Chapter 1

Data Communications: An Introduction

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CMP 110: Data Communications & the Internet
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What Is Data Communications?

- Simple answer: Getting data from Point A to Point B
- Better answer: Getting data from Point A to points B, C, D, ...
- Best answer: Transmission of **encoded** data and information in a **medium**-specific format between two or more **nodes**

Bits & Bytes

- Humans use natural language to communicate
- Computers only understand numbers
- We represent these numbers in **binary** with ones and zeroes
- Data must be **encoded** into a format that both sender and receiver understand

Encoding Schemes

- **ASCII**: 7-bit encoding scheme
  - American Standard Code for Information Interchange
- **EBCDIC**: 8-bit encoding scheme
  - Extended Binary-coded Decimal Interchange Code
- **Unicode**: 16-bit encoding scheme
  - The first 128 entries are the same as ASCII

Analog vs. Digital

- **Analog Data:** *Continuously* variable level of light, sound, electricity, or other input
- **Digital Data:** *Discretely* variable level of input
- **Analog Transmission:** Utilizes *continuous* changes in voltage or light across a medium to convey data between two or more endpoints
- **Digital Transmission:** Utilizes *discrete* changes in voltage or light across a medium to convey data between two or more endpoints

Other Transmission Characteristics

- **Parallel Transmission** uses multiple parallel data paths to transmit multiple data bits *simultaneously*
- **Serial Transmission** uses one data path, which can only transmit one data bit at a time
- **Asynchronous Transmission** surrounds each data byte with a *start bit* and a *stop bit*, adding considerable overhead
- **Synchronous Transmission** uses occasional *sync bits* to synchronize sender & receiver

Other Transmission Characteristics

- **Simplex Transmission:** Data only travels in one direction; sender and receiver never switch roles
- **Duplex Transmission:** Nodes on the network can transmit data *and* receive data
  - **Half-Duplex Transmission:** A node must either send or receive data, but can not do both at the same time
  - **Full-Duplex Transmission:** Nodes can send and receive *simultaneously*
  - Full-duplex transmission requires more transmission media

Other Transmission Characteristics

- **Guided Media** consists of physical wiring or cabling
  - **Coaxial Cable:** Core conductor surrounded by insulation and grounding mesh
  - **Unshielded Twisted Pair (UTP):** One or more pairs of solid-core copper wire twisted together
  - **Fiber-Optic Cable:** Glass fiber core through which pulses of light pass

Other Transmission Characteristics

- **Unguided Media** uses radio or light waves to transmit data without wires or cabling
  - **Microwave Transmission** uses directionally-focused high-frequency radio waves
    - **Terrestrial Microwave Transmission** requires line-of-sight between sender and receiver
    - **Satellite Microwave Transmission** requires sender and receiver to each have line-of-sight with a satellite in *geosynchronous orbit*
  - **Infrared Transmission** uses light waves just outside the visible spectrum
  - **WiFi**, **Bluetooth**, etc. use lower-frequency radio waves

Data Transmission Security

- Transmissions must be secure against theft *and* data corruption
- Some transmission protocols employ **error detection** and retransmit corrupt packets
- Other protocols employ **error correction**, avoiding retransmissions
- Many **encryption** schemes exist to secure against data theft

Standards

- **Standards** provide a basic level of compatibility and interoperability among devices and services
  - ***De facto* standards** arise from commonly-accepted practice
  - ***De jure* or *formal* standards** are developed and published by a standards organization

Standards Organizations

- **ANSI:** Private, non-profit membership organization supported by private-sector and public-sector organizations, to coordinate and administer a *national standards system* in the US. ANSI is a member of ISO. http://www.ansi.org/
- **IEEE:** Develops standards in wired and wireless communications and in light & power systems. http://www.ieee.org/
- **ITU:** Part of the United Nations that coordinates international communications standards. http://www.itu.int/
- **ISO:** Coordinates international standards in a variety of areas (not just telecommunications). http://www.iso.org/

Standards Organizations

- **ISOC:** Assures the open development, evolution, and use of the Internet. Founded by **Vinton Cerf**.
- **IETF:** Publishes *RFCs*, written by engineers and computer scientists to invite peer review, or to share information or new ideas
  - **RFC 114:** FTP
  - **RFC 791:** Internet Protocol
  - **RFC 1157:** SNMP
  - **RFC 1945:** HTML
- **IAB:** Oversees technical and engineering development of the Internet; oversees many of ISOC's task forces, such as IETF

