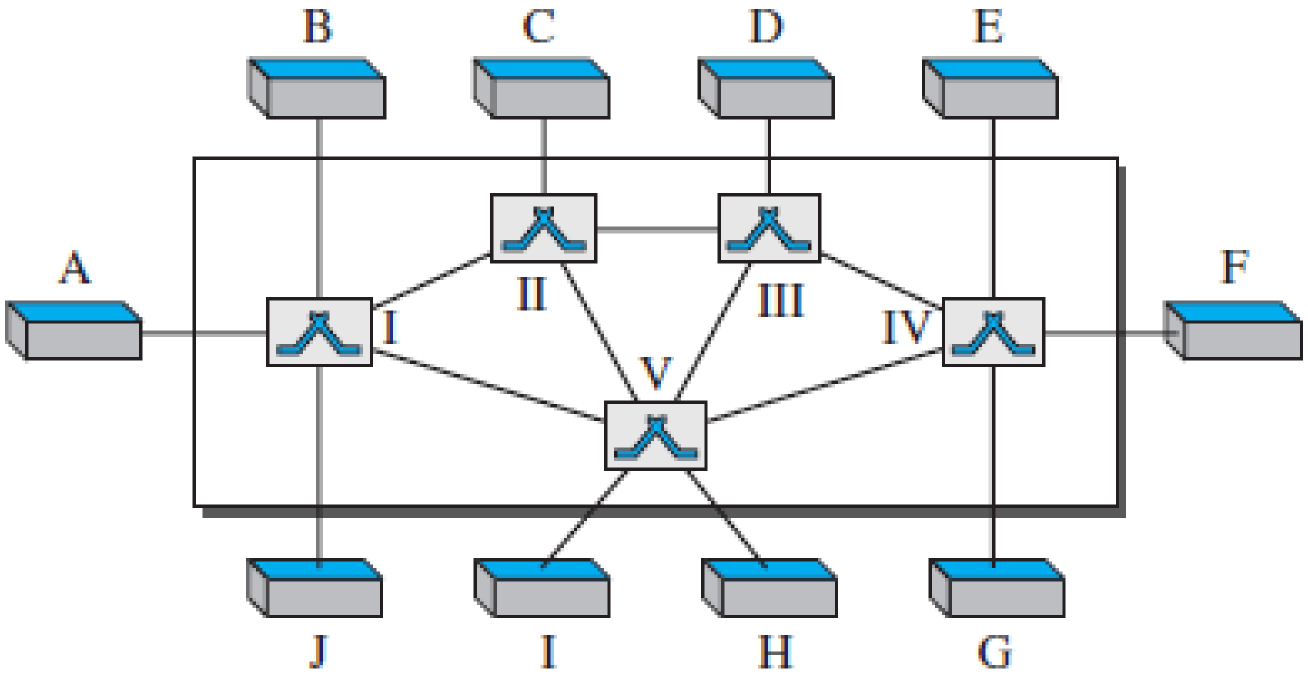
# Switching

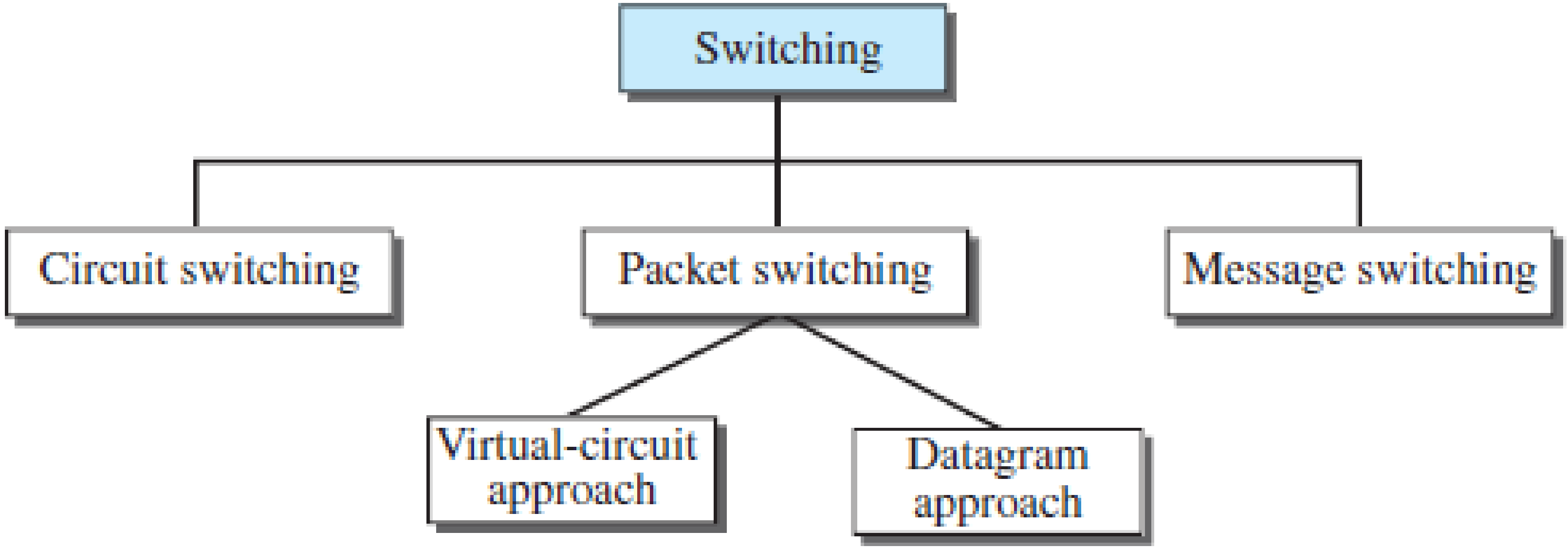
ICT 2255

# Introduction

- Why switching?
- A **switched network** consists of a series of interlinked nodes, called ***switches*.**

