Part I Syllabus

Lecture	Date	Subject
1	10/08/2016	Introduction
2	10/08/2016	Layered network architecture & Physical resilience
3	17/08/2016	Data link layer – flow control
4	17/08/2016	Data link layer – error control
5	24/08/2016	Data link layer – HDLC
6	24/08/2016	Local area network – introduction
7	31/08/2016	Local area network – MAC
8	31/08/2016	Local area network – Ethernet
9	07/09/2016	Local area network – WLAN
10	**07/09/2016**	**Packet switch network - Introduction**
11	14/09/2016	Packet switch network – queue analysis
12	14/09/2016	Review and examples

How do you get your water?

CE3005/CPE302 Computer Networks

Lecture 10
Packet Switched Networks

Contents

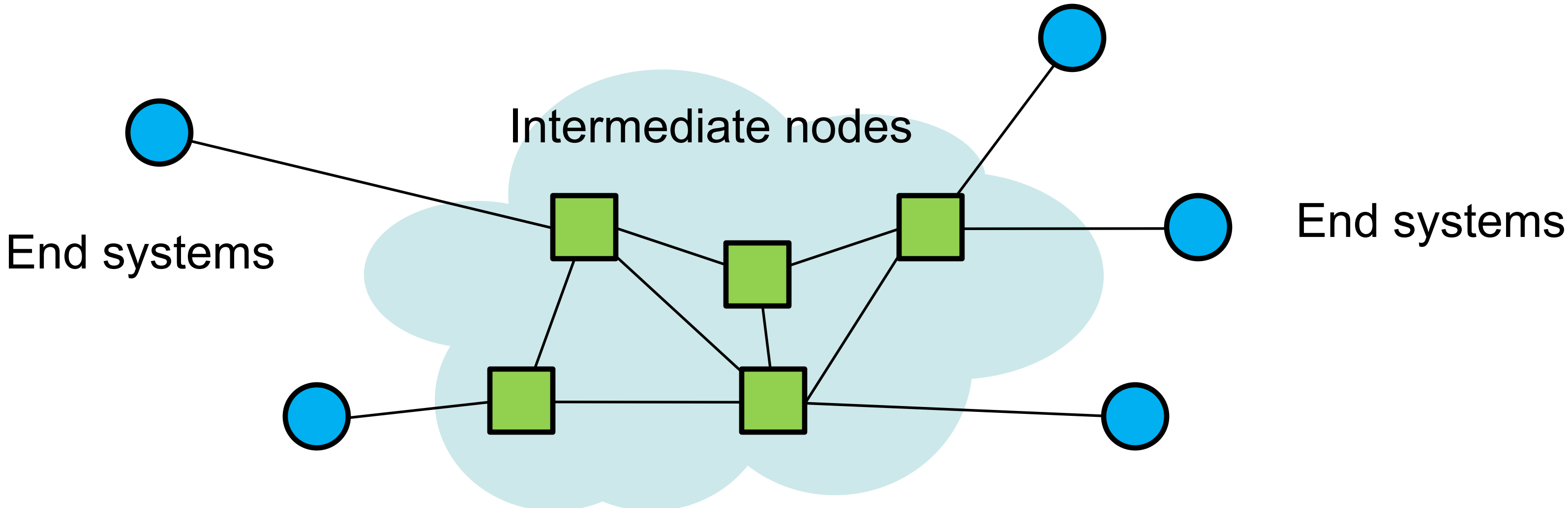
- **Data Transmission Technologies**
  - Network Design Approaches
  - Circuited Switched Network
  - Packet Switched Network
  - Connection-Oriented vs Connectionless
- **Internet Network Design Patterns**
  - Communication module pattern
  - Interface pattern
  - Decision-execution separation pattern
- **Delay in Packet Switched Network**
  - Delay components in packet switched network
  - Transmission delay calculation
  - Pipeline

Data Transmission Paradigms

Overview

- **Networks are used to interconnect many devices: LAN/WAN**
- **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)

Network Design



Approach 1: Smart Intermediate nodes & dumb end systems

- **eg. Telecommunication networks**
- **Achieve very complex traffic management but difficult to upgrade**

Approach 2: Dumb Intermediate nodes & smart end systems

- **eg. The Internet**
- **Attract innovation at applications but difficult to manage traffic**

