# Switching

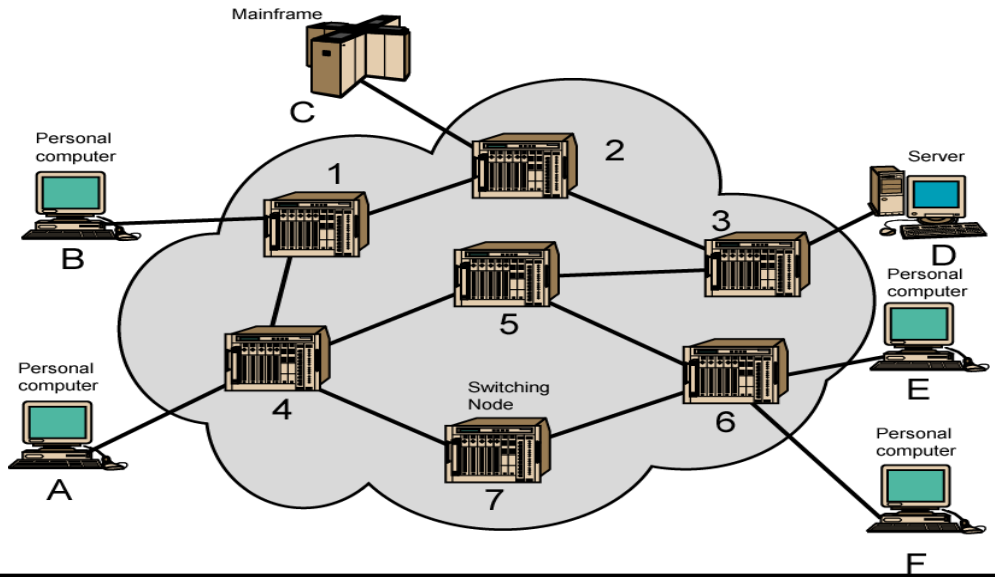
## Switched Networks

- Long distance transmission is typically done over a network of switched nodes
- Switching nodes not concerned with content of data
- End devices are hosts
  - Computer, server, phone, etc.
- A collection of nodes and links is a communication network
- Data (packet/message/circuit) routed by being switched from node to node

# Nodes

- Nodes may connect to other nodes only, or to stations and other nodes
- Node to node links usually multiplexed
- Network is usually partially connected
  - Some redundant connections are desirable for reliability
- Three different switching technologies
  - Circuit switching
  - Packet switching
  - Virtual circuit switching

# Simple Switched Network



# Switching

- Circuit Switching
  - Fixed and mobile telephone network
    - Frequency Division Multiplexing (FDM)
    - Time Division Multiplexing (TDM)
  - Optical rings (SDH)
- Packet Switching
  - Internet
    - Statistical multiplexing
- Virtual circuit switching
  - Data is switched as packets but routed through logical circuits
  - Takes the best of both forms of switching

