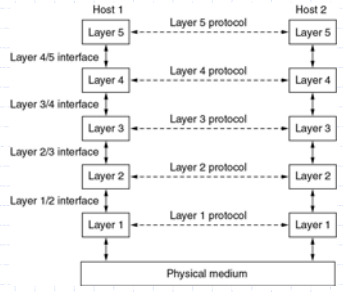
Recap - Introduction

1

Three Concepts

- Services
- Interfaces
- Protocols

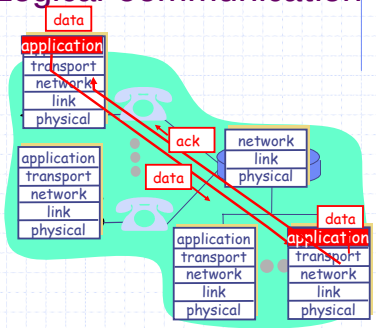


2

Layering: Logical Communication

E.g.: application

- Open a brower
- Type in web address (send in a request)
- wait for peer to ack receipt and return result



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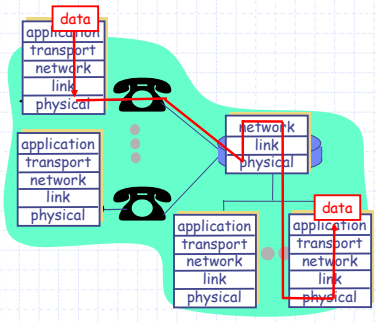
Layering: Physical Communication



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Discussion

- Explain why SETI@home application follows peer-to-peer model?
  - http://setiathome.berkeley.edu/
- In depth on packet-switching vs. circuit switching
  - Scenario 1:
    - Assume each user is active 10% of their time. When active, they generate data at a constant rate of 100Kbps. The whole bandwidth is 1Mbps
    - How many users if we use circuit switching? (10)
    - How many if we use packet switching?
  - Scenario 2:
    - Assume there are 10 users and one user suddenly generates one thousand 1,000-bit packets, while others remain inactive.
    - How long does it take to transmit the 1M bits if using circuit switching?
    - How long if using packet switching?

Statistical Multiplexing

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ECE 453 – Introduction to Computer Networks

Lecture 2 – Physical Layer - I

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Physical Layer

- Service - transmit bits from sender to receiver
- Transmission media – the basis
  - Characteristics of each media
    - Bandwidth
    - Maximum data rate
    - Wavelength vs. frequency vs. data rate
  - Different types of media
    - Guided: twisted pair, coax, fiber
    - Wireless: microwave, infrared

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Fourier Analysis and Bandwidth

$$g(t) = \frac{1}{2}c + \sum_{n=1}^{\infty} a_n \sin(2\pi nft) + \sum_{n=1}^{\infty} b_n \cos(2\pi nft)$$

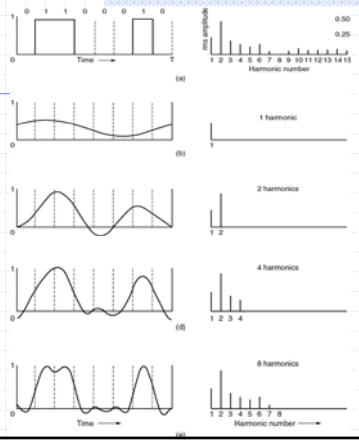
Amplitude of nth harmonic

Fundamental frequency

nth harmonic

All transmission facilities diminish different Fourier components by different amounts

Bandwidth: the range of frequencies being transmitted without being strongly attenuated.
In practice, this is from 0 to the frequency at which half the power gets through (f_c)



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Data Rate (bps) and Harmonics

Bps	T (msec)	First harmonic (Hz)	# Harmonics sent
300	26.67	37.5	80
600	13.33	75	40
1200	6.67	150	20
2400	3.33	300	10
4800	1.67	600	5
9600	0.83	1200	2
19200	0.42	2400	1
38400	0.21	4800	0

