Agenda

- Requirements and marketplace
- Introduction to Radio technology
- Mobile Wireless Overview
- Fixed Wireless Overview
- Wireless LAN Overview
- Summary
- Q&A

Wireless Data Network Drivers

- Information access
- PDAs
- Network computers
- Alpha paging, information distribution
- Web
- Audio and video

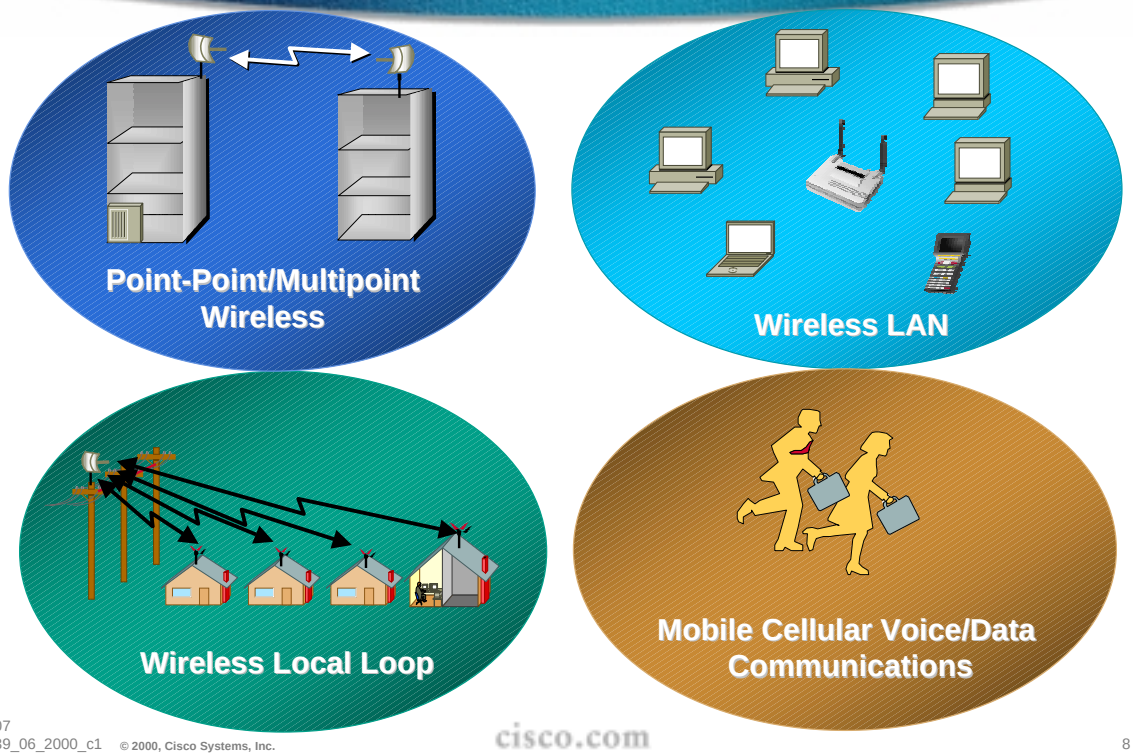
What Is the Interest in Wireless?

- Look ma, no more cables…
- Mobility
- Increased productivity
- Competition
- Flexibility
- Many others

Some Wireless Data Solutions

- Field service—dispatch, parts/order, electronic signature, package tracking
- Public safety—parking enforcement, ambulance-hospital links, anti-theft
- Financial—news, brokerage, pricing
- Telemetry—Health care, vending machines, alarm systems, energy
- Identification—inventory in warehouse and stores, anti-theft

Cisco's Wireless Data Initiatives



Mobile Subscribers Growing Fast!

"The number of mobile phone subscribers in Japan at the end of March exceeded fixed-phone subscriptions for the first time as the popularity of mobile communications continued to expand, according to the Ministry of Posts and Telecommunications."

Tokyo, April 7, 2000
Bloomberg

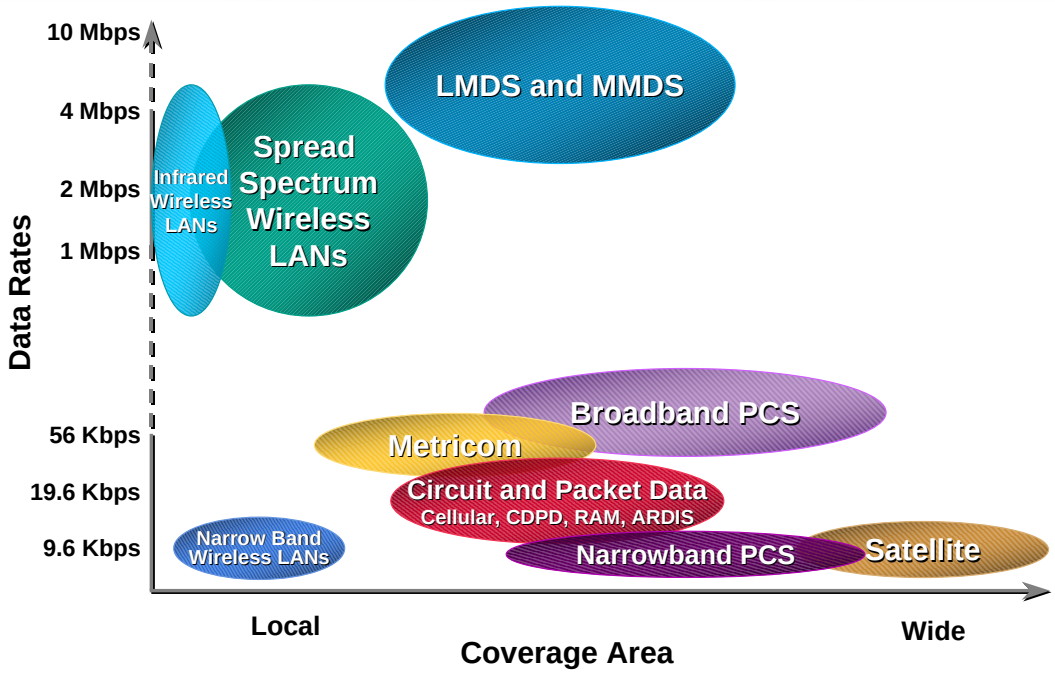
But Wait, More Wireless Data to Come

- Bluetooth to hit 448 million enabled in 2004
- Internet mobile will hit 61.5 million in 2003, probably more
- Some analyst indicate "More people will access the Internet via wireless than wired connections." (ISP Planet, Feb 2000)

Emerging and Existing Wireless Data Technologies

- **Wireless LAN: IEEE 802.11, Bluetooth, HomeRF**
- **Fixed wireless: MMDS, LMDS, satellite dish, microwave, optical**
- **Mobile wireless: PCS, GSM, CDMA, TDMA**

Wireless Data Networks



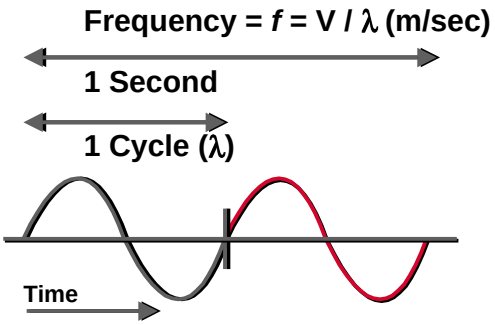
What Is Radio?

Radio: The wireless transmission through space of electromagnetic waves in the approximate frequency range from 10 kilohertz to 300,000 megahertz.

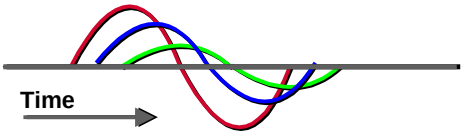
Webster Dictionary

Radio Basics

- **Waves are measured by frequency of movement**
- **Radio devices operate in bands or a designated frequency range**