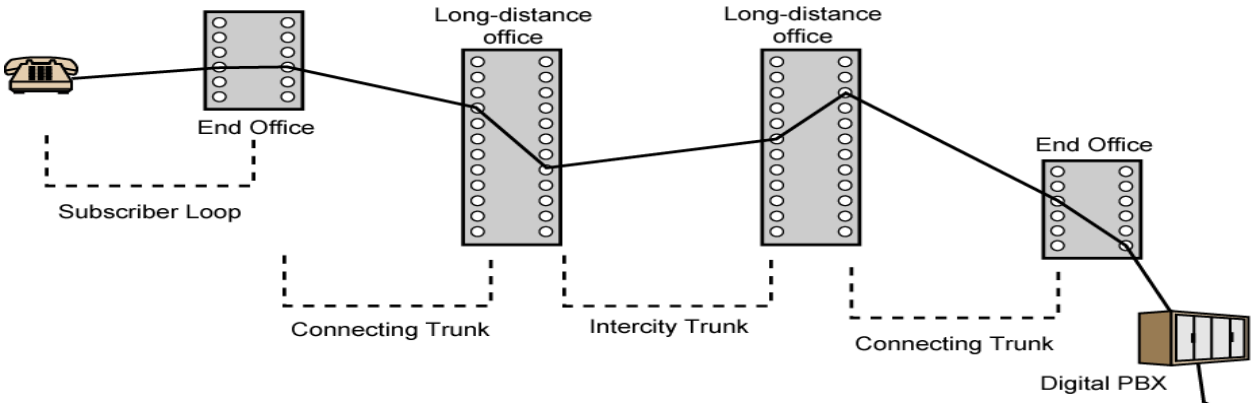
# Circuit Switching

- Dedicated communication path between two stations
- Three phases
  - Establish
  - Transfer
  - Disconnect
- Must have switching capacity and channel capacity to establish connection
- Must have intelligence to work out routing

# Circuit Switching - Applications

- Inefficient
  - Channel capacity dedicated for duration of connection
  - If no data, capacity wasted
- Set up (connection) takes time
- Once connected, transfer is transparent
- Developed for voice traffic (phone)

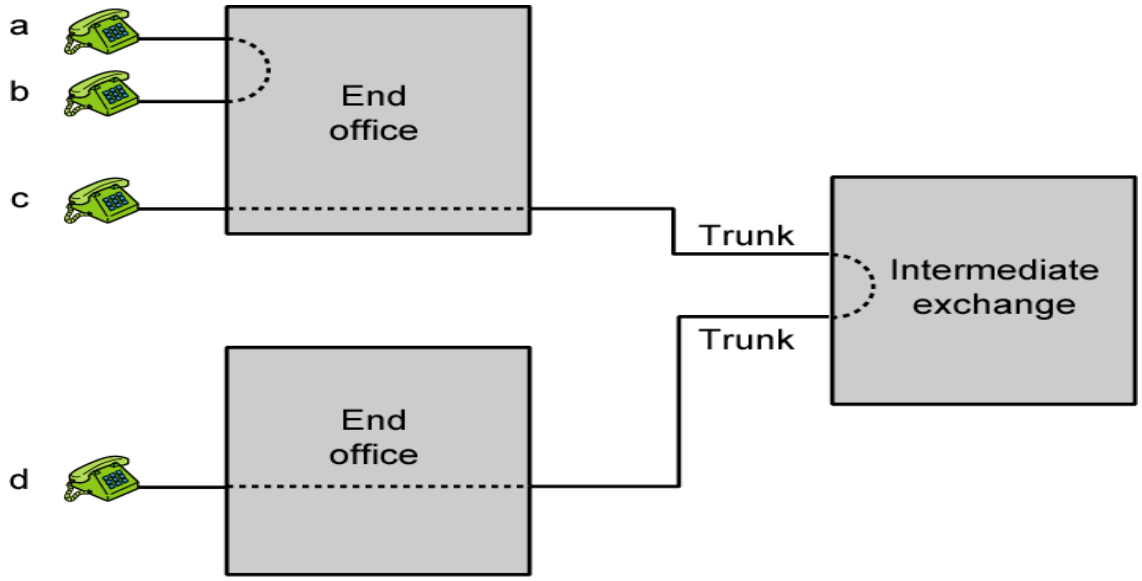
# Public Circuit Switched Network



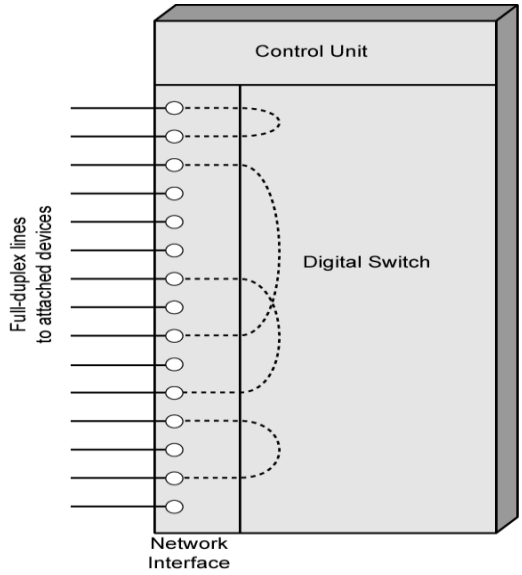
# Telecom Components

- Subscriber
  - Devices attached to network
- Subscriber line
  - Local Loop
  - Subscriber loop
  - Connection to network
  - Few km up to few tens of km
- Exchange
  - Switching centers
  - End office - supports subscribers
- Trunks
  - Branches between exchanges
  - Multiplexed

