King Fahd University of Petroleum & Minerals
Computer Engineering Dept

COE 540 – Computer Networks

Term 142

Dr. Ashraf S. Hasan Mahmoud

Rm 22-420

Ext. 1724

Email: ashraf@kfupm.edu.sa

Lecture Contents

These slides are based on the Tanenbaum's textbook and original author slide

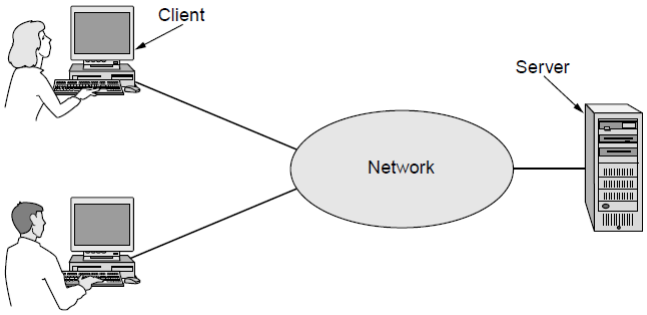
Computer Network Versus Distributed System

- Computer Network: collection of autonomous computers interconnected a single technology
- Examples:
  - Two computers in LAN
  - Internet – network of networks
- Distributed System: collection of independent computers that appears to users as a single coherent system
  - Single model or paradigm that is presented (or apparent) to users
  - Middleware – layer of software (above the OS) responsible for implementing the model
  - Software system built on top of network
  - Example: World Wide Web

Uses of Computer Networks – Business Applications

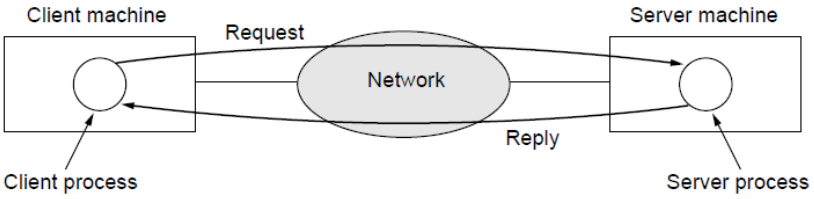
- Resource sharing – make all programs, equipment, and especially data available regardless of physical location of the resource or user.
  - Example – sharing of printers, backup systems, etc.
- Tools and Models:
  - Virtual Private Network (VPN) – joins individual networks at different sites into one extended network
  - Client-Server model - Example – Web applications, Databases, etc.
  - Electronic mail (email) – powerful communication medium for work environment
  - IP telephony or voice over IP (VoIP)
  - Desktop sharing
- Doing business electronically – electronic commerce (e-commerce)

Client-Server Model



Example of a network with two clients and one server.

Client-Server Model – cont'd



The client-server model involves requests and replies

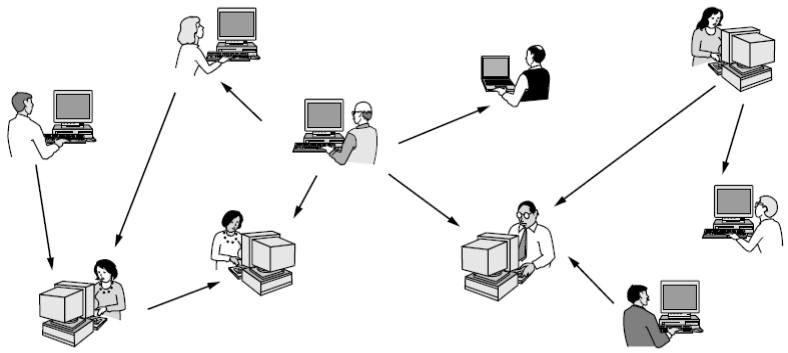
- Client process – issues requests
- Server process – receives/interprets requests and produces replies

Uses of Computer Networks – Home Applications

Person-to-remote database (info) (1)

- Why to have a computer at home:
  - Word processing and games
  - Internet access (to be connected!)
- Internet connectivity
  - Metcalfe's law: the value of the network is proportional to the square of the number of users
- Access to remote information
  - WWW – all kinds of info
- Models:
  - Client-Server model
  - Peer-to-Peer model

Peer-to-Peer Model



- In a peer-to-peer system there are no fixed clients and servers.
- No central database
- Example – BitTorrent
- Sharing of music, videos, etc.
- Napster shut down early 2000s

Home Applications – Person-to-Person Communication (2)

