CS 294-7: Wireless Local Area Networks

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Desirable Features

- **Ability to operate worldwide**
- **Minimize power drain**
- **License free operation**
- **Robust transmissions with security**
- **Collocated operation**
- **Easy operation and management**
- **Protection of investment**

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Historical Perspectives

- Early 1970s
  - IBM: Diffused IR technology (100 kbps)
  - HP: Direct Sequence Spread Spectrum (required allocation of a commercial band)
  - Motorola RF network @ 1.7 GHz
- 1981
  - HP Labs petitions the FCC for a data band
  - 1985: FCC supports commercial spread spectrum in the ISM bands
  - Motorola license @ 18-19 GHz
- 1990s
  - WLAN products come to market
  - 802.11 Committee formed
  - 1992: WINFORUM formed yielding etiquette rules in 1995

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Evolution of Wireless LANs

- First Generation
  - For workstations, 20 W transmitters, LAN extensions
  - Extend LANs to areas inside buildings that are hard to reach
  - Building-to-building connectivity
- Second Generation
  - Laptop/palmtop computers + PCMCIA card network interfaces
  - Ad-hoc networking (e.g., conference room)
  - "Ubiquitous" computing

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Physical Layer

- **Infrared versus Radio Frequency**
  - IR advantages:
    - » Inexpensive due to simple amplitude detection schemes and technology: LEDs & photosensitive diodes
    - » No regulation necessary
    - » Advantageous containment yielding high re-use of spectrum
  - IR disadvantages:
    - » Interference from sun, incandescent light: cannot be used outside
    - » Shadows from moving objects near receivers/transmitters
  - RF advantages:
    - » Riding the cellular/cordless telephone learning curves towards lower costs
    - » Wide-area coverage
  - RF disadvantages:
    - » Licensed operation (except for unlicensed bands)
    - » Complexity of propagation and interference

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Physical Layer

- **Propagation Effects and Coverage**
  - IR: Short wavelengths + room-sized distances + detectors large wrt to wavelength imply Rayleigh fading is not a problem
  - RF: Big problem for radio waves
  - IR: direct beam, ceiling bounce, diffused
    - » Direct beam: up to kilometer
    - » Diffused: 20 m
    - » Theoretical limit = 260 Mb-m/s (20 m room implies 13 Mbps)
  - RF: 50-100 m typical, but depends on local geometric details, like corridors
  - IR, RF: Intersymbol interference limits effective bandwidth

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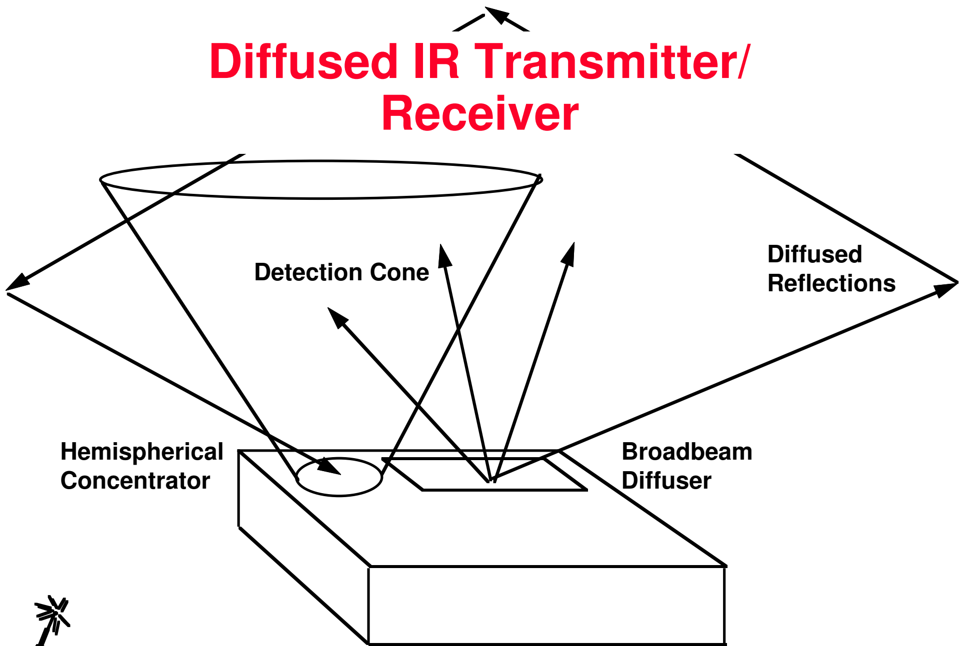
Diffused IR Transmitter/ Receiver