# Circuit Establishment



# Circuit Switch Elements




# Circuit Switching Concepts

- Digital Switch
  - Provide transparent signal path between devices
- Network Interface
- Control Unit
  - Establish connections
    - Generally on demand
    - Handle and acknowledge requests
    - Determine if destination is free
    - construct path
  - Maintain connection
  - Disconnect

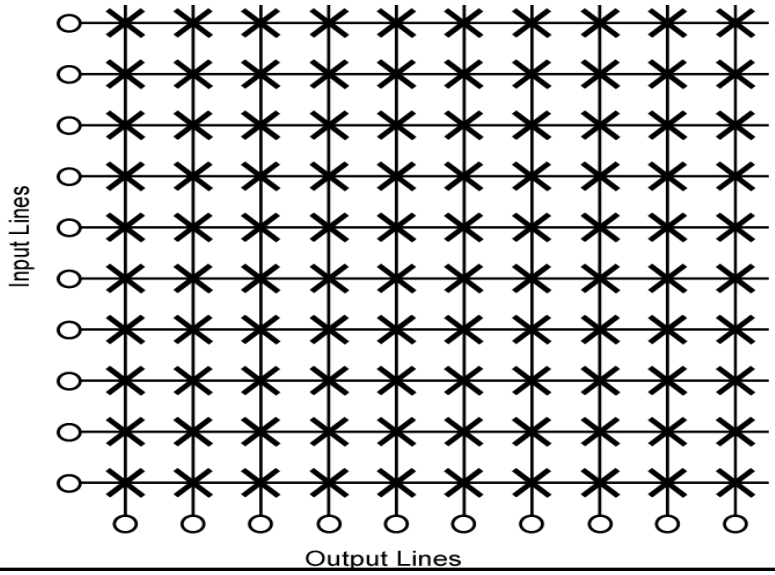
# Blocking or Non-blocking

- Blocking
  - A network is unable to connect stations because all paths are in use
  - A blocking network allows this
  - Used on voice systems
    - Short duration calls
- Non-blocking
  - Permits all stations to connect (in pairs) at once
  - Used for some data connections

# Space Division Switching

- Developed for analog environment
- Separate physical paths
- Crossbar switch
  - Number of crosspoints grows as square of number of stations
  - Loss of crosspoint prevents connection
  - Inefficient use of crosspoints
    - All stations connected, only a few crosspoints in use
  - Non-blocking

