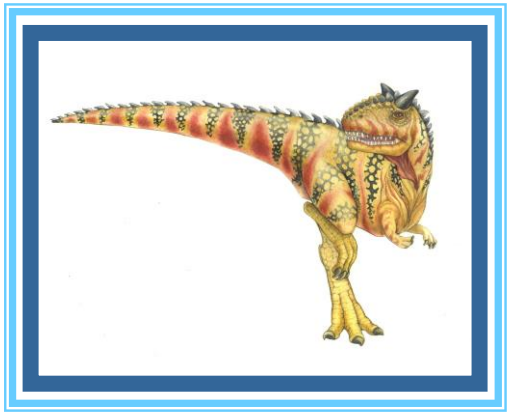
# Chapter 9: Distributed Systems



# Chapter 9: Distributed Systems

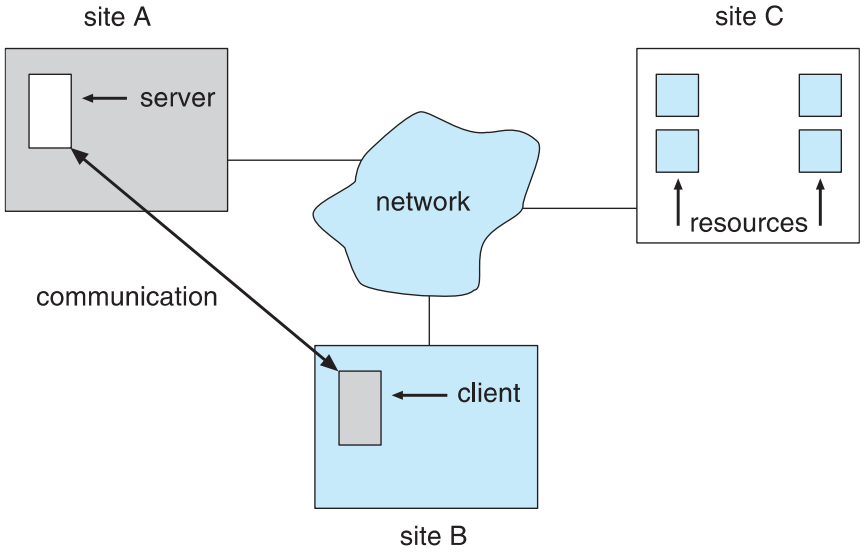
- Advantages of Distributed Systems
- Network Structure
- Communication Protocols
- Network and Distributed Operating Systems
- Design Issues of Distributed Systems

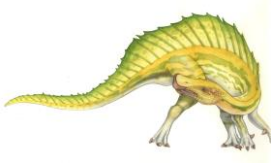
# Chapter Objectives

- Explain the advantages of networked and distributed systems
- Define the roles and types of distributed systems in use today

# Overview

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



# Overview (cont.)

- Nodes may exist in a ***client-server***, ***peer-to-peer***, or ***hybrid*** configuration.
  - In client-server configuration, server has a resource that a client would like to use
  - In peer-to-peer configuration, each node shares equal responsibilities and can act as both clients and servers
- Communication over a network occurs through **message passing**
  - All higher-level functions of a standalone system can be expanded to encompass a distributed system

