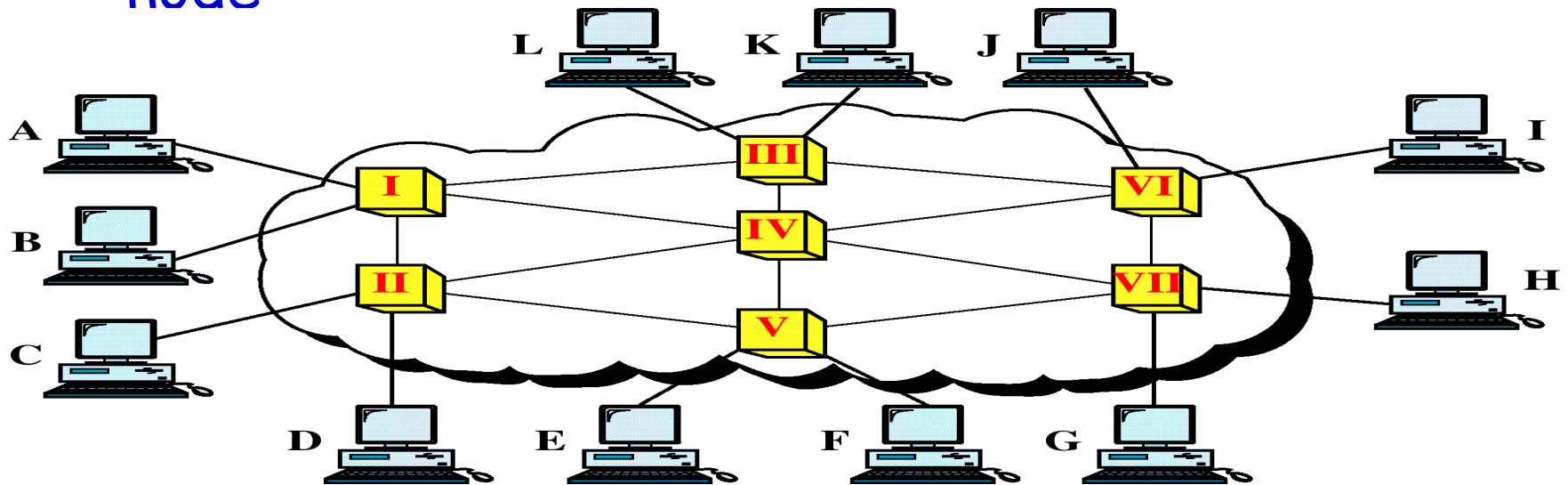

Switching Technologies

EE450: Introduction to Computer Networks

Professor A. Zahid

Switched Network

- Long distance transmission is typically done over a network of switched nodes
- Nodes not concerned with content of data
- Data routed by being switched from node to node



Switching Nodes

- Nodes may connect to other nodes only (Transit Switches), or to end hosts and other nodes
- Node to node Trunks are multiplexed (TDM, FDM, WDM)
- Network is usually partially connected
 - Some redundant connections are desirable for reliability
- Two different switching technologies
 - Circuit switching
 - Packet switching
 - Connection-less (ex. IP)
 - Connection-Oriented, a.k.a. Virtual Circuit (ex: ATM, FR)

Circuit Switching

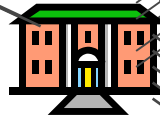
- A **Circuit** is a dedicated (for the duration of the call) communication path between two stations.
- Circuit switching requires three phases namely circuit establishment, data transfer and circuit termination
- Must have switching capacity and channel capacity to establish connection
- Must have intelligence to work out routing
- Once connected, transfer is transparent
- Developed for voice traffic (Telephony)

Circuit Switching: The PSTN

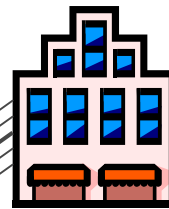
Each phone call is allocated 64kb/s. So, a 2.5Gb/s trunk line can carry about 39,000 calls.



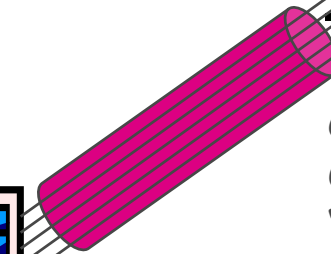
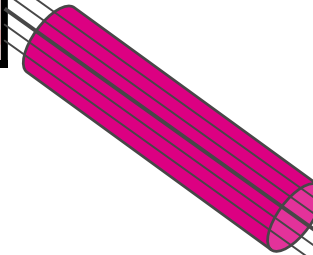
Source
"Caller"



Central
Office
"C.O."



