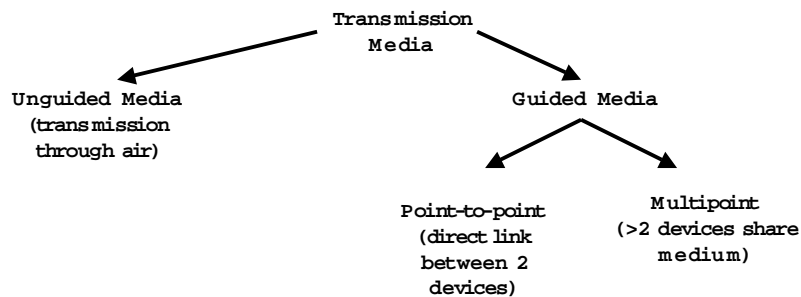


# Physical Layer

Transmission Media  
Bandwidth and Capacity  
Data Encoding  
Multiplexing

## Transmission Media

- The transmission medium is the physical path between transmitter and receiver in a data transmission system.



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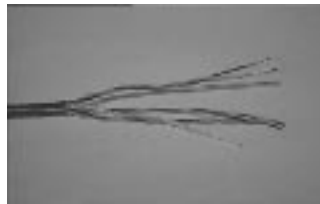
## Transmission Media

- Transmission Medium can be:
  - **Simplex**
    - Transmission in one direction only.
  - **Half-duplex**
    - Transmission in both directions; but not at the same time.
  - **Full-duplex (duplex)**
    - Simultaneous transmission in both directions.

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## Twisted Pair

- Two insulated wires are twisted around each other, and combined with others into a cable
- Used to connect telephone subscribers to switching centers and for wiring local area networks
- Different qualities:
  - Two popular varieties:
    - Category 3: 10 Mbps
    - Category 5: 100 Mbps



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## Coaxial Cable

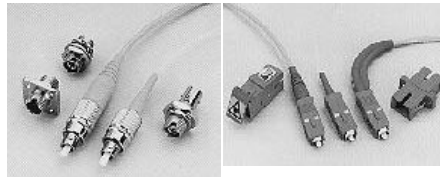
- Like twisted pair a coaxial cable ("coax") has two conductors that are shielded
- Used for digital transmissions in local area networks (e.g., Ethernet) and analog analog transmissions for cable television
- Coax used for Cable TV supports a spectrum of 50 - 750 Mhz



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## Optical Fiber

- Optical fiber is a thin, flexible medium capable of conducting an optical ray.
- Fiber is built of various glasses or plastics.
- Very high bandwidth (more than 10 Gbps).
- Used for long-distance trunks, local area networks, high-speed transmissions.
- Inherently unidirectional.

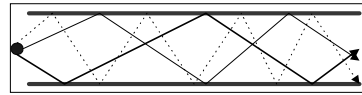


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## Types of Optical Fiber

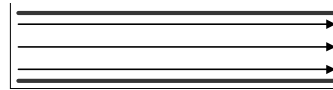
- **Multimode Fiber:**

- Rays may take different paths (100Mbps, 2km)



- **Single Mode Fiber:**

- By reducing the radius of the fiber core to the order of the wavelength, only the axial ray can pass.
- Single Mode fiber has superior performance but is more expensive (2.4Gbps, 40km)



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## Leased Lines

- T1: 1.544 Mbps (24 voice circuits, 64Kbps each)
  - T3: 44.7 Mbps
  - OC-1: 51.8 Mbps
  - OC-3: 155.25 Mbps
  - OC-12: 622. Mbps
  - OC-24: 1.244 Gbps
  - OC-48: 2.4 Gbps
  - OC-192: 10 Gbps
- T=DS, OC=STS



## Last Mile Links

---

- POTS: 28.8-56Kbps
  - Plain Old Telephone Service
- ISDN: 64-128Kbps
  - Integrated Services Digital Network
- xDSL: up to 55.2Mbps
  - Digital Subscriber Line
  - ADSL: Asymmetric DSL (up to 8.4 Mbps, 9000ft)
  - VDSL: Very high data rate DSL (up to 55.2 Mbps)
- Cable TV: up to 40Mbps

