Wireless Data Networking

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Prof s

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Washington University in Saint Louis
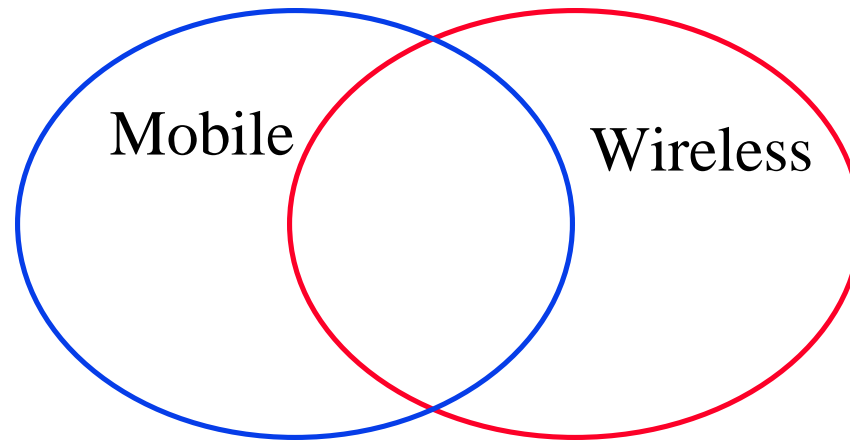Jain@cse.wustl.edu
http://www.cse.wustl.edu/~jain/

Overview

- q Terminology
- q Access Methods
- q Spread Spectrum
- q Wireless local area networks
- q Wireless wide area networks

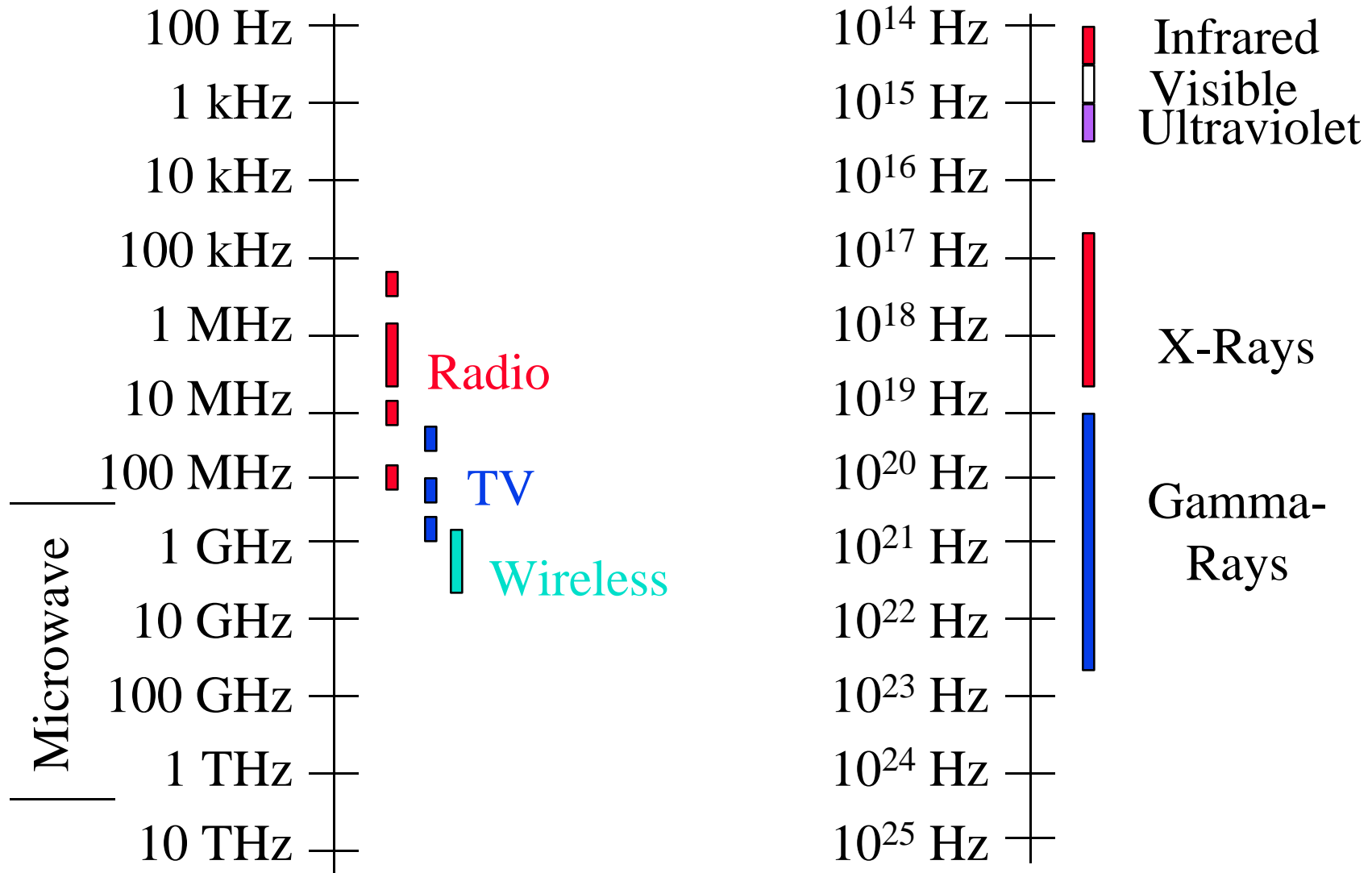Note: wireless phone services and standards not covered.

Mobile vs Wireless

q   Mobile vs Stationary

q   Wireless vs Wired

q   Wireless $\Rightarrow$ media sharing issues

q   Mobile $\Rightarrow$ routing, addressing issues

Physical Layer

q Analog vs Digital

q Infrared, Microwave, Radio

q Multiplexing: Frequency, Time, Space, Code division

Electromagnetic Spectrum

100 Hz	
1 kHz	
10 kHz	
100 kHz	
1 MHz	Radio
10 MHz	
100 MHz	TV
1 GHz	Wireless
10 GHz	
100 GHz	
1 THz	
10 THz	

Microwave

|	
10^{14} Hz	Infrared
10^{15} Hz	Visible
	Ultraviolet
10^{16} Hz	
10^{17} Hz	
10^{18} Hz	X-Rays
10^{19} Hz	
10^{20} Hz	Gamma-
10^{21} Hz	Rays
10^{22} Hz	
10^{23} Hz	
10^{24} Hz	
10^{25} Hz	

