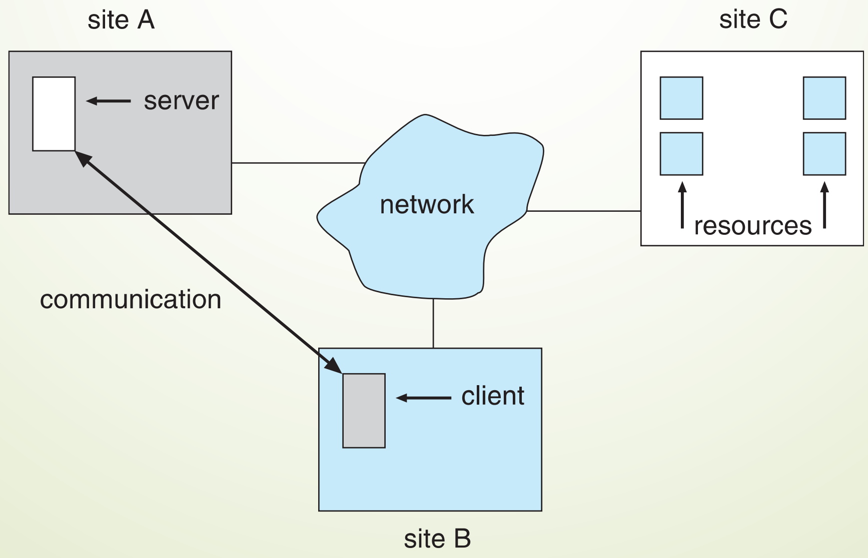
Distributed Systems

Overview

- **Distributed system** is collection of loosely coupled processors interconnected by a communications network
- Processors variously called ***nodes, computers, machines, hosts***
  - ***Site*** is location of the processor
  - Generally a ***server*** has a resource a ***client*** node at a different site wants to use



Reasons for Distributed Systems

- Reasons for distributed systems
  - **Resource sharing**
    - Sharing and printing files at remote sites
    - Processing information in a distributed database
    - Using remote specialized hardware devices
  - **Computation speedup** – **load sharing** or **job migration**
  - Reliability – detect and recover from site failure, function transfer, reintegrate failed site
  - Communication – **message** passing
    - All higher-level functions of a standalone system can be expanded to encompass a distributed system
  - Computers can be downsized, more flexibility, better user interfaces and easier maintenance by moving from large system to multiple smaller systems performing distributed computing

Types of Distributed Operating Systems

- Network Operating Systems
- Distributed Operating Systems

Network-Operating Systems

- Users are aware of multiplicity of machines
- Access to resources of various machines is done explicitly by:
  - Remote logging into the appropriate remote machine (telnet, ssh)
  - Remote Desktop (Microsoft Windows)
  - Transferring data from remote machines to local machines, via the File Transfer Protocol (FTP) mechanism
- Users must change paradigms – establish a **session**, give network-based commands
  - More difficult for users

Distributed-Operating Systems

- Users not aware of multiplicity of machines
  - Access to remote resources similar to access to local resources
- **Data Migration** – transfer data by transferring entire file, or transferring only those portions of the file necessary for the immediate task
- **Computation Migration** – transfer the computation, rather than the data, across the system
  - Via remote procedure calls (RPCs)
  - or via messaging system