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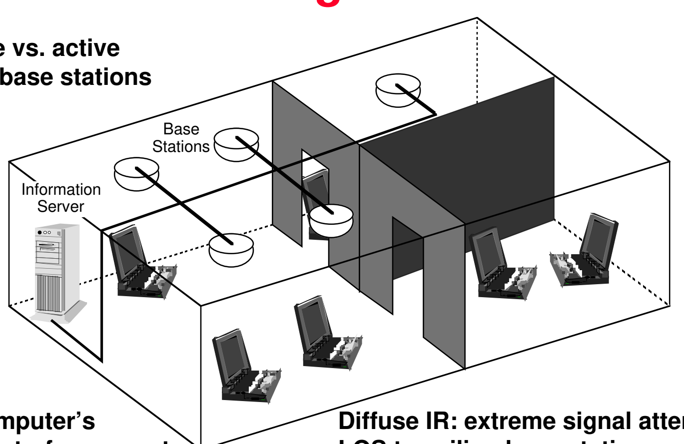
IR with Ceiling Base Stations

Passive vs. active
ceiling base stations



Computer's
IR interfaces must
point towards ceiling

Diffuse IR: extreme signal attenuation
LOS to ceiling base stations can yield
higher bandwidth at lower power
(Rednet: 2 mbps at $10 parts cost)

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RF WLANs

- Technology Alternatives
  - Spread spectrum technology
    - » Frequency hopping spread spectrum
    - » Direct sequence spread spectrum
  - FCC Part 15.247
    - » ISM bands made available for wide-band data communications systems (26Mhz@915 MHz, 83.5MHz@2.4 GHz, 125MHz@5.8 GHz)
    - » FHSS: all or most of the available channels must be used on average (FCC: 0.5-1.0 MHz min channel b/w; 50 of 52, 75 of 83, and 75 of 125 available channels must be used)
    - » DSSS: chipping rates of 10-100 commonly used (FCC: $\geq$10); Low spreading factors are not as interference tolerant
    - » FHSS has some advantages wrt interference: easier to reject a high powered narrow band interferer than in DSSS systems

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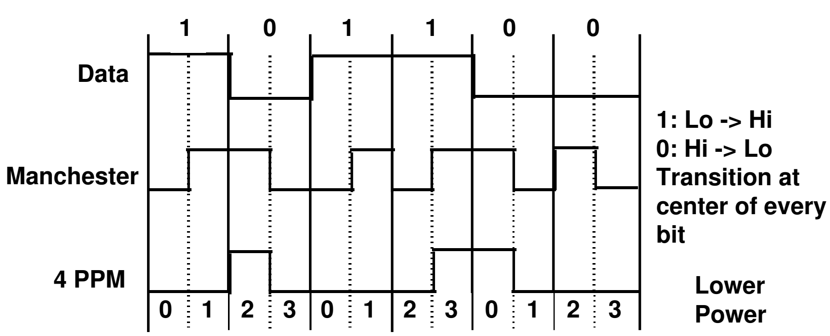
IR WLANs

- Direct Modulation Schemes
  - On-off keying (up to 2 mbps)
  - Pulse Position Modulation (up to 4 mbps)



- Carrier Modulation Schemes (up to 10 mbps)