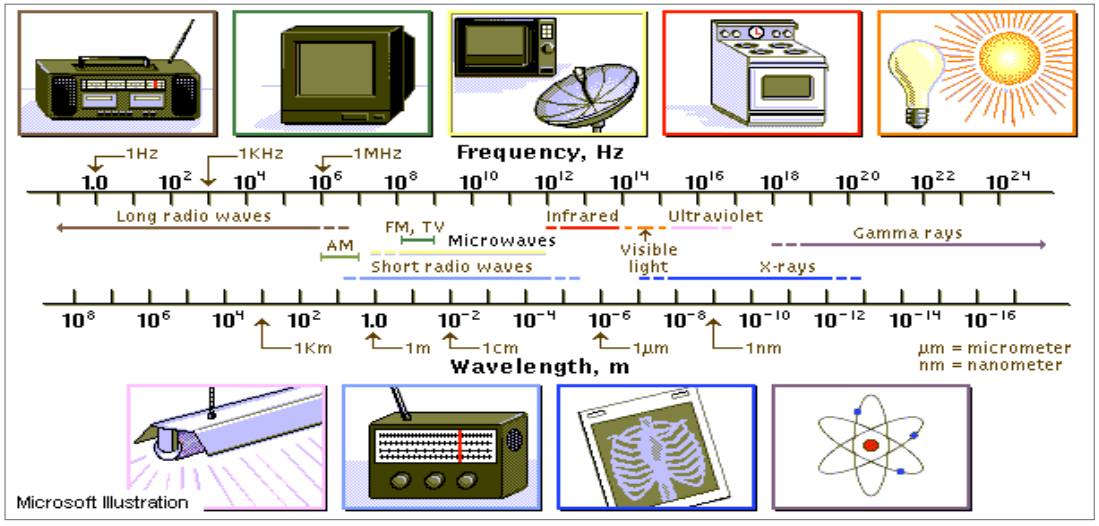


2 cCcles in 1 Second = 2 Hertz



Different Frequencies Share the Same Electromagnetic Space

Electromagnetic Spectrum



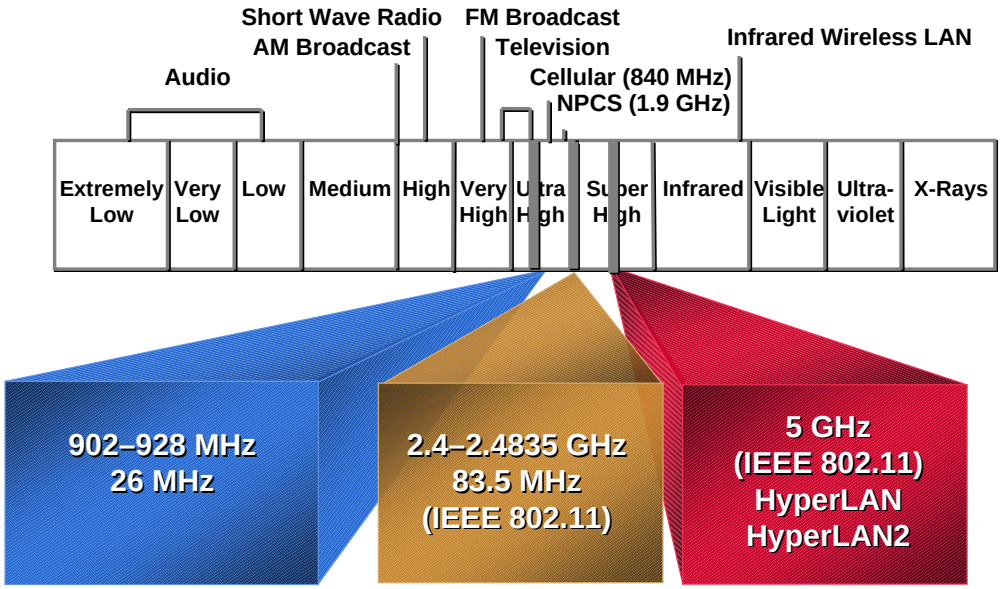
Regulation of Wireless

- **Radio Frequency (RF) is a scarce and shared resource**
  - **Each country governs the use of radio spectrum**
  - **In the U.S. the F.C.C. allocates spectrum for use and resolves conflict disputes**
  - **Internationally coordinated through the ITU**

Spectrum Licensing

- **Spectrum can be allocated for specific users**
  - **Government**
  - **Licensed**
- **Unlicensed or Industrial, Scientific and Medical (ISM) bands**
  - **902–928 MHz (US only)**
  - **2400 MHz**
  - **5800 MHz worldwide**

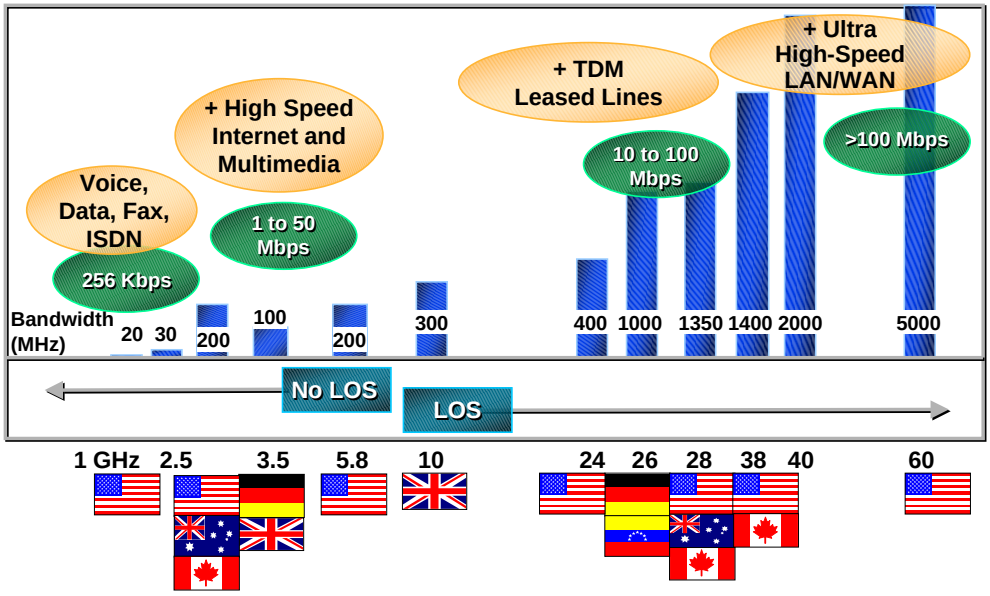
ISM Unlicensed Frequency Bands



What Is Spread Spectrum RF Technology?

- Data sent over the air waves
- Two-way radio communications
- Same radio frequency for sending and receiving
- No licensing required

Access Spectrum Availability and Comparison



Spectrum Suitability

- **Less than 6 GHz**

  Long range (up to 45 km), non Line of Sight (LOS), not affected by weather

- **Greater 6 GHz**

  Line of Sight (LOS), short range (1–5 km), affected by weather, more spectrum (1 Ghz)

Wireless Basics

- Signals
- Modulation
- Access technology
- Antenna theory
- Range
- Interference

Data Bandwidth Depends On...

- Frequency bandwidth
- Modulation techniques

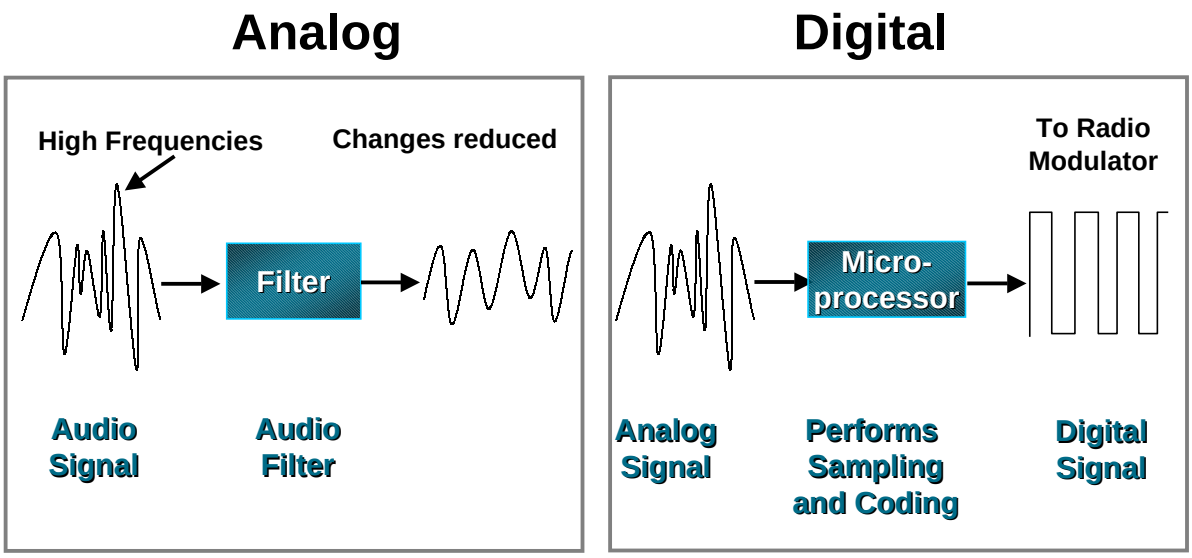
Transmitting a Signal

- The goal of sending data over RF is to get information across with as much data as possible, sending it as far as possible and as fast as possible.
- More data can be placed on a signal in one of two ways:

