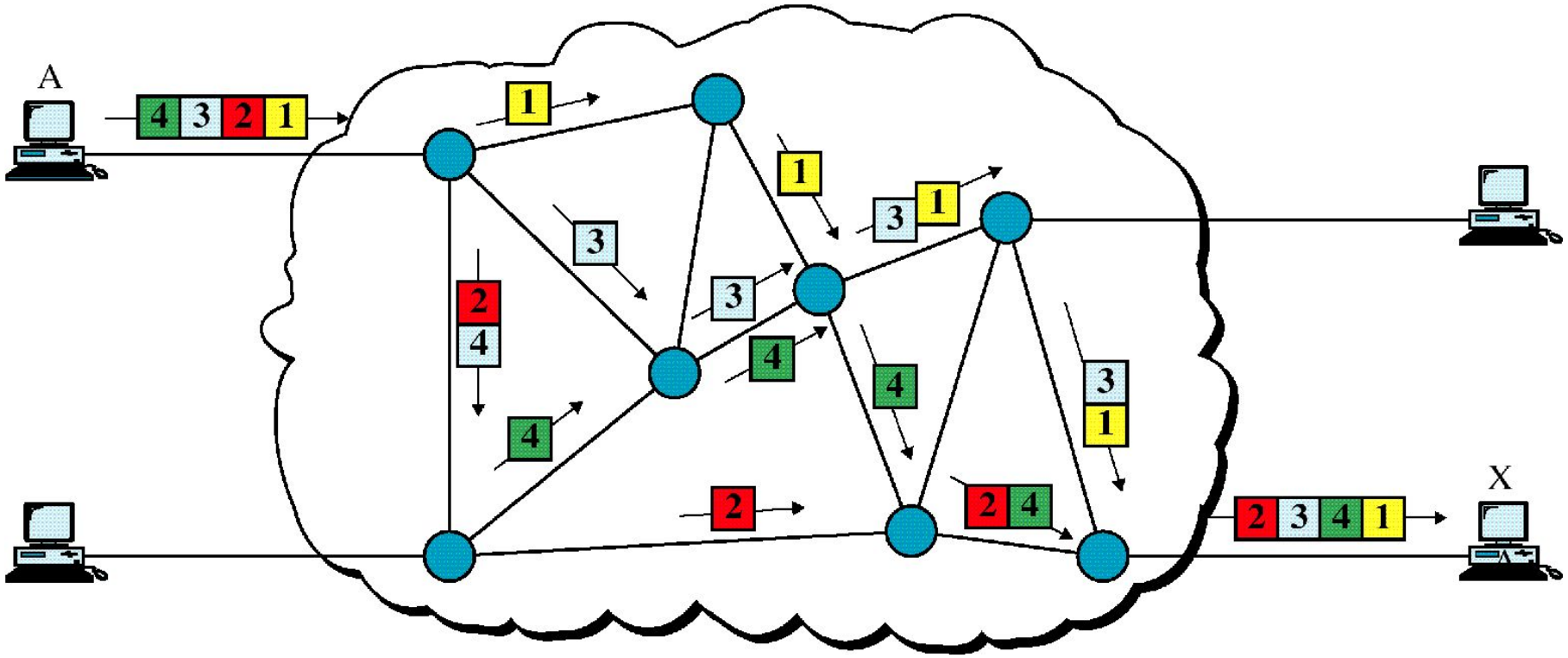
Datagram

- 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

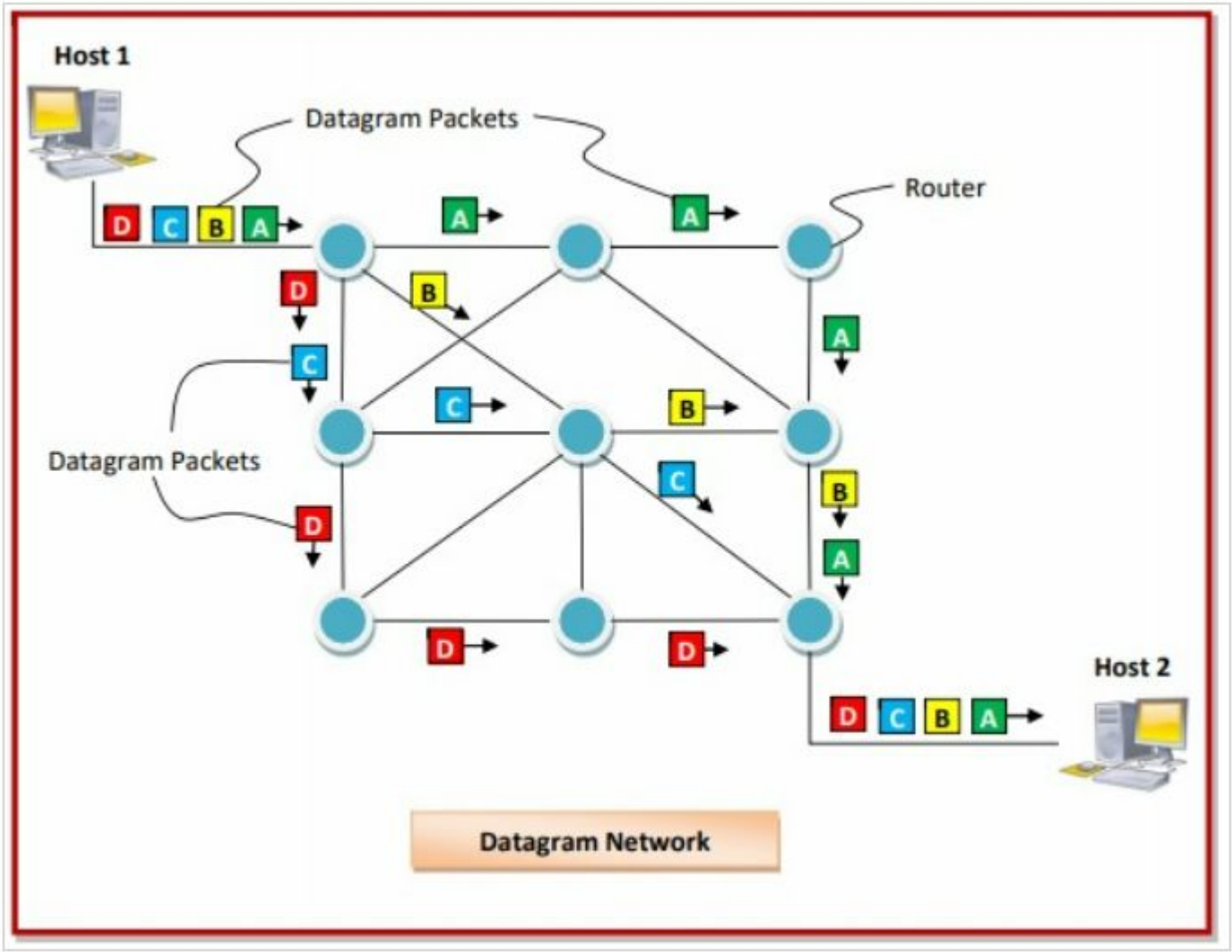
Datagram



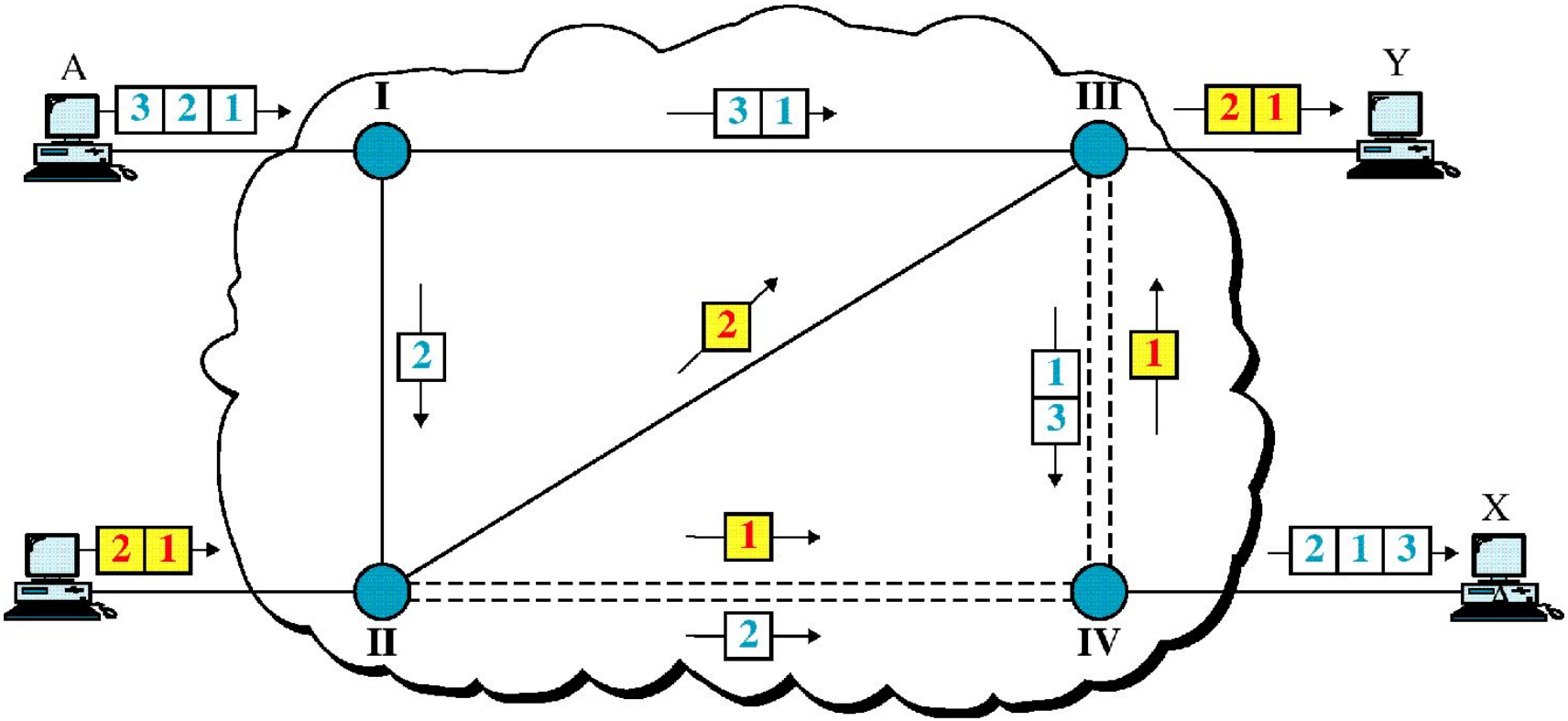
Datagram Approach



Datagram Approach



