EEC-682/782
Computer Networks I

Lecture 2

Wenbing Zhao
w.zhao1@csuohio.edu
(Lecture nodes are based on materials supplied by Dr. Louise Moser at UCSB and Prentice-Hall)

Cleveland State University

Outline

- Review of lecture 1
- Reference models
- Example networks
- Network standardization
- Metric units

Review of Lecture 1

- Uses of computer networks
- Network Hardware
- Network software

Uses of Computer Networks

- Business applications
- Home applications
- Mobile users
- Social issues

Network Hardware

- No generally accepted taxonomy.
  Two dimensions
  - Transmission technology
  - Scale
- Transmission technology
  - Broadcast links
  - Point-to-point links (unicasting)
- Scale
  - Personal area networks
  - Local area networks
  - Metropolitan area networks
  - Wide area networks
  - The Internet

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

Wide Area Networks

- Spans a large geographical area, often a country or continent
- Network structure in WAN
  - **Host** or end system
    - Collection of machines that run user (application) programs
  - **Communication Subnet** – connects hosts
    - Two distinct components
      - Transmission lines – move bits (circuits, channels, trunks)
      - Routers or switching elements that connect two or more transmission lines
    - Two types of designs
      - Point-to-point channels
      - Broadcast channels

Network Software

- Protocol hierarchies / Network architectures
- Design issues for the layers
- Connection-oriented and connectionless services
- Service primitives
- The relationship of services to protocols

Protocol Hierarchies

- **Protocol hierarchies** are organized into layers or levels with different protocols at each layer
- Each layer offers certain services to higher layers, hiding the details of implementation of those services
- Layer n on one machine communicates with layer n on another machine
- Interface between adjacent layers defines operations and services offered by lower layer to upper layer

Network Architectures

- **Network Architecture** - A set of layers and protocols
  - Must contain enough information for implementation
  - Does not contain details of the implementation and specification of the interfaces
  - It is not even necessary that the interfaces on all machines in a network be the same
- **Protocol Stack** - A list of protocols used by a certain system, one protocol per layer
- The subjects of network architectures, protocols stacks, and the protocols themselves are the principal topics of this course

Design Issues for the Layers

- Each layer needs
  - Mechanisms for connection management and addressing
  - Rules for data transfer
  - Error control
  - Flow control
  - Finite buffers
  - Routing

Connection-Oriented and Connectionless Services

- Connection-oriented service
  - Modeled after telephone system – establish connection before communication
  - Some service allow a **negotiation** among sender, receiver and subnet regarding the parameters to be used, such as max message size, etc.
- Connectionless service
  - Modeled after postal system – a message carries full destination address, and each one is routed through the system independent of all the others
    - Ordering of messages are not guaranteed
- Quality of Service
  - **Reliable service** – it does not lose data
    - Implemented by having the receiver acknowledge the receipt of each message
    - The acknowledgement process introduces overhead and delays

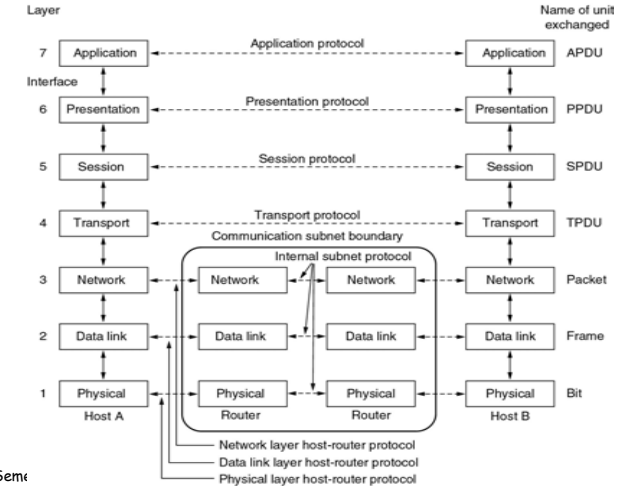
Today's New Topics

- Reference models
- Example networks
- Network standardization
- Metric units

Reference Models

- The OSI Reference Model
  - ISO – International Standards Organization
  - OSI – Open Systems Interconnection
    - Open – open for communication with other systems
- The TCP/IP Reference Model
- A Comparison of OSI and TCP/IP
- A Critique of the OSI Model and Protocols
- A Critique of the TCP/IP Reference Model