(Intermediate) 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

Communication Networks Taxonomy

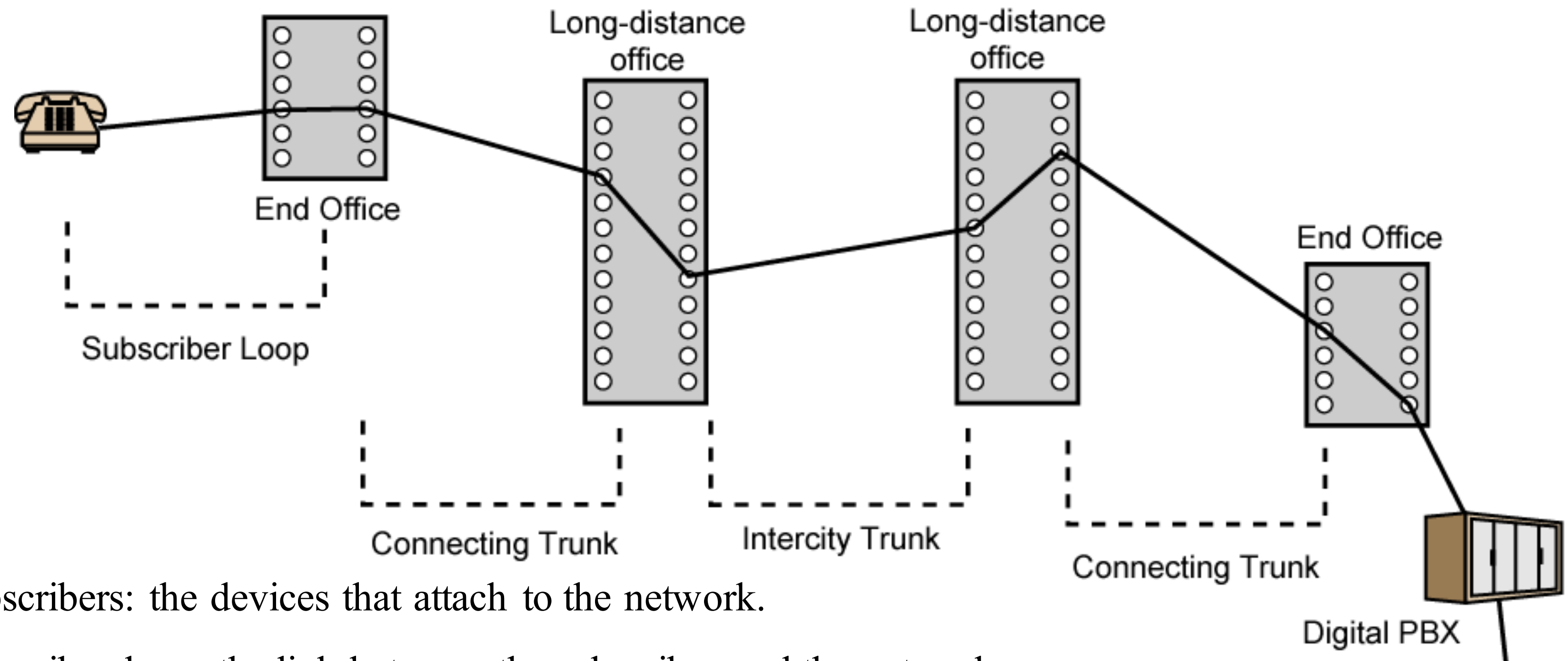
Communication Networks

- **Circuit Switched**
  (Telephone Calls)
- **Packet Switched**
  (Data Communications)
  - **Virtual Circuit Switching**
    (Connection Oriented)
    eg. X.25, ATM, etc
  - **Datagram Switching**
    (Connectionless)
    eg. Internet

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.**

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.