  More frequency used or

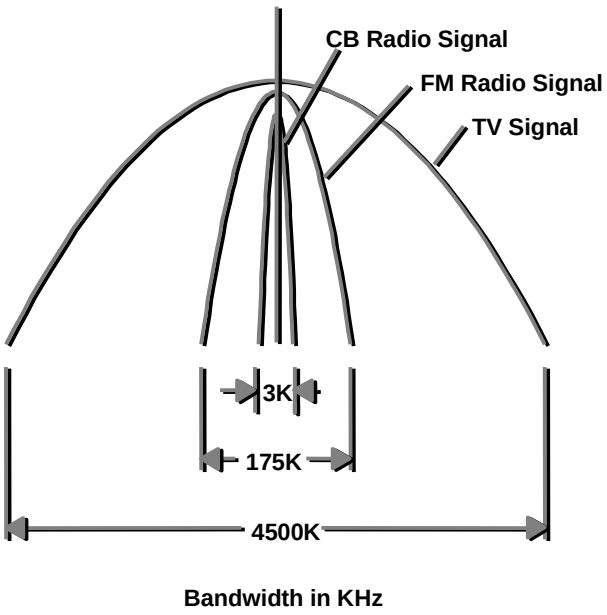
  Complex modulation

Signal Processing



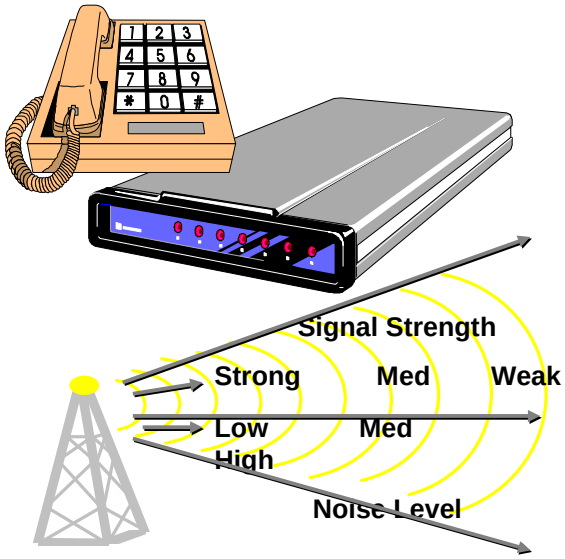
Radio Modulation

- More information =
- More frequency spectrum used



Radio Modulation

- High speed modem compress the data to use the same line as an old 300 baud modem. This means the same bandwidth is available.
- 56Kmodems require a better (quieter) phone line to communicate at the higher speed
- If there is noise on the line, the modem will drop down in speed to connect.
- Mode noise, less speed
- Complex modulation requires better signal strength, therefore less coverage is available

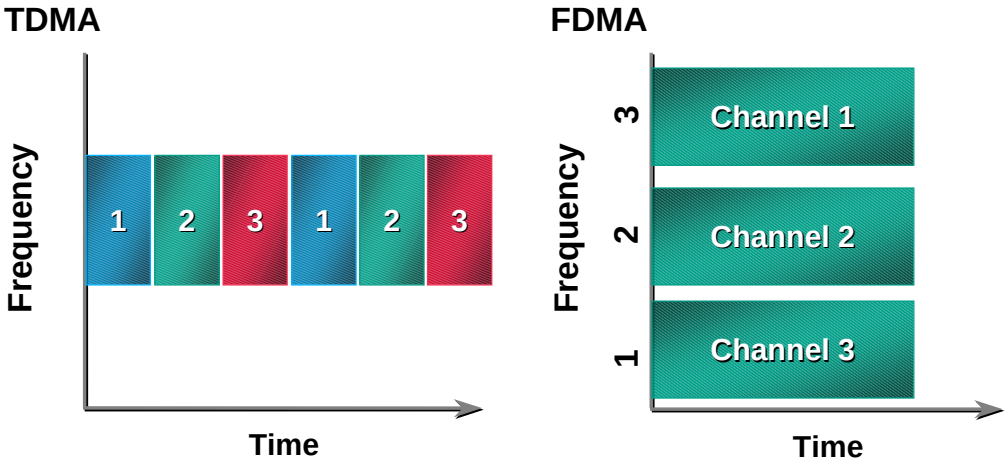


System Access Technology

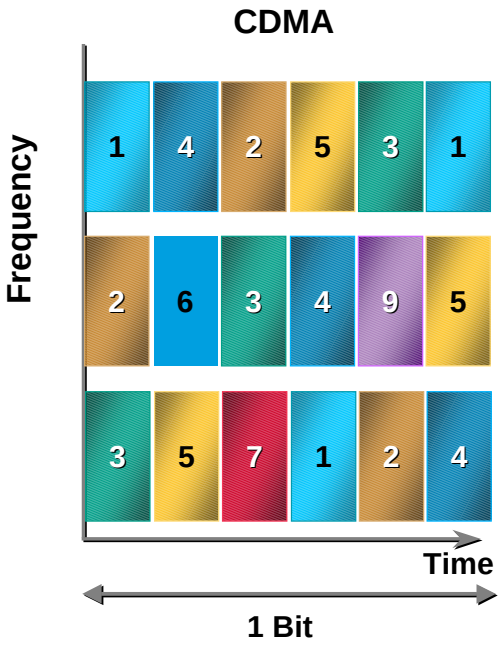
- Frequency division multiple access
- Time division multiple access
- Code division multiple access
- Frequency hopping

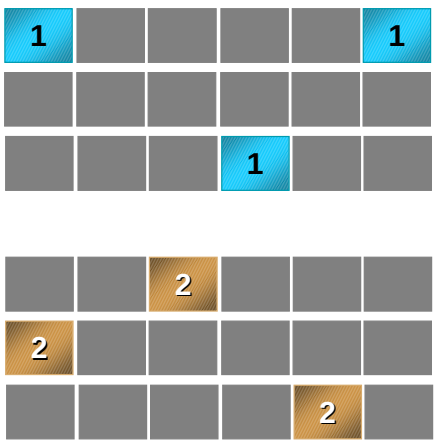
Each technique varies in its efficiency (throughput), interference and range. Depends on application and environment.

TDMA and FDMA



CDMA

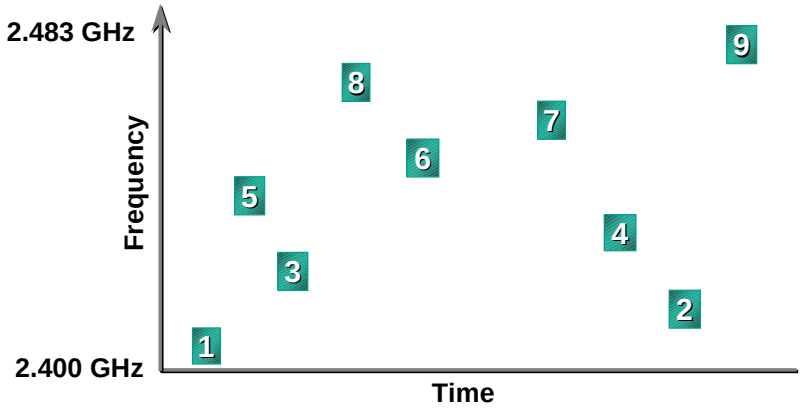




A long code is used to generate a mask for each radio.

Typically a code is transmitted on a separate channel

Frequency Hopping



- 79 channels, 1 MHz each
- Changes frequency (hops) at least every 0.4 seconds
- Synchronized hopping required

Frequency Hopping

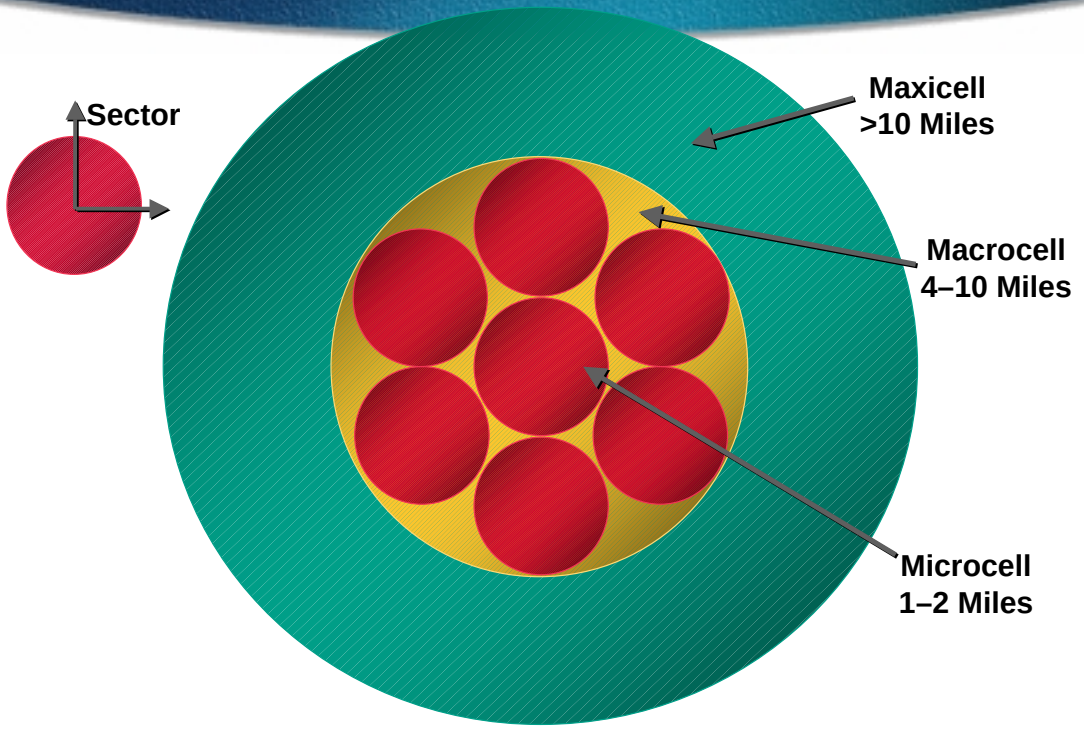
Pattern Number	Channel Numbers									
1	1	8	4	9	*2*	6	*5*	3	7	0
2	4	6	8	3	*2*	7	1	*0*	9	
5	*9*	7	2	1	3	8	4	6	0	
5	*9*	3	6	8	4	1	*5*	*0*	2	