- Instant messaging – (old UNIX talk program)
  - multi-person messaging (Twitter service – tweets to circle of friends)
- Audio and video between people
  - Telelearning
- Social networking
  - Facebook, Twitter
  - Wikis – collaborative effort to create a content – example Wikipedia

Home Applications – Electronic Commerce (3)

- Buying products over the Internet
- Paying bills
- Managing bank accounts
- Electronic flea markets – online auctions (follow the peer-to-peer model)

Home Applications – Entertainment (4)

- Distribution of music, radio, television programs, and movies over the Internet
- IP TeleVision (IPTV)
- Game playing
  - Multi-team real-time simulation games – example hide-and-seek in a virtual dungeon; flight simulators with players shooting at each other; etc.

Home Applications – Ubiquitous Computing

- Computing embedded into everyday life.
- Security systems connected to doors and windows – calling police department
- Smoke/fire detectors – calling fire department
- Consumer electronics (cameras, DVD players, etc) are seamlessly connected to other consumer electronics
- Two technologies - facilitate ubiquitous computing at home
  - Power-line networks
  - Radio frequency identification (RFID)

Mobile Users

- Connectivity to the Internet is the main drive
- Hotspots – e.g. Laptops/Mobile phones connect the Internet using wireless LAN
- Mobile phone - Text messaging (Short Message Service) very popular application
- Smart phones – convergence of telephony and the Internet
  - E.g. iPhone (3G and 4G phones)
- Location dependant services for mobile phones equipped with GPS receivers
  - E.g. searching for nearby restaurants, etc.
- Mobile-Commerce (m-commerce) – short text messages from mobile phone are used to authorize payments for food in vending machines, movie tickets, and other small items
- Useful (growing) technologies – Sensor Networks, Wearable computers

Social Issues

- Social networks – message boards, content sharing sites, etc.
- Network neutrality
- Digital Millennium Copyright Act (DMCA) – automated systems that search peer-to-peer networks and fire off warnings to network operators and users for suspected copyright infringement
- User profiling – cookies, Gmail (?)
- Spam email
- Phishing – messages masquerade as originating from a trustworthy party

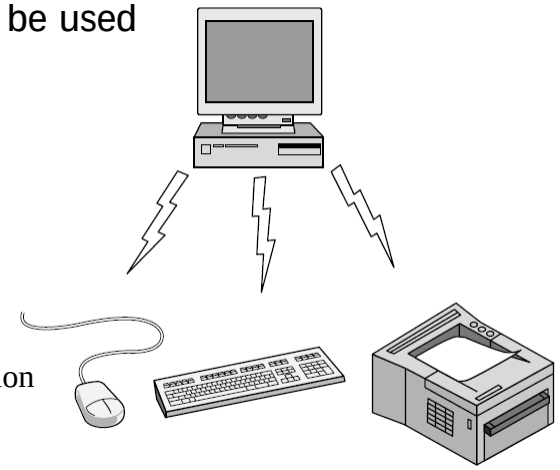
Network Hardware

- Transmission technologies typically used:
  - Broadcast
  - Point-to-point (unicast)
- Packets – unit of transmission
- Classification based on physical size

Interprocessor distance	Processors located in same	Example
1 m	Square meter	Personal area network
10 m	Room	Local area network
100 m	Building	
1 km	Campus	
10 km	City	Metropolitan area network
100 km	Country	Wide area network
1000 km	Continent	
10,000 km	Planet	The Internet

Personal Area Networks (PANs)

- Main technology – Bluetooth
- RFID – can also be used

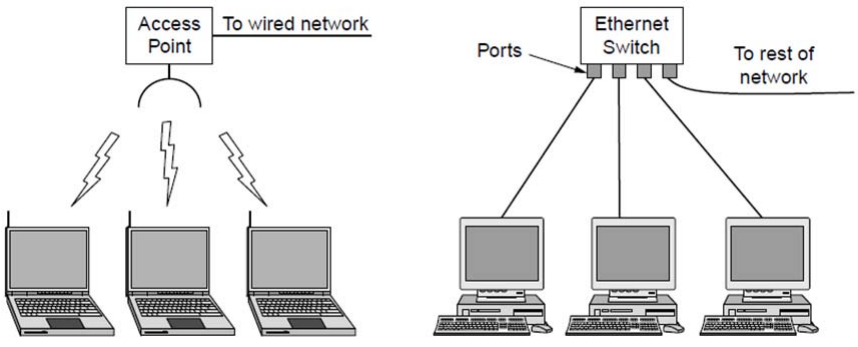


Bluetooth PAN configuration

Local Area Networks (LANs)