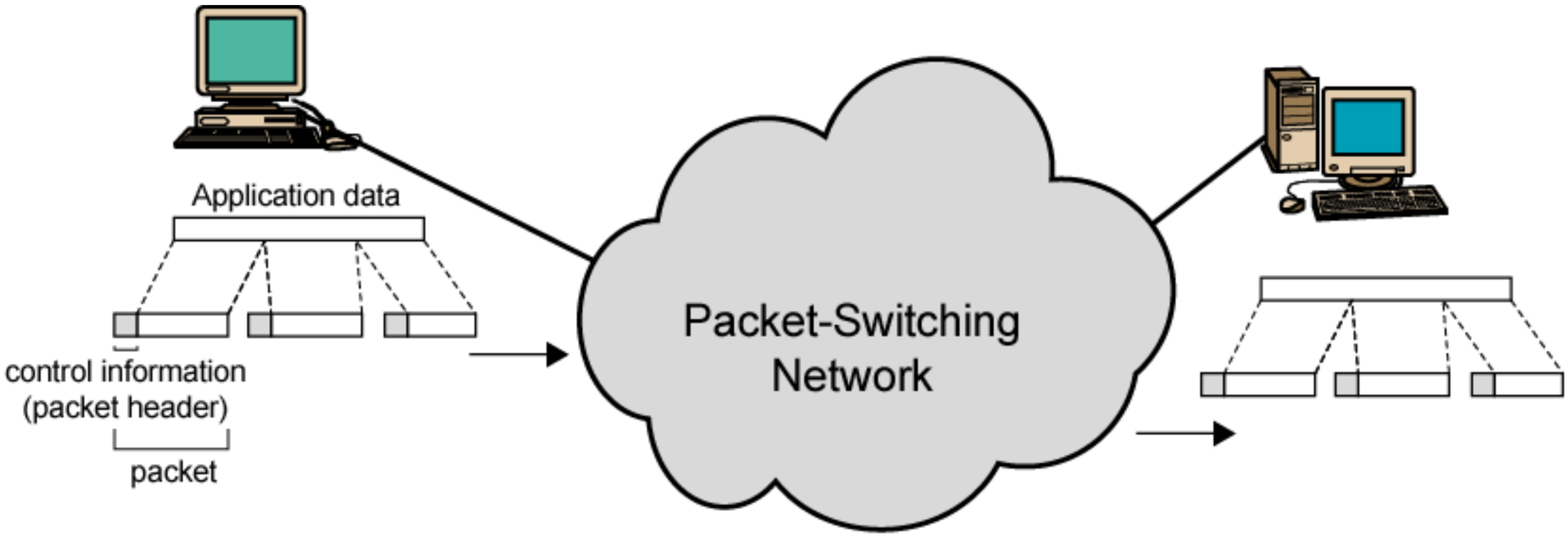
Packet Switching Principles

- **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

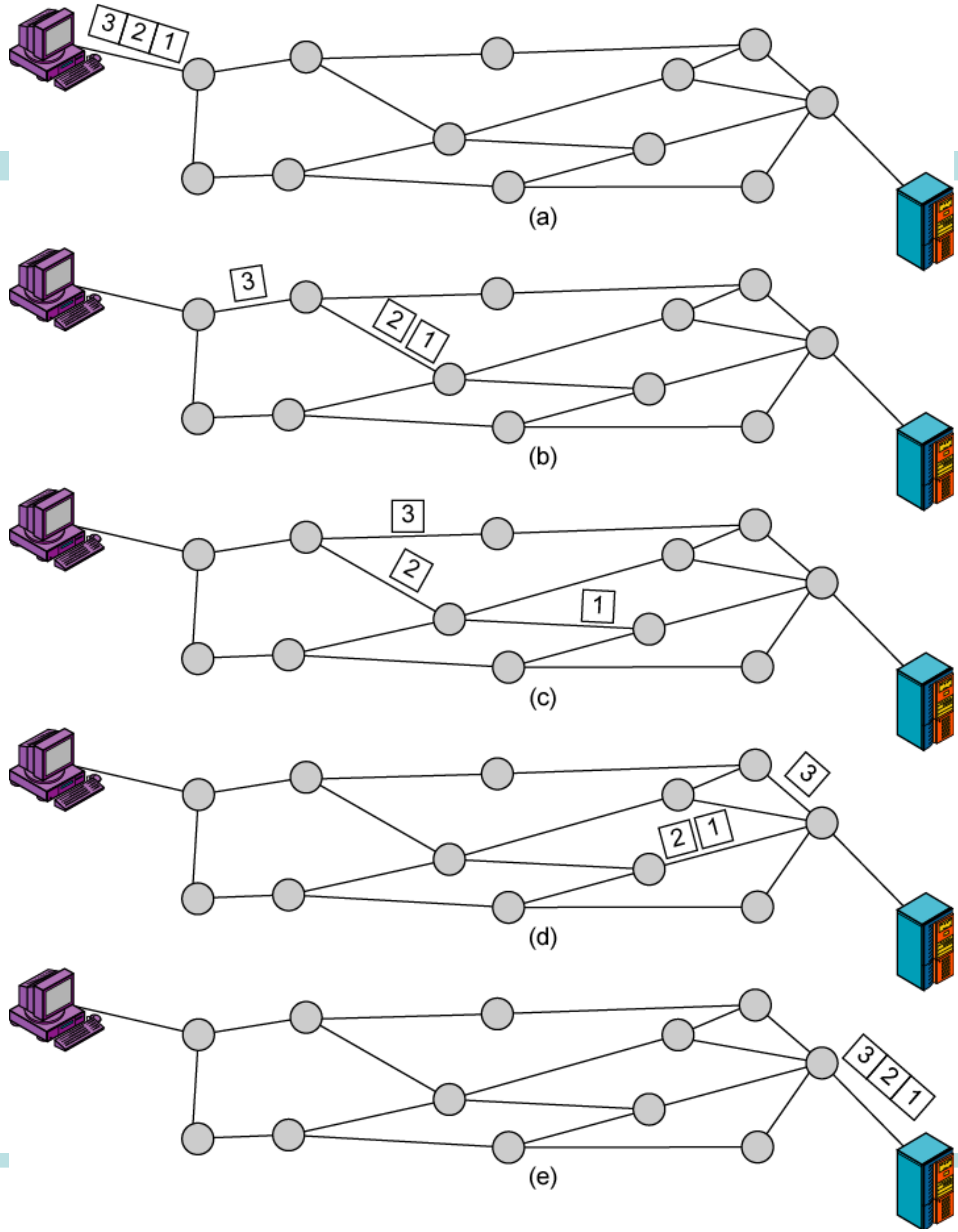
- **A station breaks long message into packets**
- **Packets are sent out to the network sequentially, one at a time**
- **How will the network handle this stream of packets as it attempts to route them through the network and deliver them to the intended destination?**
  - Two alternative approaches
    - **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

