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Wi-Fi® 101

Agenda

- Wi-Fi Uses
- Governing Organizations
- IEEE Standards
- Wi-Fi Infrastructure and Client Devices
- Terminology and Operation
- RF Fundamentals – Wi-Fi Style…
- Antennas and Accessories
- Wi-Fi: Under the Hood
- Wi-Fi Site Surveys

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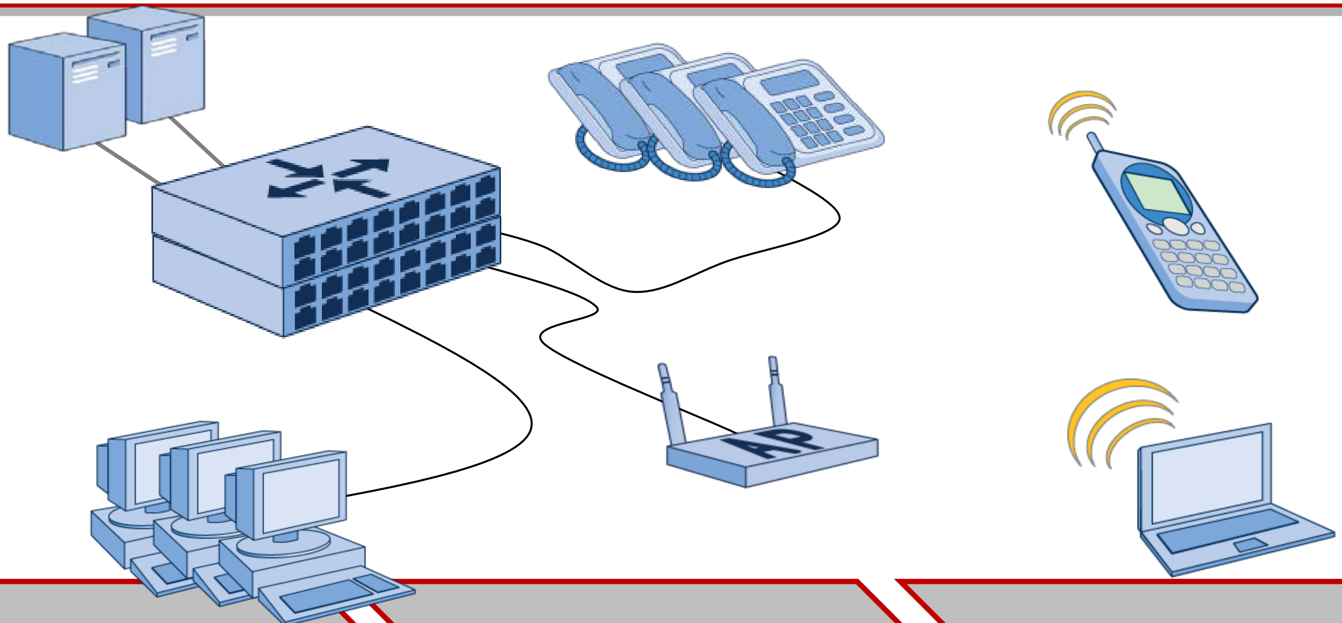
Where is Wi-Fi Used?

Extending the Wired LAN

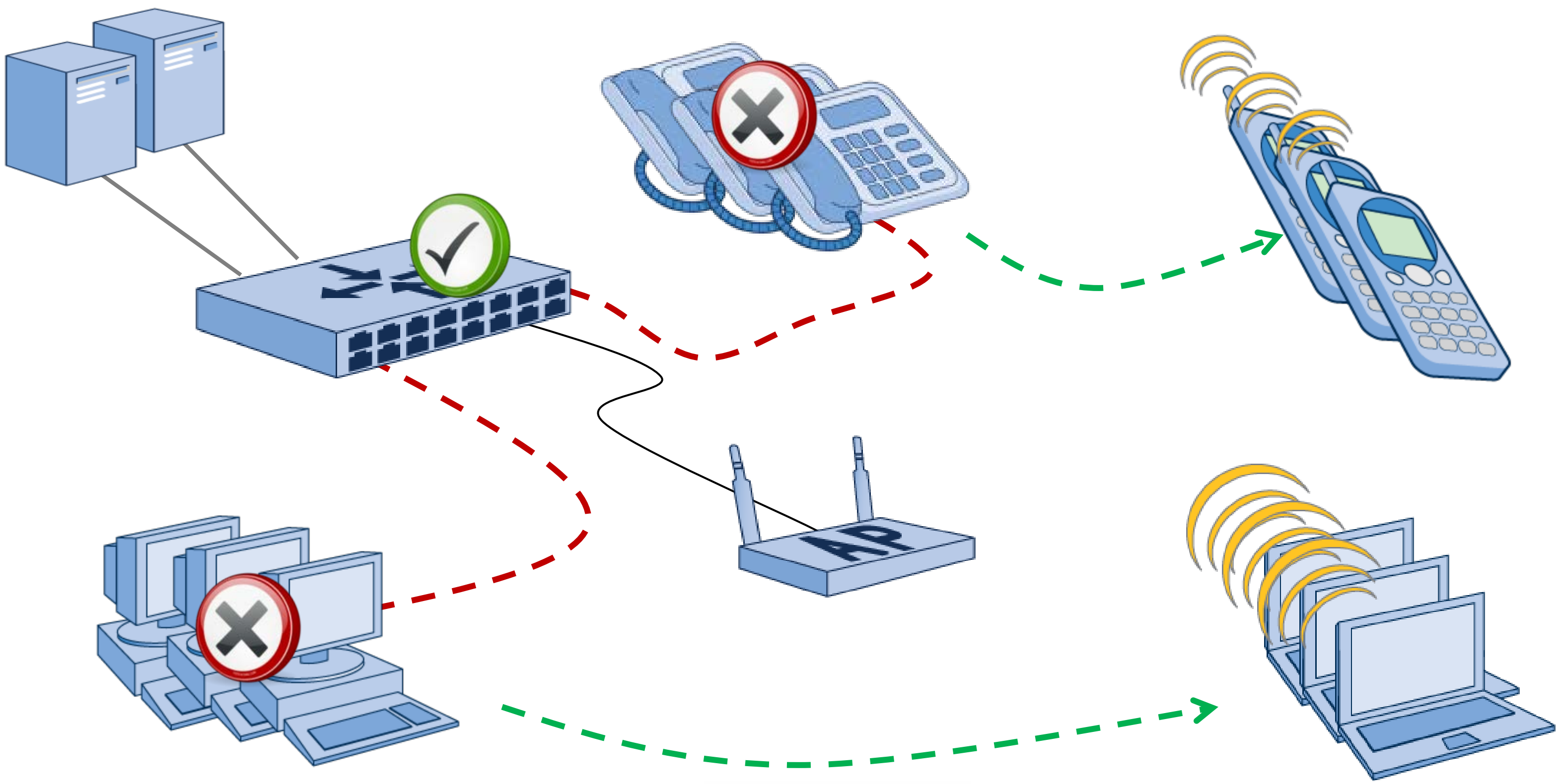
- **The wired LAN is useful for connecting high-speed end-point devices such as servers and desktop PCs**
- **Access points connect via Ethernet to the wired infrastructure, extending access to wireless devices.**



Convenience → **Mobility** → **Efficiency**

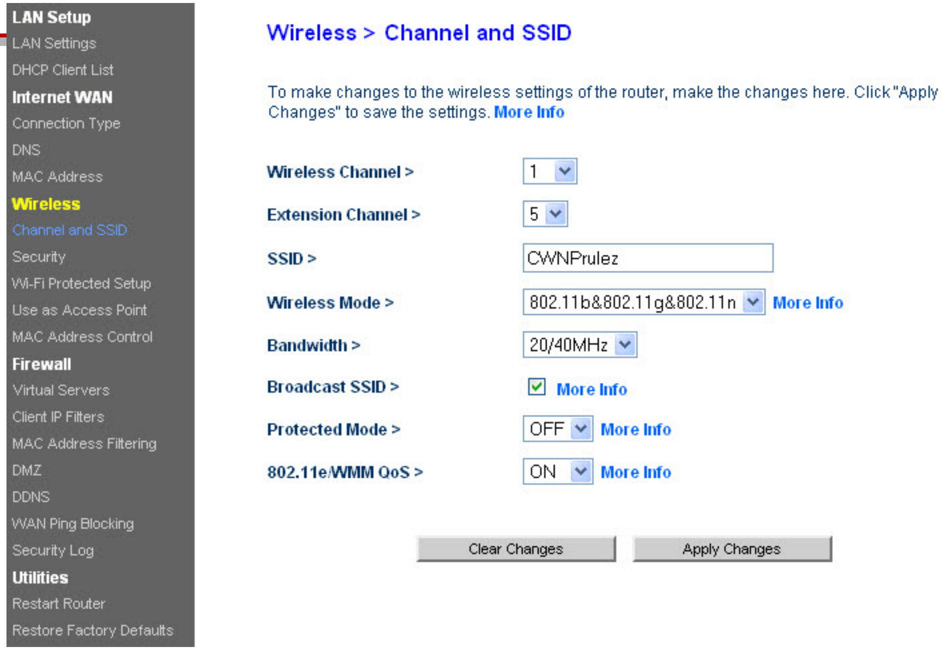
Replacing the Wired LAN

- **One wireless access point could feasibly replace 20 wired data and voice lines**
- **Reduced cost of Ethernet ports, and thus fewer (or smaller) Ethernet switches**
- **Reduced number of Ethernet cables required (lower deployment cost)**



Small Office / Home Office

- **SOHO Wi-Fi infrastructure devices come in two flavors:**
  - **Wi-Fi Router**
  - **Wi-Fi Access Point**
- **A Wi-Fi Router is the combination of a wired router and a Wi-Fi access point**
- **Most devices in this class lack advanced security features, but are simple to configure**



Public Hotspots

- **Provided to the public or guests by business owners either as a for-profit or complimentary service**
- **As they are typically unsecured, there are many attacks against open hotspots**
- **Typically available in locations such as:**
  - **Hotels, restaurants, airports, hospitals, bookstores, libraries, and more**

Security Recommendations

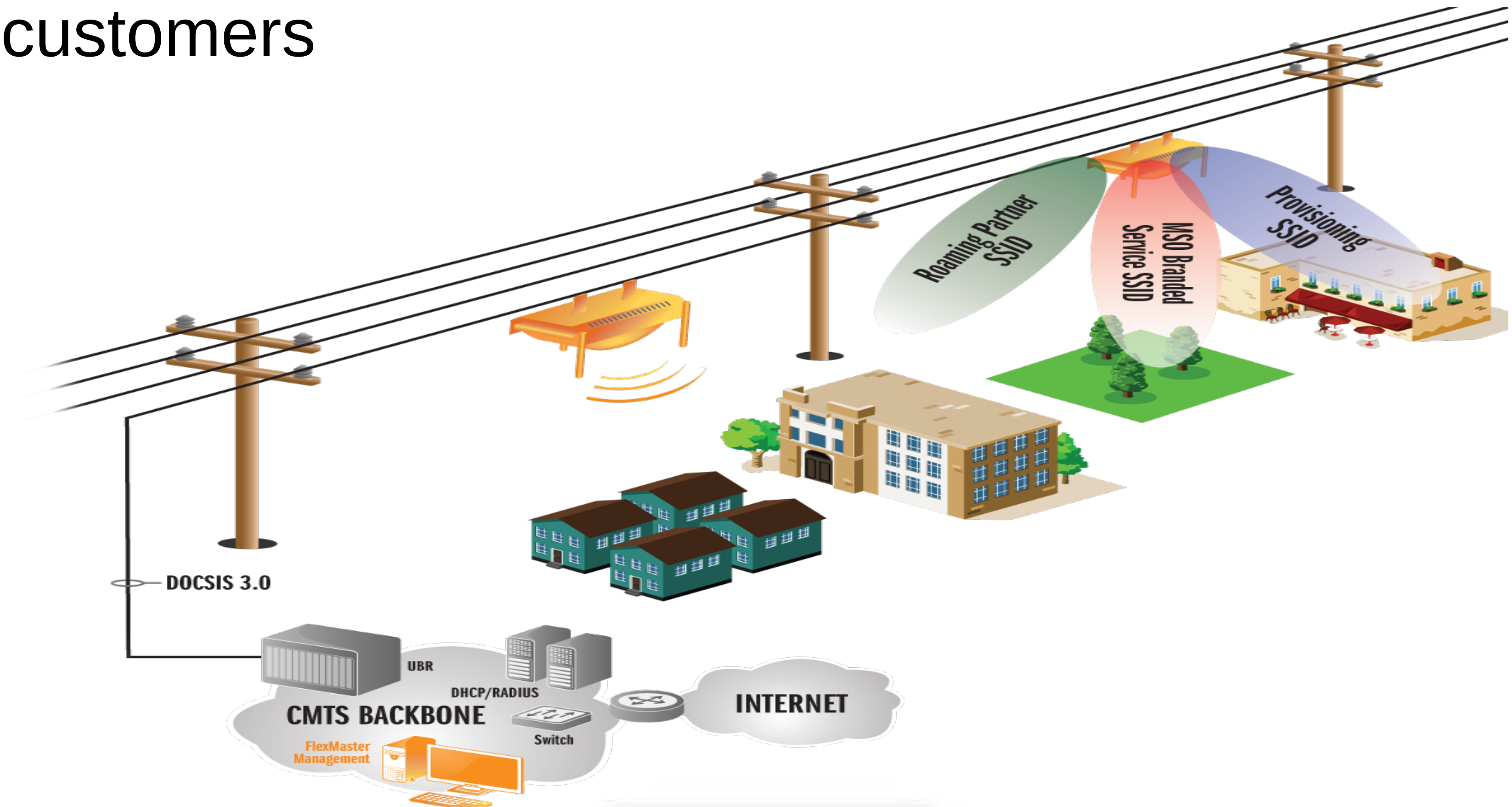
Use only secure applications (https, ftp/s, pop3/s, ssh)

Always have your personal firewall and anti-virus software enabled

Use a VPN solution when possible

Carrier/MSO Wi-Fi

- Adoption by Carriers and MSO's to compliment and expand their current Data offerings to customers



Wi-Fi Organizations

IEEE, Wi-Fi Alliance, and CWNP

IEEE

- Consists of member individuals, many of whom work at Wi-Fi Alliance member companies
- Design and document network protocols, such as:
  - 802.3 Ethernet
  - 802.11 Wi-Fi
  - 802.15 Bluetooth
  - 802.16 WiMAX

Wi-Fi Alliance

- Consists of member organizations – primarily equipment vendors
- Certifies 802.11 equipment for interoperability
- Expedite adoption of IEEE 802.11 standards in the market

Regulatory Bodies

Government entities who create and enforce rules for frequency use

- Maximum transmit power
- Useable frequencies
- Equipment use and placement

Japan (MKK)	***TELEC 33B*** ***TELEC ARIB STD-T71***
Canada	***ISC RSS-210***
Europe (ETSI)	***ETS 300.328*** ***ETS 301.893***
USA	***FCC (47 CFR) Part 15C, Section 15.247***

China	**RRL/MIC** **Notice 2003-13**
Israel	***MOC***
Singapore	**IDA/ TS SSS Issue 1**
Taiwan	***PDT***

IEEE Standards

Standards, Amendments, & Drafts

Draft

- A document created to standardize the implementation of a newly-introduced technology.
- May go through several versions before becoming an amendment.