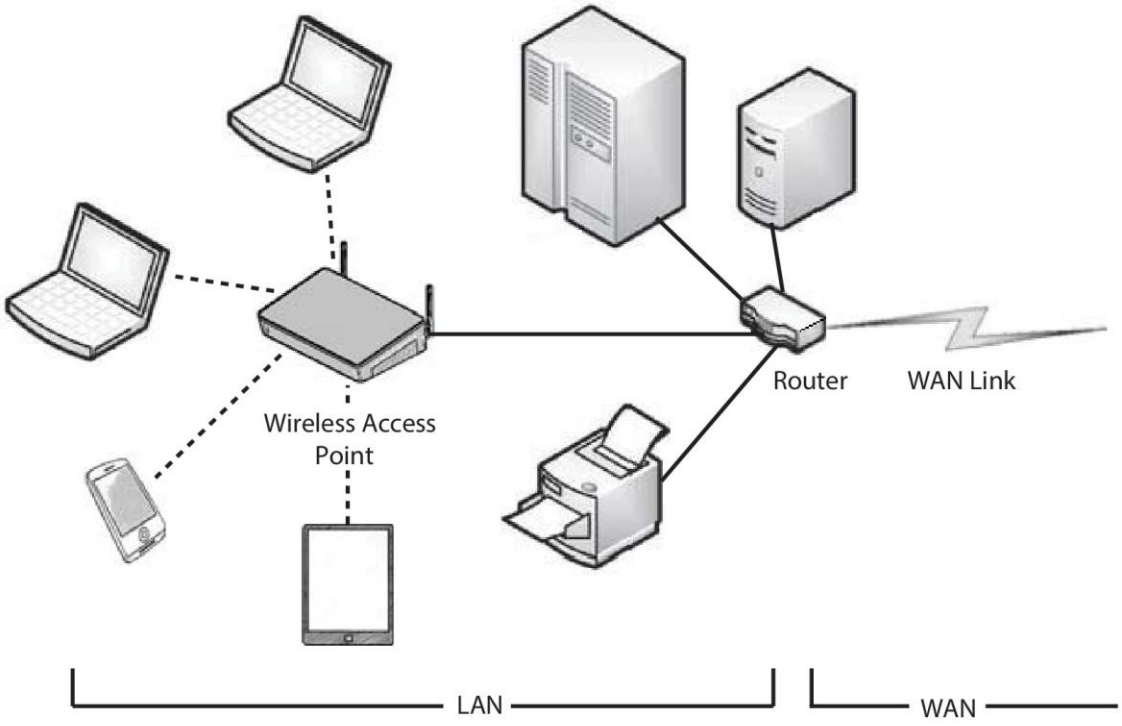
# Reasons for Distributed Systems

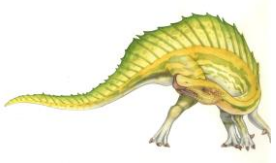
- **Resource sharing**
  - Sharing files or printing at remote sites
  - Processing information in a distributed database
  - Using remote specialized hardware devices such as ***graphics processing units*** (GPUs)
- **Computation speedup**
  - Distribute subcomputations among various sites to run concurrently
  - **Load balancing** – moving jobs to more lightly-loaded sites
- **Reliability**
  - Detect and recover from site failure, function transfer, reintegrate failed site

# Network Structure

- **Local-Area Network** (**LAN**) – designed to cover small geographical area
  - Consists of multiple computers (workstations, laptops, mobile devices), peripherals (printers, storage arrays), and routers providing access to other networks
  - Ethernet and/or Wireless (**WiFi**) most common way to construct LANs
    - Ethernet defined by standard IEEE 802.3 with speeds typically varying from 10Mbps to over 10Gbps
    - WiFi defined by standard IEEE 802.11 with speeds typically varying from 11Mbps to over 400Mbps.
    - Both standards constantly evolving