Spectrum Issues

q For the same power, lower frequencies travel farther than higher frequencies ⟹ Short wave for Voice of America Medium wave for local radio

q US allocations of spectrum is not the same as in other countries ⟹ You can't use the same equipment everywhere

q There is a shortage of available spectrum.
⟹ A source of income for the Government
⟹ Spectrum no longer given by lottery but by bids

q Federal Government uses up 30% of available spectrum

q Earlier communications used up all lower frequencies

q Frequencies once considered unusable are now being used. 915 MHz, 2.4 GHz, 5.8 GHz

Other Radio Problems

q Broadcast $\Rightarrow$ Received by all receivers

q Air $\Rightarrow$ Simple to tap the transmission
$\Rightarrow$ More subject to security risk

q Radio $\Rightarrow$ Easy to jam

q Portable $\Rightarrow$ Easy to steal, loose, and damage

q Easily monitored using scanners

q In 1992, 1.7M scanners vs
1.3M Phones sold in US

q Toronto Study: 80% of cellular traffic monitored

q 60% of calls are taped [Boston Globe 4/14/94]
$\Rightarrow$ NH Lawyers can't use cellular with clients

Frequency Division Multiple Access
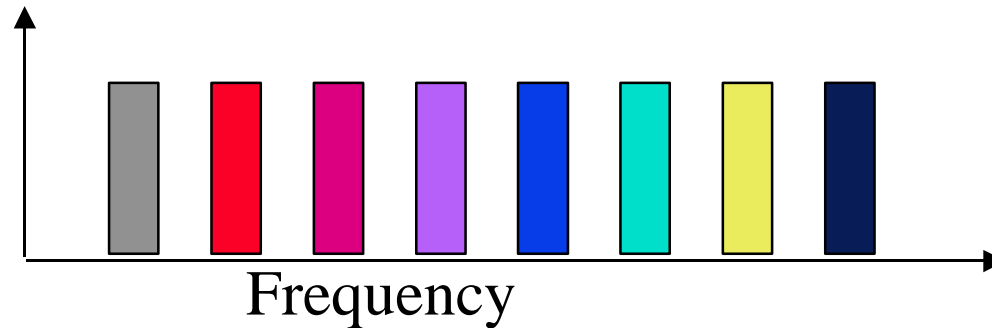
Frequency

- q Frequency band = Channel (as in TV or Public Radio)
- q Adjacent Channels ⇒ Interference
- q Dynamic on-demand allocation of channels
- q Number of Channels, Arrival rate of calls, Duration of calls, User population ⇒ Blocking probability
- q Downstream and upstream channels use different frequency bands
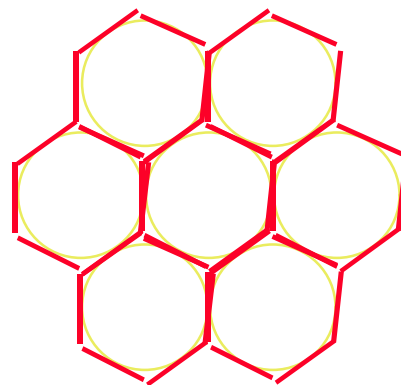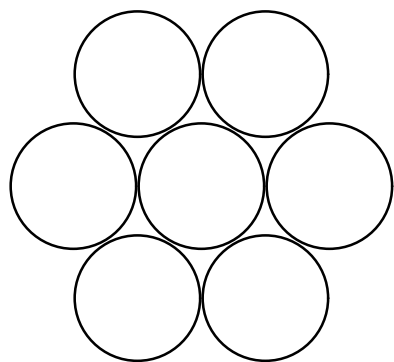- q FDMA used in all analog systems (including US cellular phone system)

Time Division Multiple Access

Time
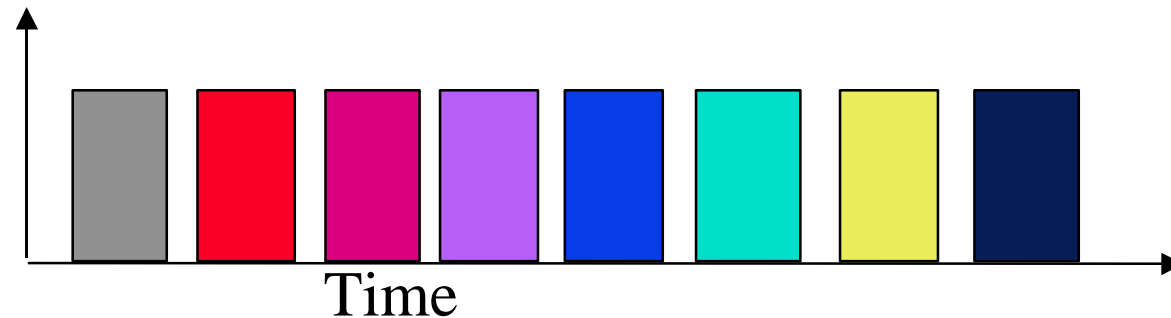
q   Adjacent slots $\Rightarrow$ Synchronization and Interference

q   TDMA used in IS-54 (GSM)
    Global System for Mobile Communications (GSM) is a
    digital cellular radio system

q   Channel rate = Sum of slot data rate

Space Division Multiple Access Cellular Technology

q Repetitive 7-pattern

q Cell size 0.5 mile to 10 miles

q Terrain topology, weather affects coverage

q Smaller cells $\Rightarrow$ More reuse
   $\Rightarrow$ More capacity $\Rightarrow$ Smaller power $\Rightarrow$ lighter hand sets