Amendment

- A ratified (voter-approved) version of a draft that will be added to a standard in the future
- 802.11g, 802.11i, and 802.11r are examples of ratified amendments

Standard

- A comprehensive document created to detail and standardize the operation of a technology
- Amendments are added to a "rolled-up" standard periodically. Standards are then re-dated.

802.11 Standard

802.11 Standard	PHY Support	Amendments Included	Year Ratified
802.11-1997	Infrared FHSS DSSS	None	1997
802.11-1999	Infrared FHSS DSSS	None	1999
802.11-1999 (Reaffirmed in 2003)	Infrared FHSS DSSS	None	2003
802.11-2007	Infrared FHSS DSSS HR/DSSS OFDM ERP	802.11a, 802.11b 802.11c, 802.11d 802.11e, 802.11g 802.11h, 802.11i 802.11j	2007

802.11 PHY Amendments

802.11 Standard or Amendment	Frequency	Data Rates (Mbps)	PHY Support	Ratified
802.11-1997 802.11-1999 Reaffirmed 2003	2.4 GHz	1,2	Infrared FHSS DSSS	1997 1999 2003
802.11a 802.11-2007 Clause 17 OFDM	5 GHz	6, 9, 12, 18, 24, 36, 48, 54	OFDM	1999
802.11b 802.11-2007 Clause 18 HR/DSSS	2.4 GHz	1,2, 5.5, 11	DSSS HR/DSSS	1999
802.11g 802.11-2007 Clause 19 ERP	2.4 GHz	1,2, 5.5, 11 6, 9, 12, 18, 24, 36, 48, 54	DSSS HR/DSSS ERP	2003
802.11n	2.4 / 5 GHz	Up to 600	HT-OFDM + all previous	2010

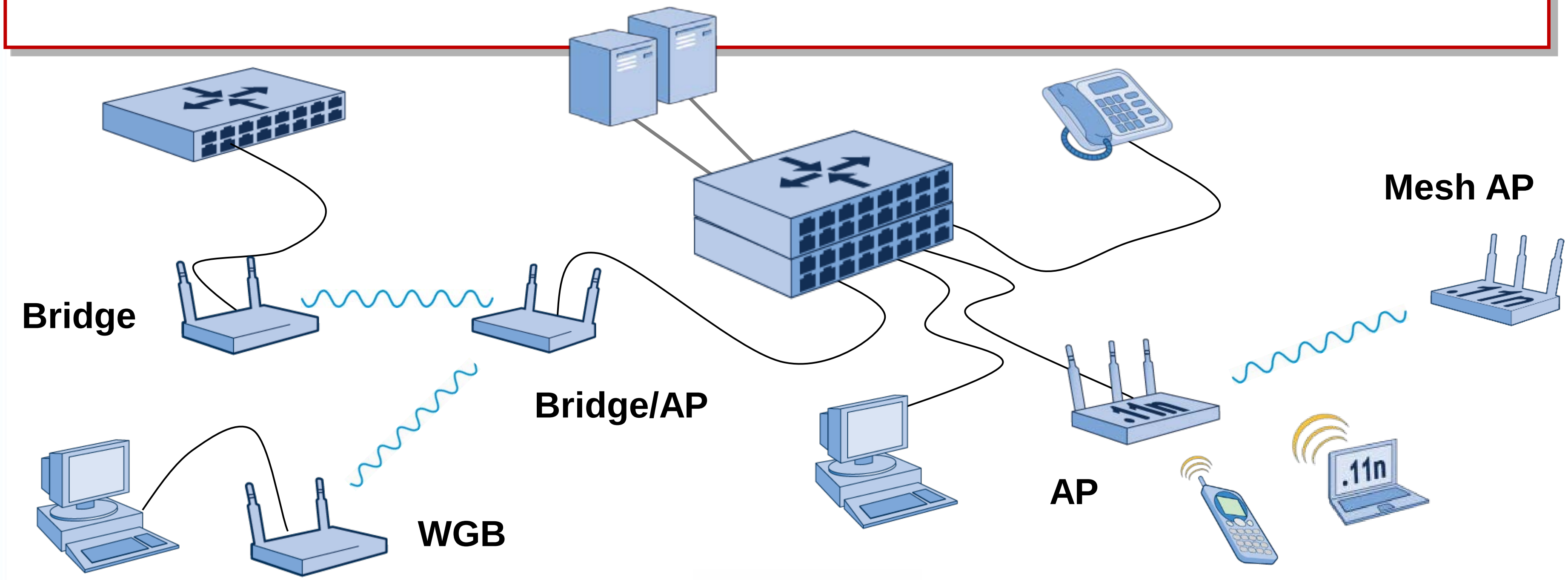
802.11 Amendments

802.11 Amendment	Purpose	Wi-Fi Alliance Certification	Year Released
802.11e	Quality of Service	Wi-Fi Multimedia (WMM, WMM-PS)	2005
802.11i	Security	Wi-Fi Protected Access (WPA / WPA2)	2004
802.11k	Radio Resource Measurement	Voice-Enterprise	2008
802.11r	Fast BSS Transition	Voice-Enterprise	2008
802.11AC	Increased Speeds	"Gigabit Wi-Fi"	2014 (Expected)

Wi-Fi Infrastructure and Client Devices

Access Points (APs)

- **An access point provides network access to wireless client devices through a radio link with those client devices. APs can play various roles in the network, such as: Access Point, Repeater, Bridge, Mesh AP, Mesh Portal**
- **An access point can contain all MAC functionality or only part of it. For this reason, APs can be:**
  - **Autonomous (Fat, Stand-alone)**
  - **Controller-based (Thin, Lightweight)**

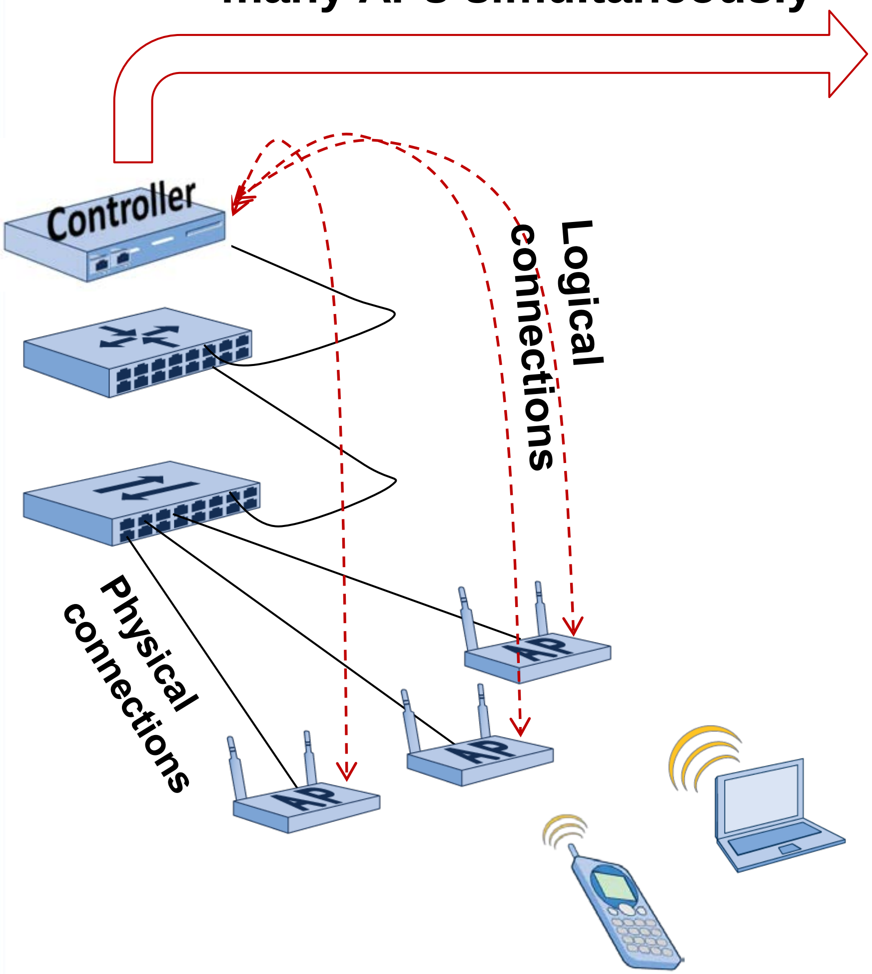


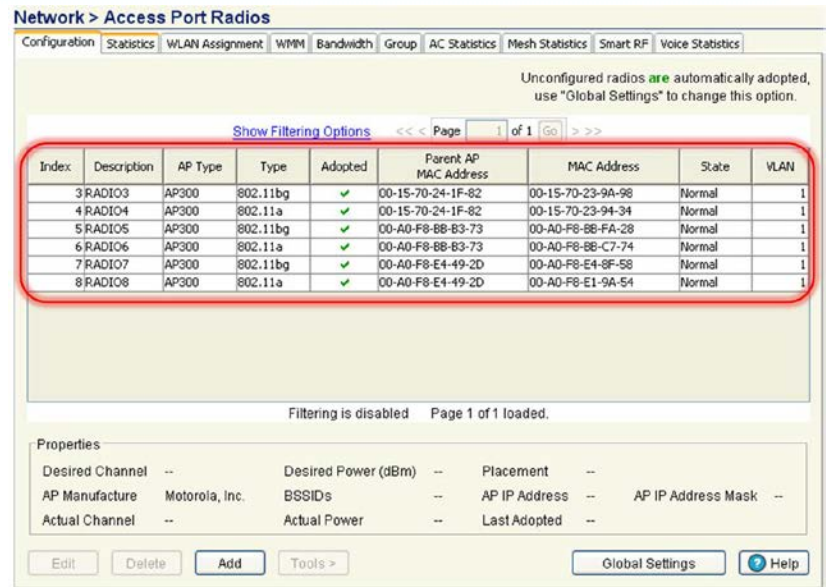
Autonomous APs

- **Autonomous APs are responsible for all MAC (Data Link) functionality**
- **Each AP is an independent network entity and must be individually managed**

Controller-based APs

Controllers can manage many APs simultaneously





Network > Access Port Radios

Configuration | Statistics | WLAN Assignment | WMM | Bandwidth | Group | AC Statistics | Mesh Statistics | Smart RF | Voice Statistics

Unconfigured radios are automatically adopted, use "Global Settings" to change this option.

Show Filtering Options << < Page 1 of 1 Go > >>

Index	Description	AP Type	Type	Adopted	Parent AP MAC Address	MAC Address	State	VLAN
3	RADIO3	AP300	802.11bg	✔	00-15-70-24-1F-82	00-15-70-23-9A-98	Normal	1
4	RADIO4	AP300	802.11a	✔	00-15-70-24-1F-82	00-15-70-23-94-34	Normal	1
5	RADIO5	AP300	802.11bg	✔	00-A0-F8-BB-B3-73	00-A0-F8-BB-FA-28	Normal	1
6	RADIO6	AP300	802.11a	✔	00-A0-F8-BB-B3-73	00-A0-F8-BB-C7-74	Normal	1
7	RADIO7	AP300	802.11bg	✔	00-A0-F8-E4-49-2D	00-A0-F8-E4-8F-58	Normal	1
8	RADIO8	AP300	802.11a	✔	00-A0-F8-E4-49-2D	00-A0-F8-E1-9A-54	Normal	1

Filtering is disabled   Page 1 of 1 loaded.

Properties

Desired Channel	--	Desired Power (dBm)	--	Placement	--		
AP Manufacture	Motorola, Inc.	BSSIDs	--	AP IP Address	--	AP IP Address Mask	--
Actual Channel	--	Actual Power	--	Last Adopted	--		

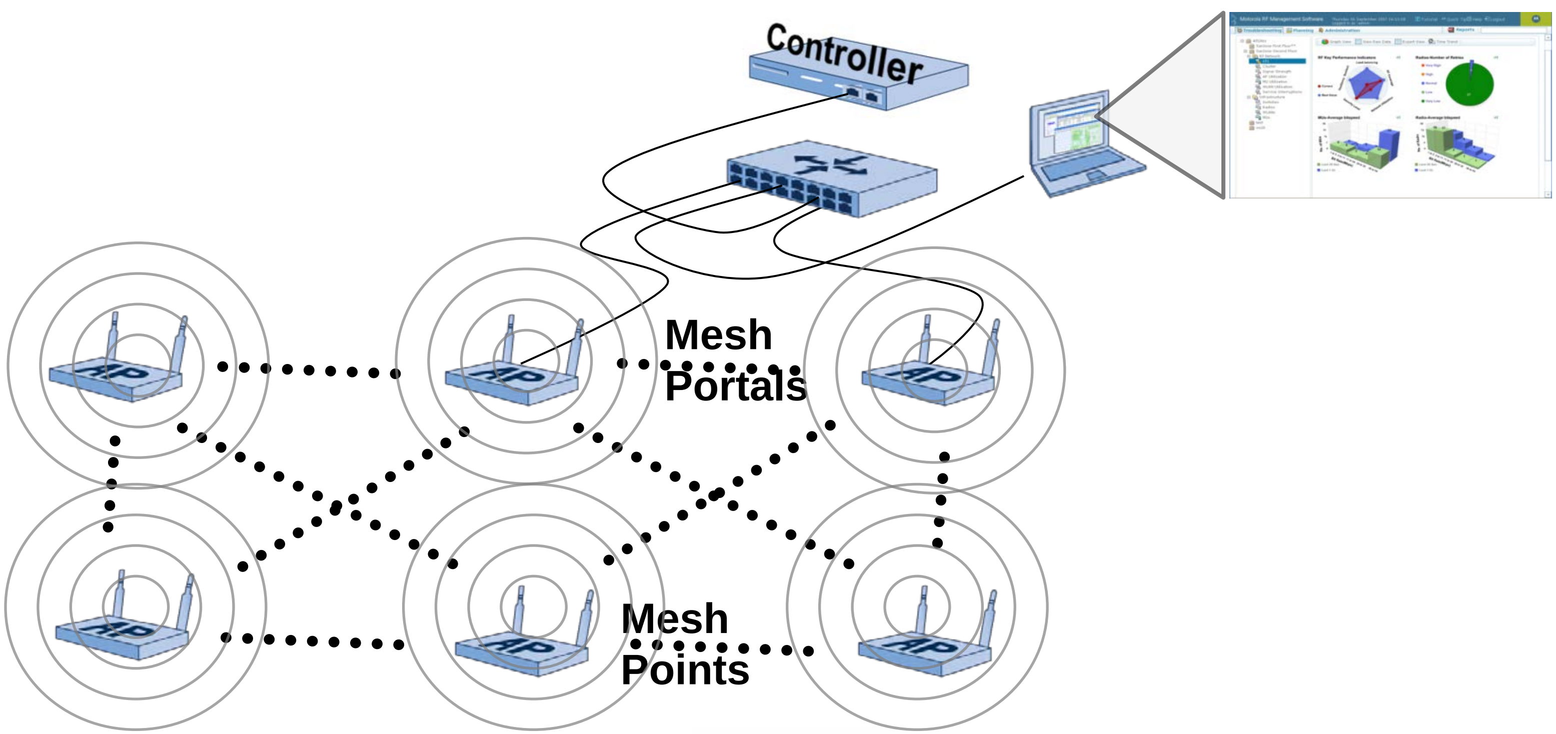
Edit | Delete | Add | Tools > | Global Settings | Help