Time →

- Each radio transmits on a channel briefly and then changes to another channel
- Channel numbers in *N* print are actually interfering with other channels at the point in time
- In any multichannel scheme, there is the possibility of interference

Antenna Concepts

Coverage Area



Antenna Concepts

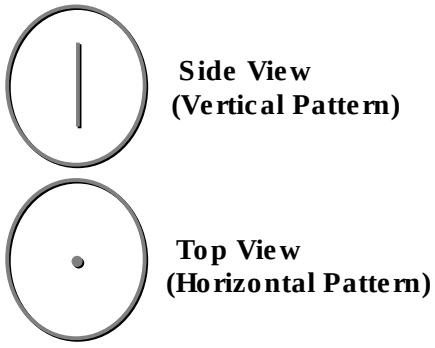
- **Directionality**
  - **Omni (360 degree coverage) directional**
  - **Directional (limited range of coverage)**
- **Gain**
  - **Measured in dBi and dBd. (0 dBd = 2.14 dBi)**
  - **More gain means more coverage—*in certain directions!***
- **Polarization**
  - **Antennas are used in the vertical polarization**

Antenna Gain

- **In life you never get ‘something for nothing’, the same is true in antenna gain**
- **If the gain of an antenna goes up, the coverage area or angle goes down**
- **Coverage areas or radiation patterns are measured in degrees**
- **These angles are referred to as beamwidth, and have a horizontal and vertical measurement**

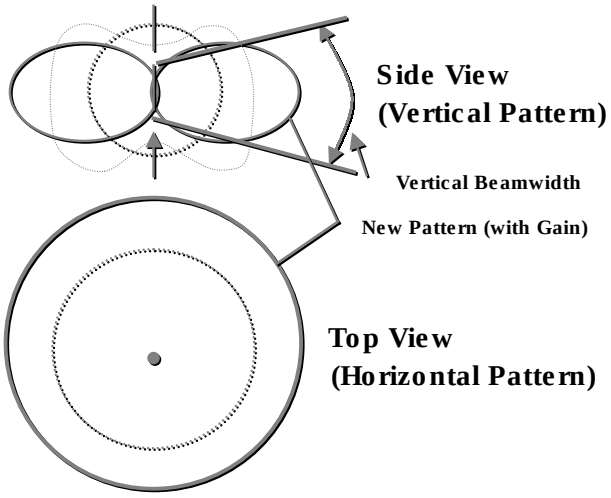
Antenna Theory

- A theoretical antenna (Isotropic) has a perfect 360 degree vertical and horizontal beamwidth
- This is a reference for all antennas



Antenna Theory—Dipole

- To obtain omnidirectional gain from an isotropic antenna, the energy lobes are 'pushed in' from the top and bottom, and forced out in a doughnut type pattern.
- The higher the gain smaller the vertical beamwidth, and the more horizontal lobe area
- This is the typical dipole pattern. Gain of a dipole is 2.14dBi (0dBd)



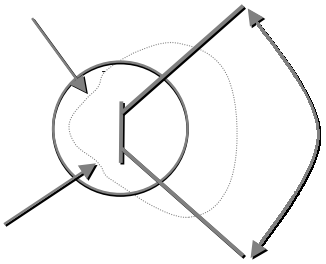
High Gain Omnidirectionals

- High gain omnidirectional antennas will create more coverage area in far distances, but the energy level directly below the antenna will become lower, and coverage here may be poor

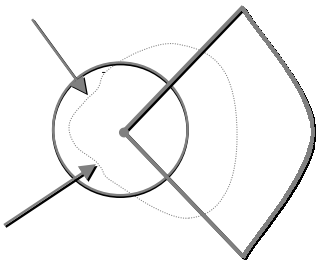
Area of Poor Coverage Directly Under the Antenna

Directional Antennas

- For directional antennas the lobes are pushed in a certain direction, causing the energy to move be condensed in a particular area
- Very little energy is in the back side of a directional antenna



Side View
(Vertical Pattern)



Top View
(Horizontal Pattern)

Cables Lengths Example for Aironet Antennas

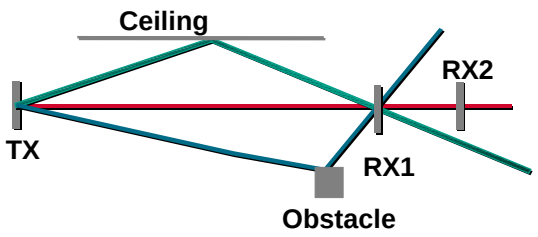
- Coax cable presents a loss for the RF signal
- 2.4 GHz maximum recommended length is 100 feet—with the new cable

Loss Factor	Cable
20 ft cable	N/A
50 ft cable	2.2
75 ft cable	3.3
100 ft cable	4.4

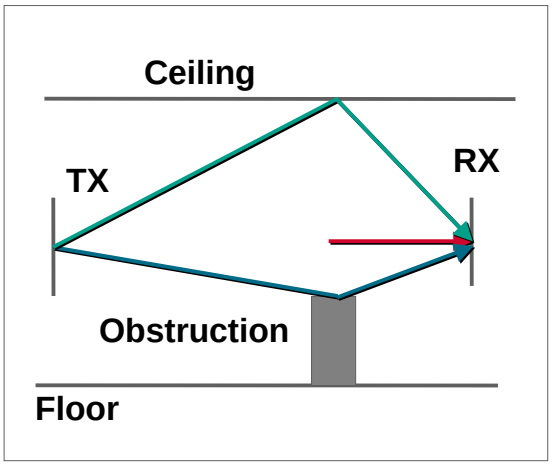
Diversity and Multipath

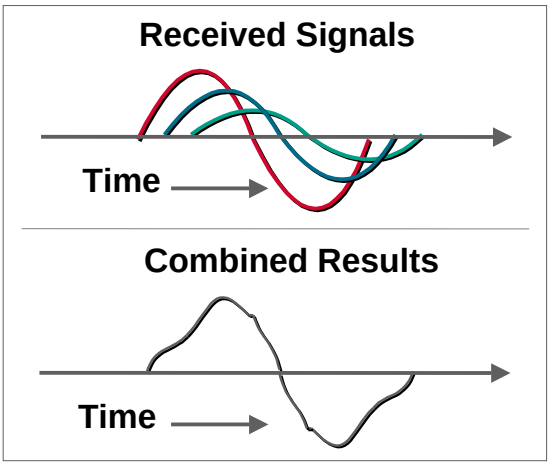
- In a multipath environment, signals null points are located throughout the area
- Moving the antenna slightly will allow you to move out of a null point and receive the signal correctly

Dual antennas typically mean if one antenna is in a null, the other one will not be, therefore providing better performance in multipath environments.



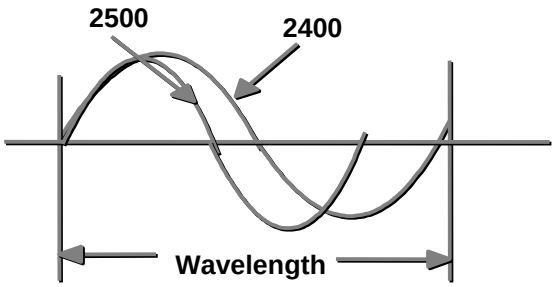
Multipath

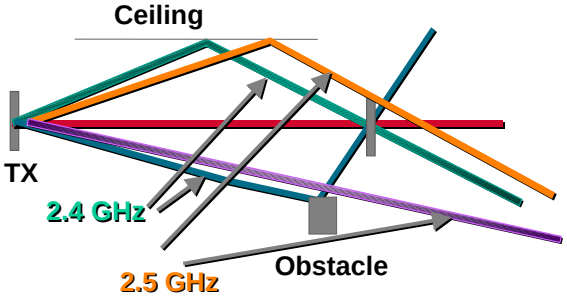




Multipath and FH

- The distance an RF wave travels, how it bounces and where the multipath nulls occur are based on the wavelength of the frequency
- As Frequency changes, so does the wavelength
- Therefore as frequency changes, so will the location of the multipath null





Multipath (Cont.)