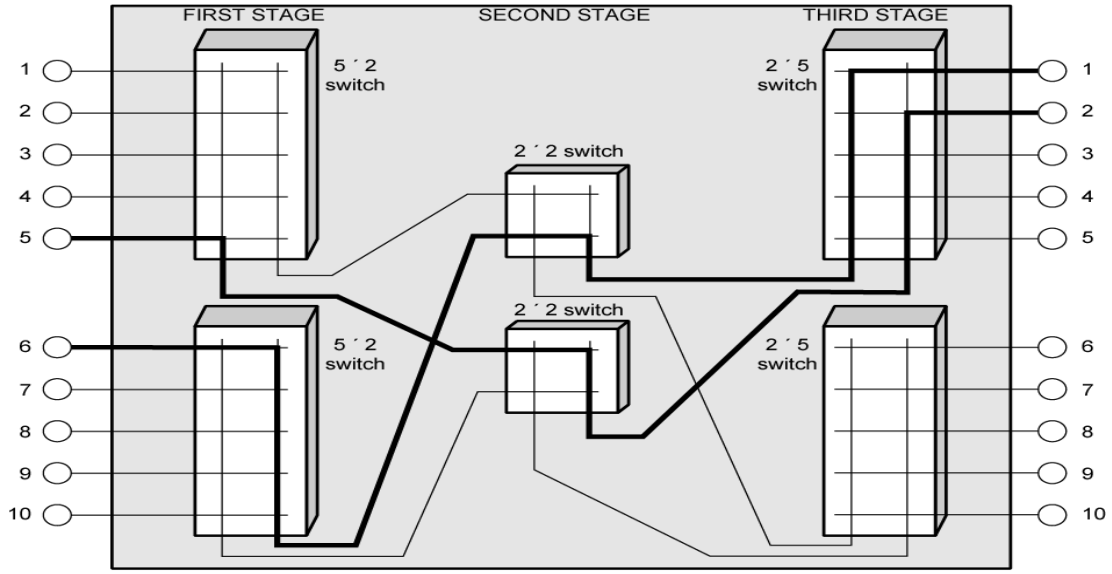
# Space Division Switch




# Multistage Switch

- Reduced number of crosspoints
- More than one path through network
  - Increased reliability
- More complex control
- May be blocking
  - No path available through the fabric even if the output port is free

# Three Stage Space Division Switch

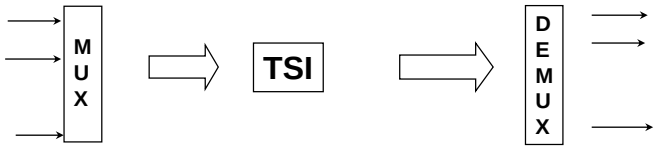



# Time Division Switching

- Modern digital systems rely on intelligent control of space and time division elements
- Use digital time division techniques to set up and maintain virtual circuits
- Partition low speed bit stream into pieces that share higher speed stream

# Time division switching

- Key idea: when demultiplexing, position in frame determines output link
- Time division switching interchanges sample position within a frame:
  - Time slot interchange (TSI)

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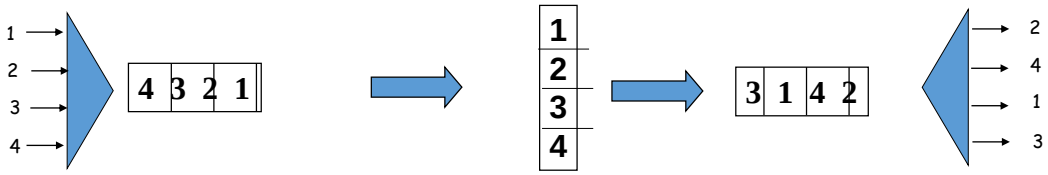
# Time Slot Interchange (TSI) : example