- **Physical appearance of autonomous APs**
- **Some functions become centralized (in the controller)**
- **Benefits include lower TCO and consistent security**
- **APs can forward all data directly to its destination or through the controller**

Mesh APs

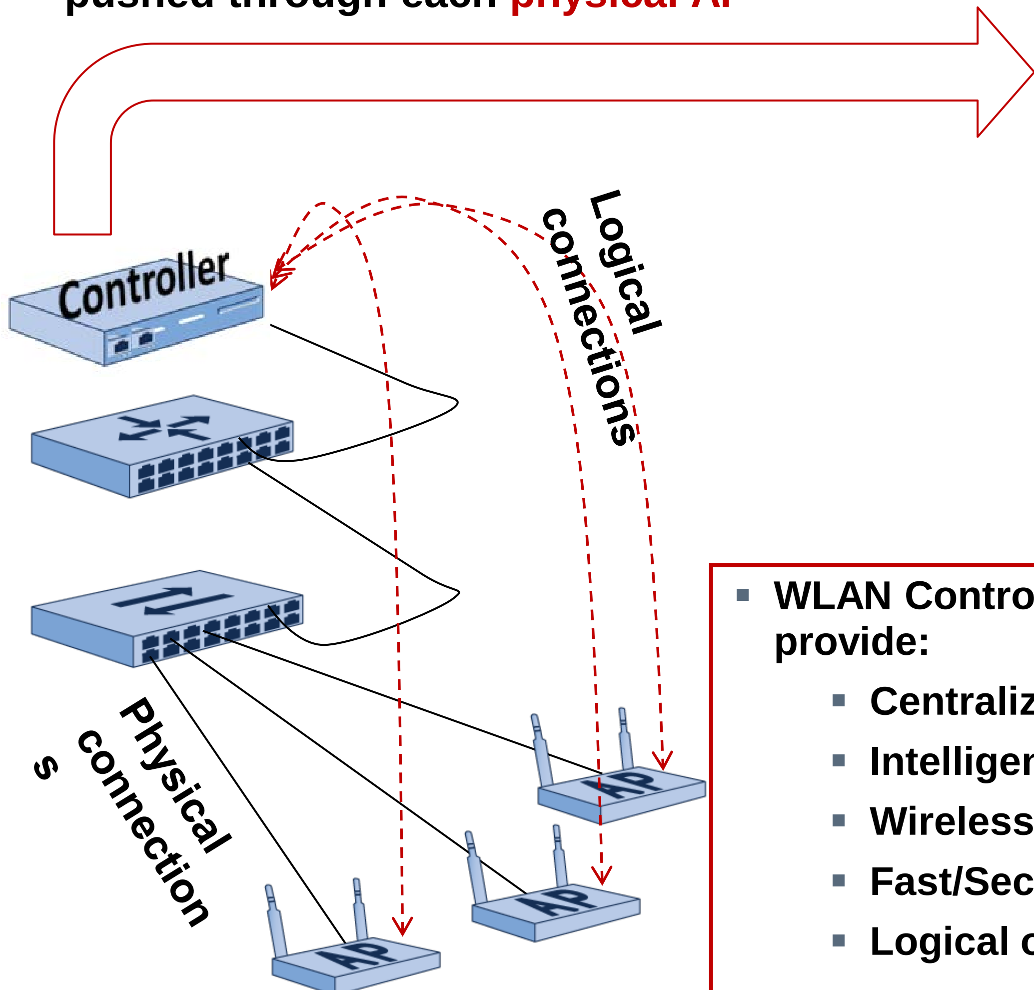
- Mesh APs provide data backhaul to other APs through wireless infrastructure
- Mesh APs can be controller-based or autonomous
- Benefits: Reduced cost of wired infrastructure and added infrastructure redundancy

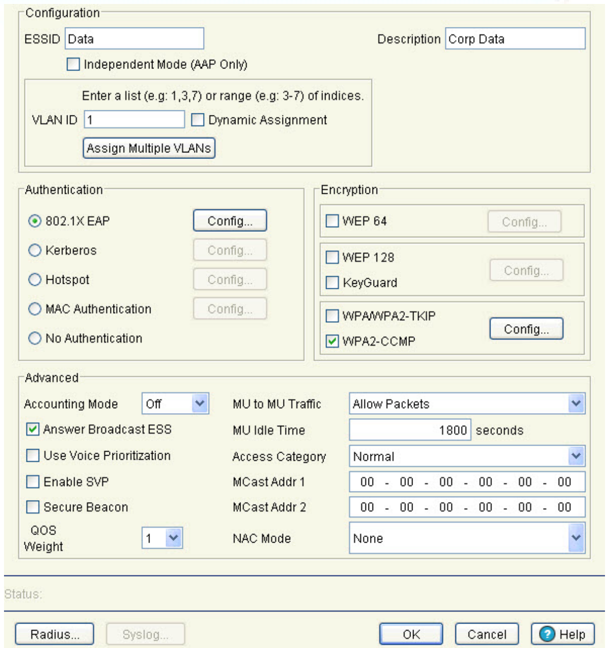
Mesh APs are typically managed by management software, often called WNMS.



WLAN Controllers

WLAN Profiles allow multiple virtual APs to be pushed through each physical AP



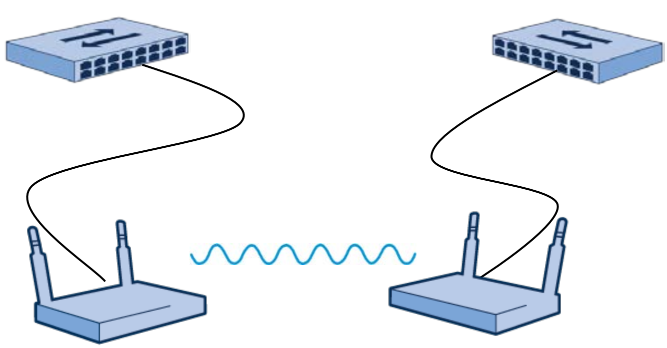


- **WLAN Controllers are appliances that may provide:**
  - **Centralized AP management**
  - **Intelligent RF control**
  - **Wireless Intrusion Prevention**
  - **Fast/Secure client roaming**
  - **Logical or direct physical connections to APs**

Wireless Bridges

- **Proprietary implementation of an 802.11 device that connects two or more wired LANs**
  - **WLAN bridging not specified by IEEE 802.11 standard**
  - **No Wi-Fi Alliance certification for interoperability**
- **May be implemented in a Point-to-Point (PTP) or Point-to-Multipoint (PTMP) configuration**
- **Systems may be Line-of-site (LoS) or non Line-of-Site (nLoS) capable**
- **Typically implemented outdoors, therefore ruggedized & weatherproofed**
- **Distance, antenna height/type, frequency, and modulation affect connectivity**

Buzzword:
Proprietary



PTMP Example: Last-mile data delivery from ISP

Client Devices

- **A client device is a radio hardware device that connects to an access point.**
- **A client device is used as part of a computer or appliance to provide connectivity.**
- **Multiple client radio form factors are available, such as those shown below. Additionally, client radios may be found in cell phones, handheld computers, medical equipment, and workgroup bridges.**

PCI Bus

Wi-Fi RFID Tag

Express Card

Mini PCIe

Mini PCI

Universal Serial Bus (USB) Adapter

Secure Digital (SDIO)

CardBus

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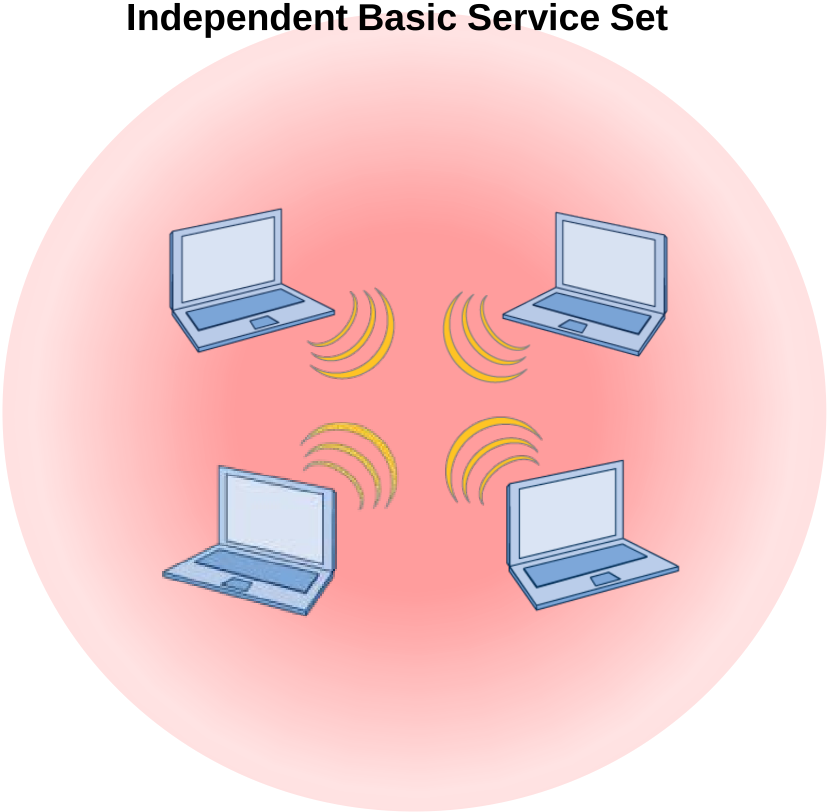
Wi-Fi Terminology and Operation

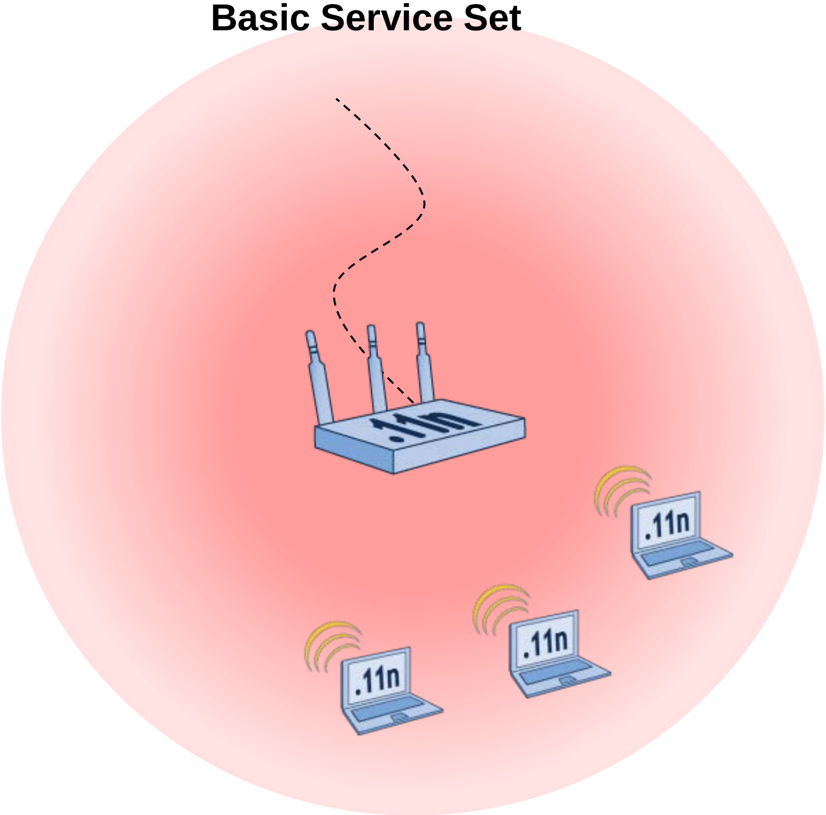
Wi-Fi Modes of Operation

IBSS	**Ad Hoc - Two or more client devices connected together without an AP**
BSS	**Infrastructure - AP with stations connected**