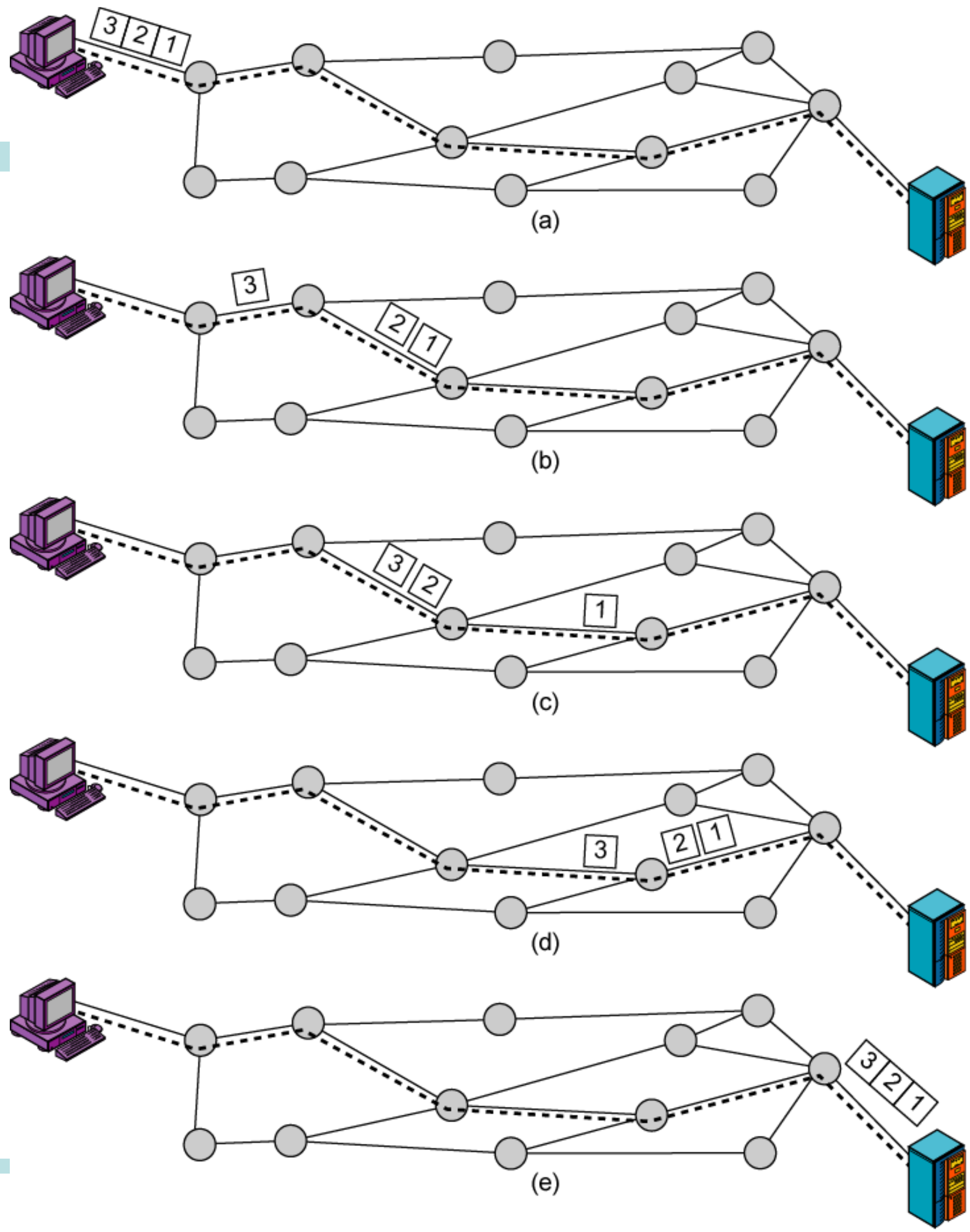
- Each packet carries the full destination address.
- Each packet is treated independently.
- Packets may arrive out of sequence.
- Packets are called datagrams.



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.