Trunk
Exchange



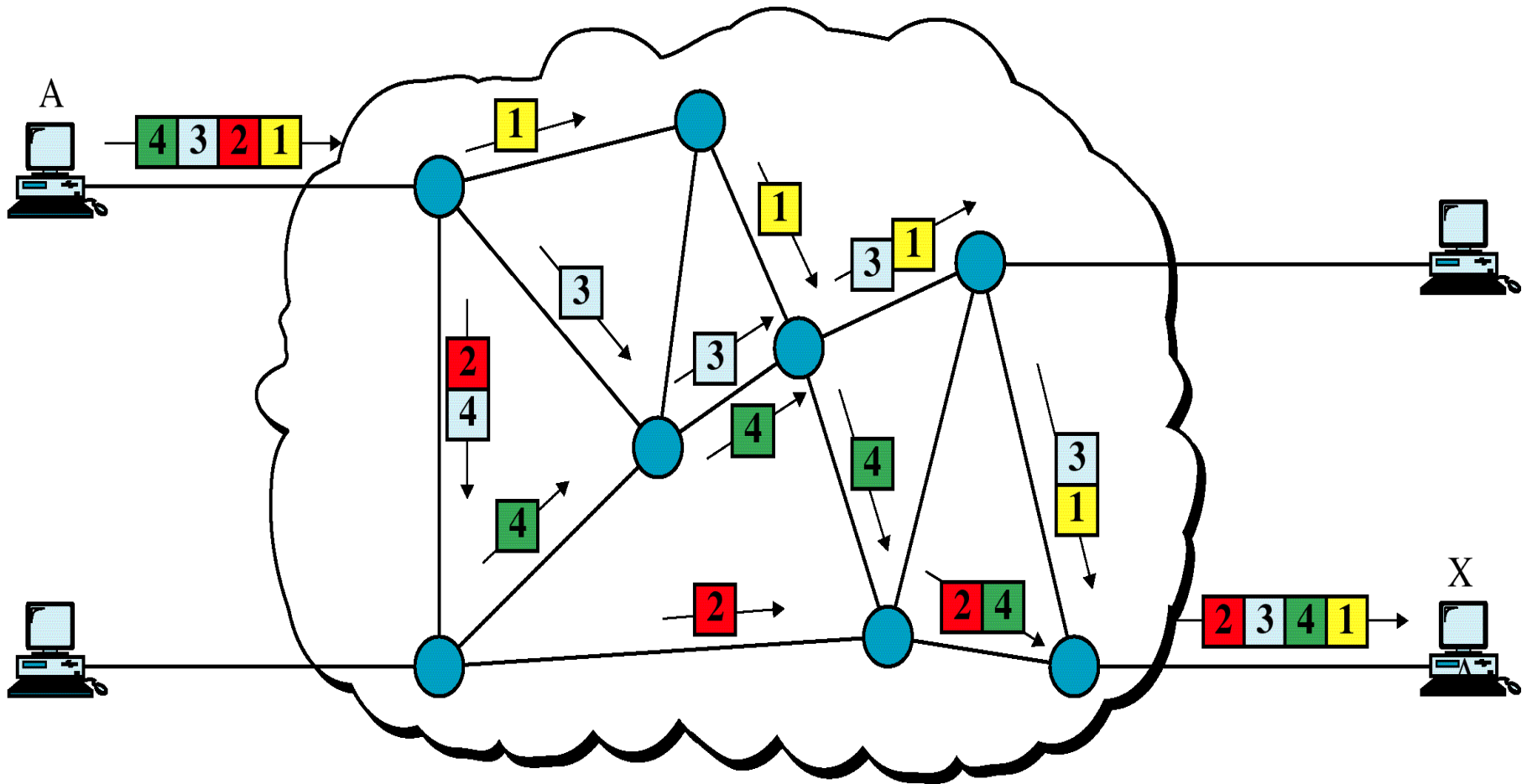
Central
Office
"C.O."



