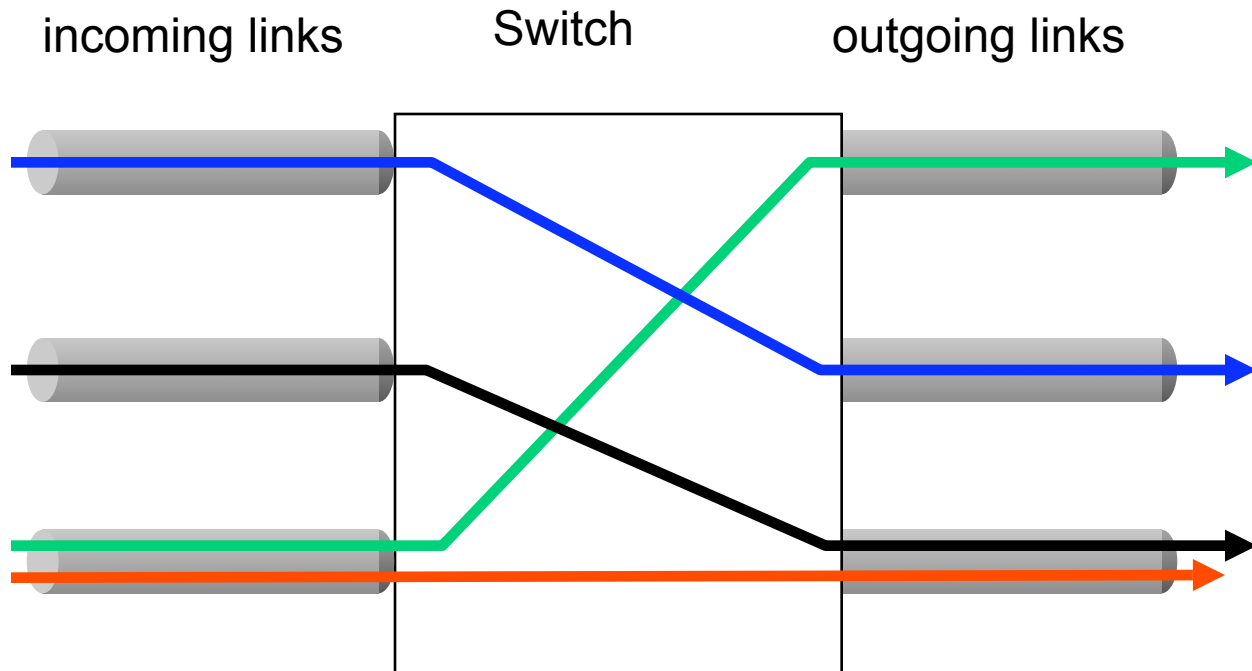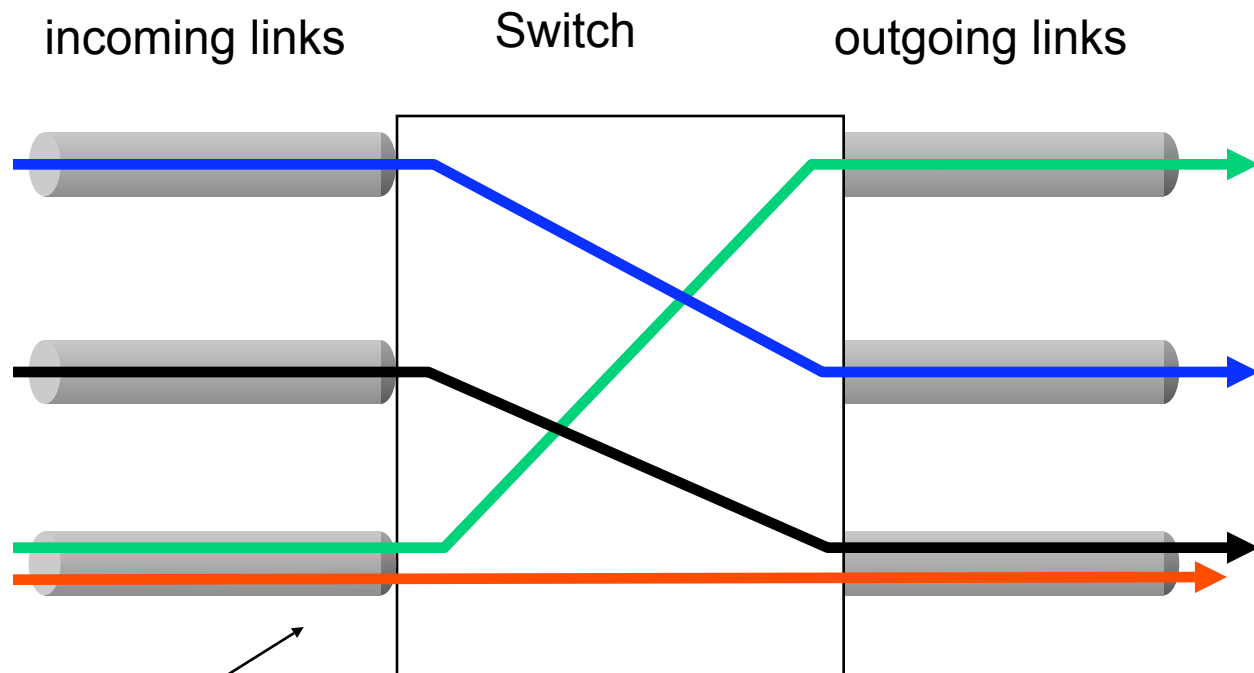# CS4700/CS5700
Fundaments of Computer Networks

Lecture 4: Fundamental network design issues

Slides used with permissions from Edward W. Knightly,
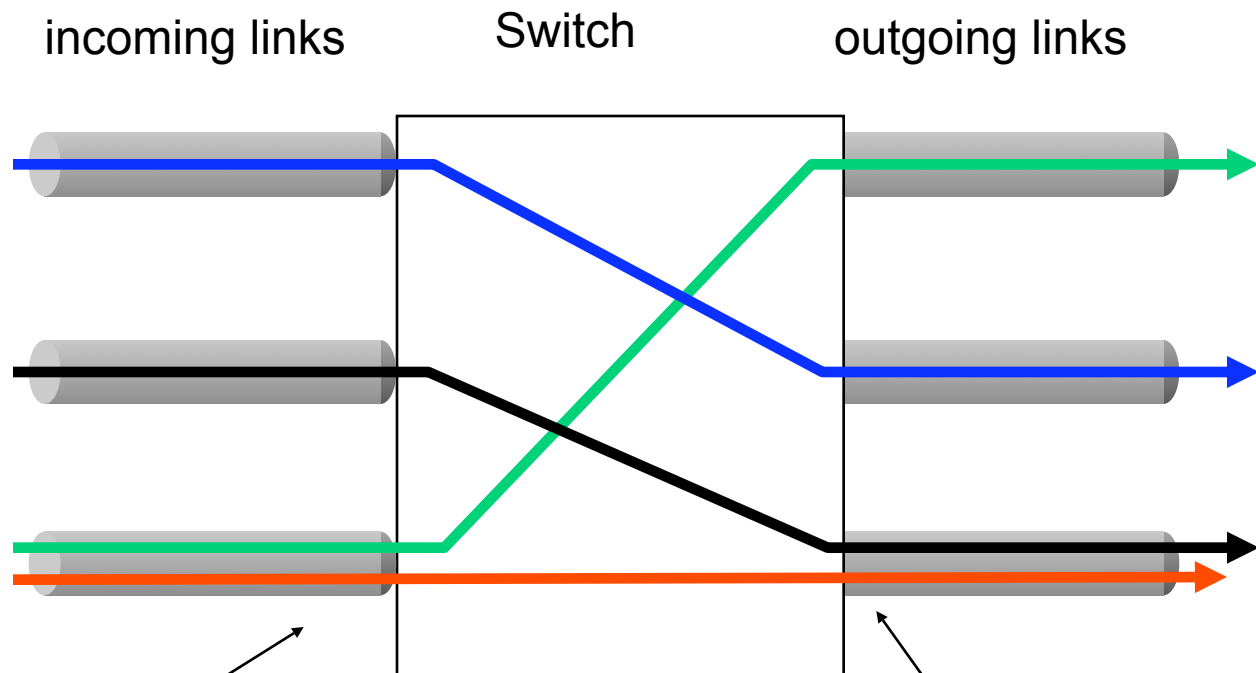T. S. Eugene Ng, Ion Stoica, Hui Zhang