- **Multipath signals can cause high RF signal strength, but poor signal quality levels**
- **Bottom line-**

  Low RF signal strength does not mean poor communications

  Low Signal Quality DOES mean poor communications

The LOS Problem

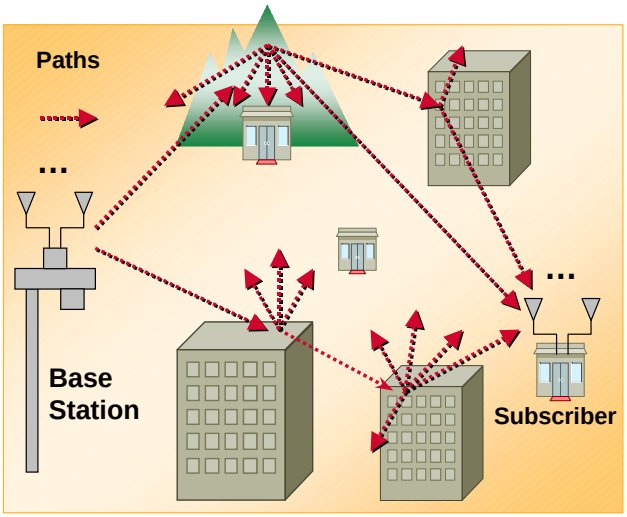
Line-of-Sight:

The technology, while promising, continues to have nagging "line-of-sight" issues. Wireless signals in these systems must have a clear path to travel as they bounce from rooftop to rooftop. Trees, buildings and even inclement weather, such as snow and pelting rain, can cause static, dropped calls and hazy connections.

Leslie Cauley
staff reporter in The Wall Street Journal's New York bureau
September 20, 1999

The LOS Solution

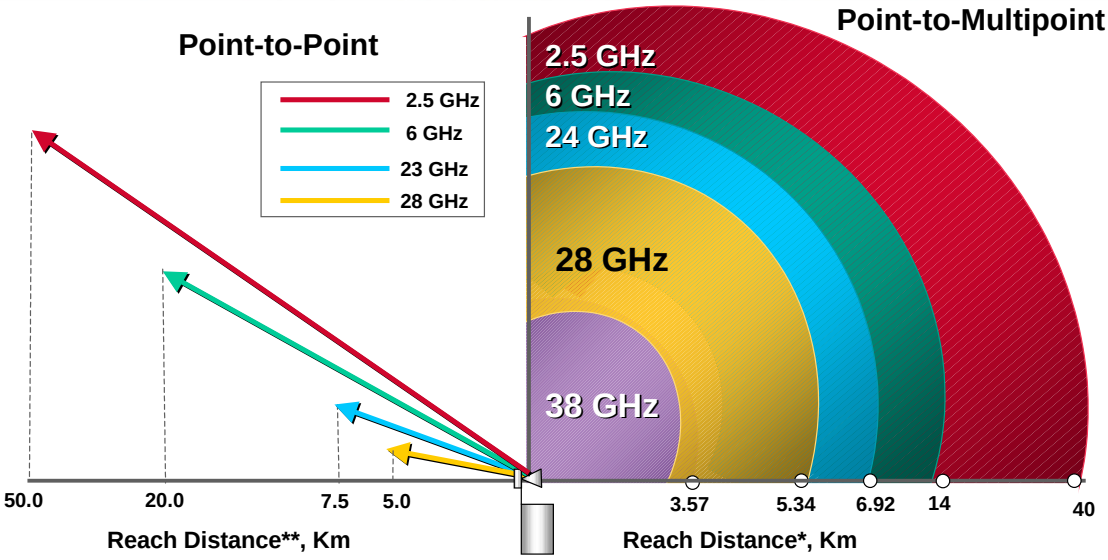
- VOFDM (Vector Orthogonal Frequency Division Multiplexing) technology employs both frequency and spatial diversity to create a robust processing technique for multipath fading and narrow band interference
- VOFDM enables greater coverage and substantially reduces LOS limitations



Range Depends On...

- Frequency
- Transmit power
- Radio sensitivity
- Processing gain from access technique and redundancy
- Interference effects (-)

Reach Distance From Hub



**Assume Rain Zone K, 6cm antennae for 99.995% average availability, vertical polarization.

*Assume Rain Zone K, Single Channel per Transmitter, same power, same dB gain antennas for all frequencies.

Interference Is Caused By...

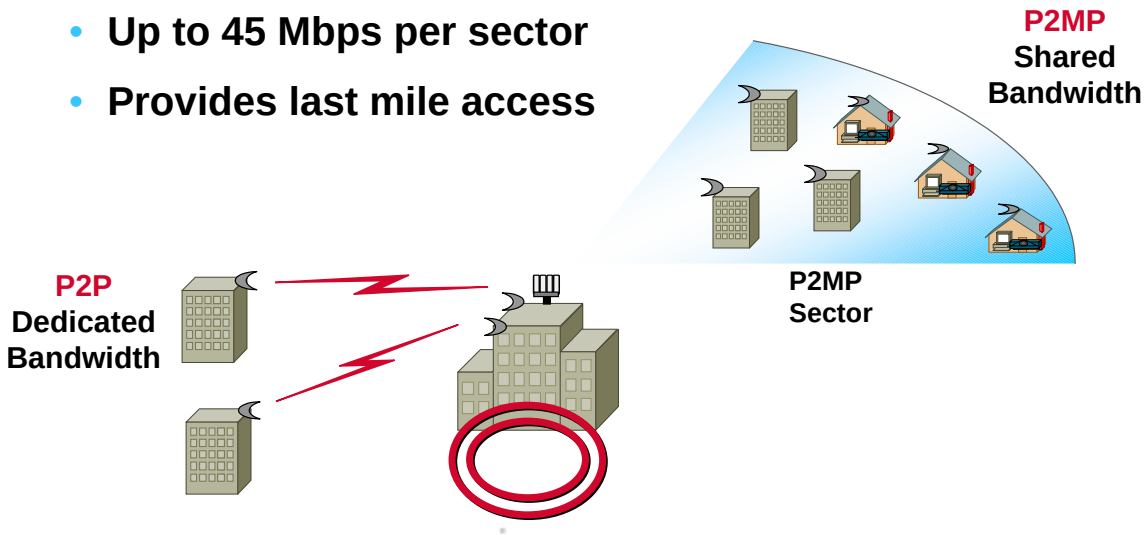
- Obstacles like buildings, trees, walls that absorb or refract signals
- Atmospherics like rain, fog, solar spots
- Other electromagnetic devices

Interference can appear as noise or can cause loss of signal strength

Fixed Wireless Overview

Cisco's Fixed Wireless

- Point to point—2.5 GHz, 5.7 GHz and 28 GHz
- Point to multipoint—2.5 GHz, 5.7 GHz and 28 GHz
- Up to 45 Mbps per sector
- Provides last mile access

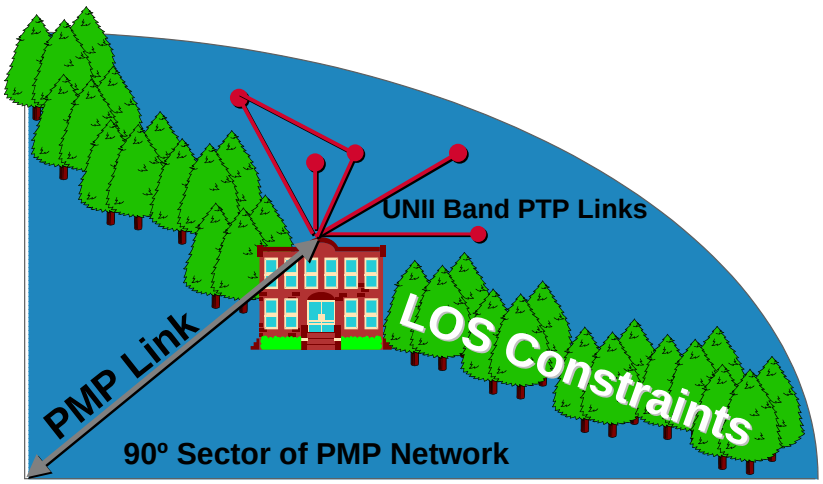


MMDS vs. LMDS

- **Multichannel multipoint distribution service**
  - **2.5 GHz/5.7 GHz**
  - **Not affected by weather**
  - **25 mile range LOS, up to 10 miles NLOS—*only RF with NLOS***
  - **Spectrum more suitable for mass market deployments**
  - **Sometimes called “wireless cable”**
- **Local multichannel distribution service**
  - **28 GHz**
  - ***LOS only*, short range (1–3 miles), affected by weather, more spectrum (1 Ghz)**
  - **Spectrum used specifically for urban deployments to large business or multitenant units**

PTP for Campus Networks

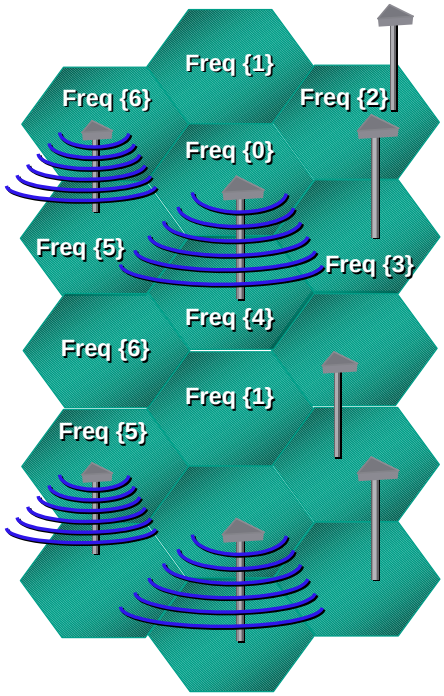
- **PTP links in UNII bands available to extend PMP coverage beyond LOS constraints**
- **Intra-campus data can be transported without using up cell capacity**



Mobile Wireless Overview

Why Is it Called Cellular?

