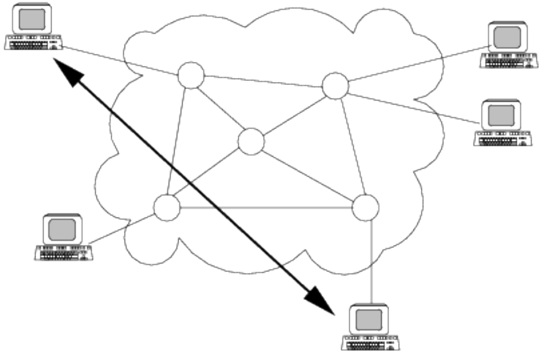
Review



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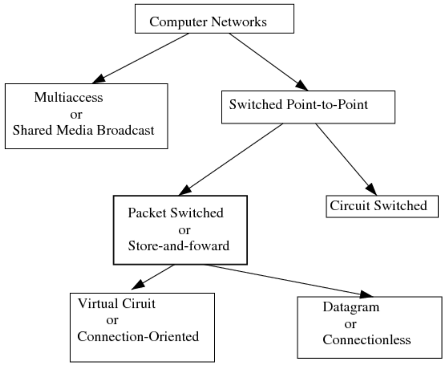
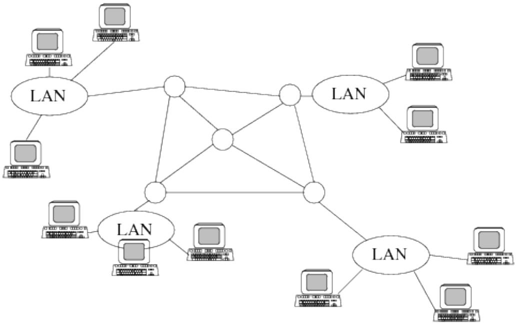
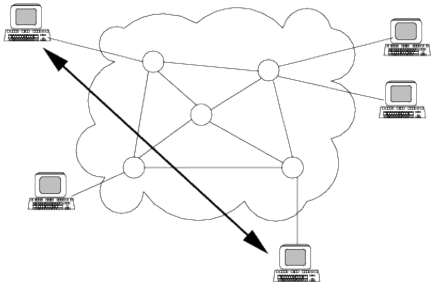

Computer Networks
Multiaccess or Shared Media Broadcast
Switched Point-to-Point
Packet Switched or Store-and-foward
Circuit Switched
Virtual Ciruit or Connection-Oriented
Datagram or Connectionless

Review



How to Send a Message over a Network?



- Routing
- Addressing
- Reliable Data Transfer
- Congestion Control

How to Master Complexity?

- Computer networks are very complex; many issues to address:
  - connection setup, message segmentation, multiplexing, routing, flow control, security, error control, encoding, addressing, ...
- Useful method for dealing with complexity is using "**modularity**".
  - break complex problem into simpler sub-problems
  - use "black box" (input/output) abstraction for sub-problems

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SMTP (Simple Mail Transfer Protocol)

S: 220 sf.com

C: HELO toronto.edu

S: 250 Hello toronto.edu, pleased to meet you

C: MAIL FROM: <alice@toronto.edu>

S: 250 alice@toronto.edu... Sender ok

C: RCPT TO: <bob@sf.com>

S: 250 bob@sf.com ... Recipient ok

C: DATA

S: 354 Enter mail, end with "." on a line by itself

C: How are you?

C: See you soon.

C: .

S: 250 Message accepted for delivery

C: QUIT

S: 221 sf.com closing connection

Modularity for Computer Networks

- **Hierarchical Layering:** The type of functional modularity used for computer networks is hierarchical layering. What is special about this architecture is that it is distributed and connected through unreliable links with delays.
- Example: Postal Service
  - When I bring a letter to the post office, I don't know how it gets delivered from there. The office clerk doesn't know the exact details either, and so on.

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Layered Network Architecture

Application Layer
Transport Layer
Network Layer
Data Link Layer
Physical Layer

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There are several ways to define a layered network architecture. In this course, we consider the 5 Internet layers. Another model consists of the 7 OSI layers.