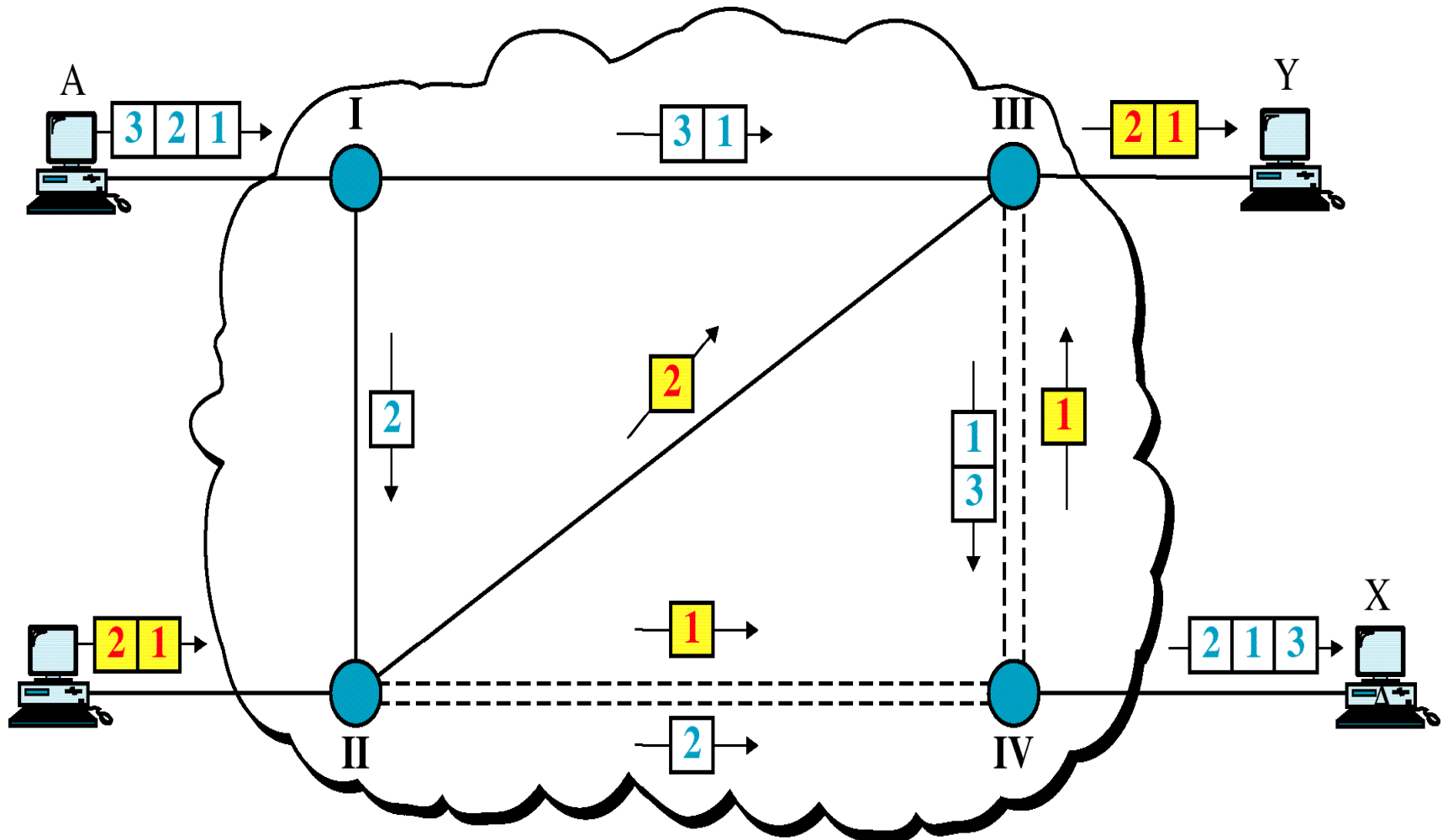
Packet Switching; Connectionless

- Each packet routed independently using local routing table
- Packets can take any practical route
- Packets may arrive out of order
- Packets may be lost (dropped)
- Routers maintain no per-flow state
- Up to receiver to re-order packets and recover from missing packets
- Store and Forward