The OSI Reference Model



Physical Layer

- Transmission of raw bits over communication channel
- No regard for meaning or structure
- Design issues concern
  - Ensuring that if a 1(0) bit is sent then a 1(0) bit is received
  - Electrical, mechanical, timing interfaces, and physical communication medium

Data Link Layer

- Takes raw bits and ensures that they are free of transmission errors
- Breaks data into frames (few hundred or few thousand bytes), transmits frames sequentially, processes ack frames sent back by receiver
- Creates and recognizes frame boundaries by attaching special bit patterns to beginning and end of frame
- Retransmits lost, corrupted, or duplicated frames

Network Layer

- Concerned with controlling operation of subnet
- Routing of packets from source to destination
  - Routes can be determined statically, at start of session, dynamically
- Congestion control
  - Avoiding and alleviating bottlenecks
- Quality of service
  - Delay, transit time, jitter, etc.
- Resolve incompatibility between networks due to differences in
  - Addressing, packet size, protocols

Transport Layer

- Source to destination / end-to-end
- Accepts data from session layer, splits into smaller units, if necessary passes down to network layer and ensures arrives at destination correctly
- Most common type of transport connection
  - Error-free, point-to-point, ordered delivery

Session Layer

- Allow users at different machines to establish sessions between them. Offer various services:
  - Manages dialogue control
    - Whose turn is it?
  - Token management so two machines do not attempt same operation at same time
  - Synchronization
    - Inserts checkpoints into data stream so that, if machine crashes, only data after checkpoint have to be resent

Presentation Layer

- Concerned with syntax and semantics of info, not just bits
- Encoding and decoding of abstract data types, e.g., records
- Data compression
- cryptography

Application Layer

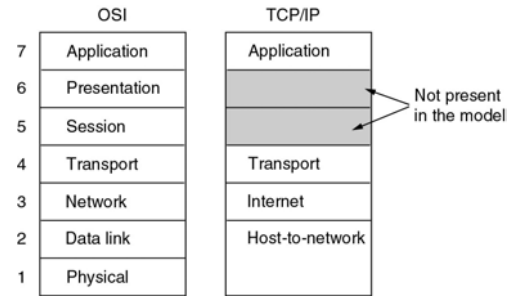
- Handles incompatibilities between networks
- Provides software for dealing with different terminal types
  - Creates virtual terminal that looks same throughout network
- Facilities for
  - File transfer
  - Electronic mail
  - Network news
  - HTTP (HyperText Transfer Protocol)
  - Etc.

Principles Applied in Deriving the Layers

- A layer should be created where a different level of abstraction is needed
- Each layer should perform a well-defined function
- The function of each layer should be chosen with the aim of defining internationally standardized protocols
- The layer boundaries should be chosen to minimize info flow across interfaces
- The number of layers should be
  - large enough to separate distinct functions
  - small enough to have a manageable architecture

TCP/IP Reference Model

- TCP – Transmission Control Protocol
- IP – Internet Protocol
- Used in Internet and its predecessor ARPANET
- TCP/IP invented by Cerf and Kahn in 1974, became official protocol of ARPANET in 1983



TCP/IP Reference Model

- Internet Layer
  - Packet switched
  - Connectionless
  - Injects packets into the network; delivers them to the destination
  - May be delivered out-of-order
  - Packet routing and congestion control are key issues
  - Uses IP

TCP/IP Reference Model

- Transport layer, two protocols
- TCP – Transmission Control Protocol
  - Point-to-point
  - Connection-oriented
  - Reliable (no message loss or corruption)
  - Source ordered (sequenced)
  - Flow control
  - Bye stream, does not maintain message boundary
- UDP – User Datagram Protocol
  - Point-to-point
  - Connectionless
  - Unreliable
  - Not source ordered
  - No flow control
  - Preserve message boundary
  - Used when prompt more important than accurate