Outline

- Description of the different network layers
- Issues in layered network architecture

$->$ Read Chapter 1 in Textbook

Goals

- Know what the different layers do
- Know how layers interact
- Terminology: peer process, protocol, service

Application Layer

- **Service:** Supports applications
- **Tasks:**
  - Connection Setup
  - Flow control
  - Error control
- **Protocols:** HTTP to support Web, SMTP to support email, FTP to support file transfer.
- **Location**: End Systems/Hosts

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- **Service:** Prepares messages for being transported over the network.
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  - Message fragmentation and reassembly
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- **Tasks:**
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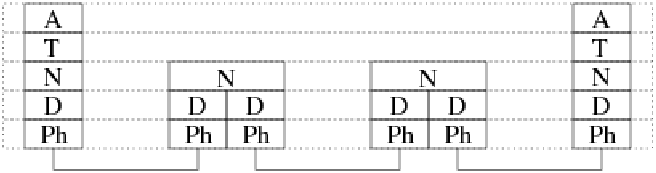
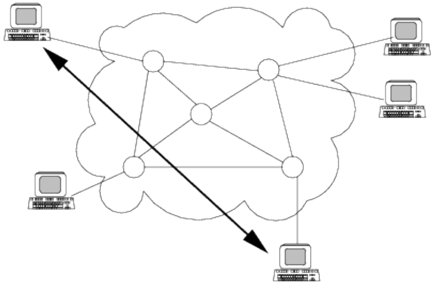
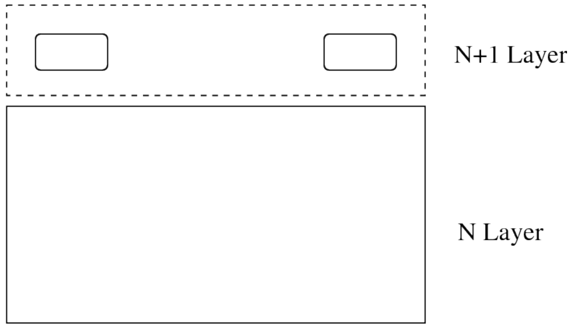
“The Roller-Coaster Ride of a Message”





A Closer Look



Terminology

- **Peer or Peer Processes:**
  Members of the same layer at different locations
- **Protocol:**
  Set of rules for how peers interact
- **Protocol Stack:**
  Set of protocol used (one per layer)
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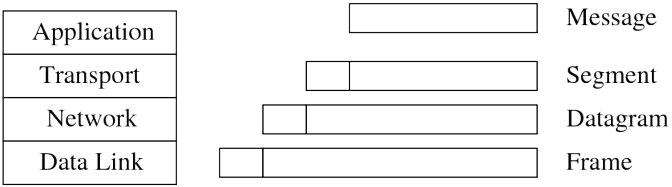
“Growing” Data Units



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- Protocol Control Information (PCI) or Header
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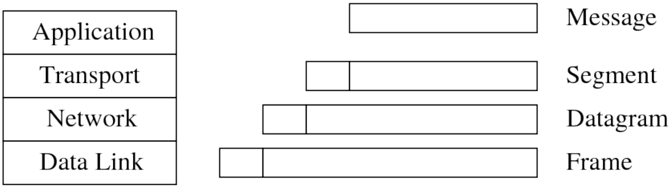

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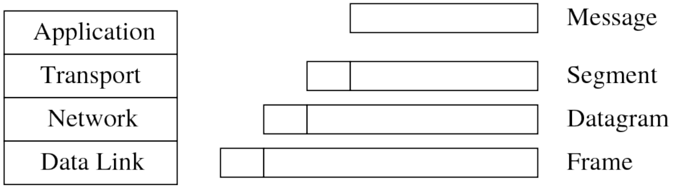

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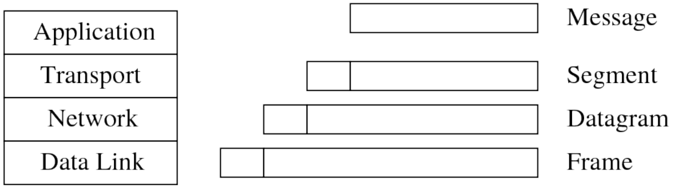

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Question: Why Layers?

Layer Functions

- **Error Control:** makes the logical channel between two peer processes reliable.
- **Flow Control:** avoids overwhelming a slower peer process with protocol data units.
- **Segmentation and Reassembly of Data Units**
- **Multiplexing:** allows several higher-level sessions to share a single lower-level connection.
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- **Connectionless:** No connection setup. Data messages are sent immediately. A connectionless service is by its nature unreliable.

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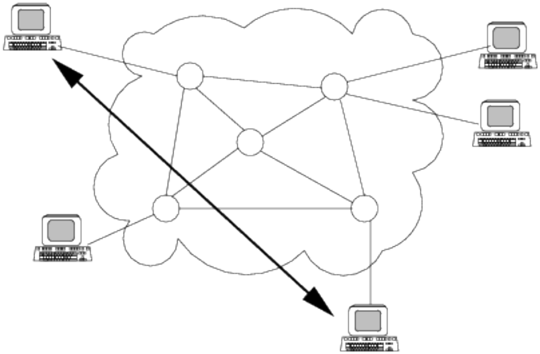
Distributed Protocols

Issues



- Reliability
- Performance/Quality-of-Service (QoS)