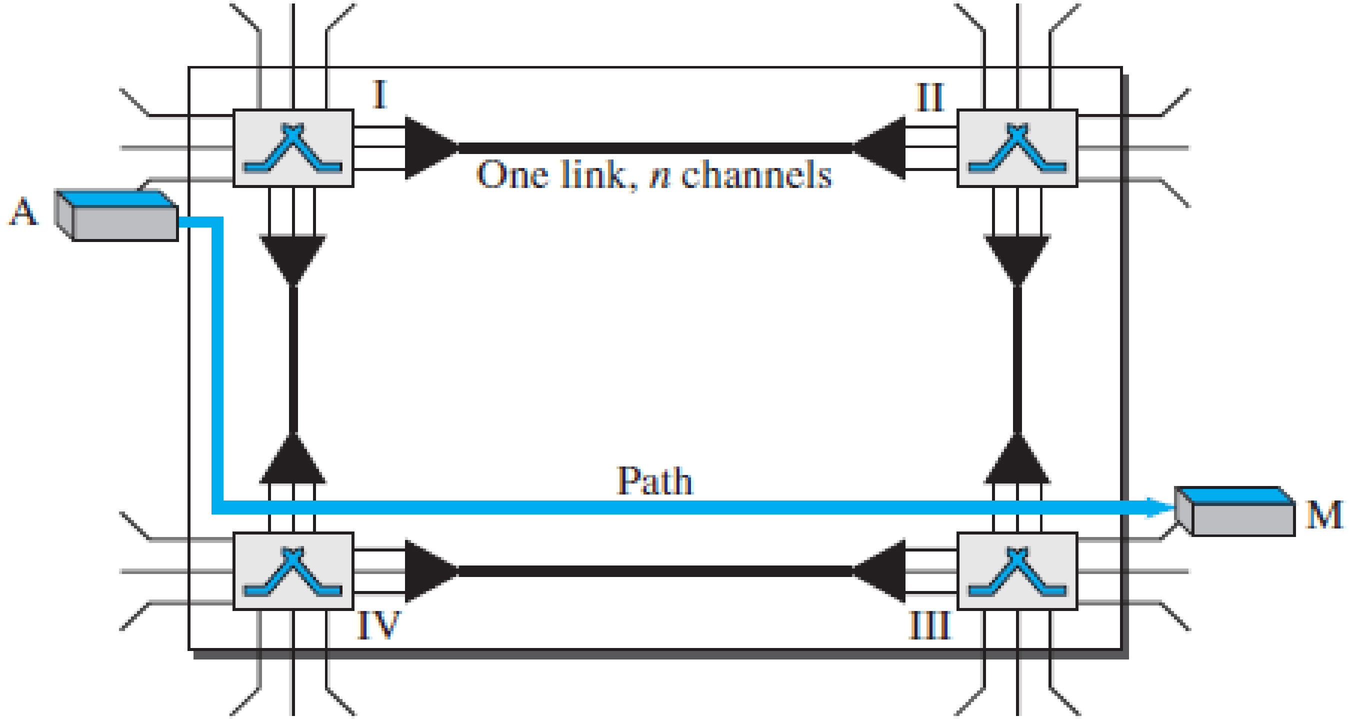


# Methods of Switching

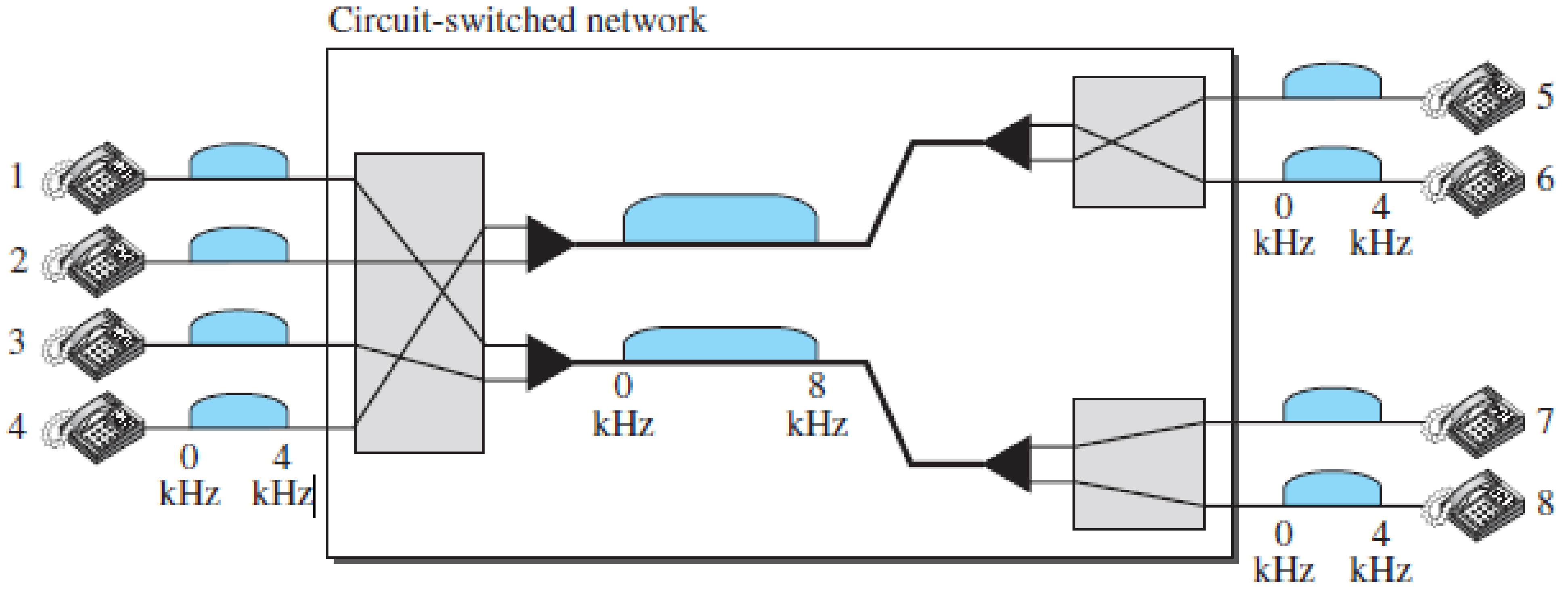


# Circuit-Switched Networks

- A circuit-switched network is made of a set of switches connected by **physical links**, in which each **link** is divided into ***n* channels**.



# Circuit-Switched Networks



# Circuit-Switched Networks: Phases

**Setup**

- A dedicated **circuit** needs to be established.
- Make a reservation of the **resources**.
- End-to-end addressing for creating a connection.