q Macro (<35km), Micro (<1km), and Pico (<100m) cells
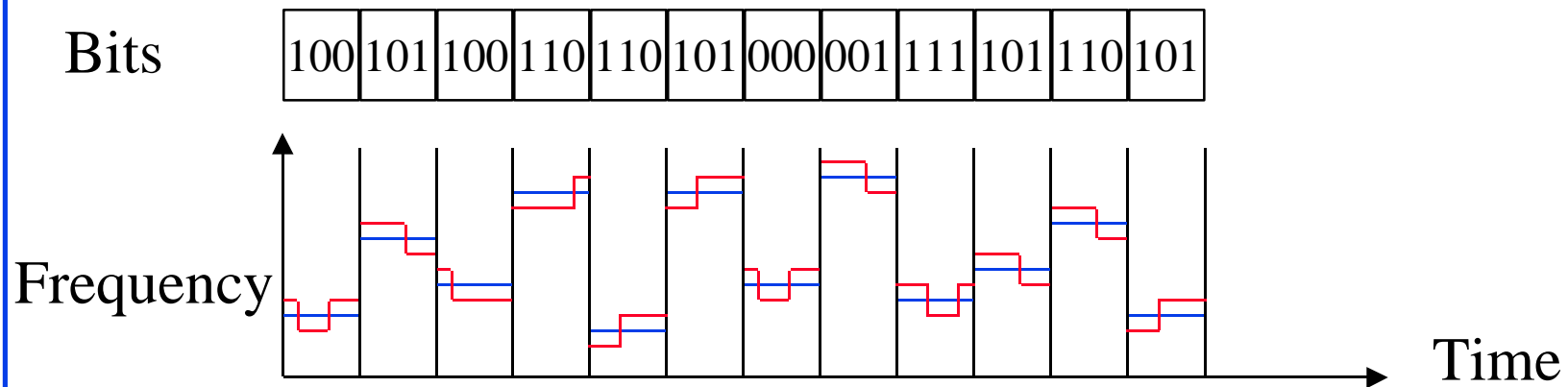
Frequency Hopping Spread Spectrum
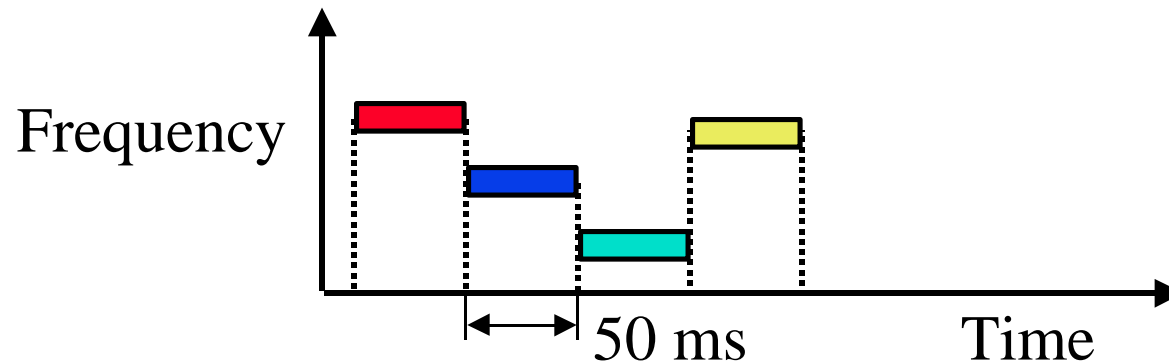
- q Pseudo-random frequency hopping
- q Spreads the power over a wide spectrum
  $\Rightarrow$ Spread Spectrum
- q Developed initially for military
- q Patented by actress Hedy Lamarr
- q Narrowband interference can't jam

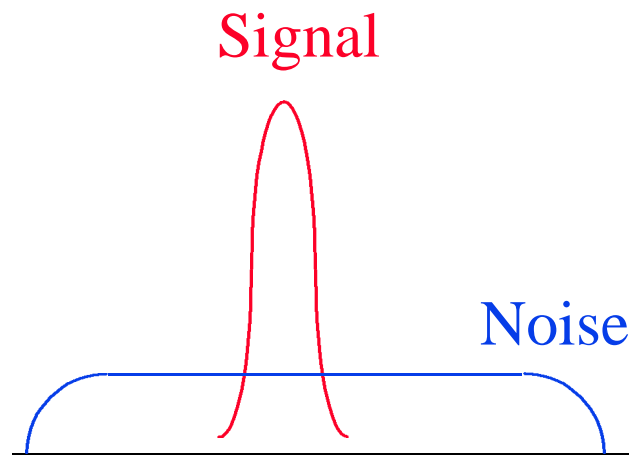# Fast and Slow FH
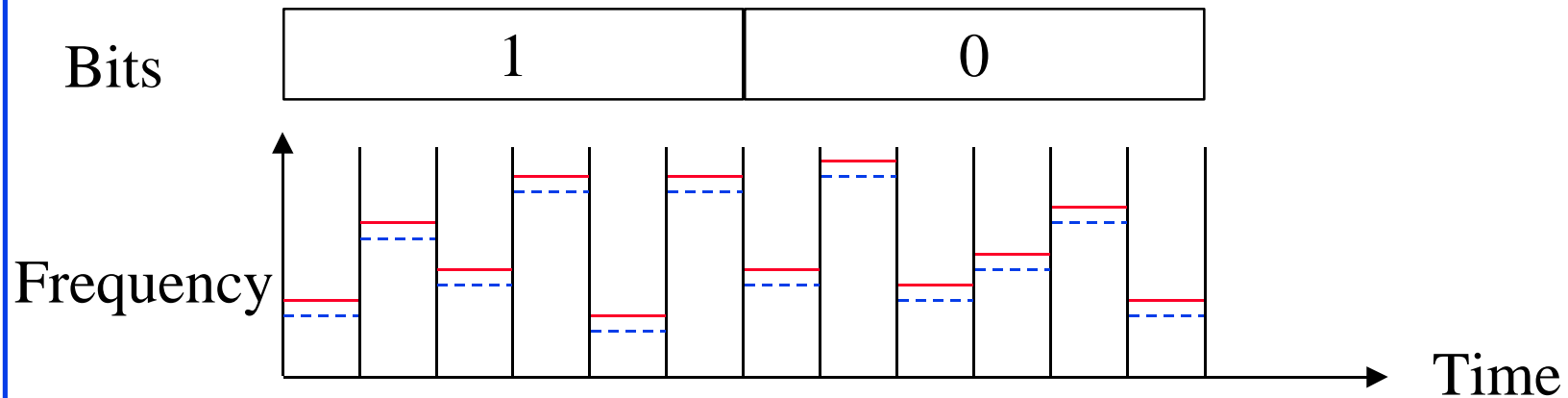
(a) Fast hopping with 6 hops per bit

(b) Slow hopping with 3 bits per hop

Spectrum
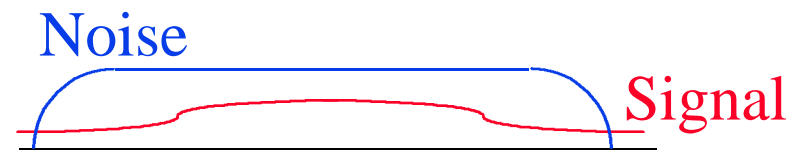
(a) Normal   (b) Frequency Hopping