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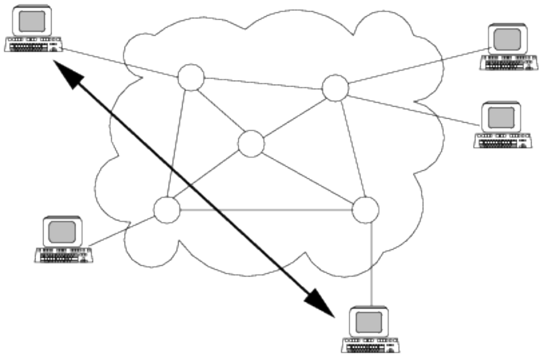

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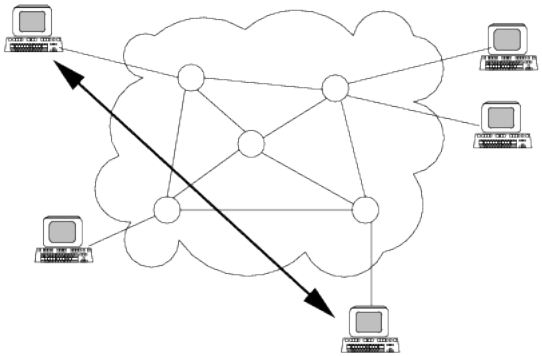

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Quality of Service

Factors Determining the Quality of Service

- Delay
- Packet Loss
- Transmission Rate

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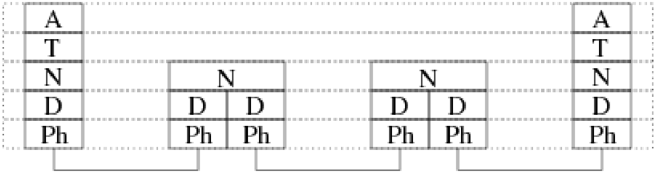
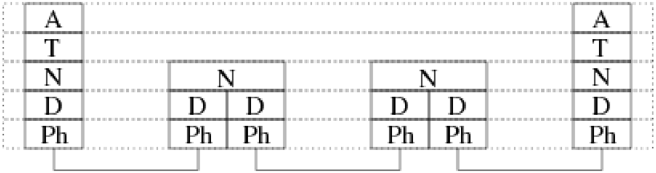
Why is Quality of Service Important?

Delay



- Processing Delay
- Queueing Delay
- Transmission Delay
- Propagation Delay

Delay



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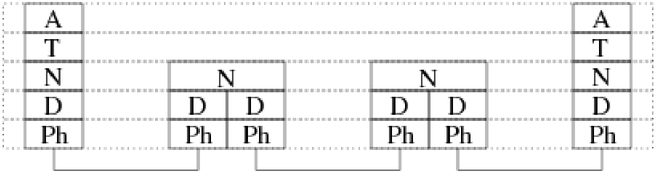

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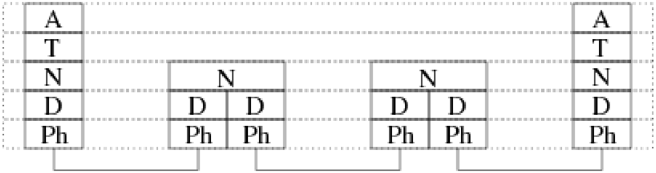

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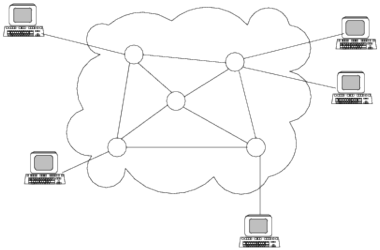
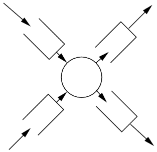
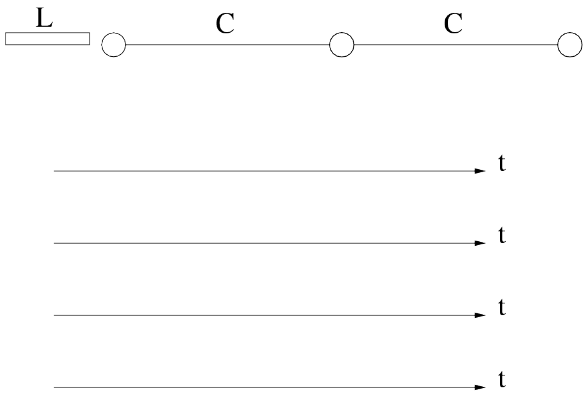
Queueing Delay





Transmission Delay vs. Propagation Delay



Approach

1. Reliable Data Transfer
2. Tools for Performance Analysis/QoS Evaluation
3. Modelling and Analysis of Protocols
4. Implementation Issues