**Data Transfer**

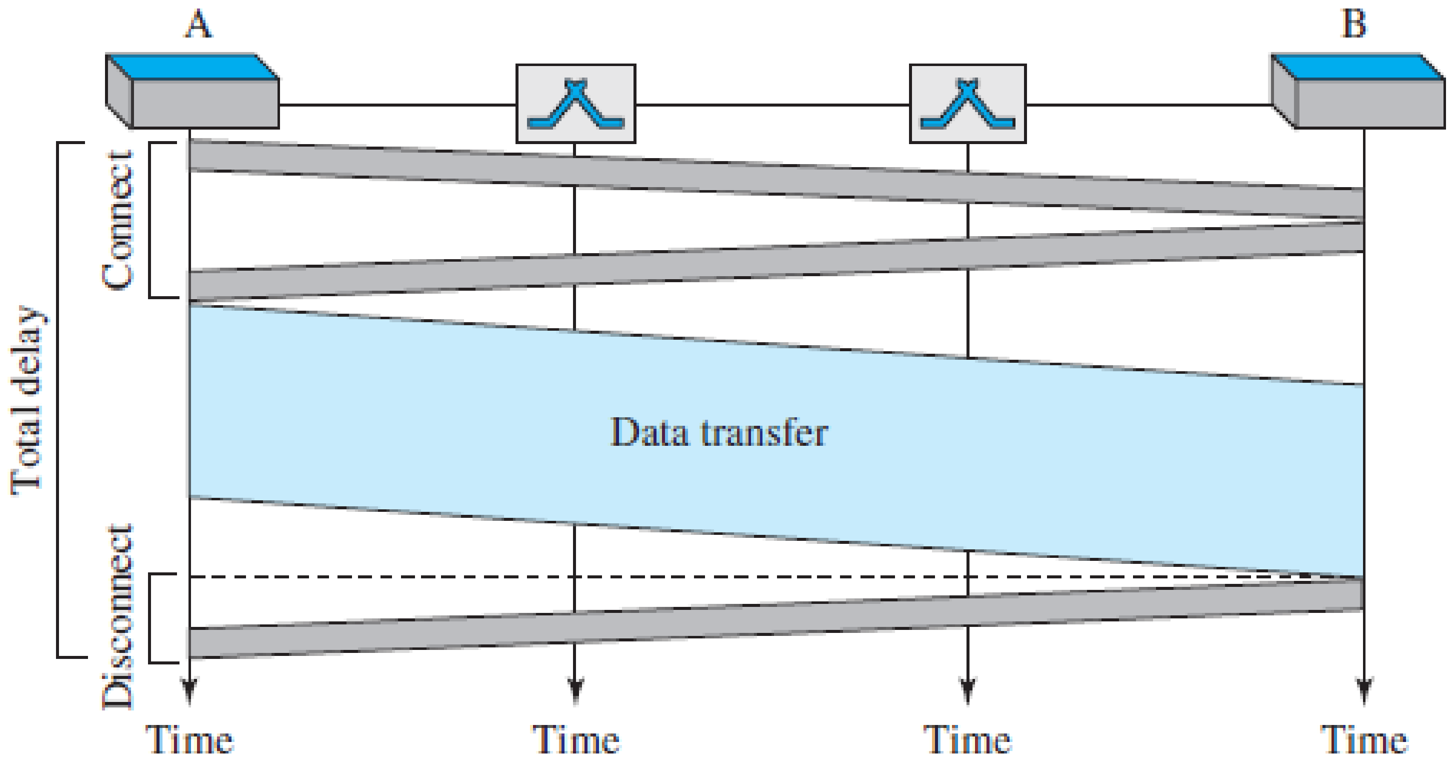
- Continuous flow of data; not packetized.

**Teardown**

- Signal sent to release resources.
  Who sends the signal for disconnection?

# Circuit-Switched Networks: Evaluation

- Efficiency
    - Not as efficient. Why?
- Delay
    - Minimal Delay.
    - Delay=?

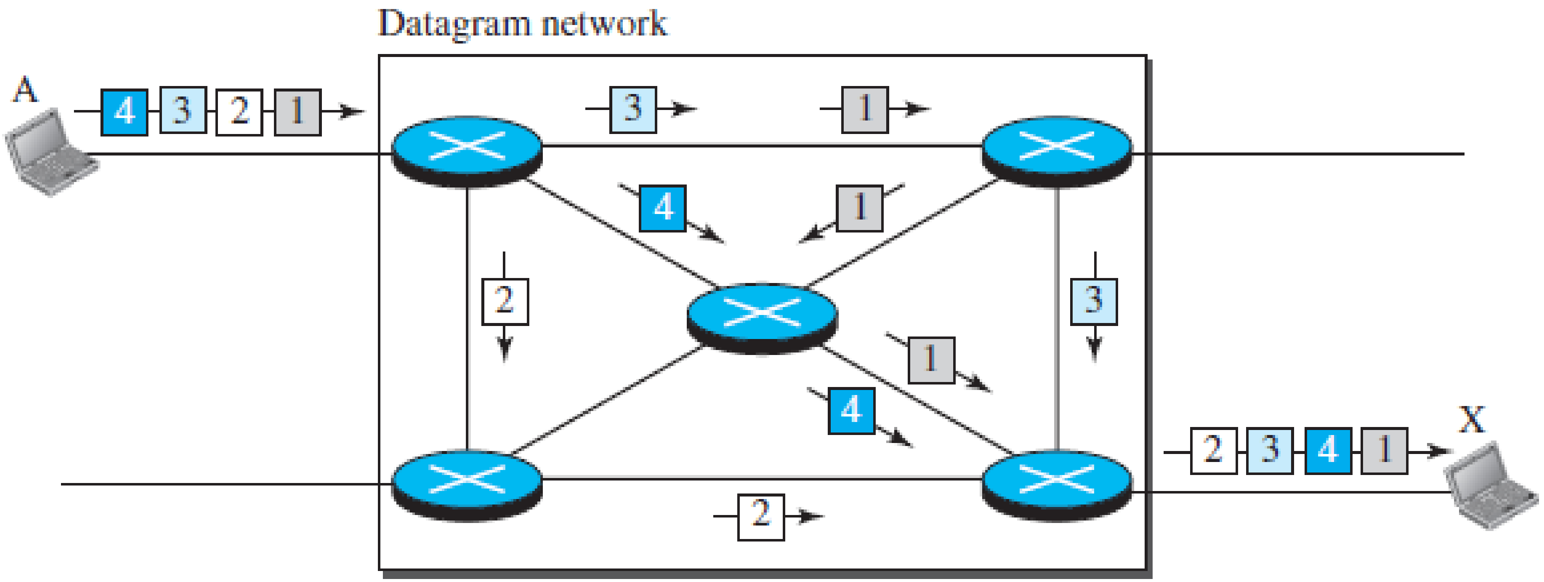


# Packet Switching

- Messages are divided into packets of fixed or variable **size**.
- No prior resource allocation. Resource allocation: **on demand**.
- Waiting time at switches.
- Two types of packet-switched networks:
    - Datagram networks.
    - Virtual-circuit networks.

# Datagram Networks

- Packets/Datagrams treated independently.
- Performed at NL.
- Switches here are referred as routers.

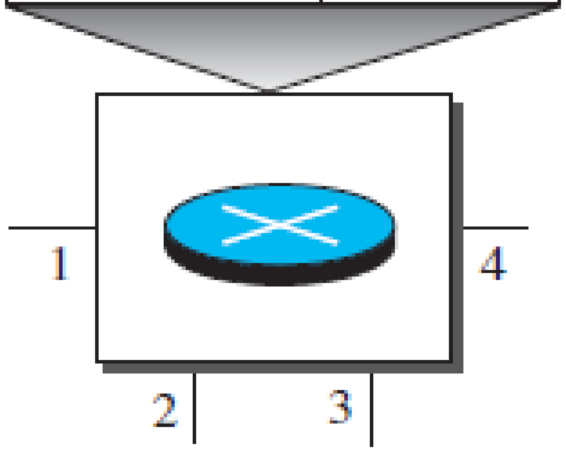



In the absence of a setup phase, how do the switches know where to send the individual packets?