A Generic Switch

incoming links   Switch   outgoing links
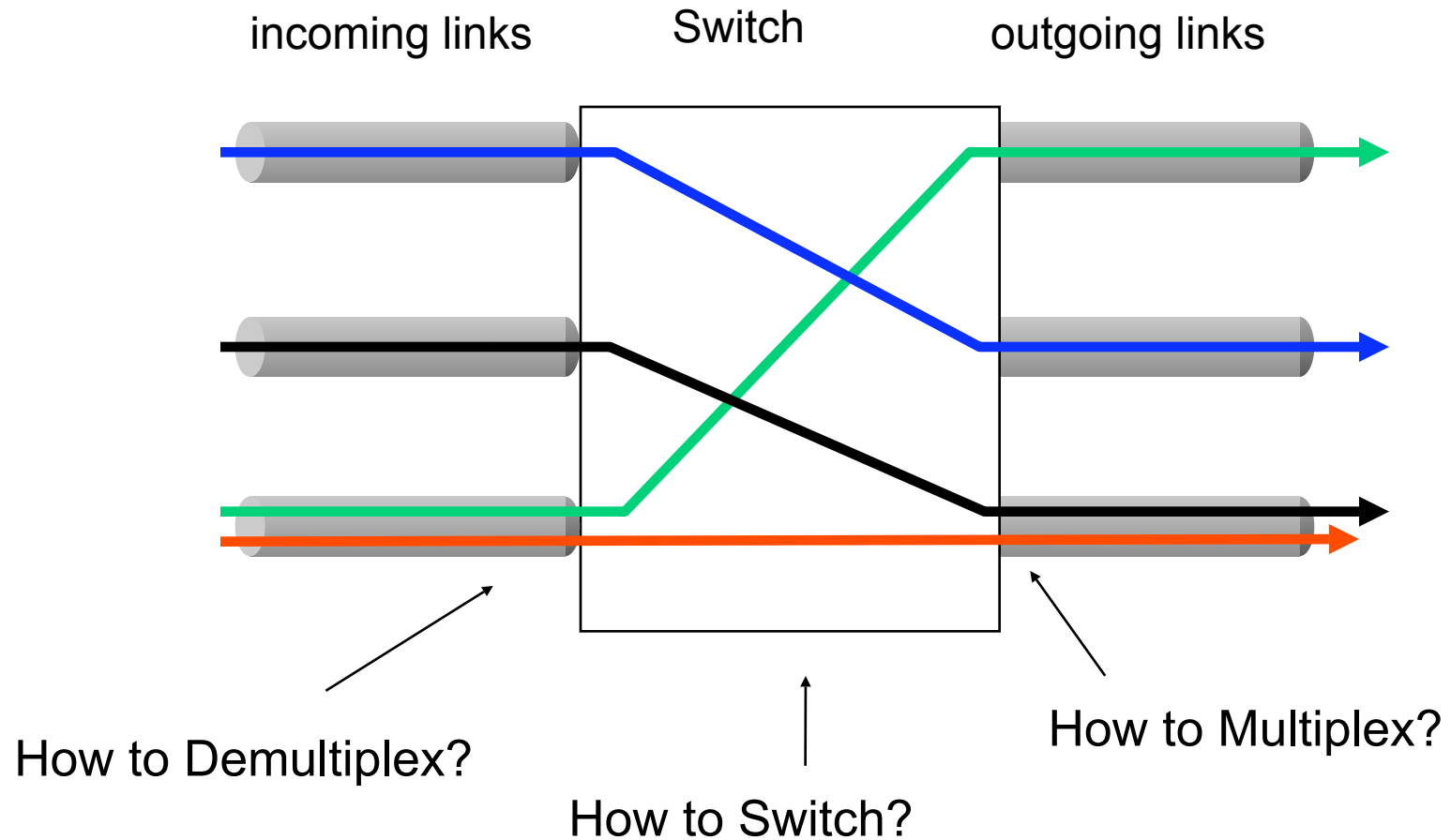
A Generic Switch

incoming links   Switch   outgoing links

How to Demultiplex?

A Generic Switch

incoming links   Switch   outgoing links

How to Demultiplex?

How to Multiplex?

A Generic Switch
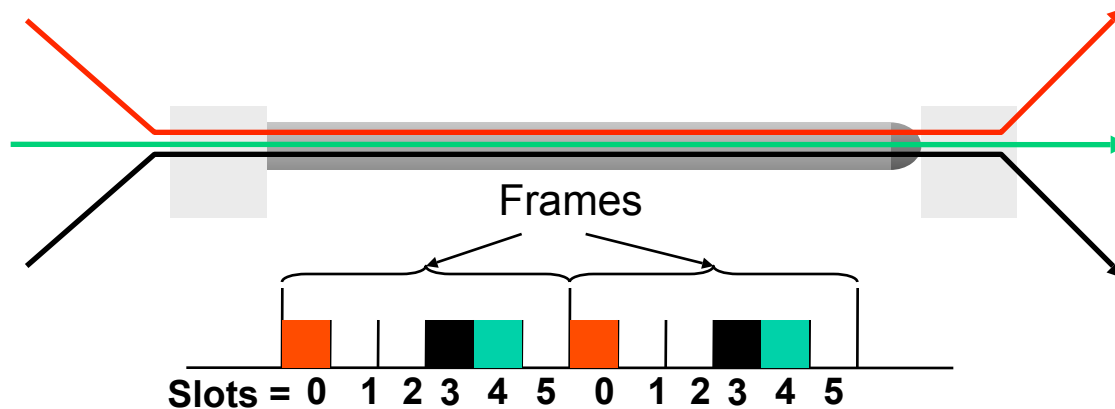
incoming links   Switch   outgoing links

How to Demultiplex?

How to Switch?

How to Multiplex?

Circuit Switching: Multiplexing/Demultiplexing

Frames

Slots = 0 1 2 3 4 5 0 1 2 3 4 5

Circuit Switching: Multiplexing/ Demultiplexing

Frames

Slots = 0 1 2 3 4 5 0 1 2 3 4 5
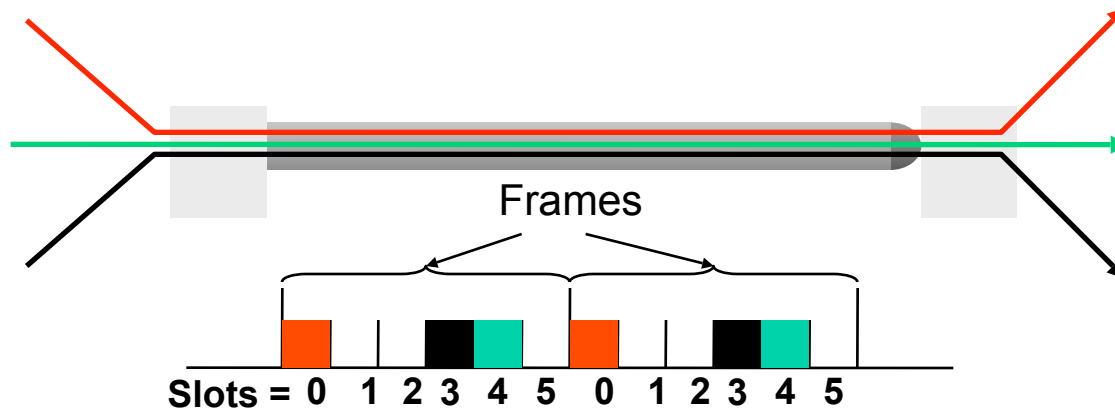
- Time divided in frames and frames divided in slots

Circuit Switching: Multiplexing/ Demultiplexing
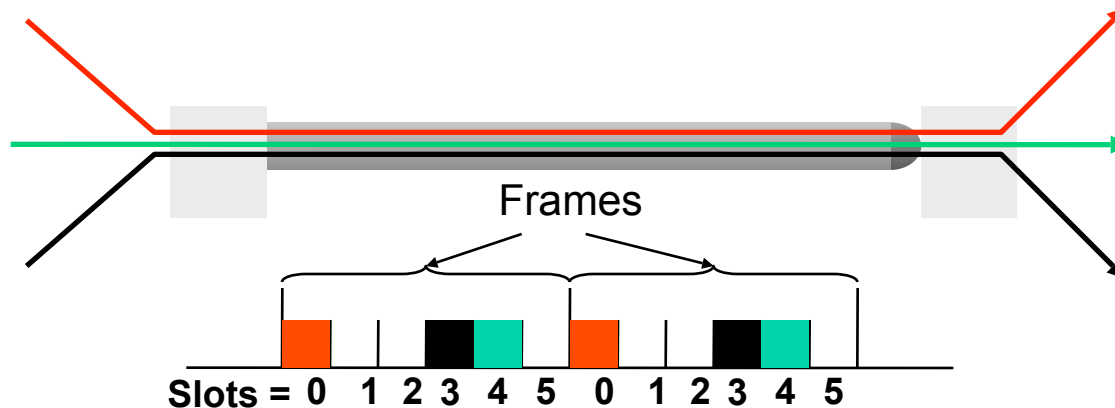
Frames

Slots = 0 1 2 3 4 5 0 1 2 3 4 5

- Time divided in frames and frames divided in slots
- Relative slot position inside a frame determines which conversation the data belongs to
  - E.g., slot 0 belongs to red conversation
- Needs synchronization between sender and receiver