Datagram Approach, Multiple Channels



Virtual Circuit

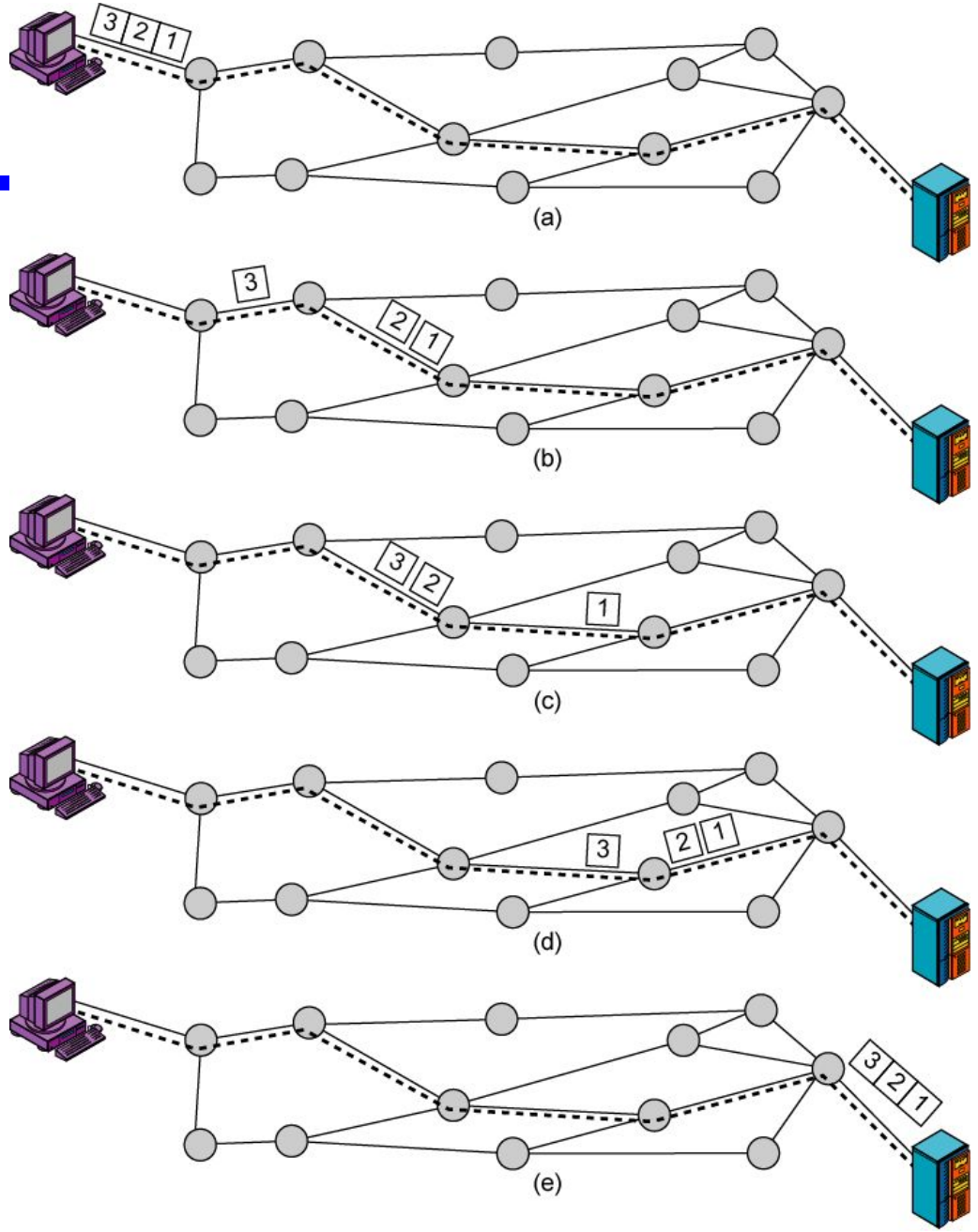
- In virtual circuit, a preplanned route is established before any packets are sent, then all packets follow the same route.
- Each packet contains a **virtual circuit identifier** instead of destination address, and each node on the preestablished route knows where to forward such packets.
  - The node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