- Typically privately owned and operates with or nearby a building (home, office, factory, etc.)
- Wireless LAN – IEEE802.11 versus WiFi
  - Access point (aka wireless router or basestation)
  - 100s of Mb/s
- Wired LAN – IEEE 802.3 or (switched) Ethernet is the main technology
  - Speed ranging from Mb/s to 10 Gb/s
  - Switch – ports
- Power-line networks – competing technology

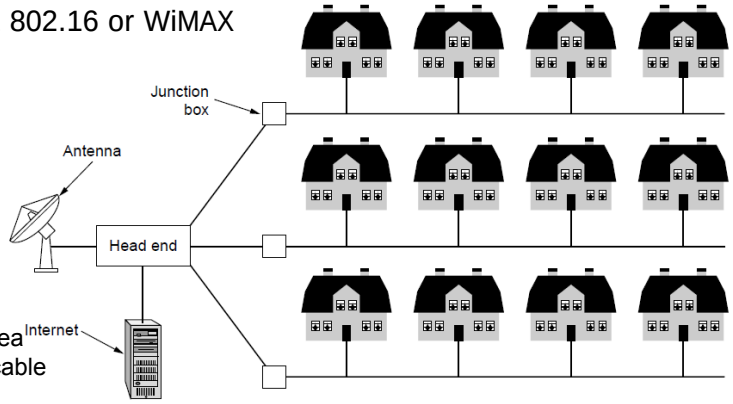
Local Area Networks (LANs) – cont'd



Wireless and wired LANs. (a) 802.11. (b) Switched Ethernet.

Metropolitan Area Networks (MANs)

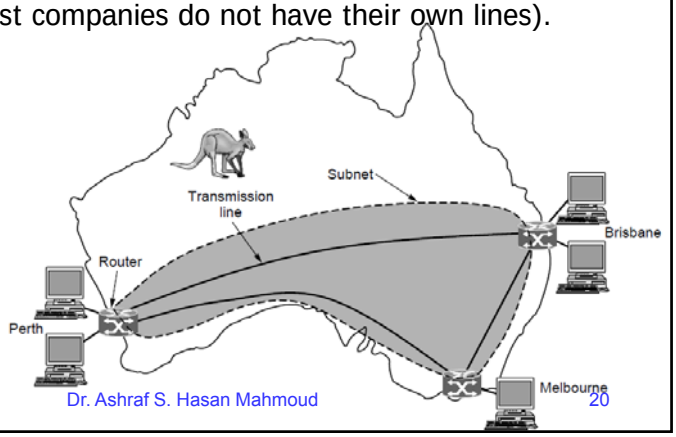
- Covers a city
- Examples:
  - Cable television distribution network
  - IEEE 802.16 or WiMAX



A metropolitan area network based on cable TV.

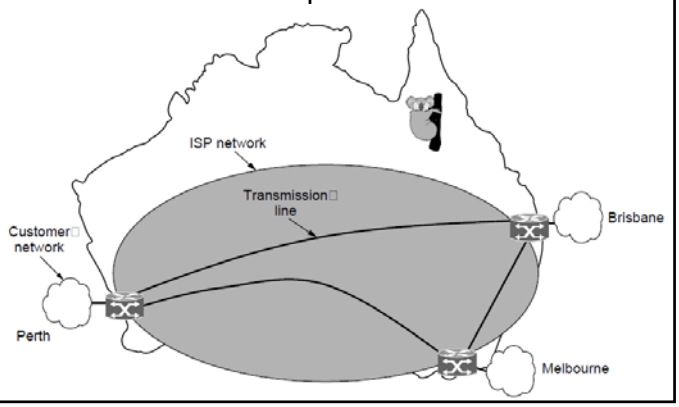
Wide Area Networks (WANs)

- Connect devices over a country
- Example WAN connecting three branch offices:
  - The company probably leases the transmission lines (since most companies do not have their own lines).