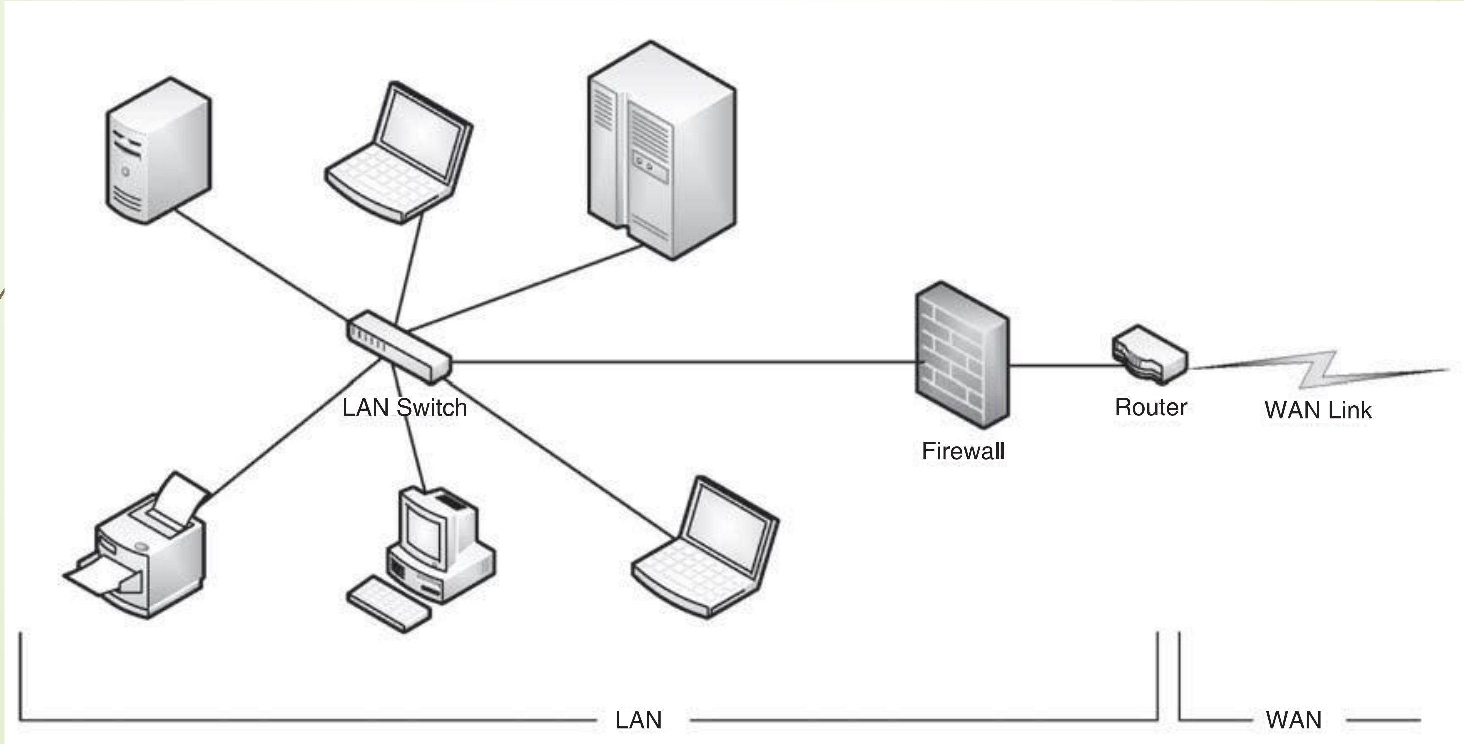
Distributed-Operating Systems (Cont.)

- **Process Migration** – execute an entire process, or parts of it, at different sites
  - **Load balancing** – distribute processes across network to even the workload
  - **Computation speedup** – subprocesses can run concurrently on different sites
  - **Hardware preference** – process execution may require specialized processor
  - **Software preference** – required software may be available at only a particular site
  - **Data access** – run process remotely, rather than transfer all data locally
- Consider the World Wide Web

Network Structure

- **Local-Area Network** (**LAN**) – designed to cover small geographical area
  - Multiple topologies like star or ring
  - Speeds from 1Mb per second (Appletalk, bluetooth) to 40 Gbps for fastest Ethernet over twisted pair copper or optical fibre
  - Consists of multiple computers (mainframes through mobile devices), peripherals (printers, storage arrays), routers (specialized network communication processors) providing access to other networks
  - Ethernet most common way to construct LANs
    - Multiaccess bus-based
    - Defined by standard IEEE 802.3
  - Wireless spectrum (**WiFi**) increasingly used for networking
    - I.e. IEEE 802.11g standard implemented at 54 Mbps