Virtual Circuit

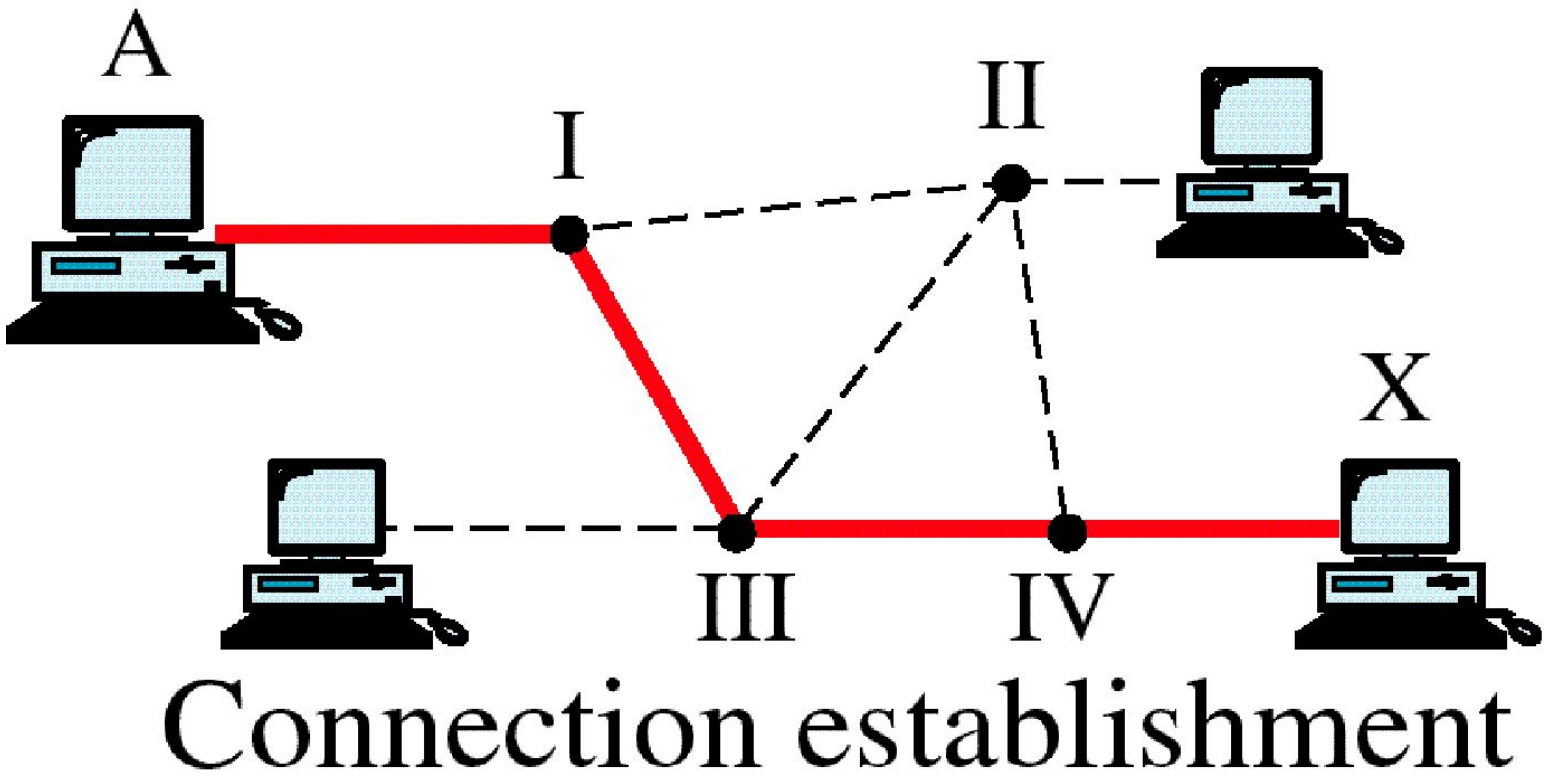
A route between stations is set up prior to data transfer.

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.