Independent Basic Service Set

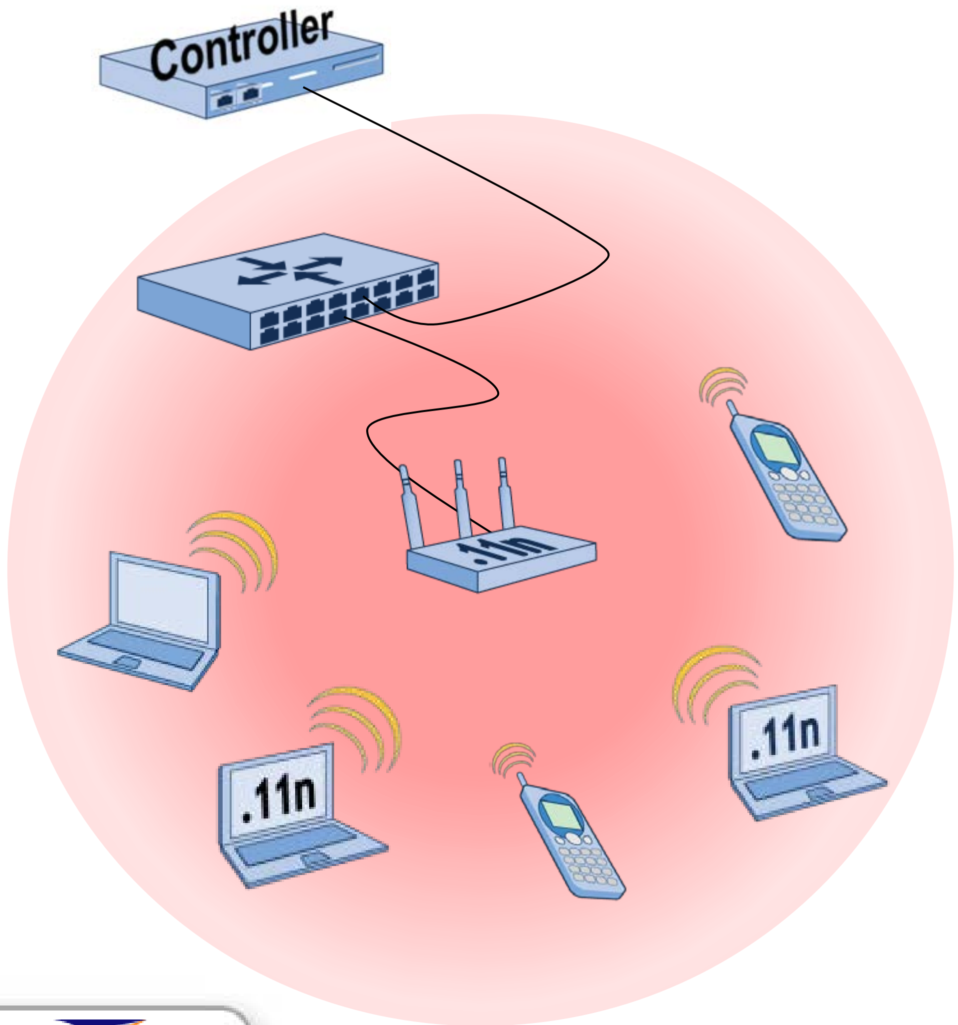


Basic Service Set



BSS, BSA, and BSSID

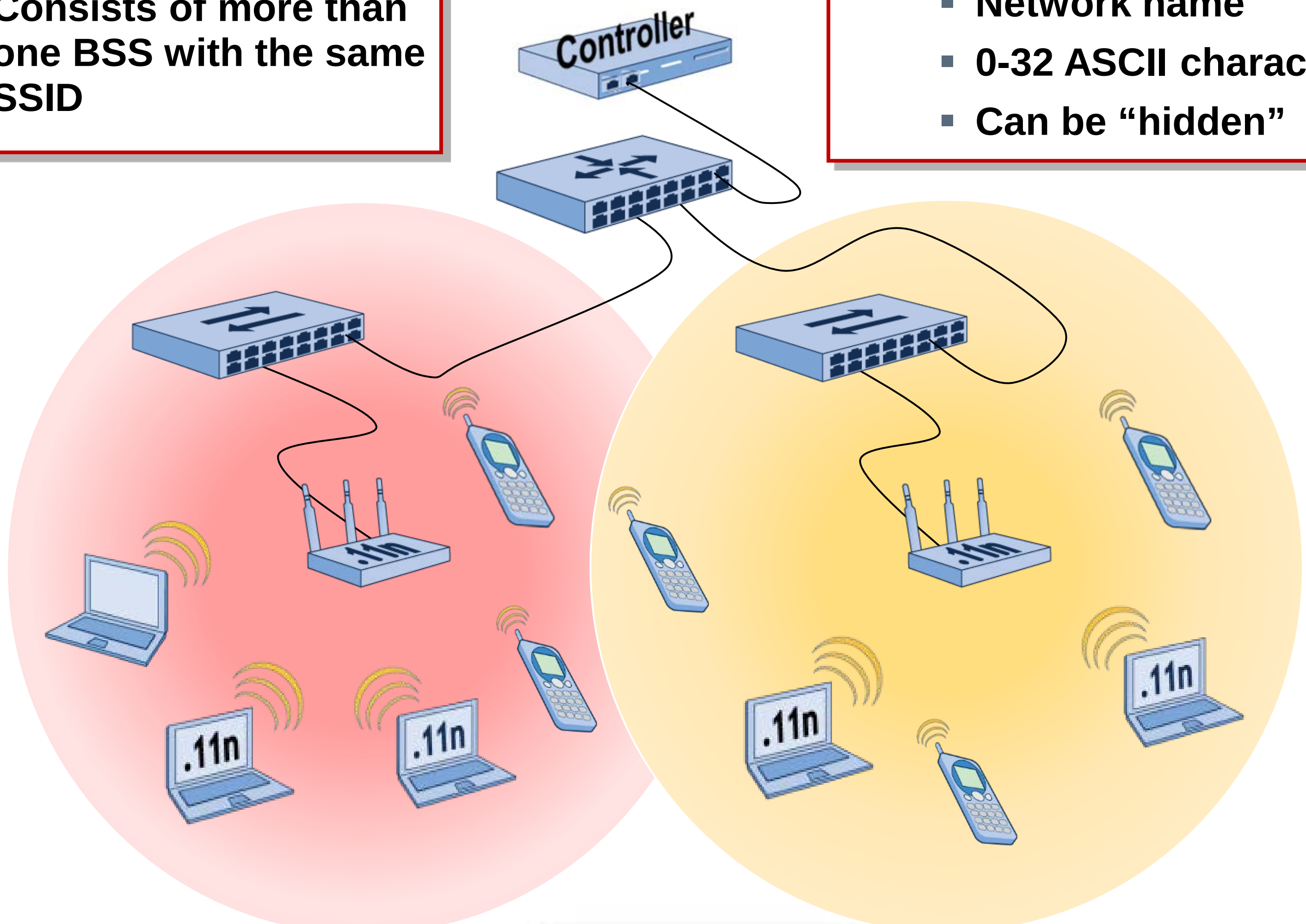
- **Basic Service Set (BSS)**
  - **One AP and its associated stations**
- **Basic Service Area (BSA)**
  - **The RF coverage area around an AP's radio that is used to provide connectivity to clients**
- **Basic Service Set Identifier (BSSID)**
  - **The MAC (physical) address of the AP's radio**
  - **The identifier by which the AP's radio is known to the clients in the BSS**
  - **A dual-radio AP will have two physical BSSIDs**
  - **Using WLAN Profiles, each AP radio can have multiple BSSIDs**
  - **In Ad Hoc networks, the BSSID is generated by the client device that starts the IBSS**



ESS and SSID

- **Extended Service Set (ESS)**
  - **Consists of more than one BSS with the same SSID**

- **Service Set Identifier (SSID)**
  - **Network name**
  - **0-32 ASCII characters**
  - **Can be "hidden"**



Client Association Process

Discovery

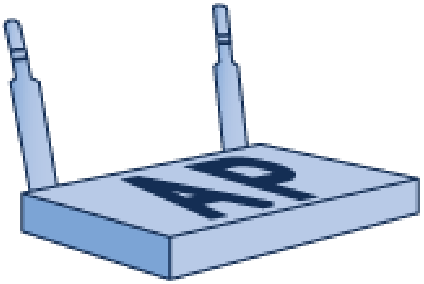
- I can hear APs! Lots of APs!
- Oh APs…where are you…?

Authenticatio n

- Who are you?
- Agent 86. Here is proof.

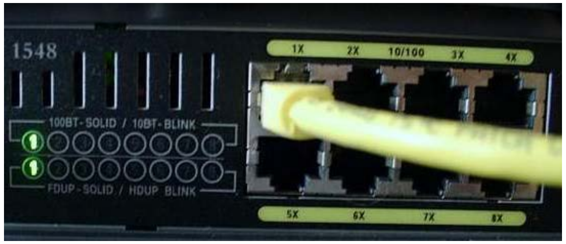
Associatio n

- Can I come in?
- Sure…or not.



Buzzword: Connected

Association isn't quite as simple as getting (and keeping) a link light with Ethernet



Reassociation & Roaming

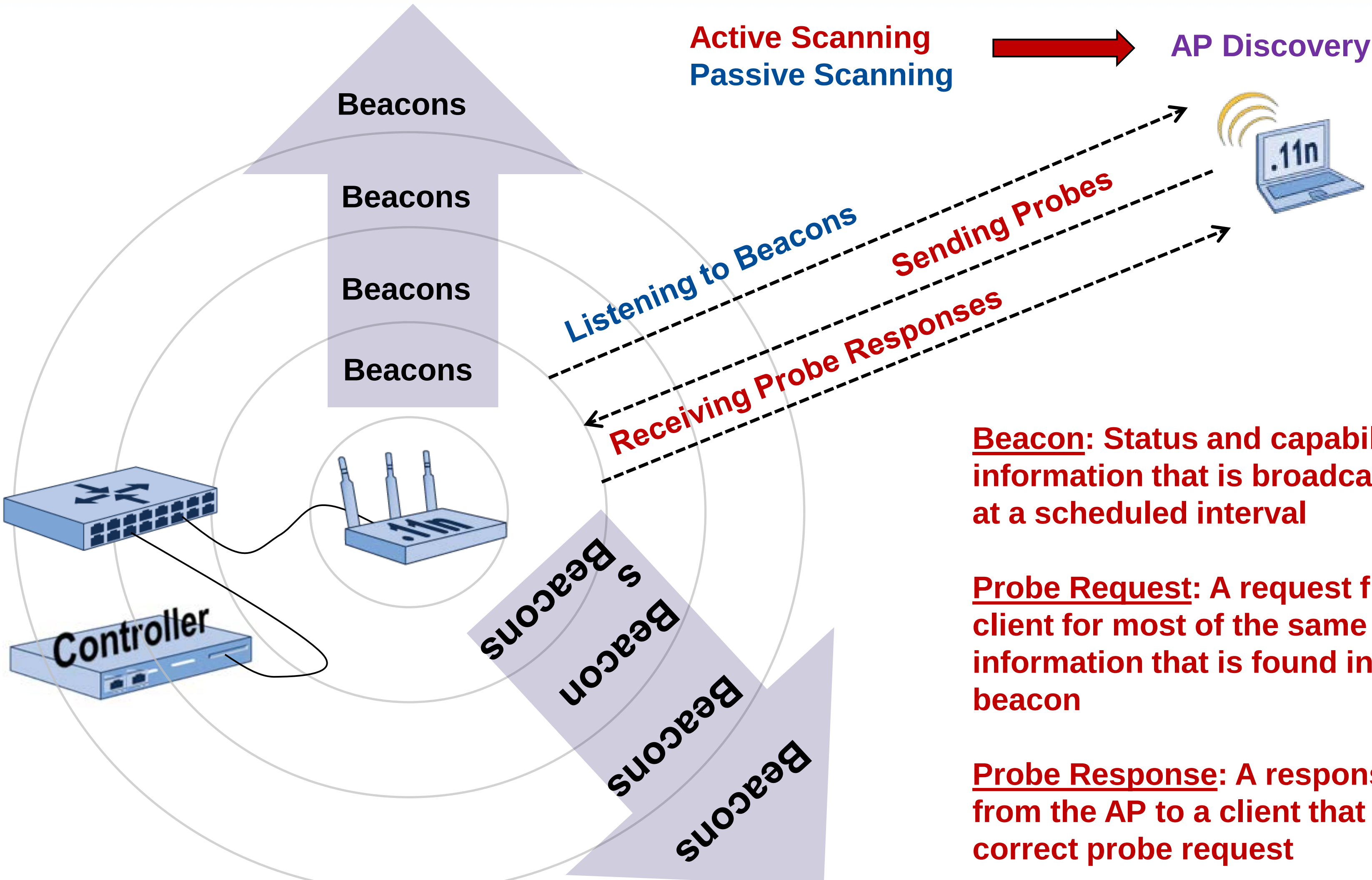
- **I'm moving to a new bedroom in the same house**

Disassociation

Deauthentication

- **Not happy with you…**
- **I just don't know you any more!**

Discovery / Scanning

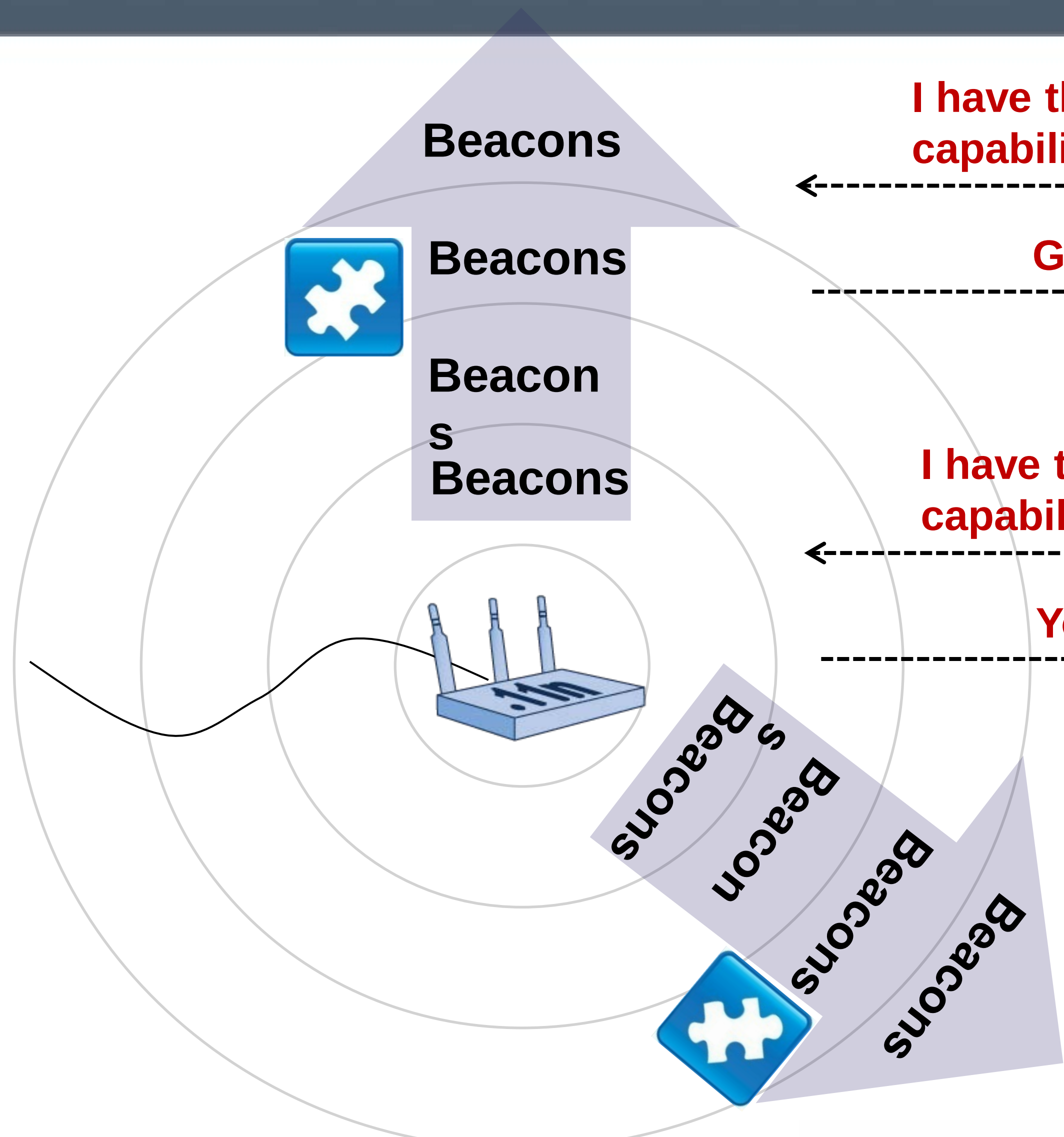


Beacon: Status and capability information that is broadcasted at a scheduled interval

Probe Request: A request from a client for most of the same AP information that is found in a beacon

Probe Response: A response from the AP to a client that sent a correct probe request

Association



I have the following capabilities. May I join?

Go away.

I have the following capabilities. May I join?

You're in.