Packet Switching; Connectionless

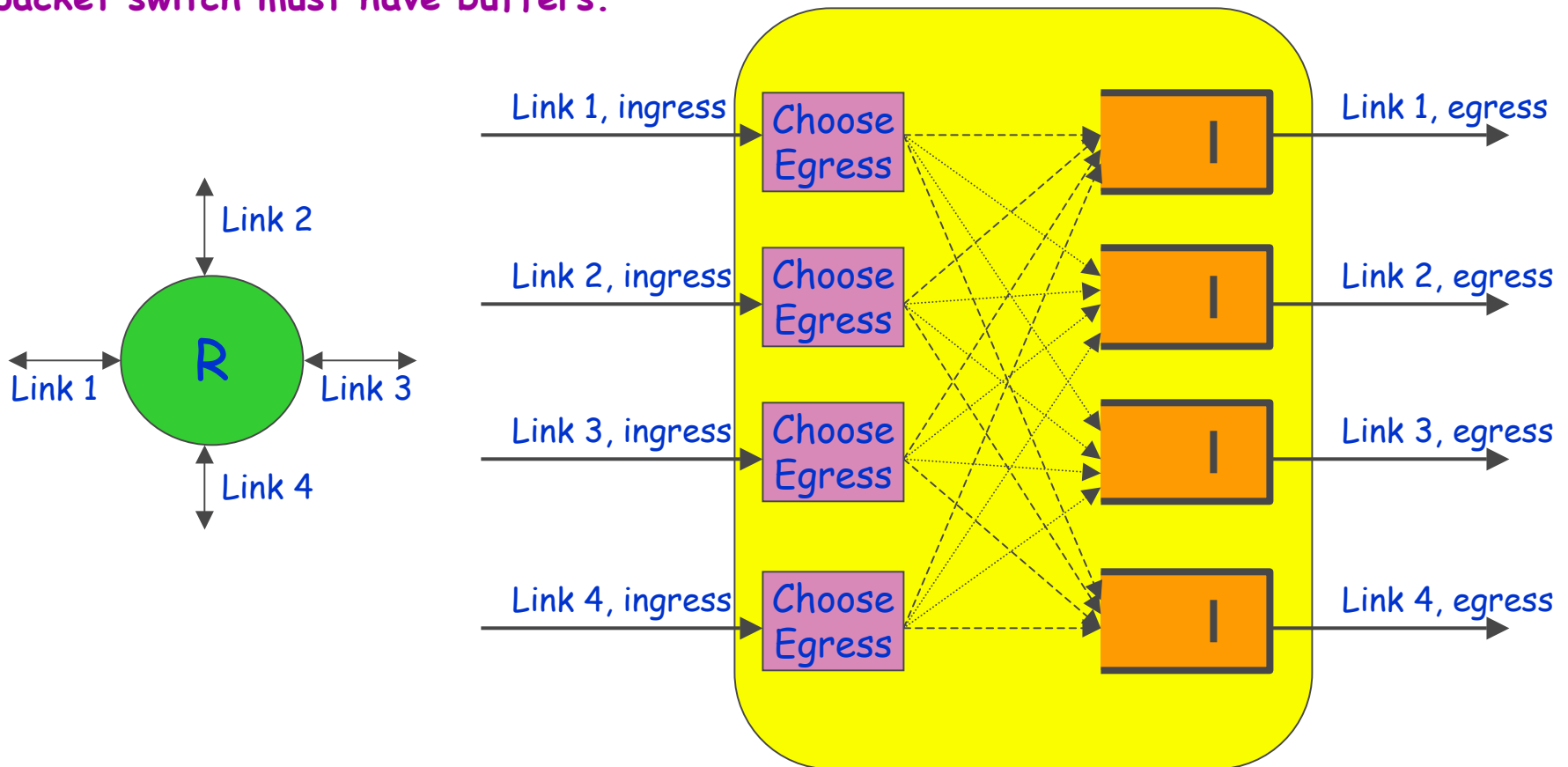


Packet Switching: Multiple Users



Packet Switch Model

Several packets may arrive for the same egress at the same time. A packet switch must have buffers.