*sessions: (1,3) (2,1) (3,4) (4,2)*




**Read and write to shared memory in different order**

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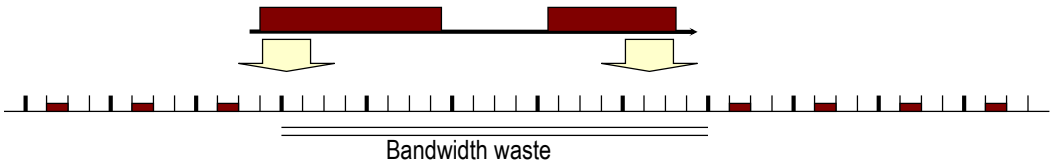
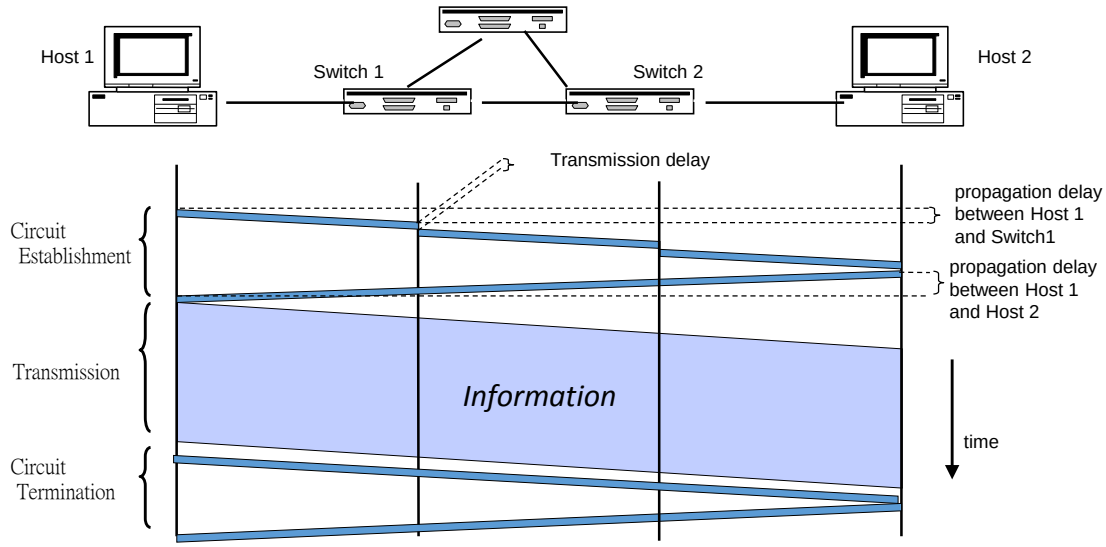
# Circuit Switching Pros & Cons

- Advantages
  - Limited overhead
  - Very efficient switching fabrics
    - Highly parallelized
- Disadvantages
  - Requires signalling for switching tables set-up
  - Underutilization of resources in the presence of bursty traffic and variable rate traffic




## Example of Timing in Circuit Switching

(Details could vary depending on the implementation of circuit setup and termination)

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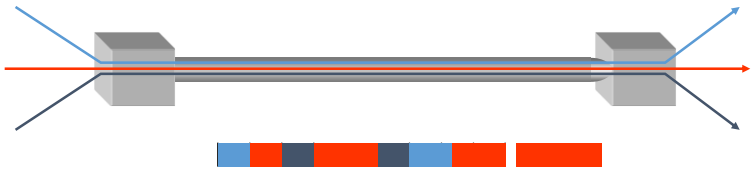
# Example of bursty traffic (ON/OFF voice flows)


VOICE SOURCE MODEL for conversation (Brady):
average ON duration (talkspurt): 1 second
average OFF duration (silence): 1,35 seconds

$$activity = \frac{T_{ON}}{T_{ON} + T_{OFF}} = \frac{1}{1+1.35} = 42.55\% \quad (\text{before packetization})$$

Efficiency = utilization % = source activity

# 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

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## Message/packet Switching vs circuit switching

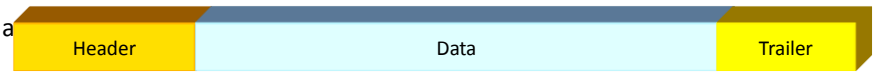

| header | mesg/pack |
|---|---|

Router:
- reads header (destination address)
- selects output path

- Advantages
  - Transmission resources used only when needed (data available)
  - No signalling needed
- Disadvantages
  - Overhead
  - Inefficient routing fabrics (needs to select output per each packet)
  - Processing time at routers (routing table lookup)
  - Queueing at routers

## Packet Switching

- Data are sent as formatted bit-sequences, so-called packets.
- Packets ha




  - 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

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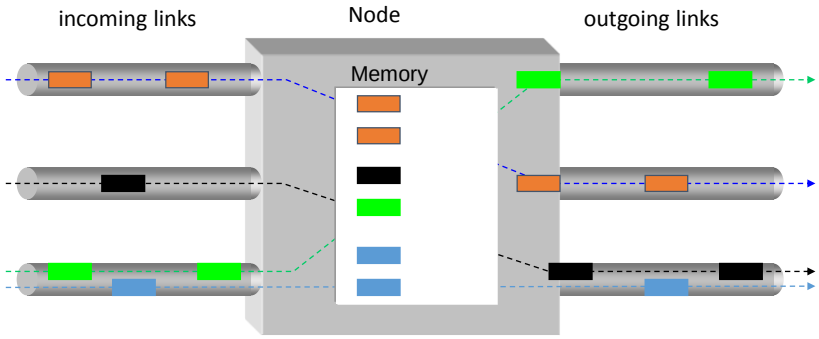
# Packet Switch