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

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

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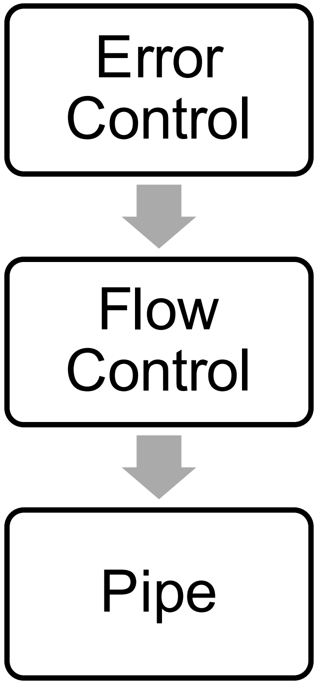
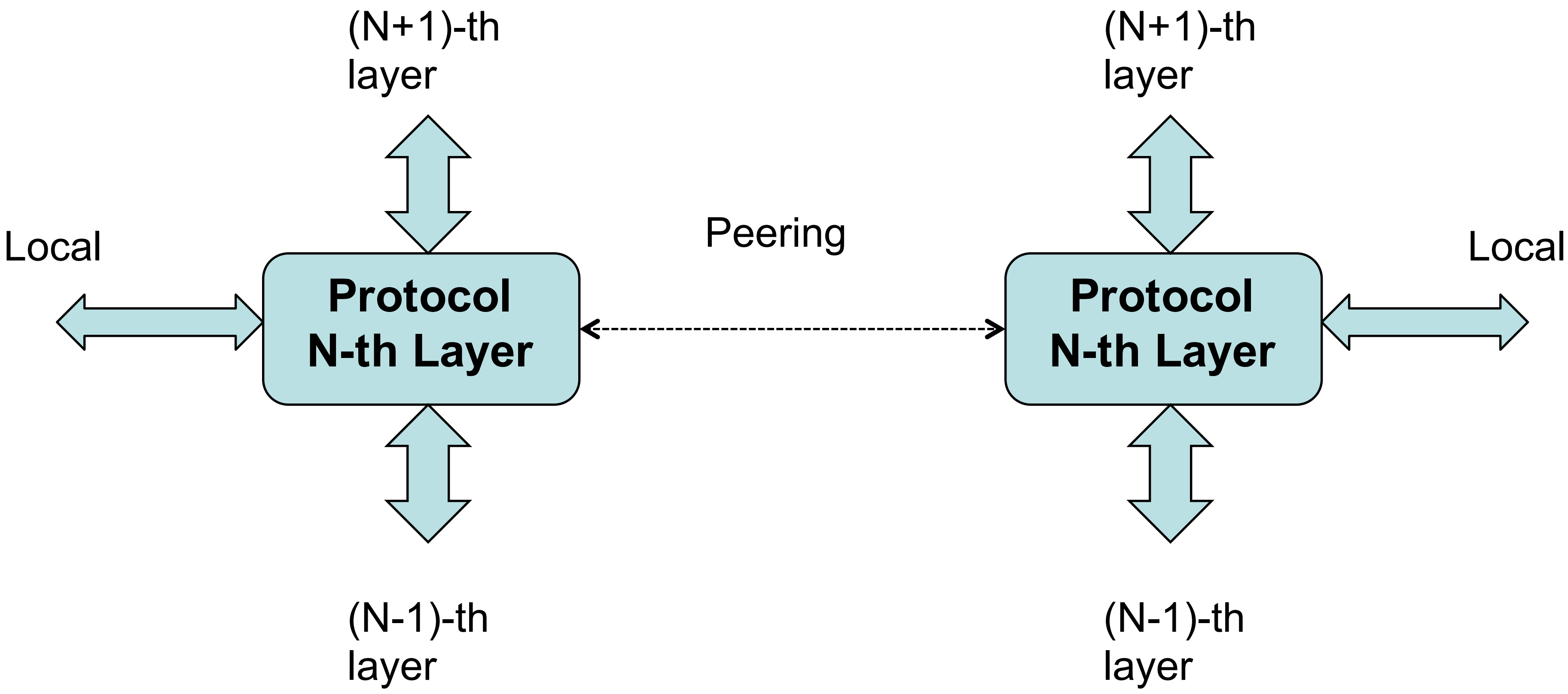
Internet Network Design Patterns

Communication Module Pattern

- **Communication Module**
  - Pipe
  - Flow Control
  - Error Control
- **Instances**
  - Physical layer + DLL
  - TCP/IP
  - HTTP