TCP/IP Reference Model

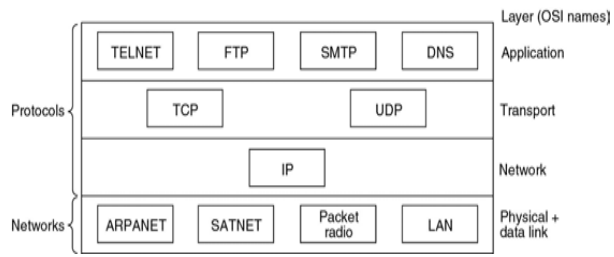
- Application Layer – contains higher-level protocols
  - TELNET – allows user on one machine to log into remote machine and work there
  - FTP – File Transfer Protocol
    - Allows user to transfer files efficiently from one machine to another
  - DNS – Domain Name Service
    - Maps host names onto their network addresses
  - HTTP – HyperText Transfer Protocol
    - Fetches pages on the World Wide Web

TCP/IP Reference Model

- Host-to-Network Layer
  - Host has to connect to the network using some protocol so it can send IP packets to it
  - No protocol is defined

TCP/IP Reference Model

- Protocols and networks in the TCP/IP model initially.



Comparing OSI and TCP/IP Models

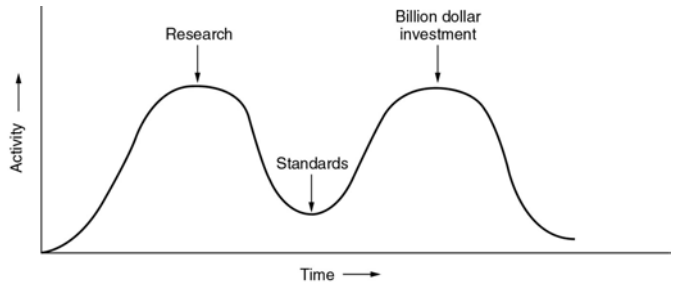
- Concepts central to the OSI model
  - Services – what layer does
  - Protocols – how layer does it
  - Interfaces – tells upper layer how to access services of lower layer
- OSI model was devised before the corresponding protocols were invented
  - Good - Not biased toward one particular set of protocols
  - Bad – designers did not have much experience with subject
    - MAC layer was grafted into data link layer
- TCP/IP model came after the protocols
  - Model simply a description of the existing protocols
  - Not good to describe protocols other than TCP/IP
- Connectionless vs. connection-oriented communication
  - OSI model supports both in the network layer, but only connection-oriented comm. In transport layer
  - TCP/IP model supports only connectionless comm. In the network layer, but support both in the transport layer, where it counts

A Critique of the OSI Model and Protocols

- Why OSI did not take over the world
  - Bad timing
  - Bad technology
  - Bad implementations
  - Bad politics

Bad Timing

- The apocalypse of the two elephants.



A Critique of the TCP/IP Reference Model

- Service, interface, and protocol not distinguished
- Not a general model
- Host-to-network "layer" not really a layer
- No mention of physical and data link layers
- Minor protocols deeply entrenched, hard to replace

Hybrid Model

- The hybrid reference model to be used in the textbook and this course

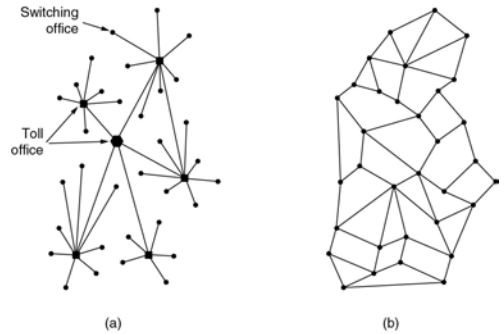
5	Application layer
4	Transport layer
3	Network layer
2	Data link layer
1	Physical layer