Circuit Switching: Multiplexing/ Demultiplexing
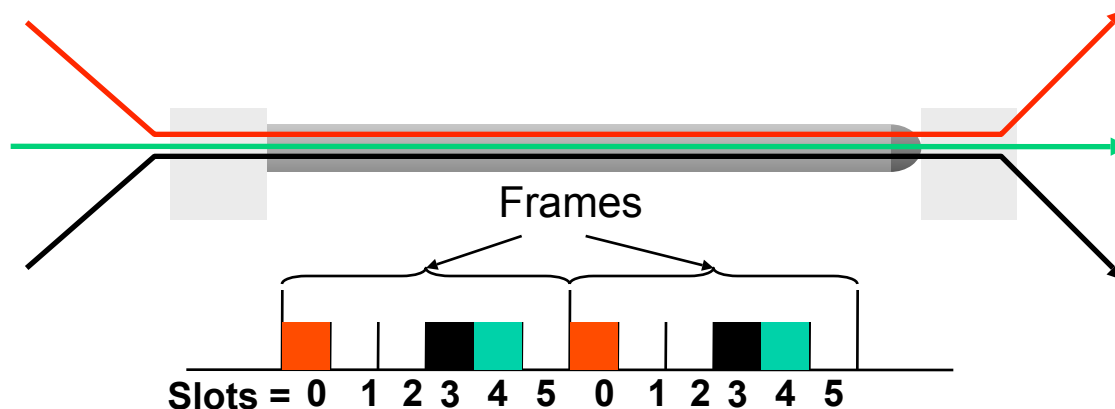
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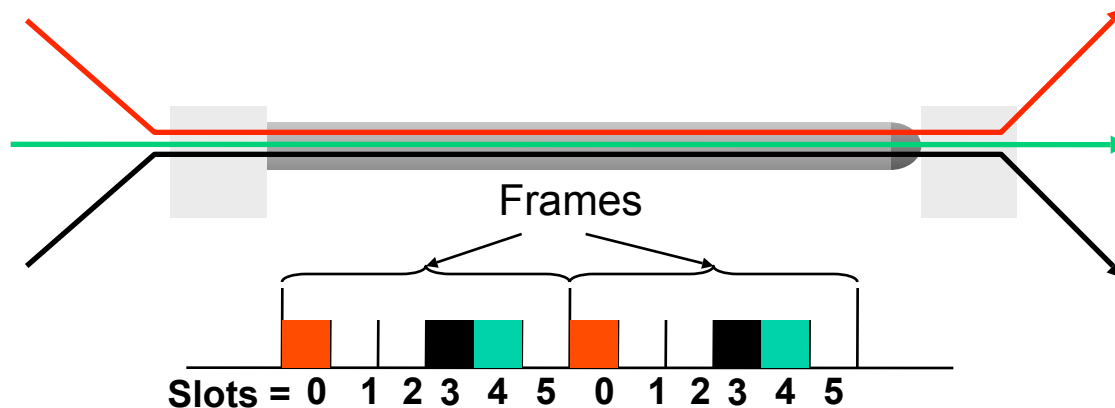- Needs synchronization between sender and receiver
- In case of non-permanent conversations
  - Needs to dynamic bind a slot to a conservation
  - How to do this?