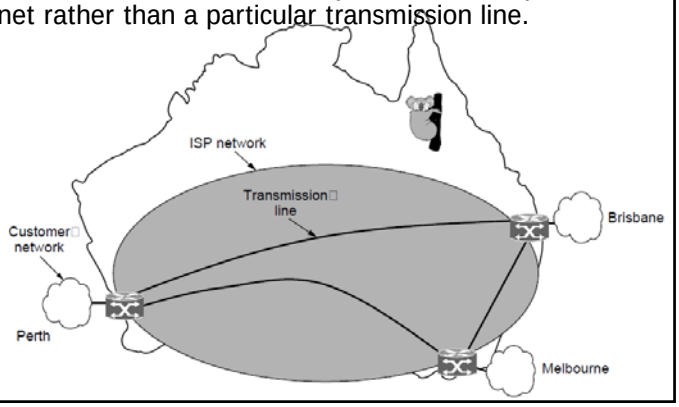
Wide Area Networks (WANs) – cont'd

- An ISP (Internet Service Provider) network is also a WAN.
- Customers buy connectivity from the ISP to use it.
  - Now the company/customer buys service from an ISP who uses its own lines to deliver packets.



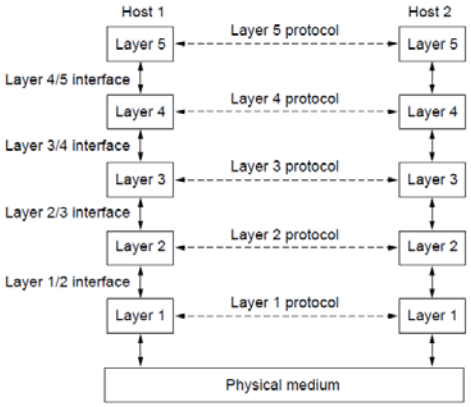
Wide Area Networks (WANs) – cont'd

- A VPN (Virtual Private Network) is a WAN built from virtual links that run on top of the Internet.
  - Now the company/customer uses the Internet (might be multiple ISPs) for connectivity.
  - The links are virtual in the sense that they refer to some path via the Internet rather than a particular transmission line.



Network Software

- Stack of layers or levels – abstraction of network functions and grouping them into different layers
- Protocol – convention governing communication between entities
- 5-layer architecture is shown in figure
- Peer entities – software processes or hardware devices
- Each layer (n>1) utilizes the services of the layer below to communicate with its peer entity
  - Interface or Service Access Point (SAP)
- Only true physical communication occurs on the physical medium



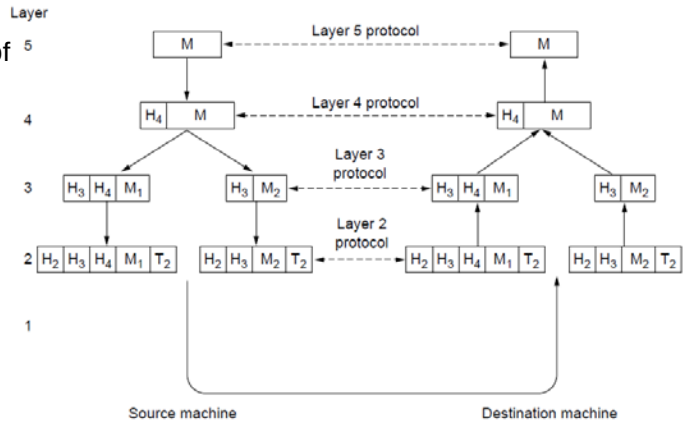
Network Architecture

- Set of layers and corresponding protocols
- Protocol stack – set of protocols used by a particular system (one protocol per layer)
  - TCP/IP protocol stack

Headers, Segmentation, and Re-assembly

- Information flow between to machines
- Applicable to the case where A and B are connected using a network

- Note the use of headers and trailers
- Enforce separation of functions and layer independence



Design Issues for the Layers

Each layer solves a particular problem but must include mechanisms to address a set of recurring design issues

Issue	Example mechanisms at different layers
Reliability despite failures	Codes for error detection/correction (§3.2, 3.3) Routing around failures (§5.2)
Network growth and evolution	Addressing (§5.6) and naming (§7.1) Protocol layering (§1.3)
Allocation of resources like bandwidth	Multiple access (§4.2) Congestion control (§5.3, 6.3)
Security against various threats	Confidentiality of messages (§8.2, 8.6) Authentication of communicating parties (§8.7)

Connection-Oriented Versus Connectionless Services

- Connection-oriented
  - Similar to circuit switched
  - Three main phases: dial-up (set up), data transfer, tear-down.
- Connectionless
  - Unreliable delivery of packets – datagram service
- Upper layers may convert unreliable datagram service into reliable connection
- Unit of transmission – Packet
- Routing function
  - Store-and-forward switching
  - Cut-through switching