# Datagram Networks- Routing Table

- Based on **destination address**.
- Dynamic tables.
- Updated periodically.
- **The destination address in the header of a packet in a datagram network remains the same during the entire journey of the packet.**

| Destination address | Output port |
|---|---|
| 1232 | 1 |
| 4150 | 2 |
| ⋮ | ⋮ |
| 9130 | 3 |



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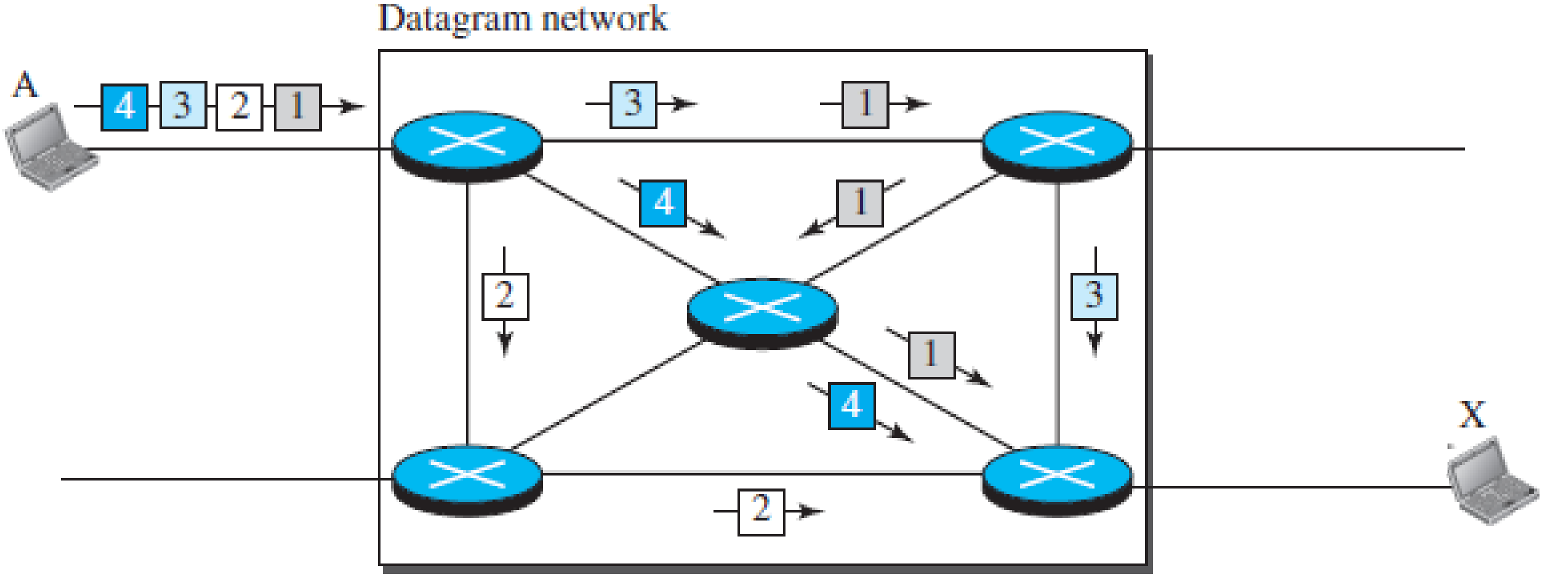
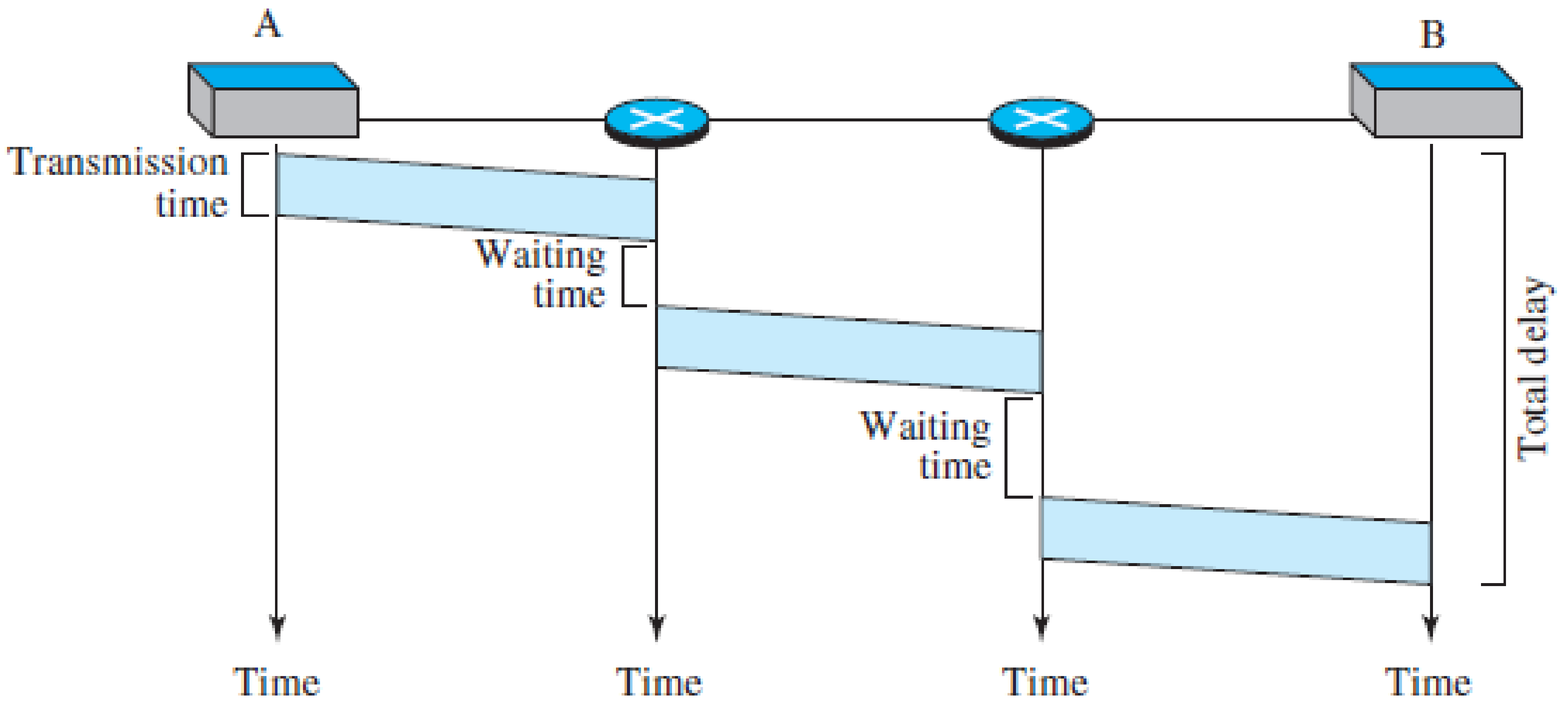