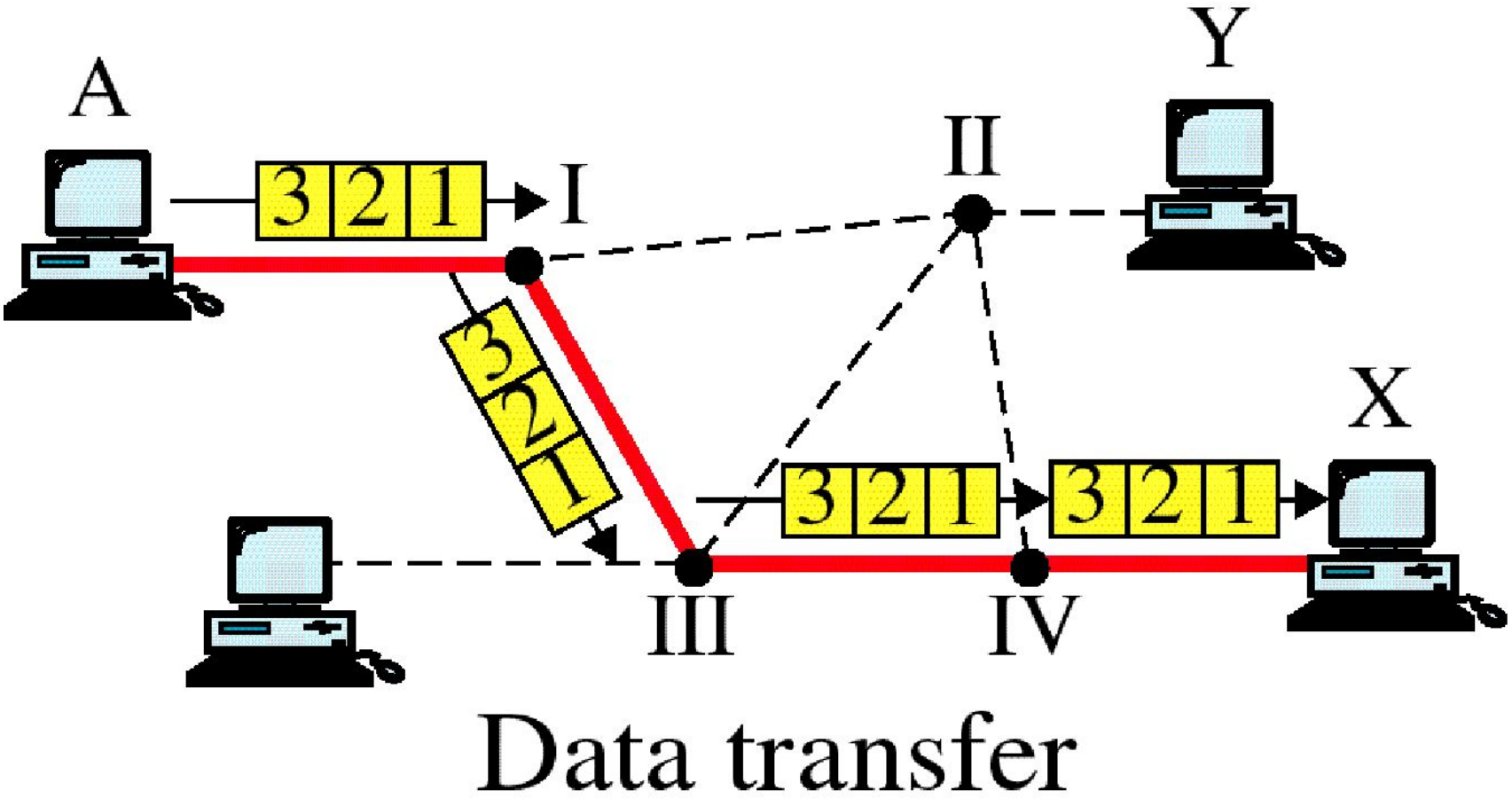


Switched Virtual Circuits

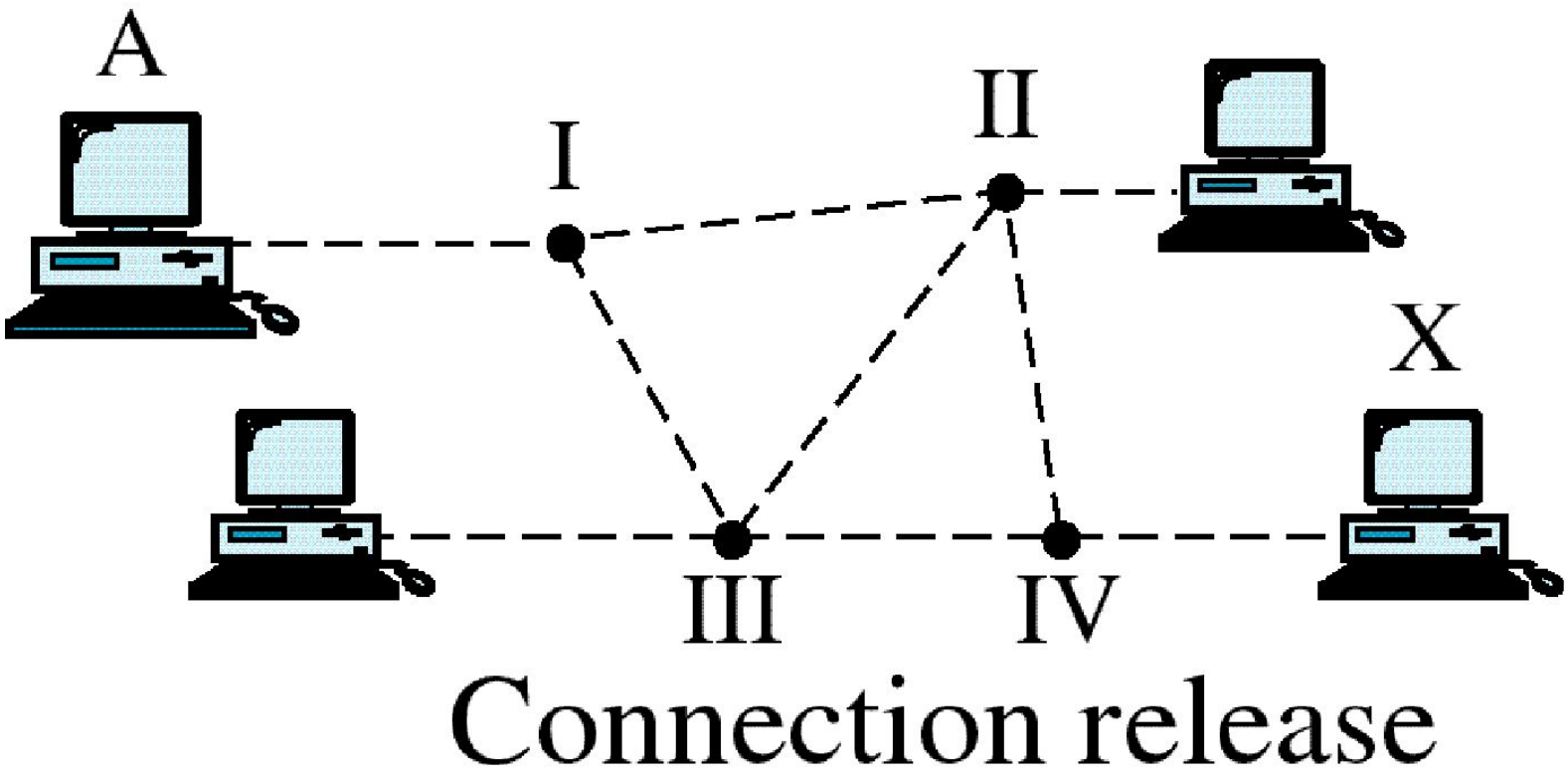


Connection establishment

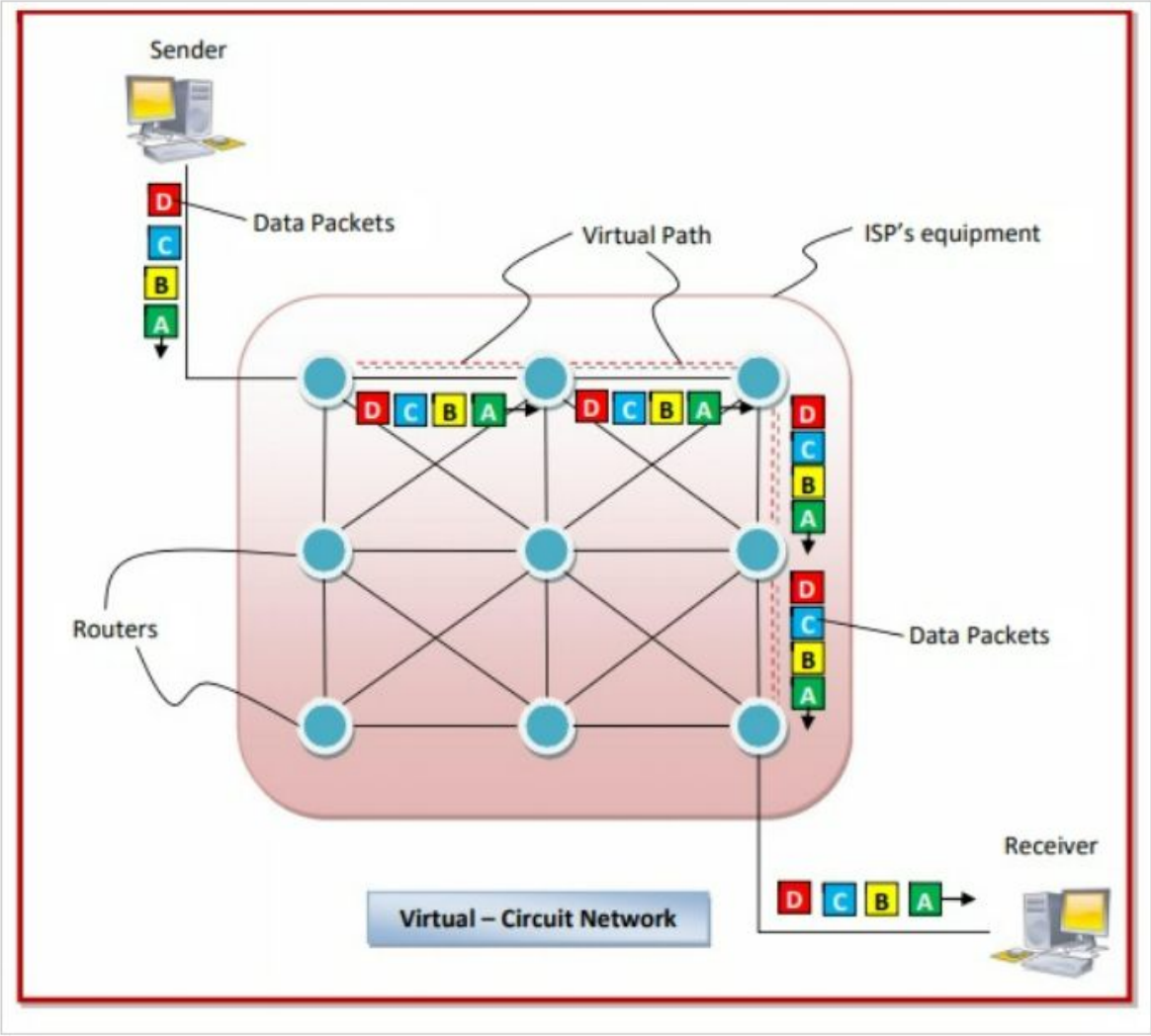