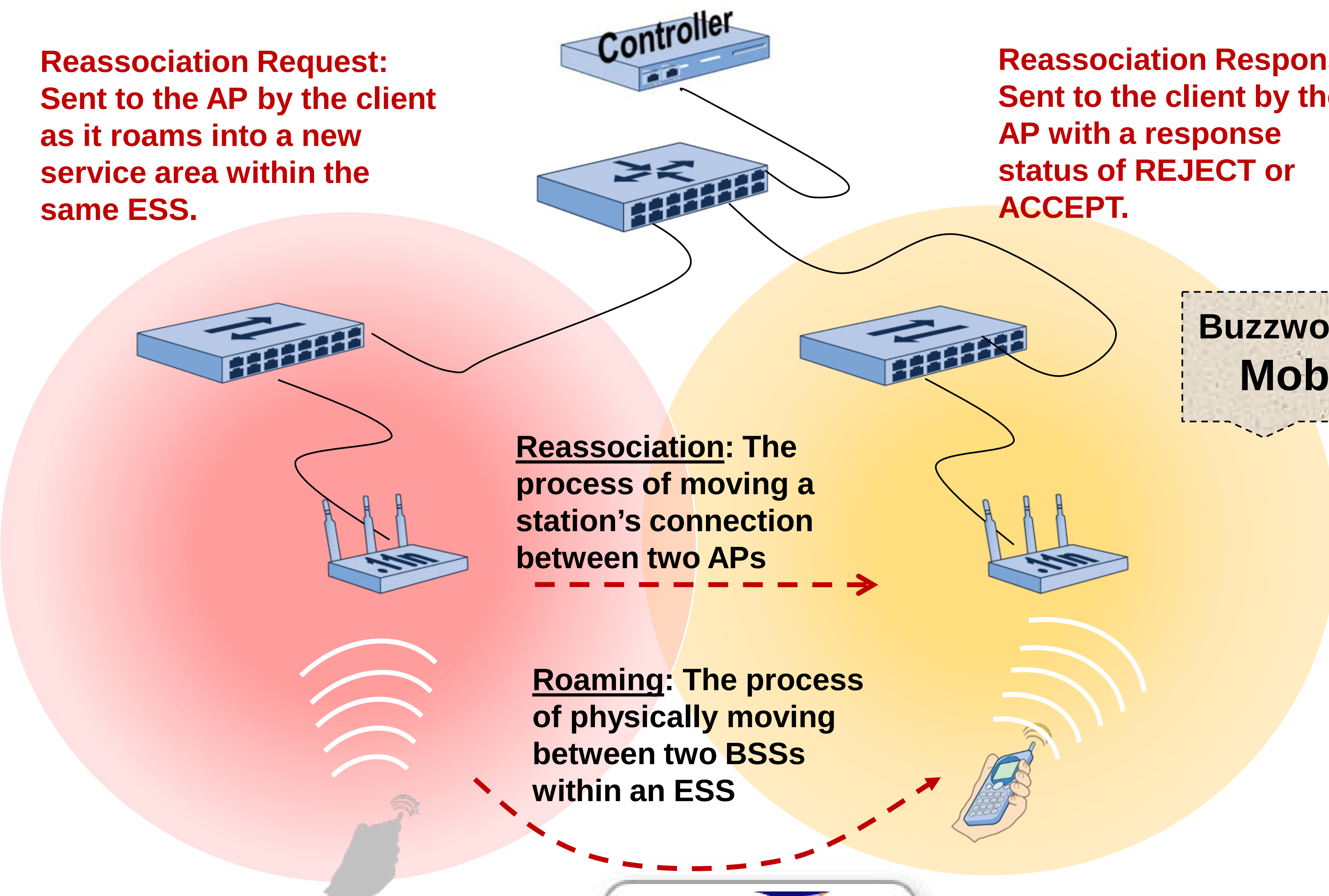
Buzzword:
Associated

Purpose of Association:
Mapping client connections to specific APs to facilitate data forwarding

Reassociation / Roaming

Reassociation Request: Sent to the AP by the client as it roams into a new service area within the same ESS.

Reassociation Response: Sent to the client by the AP with a response status of REJECT or ACCEPT.



Buzzword:
Mobility

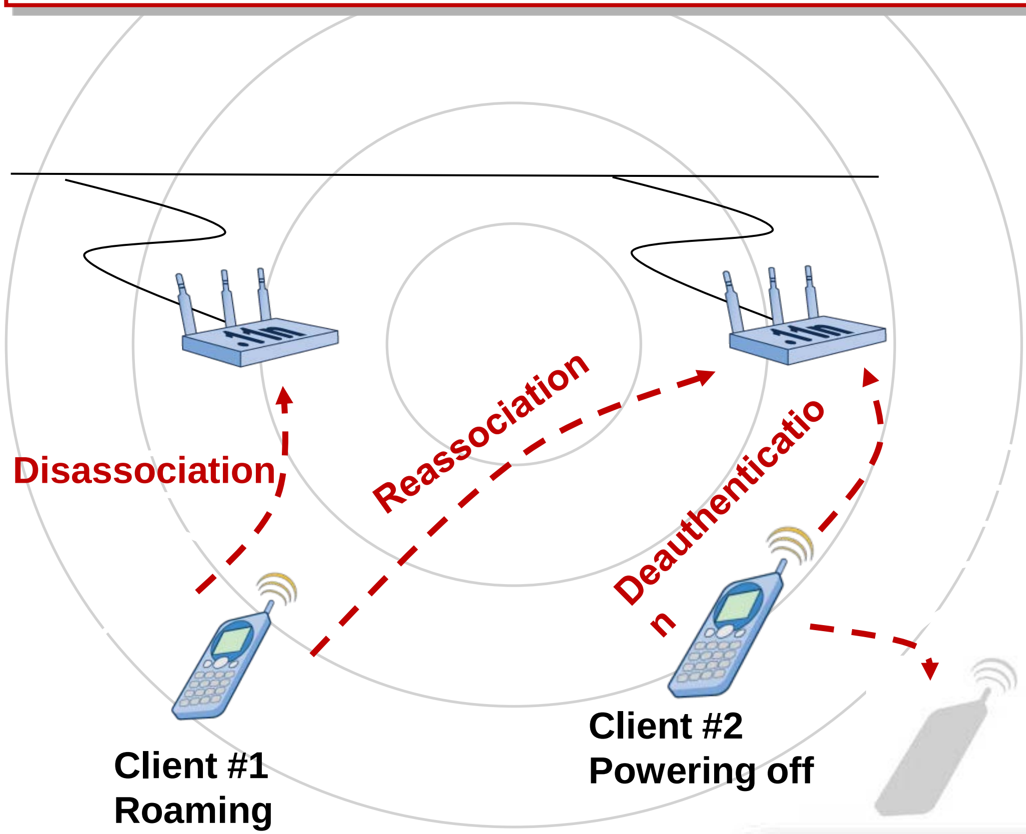
<u>Reassociation</u>: The process of moving a station's connection between two APs

<u>Roaming</u>: The process of physically moving between two BSSs within an ESS

Disassociation & Deauthentication

- Deauthentication terminates the authentication and association (most invasive)
  - Notification only – not a request, can be sent by AP or client at any time
- Disassociation terminates an AP/Client association while leaving the authentication intact
  - Notification only – not a request, can be sent by AP or client at any time

Buzzword: Terminate



Disassociation:

✓ May be used during roaming to remove the client's association from the previous AP

✓ May be used by APs to load-balance clients

Deauthentication:

✓APs deauthenticate clients that provide invalid PSK or 802.1X/EAP credentials

✓Often used by hackers to bump clients off APs

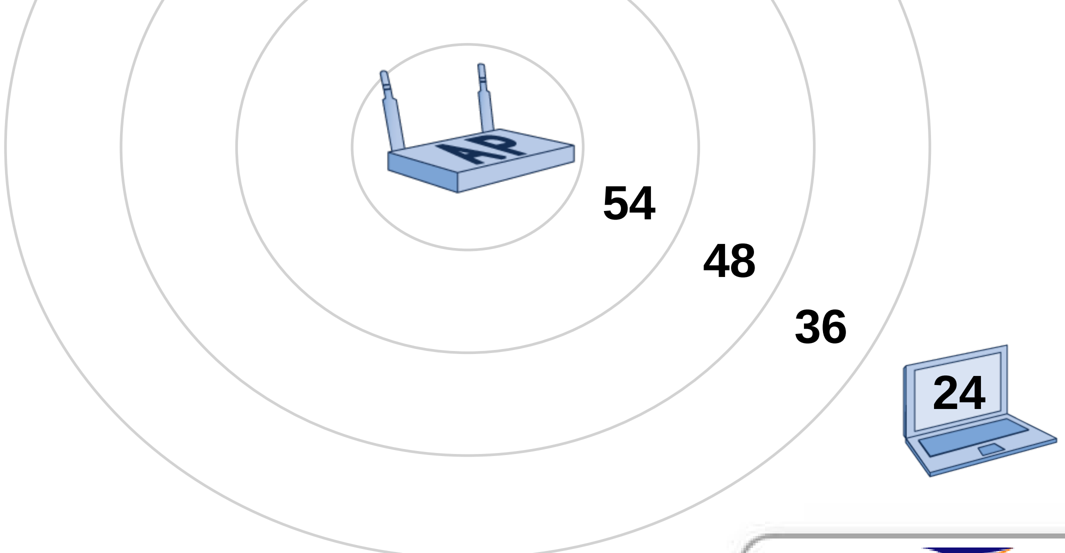
✓ Used by clients when powering off

Data Rates

- **Data Rate vs. Throughput – Data rate is the connection rate between the AP and client. Throughput is the amount of data moving between the AP and client at a given point in time.**
  - **Dependent on client density and RF interference in & around a BSA**
- **Dynamic Rate Switching (DRS) – The mechanism by which stations shift their data rates higher and lower based on environmental factors**
- **PHY - Each Physical layer technology (PHY) has its own data rate capabilities**
- **Wired LANs - have consistent throughput up to their Ethernet cable's maximum distance**

Buzzword:
MCS

Dynamic Rate Switching (DRS)



❖ **Name Change:**
The term *Data Rate* is only applicable prior to 802.11n. 802.11n introduces a new term called Modulation & Coding Scheme (*MCS*) as a replacement. This is due to having 7 mandatory and 70 optional data rates that depend on many variables.

Data Rates (cont)

Receiver sensitivity for a typical 802.11b/g wireless client NIC			
Signal Strength (RSSI)	Link Speed	Theoretical free space range (feet)	Theoretical free space range (meter)
-94 dBm	1 Mbps	1,543	470
-93 dBm	2 Mbps	1,375	419
-92 dBm	5.5 Mbps	1,226	374
-86 dBm	6 Mbps	614	187
-86 dBm	9 Mbps	614	187
-90 dBm	11 Mbps	974	297
-86 dBm	12 Mbps	614	187
-86 dBm	18 Mbps	614	187
-84 dBm	24 Mbps	488	149
-80 dBm	36 Mbps	308	94
-75 dBm	48 Mbps	173	53
-71 dBm	54 Mbps	109	33

RF Fundamentals – Wi-Fi Style…

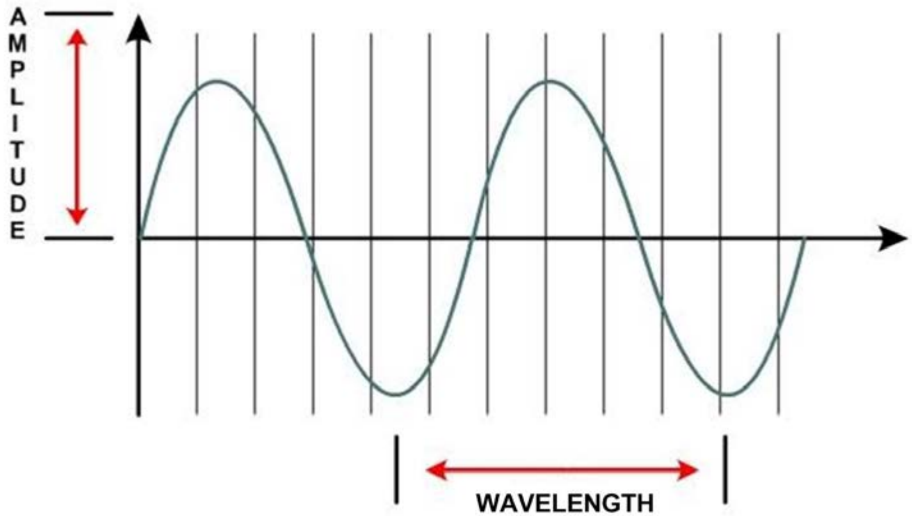
RF Wave Fundamentals

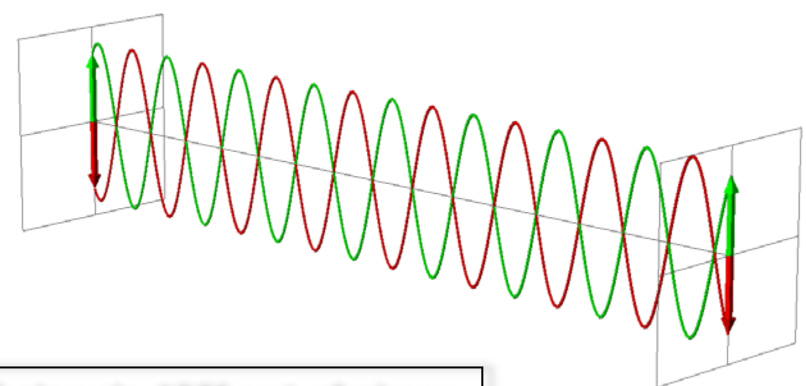
Wavelength: 360º movement of an RF wave, called a Hertz (Hz)

Amplitude: Power level of an RF wave. In Wi-Fi, typically measured in milliwatts (mW) or decibels relative to 1 mW (dBm)

Period: The distance between two identical points on an RF wave

Phase: the relationship between *two* signals based on *when* their alternative current levels are rising and falling



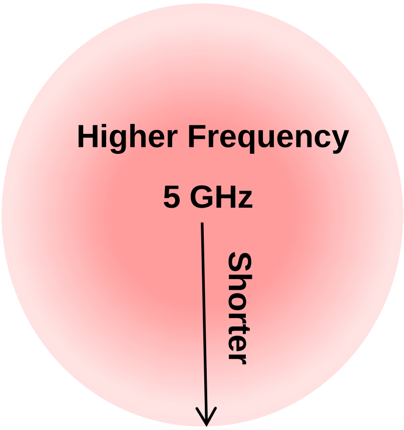


Two RF signals 180º out of phase

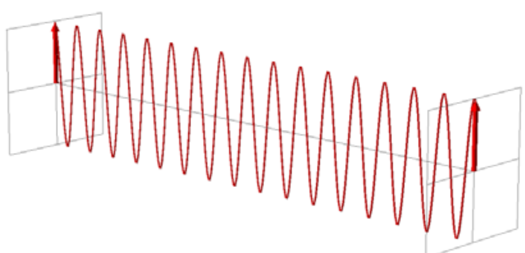
Frequency Fundamentals

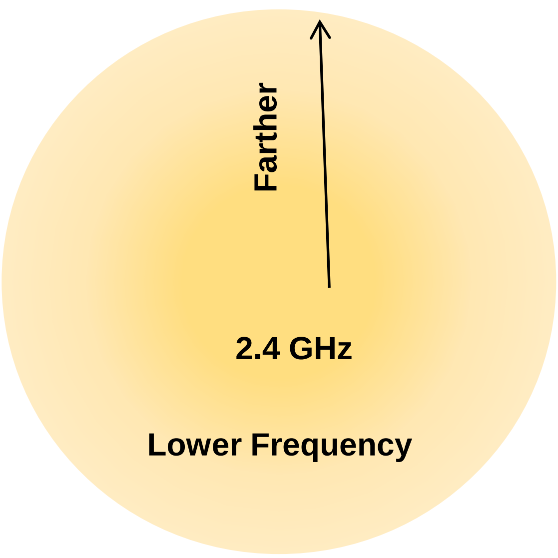
<u>Frequency</u>: How often an RF wave cycles per second.