Direct-Sequence Spread Spectrum

0   1

Data

0100101101 1011010010

Frequency

5μs   Time
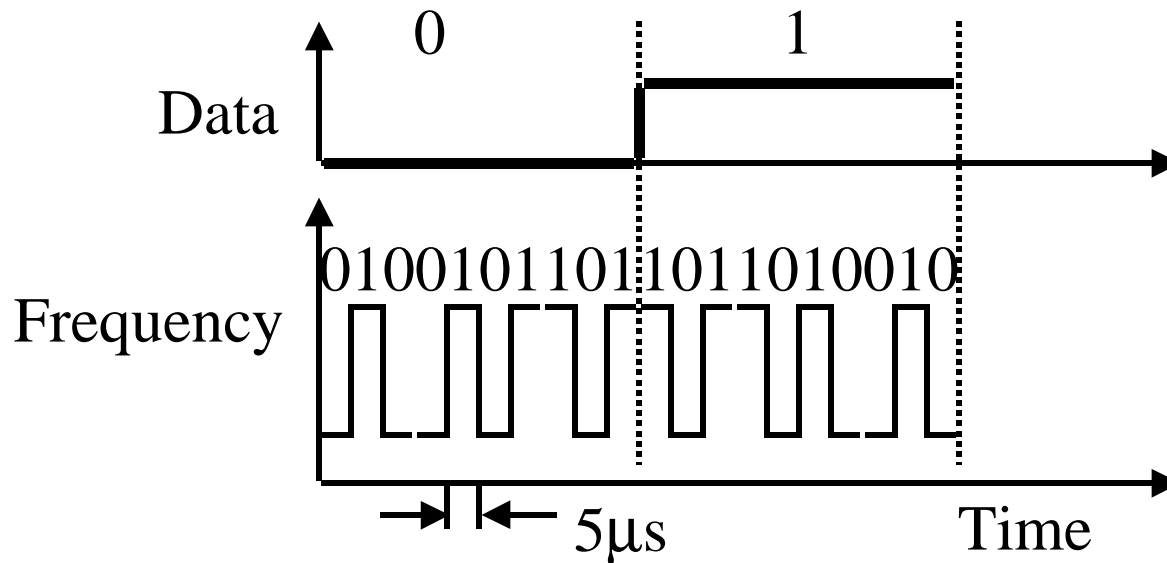
- q Spreading factor = Code bits/data bit
  10-100 commercial (Min 10 by FCC), 10,000 for military
- q Signal bandwidth >10 X data bandwidth
- q Code sequence synchronization
- q Correlation between codes
  $\Rightarrow$ Interference $\Rightarrow$ Orthogonal codes

DS Spectrum

Time Domain   Frequency Domain

Time

(a) Data
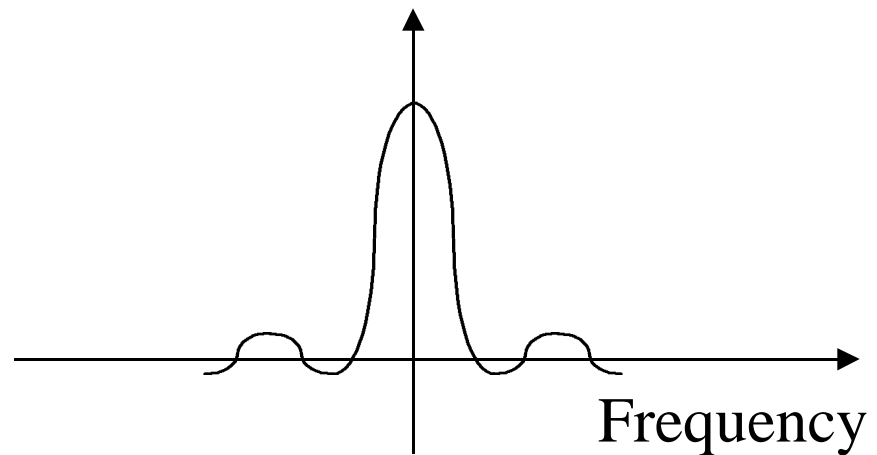
Frequency
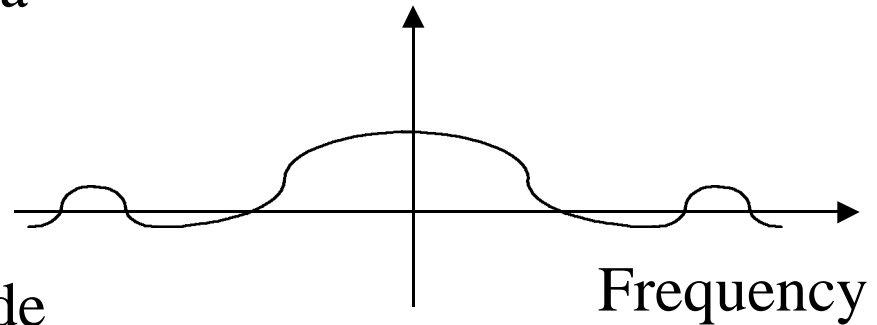
(b) Code

Frequency

CDMA

q Advantages:

   q Little Intereference
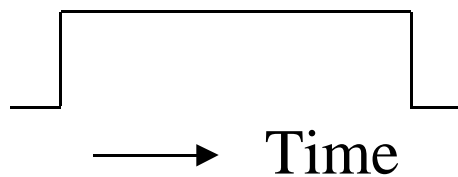
      : Noise can be 18 dB higher than signal

   q No channel assignment
      $\Rightarrow$ Frequency reuse in every cell
      $\Rightarrow$ 20 times more users than FDMA

   q Enhanced security

q Disadvantages:

   q Code synchronization and tracking

   q Tight power control to ensure equal power reception at the base from all mobile

q IS-95 US Digital Cellular standard is based on CDMA

Wireless LANs Market Growth

$300M in 1992 to over $1.5B in 1997

q   Portable computing

q   Standard interfaces: ISA, PCMCIA

q   RF technology: Spread Spectrum Multiplexing

q   FCC spectrum allocation for unlicensed use

    q   902-928, 2400-2483, 5725-5850 MHz

Wireless LANs
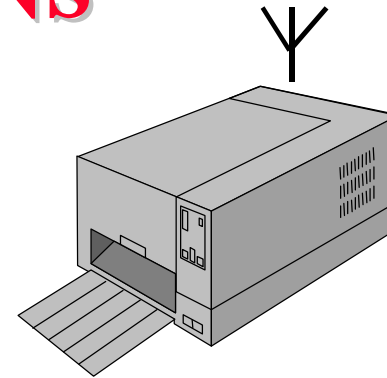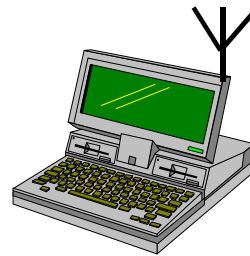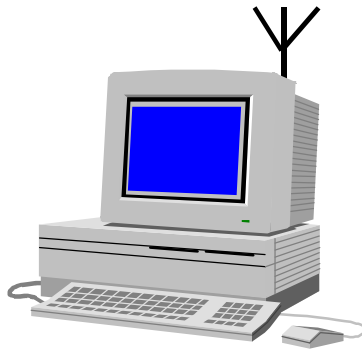
q IR $\Rightarrow$ Line of sight, short range, indoors