Switched Virtual Circuits



Switched Virtual Cirtuits



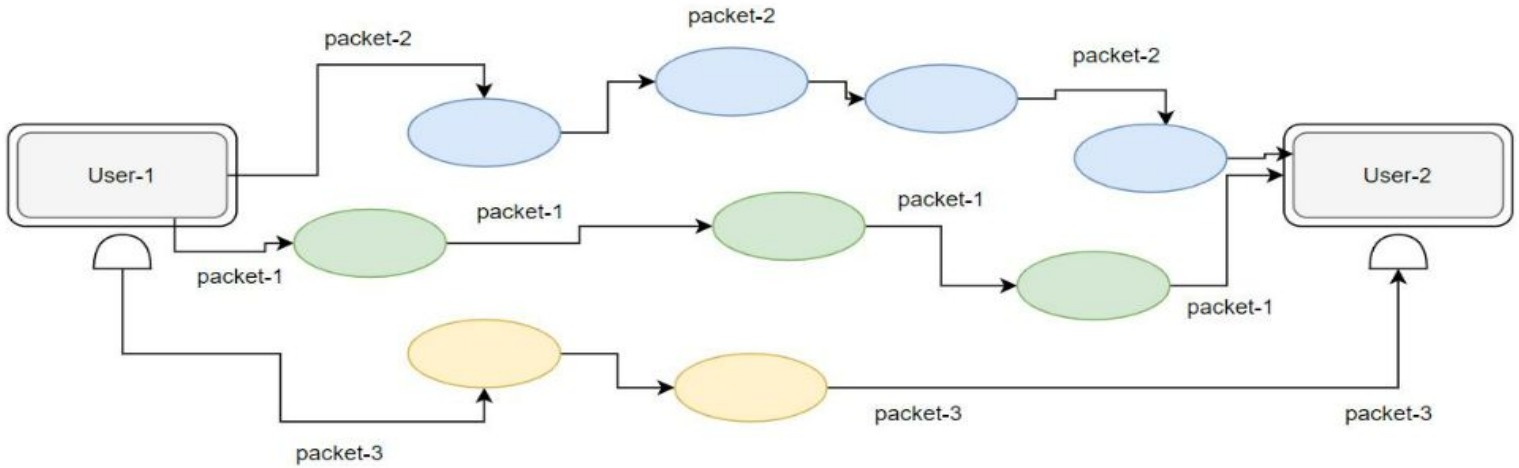
Virtual Circuits

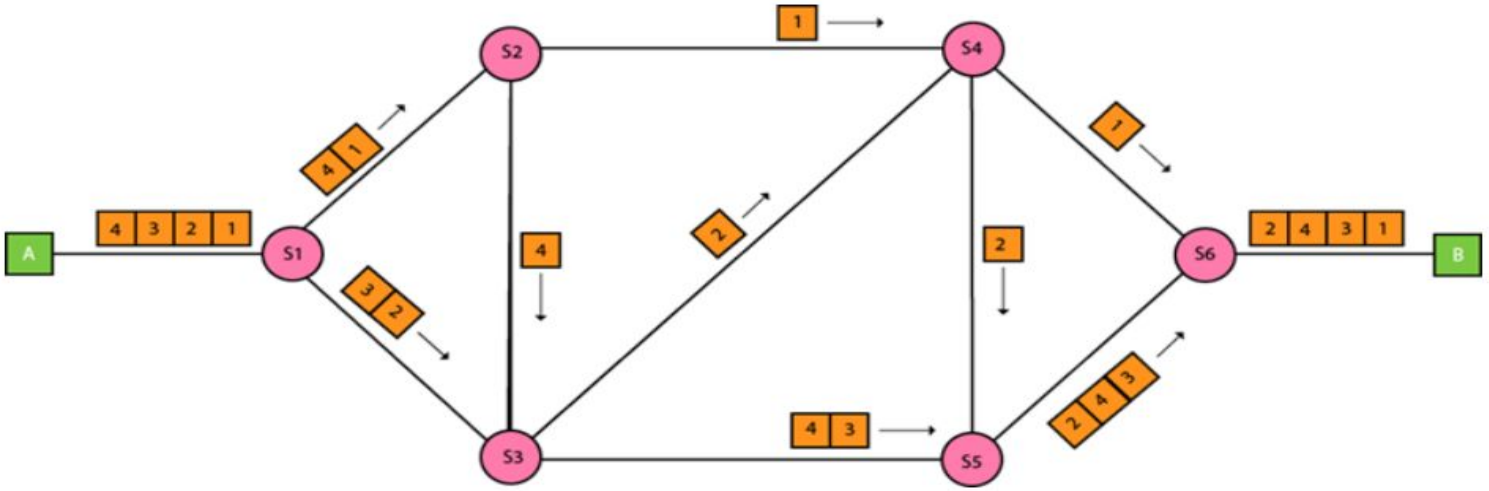


Virtual Circuits v Datagram

- 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

Examples


packet-2
packet-2
packet-2
User-1
User-2
packet-1
packet-1
packet-1
packet-1
packet-3
packet-3
packet-3