Bandwidth (voice-grade telephone line) = 3000Hz

Limiting the bandwidth limits the data rate

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Maximum Data Rate

- Noiseless channel
  - Reconstruction: Sampling rate = 2H
  - Nyquist theorem:

$$\text{maximum data rate} = 2H \log_2 V \text{ bits/sec}$$

- Noisy channel (Shannon's theory)

$$\text{maximum data rate} = H \log_2 (1 + S/N) \text{ bits/sec}$$

  - SNR (signal-to-noise ratio)

    S/N in decibel (dB) ($10\log_{10} S/N$)

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Example

- What is the maximum data rate for a channel of 3000-Hz bandwidth with a signal to thermal noise ratio of 30dB?
- According to a report, during the 1998 Tennessee-Florida game, the crowd noise measured at Neyland stadium peaked at 117dB, twice as high as the one measured at Tiger stadium during the 2000 LSU-Alabama game (111dB). In order to transmit a voice signal over this crowd at a rate of 1000bps at Neyland stadium, what kind of minimum bandwidth is required?

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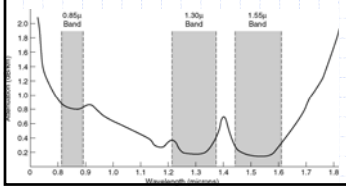
Frequency vs. Wavelength vs. Data rate

- In vacuum

$$\lambda f = c$$

- Given the width of a wavelength band, how to calculate the corresponding frequency?



$$\Delta f = \frac{c}{\lambda^2}\Delta\lambda$$

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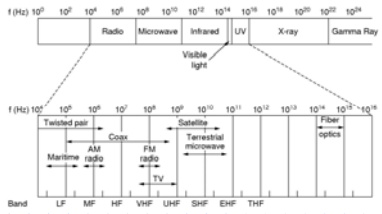
Transmission Media and EM Spectrum

- Guided media
  - Twisted pair, coax, fiber
- Unguided media
  - Radio, microwave, infrared



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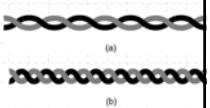
Twisted Pair – Why Twisted?

- Two insulated copper wires twisted in a helical form
  - 1 mm thick, run several km
  - Bandwidth: several Mb/s for a few km
- Used in telephone system
  - Category 3 UTP (16MHz).
  - Category 5 UTP (100MHz).
  - Category 6 UTP (250MHz)
  - Category 7 UTP (600MHz)



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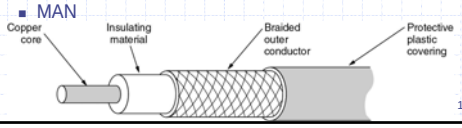
Coaxial Cable

- Better shielding than twisted pairs
- Longer distance at higher speed, better SNR
- Bandwidth: 1GHz
- Applications
  - Telephone system for long-distance lines
  - Digital transmission – 50-ohm cable
  - Analog transmission and cable TV – 75-ohm cable
  - MAN



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Optical Transmission System

- Light source
  - 1: a pulse of light
  - 0: no light
  - LED or semiconductor laser
- Transmission medium
  - Ultra-thin fiber of glass
- Detector
  - Detects light and generates electrical pulse

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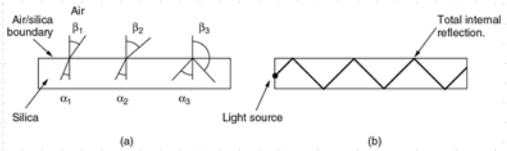
Fiber Optics

- A light ray from inside a silica fiber impinging on the air/silica boundary at different angles.
- Light trapped by total internal reflection.



