Chapter 16 – Networking

Outline

Chapter 16 – Networking

Outline (continued)

Objectives

- After reading this chapter, you should understand:
  - the central role of networking in today's computer systems.
  - various networking types and topologies.
  - the TCP/IP protocol stack.
  - the capabilities of TCP/IP's application, transport, network and link layers.
  - protocols such as HTTP, FTP, TCP, UDP, IP and IPv6.
  - network hardware and hardware protocols such as Ethernet and Wireless 802.11.
  - the client/server networking model.

16.1 Introduction

- Hosts
  - Entities that receive and provide services over a network
  - Connected by links
- TCP/IP protocol stack
  - Provides well-defined interfaces to enable communication between computers across a network and to allow problems to be fixed as they arise
  - Layers
    - Implemented by following certain protocols

16.2 Network Topology

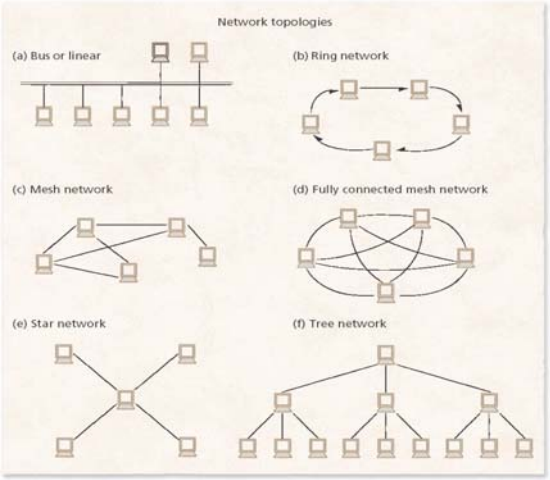
- Network topology
  - Describes relationship between different hosts
  - Logical topology
    - Displays which nodes in a network are directly connected
  - Ring networks
    - Consist of a set of nodes, each maintaining exactly two connections to other nodes
    - Each node in the ring forwards each message, limiting attenuation but introducing a delay for retransmission
  - Star networks
    - Contain a hub that is connected to all other nodes in the network
    - Lower transmission delay than ring networks
    - Messages cannot reach recipients if central hub fails

16.2 Network Topology

- Network topology (cont)
  - Tree networks
    - Hierarchical networks that consist of a root node and several children that can have children of their own
  - Mesh networks
    - At least two nodes have more than one path connecting them
    - Fully-connected mesh network
      - Directly connects every node to every other node
  - Ad hoc networks
    - Spontaneous
      - Any combination of wireless and wired devices may be connected to it at any time
    - The network topology is not fixed
      - Difficult to have a network governed by central node

16.2 Network Topologies

Figure 16.1 Network topologies.



16.3 Network Types

- Local area network (LAN)
  - Limited geographic dispersion and designed to optimize data transfer rates between its hosts
  - Interconnect resources using high-speed communication paths with optimized network protocols for local area environments
  - Error rates lower than those of larger networks
  - Greater management flexibility
  - Independence from constraints of public networking system
- Wide area networks (WANs)
  - Broader than LAN, connecting two or more LANs
  - Example: the Internet
  - Generally employ mesh topology
  - Operate at slower speeds than LANs and have higher error rates

16.4 TCP/IP Protocol Stack

- TCP/IP protocol stack
  - Composed of four logical levels called layers
    - Application layer
      - Highest level
      - Provides protocols for applications to communicate
    - Transport layer
      - End-to-end communication
      - Relies on network layer to determine proper path from one end of communication to the other
    - Network layer
      - Moving data between computers
    - Link layer
      - Provides an interface between the network layer and the underlying physical medium of the connection

16.5 Application Layer

- Application layer protocols
  - Specify rules that govern remote interprocess communication
  - Determine how processes should interact
- Many of the protocols interact with resources on remote hosts
  - Resources are specified by a Uniform Resource Identifier (URI)

16.5.1 Hypertext Transfer Protocol (HTTP)

- The Hypertext Transfer Protocol (HTTP)
  - An application layer protocol that allows the transfer of a variety of data formats
  - HTTP defines a request for a resource and a response
  - Remote host processes the request and replies with a response

16.5.2 File Transfer Protocol (FTP)

- FTP
  - Application layer protocol that allows file-sharing between remote hosts
  - Specifies connections between two pairs of ports
    - One pair sends control information that governs the session
    - The other sends actual data
  - After a connection is established, the client specifies actions for the FTP server to perform by issuing various requests to server
  - Server attempts to satisfy each request, then issues a response specifying the result

16.5.2 File Transfer Protocol (FTP)

Figure 16.2 FTP commands.