A
B
S1
S2
S3
S4
S5
S6
4 3 2 1
2 4 3 1

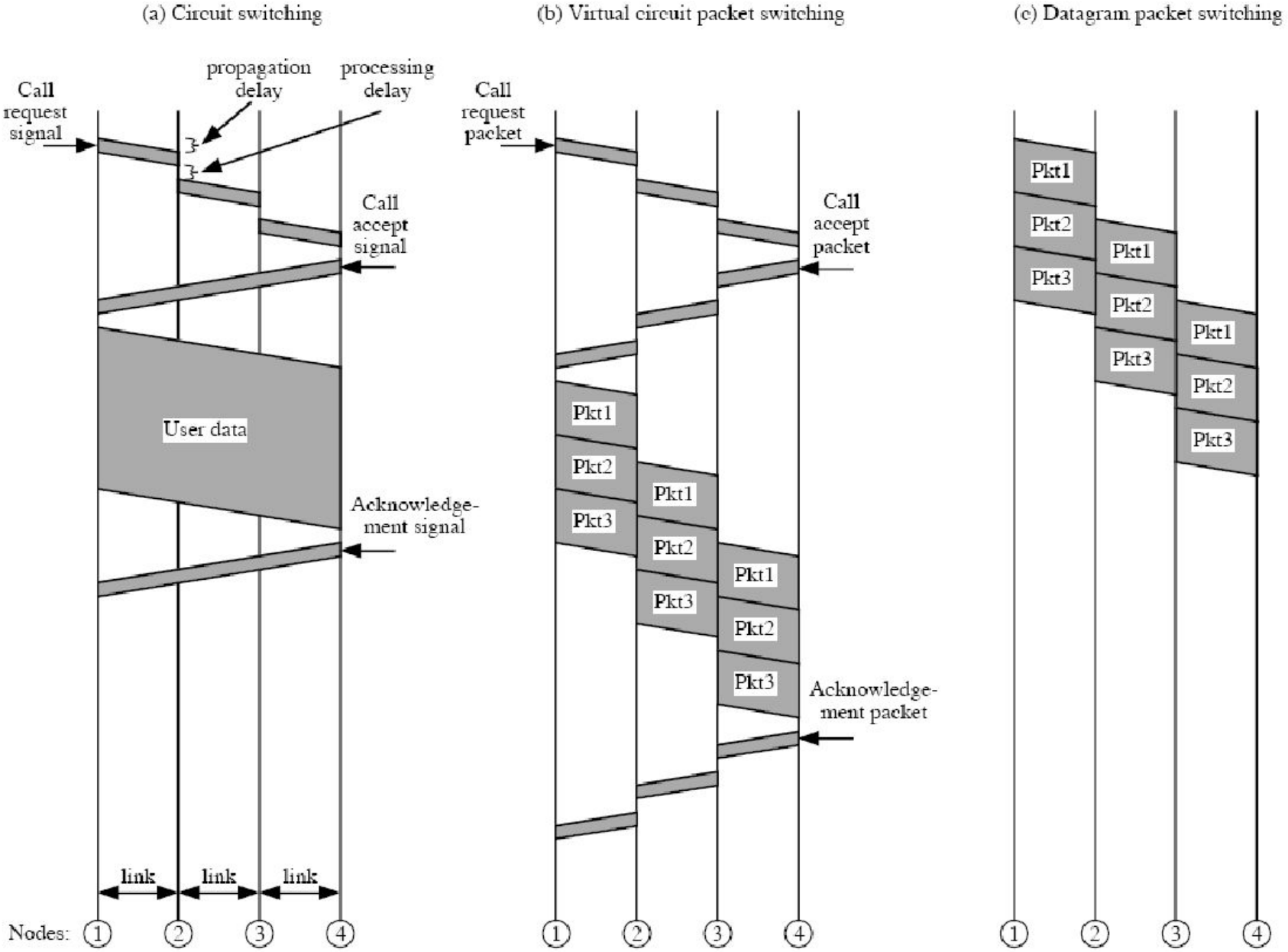


Figure 10.15 Event Timing for Circuit Switching and Packet Switching

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

You first need to understand difference between connection oriented path and dedicated oriented path.

Connection oriented path: where the source to destination route preplanned but not necessarily reservation of resources, resources can be shared by any other source and destination pairs.

Dedicated oriented path: Connection oriented path and resources reservation and resources are allocated for one and only dedicated sender and receiver.

Virtual circuit switching uses both features of circuit switching and datagram switching. So virtual circuit switching doesn't necessarily have a dedicated path(i.e. have Connection oriented path) and resources may or may not be allocated in advance. But definitely it is connection oriented which is one of the feature of circuit switching.

Virtual circuit communication resembles circuit switching, since both are connection oriented, meaning that in both cases data is delivered in correct order, and signalling overhead is required during a connection establishment phase. However, circuit switching provides a constant bit rate and latency, while these may vary in a virtual circuit service due to factors such as:

- varying packet queue lengths in the network nodes,
- varying bit rate generated by the application,
- varying load from other users sharing the same network resources by means of statistical multiplexing, etc.

Related **What is the difference between a virtual circuit and a circuit switch?**

Circuit switch is similar to the switching used in telephony. The resources are dedicated, bandwidth is not shared, follows the 3 steps of setup, data transfer and tear down phases, is wasteful of bandwidth, suitable for voice transmission.

On the other hand, a virtual circuit is the in between of circuit and message switching, the middle of the road variety. Difference with the foirst one is that even if the resources are dedicated during a session, band width is shared between different messages,also follows a 3 phase connection and tear down, not wasteful of the bandwidth because it is optimally utilized, suitable for data message switching with a decreased delay than pure message switching mode of data transfer