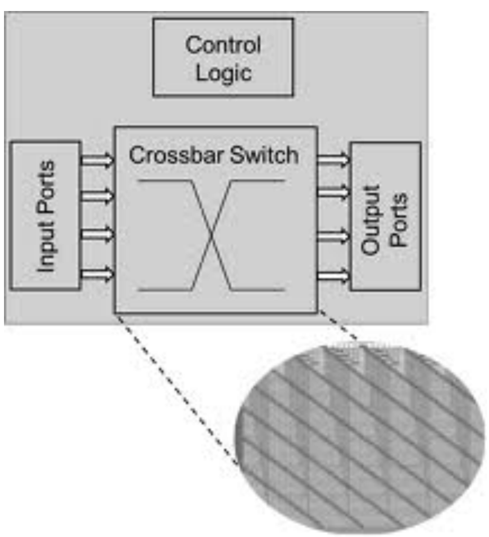


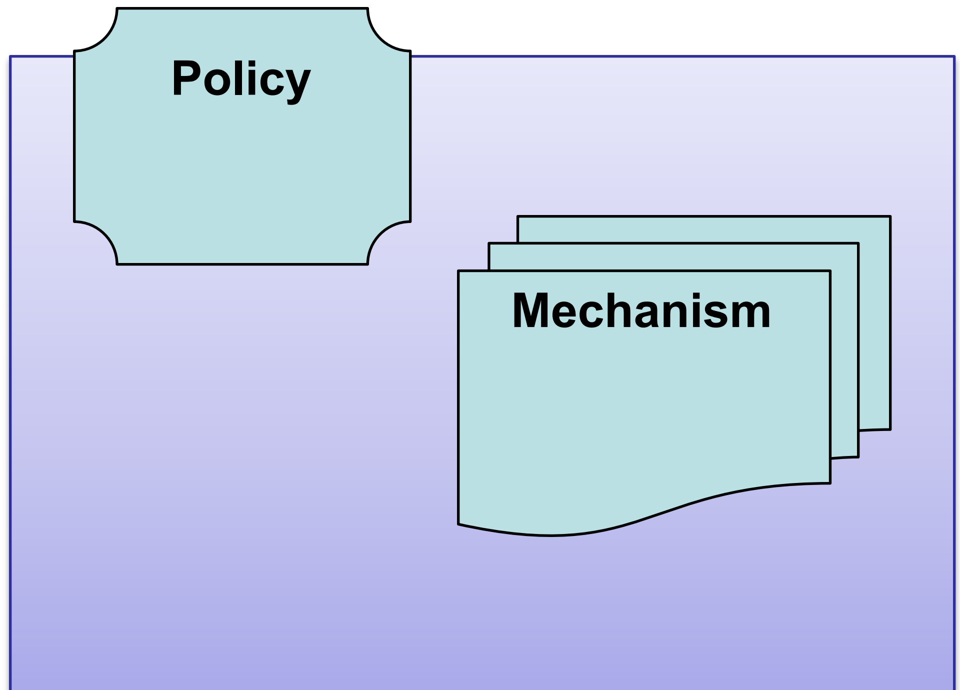
Interface Pattern



Separation between Decision & Execution

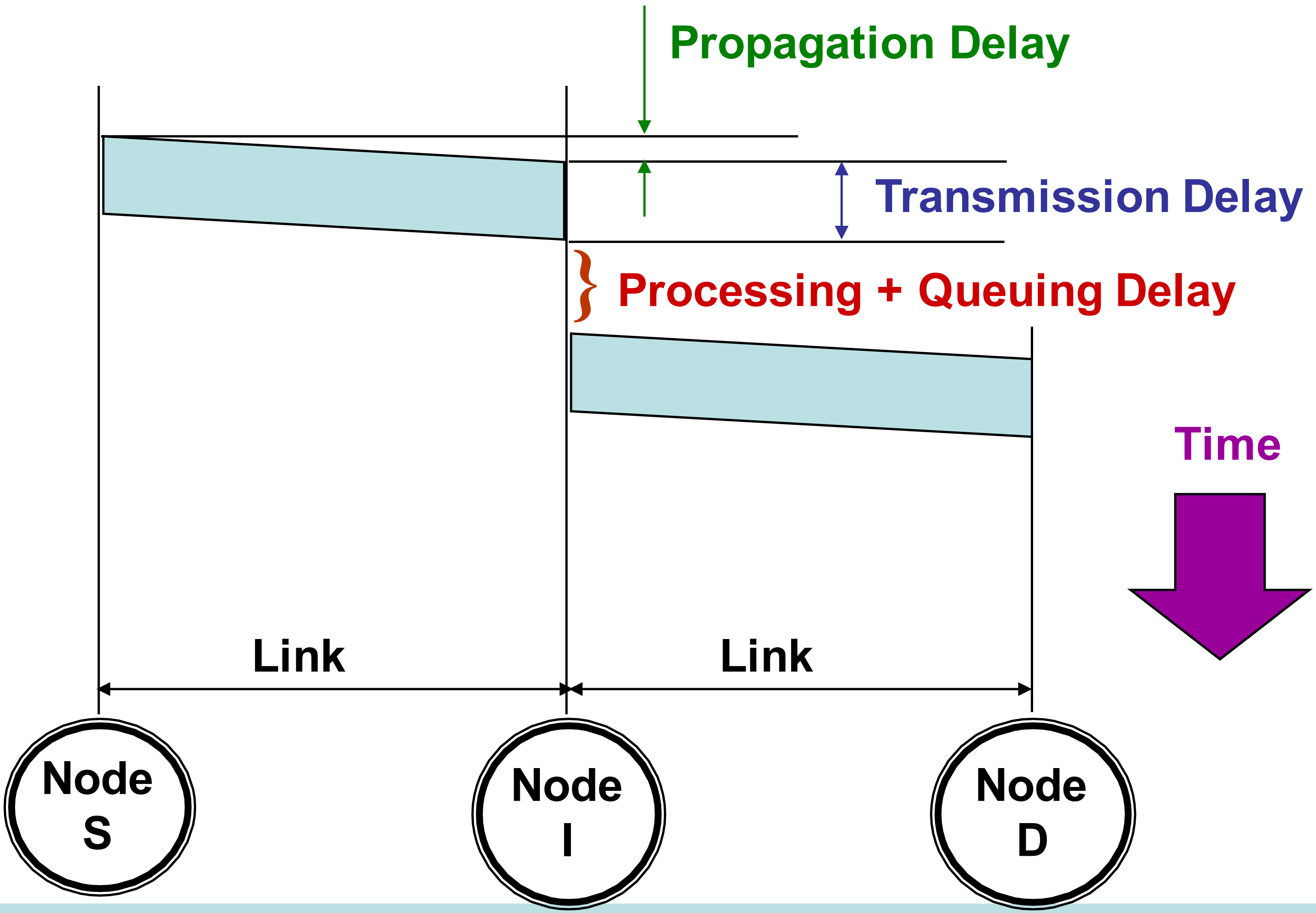
- **Two components**
  - Policy: decision making
  - Mechanism: execution and implementation
- **Example**
  - Switch: fabric & NPU