Name	Function
CDUP	Change from the current directory to the parent of the current directory.
CWD	Change the working directory.
PWD	Print the path of the working directory.
LIST	List the contents of the working directory.
DELE	Delete the specified file.
RETR	Retrieve the specified file.
STOR	Upload the specified file.
QUIT	Terminate the FTP session.

16.6 Transport Layer

- Transport layer is responsible for end-to-end communication of messages
  - Connection-oriented approach
    - Hosts send each other control information through handshaking to set up a logical end-to-end connection
    - Imposes reliability on unreliable networks
    - Guarantees that data sent from sender will arrive at intended receiver undamaged and in correct sequence
  - Connectionless approach
    - Two hosts do not handshake before transmission
    - No guarantee that sent messages will be received in their original order, or at all

16.6.1 Transmission Control Protocol (TCP)

- TCP is a connection-oriented transmission protocol
  - Guarantees that segments sent from a sender will arrive at the intended receiver undamaged and in correct sequence
  - Handles error control, congestion control, and retransmission
  - Allow protocols like HTTP and FTP to send information into network as simply and reliably as writing to a file on the local computer

16.6.2 User Datagram Protocol (UDP)

- Connectionless User Datagram Protocol (UDP)
  - Provides minimum overhead necessary for the transport layer
  - No guarantee that UDP datagrams will reach their destination in their original order, or at all

16.7 Network Layer

- Network layer
  - Receives segments from transport layer and is responsible for sending these packets to the next stop toward destination through process known as routing
    - Routing is a two-step procedure
      - Determine the best route between two points
      - Send packets along this route
    - Routers determine the next host for a given datagram based on information, such as network topologies and link quality
      - Link quality includes strength of signal, error rate and interference
        - Interference is broadcast throughout networks using various router protocols, such as Routing Information Protocol (RIP)

16.7.1 Internet Protocol (IP)

- Internet Protocol version 4 (IPv4) is the dominant protocol for directing information over a network
  - Destinations on the Internet are specified by IP address
    - IP addresses are 32-bit numbers in IPv4
    - One of more names can be mapped to an IP address through the Domain Name System (DNS)

16.7.2 Internet Protocol version 6 (IPv6)

- In the near future, there will be more addressable nodes on the Internet than available addresses using IPv4
  - To combat this problem, Internet Engineering Task Force (IETF) introduced Internet Protocol version 6 (IPv6)
    - IPv6 specifies three types of addresses
      - Unicast
        - Unicast address describes a particular host on the Internet
      - Anycast
        - Anycast addresses are designed to be sent to the nearest host in a group of hosts
      - Multicast
        - Multicast addresses are designed to send packets to all hosts in a group

16.8 Link Layer

- The link layer
  - Interfaces the software-oriented layer with the physical medium over which frames are sent
  - Is responsible for detecting and, if possible, correcting transmission errors
    - Some systems employ error-correcting codes to correct corrupted frames

16.8.1 Ethernet

- Ethernet uses Carrier Sense Multiple Access with Collision Detection (CSMA/CD) protocol
  - 802.3-style CSMA/CD
    - A transceiver tests a shared medium to determine if it is available before transmitting data
    - Due to delays in medium, it is possible that multiple transceivers may decide that the medium is clear and begin transmitting simultaneously
    - If transceivers detect a collision caused by simultaneous transmissions, they continue to transmit bytes for a specific period of time to ensure that all transceivers become aware of the collision
    - Each transceiver, after learning of a collision, waits for a random interval before attempting to transmit again

