

Introduction to Networks and the Internet

CMPE 80N

Spring 2003



Class Information

- **Class time and location:**
 - Tuesday/Thursday 2:00 - 3:45pm
 - BE152
- **Class Web page:**
 - <http://www.cse.ucsc.edu/classes/cmpe080n/Spring03>
- **Instructor:**
 - Katia Obraczka
 - BE 329
 - Office hours: Wed 12:30-2pm
 - katia@soe.ucsc.edu



Class Information

- **Teaching Assistant**
 - Ignacio (Nacho) Solis (isolis@soe)
 - Chandramouli Balasubramanian (chandrab@soe)
- **Textbooks:**
 - No required textbooks.
 - Class notes (posted on the Web page).
 - Suggested references on Web page.



CE80N Course Objective

To understand both the “What” and the “Why” of networks in general and the Internet specifically.

Note: This course is not specific to CE/CS/EE majors. It is intended for a wide audience with little or no prior experience with the Internet, or networks in general.



Grading

- **3 Quizzes (50%)**
- **Final Exam (30%) – June 11th. 4-7pm**
- **Projects (20%)**

Academic Integrity

- **Academic Integrity policies will be strictly enforced!**
- http://www.ucsc.edu/academics/academic_integrity/policy.html

Pre-requisites

- **Our assumptions about you:**
 - No computer networks background.
 - No prior Internet experience.
 - CATS account
 - Access to a computer

Course Outline

- **Introduction**
 - History, basic concepts, terminology.
 - More, "not-so-basic" concepts: layering, e2e design, etc.
- **Physical layer**
 - Transmitting data.
- **Accessing the medium**
 - Medium access control protocols.
- **LANs**
 - Ethernet, token ring, wireless LANs.
- **Data link layer**
 - Reliable transmission.

Course Outline (cont'd)

- Network layer
 - Types of network services.
 - Circuit- vs. packet switching.
 - Virtual circuits and datagrams.
 - Routing.
 - Addressing.
 - Unicast and multicast.
- Internetworking
 - IP.
 - The Internet.
 - IP addresses.

Course Outline (cont'd)

- Transport layer
 - E2E communication..
 - Types of transport service.
 - Connectionless versus connection-oriented.
 - UDP.
 - TCP.
- Application layer
 - DNS, ssh, telnet, ftp, news, e-mail.
 - The Web.
 - HTTP.
 - HTML.
 - Search engines.
 - Proxy and caches

Course Outline (cont'd)

- Security.
- Peer to peer.

What's a network?

What's a network?

- Merriam-Webster Dictionary:
 - “[A fabric or structure of cords or wires that cross at regular intervals...”
 - “A system of computers, terminals and databases connected by communication lines”
- “A computer network is defined as the interconnection of 2 or more independent computers.” [Ramteke, “Networks”, pg. 24].

Why network?

- Before networks:
 - One large computer (mainframe) used for all processing in businesses, universities, etc.
- Smaller, cheaper computers...
 - Personal computers or workstations on desktops.
 - Interconnecting many smaller computers is advantageous! Why?

Ubiquitous Computing

- Computers everywhere.
- Also means ubiquitous communication.
 - Users connected anywhere/anytime.
 - PC (laptop, palmtop) equivalent to cell phone.
- Networking computers together is critical!

Computer Network

- Provide access to local and remote resources.
- Collection of interconnected end systems:
 - Computing devices (mainframes, workstations, PCs, palm tops)
 - Peripherals (printers, scanners, terminals).

Why network?

- Resource sharing!
 - Hardware: printers, disks, terminals, etc.
 - Software: text processors, compilers, etc.
 - Data.
- Robustness.
 - Fault tolerance through redundancy.
- Load balancing.
 - Processing and data can be distributed over the network.
- Location independence.
 - Users can access their files, etc. from anywhere in the network.

Problems?

- Security!
 - It's much easier to protect centralized resources than when they are distributed.
 - Network itself as the target..

The Telephone Network

- Telephone was patented by G. Bell in 1876.
- For one telephone to be able to talk with another telephone, a direct connection between the two telephones was needed.
 - Within one year, cities were covered with a wild jumble of wires!



