The Next Few Classes

- Distributed File Systems
- Distributed Operating Systems
- Distributed Services (email, www, telnet)
- Networking Basics
- Distributed Systems

Course Snapshot

We have covered all the fundamental OS components:

- File systems and I/O
- Memory management
- Process scheduling
- Synchronization and deadlock
- Processes and threads
- Architecture and OS interactions
Parallel versus Distributed Systems

- Communication should be less frequent
- Each processor runs an independent OS
- Each processor has its own memory

Loosely-coupled systems: “distributed computing”

- Frequent communication
- Processors share clock, memory, and run one OS

Tightly-coupled systems: “parallel processing”

Distributed Systems

- Nearly all systems today are distributed in some way:
- Email, file servers, network printers, remote backup, world wide web

a set of physically separate processors connected by one or more communication links
- For example, mail, transaction processing systems like airlines and banks, WWW.
- Users/processes on different systems can communicate.

Communication:

- If the server crashes, none of the workstations are useful.
- Example if an E-box workstation crashes, you can use another workstation. If the
  server is down a single point of failure.
- However, if some component of the system is centralized, a single point of failure
  may result.
- Performance will degrade but system remains operational.
- For example, if one node crashes, the user can work on another.
- Replication of resources yields fault tolerance.

Reliability:

Advantages of Distributed Systems

- Exchange of results is needed.
- Coordination and communication between cooperating processes (synchronization).
- Problem must be decomposable into subproblems.
- n processors potentially gives you n times the computational power.

Computational speedup:

- Keeping files on a file server.
- Each processor can present the same environment to the user (for example, by
  - Expensive (scarce) resources can be shared (for example, printers)
  - Resources need not be replicated at each processor (for example, shared files)

Resource sharing:

Advantages of Distributed Systems
Wide Area Network (WAN) connects nodes across the state, country:

- Typical bandwidth: 1.5-44 Mbps (T1), 45 Mbps (T3)
- Media: telephone lines (T1 service), microwave links, satellite channels

Local Area Network (LAN) usually connects nodes in a single building:

- Robust message passing between two separate nodes.

Networks are usually concerned with providing efficient, correct, and reliable service.

Distributed Systems

Modern work environments are distributed → operating systems need to be distributed.

What do we need to consider when building these systems?

- Programming models
- Performance and scalability
- Reliability
- Security
- Transpareny (how visible is the distribution?)
- Communication and networks

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WANs typically use this structure:

- Routing algorithms.
- Sending a message to a node may have to go through several other nodes if needed.
- Less expensive, but less tolerant to failures. A single failure can partition the network.

Partially Connected: links between some, but not all nodes.

Partially Connected

Point-to-Point Network Topologies

Expensive, especially with lots of nodes, not practical for WANs.

- Failure of any one node does not affect communication between other nodes going through any other node.
- Each message takes only a single "hop," i.e., goes directly to the destination without

Fully Connected: all nodes connected to all other nodes.

Fully Connected

Point-to-Point Network Topologies
- Inexpensive, and sometimes used for LAN
- If one piece of hardware fails, the entire network stops
- Each message takes only two hops
- The central site is generally dedicated to network traffic

**Star:** all nodes connect to a single centralized node

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**Tree Structure:** network hierarchy

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- More expensive, but more tolerant of failures.
- A message takes at most \( n/4 \) hops.

**Doubly connected ring** nodes connected to neighbors and one way

**Ring Networks Topologies**
Principles of Network Communication

- **Bus** - single shared link
  - Inexpensive (linear in the number of nodes) and tolerant of node failures.
  - Nodes connect directly to each other using multiaccess bus technology.

- **Ring** - single shared circular link
  - Ethernet LAN use this structure.

- **Linear** - single shared link
  - Same technology and tradeoffs as a linear bus.

Analogies:
- Shared resources can lead to contention (traffic jams).

Computers at the switching points control the packet flow.

- **Transmission unit** -
  - Data sent into the network is chopped into "packets", the network's basic

**Bus Network Topologies**

- **Ring Bus**
- **Linear Bus**
ISO Network Protocol Stack

- Physical layer: Electromagnetic signals, sometimes in hardware, sometimes in software (e.g., PPoE).
- Data link control layer: Reliable point-to-point communication of packets over an unreliable channel. Usually implemented in OS.
- Network Layer: Routing and congestion control. Usually implemented in O/S.
- Transport layer: Reliable end-to-end communication between any set of nodes.
- Session layer: Implements the communication protocol, such as RPC. Provided by libraries.
- Presentation layer: Data format conversion, e.g., little endian integer format. Text encoding, compression, encryption, etc.

**Communication Protocols**
- Protocol stack: Networking software is structured into layers.
- Protocol: a set of rules for communication that are agreed to by all parties.

Example: International Standards Organization/ Open Systems Interconnection (OSI) and the Internet's TCP/IP stack. Each layer N provides a service to layer N+1 by using its own layer N procedures. The interface to the N-1 layer is defined in the standard.
The data segment of the packet contains headers for higher protocol layers and actual application data.

- Each packet contains all the information needed to recreate the original message.
- Each message is chopped into packets.

- Ethernet packet contents
- To put them back into order.
- For example, packets may arrive out of order and the destination node must be able to put them back into order.


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TCP/IP Protocol Stack

```plaintext
Layer 4: Application (Protocols like HTTP, FTP, SMTP, etc.)
Layer 3: IP (Internet Protocol)
Layer 2: Ethernet (MAC Address)
Layer 1: Physical (Cables, Wires, etc.)
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- UDP (user datagram protocol) is unreliable protocol (no guarantee of delivery).
- TCP is a reliable protocol - packets are received in the order they are sent.
- Consists of a suite of protocols: TCP, IP...
Summary

Networks make tradeoffs between speed, reliability, and expense.

Networks hook them together.

Virtually all computer systems contain distributed components.