Circuit Switching: Multiplexing/ Demultiplexing

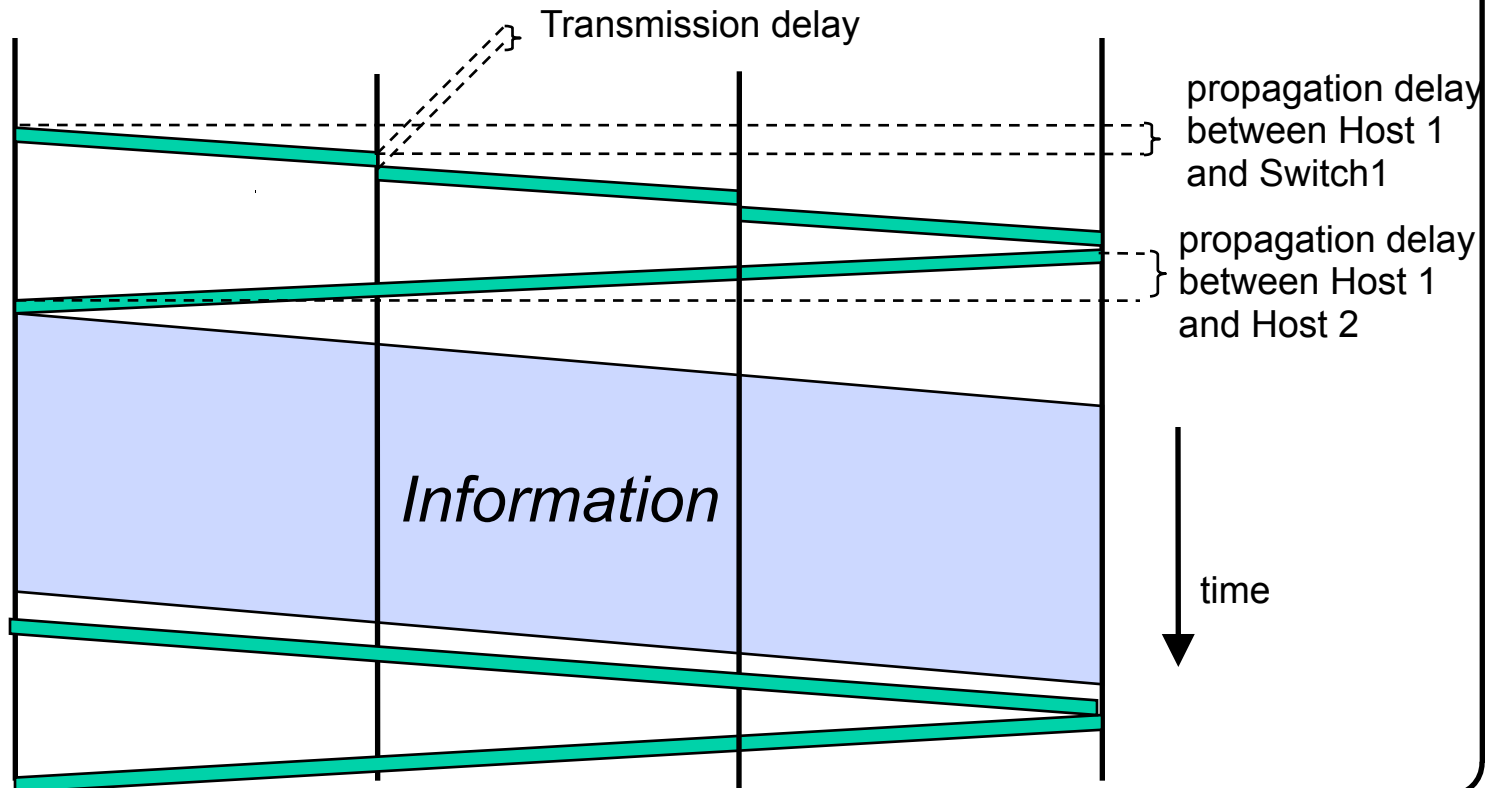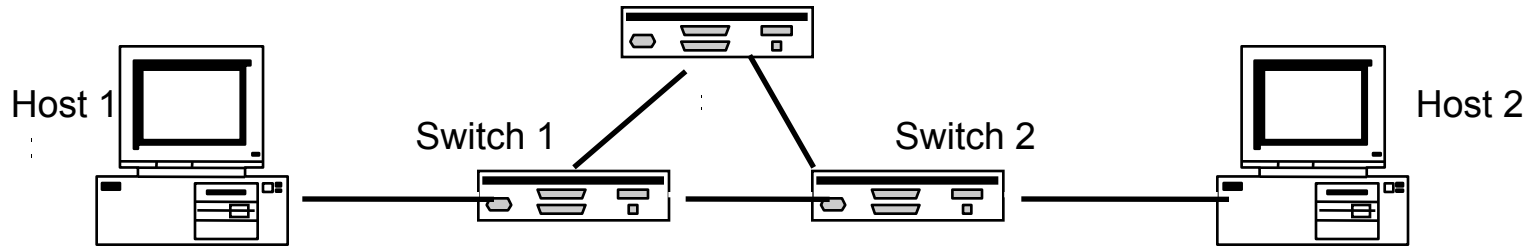

Frames

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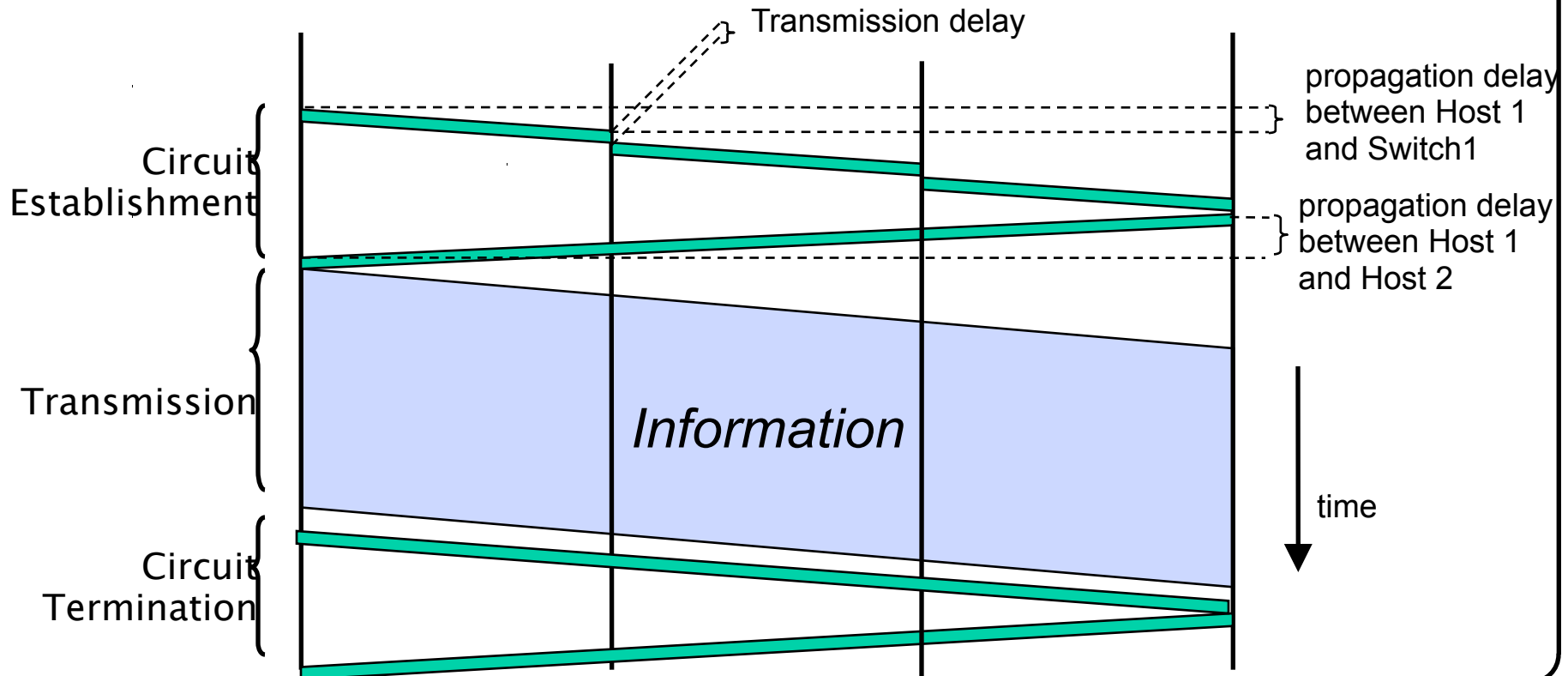- If a conversation does not use its circuit the capacity is lost!
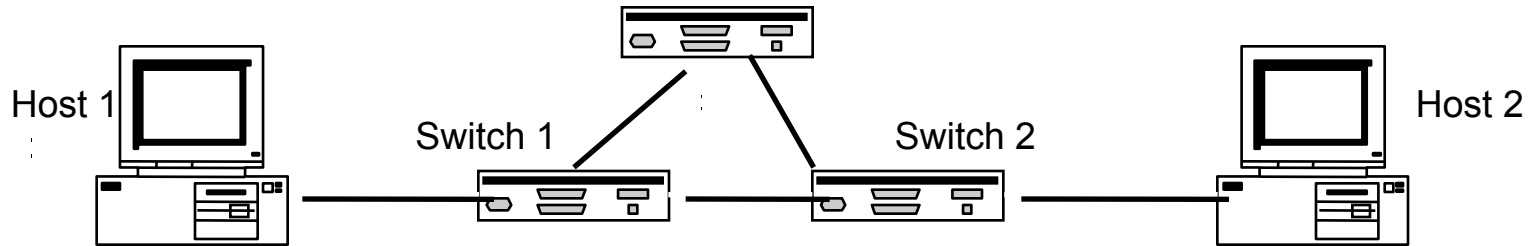
Circuit Switching

- Three phases
  1. circuit establishment
  2. data transfer
  3. circuit termination
- If circuit not available: busy
- Examples
  - Telephone networks
  - ISDN (Integrated Services Digital Networks)

Timing in Circuit Switching

Host 1

Switch 1

Switch 2

Host 2

Transmission delay

propagation delay between Host 1 and Switch1

propagation delay between Host 1 and Host 2

Information
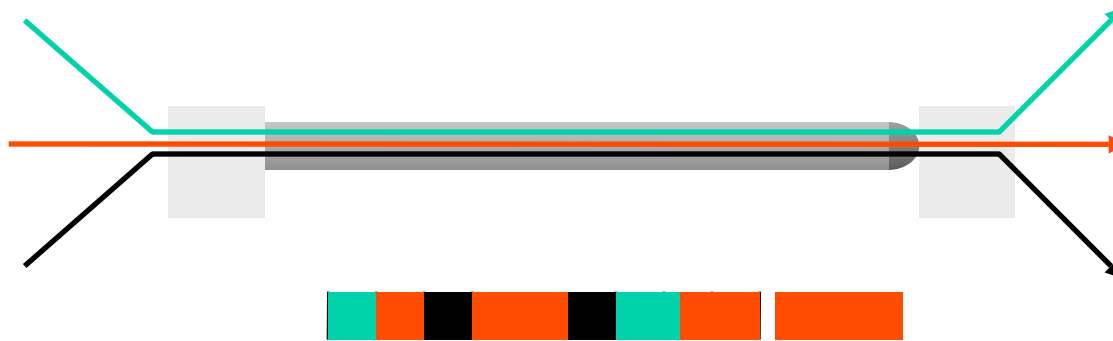
time

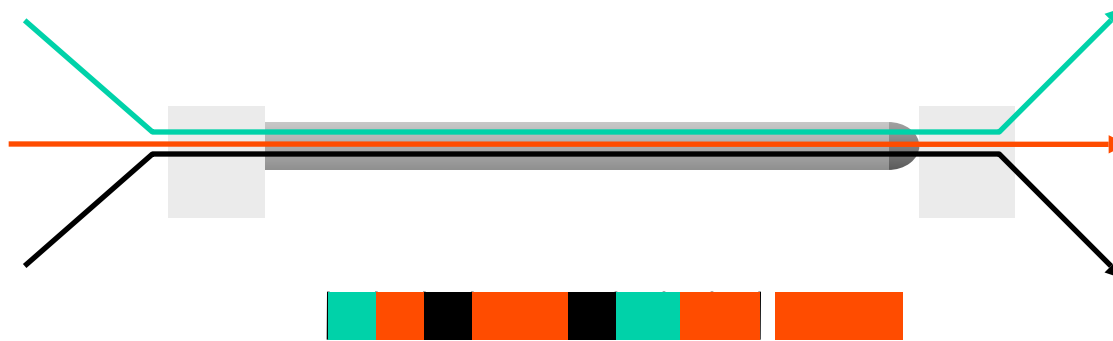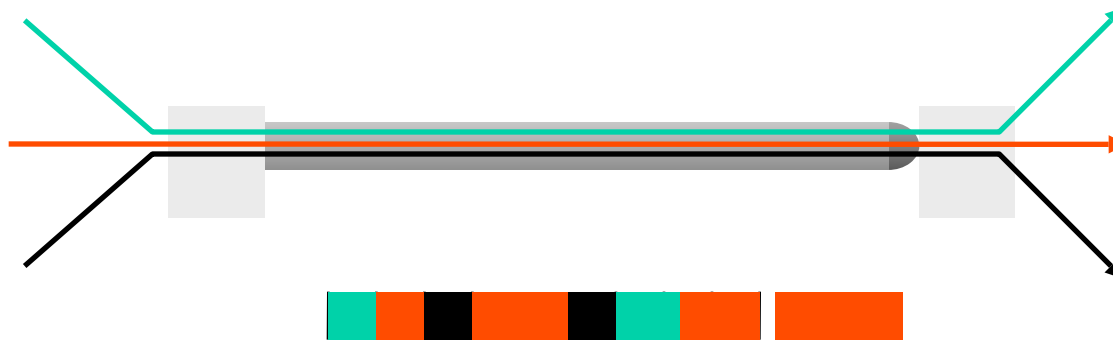# Timing in Circuit Switching

Packet Switching: Multiplexing/Demultiplexing
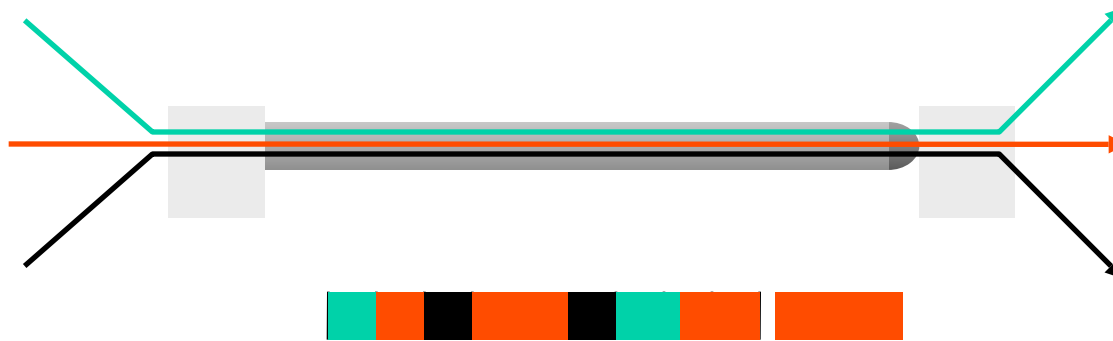
Packet Switching: Multiplexing/Demultiplexing