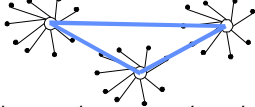
The Telephone Network (cont'd)

- In 1878, the Bell Telephone company opened its first switching office (in New Haven, CT).
- Each user would connect to the local switching office.
 - When a user wanted to make a call, s/he rang to the office, and would be manually connected to the other end.



The Telephone Network (cont'd)

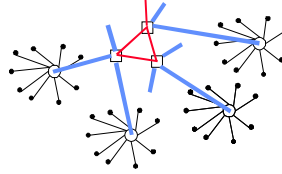
- To allow for long-distance calls, switching offices (switches) were connected.



- Several connections can go through inter-switch trunks simultaneously.
- At some point, there were too many connections between switching offices!

The Telephone Network (cont'd)

- Thus, a second-level hierarchy was added.



- The current telephone system has five levels of hierarchy.

POTS or PSTN

- For over 100 years, the **POTS** (Plain Old Telephone System) a.k.a. **PSTN** (Public Switched Telephone Network) handles **voice-band communications**.
- POTS network is well designed and engineered for the transmission and switching of **voice**
 - Real-time.
 - Low latency.
 - High reliability.
 - Moderate fidelity.

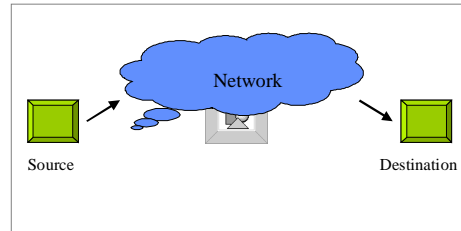
Evolution of Communications Networks

- POTS network is not designed for other forms of communications (audio, video, and data).
- About 30 years ago, a second communications network was created with the goal of providing a better transport mechanism for data.
- In this class, we will study the technology underpinning **data networks**.

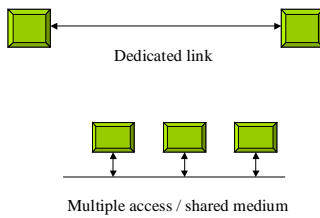
Data Networks

- Components:
 - End systems (or hosts),
 - Routers/switches/bridges, and
 - Links (twisted pair, coaxial cable, fiber, radio, etc.).

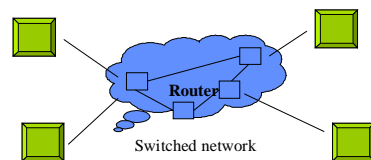
Communication Model



Connecting End Systems



Connecting End Systems (cont'd)

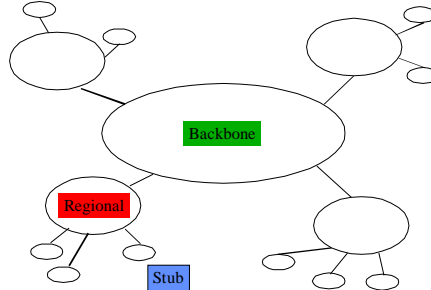


Router: switching element; a.k.a., IMPs (Interface Message Processors) in ARPAnet's terminology.

Types of Data Networks

- Several ways to classify data networks.
- For example, according to “coverage”:
 - Local Area Networks (LANs) typically provide networking capabilities within a building, campus.
 - Typically within 5-mile radius.
 - Wide-Area Networks (WANs) span greater geographic distances (e.g., world-wide).
 - Metropolitan Area Networks (MANs) span more restricted distances, e.g., geographic regions (e.g., Los Nettos network in Southern California, etc.)

The Internet



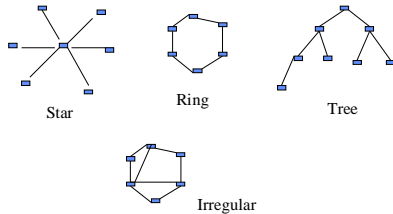
Types of Networks (cont'd)

- Classification according to type of connection.
 - Dedicated link.
 - Shared medium (multiple access).
 - Switched point-to-point.

Types of Networks (cont'd)

- Classification according to topology...
- What is network topology?
 - The way network elements are interconnected.