q RF $\Rightarrow$ Need license

q Spread-Spectrum: Resistance to interference

μwave   Infrared   Visible   Ultraviolet   x-rays

10^9 10^{10} 10^{11} 10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18}
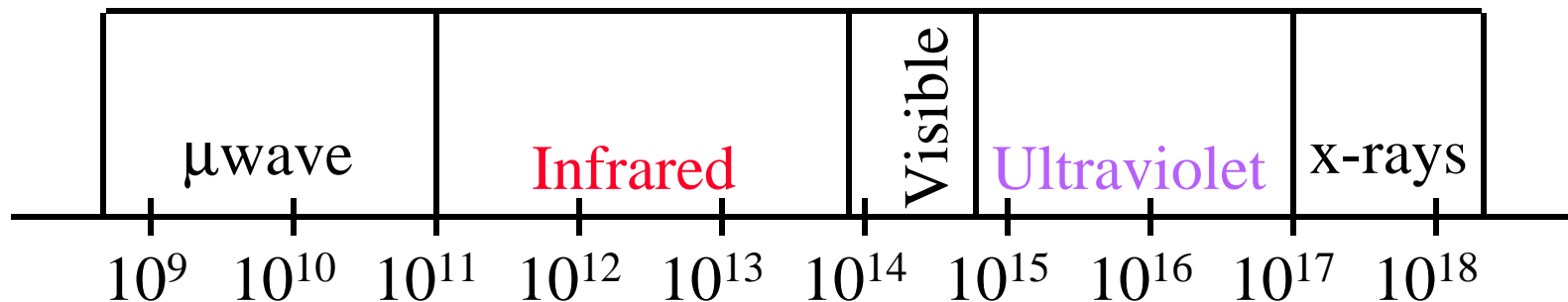
Wireless LANs

Wireless LANs
- Infrared
  - Line of Sight
    - InfraLAN
  - Diffuse
    - Photonics Collaborative
- Radio
  - Spread Spectrum
    - 902 GHz
      - DS
        - Proxim RangeLAN
        - NCR WaveLAN
        - Telesystems ArLAN
      - FH
    - 2.4 GHz
      - DS
      - FH
        - Proxim RangeLAN2
    - 5.7GHz
      - Windata Freeport
  - Narrowband
    - Motorola ALTAIR

Raj Jain
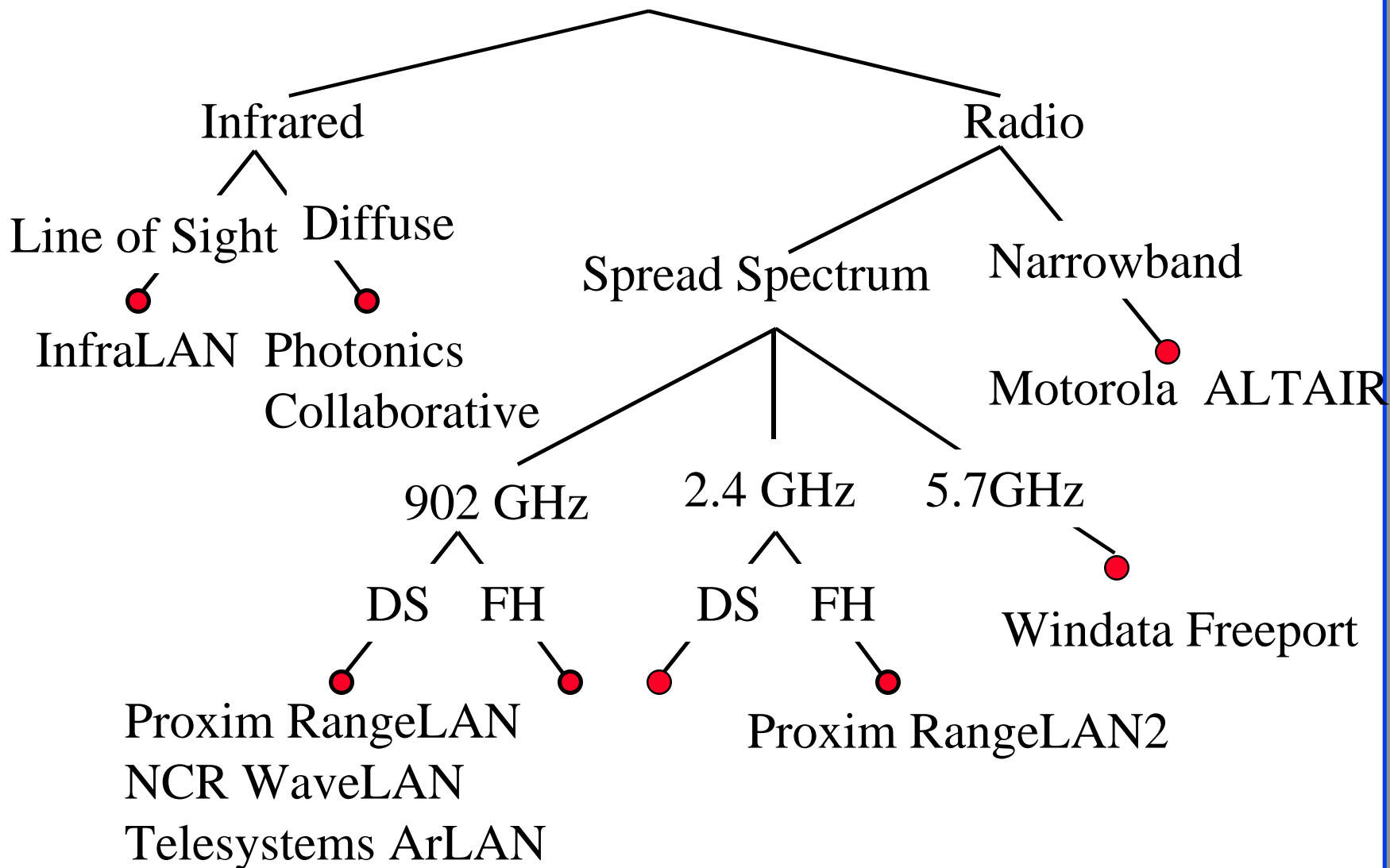
Wireless LANs Examples

System	Medium	Rate	Protocol	Remark
Altair Plus II	18 Ghz Microwave	10 Mbps	Ethernet	50 Users/base
RangeLAN	Spread spectrum	242 kbps	Proprietary	Peer-to-peer or server-based
InfraLAN	Infrared	4/16 Mbps	Token ring	6 Users per base, 80'
WaveLAN	Spread Spectrum	2 Mbps	Proprietary	Peer-to-peer