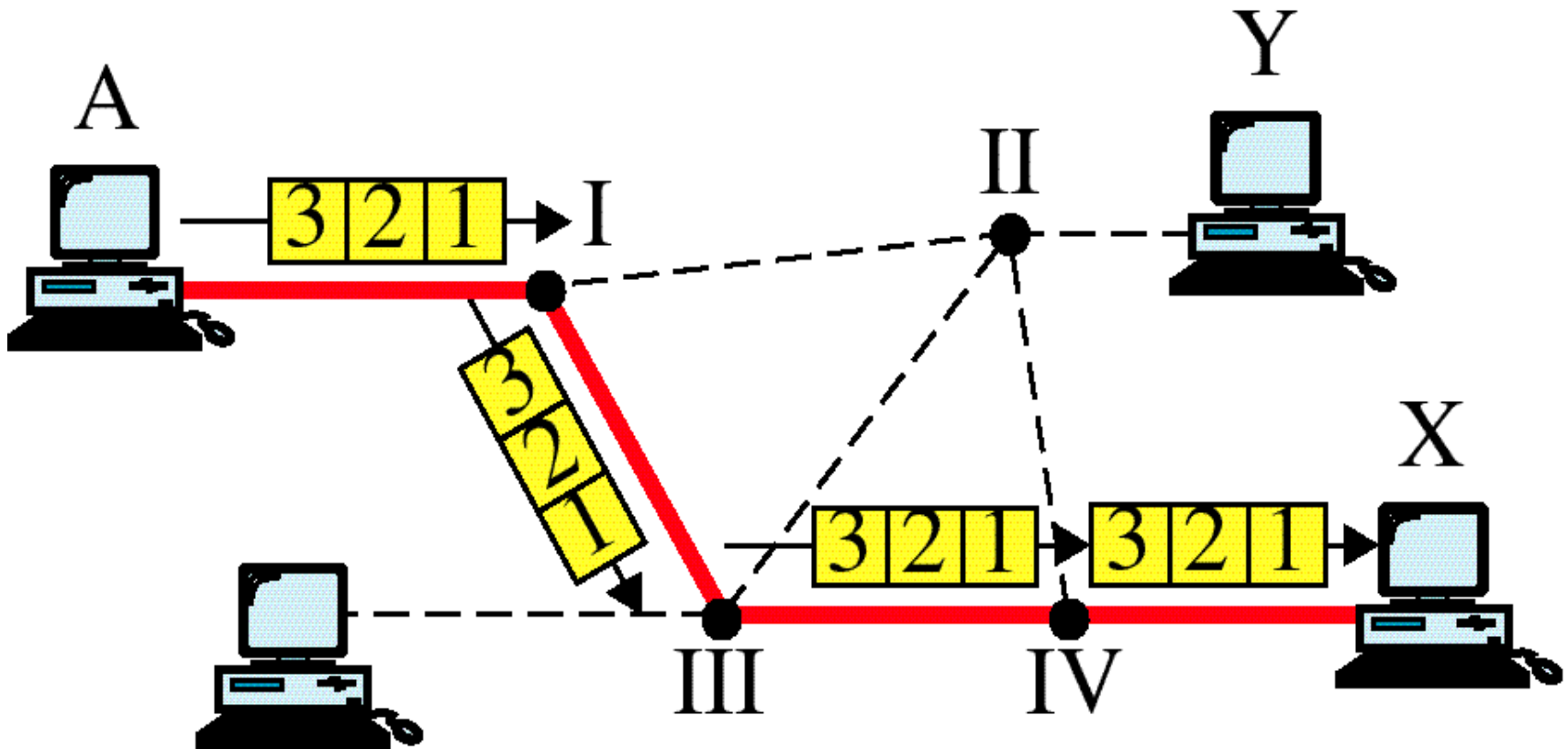
Packet Switching; Internet (Why?)

1. Efficient use of expensive links:
 - The links are assumed to be expensive and scarce.
 - Packet switching allows many, bursty flows to share the same link efficiently.
 - Circuit switching is rarely used for data networks because of very inefficient use of the links
2. Resilience to failure of links & routers:
 - For high reliability, the Internet was to be a packet network, so if some lines and routers were destroyed, messages could be rerouted