# Datagram Networks: Evaluation

- Efficiency
  - Better than circuit-switched networks. Why?
- Delay



# Virtual-Circuit Networks

- Cross between circuit-switched network and datagram network.
- Comparison

| | Circuit-Switched Networks | Virtual-Circuit Networks | Datagram Networks |
|---|---|---|---|
| Setup and Teardown | Yes | Yes | No |
| Resource Allocation | Prior | Prior/On-Demand | On-Demand |
| Data | In a flow from sender to receiver. No address. | Packetized. Each packet has **local address**. | Packetized. Each packet has **global address.** |
| Path followed | Packets follow same path. | Packets follow same path. | Packets follow different path. |
| Implemented in | PL | DLL | NL |

# Virtual-Circuit Networks: Addressing

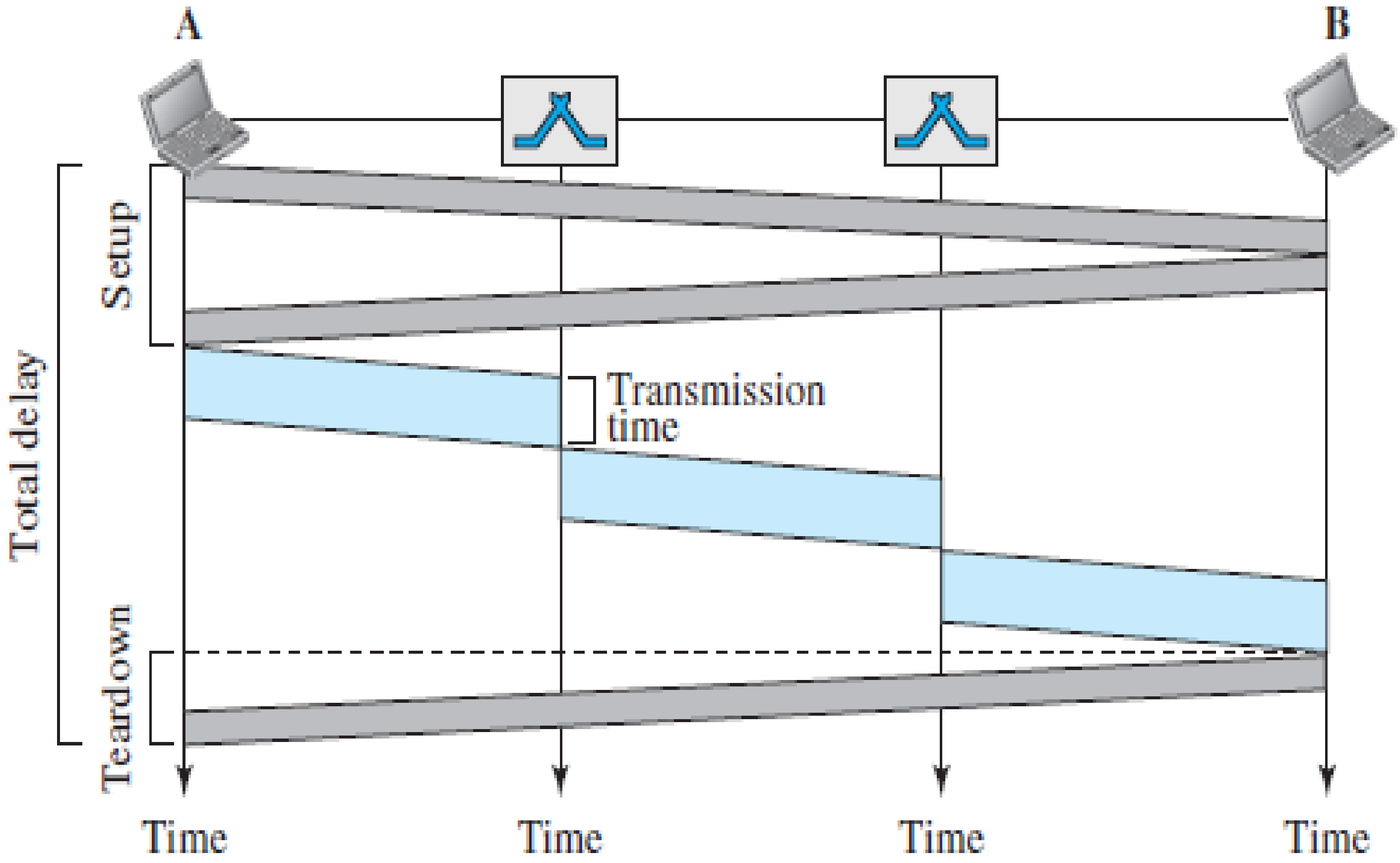
- Global Addressing
  - To create a VCI.
- Local Addressing (**Virtual-Circuit Identifier** or **VCI** or **label**)
  - Used for data transfer.
  - Switch scope – used by frames between 2 switches.
- Switch has its own unique set of VCIs.

# Virtual-Circuit Networks: Phases

- Setup Phase
  - Use global address to switch table entries.
  - Steps
    - Setup Request
    - Acknowledgement
- Data-Transfer Phase
- Teardown Phase
    - Teardown Request
    - Teardown Confirmation

# Virtual-Circuit Networks: Evaluation

- Efficiency
  - Depends on the type of resource allocation.
- Delay
  - Total delay (ignoring switch processing) =?



# Question

- A path in a digital circuit-switched network has a **data rate of 1 Mbps**. The exchange of **1000 bits is required for the setup and teardown phases**. The distance between two parties is **5000 km**. The propagation speed is **$2 \times 10^8$ m/s**. What is the **total delay** if **1000 bits** of data are exchanged during the data transfer phase?

# Question

- Five **equal-size datagrams** belonging to the same message leave for the destination one after another. However, they travel through different paths as shown in the table. We assume that the **delay for each switch (including waiting and processing) is 3, 10, 20, 7, and 20 ms respectively**. Assuming that the **propagation speed is 2 x $10^8$ m/s**, find the **order the datagrams arrive** at the destination and the delay for each. Ignore any other delays in transmission.