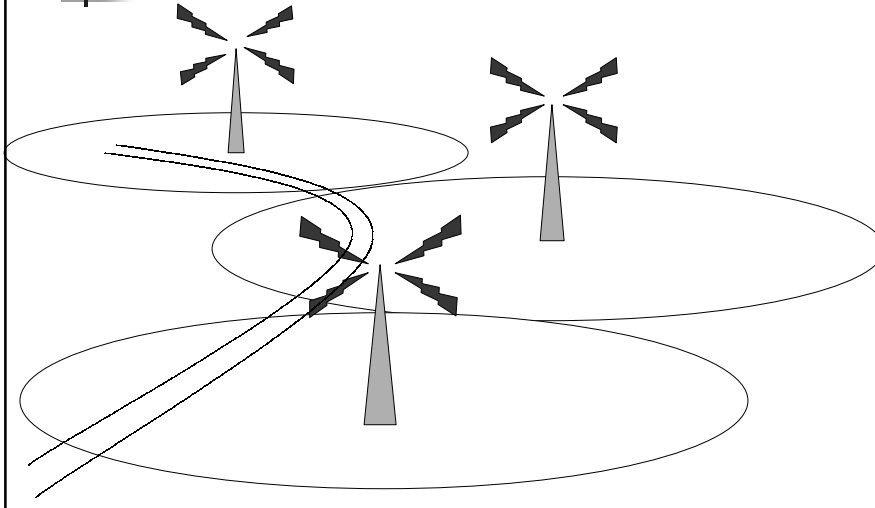


## Wireless

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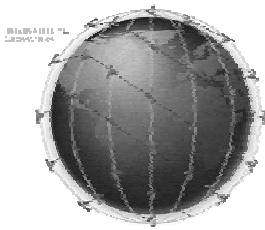
- AMPS (Advanced Mobile Phone System)
  - Older analog technology
- PCS (Personal Communication Services)
  - Digital: the clear alternative to cellular 😊.
- GSM (Global Mobile System)
  - Digital standard in the rest of the world
- Use a grid of towers to transmit signals

## Today's Cellular Infrastructure



## Global Satellite Networks

- ICO (10 satellites)
- Glogalstar (48 satellites)
- Irdium (66 satellites)
- Teledesic (288 satellites)



Iridium Coverage

Main attraction: Providing satellite phone service coverage in areas of the world where cellular/PCS is not available, e.g., the ocean areas, poles, etc.

Are you **REALLY** the **OUTDOORS** type?  
<http://outfittersatellite.com/>

## Bluetooth – Goodbye to cables!

- A wireless standard designed for short distance communication (WPANs)
- Developed by Ericsson, Nokia, IBM, Toshiba, and Intel
- Operates in the 2.45 GHz frequency band
- Is envisioned to eliminate wires in the office
- Connects PDAs, 3G phones, laptops, projectors, printers, workstations, home appliances, ...

## Bluetooth versus Wireless LAN 802.11 (Wi-Fi Technology)

- Bluetooth initial sales pitch (year 2000): *No cables!!*
- Bluetooth sales pitch today: *Native ad hoc connectivity!!*
- Technical comparison:
  - Bluetooth is cheaper, shorter range, smaller bandwidth.
  - Both support wireless ad hoc connectivity
- Who will prevail? *Join the debate...*
  - <http://www.ce-mag.com/archive/01/05/lansford.html>
  - [http://www.mobileinfo.com/News\\_2003/Issue20/Forrester\\_WiFiBluetooth.htm](http://www.mobileinfo.com/News_2003/Issue20/Forrester_WiFiBluetooth.htm)
  - <http://www.mobileinfo.com/Bluetooth/Bluetooth-vs-WLAN.htm>

## Bluetooth Gadgets

Bluetooth printer module



Headsets



PDA Adapter



Bluetooth phones



GPS

## Wi-Fi Gadgets



AIBO talks 802.11



Laptop adapter



Wireless camera



Tablet PCs



Access Point



## Project Idea

---

- Building data services in an ad hoc wireless network
  - An ad hoc wireless network is formed of all devices on customers in a mall, park, club, coffee shop, or airport.
  - Network supports a specific service (e.g., directory, shopping, social, ...)
  - Implementation on laptops (must have your own). Wireless network cards will be provided



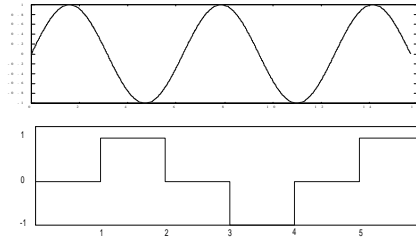
## Basic Foundations

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- What is a signal?
- What is channel bandwidth?
- What is channel capacity?
- How is capacity related to noise?
- Can analog data be sampled?
- How is data encoded on the link?
- What is multiplexing?

# Signals

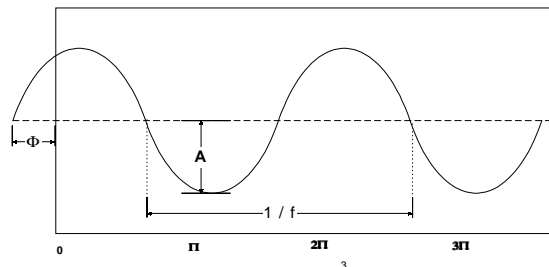
- Signals, electromagnetic or optical, are used to transmit data.
  - Signal frequency
  - Signal wavelength
- A signal can be viewed as a function of time (time-domain) or a function of its frequencies (frequency-domain)
- Signals:
  - Continuous (Analog)
  - Discrete (Digital)