Wireless LAN (Mobile) Products

Product	Data Rate	Freq-uency	Techno-logy	Range	Access Points
ATT GIS	2 Mbps	900 MHz	DSSS	50 m	Optional
IBM	1 Mbps	2/4 GHz	FHSS	50 m	Required
Proxim	1.6 Mbps	2.4 GHz	FHSS	50 m	Optional
Xircom	1 Mbps	2/4 GHz	FHSS	50 m	Optional
Photonics	1 Mbps	IR	PPM	10 m	Optional
Spectrix	4 Mbps	IR	OCK	10 m	Required

Wireless LANs (fixed)

Product	Datarate	Frequency	Technology	Range	Access Point
Motorola Altair	10 Mbps	18 GHz	Narrowband	15 m	Required
Windata	10 Mbps	2.4, 5.7 GHz	DSSS	25 m	Required
InfraLAN	4, 10, 16 Mbps	IR	OCK	25 m	Required

Wireless WAN Services
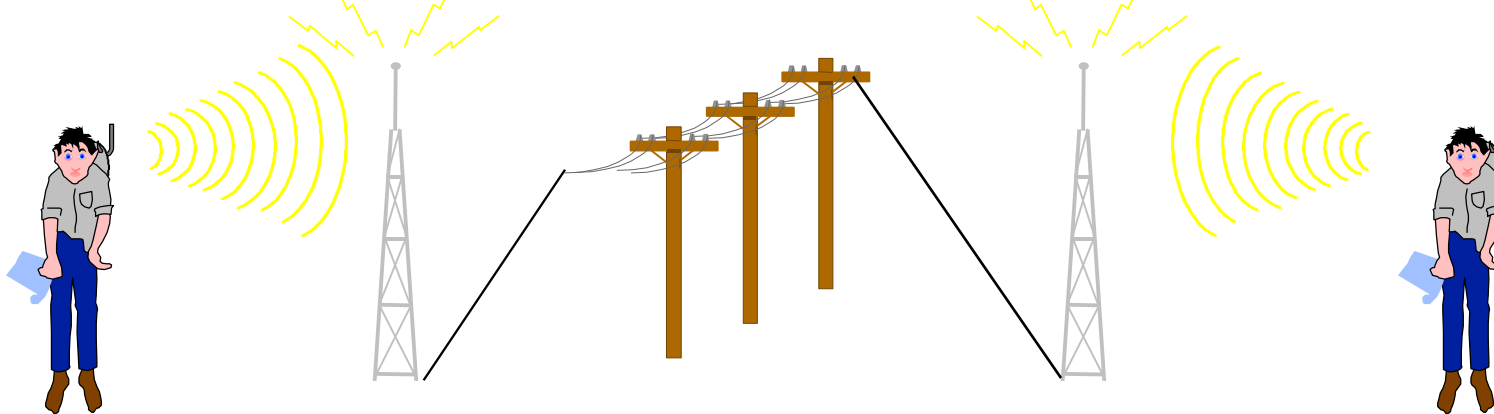
q 4.8 kbps to 19.2 kbps nominal

q Throughput 2 to 8 kbps

q Wired backbone using leased lines

q Packetized short transmission

q Email, stock quotes, weather

q Options: ARDIS, RAM Mobile Data, Cellular, Cellular Digital Packet Data (CDPD), NWN, and Metricom

ARDIS

q Initially designed for IBM's field service use only.

q Now offered as a service by Motorola and IBM

q Available nationwide since April 1990. Covers 8000 cities

q In mid-1993: 1300 base stations connected to 35 radio node controllers connected to 3 message switches

q Designed for field workers, e.g., UPS uses ARDIS + Cellular

q Network Control Processors maintain location information in its area

q 800 MHz. Single licensed channel. Being extended.

q 4800 bps duplex connections with error correction. 19.2 kbps available at some places.

q Good in-building access. 2 W power. 6 hours/charge.

RAM Mobile Data

q   Uses Mobitex technology developed by Ericson

q   Adaptation of a specialized mobile ratio (SMR) system with 10 to 30 channels per area

q   Operational in Europe. Started December 92 in North America

q   By 1993: 800 base stations covering 100 metropolitan areas or 90% of US population

q   Subscriber access via radio to base station

q   512 byte packets, per-hop ack

q   Mobile monitors the reception and reregisters

q   8 kbps interface over 12.5 kHz channels

q   Supports store and forward

q   In-building penetration and roaming

Data over Cellular

q US Cellular system is an analog system known as Advanced Mobile Phone System (AMPS) designed for analog voice and not data

q FDMA, 824-849 MHz Upstream, 869-894 MHz Downstream.

q Each channel is 30 kHz wide
$\Rightarrow$ Two sets of 333 duplex channels
One set for wireline and one for non-wireline carrier

q Need data-compatible cellular phone, and cellular compatible modem

q Handover times of 300 ms or longer
$\Rightarrow$ Connections can be broken if you change the location or if another user initiates a call