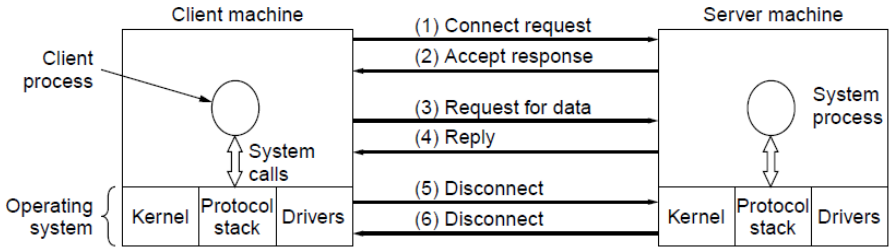
Service Primitives

- Operations or function calls available to entity process to access service from lower layer and communicate with peer entity on the other machine
- Example: 6 primitives that can be used to establish connection oriented service

Primitive	Meaning
LISTEN	Block waiting for an incoming connection
CONNECT	Establish a connection with a waiting peer
ACCEPT	Accept an incoming connection from a peer
RECEIVE	Block waiting for an incoming message
SEND	Send a message to the peer
DISCONNECT	Terminate a connection

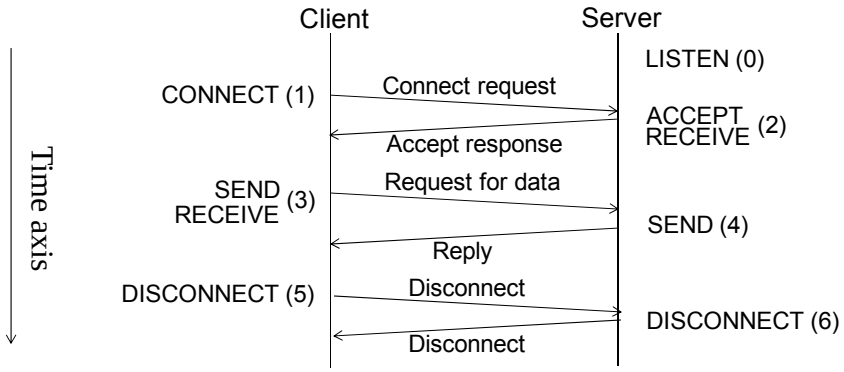
Service Primitives – cont'd

- Simple client-server interaction using acknowledged datagrams



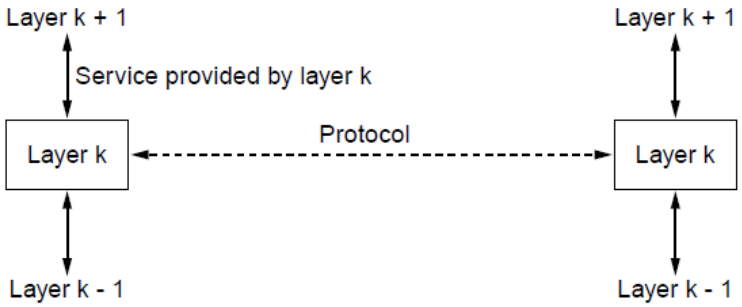
Service Primitives – cont'd

- Using message exchange timing diagram



Relationship of Services to Protocols

- Service – set of primitives that a layer provides to the layer above
- Protocol – set of rules governing the format and the meaning of the packets



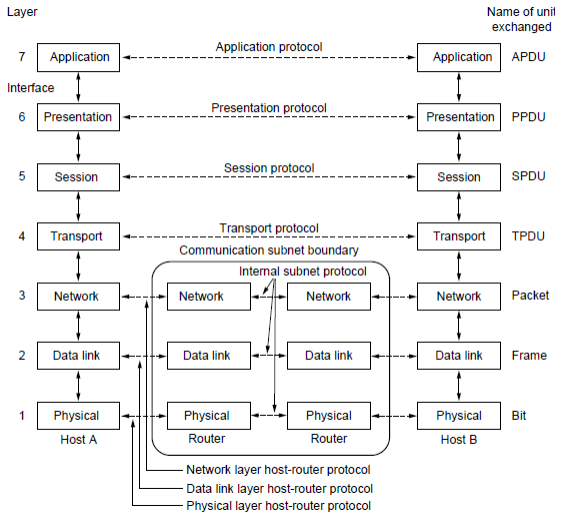
Reference Models

- Open Systems Interconnection (OSI)
  - General specification/model
  - Its protocols are not used
- TCP/IP – most popular
  - Protocols are most utilized in the Internet.