(Switched) Network Topologies



Network Architecture

- *What is it?*
- **Building complex systems is hard!**
 - Approach: “Divide and conquer”.
 - Split job into smaller jobs.
- *Analogy to other Engineering fields.*
 - Building a house: digging, foundation, framing, etc.
 - Car assembly line...
- *Basic idea: each step dependent on the previous step but does not need to be aware of how the previous step was done.*

Layering

- *Layers are the different components that need to be designed/implemented when designing/implementing networks.*
- *Each layer responsible for a set of functions.*
- *Top layer relies on **services** provided by bottom layer.*

Layering: advantages

- *Easier to design: “divide and conquer”.*
- *Modularity: layers independent of each other, thus easier to maintain, modify, etc.*
- *Flexibility: easier to extend and add new services.*

Layering: disadvantages

- Performance: incur processing/communication overhead of multiple layers.
- Some duplication of effort...

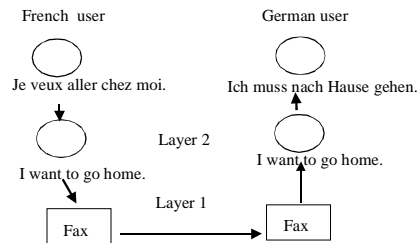
Protocols

- Set of methods and rules used in a particular layer.
- Back to "building a house" analogy:
 - For example, excavators can use picks and shovels to dig; they can later decide to change and use a backhoe.
 - For the masons, it doesn't matter how the excavators dug the hole...
- A layer provides services to the upper layer through an *interface*.

Network Architecture

- Set of layers, what their functions are, the services each of them provide, and the interfaces between them.

Another Analogy



Example 1: ISO OSI Architecture

- ISO: International Standards Organization
- OSI: Open Systems Interconnection.

Application
Presentation
Session
Transport
Network
Data link
Physical

OSI ISO's 7 Layers

- **Physical layer:** transmission of bits between two nodes.
 - Type of medium: copper wire, coaxial cable, satellite, etc.
 - Digital versus analog transmission, etc.
- **Data link layer:** reliable transmission over physical medium.
 - Takes bits received by physical layer and makes sure there are no errors.
 - If errors, request **peer** to retransmit data until it is correctly received: **error control**.
 - Synchronization, flow control; media access in shared medium.

OSI ISO's 7 Layers (cont'd)

- **Network layer:**
 - Data is received error free by network layer.
 - Main function: routing and forwarding;
 - Also, congestion control.
- **Transport layer:**
 - E2E communication.
 - Error-, flow- and congestion control end-to-end.

OSI ISO's 7 Layers (cont'd)

- **Session layer:** manages connections (sessions) between end points.
- **Presentation layer:** data representation.
 - Conversion between different codes.
 - Data compression and encryption.
- **Application layer:** provides users with access to the underlying communication infrastructure.
 - E-mail, video conferencing, file transfer, distributed information systems (e.g., the Web).

Example 2: TCP/IP Architecture

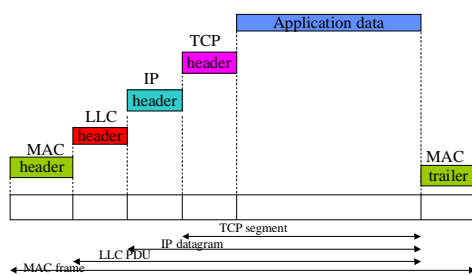
- Model employed by the Internet.

TCP/IP	Application	Application	ISO OSI
		Presentation	
		Session	
Transport		Transport	
Internet		Network	
Network Access		Data link	
Physical		Physical	

TCP/IP Protocol Suite:

- Physical layer: same as OSI ISO model.
- Network access layer: medium access and routing over single network.
- Internet layer: routing across multiple networks, or, an internet.
- Transport layer: end-to-end error, congestion, flow control functions.
- Application layer: same as OSI ISO model.

Encapsulation



The Internet: Some History

- Many independent networks!
- By the late 1970s: blossoming of computer networks.
 - Smaller, cheaper computers.
 - Single organization owned several computers.
 - E.g., each department could afford its own.
 - Need to interconnect them.
 - Proliferation of LANs.
 - Plus's: decentralization, autonomy.
 - Minus's: incompatibility.