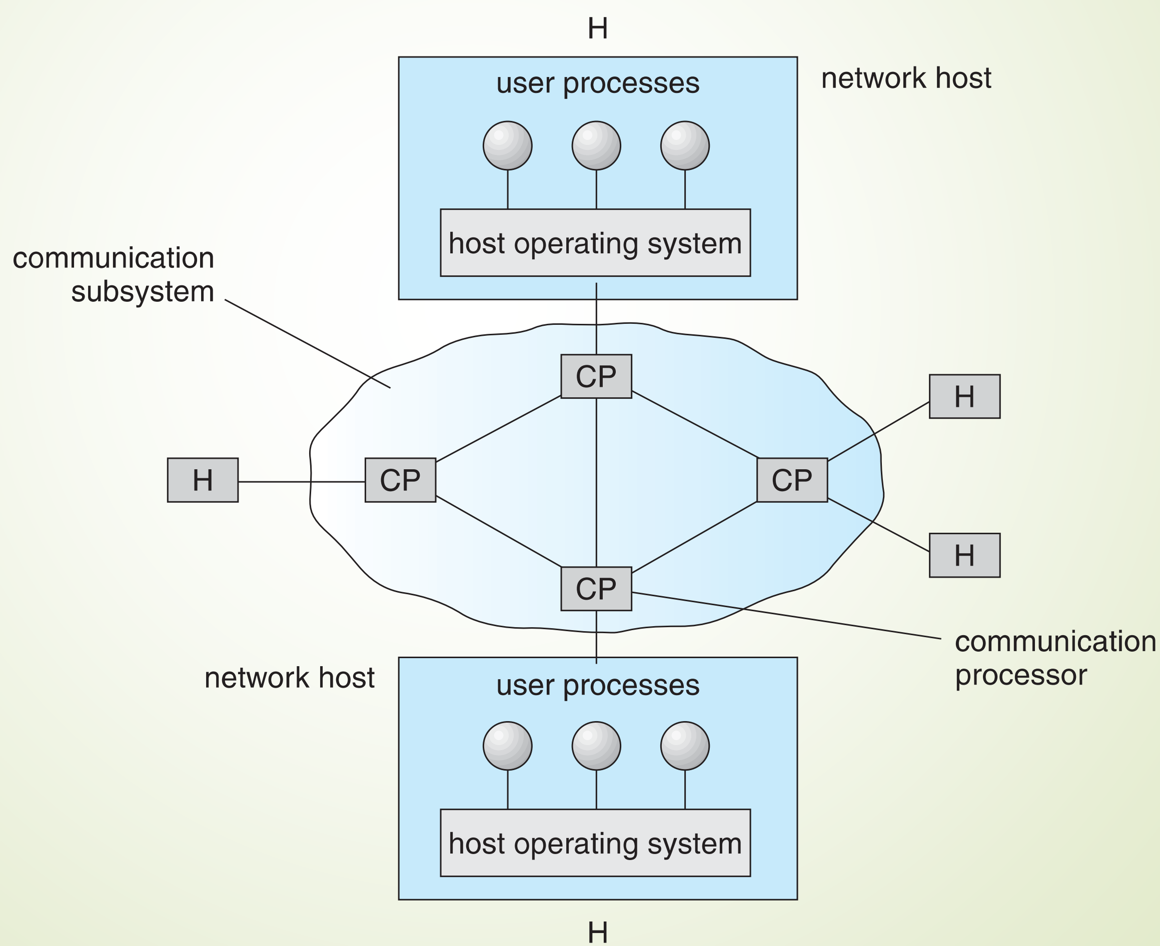
Local-area Network



Network Types (Cont.)

- **Wide-Area Network** (**WAN**) – links geographically separated sites
  - Point-to-point connections over long-haul lines (often leased from a phone company)
    - Implemented via **connection processors** known as **routers**
  - Internet WAN enables hosts world wide to communicate
    - Hosts differ in all dimensions but WAN allows communications
  - Speeds
    - T1 link is 1.544 Megabits per second
    - T3 is 28 x T1s = 45 Mbps
    - OC-12 is 622 Mbps
  - WANs and LANs interconnect, similar to cell phone network:
    - Cell phones use radio waves to cell towers
    - Towers connect to other towers and hubs

Communication Processors in a Wide-Area Network



Communication Structure

The design of a communication network must address four basic issues:

- **Naming and name resolution** - How do two processes locate each other to communicate?
- **Routing strategies** - How are messages sent through the network?
- **Connection strategies** - How do two processes send a sequence of messages?
- **Contention -** The network is a shared resource, so how do we resolve conflicting demands for its use?