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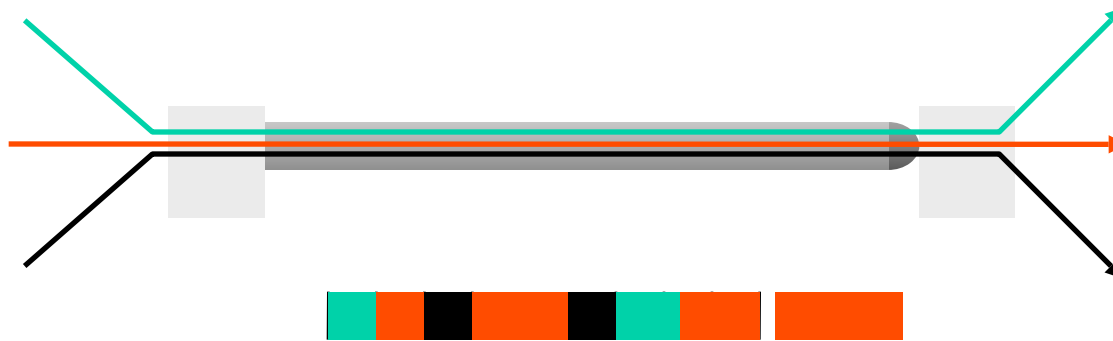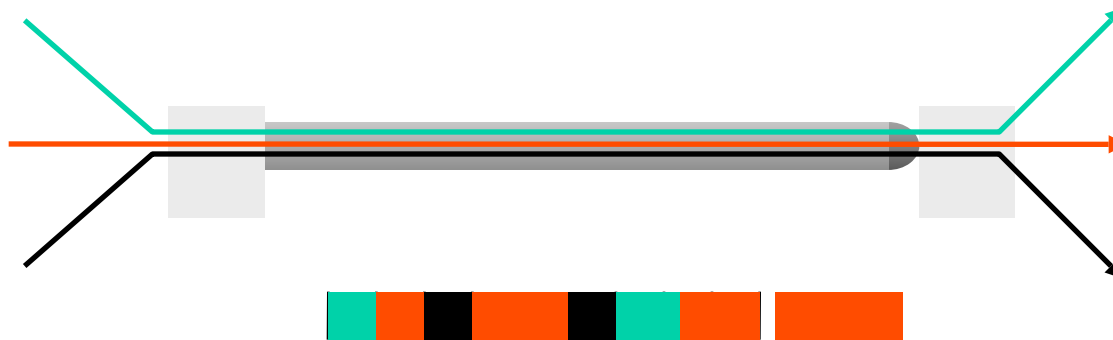- How to demultiplex?

Packet Switching: Multiplexing/ Demultiplexing

- Data from any conversation can be transmitted at any given time
  - A single conversation can use the entire link capacity if it is alone
- How to demultiplex?
  - Use meta-data (header) to describe data

Packet Switching

- Data are sent as formatted bit-sequences, so-called packets.
- Packets have the following structure:

Header	Data	Trailer

- Header and Trailer carry control information (e.g., destination address, check sum)

- At each node the entire packet is received, stored briefly, and then forwarded to the next node based on the header information (**Store-and-Forward Networks**)
- Allows statistical multiplexing