<u>Examples</u>:
- ❑ **20 Hz = 20 cycles/second**
- ❑ **900 MHz = 900 million cycles/second**
- ❑ **2.4 GHz = 2.4 billion cycles/second**

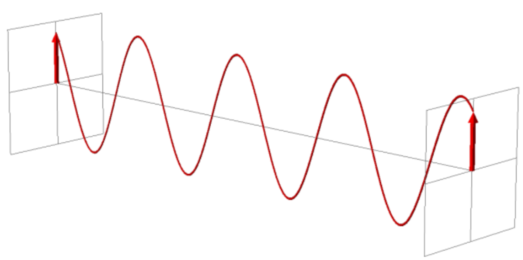


Higher Frequency



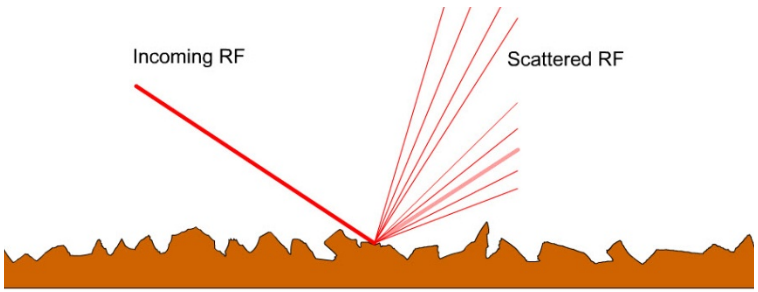


Lower Frequency

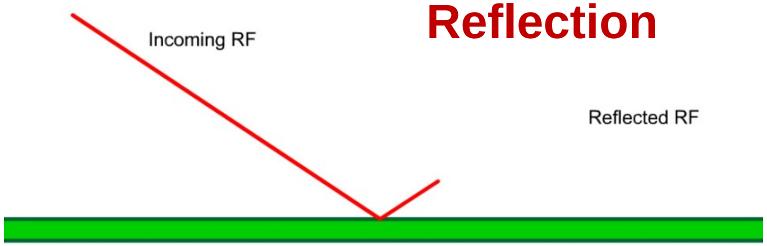


RF Characteristics

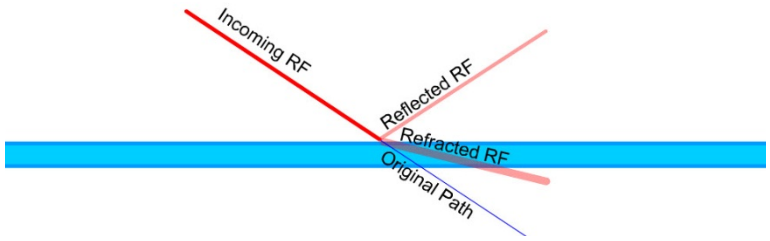
Scattering



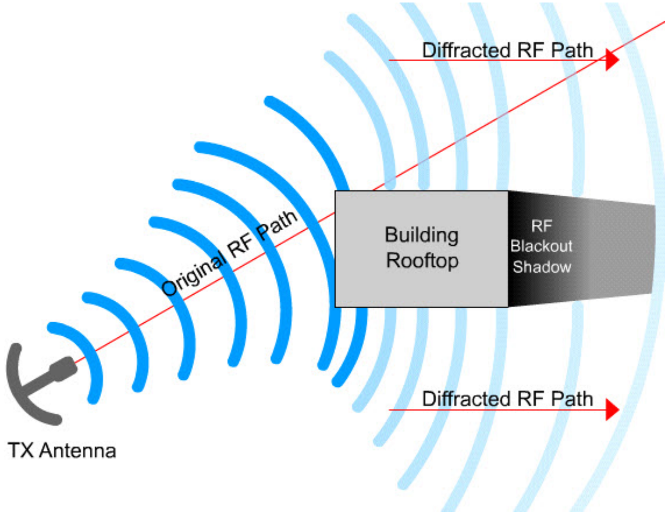
Reflection



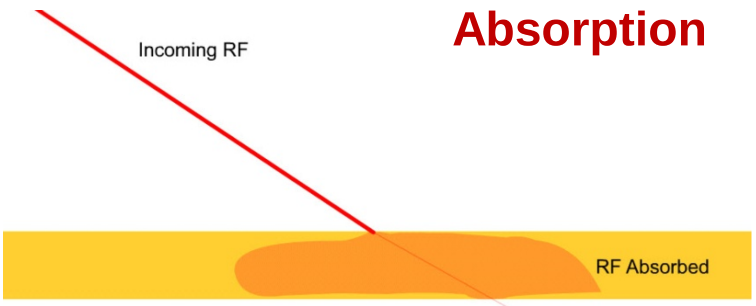
Refraction



Diffraction



Absorption



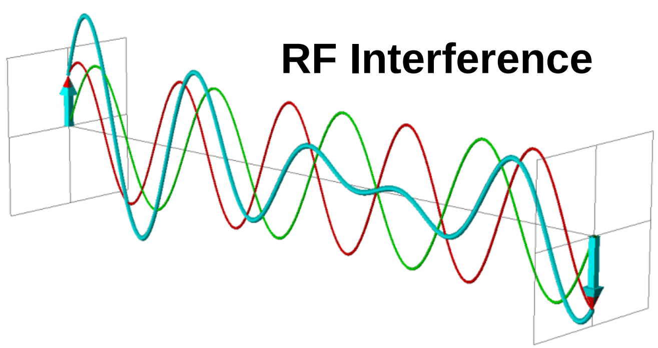
RF Interference

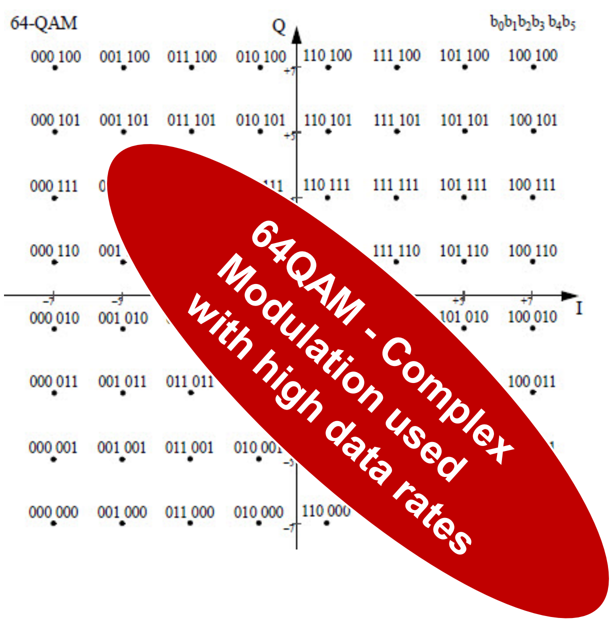
- **RF Interference – When an external modulated (data-carrying) or unmodulated (non data-carrying) RF influence affects the ability of an RF receiver to interpret a data signal**
  - **Higher data rates use more complex waveforms, which are more susceptible to error**
  - **Low signal strength and external RF interference sources are problematic for high data rates**
- **Multipath – The RF characteristic, *reflection*, may cause multiple copies of an RF wave to be received**
  - **Reception of multiple copies of the same RF wave can be detrimental to receiver signal processing in 802.11a/b/g Wi-Fi systems but beneficial in 802.11n systems**

802.11n systems have been designed to take advantage of multipath

Buzzword: Multipath

RF Interference





Relative Power Measurement

Relative Units

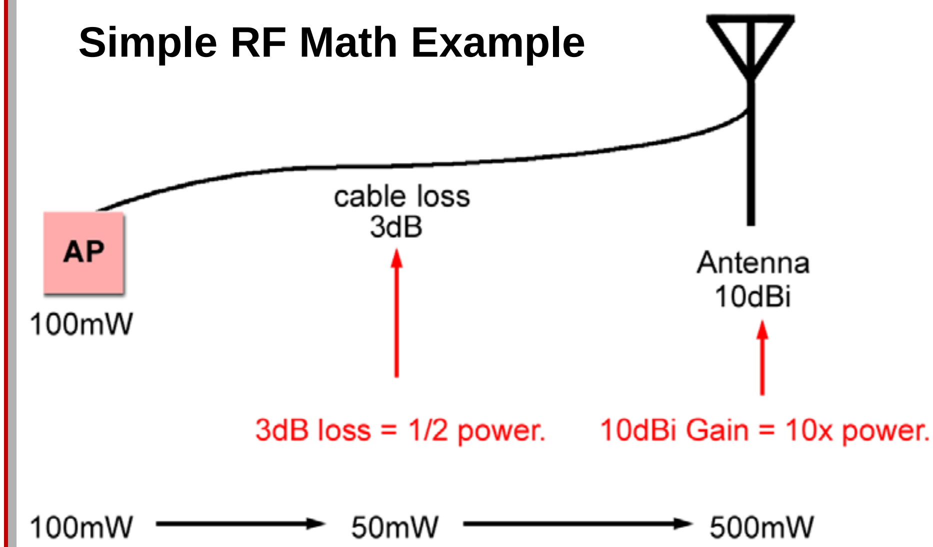
- ❖ **dB - decibel**
- ❖ **dBi - decibel relative to an isotropic radiator**

Rule of 10s and 3s

1 mW = 0 dBm	**1 mW = 0 dBm**
10 mW = 10 dBm	**2 mW = 3 dBm**
100 mW = 20 dBm	**4 mW = 6 dBm**
1W = 1000 mW = 30 dBm	**8 mW = 9 dBm**

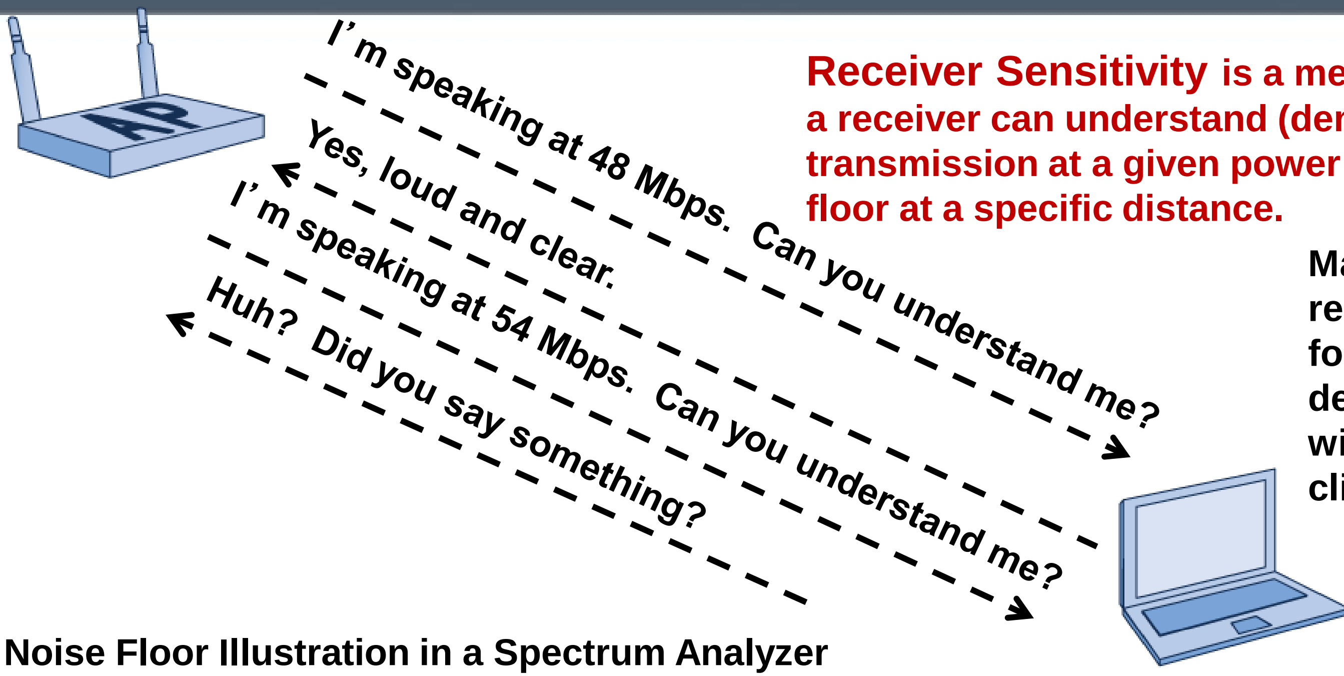
- **Relative Power Measurement**
  - **Measured in gain or loss**
  - **Measured in decibels (dB)**
- **Gain/Loss Examples:**
  - **-3 = 1/2 the original power**
  - **+3 = 2 times the original power**
  - **-10 = 1/10th the original power**
  - **+10 = 10 times the orinal power**
- **Component Examples:**
  - **Antennas & amplifiers introduce gain**
  - **Connectors & cables introduce loss**

Simple RF Math Example



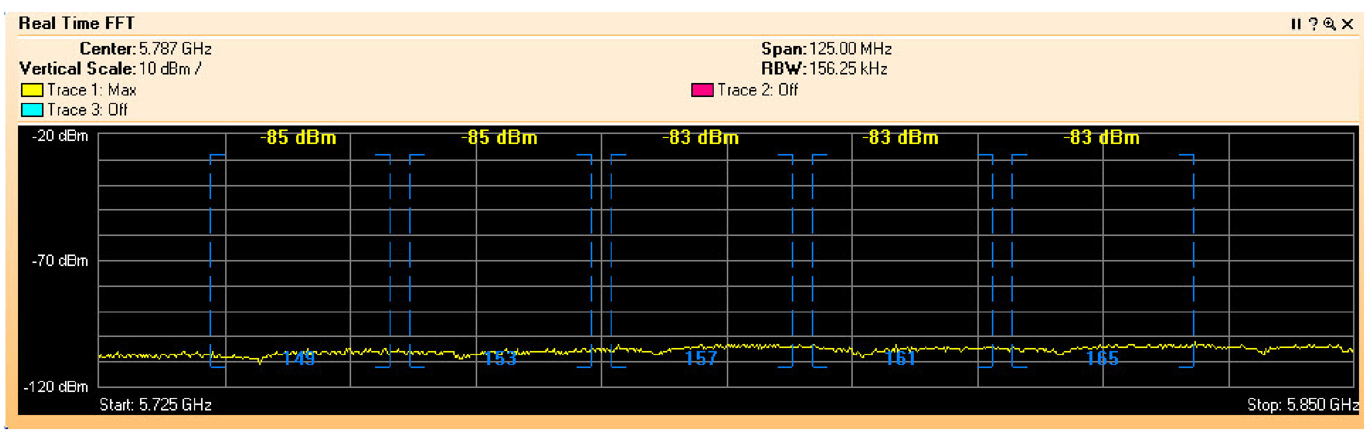
Device Receive Sensitivity

Receiver Sensitivity is a measure of whether or not a receiver can understand (demodulate) a transmission at a given power level above the noise floor at a specific distance.