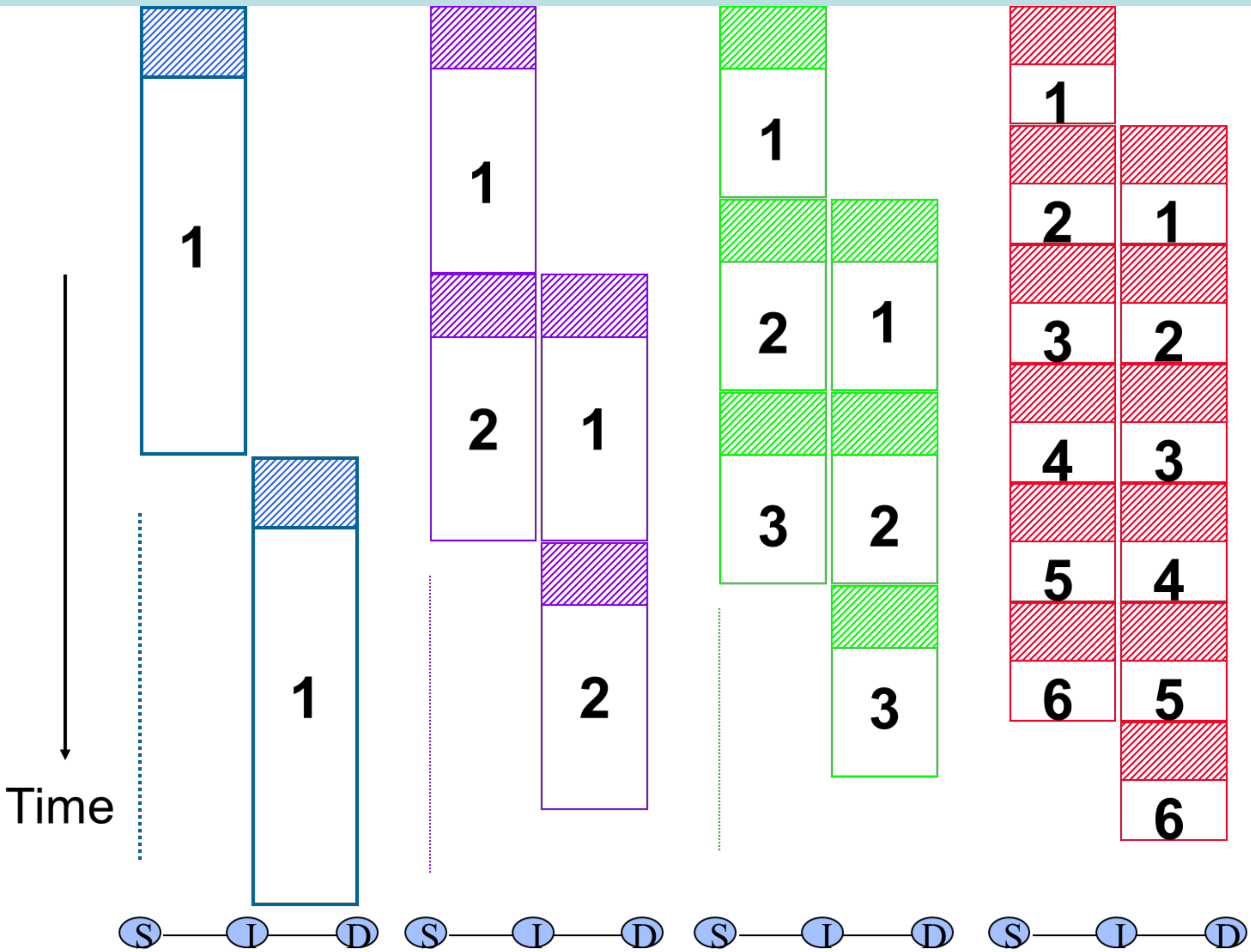


Packet Transmission Time

Delay in Packet Switched Networks



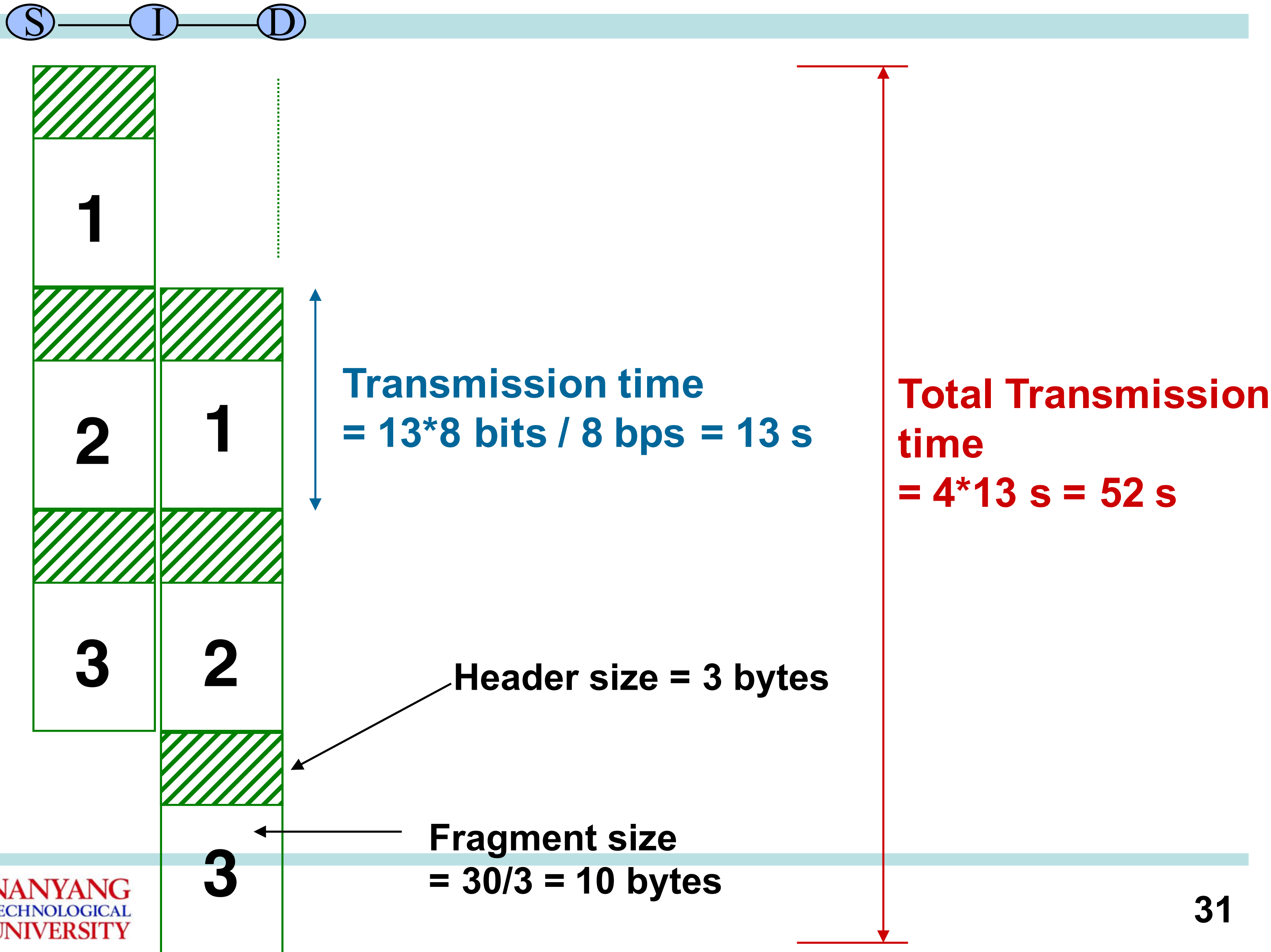
Pipeline Effect



Packet Size (Transmission Time Consideration)

- **Example 1: A packet of size 1000 bits would have transmission delay of 100 msec on a 10 Kbps link.**
- **Example 2: Consider a VC from node S to D through an intermediate node I (two hops). Link rate = 8 bps. Message is of 30 bytes. Header of a packet is 3 bytes.**
  - Case-1: Message is transmitted as a single packet.
    Tx. Delay = 33 bytes * 2 packet Txs / link rate = 66 sec
  - Case-2: Message is transmitted in 2 packets.
    Tx. Delay = 18 bytes * 3 packet Txs / link rate = 54 sec
  - Case-3: Message is transmitted in 3 packets.
    Tx. Delay = 13 bytes * 4 packet Txs / link rate = 52 sec
  - Case-4: Message is transmitted in 6 packets.