- Originally one set of frequencies across a metro
- Limited number of simultaneous conversations
- Idea was to allocate a subset of frequencies to small areas or"cells"
- Allowed re-use of frequency sets as long as not adjacent
- Vastly increased capacity
- Shrink cell sizes to add even more
- Mobility (call hand-off) required
- Roaming



Differences Between Cellular and PCS

- **Cellular**
  - Described “cell” approach to reuse of frequencies
  - Refers to 800 MHz spectrum
  - Originally analog (A.K.A. 1st generation)
  - Can be digital (CDMA or TDMA—2nd generation)
- **PCS—Personal Communications Services**
  - Meant to compete with cellular
  - Merely another band of spectrum (1.9 GHz)
  - Mandated to be fully digital (CDMA or TDMA)
    - More efficient network utilization
    - Provide enhanced service capability
- **GSM—Global System for Mobile communication**
  - Based on European digital standards
  - Deployed in much of the world including USA

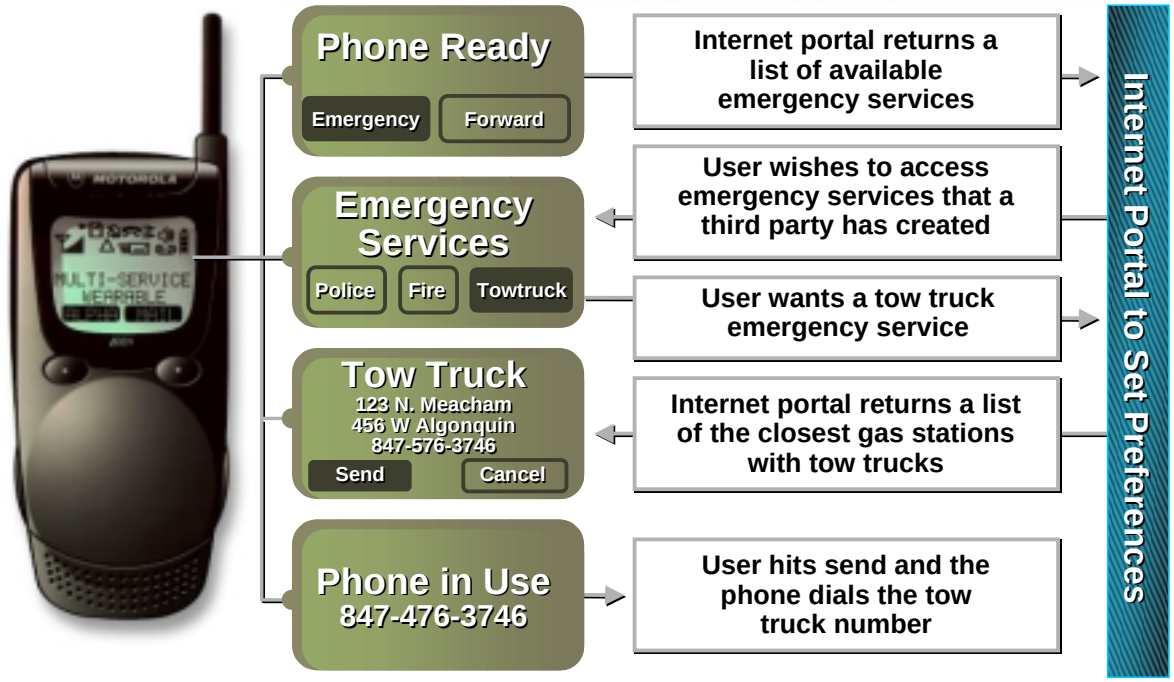
Cellular Data

- **Analog interface**
  - Connect analog cellular phones to modems
  - MNP-10 protocol
  - Slooooooow
- **Cellular Digital Packet Data (CDPD)**
  - Still pretty slooooow—19.2 bps
  - Not widely deployed
- **New “2.5 G” solutions**
  - PDSN for CDMA
  - General Packet Radio Service (GPRS) for GSM

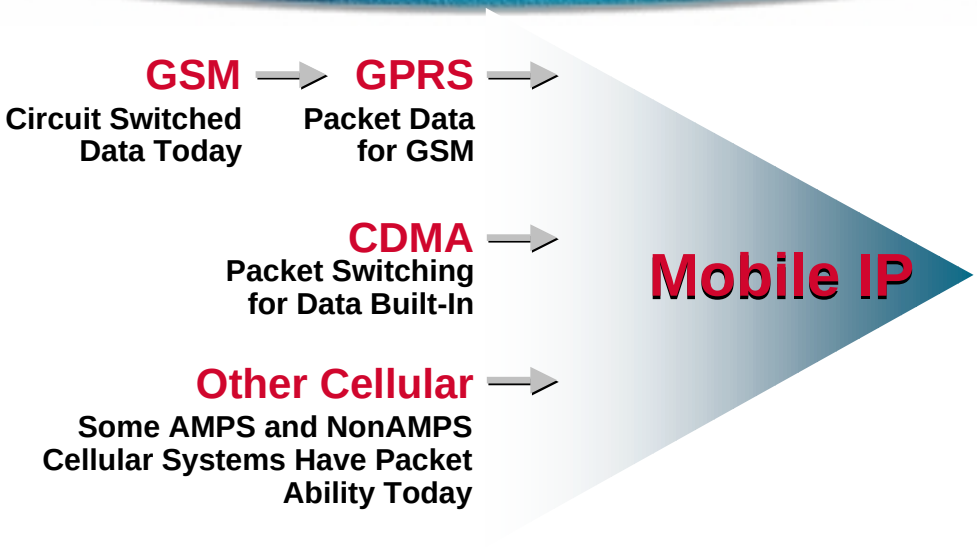
Third Generation Wireless (3G)—Objectives

- Global roaming
- High-speed data transmissions rates
- Support for both symmetric and asymmetric applications
- Toll quality voice transmission
- Simultaneous connections (e.g. browsing Internet while holding voice conversation)

Personalized Service Today



Evolution of Data Services



Cellular Systems Are Moving Toward Support for Packet Data; This Is the Foundation for Mobile IP

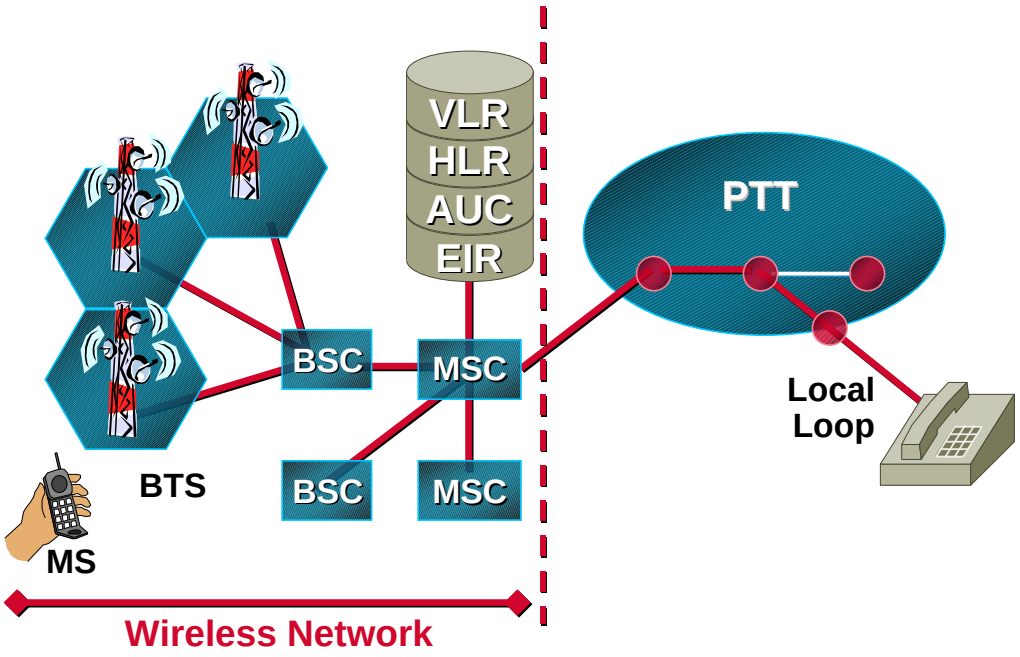
Packet-Based Data Allows

- True mobility—not tied to a circuit
- Always on and always connected
- With mobile IP:
  - The ability to tie into the home network and the Internet
  - Roaming while retaining connectivity and identity