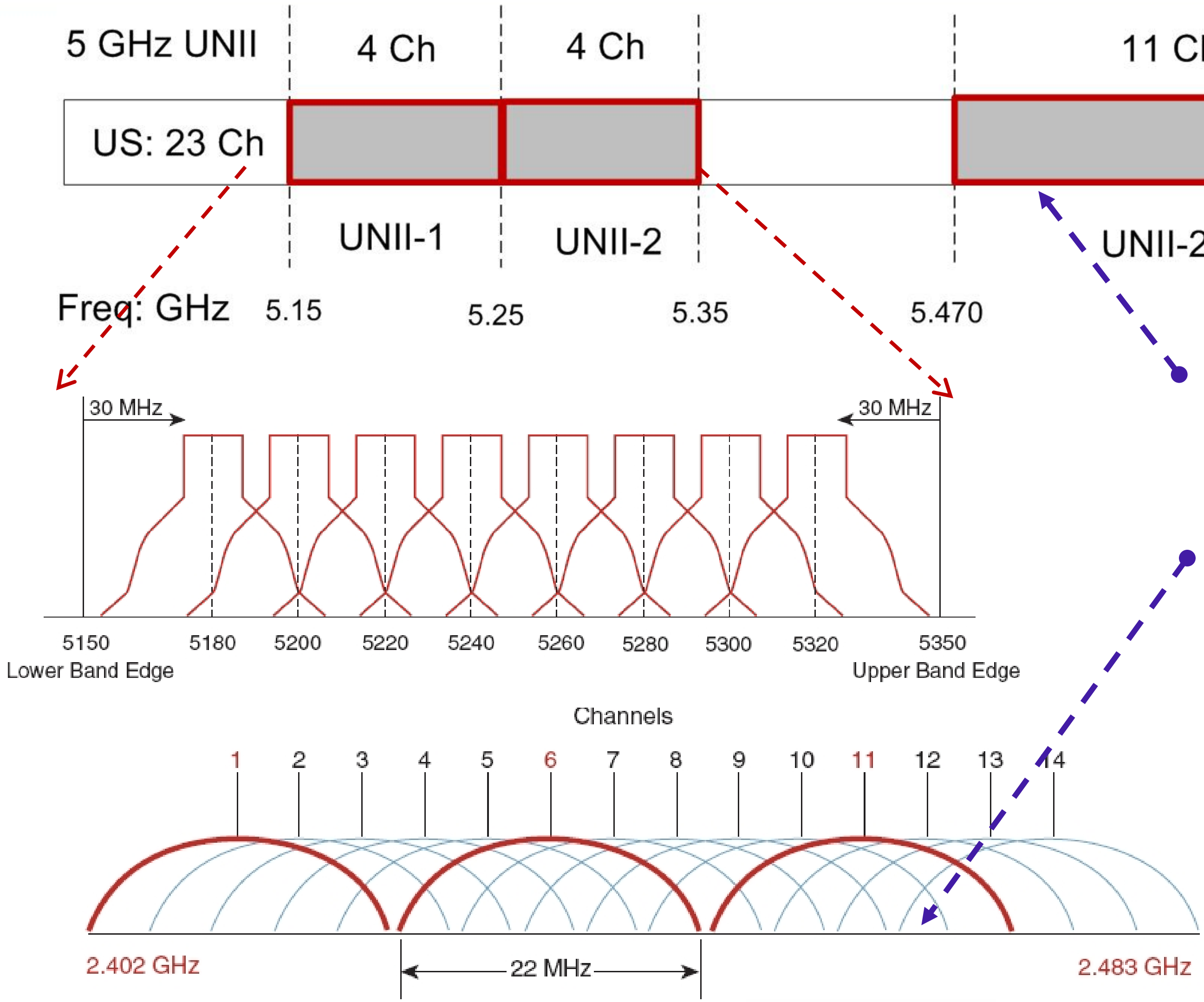


Manufacturers publish receive sensitivity values for their client and AP devices, but there can be wide variability between client devices

Noise Floor Illustration in a Spectrum Analyzer



Wi-Fi Channels



A **Band** is a range of frequency space containing multiple channels

A **Channel** is a range of frequency space defined by a center frequency and a spread of used frequencies called the channel width

Regulatory Domains are government controlled areas around the globe where channel use is regulated.

2.4 GHz Channels Used in Wi-Fi

Channel Number	Center Fre (GHz)	Americas	EMEA	China	Japan
1	2.412	x	x	x	x
2	2.417	x	x	x	x
3	2.422	x	x	x	x
4	2.427	x	x	x	x
5	2.432	x	x	x	x
6	2.437	x	x	x	x
7	2.442	x	x	x	x
8	2.447	x	x	x	x
9	2.452	x	x	x	x
10	2.457	x	x	x	x
11	2.462	x	x	x	x
12	2.467		x		x
13	2.472		x		x
14	2.484				x

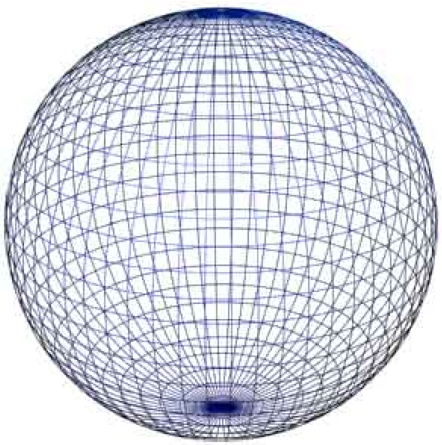
5 GHz Channels used in Wi-Fi

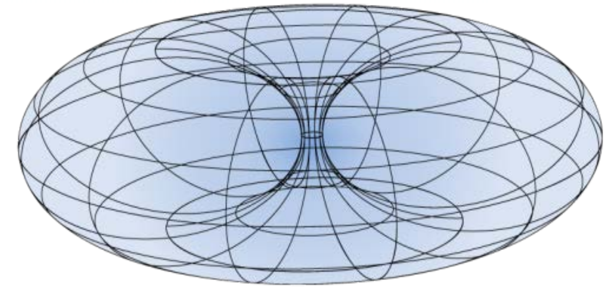
Regulatory Domain	Band (GHz)	# of Channels	Channel Number	Center Frequency (MHz)
Americas / EMEA	UNII-1 Band (5.15 - 5.25)	4	36, 40 44, 48	5180, 5200 5220, 5240
Americas / EMEA	UNII-2 Band (5.25 - 5.35)	4	52, 56 60, 64	5260, 5280 5300, 5320
Americas / EMEA	UNII-2e Band (5.470 - 5.725)	11	100, 104, 108, 112, 116, 120, 124, 128, 132, 136, 140	5500, 5520, 5540, 5560, 5580, 5600, 5620, 5640, 5660, 5680, 5700
Americas / EMEA (with restrictions)	UNII-3 Band (5.725 - 5.825)	4	149, 153 157, 161	5745, 5765 5785, 5805
Americas	ISM (5.725 - 5.850)	1	165	5825
USA	Public Safety (4.940 - 4.990)	2 x 20 MHz 4 x 10 MHz 10 x 5 MHz	1-18	4942.5-4987.5 @5MHz 4945-4985 @10MHz 4950-4980 @20MHz

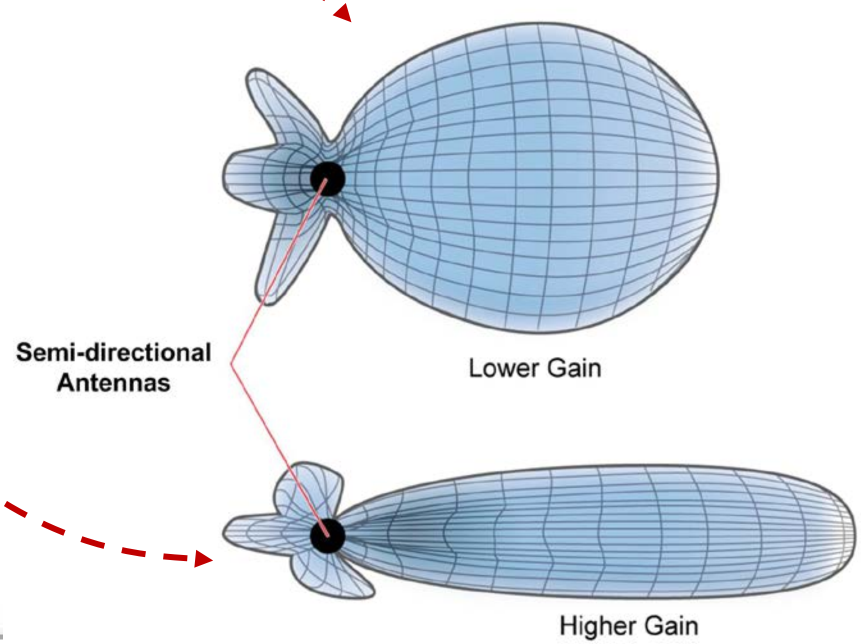
Antennas and Accessories

Antenna Function

Starting with a sphere (Isotropic Radiator) as a reference, antennas are used to shape an RF energy pattern





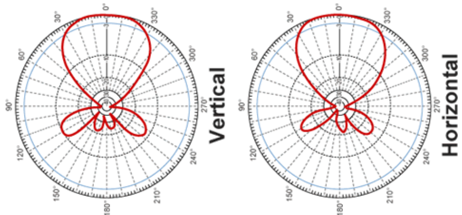


Buzzword:
Shaping

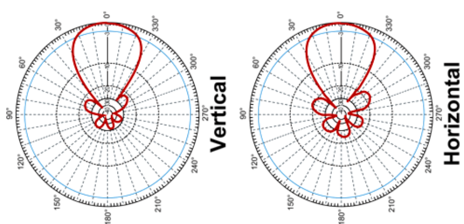
There is no *better* or *worse* antenna. Each antenna type is designed to produce a different shape.

Antenna Gain

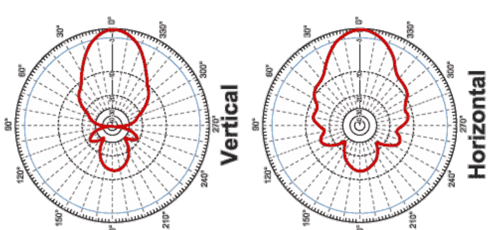
9 dBi Yagi



12 dBi Yagi



15 dBi Yagi



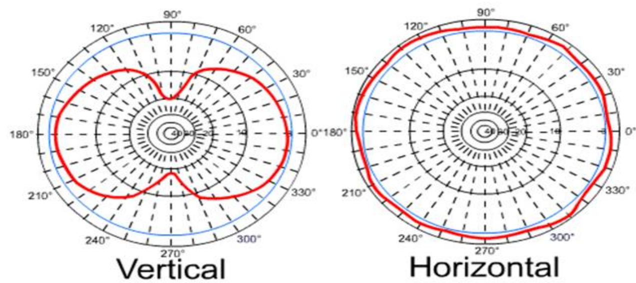
Passive Gain

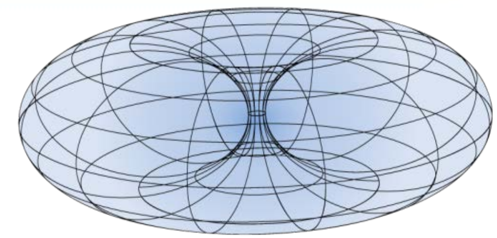
Passive Gain is the focusing and shaping of input energy by an antenna to increase the received signal strength.

High Gain antennas focus the signal energy more tightly.

Omni-directional Antenna

Low Gain Omni-directional Antenna





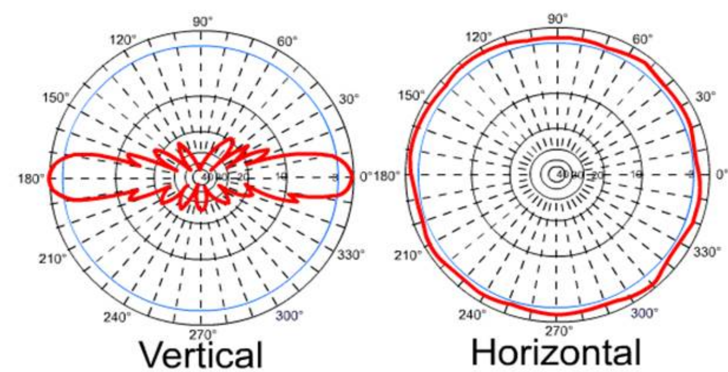
Buzzword:
Dipole

The omni antenna is the most commonly used antenna type

Omni-directional Antennas

- ❖ **Provides 360º horizontal coverage pattern along a flat plane.**
- ❖ **Gain of signal along the horizontal plane means less signal along the vertical plane**
- ❖ **Omni-directional antennas are also known as dipoles.**

High Gain Omni-directional Antenna



Line of Sight

Visual LoS

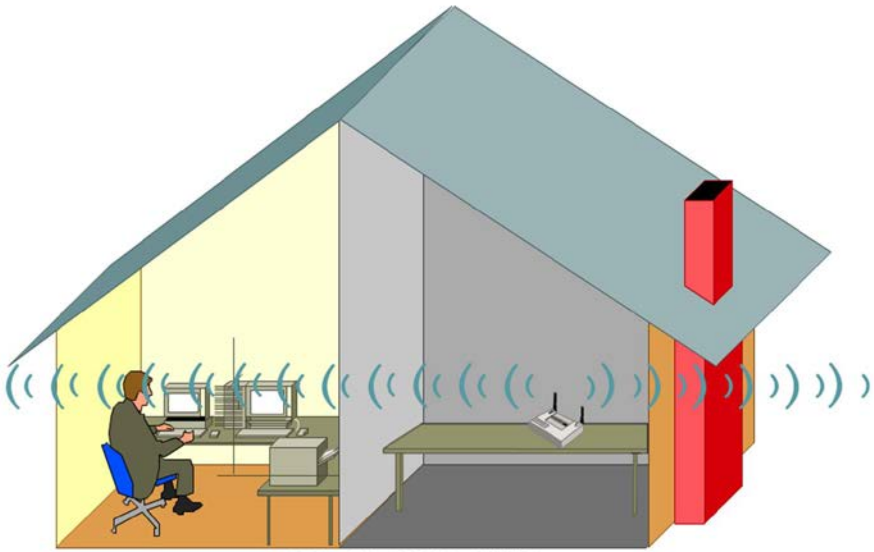
<u>Visual Line of Sight</u> – You can *see* one point from another point. Light waves have different characteristics than RF waves. RF can penetrate many types of substances, and therefore Visual LoS is not always required for an RF link.

RF LoS

<u>Radio Frequency Line of Sight</u> – When two RF transceivers (transmitter/receiver) can hear each other's transmissions. A good example of RF LoS is an AP/Client connection in a home through walls.

