# 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.*

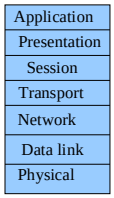


## Last class…

- *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.*

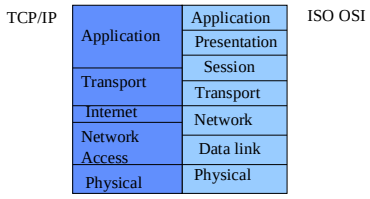


## ISO OSI Network Architecture



## TCP/IP Architecture

- *Model employed by the Internet.*



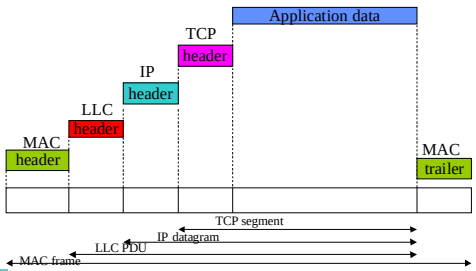



## TCP/IP Protocol Suite:

- *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






## 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



## 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, 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)*

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



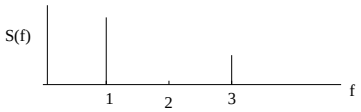
## Frequency Domain

- *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 $2f_1$.*

## 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 use **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 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 **bi**nary digi**t**)*
- *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 powr 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*



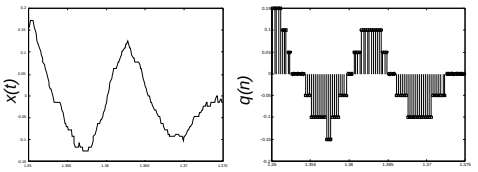
## Digitization

- ***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.*

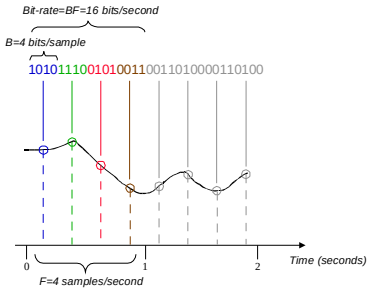


## Bit-rate

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



## Example of Digitization






## Bit-rate - Example 1

- *What is the **bit-rate** of **digitized audio**?*
  - *Sampling rate: F= 44.1 KHz*
  - *Quantization with B=16 bits*
  - ***Bit-rate** = BF= 705.6 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 Kb/s*



## 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).*