Packet Switch

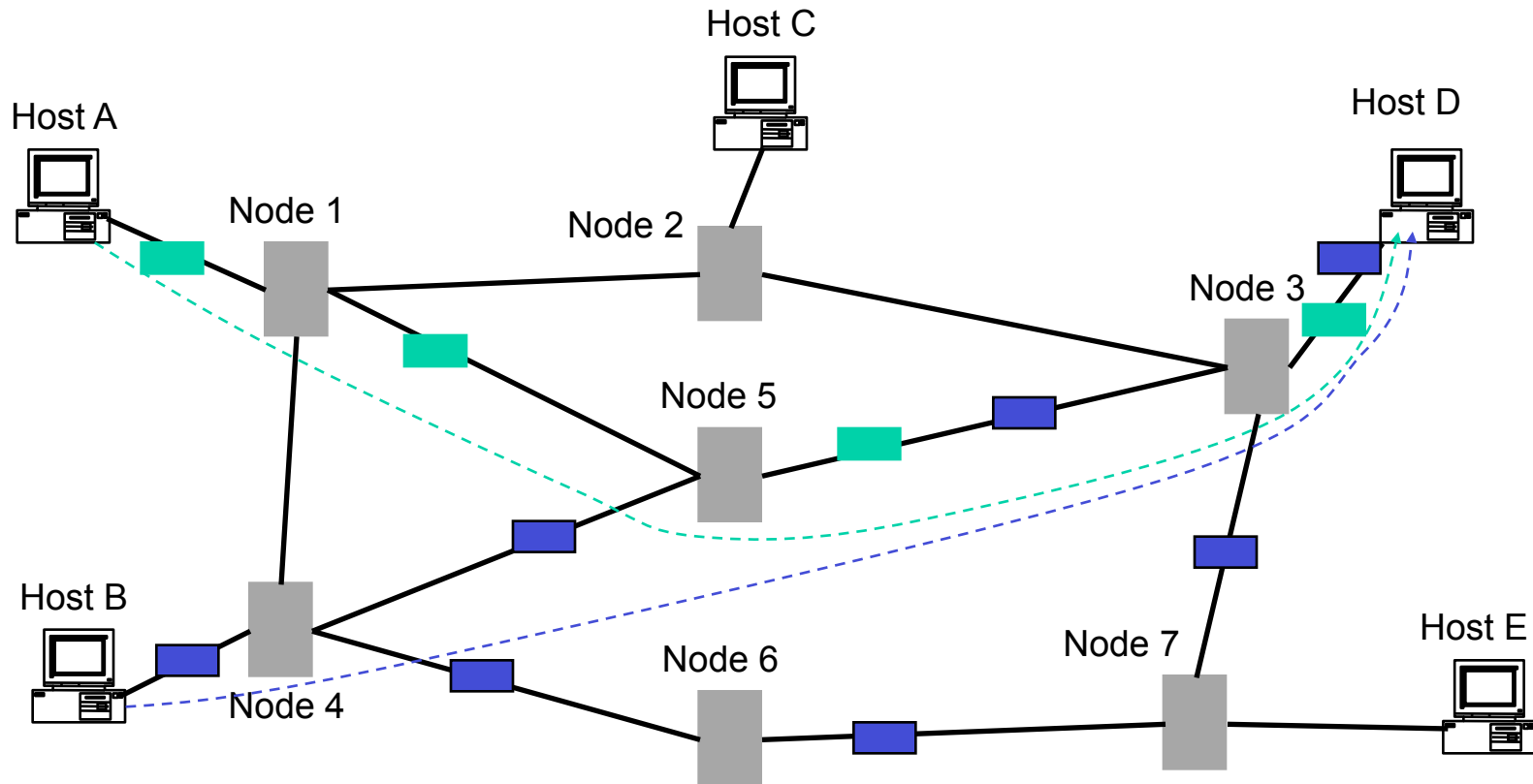incoming links   Node   outgoing links

Memory
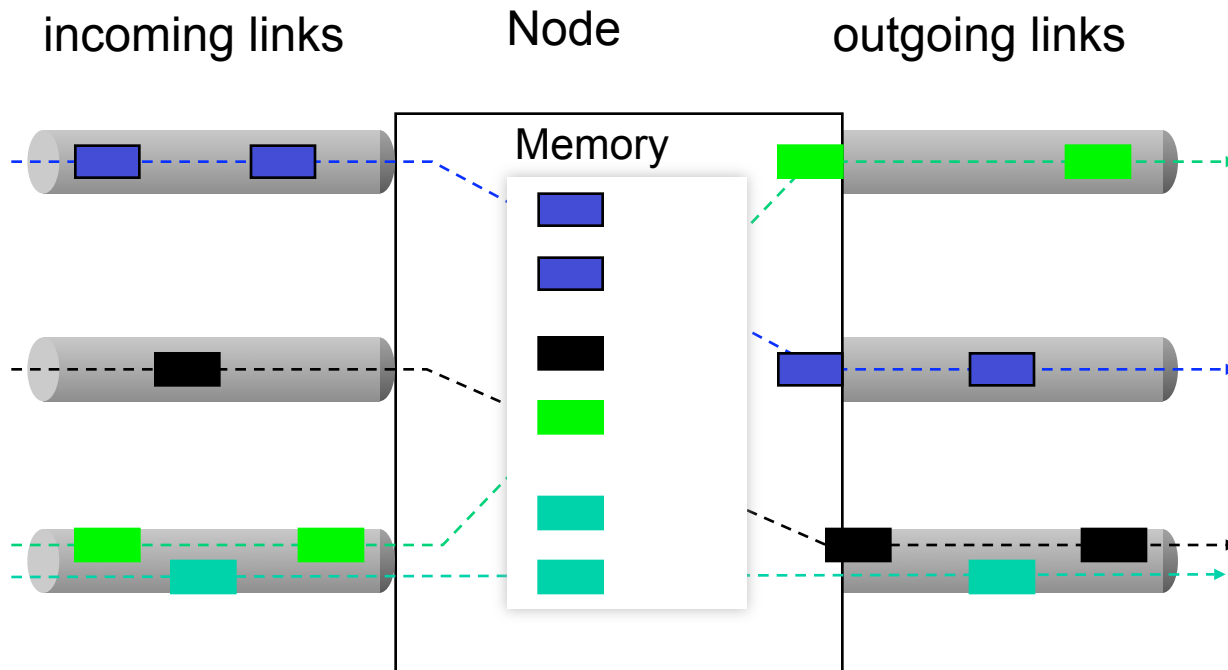
Datagram Packet Switching

Datagram Packet Switching

Host C

Host A

Host D

Node 1

Node 2

Node 3

Node 5

Host B

Node 6

Node 7

Host E

Node 4
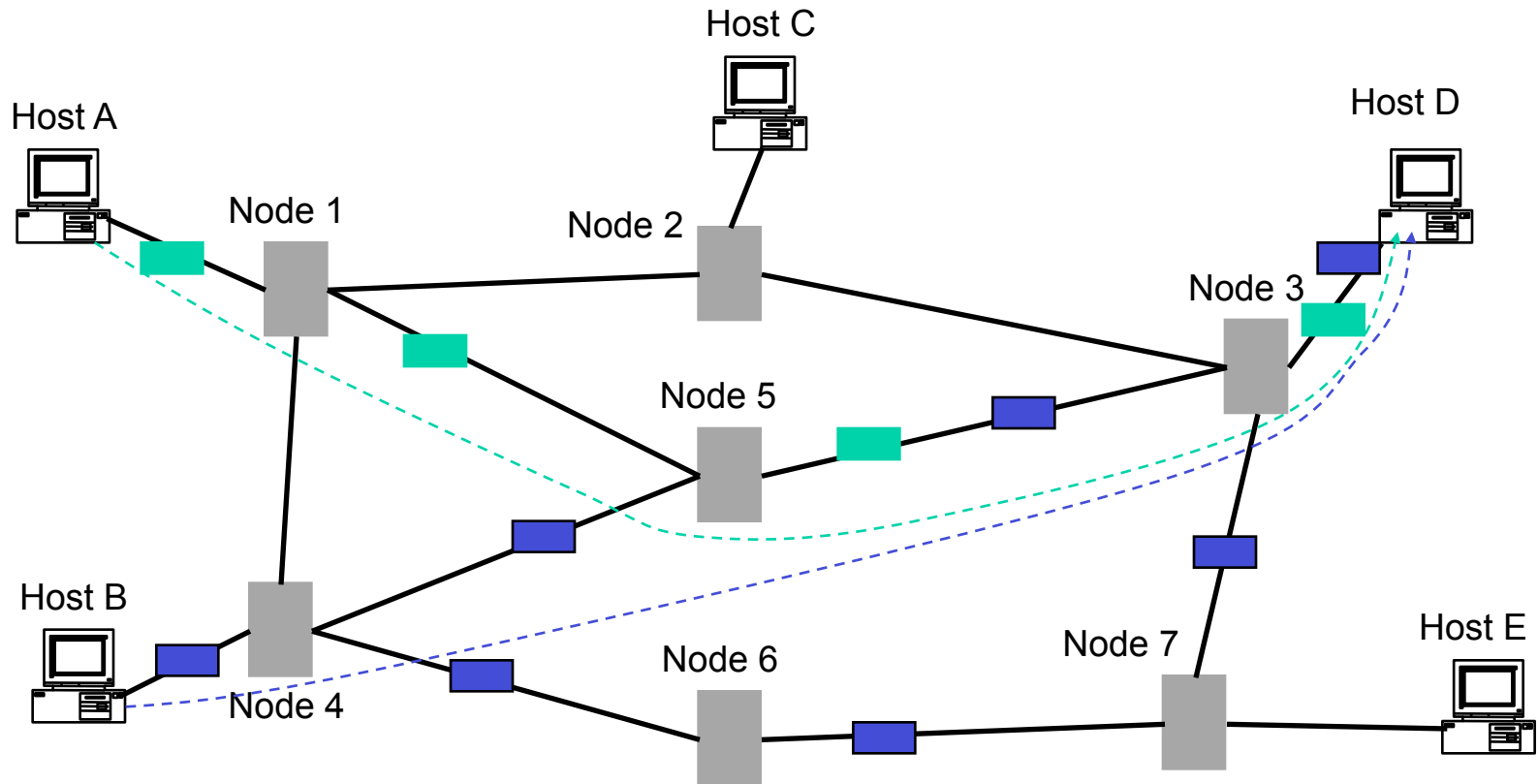
- Each packet is independently switched

Datagram Packet Switching

Host C

Host A

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Node 1

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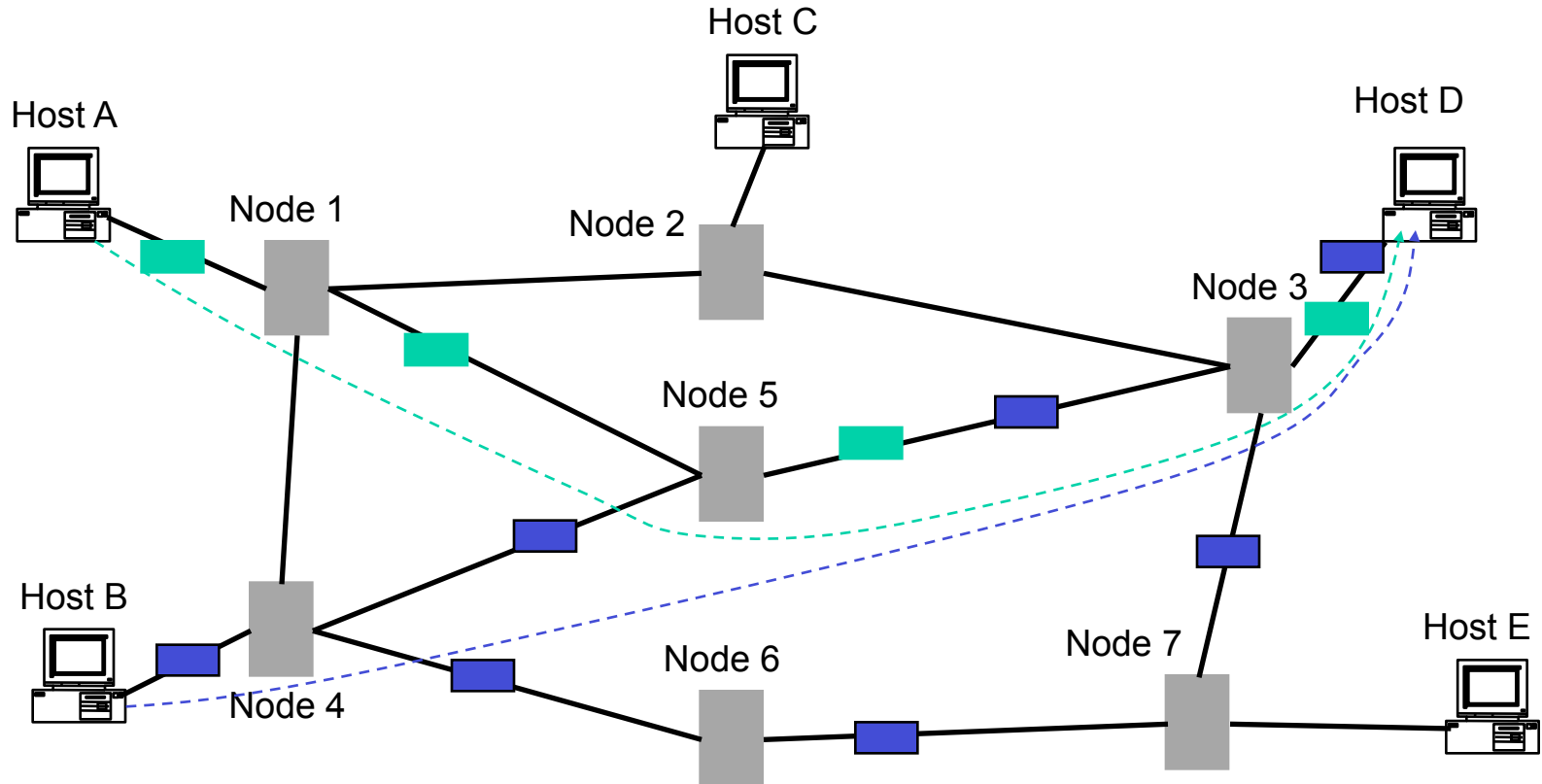
- Each packet is independently switched
  - Each packet header contains destination address