Virtual Circuit Switching

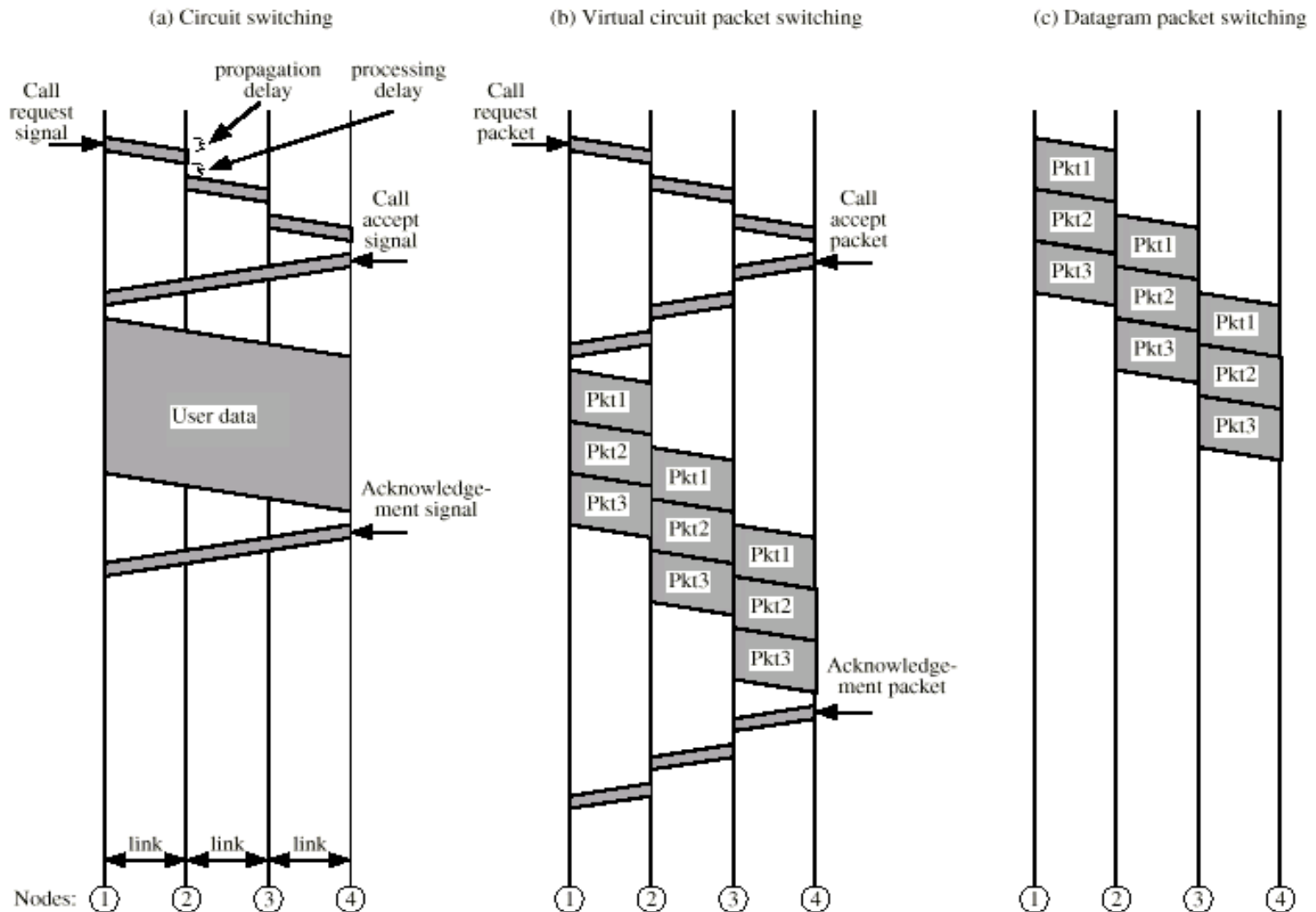
- A virtual connection (not a dedicated path) is established before any packets are sent
- Call request and call accept packets establish connection (handshake)
- Each packet contains a virtual circuit identifier instead of destination address
- No routing decisions required for each packet
- Clear request to drop virtual connection

