Introduction to Networks
and the Internet

CMPE 80N

Spring 2003

Week 2

Announcements

• Projects 1 and 2 posted on the Web page.
  – Project 1: ongoing.
  – Class newsgroup participation.
  – Nacho will be here today for a brief tutorial on
    newsgroup usage.
  – Project 2: due 06.05 (last day of class).
  – Web page design.
  – Minimum requirements.
  – Including page with references relevant to your
    academic interests.
  • Brief in-class tutorial on HTML.

Last class...

• Some very important concepts.
• Network architecture:
  – Set of layers, their functions, services each of
    them provide, and interfaces between them.
• Protocols:
  – Set of methods and rules used in a particular
    layer.

ISO OSI Network Architecture

Application
Presentation
Session
Transport
Network
Data link
Physical
**TCP/IP Architecture**

- Model employed by the Internet.

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<thead>
<tr>
<th>TCP/IP</th>
<th>ISO OSI</th>
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<td>Application</td>
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<td>Access</td>
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**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, plus session and presentation layers.

**Encapsulation**

Applying data

**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.
- A.k.a 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

- Sending raw bits across “the wire”.
- Issues:
  - What’s being transmitted.
  - Transmission medium.
  - How it’s being transmitted.
**Signal**
- Signal: electro-magnetic wave carrying information.
- Time domain: signal as a function of time.
  - Analog signal: signal’s amplitude varies continuously over time, i.e., 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 (\( \phi \))
    \[
    s(t) = A \sin(2\pi ft + \phi)
    \]

**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:**
- Spectrum of \( S(f) \) extends from \( f_1 \) to \( 3f_1 \).
- Bandwidth is \( 2f_1 \).
- \[
  s(t) = \sin(2\pi f_1 t) + 1/3 \sin(2\pi (3f_1) t)
  \]
- \[ S(f) \]

\[
\begin{array}{c|c|c|c}
\hline
f & S(f) & 1 & 2 & 3 \\
\hline
1 & & & & \\
2 & & & & \\
3 & & & & \\
\hline
\end{array}
\]
**Analog Technology**

- Analog devices maintain exact physical analog of information
  - E.g., microphone: the voltage at the output of the mic is proportional to the sound pressure
- Early telephones were all analog
- Problems with analog signals:
  - Difficult to store (e.g., audio tapes, videotapes)
  - Must be processed by analog systems which often add distortion
  - Noise always adds to the signal

**Digital Technology**

- It uses numbers to record and process information
  - Inside a computer, all information is represented by numbers
  - Analog-to-digital conversion: ADC
  - Digital-to-analog conversion: DAC
- All signals (including multimedia) can be encoded in digital form
- Digital information does not get distorted while being stored, copied or communicated

**Digital Communication Technology**

- Example: The telegraph (Morse code)
  - Uses dots and dashes to transmit letters
  - It is digital even though it uses electrical signals
- The telephone has become digital
- CDs and DVDs
- Digital communication networks form the Internet
- The user is unaware that the signal is encoded in digital form

**2 Levels Are Sufficient**

- Computers encode numbers using only two levels: 0 and 1
- A bit is a digit that can only assume the values 0 and 1 (it is a binary digit)
- A word is a number formed by several bits
  - Example: ASCII standard for encoding text
  - A = 1000001; B = 1000010; …
- A byte is a word with 8 bits
Definitions
- 1 byte = 8 bits
- 1 KB = 1 kilobyte = 1,024 bytes = 8*1,024 bits
  - $2^{10} = 1,024$ is power of 2 closest to 1,000.
  - [also 1,000 bytes]
- 1 MB = 1 megabyte = 1,000 KB
- 1 GB = 1 gigabyte = 1,000 MB
- 1 TB = 1 terabyte = 1,000 GB

Definitions (cont’d)
- 1 Kb = 1 kilobit = 1,024 bits
  - [also, 1,000 bits]
- 1 Mb = 1 megabit = 1,000 Kb
- 1 Gb = 1 gigabit = 1,000 Mb
- 1 Tb = 1 terabit = 1,000 Gb

Digitization
- Digitization is the process that allows us to convert analog to digital (implemented by ADC)
- Analog signals: $x(t)$
  - Defined on continuum (e.g., time)
  - Can take on any real value
- Digital signals: $q(n)$
  - Sequence of numbers (samples) defined in a discrete set (e.g., integers)

Digitization - Example
Analog signal $x(t)$

Digitized signal $q(n)$
**Some Definitions**

- Interval of time between two samples:
  - **Sampling Interval** (T)
- **Sampling frequency** \( F = 1/T \)
- **E.g.**: if the sampling interval is 0.1 seconds, then the sampling frequency is \( 1/0.1 = 10 \)
  - Measured in samples/second or Hertz
- Each sample is defined using a **word** of \( B \) bits
  - E.g.: we may use 8 bits (1 byte) per sample.

**Bit-rate**

- **Bit-rate** = numbers of bits per second we need to transmit
  - For each second we transmit \( F = 1/T \) samples
  - Each sample is defined with a word of \( B \) bits
  - **Bit-rate** = \( F \times B \)

- Example: if \( F \) is 10 samples/s and \( B = 8 \), then the bit rate is 80 bits/s

**Example of Digitization**

![Example of Digitization](image)

**Bit-rate - Example 1**

- What is the **bit-rate of digitized audio**?
  - Sampling rate: \( F = 44.1 \text{ kHz} \)
  - Quantization with \( B = 16 \text{ bits} \)
  - **Bit-rate** = \( 705.6 \text{ Kb/s} \)
  - Example: 1 minute of uncompressed stereo music takes more than 10 MB!
**Bit-rate - Example 2**

- What is the bit-rate of digitized speech?
  - Sampling rate: $F = 8$ KHz
  - Quantization with $B = 16$ bits
  - Bit-rate $= BF = 128$ Kbps

**Bandwidth and Bit Rate**

- Bit rate: rate at which data is transmitted; unit is bits/sec or bps (applies to digital signal).
  - Example: 2Mbits/sec, or 2Mbps.
- If data rate of signal is $W$ bps, good representation achieved with $2^W$ Hz bandwidth.

**Data Transmission**

- 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).