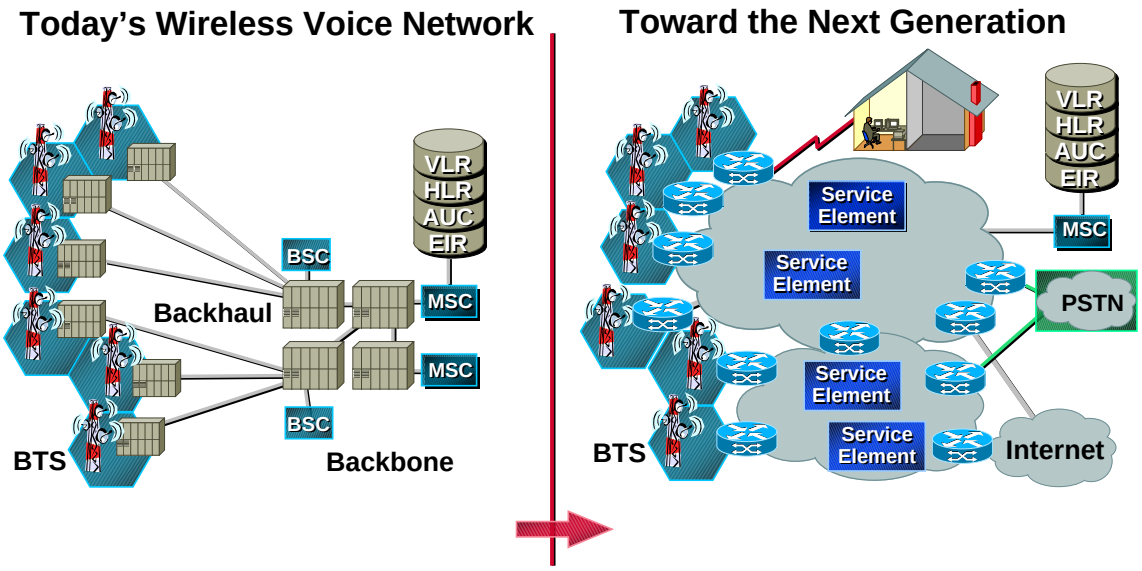
GPRS and Others

Technology	Speed*	C/I	Who	When
• GSM data Circuit	9.6 kbits/s	Low	ETSI	Now
• HSCSD Circuit	56 kbits/s	Medium	ETSI	1999–2000
• GPRS Packet	150 kbits/s	Medium	ETSI	2000–2001
• EDGE Packet	380 kbits/s	Medium	ERICY	2000–2001
• UMTS Packet	2 Mbits/s	High	ETSI	2002

Cellular Telephony Network



Cellular Network Transition



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- "Mobile and Wireless Networks", Black, Uyless, Prentice Hall, 1999
- Cisco IOS Mobile IP:

  http://www.cisco.com/warp/public/cc/cisco/mkt/ios/rel/120/prodlit/817_pb.htm

Customer WLAN Requirements

Market Requirement	Proof Points
Secure	**Up to 128 Bit Wired Equivalent Privacy (WEP)**
Manageable	**Must Integrate with Existing LAN Management Infrastructure**
Scalable	**Roaming to Extend the Network; Deployment in Large Enterprise Facilities**
Standards-Based	**802.11(b); FCC-Certified**

IEEE 802.11 Standard

- IEEE 802.11 became a standard in July 1997
- IEEE 802.11B became a standard in September 1999
- Three technologies defined:
  - FHSS—1 Mbps and 2 Mbps
  - DSSS—2 Mbps and 11Mb
  - Infrared
- 802.11 defines a high-performance radio
- 802.11 promises true vendor interoperability (over the air)

IEEE 802.11 Standard

- 802.11 incorporates many ARLAN features
  - Power management
  - Active scanning
  - Registering (association) with AP
  - Concept of roaming

IEEE 802.11 Impact

- Enables BASIC interoperability over the air
  - DS adapters from different vendors can interact
  - FH adapters from different vendors can interact
- System Level interoperability requires more...
  - Vendor co-operation
  - Higher level protocol agreement

802.11b—Higher Datarate

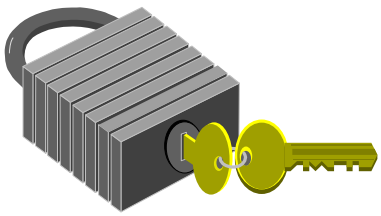
- With the need for higher datarate, 802.11 decided to add more specifications
- Ratified in September, 1999 an 11 MB specification was ratified
- Direct sequence only
- Utilizing CCK modulation

Radio Technology

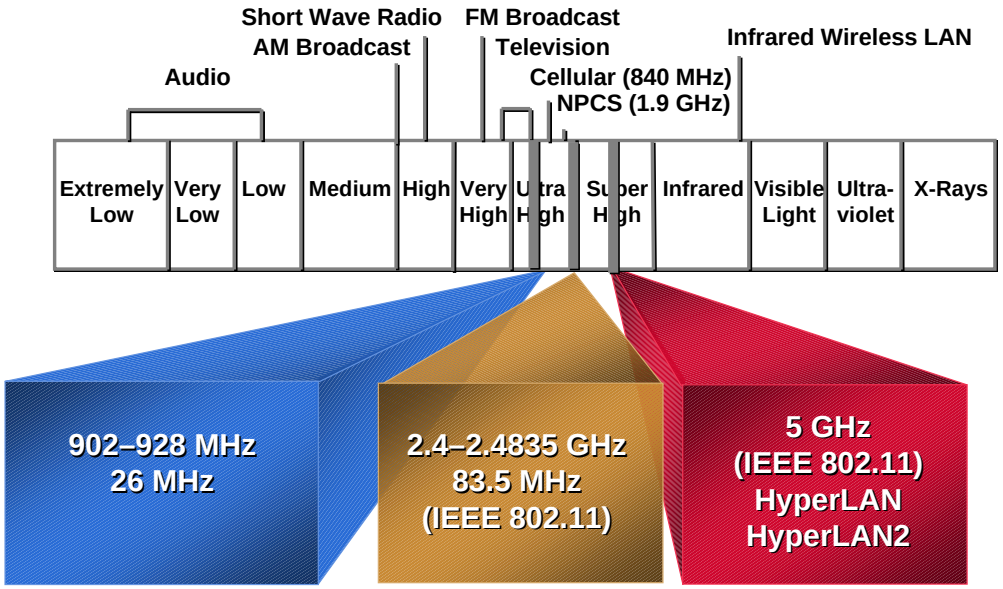
- **Direct Sequence Spread Spectrum (DSSS)**
  - 900 MHz, 2.4 GHz
  - One piece PCMCIA radio product
  - 1, 2, 5.5 and 11 MB
  - 25 mile bridge links
  - Fully compliant 802.11 at all speeds
- **Frequency Hopping Spread Spectrum (FHSS)**
  - 2.4 GHz frequency
  - One piece PCMCIA radio product
  - Fully compliant 802.11
  - 1 and 2 MB

Security

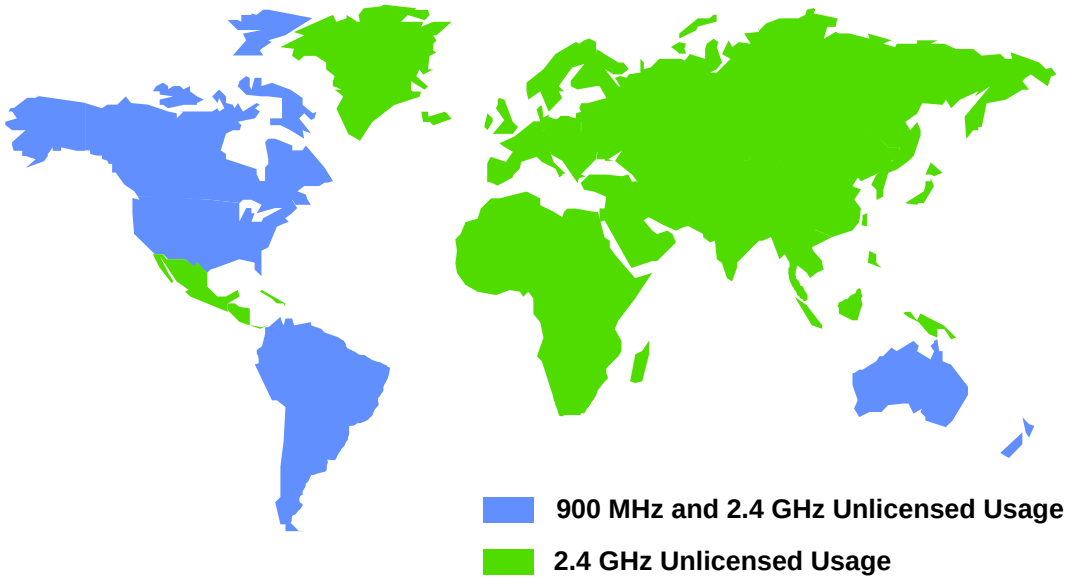
- **128-bit (strong encryption) 802.11 optional Wired Equivalent Privacy (WEP)**
- **Inherent security of spread spectrum**



ISM Unlicensed Frequency Bands



Global RF Regulations



900 MHz vs. 2.4 GHz vs. 5GHz

	900 MHz	2.4 GHz	5 GHz
PROs	Greater Range than 2.4 GHz (For In- Building LANs)	Global Market IEEE 802.11 Higher Data Rates (10+ Mbps)	Global Market IEEE 802.11 Higher Data Rates (20+ Mbps)
CONs	Maximum Data Rate 1 Mbps Limited Bandwidth Crowded Band	Less Range than 900 MHz (For In-Building LANs)	Much Less Range than 900 or 2.4 GHz Higher Cost RF Components Large Antenna Required

What's the Difference?