Example Networks

- The Internet
- Connection-Oriented Networks: X.25, Frame Relay, and ATM
- Ethernet
- Wireless LANs: 802:11

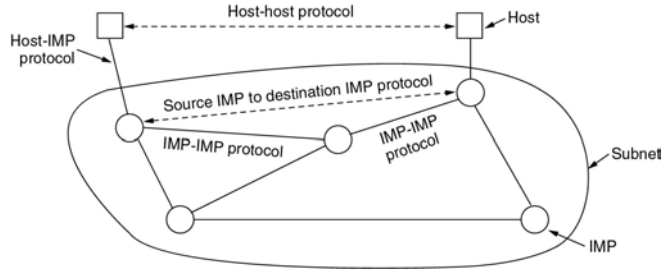
The ARPANET

(a) Structure of the telephone system.
(b) Baran's proposed distributed switching system.

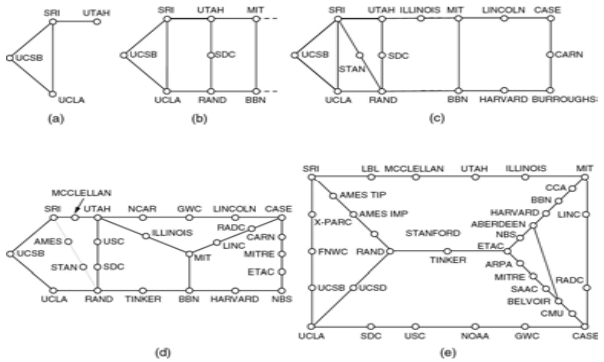


The ARPANET

- The original ARPANET design
  - IMP – Interface Message Processors



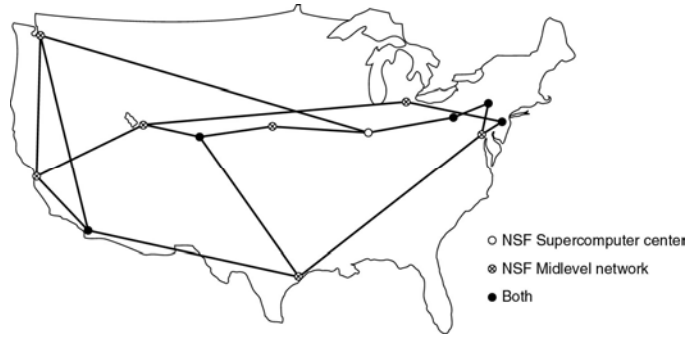
The ARPANET



Growth of the ARPANET (a) December 1969. (b) July 1970. (c) March 1971. (d) April 1972. (e) September 1972.

NSFNET

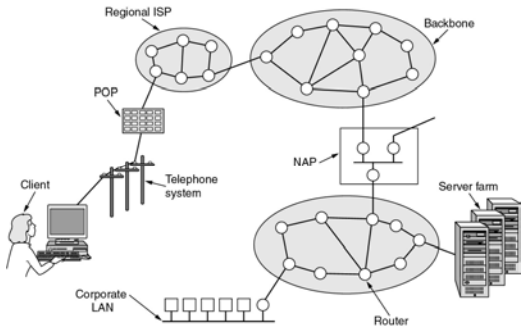
- The NSFNET backbone in 1988.



Internet Usage

- Traditional applications (1970 – 1990)
  - E-mail
  - News
  - Remote login
  - File transfer
- World Wide Web (1990-present)
  - WWW made it possible for a site to set up a number of pages of info containing text, pictures, sound and even video, with embedded links to other pages
  - Growth was fueled by ISPs (Internet Service Providers)