    Tx. Delay = 8 bytes * 7 packet Txs / link rate = 56 sec

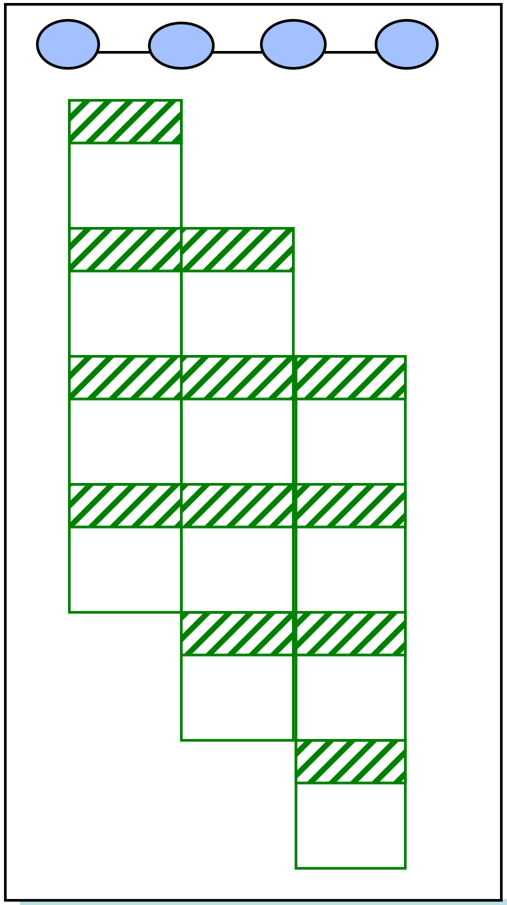
Transmission Time



Packet Transmission Time: Overhead vs. Pipeline

Example:
3 hops & 4 fragments

$\therefore$ **Tx time = 4 T_{frame} + (3-1) T_{frame}**



In general:

Tx Delay

= Tx Delay of all packets in first hop

+ (# of hops-1) * Tx Delay of 1 packet

To find the optimum packet size, other delays should also be considered:

- **Processing Delay**
- **Queuing Delay**
- **Signal Propagation Delay**

Learning Objectives

- **Data Transmission Technologies**
  - Understand difference between circuit and packet switched networks
  - Understand difference between datagram and virtual circuit switching
- **Internet Network Design Patterns**
  - Understand patterns and their instances
- **Delay in Packet Switched Networks**
  - Understand delay components in PSN
  - Calculate packet transmission delay