The Internet: Some History (cont'd)

- WAN technologies also emerged in the 70s.
- Aka long-haul networks.
- Besides links, also used specialized computers called routers or switches.
- Few WANs, many LANs.
 - WANs are more expensive.
 - Harder to deploy and administer.

The Internet: Some History (cont'd)

- Need for a single network!
 - Interconnecting various LANs.
 - Companies that are geographically distributed.
 - Researchers that need to collaborate.

The Internet: Some History (cont'd)

- Late 1970's/ early 1980's: the ARPANET (funded by ARPA).
 - Connecting university, research labs and some government agencies.
 - Main applications: e-mail and file transfer.
- Features:
 - Decentralized, non-regulated system.
 - No centralized authority.
 - No structure.
 - Network of networks.

The Internet: Some History (cont'd)

- TCP/IP protocol suite.
- Public-domain software.
 - To encourage commercialization and research.
- Internet as an open system.
- The IETF.
 - Request for Comments (RFCs).
 - Internet drafts.

The Internet: Some History (cont'd)

- *Between 1980 and 2000: the boom!*
 - *Internet changed from small, experimental research project into the world's largest network.*
 - *In 1981, 100 computers at research centers and universities.*
 - *20 years later, 60M computers!*
- *Early 1990's, the Web caused the Internet revolution: the Internet's killer app!*
- *Today:*
 - *Almost 60 million hosts as of 01.99.*
 - *Doubles every year.*



The Internet: The Future

- *End of growth?*
- *Physical resource limitations.*
- *Limitations of TCP/IP.*



The Physical Layer



Physical Layer

- *Sending raw bits across "the wire".*
- *Issues:*
 - *What's being transmitted.*
 - *Transmission medium.*



Basic Concepts

- *Signal: electro-magnetic wave carrying information.*
- *Time domain: signal as a function of time.*
 - *Analog signal: signal's amplitude varies continuously over time, ie, no discontinuities.*
 - *Digital signal: data represented by sequence of 0's and 1's (e.g., square wave).*

Time Domain

- *Periodic signals:*
 - *Same signal pattern repeats over time.*
 - *Example: sine wave*
 - *Amplitude (A)*
 - *Period (or frequency) ($T = 1/f$)*
 - *Phase(ϕ)*

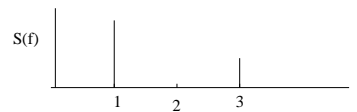
$$s(t) = A \sin(2\pi f t + \phi)$$
$$s(t + T) = s(t)$$

Frequency Domain

- *Signal consists of components of different frequencies.*
- *Spectrum of signal: range of frequencies signal contains.*
- *Absolute bandwidth: width of signal's spectrum.*

Example:

$$s(t) = \sin(2\pi f_1 t) + 1/3 \sin(2\pi (3f_1)t)$$



- *Spectrum of S(f) extends from f_1 to $3f_1$.*
- *Bandwidth is $2f_1$.*

Bandwidth and Data Rate

- *Data rate: rate at which data is transmitted; unit is bits/sec or bps (applies to digital signal).*
 - Example: 2Mbits/sec, or 2Mbps.
- *Digital signal has infinite frequency components, thus infinite bandwidth.*
- *If data rate of signal is W bps, good representation achieved with $2W$ Hz bandwidth.*

Baud versus Data Rate

- *Baud rate: number of times per second signal changes its value (voltage).*
- *Each value might "carry" more than 1 bit.*
 - Example: 8 values of voltage (0..7); each value conveys 3 bits, ie, number of bits = $\log_2 V$.
- *Thus, bit rate = $\log_2 V * \text{baud rate}$.*
- *For 2 levels, bit rate = baud rate.*

Data Transmission 1

- *Analog and digital transmission.*
 - Example of analog data: voice and video.
 - Example of digital data: character strings
 - Use of codes to represent characters as sequence of bits (e.g., ASCII).
- *Historically, communication infrastructure for analog transmission.*
 - Digital data needed to be converted: modems (modulator-demodulator).

Digital Transmission

- *Current trend: digital transmission.*
 - Cost efficient: advances in digital circuitry (VLSI).
- *Advantages:*
 - Data integrity: better noise immunity.
 - Security: easier to integrate encryption algorithms.
 - Channel utilization: higher degree of multiplexing (time-division mux'ing).