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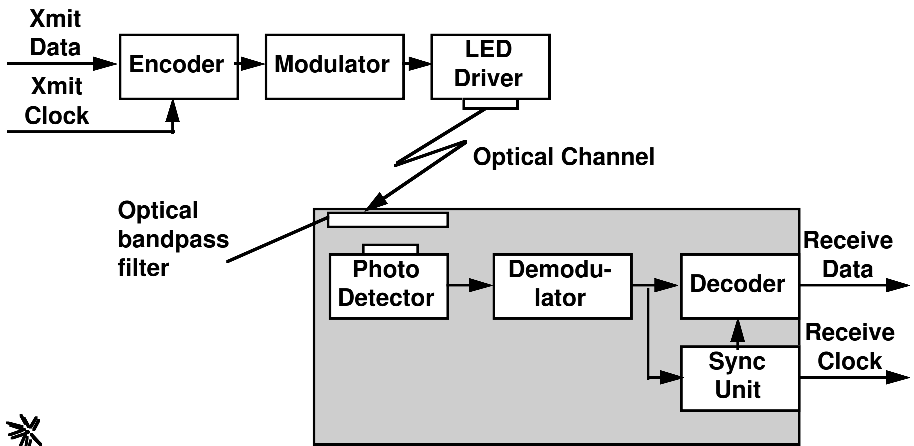
IR WLANs



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IR WLANs

- ParcTab System
  - 19.2 kbps IR links for PDA-to-BS communications
  - 850 nm wavelengths, wide-angle LEDs
  - Pulse position modulation: simple on-off scheme
  - Office-sized cells: hidden terminals not a problem
  - CSMA scheme is used: easy for near-by receivers to detect transmitted signals
  - 256 byte packets
  - Checksum + retransmissions

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IR WLANs

- **Rednet Project**
  - ATM to the mobile device (PDA, terminal, keyboard)
  - 2-5 mbps, 4 m link distance
  - Ceiling mounted IR base stations
  - On-Off Keying (ook) modulation: edge detection to separate baseband signal from low frequency noise
  - Link Protocol
    - » Slotted architecture corresponding to ATM cells
    - » Slot = Preamble + Contention + Data phases
  - Media Access Scheme
    - » Contention Protocol/Binary Countdown
    - » Each node has unique contention address;
      during contention phase, these are sent bit serial, MSB first;
      base station echos these bits to eliminate hidden nodes;
      node receives echoed bit--if match transmitted bit, continue;
      otherwise drop out of contention
    - » Unfair: so add group priority bits to address--when node loses contention, it enters higher priority for next round

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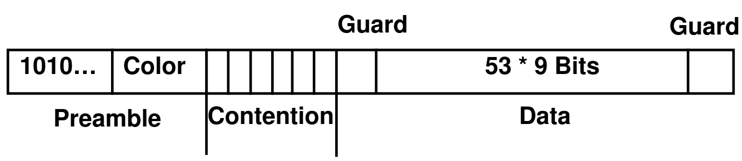
IR WLANs

- **Rednet (continued)**
  - Color codes to detect mobility (part of preamble)
    - » When BS color code does not match MH color code, MH requests new contention address using dynamic address assignment protocol



  - Dynamic Address Assignment
    - » When in new cell, use contention address of all 1's
    - » Direct an address request cell to BS, including node's global ID
    - » Receive connection address from BS
    - » Backoff if no response within timeout
    - » Reclaim connection addresses via BS "keepalive" messages

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Network Topology and Media Access Method

- CSMA/Peer-to-peer vs. TDMA/Base Station-to-remote station
- Base Stations
  - Centralized access to media (e.g., time slots, priority allocation)
  - Access point to wireline environment
  - Well defined security control point
  - Power control
- Most commercial products are spread spectrum without CDMA
- IBM's preferred WLAN: FH + TDMA @ 2.4 GHz
  - TDMA slot times a submultiple of the hopping time

Standards Developments

- Interoperable Rules
  - Different vendors products negotiate with each other
  - IEEE 802.11: DSSS (1-2 Mbps), FHSS (1-2 Mbps), DFIR (1 mbps)
  - ETSI Hiperlan: 5.2, 17.1 GHz bands (EC)
    Target bandwidth: 20 mbps, 50 m range
- Etiquette Rules
  - Minimum set of rules that allow multiple vendors to share available bandwidth fairly
  - Winforum: Unlicensed PCS bands
    - » Listen before talk, transmission time limits, power limits