The OSI Reference Model

- Model principles:

1. Layers created for different abstractions
2. Each layer performs well-defined function
3. Function of layer chosen with definition of international standard protocols in mind
4. Minimize information flow across interfaces between boundaries
5. Number of layers optimum



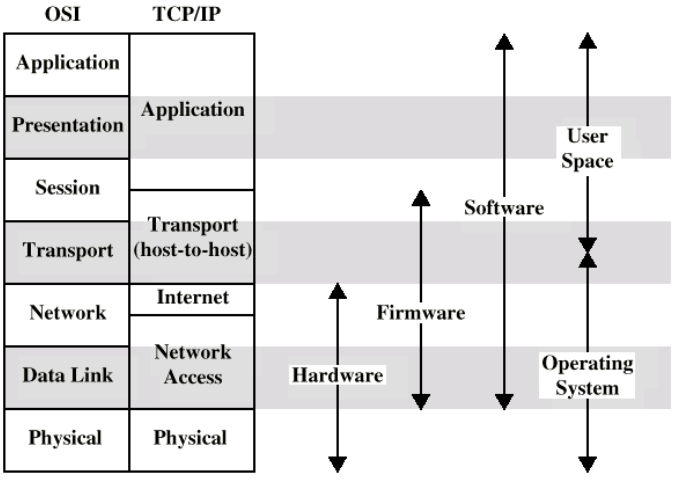
The OSI Reference Model – Layers Functions

1. Physical
   - Transmission of raw bits (1s and 0s)
2. Data link layer
   - Converting the raw stream of bits into a reliable exchange of data frames
   - Use of acknowledgement frames, error control, etc.
   - Medium access control – sublayer controlling access to the shared medium
3. Network layer
   - Deciding on routes for packets and forwarding packet in the direction of the destination
   - Controls the operation of the subnet
4. Transport
   - Accepting data from one end and reliably transferring it to the other end
   - Operates end-to-end
5. Session
   - Establishing sessions between the two parties
   - Functions include dialog control, token management, synchronization, etc.
6. Presentation
   - Syntax and semantics of information transmitted
7. Application
   - Email (SMTP), WWW (HTTP), file transfer (FTP), etc.

The TCP/IP Model

- **Model has five independent layers:**
  - **Application layer: comm between processes or applications on separate hosts**
  - **Transport layer: end-2-end transfer service – may include reliability mechanisms**
  - **Internet layer: routing data from source to destination through one or more networks**
  - **Network access layer: logical interface between end systems and the network**
  - **Physical layer: defines mechanism of transmitting raw bits depending on media characteristic**

The TCP/IP Model (using the OSI Model as a reference)



Comparing OSI and TCP/IP and Critique of the two Models

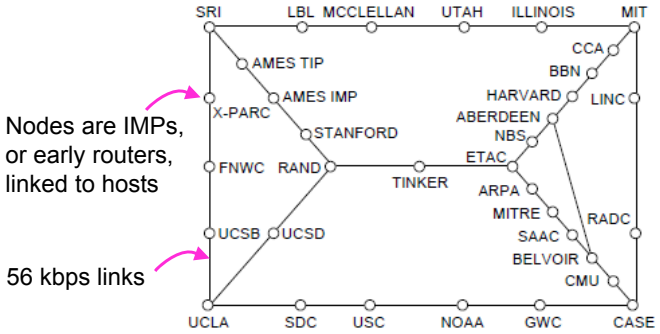
- Read textbook

Example Networks

- The Internet
- 3G/4G Mobile networks
- Wireless LANs
- RFID and wireless sensor networks

Internet (1)

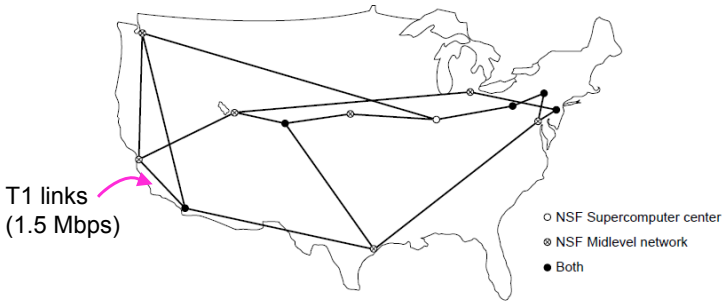
Before the Internet was the ARPANET, a decentralized, packet-switched network based on Baran's ideas.