16.8.2 Token Ring

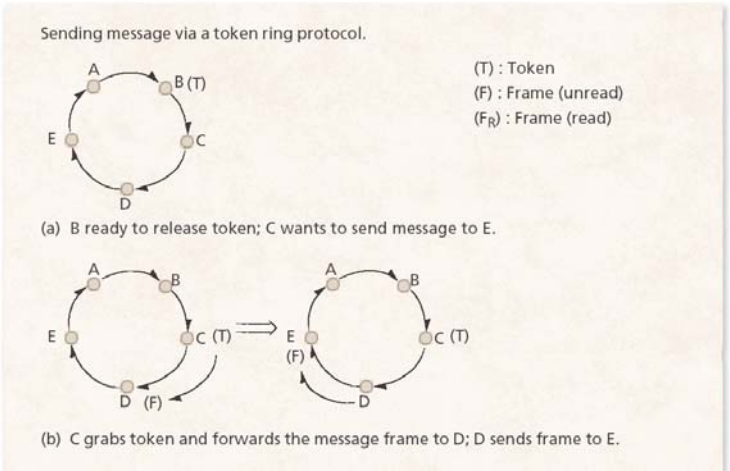
- Token Rings
  - Operate on ring networks
  - Employs tokens to gain access to the transmission medium
    - A token controls access to transmission medium is an empty frame that is circulated between machines over a network having logical ring topology

16.8.2 Token Ring

- Token
  - When machine owns the token, it generates data, places it in the frame and sends the frame to its neighbor
  - Each machine forwards the token until it reaches its destination
    - At the destination, the machine
      - Copies the content of the message
      - Marks the frame as having been delivered
      - Passes frame to its neighbor
    - When the original sender receives the frame, it
      - Removes the message from the frame
      - Passes the token to its neighbor

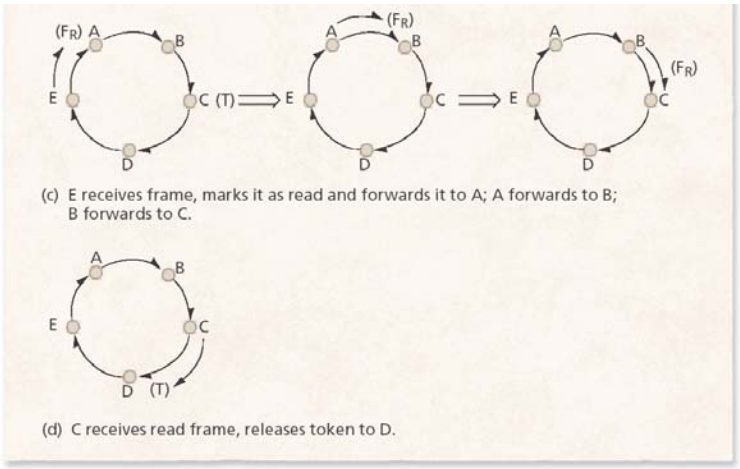
16.8.2 Token Ring

Figure 16.3 Sending a message via the Token Ring protocol (Part 1 of 2).



16.8.2 Token Ring

Figure 16.3 Sending a message via the Token Ring protocol (Part 2 of 2).



16.8.3 Fiber Distributed Data Interface (FDDI)

- Operates over fiber-optic cable
  - Support more transfers at greater speeds over larger distance
- Built on two Token Rings
  - The second usually being reserved for backup

16.8.4 IEEE 802.11 (Wireless)

- 802.11 employs a method similar to Ethernet:
  - Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)
  - Require each sender broadcast a Request to Send (RTS) to entire network
  - Upon receiving an RTS
    - Receiver broadcasts a Clear to Send (CTS) message to the entire network if the medium is available

16.9 Client/Server Model

- In a two-tier system
  - User interface resides on client
  - Data resides on server
  - Application logic lies on one or both of these components
- Three-tier system
  - Offers a clearer separation of application logic from user interface and data
- Ideally, logic resides in its own layer
  - Possibly on a separate machine
  - Independent of client and data
  - Increased flexibility and extensibility
- Trade-off in multitier system
  - Increased network latency and more areas where the network could fail

16.9 Client/Server Model

Figure 16.4 Three-tier client/server model.