# Local-Area Network (LAN)

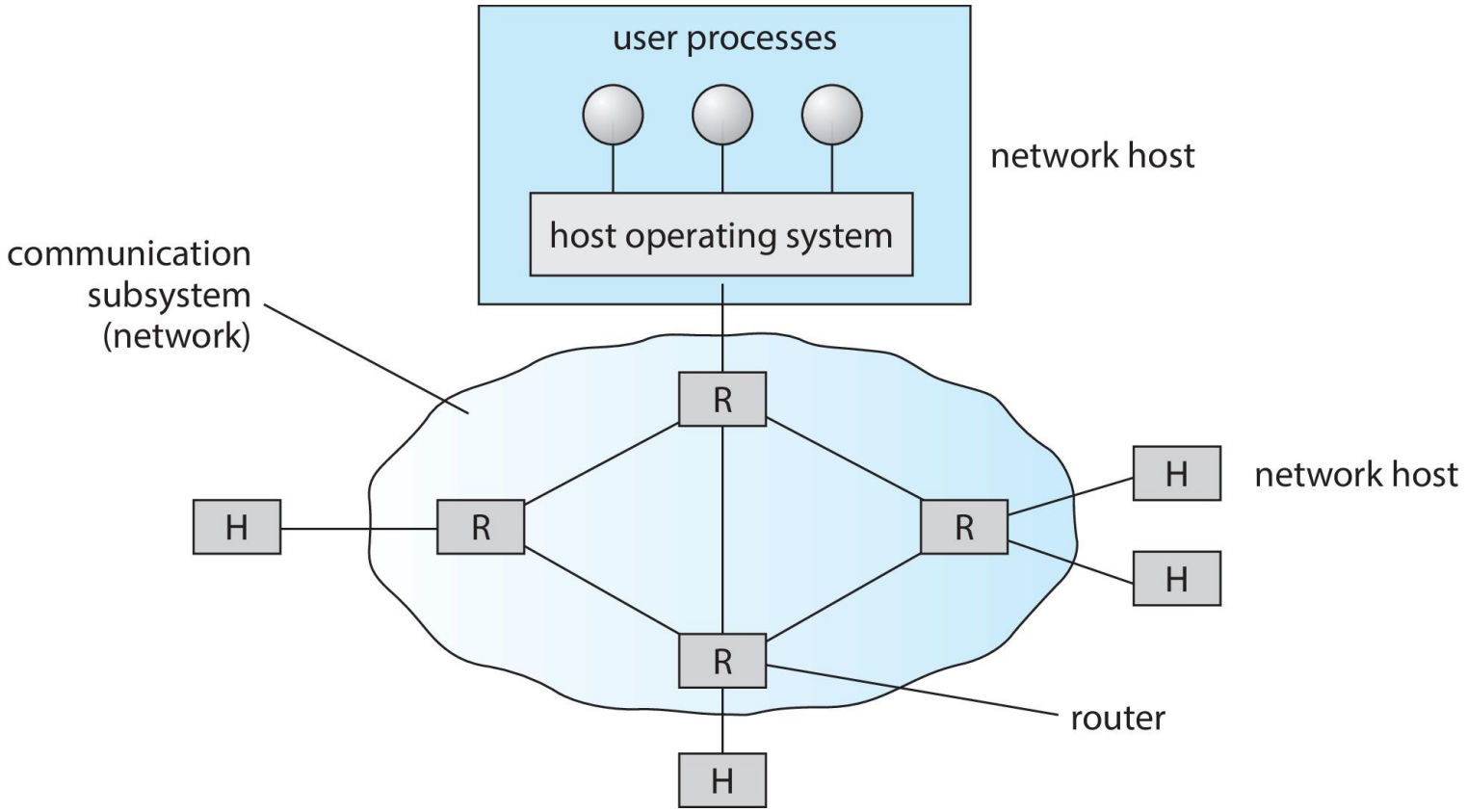


# Network Structure (Cont.)

- **Wide-Area Network** (**WAN**) – links geographically separated sites
  - Point-to-point connections via links
    - Telephone lines, leased (dedicated data) lines, optical cable, microwave links, radio waves, and satellite channels
  - Implemented via **routers** to direct traffic from one network to another
  - Internet (World Wide Web) WAN enables hosts world wide to communicate
  - Speeds vary
    - Many backbone providers have speeds at 40-100Gbps
    - Local **Internet Service Providers** (**ISPs**) may be slower
    - WAN links constantly being upgraded
  - WANs and LANs interconnect, similar to cell phone network:
    - Cell phones use radio waves to cell towers
    - Towers connect to other towers and hubs

# Wide-Area Network (WAN)



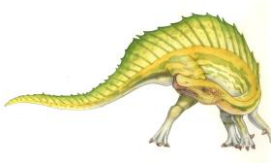

# Naming and Name Resolution

- Each computer system in the network has a unique name
- Each process in a given system has a unique name (process-id)
- Identify processes on remote systems by