Cellular Digital Packet Data (CDPD)

q Originally named "Celluplan" by IBM

q Allows data to use idle channels on cellular system

q Data hops from one channel to next as the channels become busy or idle

Voice Call   Data packets

Idle Channel
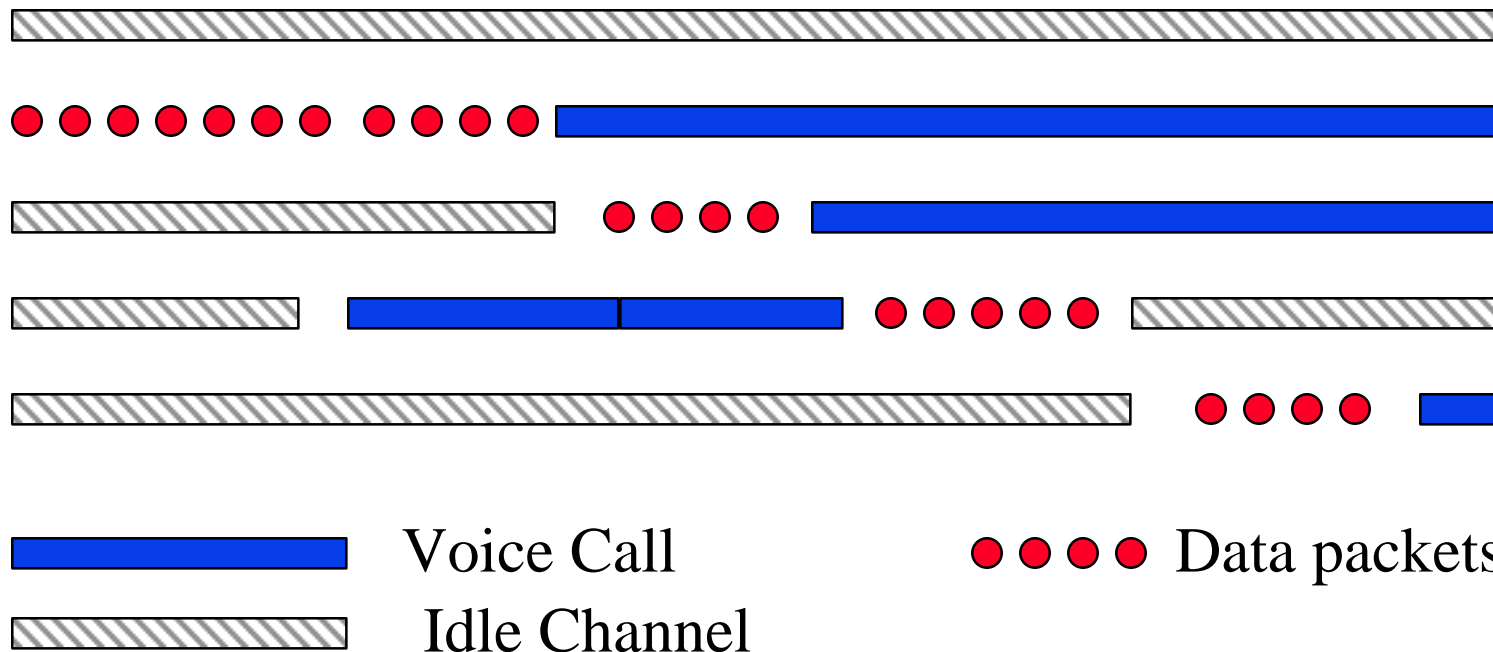
CDPD

- q Backed by 9 major service providers
- q Nationwide cellular packet data service
- q Connectionless and connection-oriented service
  Connectionless $\Rightarrow$ No ack, no guarantees
  Connection-oriented $\Rightarrow$ reliable delivery, sequencing, flow control
- q Point-to-point and multipoint connections
- q Uses only idle 30 kHz channels in the cellular system
- q Quickly hops-off a channel grabbed by cellular system
  - q Currently, extra channels dedicated for CDPD
- q Subscriber unit (SU) registers on power-up and periodically
- q Deregisters before power-down
- q Subscriber unit initiates handoff

Metricom

q   Spread-Spectrum in the 902-928 MHz band

q   In-building, campus, and metropolitan area networking

q   Nearby units can communicate directly.

q   If the intended destination is not directly reachable, go via a "node" through the network. Up to 56 kbps.

q   Nodes are cheap (less than $1000)

q   You can have a campus network of your own with a connection to the Metricom's metropolitan area network

q   Flat monthly rate based on speed only

Ref: http://www.metricom.com/ricohom.html

Nationwide Wireless Network (NWN)

q   Being designed by Mtel (owners of SkyTel)

q   Two-way messaging

q   Can acknowledge your page directly using the pager

q   Main issue: Pager's transmit power is limited and much smaller compared to the power of the base

q   Outbound 50 kHz channel similar to SkyPage system Uses high powered base transmitters in metropolitan areas

q   Inbound 12.5 kHz: Each base transmitter's area covered by multiple (inexpensive) receivers

q   Awarded a "Pioneer's Preference License" for a 900 MHz frequency

Summary
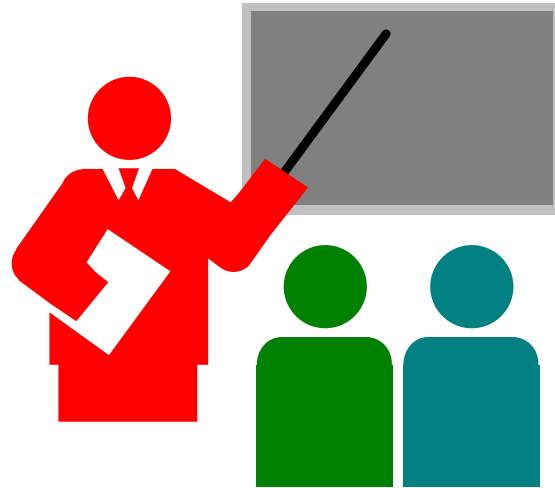
- q Multiplexing: TDMA, FDMA, SDMA, CDMA
- q CDMA = Spread spectrum: Frequency hopping or direct sequence
- q LAN Alternatives: Photonics, RangeLan, ALTAIR
- q WAN Alternatives: ARDIS, RAM, Cellular, CDPD, Metricom, NWN

References: Books

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q   P.T. Davis and C.R. McGuffin, "Wireless Local Area Networks," McGraw-Hill, 1994, 250 pp.

q   P. Wong and D. Britland, "Mobile Data Communications Systems," Artech House, 1995, 190 pp.

q   I. Brodsky, "Wireless: The Revolution in Personal Telecommunications," Artech House, 1995, 276 pp.

q   J. Gardiner and B. West, Ed., "Personal Communication Systems and Technologies," Artech House, 1995, 238 pp.

q   R. Sneiderman, "Wireless Personal Communications: The Future of talk," IEEE Press, 1994, 195 pp.

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- J.D. Parsons and J.G. Gardiner, "Mobile Communications Systems," Halsted Press, New York, 1989
- G. Calhoun, "Digital Cellular Radio," Artech House, 1988, 445 pp.