Timing of Datagram Packet Switching

Host 1

Switch 1

Switch 2

Host 2

transmission time of Packet 1 at Host 1

Packet 1

Packet 2

Packet 3

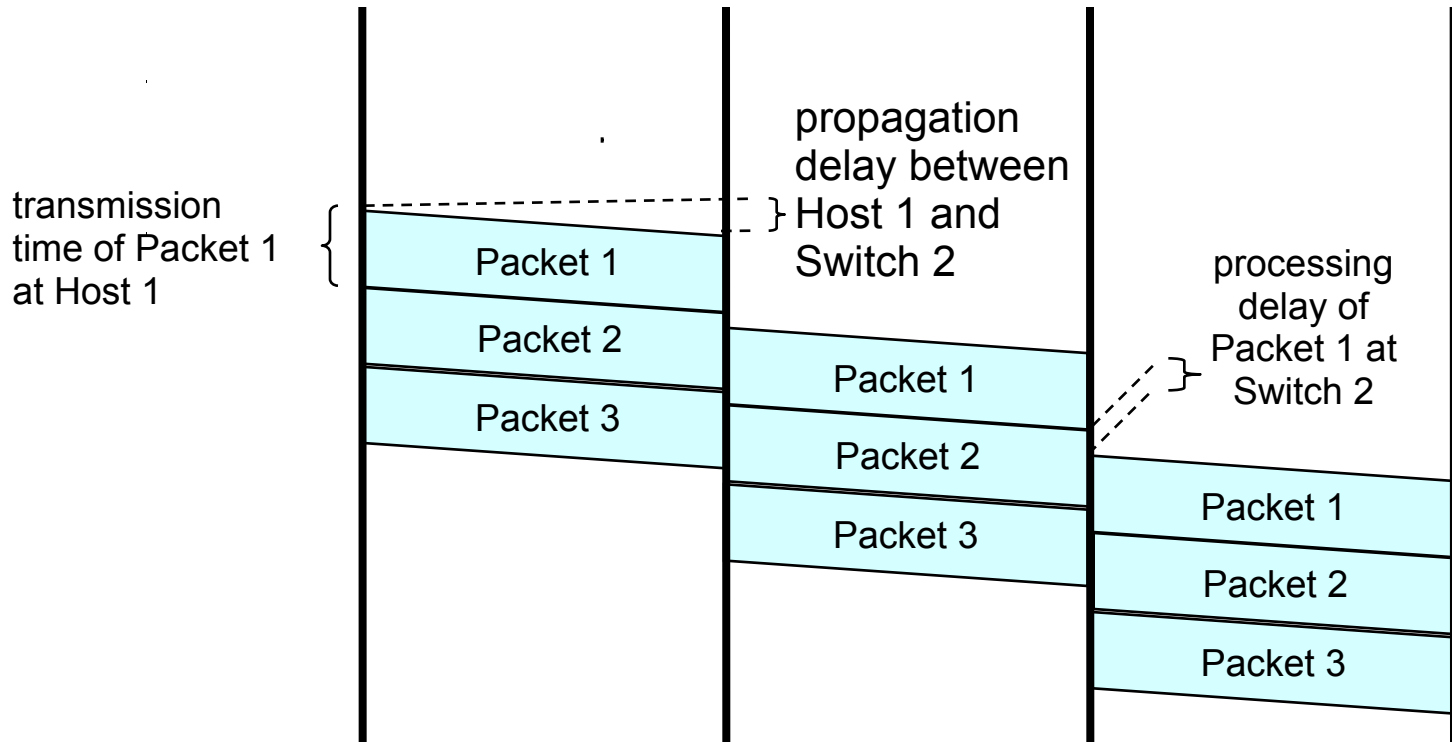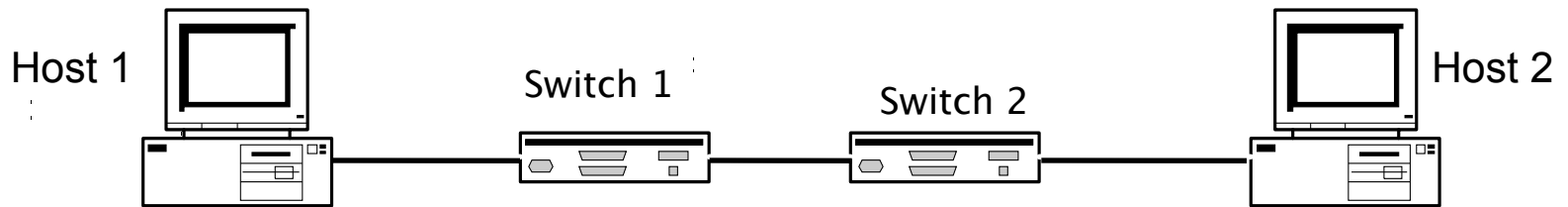propagation delay between Host 1 and Switch 2

Packet 1

Packet 2

Packet 3

processing delay of Packet 1 at Switch 2
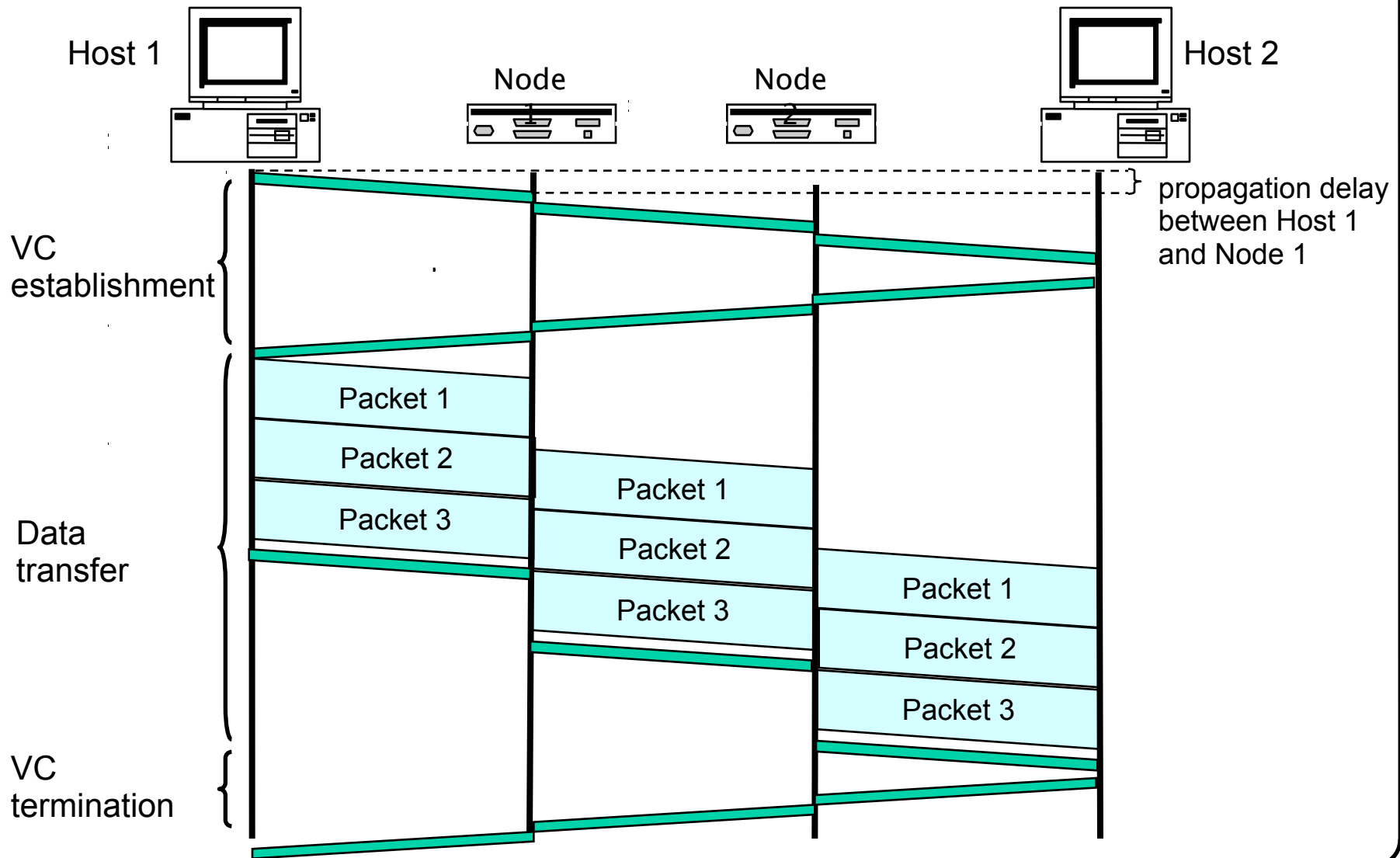
Packet 1