Development of the OSI Model

- **Problem #1:** Early hardware vendors each developed proprietary communication schemes
  - This led to *vendor lock-in* and *vendor lock-out*
  - A non-proprietary architecture was needed for inter-vendor communication

Development of the OSI Model

- **Problem #2:** Early hardware employed *time-sharing* software in a *mainframe/client* architecture
  - There was only one CPU, in the mainframe, which had to perform all processing and meta-processing
  - Adding users leads to increased processing demands
  - Adding users also leads to increased *meta-processing* demands, such as for communication
  - A *modular* solution was required to split communications processing off from the rest

Development of the OSI Model

- **ARPA** was experimenting with inter-vendor communications
- They required a *modular* solution so that separate communication processes could be handled separately
- They required a *layered* solution with internal modularity, so that separate protocols could be used on each layer

Development of the OSI Model

- **Solution:** The **OSI Model**
  (or the *Open Systems Interconnection Reference Model)*
  - Layer 7: **Application** Layer
  - Layer 6: **Presentation** Layer
  - Layer 5: **Session** Layer
  - Layer 4: **Transport** Layer
  - Layer 3: **Network** Layer
  - Layer 2: **Data Link** Layer
  - Layer 1: **Physical** Layer

The OSI Model

- **Mnemonics:**
  - **P**lease **D**o **N**ot **T**hrow **S**ausage **P**izza **A**way (1-7)
  - **A**ll **P**eople **S**eem **T**o **N**eed **D**ata **P**rocessing (7-1)

The OSI Model

- **Layer 1: The Physical Layer** defines the characteristics of data bit transmission across *specific media*:
  - Type of signaling method -- analog or digital, simplex or duplex, serial or parallel, etc.
  - Electrical/optical characteristics of the transmission signal
  - **Bandwidth** or data rate
  - Network **topology** or layout

The OSI Model

- **Layer 2: The Data Link Layer** prepares data for the Physical Layer, and provides services to the Network Layer:
  - Organizes data bits received from the Network Layer into **frames**
  - Provides hardware addressing information
    - **MAC** (Media Access Control) addresses uniquely identify each interface
  - Provides for error correction and retransmission

The OSI Model

- **Layer 3: The Network Layer** adds *network addressing* and *routing* information
  - Creates **packets** from information provided by the Transport Layer and provides packet sequencing
  - Performs **route discovery** and determines the best route for packets to travel from one network to another
  - Adds **network address** and **node address** data to each packet
  - **Establishes**, **maintains**, and **terminates** end-to-end connections between nodes on separate networks

The OSI Model

- **Layer 4: The Transport Layer** provides end-to-end control of data flow
  - Creates **segments** from information provided by the Session Layer and provides segment sequencing
  - Identifies **port numbers** or **service addresses** at destination devices
  - Some layer 4 protocols are **connection-oriented**, meaning the receiving device provides acknowledgement to the sender when segments arrive; protocols which do not do this are **connectionless**

The OSI Model

- **Layer 5: The Session Layer** establishes, maintains, and terminates communication sessions on a node-to-node level
- **Layer 6: The Presentation Layer** establishes what encoding will be used; it can also provide end-to-end encryption services
- **Layer 7: The Application Layer** provides underlying services that support user applications
  - File, print, & e-mail services
  - Remote access services (ftp, http, etc.)
  - Collaborative computing services (document management, conferencing, etc.)

The TCP/IP Model

- Developed by:
  - **Vinton Cerf**, then an assistant professor at Stanford
  - **Robert Kahn**, then working for ARPA
- The goal: to have packets traverse multiple networks, without the sender or receiver knowing or even understanding the underlying network structure

The TCP/IP Model

- Cerf & Kahn published their work on **TCP** in 1974
- They developed **IP** first as part of TCP, and published it as its own standard in the late 1970s
- TCP/IP was adopted by the US military in 1980; the ARPANET was converted to TCP/IP in 1982

The TCP/IP Model

- Today, TCP/IP is a set of protocols that are accepted as *de facto* data communication standards
  - Also known as the **Internet Model** or the **DoD Model**
- Described in layers, similar to the OSI Model

The TCP/IP Model

The OSI Model	The TCP/IP Model
7: Application Layer	4: Process/Application Layer
6: Presentation Layer	
5: Session Layer	
4: Transport Layer	3: Host-to-Host Layer
3: Network Layer	2: Internet Layer
2: Data Link Layer	1: Network
1: Physical Layer	

Why Are There Two Models?