  <**host-name**, **identifier**> pair
- **Domain name system** (**DNS**) – specifies the naming structure of the hosts, as well as name to address **resolution** (Internet)

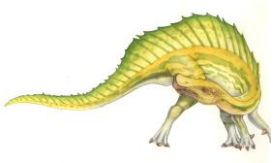
```
/**
 * Usage: java DNSLookUp <IP name>
 * i.e. java DNSLookUp www.wiley.com
 */
public class DNSLookUp {
   public static void main(String[] args) {
      InetAddress hostAddress;

      try {
         hostAddress = InetAddress.getByName(args[0]);
         System.out.println(hostAddress.getHostAddress());
      }
      catch (UnknownHostException uhe) {
         System.err.println("Unknown host: " + args[0]);
      }
    }
}
```

**Figure 19.4** Java program illustrating a DNS lookup.



# Communication Protocol

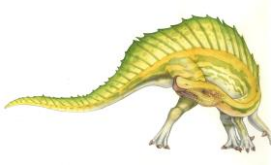
- Communication via OSI model ( 7 Layers)
- Transport Protocols:
  - TCP (Transmission Control Protocol)
    - Reliable and Connection-oriented
  - UDP (User Datagram Protocol)
    - Unreliable and Connectionless



# Network-oriented Operating Systems

- Two main types
- **Network Operating Systems**
  - Users are aware of multiplicity of machines
- **Distributed Operating Systems**
  - Users not aware of multiplicity of machines

multiplicity : ความมากมายหลากหลายรูปแบบ



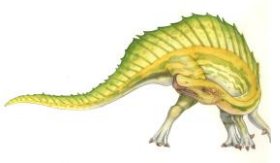
# Network Operating Systems

- Users are aware of multiplicity of machines
- Access to resources of various machines is done explicitly by:
  - Remote logging into the appropriate remote machine (ssh)
    - `ssh kristen.cs.yale.edu`
  - Transferring data from remote machines to local machines, via the File Transfer Protocol (FTP) mechanism
  - Upload, download, access, or share files through cloud storage
- Users must change paradigms – establish a **session**, give network-based commands, use a web browser
  - 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)
  - Via messaging system

migration : การเคลื่อนย้ายจากที่หนึ่งไปยังอีกที่หนึ่ง

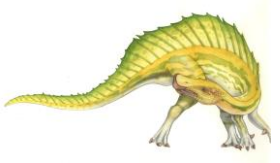


# Distributed-Operating Systems (Cont.)

- **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

# Design Issues of Distributed Systems

- We investigate three design questions:
  - ***Robustness*** – Can the distributed system withstand failures?
  - ***Transparency*** – Can the distributed system be transparent to the user both in terms of where files are stored and user mobility?
  - ***Scalability*** – Can the distributed system be scalable to allow addition of more computation power, storage, or users?



# Robustness

- Hardware failures can include failure of a link, failure of a site, and loss of a message.
- A **fault-tolerant system** can tolerate a certain level of failure
  - Degree of fault tolerance depends on design of system and the specific fault
  - The more fault tolerance, the better!
- Involves ***failure detection***, ***reconfiguration***, and ***recovery***

# 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 and Recovery

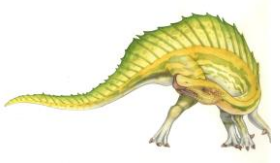
- When Site A determines a failure has occurred, it must reconfigure the system:
  - If the link from A to B has failed, this must be broadcast to every site in the system
  - If a site has failed, every other site must also be notified indicating that the services offered by the failed site are no longer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

# Transparency

- The distributed system should appear as a conventional, centralized system to the user
  - User interface should not distinguish between local and remote resources
    - Example: NFS
  - User mobility allows users to log into any machine in the environment and see his/her environment
    - Example: LDAP plus desktop virtualization

# Scalability

- As demands increase, the system should easily accept the addition of new resources to accommodate the increased demand
  - Reacts gracefully to increased load
  - Adding more resources may generate additional indirect load on other resources if not careful
  - Data **compression** or **deduplication** can cut down on storage and network resources used



# End of Chapter 9