Architecture of the Internet

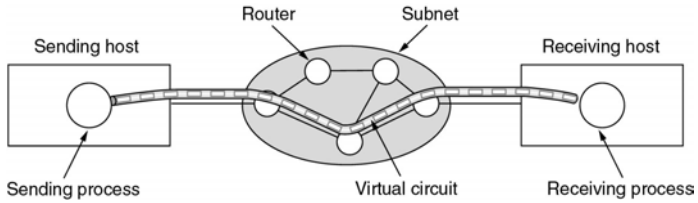


Connection-Oriented Networks

- Why do telephone companies like connection-oriented networks
  - Quality of service
  - Billing
- Example networks
  - X.25
    - First public data network, deployed in 1970s
    - Each packet contains a 3-byte header and up to 128 bytes of data. The header consisted of a 12-bit connection number, a packet sequence number, an ack number and a few misc bits
  - Frame Relay
    - Replaced X.25 in 1980s.
    - No error control and no flow control
    - Packets are delivered in order, might lose packets
  - ATM – Asynchronous Transfer Mode
    - Transmission is not synchronous (i.e., not closely tied to a clock)
    - Aimed to merge voice, data, cable tv, telegraph, etc. together
    - Designed in early 1990s and launched amid truly incredible hype

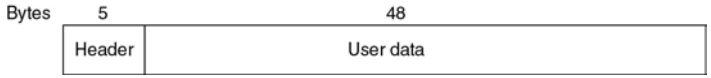
ATM Virtual Circuits

- A virtual circuit
  - Established by sending a setup packet from source to destination
    - As the setup packet wends its way through the subnet, all routers on the path make an entry in their tables and reserving resources needed for the connection



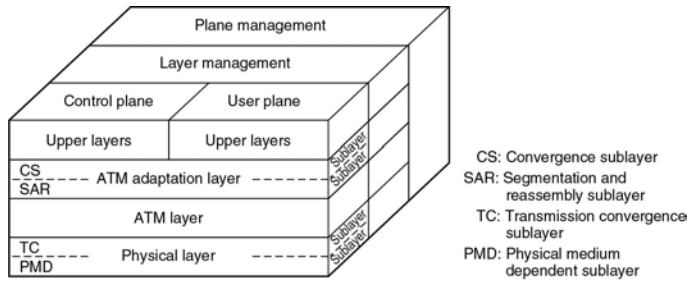
ATM Virtual Circuits

- An ATM cell.



The ATM Reference Model

- 3D planes
  - Control plane – connection management
  - User plane – data transport, flow control error correction
  - Layer and plane management – resource management, interlayer coordination



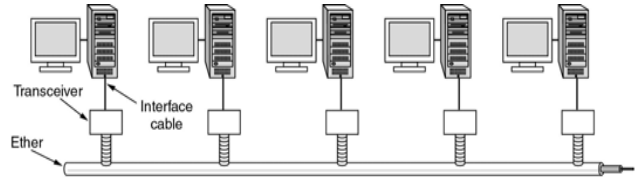
The ATM Reference Model

OSI layer	ATM layer	ATM sublayer	Functionality
3/4	AAL	CS	Providing the standard interface (convergence)
		SAR	Segmentation and reassembly
2/3	ATM		Flow control Cell header generation/extraction Virtual circuit/path management Cell multiplexing/demultiplexing
2	Physical	TC	Cell rate decoupling Header checksum generation and verification Cell generation Packing/unpacking cells from the enclosing envelope Frame generation
1		PMD	Bit timing Physical network access

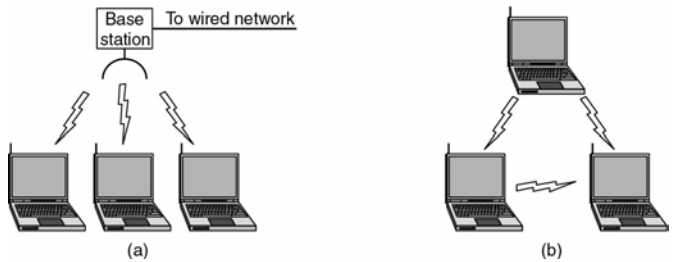
- The ATM layers and sublayers and their functions.