Routing Strategies

- **Fixed routing** - A path from *A* to *B* is specified in advance; path changes only if a hardware failure disables it
  - Since the shortest path is usually chosen, communication costs are minimized
  - Fixed routing cannot adapt to load changes
  - Ensures that messages will be delivered in the order in which they were sent
- **Virtual routing**- A path from *A* to *B* is fixed for the duration of one session. Different sessions involving messages from *A* to *B* may have different paths
  - Partial remedy to adapting to load changes
  - Ensures that messages will be delivered in the order in which they were sent

Routing Strategies (Cont.)

- **Dynamic routing** - The path used to send a message form site *A* to site *B* is chosen only when a message is sent
  - Usually a site sends a message to another site on the link least used at that particular time
  - Adapts to load changes by avoiding routing messages on heavily used path
  - Messages may arrive out of order
    - This problem can be remedied by appending a sequence number to each message
  - Most complex to set up
- Tradeoffs mean all methods are used
  - UNIX provides ability to mix fixed and dynamic
  - Hosts may have fixed routes and **gateways** connecting networks together may have dynamic routes

Routing Strategies (Cont.)

- **Router** is communications processor responsible for routing messages
- Must have at least 2 network connections
- Maybe special purpose or just function running on host
- Checks its tables to determine where destination host is, where to send messages
  - Static routing – table only changed manually
  - Dynamic routing – table changed via **routing protocol**

Routing Strategies (Cont.)

- More recently, routing managed by intelligent software more intelligently than routing protocols
  - **OpenFlow** is device-independent, allowing developers to introduce network efficiencies by decoupling data-routing decisions from underlying network devices
- Messages vary in length – simplified design breaks them into **packets** (or **frames**, or **datagrams**)
- **Connectionless message** is just one packet
  - Otherwise need a connection to get a multi-packet message from source to destination

Connection Strategies

- **Circuit switching** - A permanent physical link is established for the duration of the communication (i.e., telephone system)
- **Message switching** - A temporary link is established for the duration of one message transfer (i.e., post-office mailing system)
- **Packet switching** - Messages of variable length are divided into fixed-length packets which are sent to the destination
  - Each packet may take a different path through the network
  - The packets must be reassembled into messages as they arrive
- Circuit switching requires setup time, but incurs less overhead for shipping each message, and may waste network bandwidth
  - Message and packet switching require less setup time, but incur more overhead per message

An Ethernet Packet

bytes		
7	preamble—start of packet	each byte pattern 10101010
1	start of frame delimiter	pattern 10101011
2 or 6	destination address	Ethernet address or broadcast
2 or 6	source address	Ethernet address
2	length of data section	length in bytes
0–1500	data	message data
0–46	pad (optional)	message must be > 63 bytes long
4	frame checksum	for error detection

Robustness

- Failure detection
- Reconfiguration

Failure Detection

- Detecting hardware failure is difficult
- To detect a link failure, a **heartbeat** protocol can be used
- Assume Site A and Site B have established a link
  - At fixed intervals, each site will exchange an *I-am-up* message indicating that they are up and running
- If Site A does not receive a message within the fixed interval, it assumes either (a) the other site is not up or (b) the message was lost
- Site A can now send an *Are-you-up?* message to Site B
- If Site A does not receive a reply, it can repeat the message or try an alternate route to Site B

Failure Detection (Cont.)

- If Site A does not ultimately receive a reply from Site B, it concludes some type of failure has occurred
- Types of failures:
  - Site B is down
  - The direct link between A and B is down
  - The alternate link from A to B is down
  - The message has been lost
- However, Site A cannot determine exactly **why** the failure has occurred

Reconfiguration

- When Site A determines a failure has occurred, it must reconfigure the system:
  1. If the link from A to B has failed, this must be broadcast to every site in the system
  2. If a site has failed, every other site must also be notified indicating that the services offered by the failed site are no longer available
- When the link or the site becomes available again, this information must again be broadcast to all other sites