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Single-mode vs. Multimode Fiber

- Single light ray vs. multiple light ray
- 8 to 10 microns vs. 50 microns
- Single mode
  - Fiber diameter: a few wavelengths of light
  - Light propagate in a straight line
  - More expensive
  - Longer distance
  - 50Gbps for 100km

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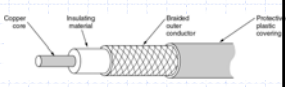
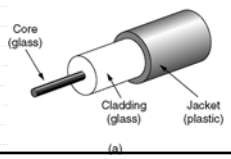
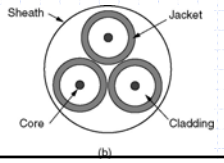
Fiber Cables

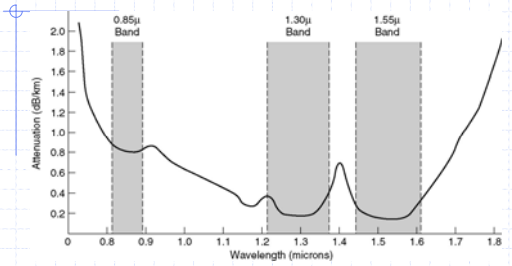
- Uses infrared frequency (850-1500nm)
- Electromagnetically isolated
- 8~10μm in diameter
- 50Gbps for 100km
- Inexpensive to build







Transmission of Light through Fiber



BW in each band is 25,000 to 30,000GHz

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Light Source

A comparison of semiconductor diodes and LEDs as light sources.

Item	LED	Semiconductor laser
Data rate	Low	High
Fiber type	Multimode	Multimode or single mode
Distance	Short	Long
Lifetime	Long life	Short life
Temperature sensitivity	Minor	Substantial
Cost	Low cost	Expensive

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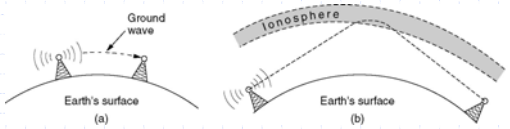
Comparison of Guided Media

	Twisted pair	Coax	Fiber optics
Construction	two insulated copper wires	Better shielding Copper core	Core glass
Thickness	1mm		Ultra thin, few microns
Length	Several km	Longer distance, higher speed	Longest distance, highest speed
Bandwidth	Several Mbps Category 3: 16 MHz Category 5: 100 MHz 6: 250 MHz, 7: 600 MHz	1 GHz	30THz
Application	Analog and digital Telephone line	Digital transmission (50-ohm cable) Analog and cable TV (75-ohm cable) Telephone for long dist.	

Radio Transmission

- Easy to generate
- Travel long distance
- Can penetrate buildings easily at LF
- Omnidirectional



VLF, LF, MF

HF, VHF

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Microwave Transmission

- Above 100MHz
- Travels in straight line
- Transmitting and receiving antennas must be accurately aligned with each other
- Easy to setup, inexpensive
- Applications:
  - Long distance telephone
  - Mobile phone
- MCI vs. Sprint

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Example

These antennas are supported by the lower portion of a **tower** originally constructed by **MCI** to support **microwave** antennas. **MCI** subsequently replaced its **microwave** network with fiber optics, and sold or removed its towers. This particular **tower** was originally much taller; only the lower 100 feet or so now remains.

Source: http://216.239.37.100/search?q=cache:8HOzC3mAKugC:www.annsgarden.com/stealth/CAPTIONS.HTM+microwave+mci+tower&hl=en&start=1&ie=UTF-8

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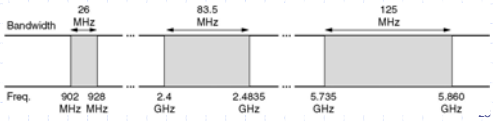
Who Gets to Use Which Frequency?

- Beauty contest
- Hold a lottery
- Not allocate freq. at all
  - Regulate the power used
  - ISM (Industrial, Scientific, Medical) bands for unlicensed usage



Infrared

- Cannot penetrate solid walls
- No government license is needed
- Relatively directional
- Application
  - Remote controller

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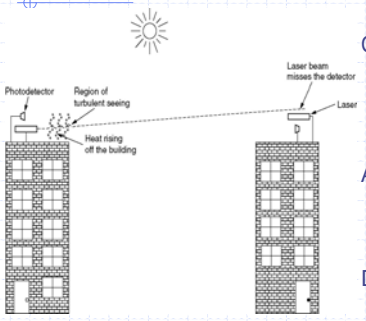
Lightwave Transmission



Convection currents can interfere with laser communication systems.

A bidirectional system with two lasers is pictured here.

Does not need license

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