Virtual Connection

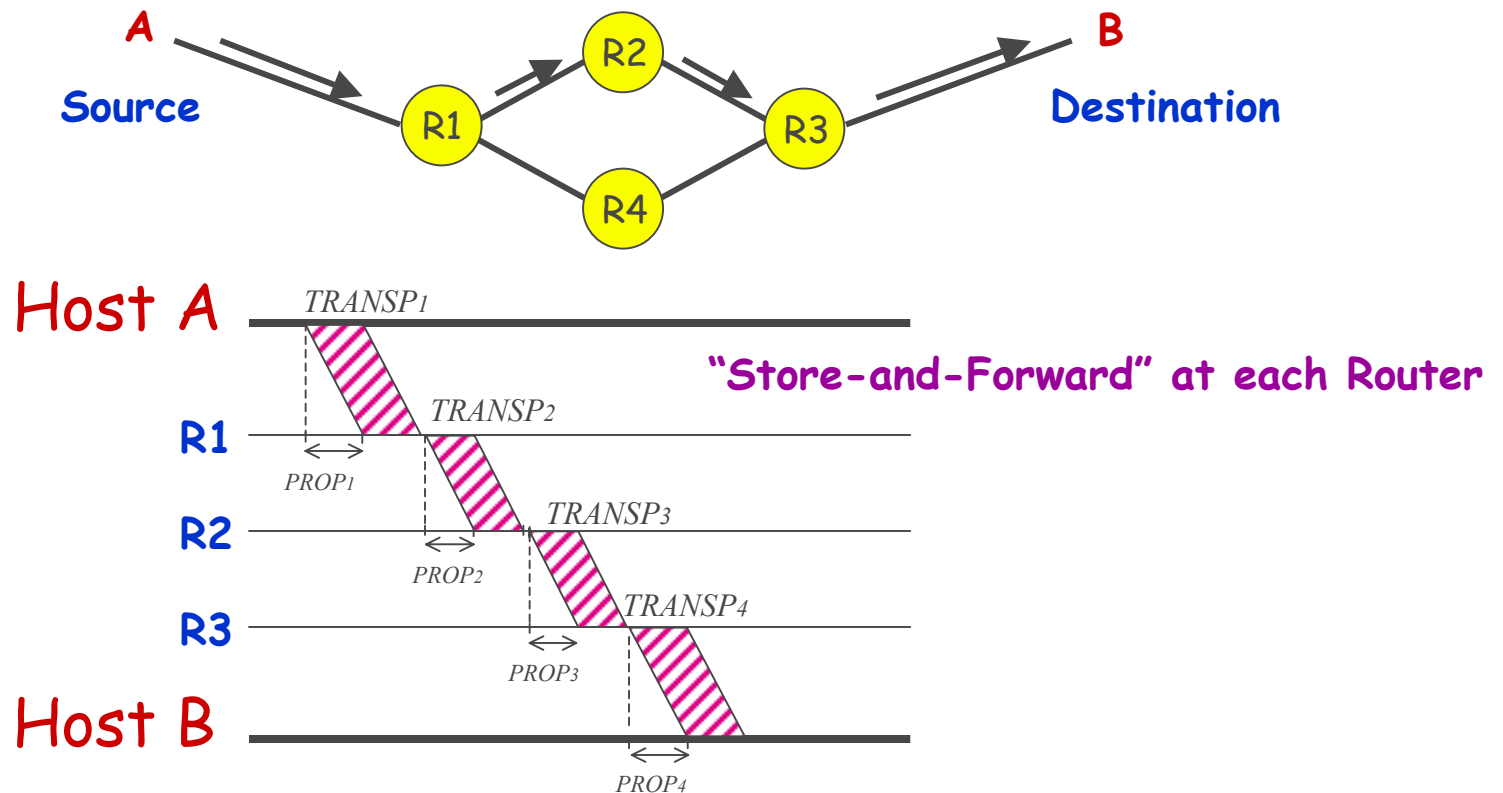


Data transfer

Timing Events in Switched Networks



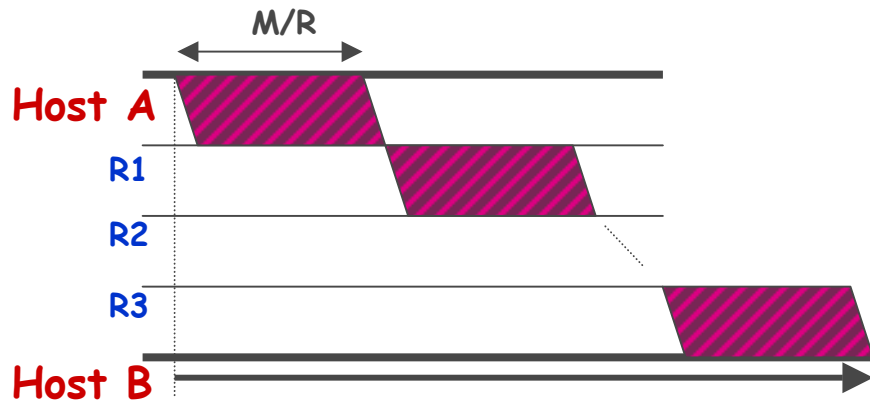
Packet Switching Timing



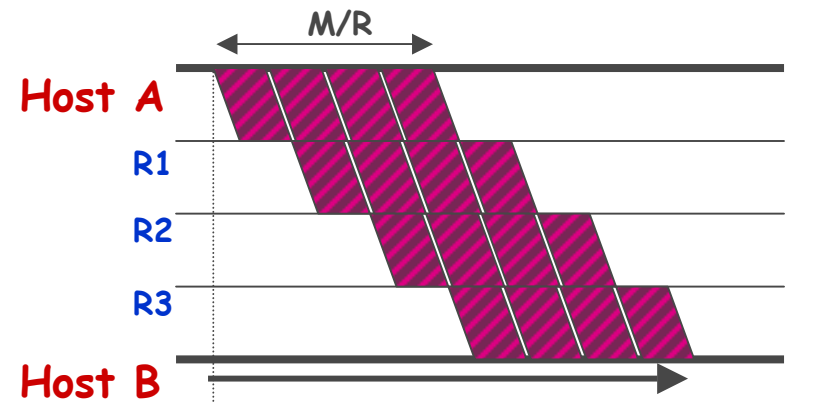
$$\text{Minimum end to end latency} = \sum_i (TRANSP_i + PROP_i)$$

Packet Switching Timing (Cont.)

Why not send the entire message in one packet?



$$\text{Latency} = \sum_i (PROP_i + M / R_i)$$

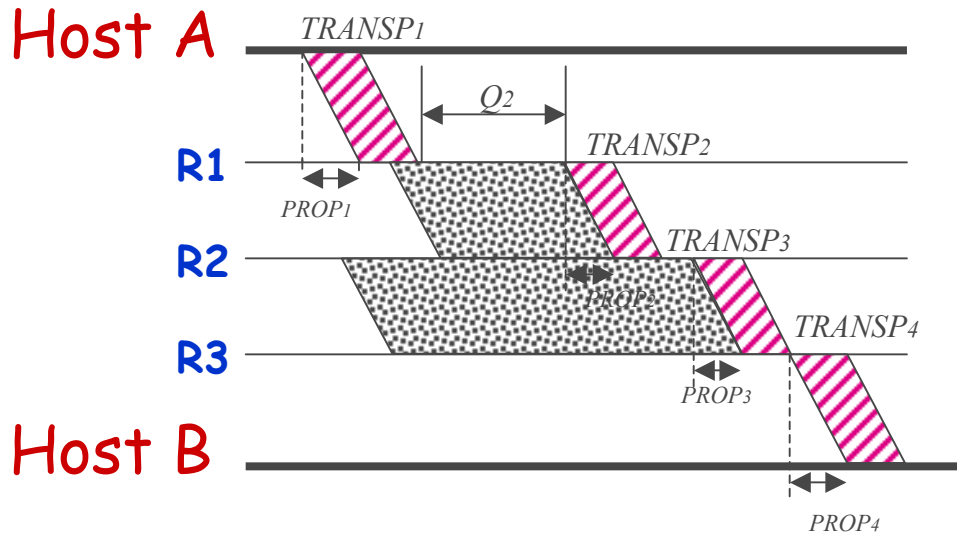


$$\text{Latency} = M / R_{\min} + \sum_i PROP_i$$

Breaking message into packets allows parallel transmission across all links, reducing end to end latency. It also prevents a link from being "hogged" for a long time by one message.

Packet Switching: Queueing Delay

Because the egress link is not necessarily free when a packet arrives, it may be queued in a buffer. If the network is busy, packets might have to wait a long time.



How can we determine the queueing delay?
EE465

$$\text{Actual end to end latency} = \sum_i (TRANSP_i + PROP_i + Q_i)$$

Virtual Circuit vs. Connectionless

- Virtual circuits
 - Network can provide sequencing and error control
 - Packets are forwarded more quickly
 - No routing decisions to make
 - Less reliable
 - Loss of a node loses all circuits through that node
- Datagram
 - No call setup phase
 - Better if few packets
 - More flexible
 - Routing used to avoid congested parts of the network

Circuit vs. Packet Switching

<i>Item</i>	<i>Circuit Switching</i>	<i>Packet Switching</i>
• Dedicated Path	Yes	No
• Bandwidth	Fixed	Dynamic
• Call Setup	Yes	No
• Store & Forward	No	Yes
• Congestion	@ set-up	anytime
• Potentially wasted BW	Yes	No
• Packets follow same route	Yes	Not necessarily

Circuit vs. Virtual Circuit

<i>Item</i>	<i>Circuit Switching</i>	<i>Virtual Circuit Switching</i>
• Dedicated Path	Yes	No
• Bandwidth	Fixed	Dynamic
• Call Setup	Yes	Yes
• Store & Forward	No	Yes
• Congestion	@ set-up	anytime
• Potentially wasted BW	Yes	No
• Packets follow same route	Yes	Yes