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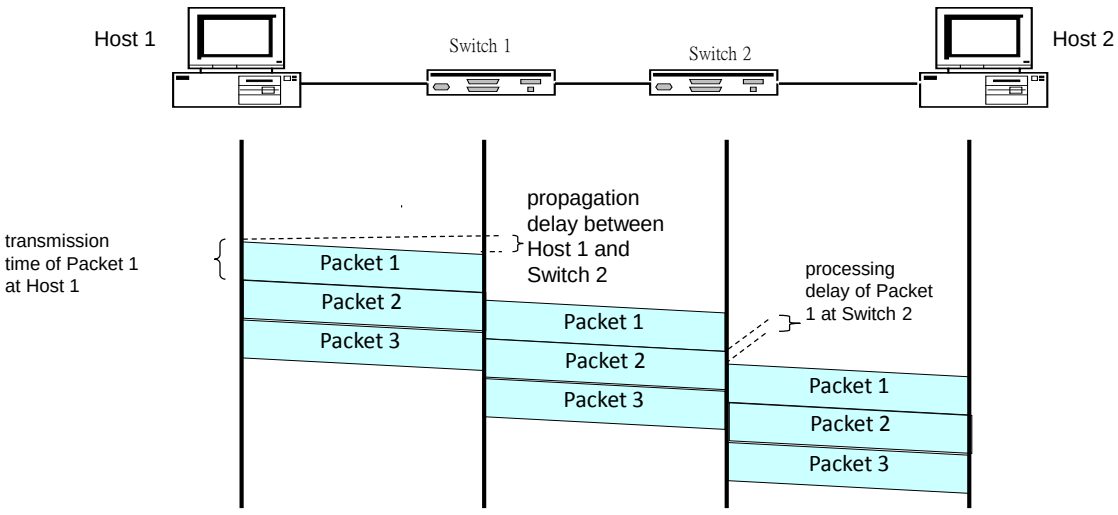
# Timing of Datagram Packet Switching

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# 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)

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# Virtual-Circuit 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/MPLS networks

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# Virtual-Circuit 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

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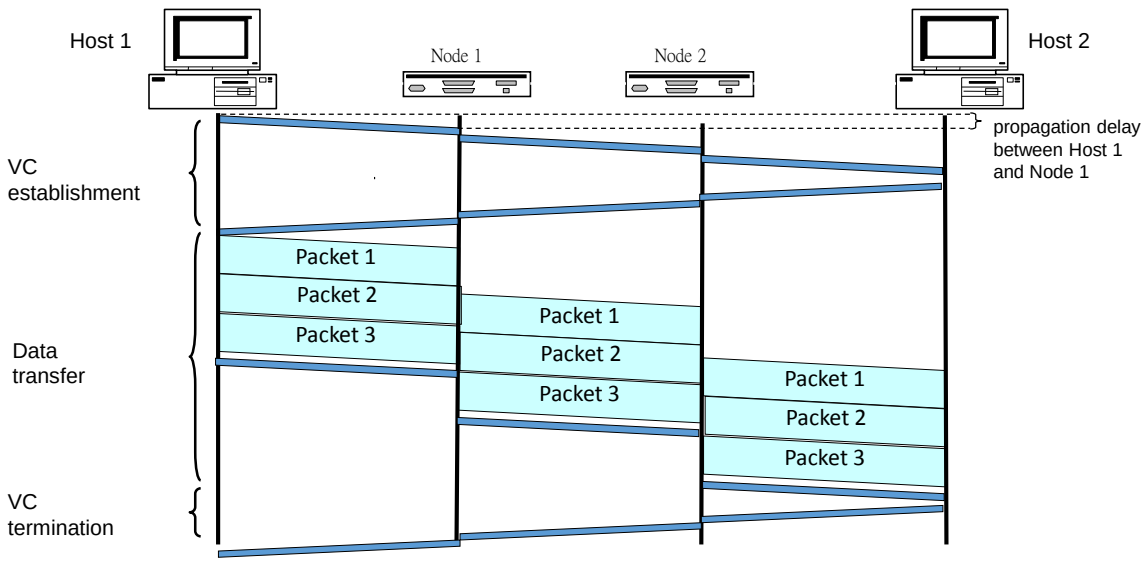
# Timing of Virtual-Circuit Packet Switching