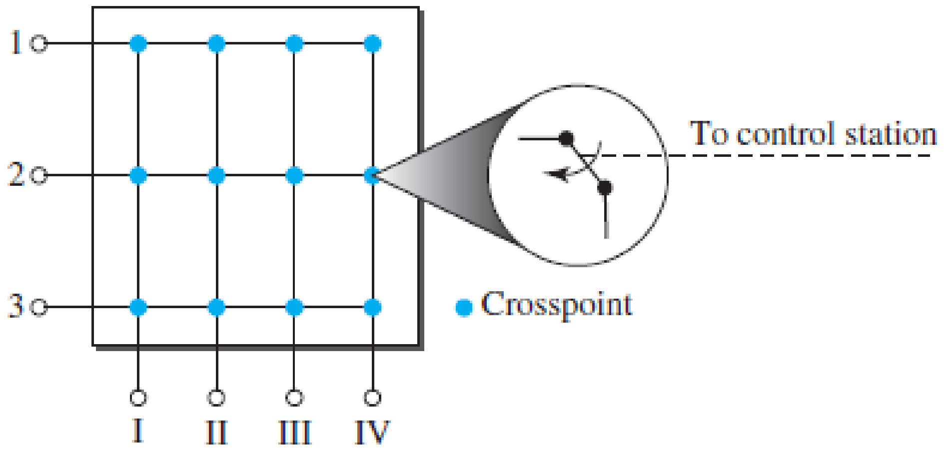
| *Datagram* | *Path Length* | *Visited Switches* |
|---|---|---|
| 1 | 3200Km | 1,3,5 |
| 2 | 11,700 Km | 1,2,5 |
| 3 | 12,200 Km | 1,2,3,5 |
| 4 | 10,200 Km | 1,4,5 |
| 5 | 10,700 Km | 1,4,3,5 |

# Structure of a Switch

- Structure of Circuit Switches
  - Space-Division Switching
    - Crossbar Switch
    - Multistage Switch
  - Time-Division Switching
- Structure of Packet Switches

# Crossbar Switch

- Uses electronic microswitches at each crosspoint.
- Number of crosspoints : impractical.
- Inefficient.

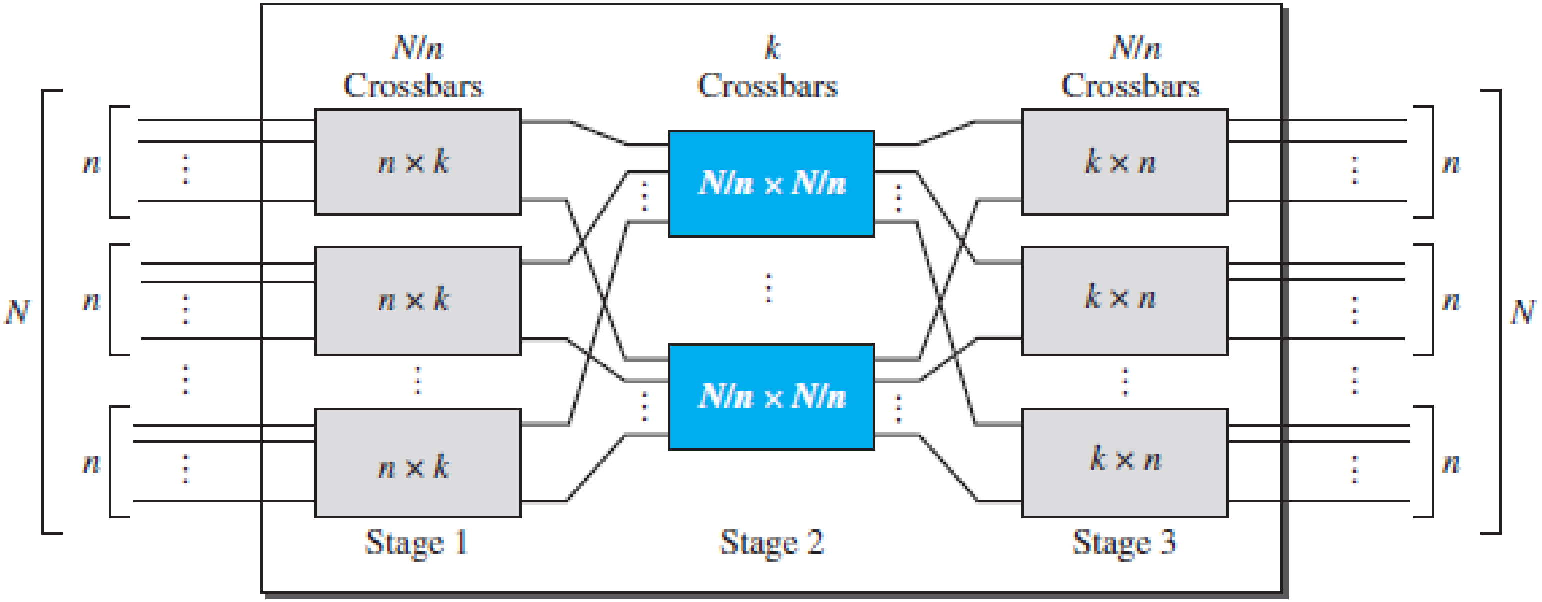



What if 2 inputs are trying to reach the same output?

# Multistage Switch

- Combines crossbar switches in several stages.
- Decreases the number of crosspoints. How?
- Each crosspoint in the middle stage can be accessed by multiple crosspoints in the first or third stage.
- #Crosspoints=?

$$2kN + k\left(\frac{N}{n}\right)^2$$



# Question

- Design a three-stage, 200 × 200 switch ($N$ = 200) with $k$ = 4 and $n$ = 20.

**Design Steps:**

- First Stage: Divide the N input lines into groups, each of ‘n’ lines.

| | #Crossbars | Size of each crossbar |
|---|---|---|
| First Stage | (N/n) | n x k |
| Second Stage | k | (N/n) x (N/n) |
| Third Stage | (N/n) | k x n |

# Multistage Switch: Clos Criterion

- In the last question, how many inputs of the first crossbar in the first stage can use the switch at a time? How many inputs of the second crossbar?
- Problem : **Blocking** during periods of heavy traffic. Real life example?
- What creates Blocking?
- Condition of non-blocking by Clos: **Clos Criterion**