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# Sine Waves

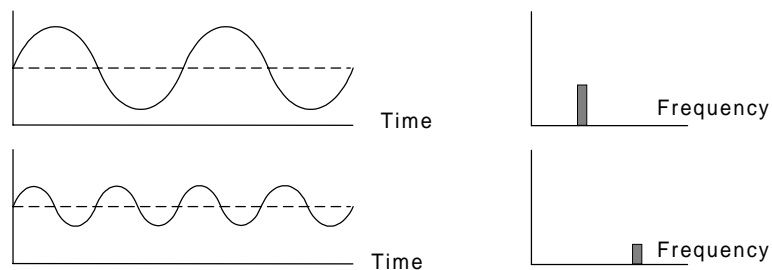
- Generic sine wave is:  $s(t) = A \cdot \sin(2\pi ft + \phi)$ 
  - Amplitude A: Peak value of a signal at any time
  - Frequency f: Inverse of the period
  - Phase  $\Phi$ : Relative position within a signal period



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## Signals in the Frequency Domain

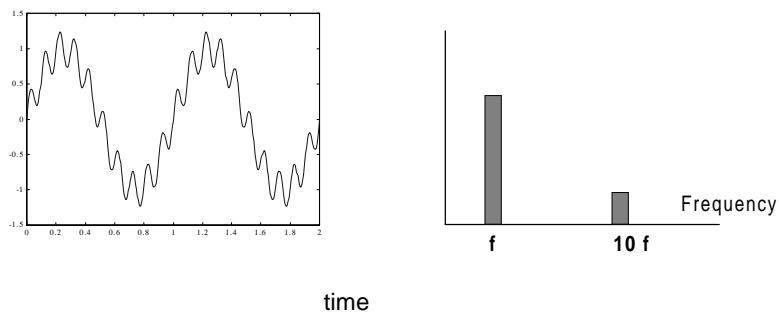
- The time-domain view represents the amplitude of the signal as a function  $s(t)$  of time
- In a similar way, one can represent a signal in terms of a frequency-domain function  $S(f)$



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## Signals

- The plot for the signal in the time domain  $s(t) = \sin(2 \pi f t) + 1/4 \sin(2 \pi (10f) t)$  looks like this:

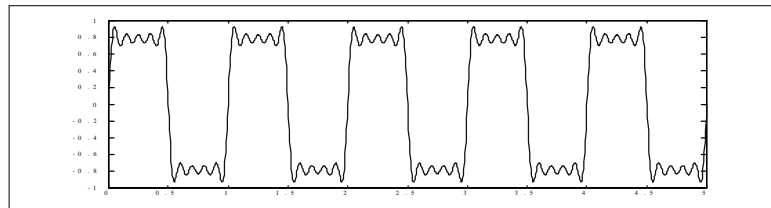


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## Fourier Analysis

- Using Fourier Analysis any signal can be represented by a number of sine waves
- Any periodic signal can be expressed as sum of sine waves:

$$s(t) = \sum_j A_j \cdot \cos(2 \cdot \pi \cdot f_j \cdot t)$$



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## Bandwidth and Capacity

**Spectrum** Range of frequencies of a signal  
[ $f_{\min}$ ,  $f_{\max}$ ]

**Bandwidth** Width of the spectrum ( $f_{\max} - f_{\min}$ )  
(measured in Hz)

**Capacity** Rate at which data can be transmitted  
(measured in bits per seconds, bps)

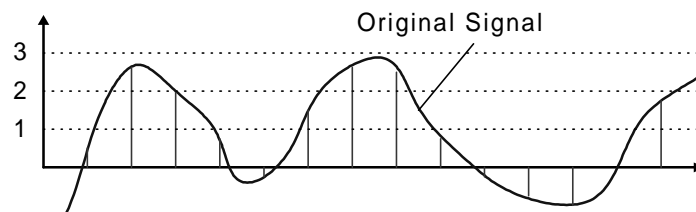
**Noise** Random noise which distorts a signal  
(measured as ratio of signal power to noise power, units are decibels (dB))

- **Signal-to-Noise Ratio**

- S: Signal Power. N: Noise Power
- signal-to-noise ratio (db) =  $10 \log_{10} S/N$

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## Sampling Theorem



### ■ Sampling Theorem (by Nyquist):

*If a signal  $f(t)$  is sampled at regular intervals of time and at a rate higher than twice the highest significant signal frequency, then the samples contain all the information of the original signal. The function  $f(t)$  may be reconstructed from these samples by the use of a low pass filter.*

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## Bandwidth and Capacity

### ■ Capacity of a noiseless channel (H. Nyquist, 1924)

- H: bandwidth;
- V: number of discrete levels of a signal;
- C: Capacity

$$C = 2 H \log_2 V \quad \text{bps}$$

### ■ Capacity of a noisy channel: (C. Shannon, 1948)

- H: bandwidth
- S/N: signal-to-noise ratio

$$C = H \log_2 (1 + S/N) \quad \text{bps}$$

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