ARPANET topology in Sept 1972.

Internet (2)

The early Internet used NSFNET (1985-1995) as its backbone; universities connected to get on the Internet



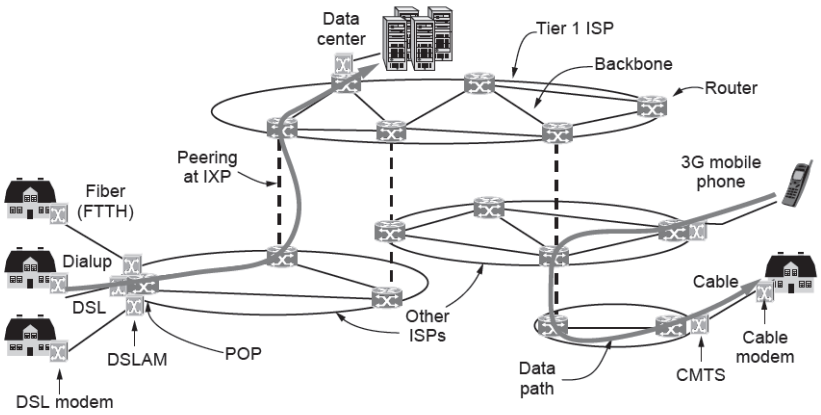
NSFNET topology in 1988

Internet (3)

The modern Internet is more complex:

- ISP networks serve as the Internet backbone
- ISPs connect or peer to exchange traffic at IXPs
- Within each network routers switch packets
- Between networks, traffic exchange is set by business agreements
- Customers connect at the edge by many means
  - Cable, DSL, Fiber-to-the-Home, 3G/4G wireless, dialup
- Data centers concentrate many servers ("the cloud")
- Most traffic is content from data centers (esp. video)
- The architecture continues to evolve

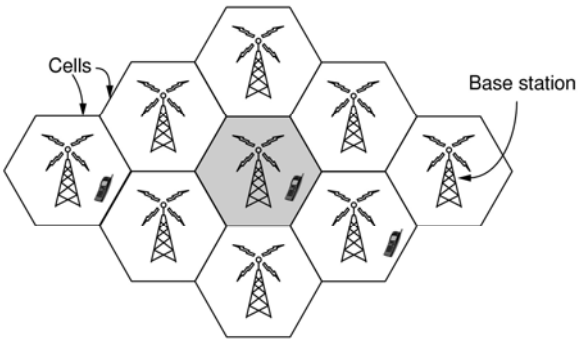
Internet (4)



Architecture of the Internet

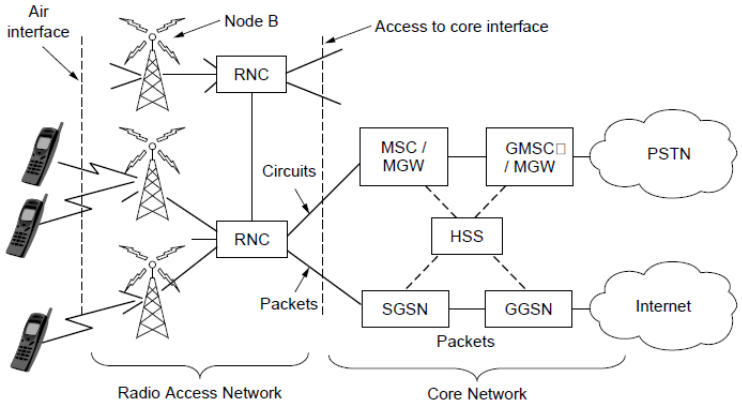
3G Mobile Phone Networks (1)

3G network is based on spatial cells; each cell provides wireless service to mobiles within it via a base station



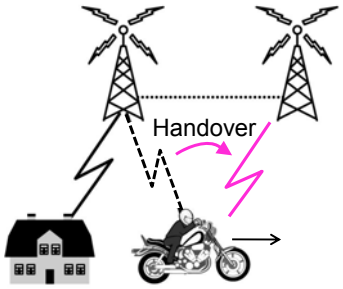
3G Mobile Phone Networks (2)

Base stations connect to the core network to find other mobiles and send data to the phone network and Internet



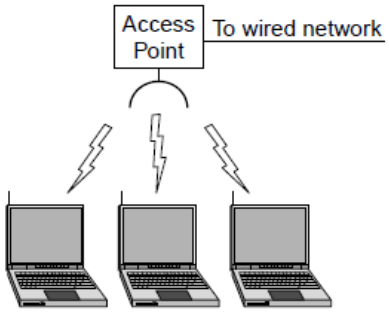
3G Mobile Phone Networks (3)