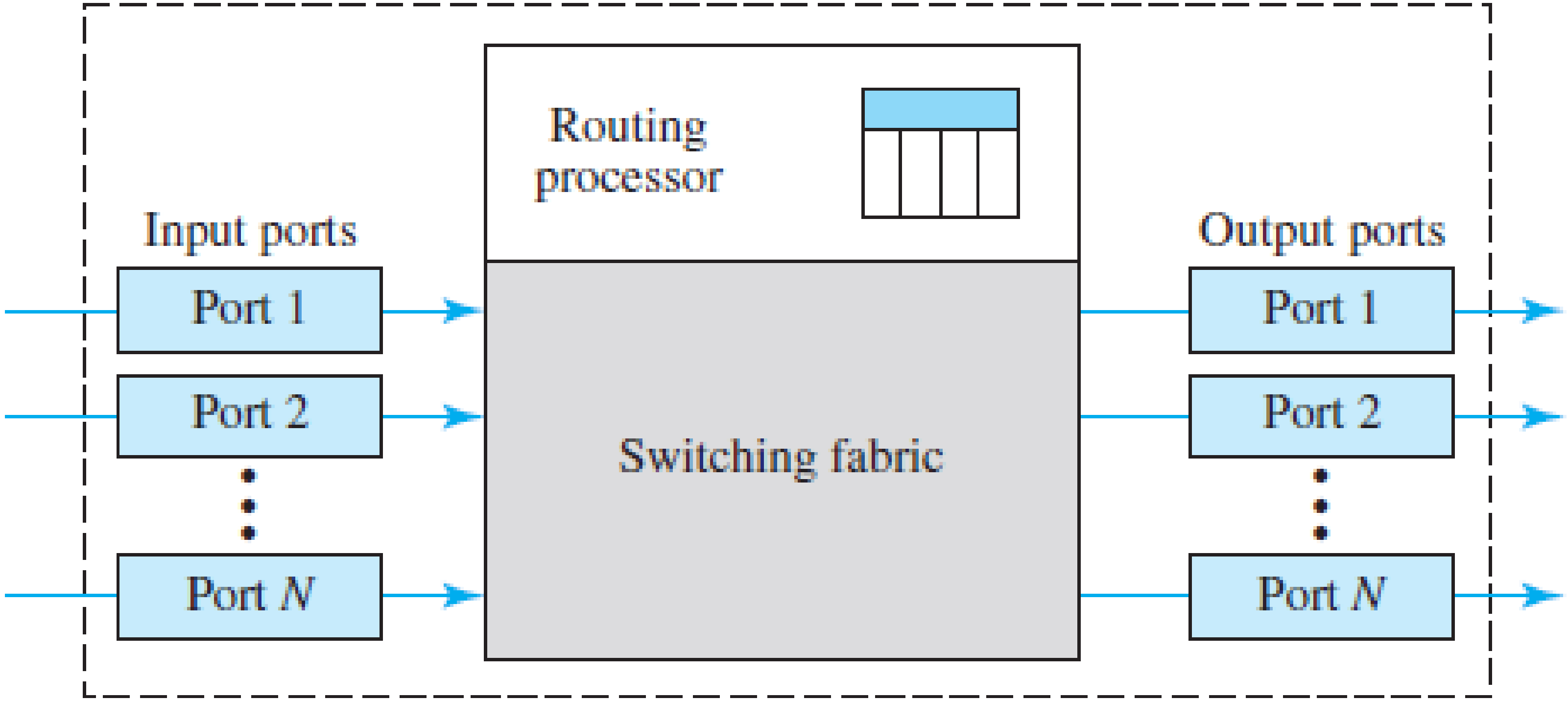
$n = (N/2)^{1/2}$ and $k \geq 2n-1$

Total number of crosspoints $\geq 4N[(2N)^{1/2} - 1]$

Minimum number of crosspoints is proportional to $N^{3/2}$.

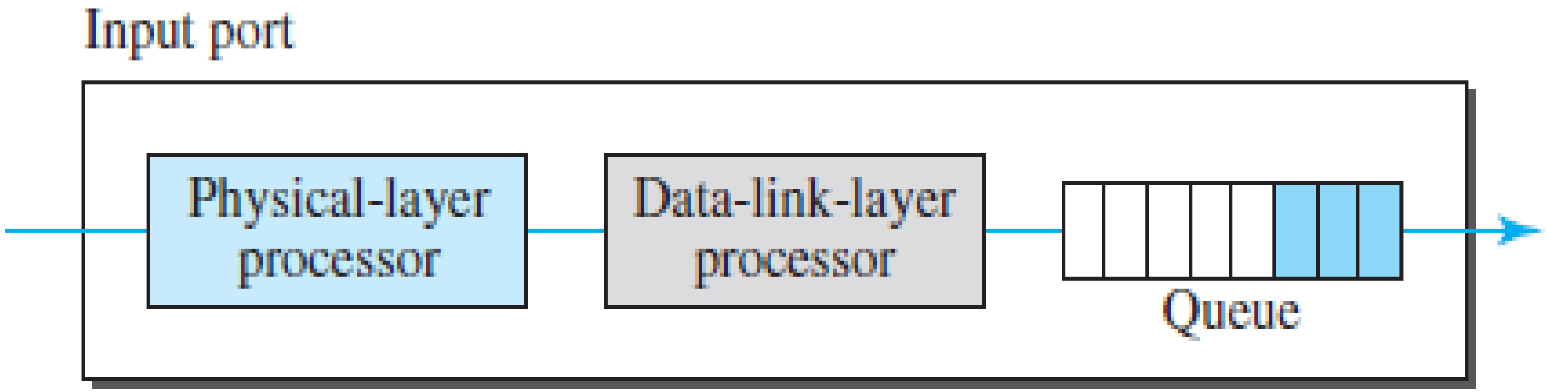
# Structure of Packet Switches

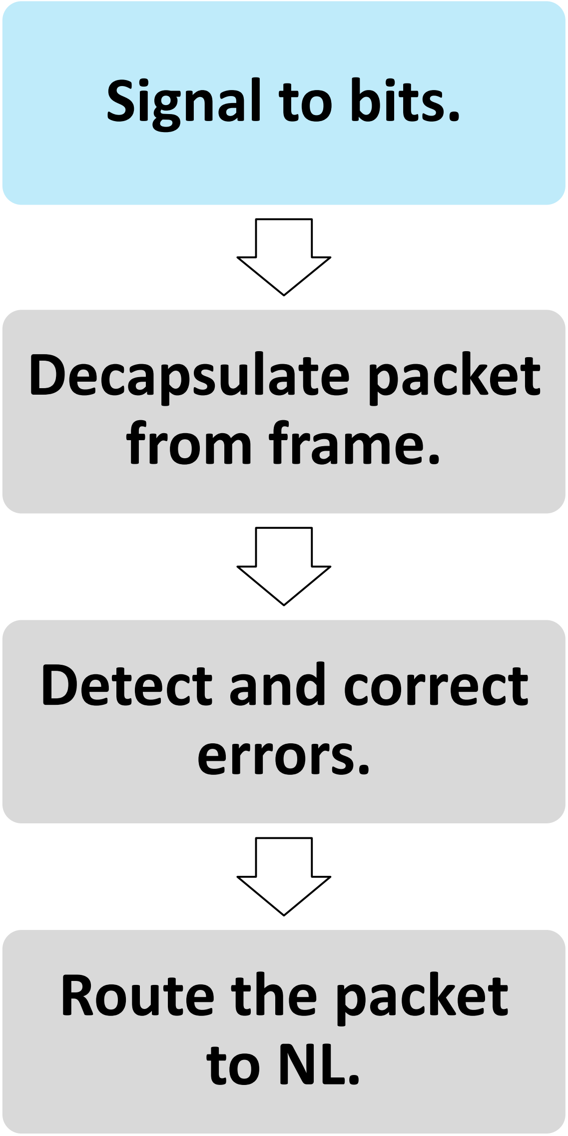
- A packet switch has four components:



# Input Port

- Performs the physical and data-link functions of the packet switch.
- Role of the queue?