References: On-line

q The WWW Virtual Library: Mobile and Wireless Computing, http://snapple.cs.washington.edu:600/mobile/mobile_www.html

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q Wireless companies, http://www.yahoo.com/Business/Corporations/Telecommunications/Wireless/

q Wireless news group: comp.std.wireless

q RAM Mobile Data, http://www.ram.co.uk/

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q K. Pahlavan, T.H. Probert, and M.E. Chase, "Trends in Local Wireless Networks," IEEE Communications Magazine, March 1995, pp. 88-95.

q E. Links. W. Diepstraten and V. Hayes, "Universal Wireless LANs," Byte, May 1994, pp. 99-108.

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q K.C. Chen, "Medium Access Control of Wireless LANs for Mobile Computing," IEEE Network, September/October 1994, pp. 50-63.

q C.A. Rypinski, "Standards Issues for Wireless Access," Business Communications Review, August 1992, pp. 40-45.

q G. Fay, "Wireless Data Networking," International Journal of Network Management, 8 March 1992, pp. 8-17.

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q D.J. Goodman, "Second Generation Wireless Information Networks," IEEE Transactions on Vehicular Technology, Vol. 40, No. 2, May 1991

q D. Buchholz, et al, "Wireless In-Building Network Architecture and Protocols," IEEE Network Magazine, November 1991, pp. 31-38.

q V. Hayes, "Standardization Efforts for Wireless LANs," IEEE Network Magazine, November 1991, pp. 19-20.

q D.J. Goodman, "Cellular Packet Communication," IEEE Transactions on Communications, August 1990, pp. 1272-1280.

Wireless LAN/WAN Products

q   Adaptec: Airport NIC

q   Aironet Wireless Communications: ArLAN 630, 631, 640 Hubs

q   Alps America: RadioPort Plus, RadioPort/parallel NICs

q   AT&T:

>   q   Safari Wireless Mailbox
>
>   q   TransTalk 9000 Wireless Communications System (Switch)
>
>   q   WaveLAN/WavePoint NIC
>
>   q   Wireless Medium Access Controller NIC
>
>   q   Wireless Services Flashpoint (Hand-Held Data Device)
>
>   q   Wireless Subscriber System (Telecom Equipment)

Wireless LAN/WAN Products (Cont.)

q Cabletron Systems: Freelink/62 Wireless Ethernet Hub

q Cincinnati Microwave: MC-Dart 100, PC-Dart 200 Modems

q Cylink: Airlink Bridge Hub

q Data Race: Wireless Redidockit NIC

q Dauphin Technology: DTR-1/GPS/LAN/WAN NICs

q Dayna Communications:

   q Daynacomm Roamer PCMCIA/Serial NIC

   q Network Access Point NIC

q DEC:

   q RoamAbout Access Point ISA/PCMCIA NICs

   q WaveLAN NIC

Wireless LAN/WAN Products (Cont.)

q Diablo Research: Mxlink/Mylink modems

q Digital Ocean: Grouper 100D/100Lt/100Mp/110Mp/NB/Manta/Starfish NICs

q Ericsson: M2190 (Wireless Modem)

q Extended Systems: JetEye NICs

q Fluke: Wireless Logger (Data Collection Device)

q Goldmine: Wireless Solution (Remote Access Software)

Wireless LAN/WAN Products (Cont.)

q IBM:

- q AS/400 Wireless LAN
- q Infrared NICs
- q Thinkpad Wireless fax modem
- q Wireless LAN Entry
- q Wireless modems for ARDIS/Cellular/CDPD/Mobitex
- q Wireless RF LANs

q Intel: Wireless modem

q K&M Electronics: Airplex wireless fax modem jack

q Kantek Spectrum: 3-D Wireless Ringmouse (Mouse)

q Travelling Software: LapLink Wireless (file transfer S/W)

Wireless LAN/WAN Products (Cont.)

- q Laser Communications:
    - q InfraLAN NIC
    - q Omnibeam 4000 Network
    - q LXE 5420/5460 wireless modems
    - q LXE RF ID NIC
- q Merritt Computer Products: Cordless printer sharing kit
- q Metricom: Ricochet wireless modem
- q Momentum Microsystems: PC-Linx NIC

Wireless LAN/WAN Products (Cont.)

q Motorola:

- q ALTAIR Plus wireless Ethernet NIC
- q ALTAIR wireless Ethernet NIC
- q Cellect 14.4 PCMCIA (wireless fax modem)
- q Envoy Wireless Communicator (PDA)
- q Infotac Two-Way Messenger (wireless modem)
- q Wireless In-Building Network

q NEC: Wireless PBX

q Northgate Computer Systems: Wireless LAN

q Notable Technologies: Airnote wireless modem

q O'Neill Communications: Local Area Wireless Network

Wireless LAN/WAN Products (Cont.)

q Olivetti: Wireless LAN

q Persoft: Intersect Remote Bridge

q Photonics Collaborative: Wireless LAN/WAN System

q Proxim:

  q Proxlink NIC

  q RangeLan/RangeLAN2 ISA/PCMCIA LANs

  q RangeLink bridge/router

q Radlinq: WL-4000/5000/6000 wireless routers

q RDC Communications: PortLAN modem

q Sierra Wireless: PocketPlus (wireless fax modem)

q Silcom Manufacturing Technology: FreeSpace NIC

Wireless LAN/WAN Products (Cont.)

q SkyTel: Skycard NIC

q Socket Communications: Pagecard wireless messaging system

q Solectek: Airlan Parallel/PCMCIA LAN/CAN NIC/bridge

q Spectrix: SpectrixLite NIC

q Spreadnet: Wireless Link (WAN Adapter)

q Telesystems: SLQ ArLAN 680 NIC

q Toshiba: Wireless Portable Workgroup (Pre-Packaged LAN)

q Triquint Semiconductor: TQ9205/TQ9206 NIC

q U.S. Robotics: Worldport dual standard PCMCIA (wireless modem)

Wireless LAN/WAN Products (Cont.)

q U.S. Wireless: Data POS-50 (point-of-sale terminal)

q USEMCO Technologies: Mobile Trader (wireless modem)

q Windata:

  q Airport I/II (wireless LAN systems)

  q Airport Wireless Interbuilding Systems (pre-packaged LAN)

  q Freeport wireless hub/LAN/transceivers

q Xircom: NetWave NICs

q Zenith Data Systems: CruiseLan ISA/PCMCIA NICs/bridges/routers

q Zyxel USA: U-1496P portable cellular fax Modem