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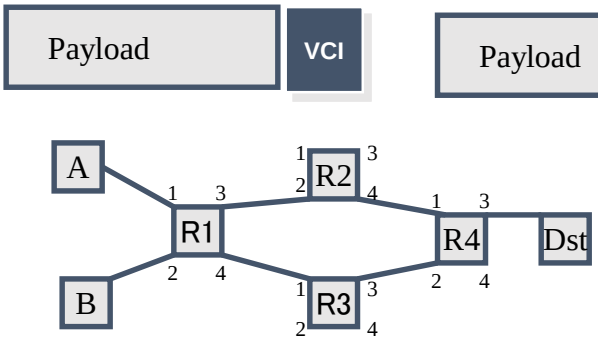
# Packet switched vs. VC




R1 packet forwarding table:

Dst R2

R1 VC table:

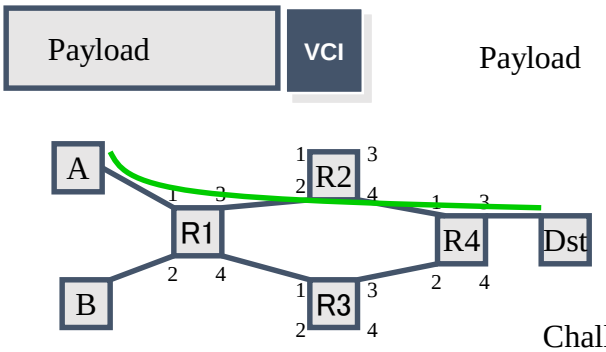
VC 1 R2

VC 2 R3

Different paths to same destination!

(useful for traffic engineering!)

# Virtual Circuit




R1 VC table:

VC 5 R2

R2 VC table:

VC 5 R4

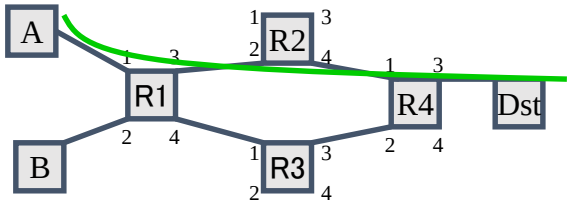
Challenges:

- How to set up path?
- How to assign IDs??

# Connections and Signaling

- Permanent vs. switched virtual connections (PVCs, SVCs)
  - static vs. dynamic. PVCs last "a long time"
    - E.g., connect two bank locations with a PVC
    - SVCs are more like a phone call
  - PVCs administratively configured (but not "manually")
  - SVCs dynamically set up on a "per-call" basis
- Topology
  - point to point
  - point to multipoint
  - multipoint to multipoint
- Challenges: How to configure these things?
  - What VCI to use?
  - Setting up the path

# Virtual Circuit Switching: Label ("tag") Swapping




- Global VC ID allocation -- Bad Solution: Per-link uniqueness. *Change VCI each hop.*

| | Input Port | Input VCI | Output Port | Output VCI |
|---|---|---|---|---|
| R1: | 1 | 5 | 3 | 9 |
| R2: | 2 | 9 | 4 | 2 |
| R4: | 1 | 2 | 3 | 5 |