Ethernet

- Developed at Xerox PARC to connection computers together in 1970s by Metcalfe and Boggs, modeled after ALOHANET
  - Metcalfe later started 3Com to commercialize Ethernet – 100milion NIC sold!
- A node listens to the cable (ether) before transmitting. Back off if the cable is not idle or if there is a collision
- Architecture of the original Ethernet.



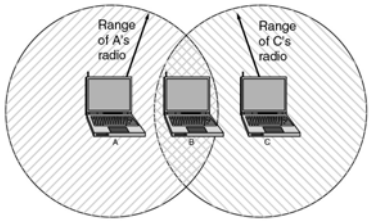
Wireless LANs



(a) Wireless networking with a base station.
(b) Ad hoc networking.

Wireless LANs

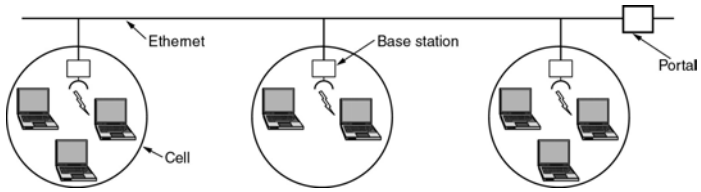
- Must address a number of issues
  - Cannot listen and then send - the range of a single radio may not cover the entire system.



  - Multipath fading
  - Software is not aware of mobility
  - Multiple cell, hands-off, base station connected by Ethernet

Wireless LANs

- A multicell 802.11 network.



Network Standardization

- Why standard?
  - Each vendor/supplier has its own ideas of how things should be done, the only way out is to agree on some network standards
  - Standards also increase the market for products adhering to them
  - Two kinds of standards
    - De facto – from the fact (standards that just happened)
    - De jure – by law (formal, legal standards adopted by authorized organization)
- Who's Who in the Telecommunications World
- Who's Who in the International Standards World
- Who's Who in the Internet Standards World

Treaty Organization between Nations

United Nations

ITU - International Telecommunications Union

CCITT/ITU-T – telephone and data communications

Voluntary, Nontreaty Organization

ISO (International Standards Organization)
issues standards on wide range of topics

200 TC (Technical Committees)

TC97 – computers and info processing

SC (Subcommittees)

WG (Working Groups)

ANSI (American National Standards Institute)

IEEE 802 Standards

Number	Topic
802.1	Overview and architecture of LANs
802.2 ↓	Logical link control
802.3 *	Ethernet
802.4 ↓	Token bus (was briefly used in manufacturing plants)
802.5	Token ring (IBM's entry into the LAN world)
802.6 ↓	Dual queue dual bus (early metropolitan area network)
802.7 ↓	Technical advisory group on broadband technologies
802.8 †	Technical advisory group on fiber optic technologies
802.9 ↓	Isochronous LANs (for real-time applications)
802.10 ↓	Virtual LANs and security
802.11 *	Wireless LANs
802.12 ↓	Demand priority (Hewlett-Packard's AnyLAN)
802.13	Unlucky number. Nobody wanted it
802.14 ↓	Cable modems (defunct: an industry consortium got there first)
802.15 *	Personal area networks (Bluetooth)
802.16 *	Broadband wireless
802.17	Resilient packet ring

Metric Units

Exp.	Explicit	Prefix	Exp.	Explicit	Prefix
10^{-3}	0.001	milli	10^{3}	1,000	Kilo
10^{-6}	0.000001	micro	10^{6}	1,000,000	Mega
10^{-9}	0.000000001	nano	10^{9}	1,000,000,000	Giga
10^{-12}	0.000000000001	pico	10^{12}	1,000,000,000,000	Tera
10^{-15}	0.000000000000001	femto	10^{15}	1,000,000,000,000,000	Peta
10^{-18}	0.000000000000000001	atto	10^{18}	1,000,000,000,000,000,000	Exa
10^{-21}	0.000000000000000000001	zepto	10^{21}	1,000,000,000,000,000,000,000	Zetta
10^{-24}	0.000000000000000000000001	yocto	10^{24}	1,000,000,000,000,000,000,000,000	Yotta