Packet 2

Packet 3

Virtual-Circuit Packet Switching

- Hybrid of circuit switching and packet switching
- Data is transmitted as packets
- All packets from one packet stream are sent along a pre-established path (=virtual circuit)
- Packet header only contains local virtual circuit identifier (VCI)
- Demultiplexing and switching based on VCI
- Guarantees in-sequence delivery of packets
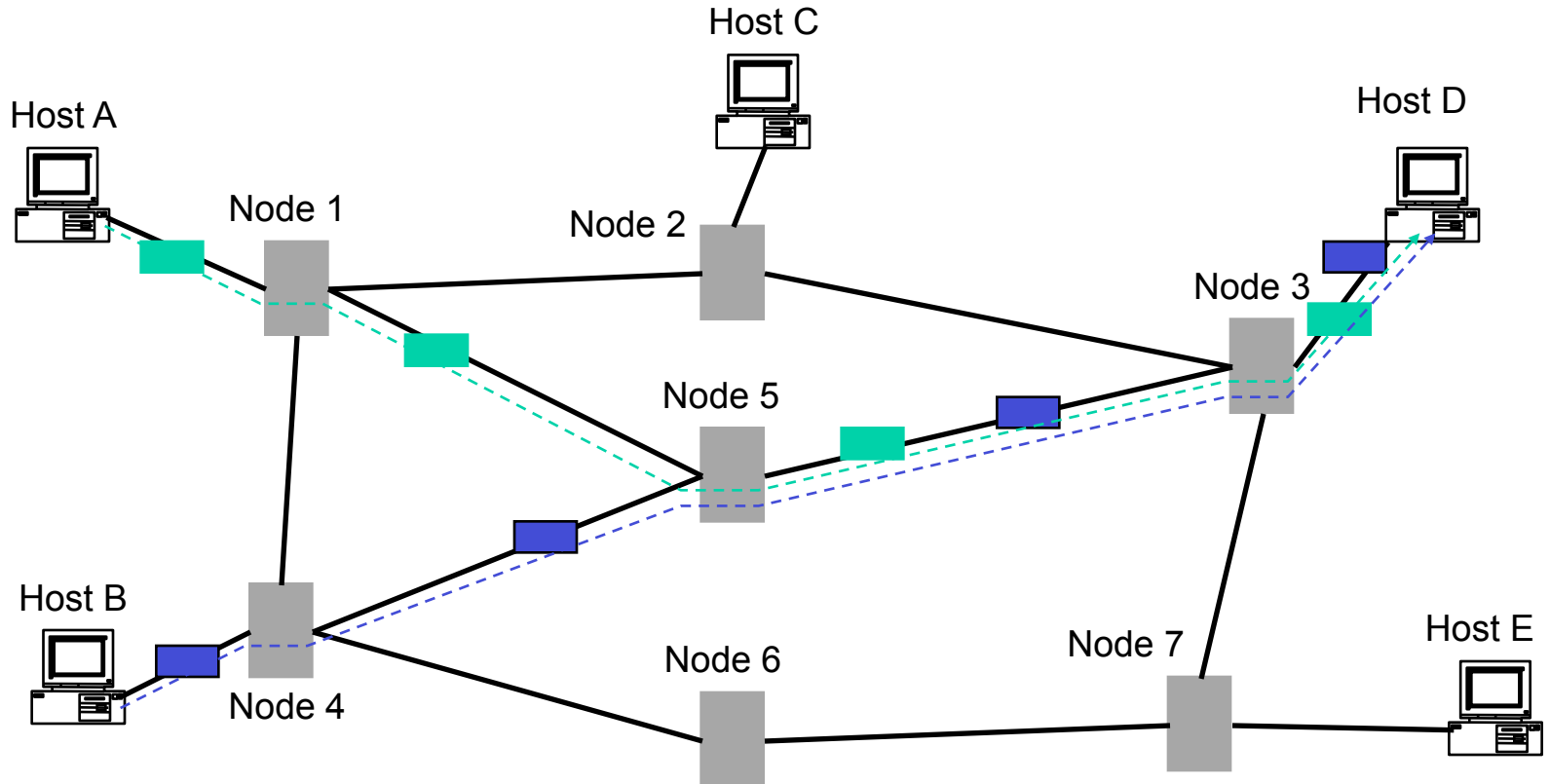- Example: ATM networks

Virtual-Circuit Packet Switching

- Communication with virtual circuits takes place in three phases
    1. VC establishment
    2. data transfer
    3. VC disconnect
- Note: packet headers don't need to contain the full destination address of the packet

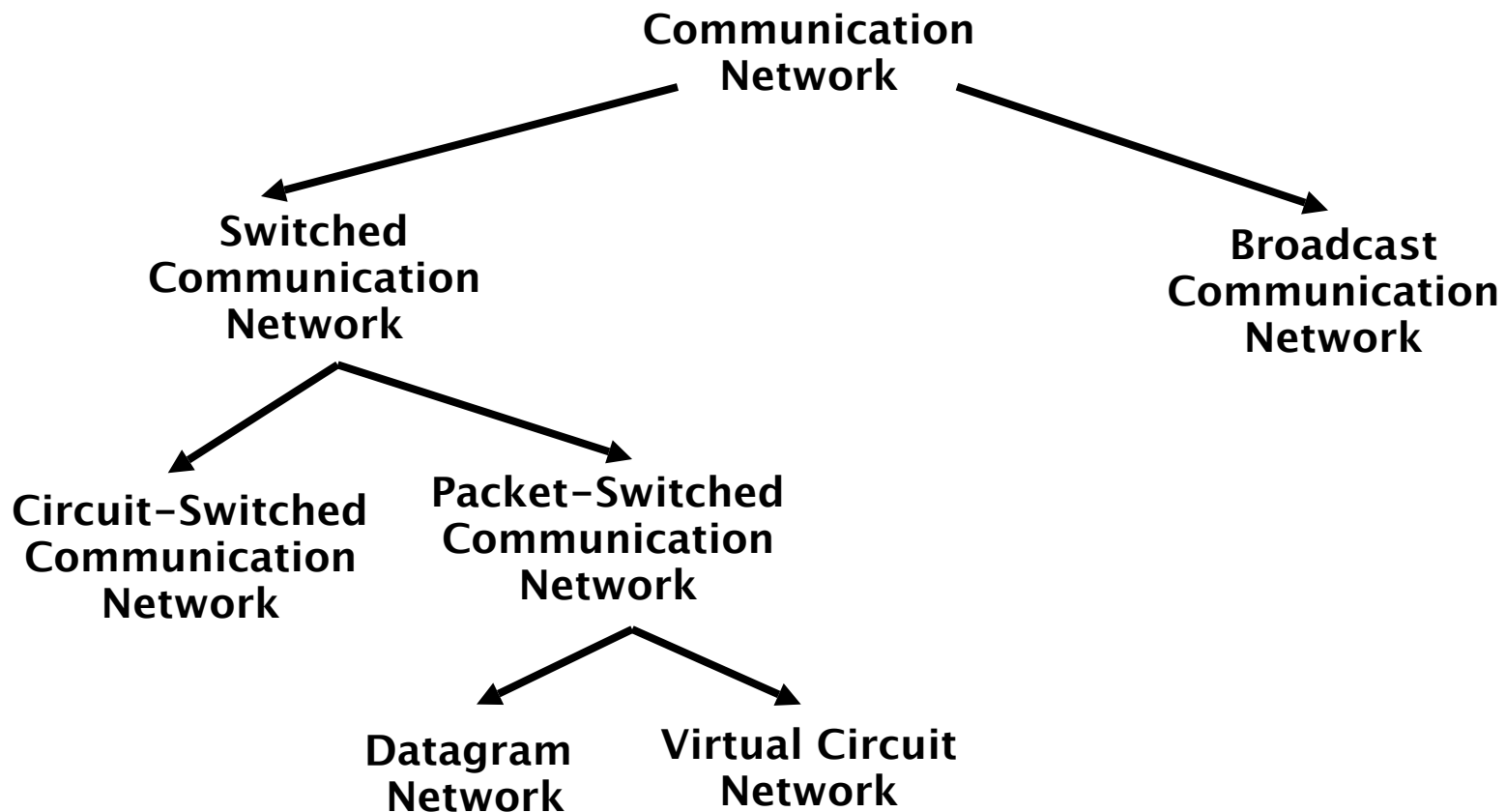# Timing of Virtual-Circuit Packet Switching

Virtual Circuit Switching

A Taxonomy of Communication Networks

- Communication networks can be classified based on the way in which the nodes exchange information:

Communication Network

Switched Communication Network

Broadcast Communication Network

Circuit-Switched Communication Network

Packet-Switched Communication Network

Datagram Network

Virtual Circuit Network

Packet-Switching vs. Circuit-Switching

Packet-Switching vs. Circuit-Switching

- Most important advantage of packet-switching over circuit switching: ability to exploit statistical multiplexing
  - More efficient bandwidth usage
- However, packet-switching needs to buffer and deal with congestion
  - More complex switches
  - Harder to provide good network services (e.g., delay and bandwidth guarantees)