As mobiles move, base stations hand them off from one cell to the next, and the network tracks their location



Wireless LANs (1)

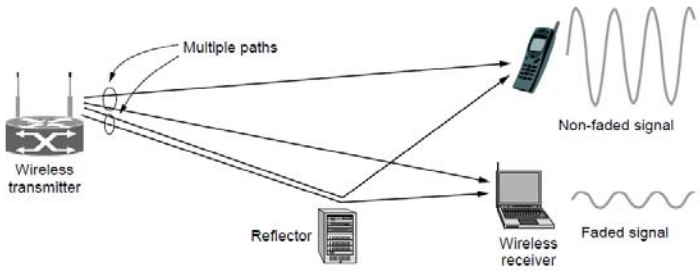
In 802.11, clients communicate via an AP (Access Point) that is wired to the rest of the network.



Wireless LANs (2)

Signals in the 2.4GHz ISM band vary in strength due to many effects, such as multipath fading due to reflections

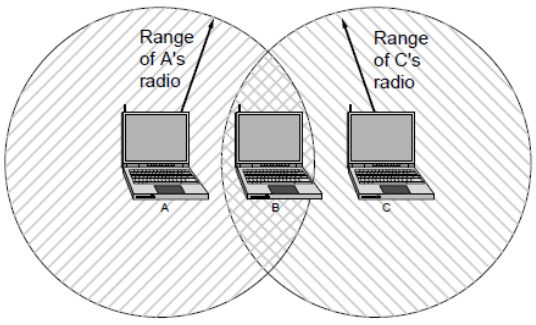
- requires complex transmission schemes, e.g., OFDM



Wireless LANs (3)

Radio broadcasts interfere with each other, and radio ranges may incompletely overlap

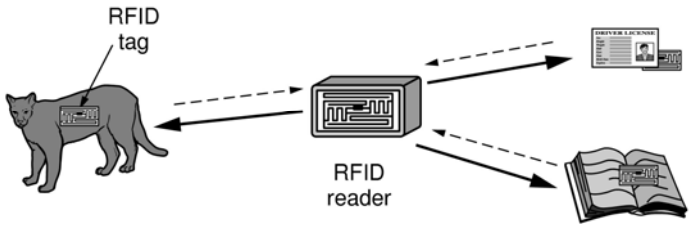
- CSMA (Carrier Sense Multiple Access) designs are used



RFID and Sensor Networks (1)

Passive UHF RFID networks everyday objects:

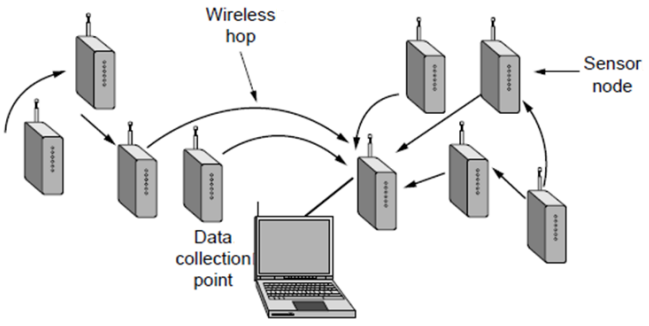
- Tags (stickers with not even a battery) are placed on objects
- Readers send signals that the tags reflect to communicate



RFID and Sensor Networks (2)

Sensor networks spread small devices over an area:

- Devices send sensed data to collector via wireless hops



Network Standardization

Standards define what is needed for interoperability

Some of the many standards bodies:

Body	Area	Examples
ITU	Telecommunications	G.992, ADSL H.264, MPEG4
IEEE	Communications	802.3, Ethernet 802.11, WiFi
IETF	Internet	RFC 2616, HTTP/1.1 RFC 1034/1035, DNS
W3C	Web	HTML5 standard CSS standard

Metric Units

The main prefixes we use:

Prefix	Exp.	prefix	exp.
K(ilo)	10^3	m(illi)	10^{-3}
M(ega)	10^6	μ(micro)	10^{-6}
G(iga)	10^9	n(ano)	10^{-9}

- Use powers of 10 for rates, powers of 2 for storage
  - E.g., 1 Mbps = 1,000,000 bps, 1 KB = 1024 bytes
- "B" is for bytes, "b" is for bits