- **Frequency hopping**
  - **Multipath interference tolerance**
- **Direct sequence**
  - **Throughput**
  - **Range**

Direct Sequence Modulation

- **Each data bit becomes a string of chips (chipping sequence) transmitted in parallel across a wide frequency range**
- **Minimum chip rate per the FCC is 10. Aironet uses 11 for 1 and 2 MB data rates**

If the data bit was: 1001

Chipping code is : 1=00110011011 0=11001100100

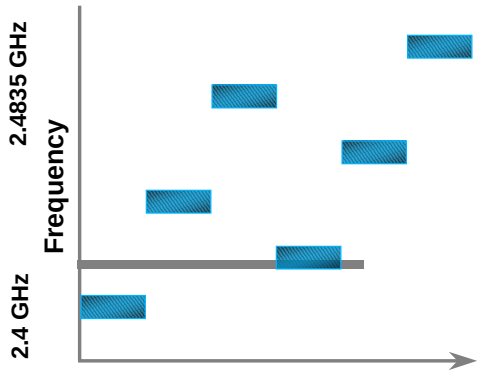
Transmitted data would be:

00110011011 11001100100 11001100100 00110011011

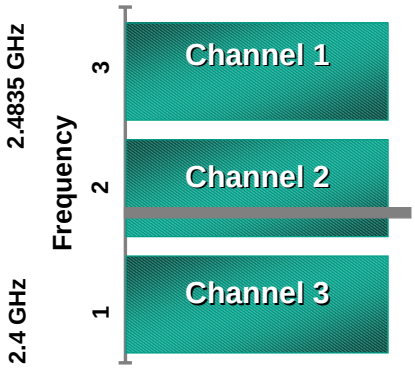
1 0 0 1

FH vs. DS: A Summary on Interference Handling

Frequency Hopping



Direct Sequence



- **FH system hops around interference**
- **Lost packets are re-transmitted on next hop**
- **Data may be decoded from redundant bits**
- **Can move to an alternate channel to avoid interference**

Direct Sequence vs. Frequency Hopping (802.11)

	DS	FH
PROs	Faster—Up to 11 Mbps Greater Range Multimedia Support	Multipath Resistant
CONs		Slower—2 Mbps Max Limited Range

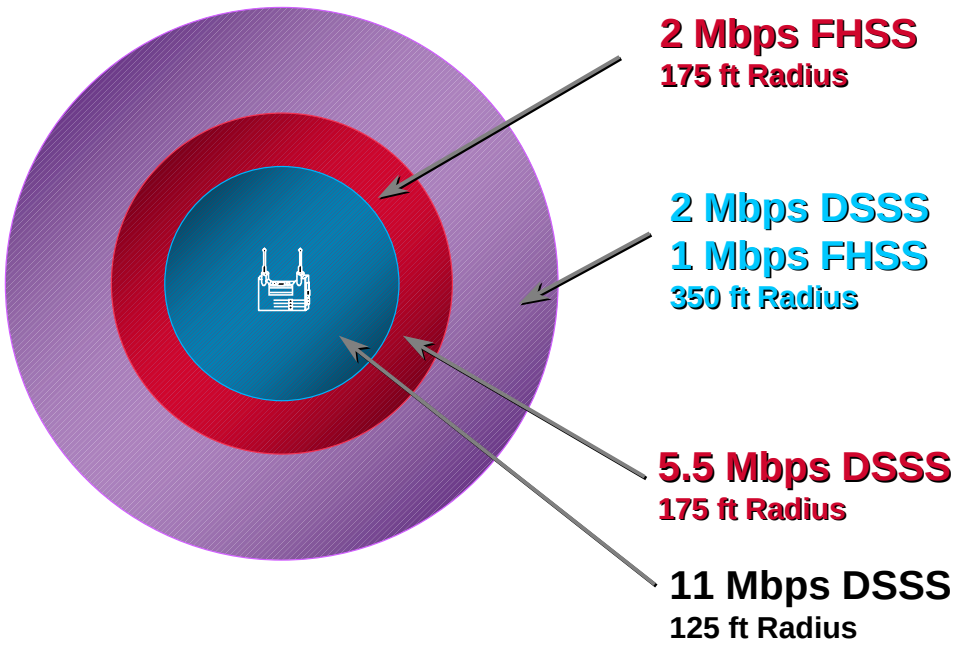
Data Rates

- The “over-the-air” data rate at a given range and given similar implementations will favor DSSS by a factor of 2 to 1
- A 1 Mbps DSSS system should have twice the range of a 1 Mbps FHSS
- 2 Mbps DSSS system will offer comparable range to 1 Mbps FHSS technology
- For these reasons, the data rate advantage goes to DSSS

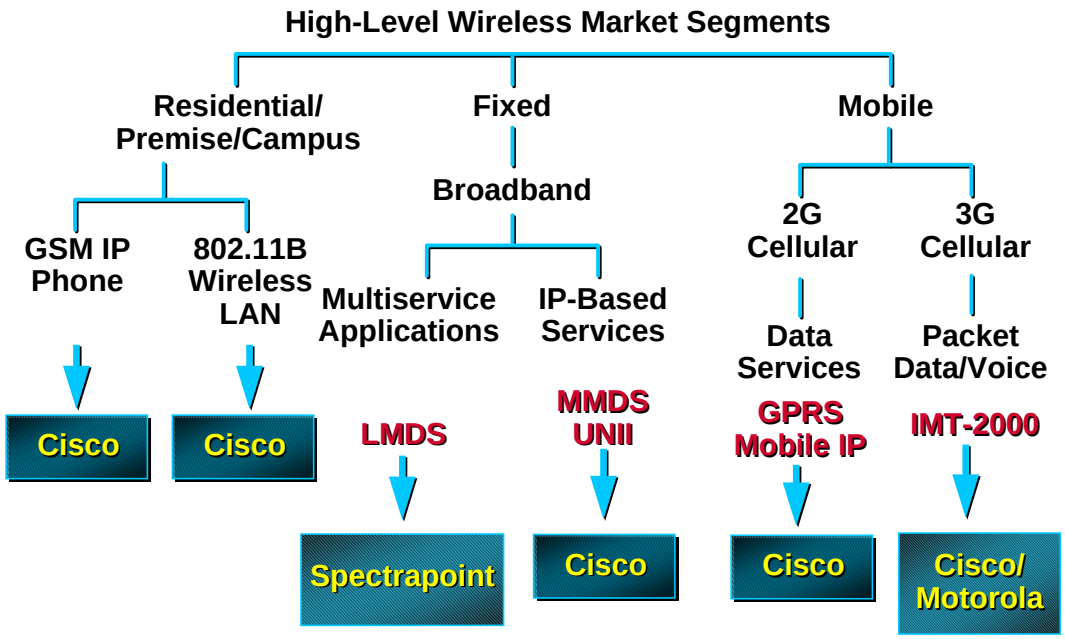
RANGE—FH vs DS

- **Because of this processing gain, the DSSS technology will have more range than FHSS at a given data rate**

Access Point Coverage



Roadmap for the Marketplace



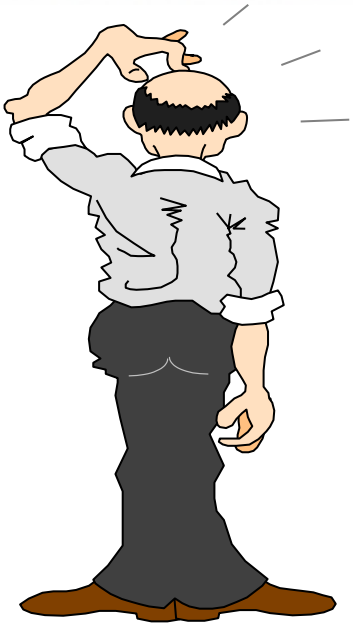
Networker's Wireless Presentations

- 2307—Introduction to Wireless Technology
- 2306—Deploying Mobile IP in Wireless Architectures
- 2309—Deploying Wireless LAN infrastructure
- 2902—Design Principles for Fixed Wireless Access Solutions

Interesting URLs

- U.S. Office of Spectrum Management http://www.ntia.doc.gov/osm
- ITU - http://www.itu.int/brfreqalloc/

Questions?



Introduction to Wireless Technology

Session 2307

CISCO SYSTEMS

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