- Most development regarding data communications compatability follows the TCP/IP model
- However, most development is *described* using the OSI model
- Data *encapsulation* occurs at each layer, as data is sent down to the physical layer and then out to the network

Honors Received by Cerf & Kahn

- 1997: National Medal of Technology (awarded by Bill Clinton)
- 2004: ACM Turing Award
- 2005: Presidential Medal of Freedom (awarded by G.W. Bush)
- 2006: National Inventors Hall of Fame

Government Regulations

- **Wireless Ship Act of 1910**
  - *Required* certain seagoing vessels to carry radios for safety
  - One of the first laws passed by the US Congress governing data communications
  - Additional regulations quickly followed

Government Regulations

- Radio communications came to be regulated by the US Secretary of Commerce and Labor
  - Restricted airwave usage for ship-to-shore distress signals
  - Apportioned specific frequencies to connect coastline islands via wireless to AT&T's network
  - AT&T successfully lobbied to stifle the burgeoning wireless communications industry

Government Regulations

- **1982 Modified Final Judgment (MFJ)**
  - Settlement agreement from antitrust suit against AT&T
  - AT&T was required to split into separate companies (effective 1984)
    - One long-distance company
    - Several Regional Bell Operating Companies (RBOCs) or "Baby Bells"

Government Regulations

- **1982 Modified Final Judgment (MFJ)**
  - The "Baby Bells" included Ameritech, Bell Atlantic (which became Verizon), BellSouth (reacquired by AT&T in 2006) , NYNEX, and Southwestern Bell (which became AT&T again in 2002)
  - The telecommunications industry was **deregulated**, allowing RBOCs to compete in the telecommunications marketplace *and* in emerging markets like information systems and computing
  - Fostered competition between long-distance companies

Government Regulations

- **Telecommunications Act of 1996**
  - Complete *deregulation* of the telecommunications industry
  - In theory, anyone who wanted to enter the market could do so (in practice, this required substantial capital)

Government Regulations

- **Telecommunications Act of 1996: Good Points**
  - **Local Competition** required each carrier to interconnect with the others
  - **Universal Service** required the FCC to enforce "...the availability of basic communications services to the public at just, reasonable, and affordable rates... taking into account advances in telecommunications technologies"

Government Regulations

- **Telecommunications Act of 1996: Good Points**
  - **E-Rate** required Universal Service, at subsidized rates, to schools, libraries, and rural health-care providers
  - **Broadband Facilities** gave the FCC the power to induce deployment of high-speed Internet access, such as DSL and cable modems

Government Regulations

- **Telecommunications Act of 1996: Bad Points**
  - Most media ownership regulations were eliminated
    - Number of major media companies in the US:
      - 1983: Around 50
      - 1996: 10
      - 2005: 6

Government Regulations

- **Telecommunications Act of 1996: Bad Points**
  - Most media ownership regulations were eliminated
    - 1996 to 2003: 5.9% increase in amount of commercial radio stations
      - Largest owner owned 60+ stations
    - 1996 to 2003: 35% *decrease* in amount of station owners
      - Largest owner owned 1200+ stations

Government Regulations

- **Telecommunications Act of 1996: Bad Points**
  - Title V: **Communications Decency Act**
    - First attempt by US Congress to regulate pornographic material on the Internet
    - Imposed *criminal sanctions* on anyone who sends or makes available "...any comment, request, suggestion, proposal, image, or other communication that, in context, depicts or describes, in terms **patently offensive as measured by contemporary community standards**, sexual or excretory activities or organs" to minors

Government Regulations

- **Telecommunications Act of 1996: Bad Points**
  - Title V: **Communications Decency Act**
    - Much of the Act was deemed unconstitutional in *Reno vs. ACLU*
    - "Good Samaritan" provision protects ISPs from liability regarding information published by their clients
      - This is still in effect