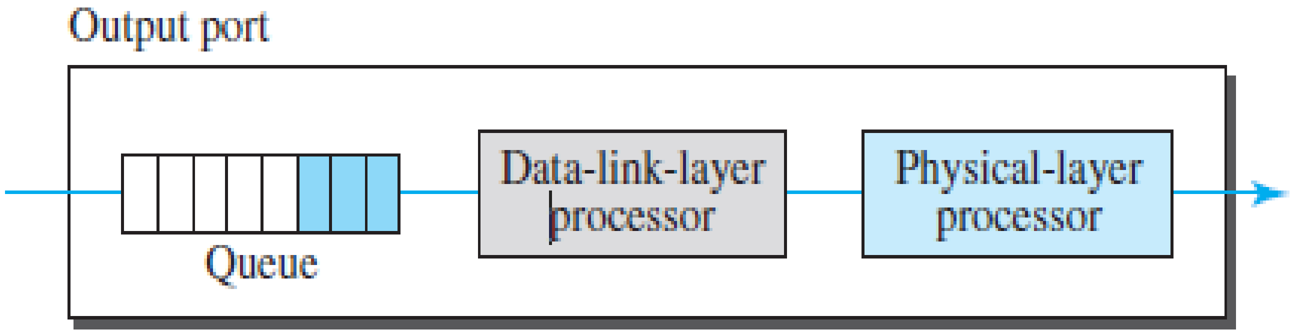


# Routing Processor

- Performs **functions of NL**.
- Find address of next hop and the output port. How?
- Table lookup.

# Output Ports




Outgoing packets are queued.

Packet is encapsulated in a frame.

Create the signal (PL functions).

# Switching Fabrics

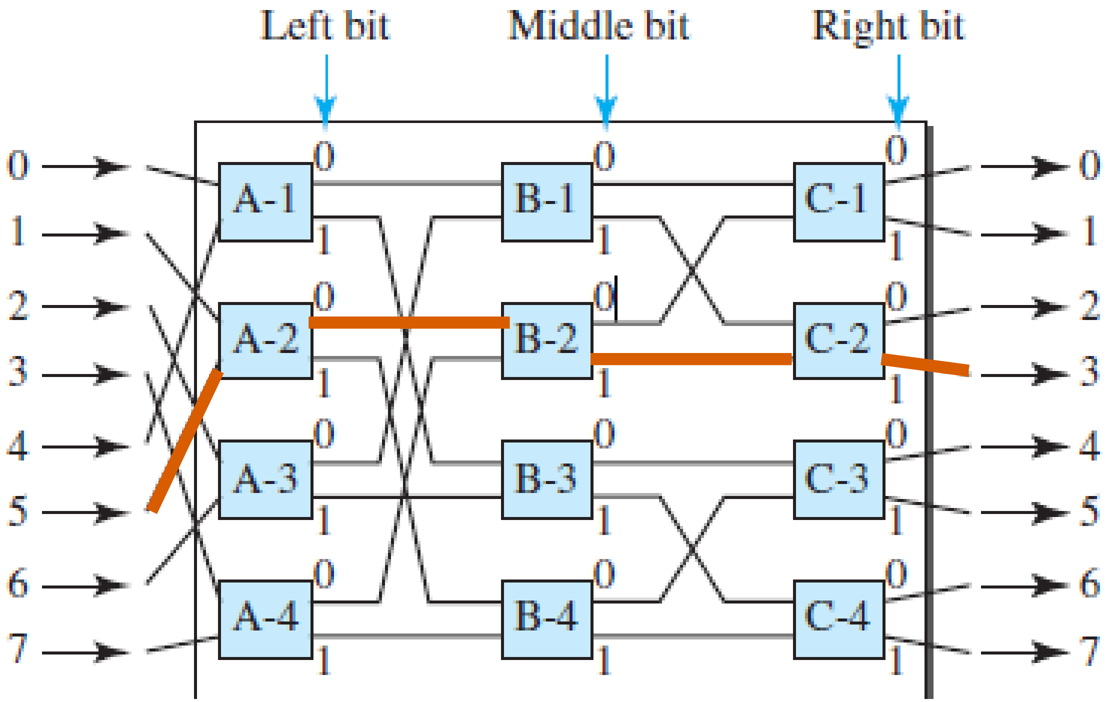
- To move the packet from the input queue to the output queue.
- Speed of this affects size of i/o queue and overall delay in packet delivery.
- Crossbar Switch
- Banyan Switch

# Banyan Switch

For an 8 input, 8 output Banyan switch,
# stages=?
# microswitches at each stage =?

- Multistage switch with microswitches at each stage.
- Route the packets based on the output port **represented as a binary string**.

| | |
|---|---|
| #Inputs | 'n' |
| #Outputs | 'n' |
| #Stages | $\log_2 n$ |
| #Microswitches at each stage | n/2 |




- How routing happens?

If a packet has arrived at **input port 5** and must go to **output port 3**?

$3 = (011)_2$

# Question

- We need a space-division switch with **N= 800.** Find the number of crosspoints for parts (a), (b), and (c).

(a) Design a single stage crossbar switch.

(b) Design a **3-stage** switch where we use **20 crossbars** at the first and third stages and **10 crossbars** at the middle stage.

(c) Design a **non-blocking 3-stage** switch.

(d) Find the possible number of simultaneous connections for part (b).

(e) Find the possible number of simultaneous connections for part (a).

(f) Find the blocking factor, the ratio of the number of connections in part (d) and in part (e).

# Network Layer Services

# Network Layer Services

- Source to destination communication.
- Packetizing
- Routing and Forwarding
- Addressing
- Security

- Error Control
- Flow Control
- Congestion Control
- Quality of Service (QoS)

# Book


- Behrouz Forouzan, Data Communications and Networking (5e), Tata McGraw Hill 2013. Chapter 8.
- Behrouz Forouzan, Data Communications and Networking (5e), Tata McGraw Hill 2013. Chapter 18.1.