Attenuation

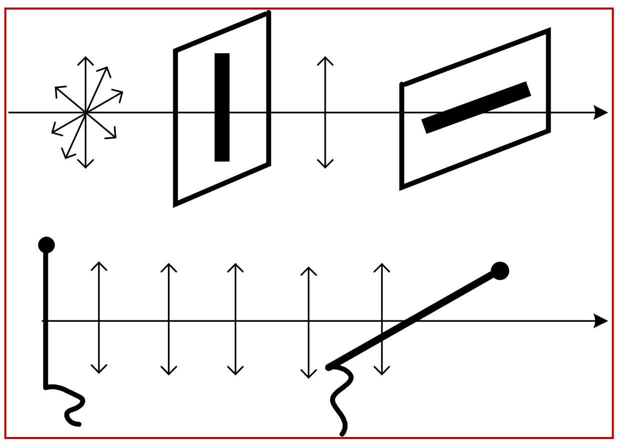
- **Occurs when RF signals pass through objects such as walls, and lose amplitude.**
- **Causes the RF signal to become weaker at the receiver possibly decreasing throughput and increasing error rates.**



Polarization

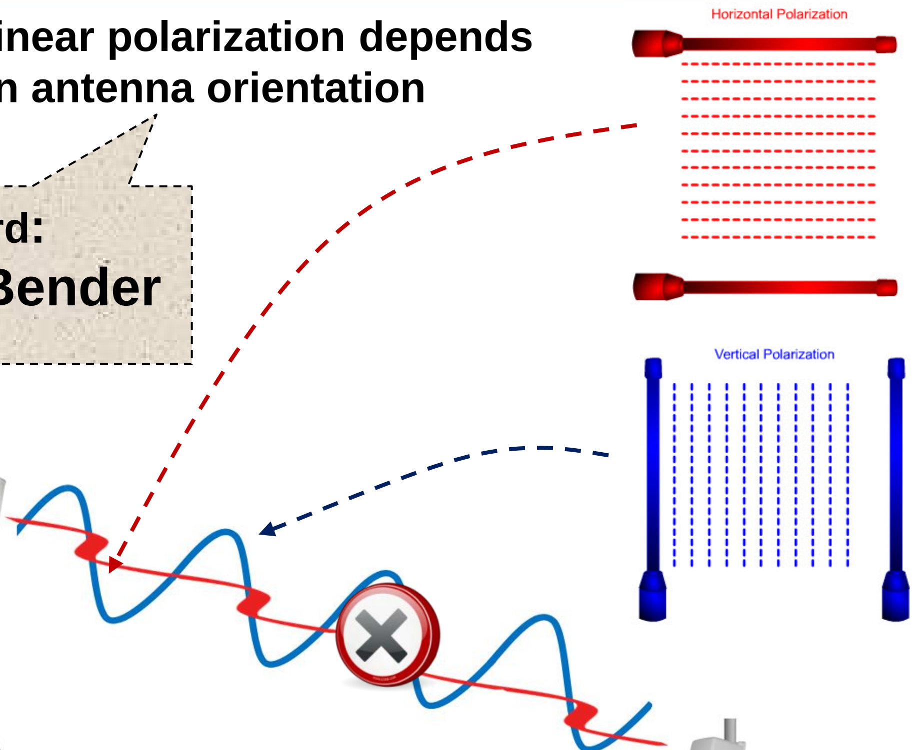
Wi-Fi Polarization Types

- Vertical Polarity
  - Waves on a lake
  - Up and down
- Horizontal Polarity
  - A snake in the desert
  - Side to side

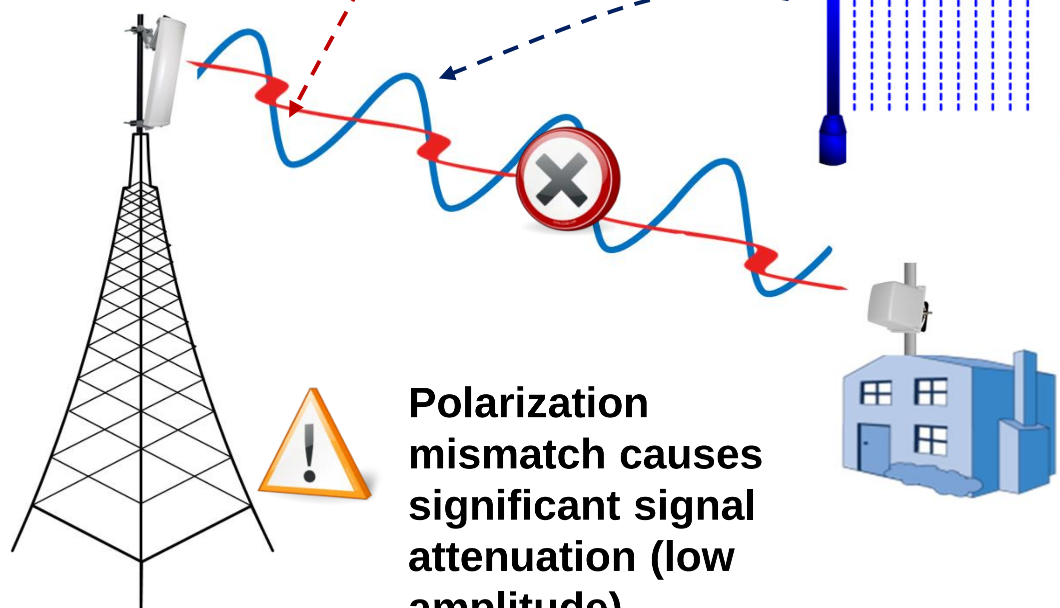


Linear polarization depends on antenna orientation

Buzzword:
Mind Bender



Polarization mismatch causes significant signal attenuation (low amplitude).



Antenna Diversity

802.11a/b/g

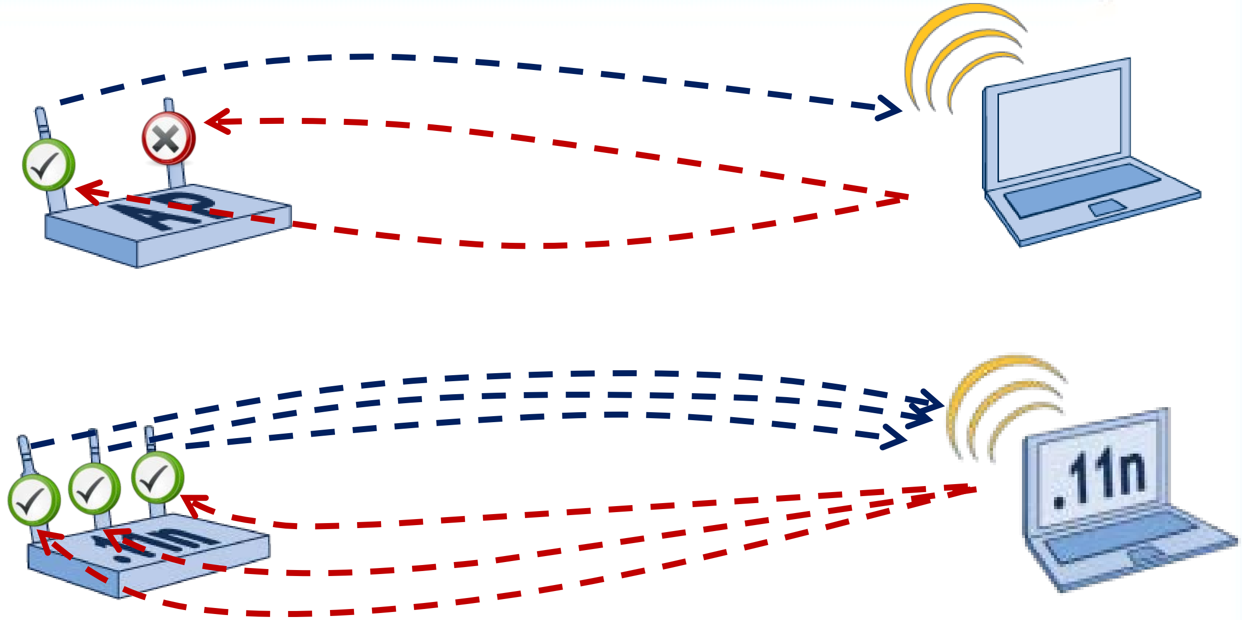
Simple Receive Diversity

Simple Transmit Diversity

802.11n

Maximal Ratio Combining (MRC)

Spatial Multiplexing (SM)



Simple Diversity systems transmit on the antenna they last used for reception. This is called Transmit Diversity.

Simple Antenna Diversity Systems

- ❖ **Simple Diversity Wi-Fi receivers have two antennas for the same reason humans have two ears**
  - ❖ **Distinguish the best of the reflected signals and listen to the best one (by sampling one at a time)**
  - ❖ **Both antennas must be the same type, have the same orientation, and cover the same physical area**

RF Cables & Connectors

RF Cables

- Carry the RF signal from the transmitter to the antenna
- Generally, the thicker the cable, the lower the signal loss
- RF cables must be rated to operate within Wi-Fi frequency ranges
- Longer RF cables introduce more signal loss into an RF system

RF Connectors

- Available in a wide variety of form factors
- Manufacturers each standardize on a specific RF connector type
- 50 Ω (ohm) cable impedance is used for Wi-Fi RF cabling

RF transmission systems are certified by regulatory domain agencies as comprehensive systems, which includes RF cables and connectors.

RF Amplifiers

RF Amplifiers

- ❖ In-line RF devices that increase the total transmit power
- ❖ Strict regulatory domain rules apply to use of RF amplifiers (see included FCC amplifier rules)

§15.204 47 CFR Ch. I (10–1–05 Edition)

The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator shall be considered sufficient to comply with the provisions of this section. The manufacturer may design the unit so that a broken antenna can be replaced by the user, but the use of a standard antenna jack or electrical connector is prohibited. This requirement does not apply to carrier current devices or to devices operated under the provisions of § 15.211, § 15.213, §15.217, §15.219, or § 15.221. Further, this requirement does not apply to intentional radiators that must be professionally installed, such as perimeter protection systems and some field disturbance sensors, or to other intentional radiators which, in accordance with § 15.31(d), must be measured at the installation site. However, the installer shall be responsible for ensuring that the proper antenna is employed so that the limits in this part are not exceeded.

[54 FR 17714, Apr. 25, 1989, as amended at 55 FR 28762, July 12, 1990]

§ 15.204 External radio frequency power amplifiers and antenna modifications.

(a) Except as otherwise described in paragraphs (b) and (d) of this section, no person shall use, manufacture, sell or lease, offer for sale or lease (including advertising for sale or lease), or import, ship, or distribute for the purpose of selling or leasing, any external radio frequency power amplifier or amplifier kit intended for use with a part 15 intentional radiator.

(b) A transmission system consisting of an intentional radiator, an external radio frequency power amplifier, and an antenna, may be authorized, marketed and used under this part. Except as described otherwise in this section, when a transmission system is authorized as a system, it must always be marketed as a complete system and must always be used in the configuration in which it was authorized.

(c) An intentional radiator may be operated only with the antenna with which it is authorized. If an antenna is marketed with the intentional radiator, it shall be of a type which is authorized with the intentional radiator. An intentional radiator may be authorized with multiple antenna types.

(1) The antenna type, as used in this paragraph, refers to antennas that have similar in-band and out-of-band radiation patterns.

(2) Compliance testing shall be performed using the highest gain antenna for each type of antenna to be certified with the intentional radiator. During this testing, the intentional radiator shall be operated at its maximum available output power level.

(3) Manufacturers shall supply a list of acceptable antenna types with the application for equipment authorization of the intentional radiator.

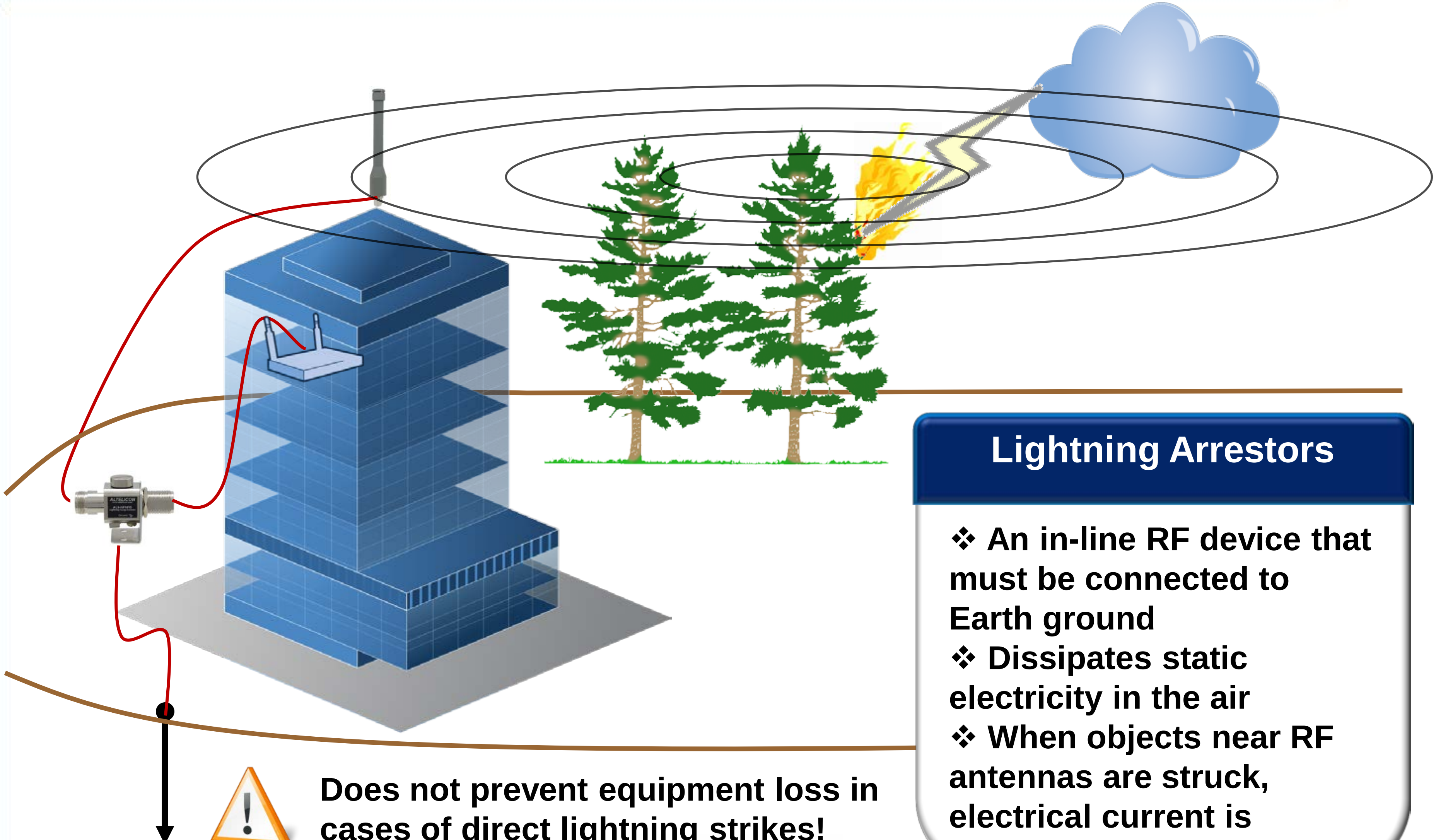
(4) Any antenna that is of the same type and of equal or less directional gain as an antenna that is authorized with the intentional radiator may be marketed with, and used with, that intentional radiator. No retesting of this system configuration is required. The marketing or use of a system configuration that employs an antenna of a different type, or that operates at a higher gain, than the antenna authorized with the intentional radiator is not permitted unless the procedures specified in § 2.1043 of this chapter are followed.

(d) Except as described in this paragraph, an external radio frequency power amplifier or amplifier kit shall be marketed only with the system configuration with which it was approved and not as a separate product.

(1) An external radio frequency power amplifier may be marketed for individual sale provided it is intended for use in conjunction with a transmitter that operates in the 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz bands pursuant to §15.247 of this part or a transmitter that operates in the 5.725–5.825 GHz band pursuant to § 15.407 of this part. The amplifier must be of a design such that it can only be connected as part of a system in which it has been previously authorized. (The use of a non-standard connector or a form of electronic system identification is acceptable.) The output power of such an amplifier must not exceed the maximum permitted output power of its associated transmitter.

(2) The outside packaging and user manual for external radio frequency

Lightning Arrestors



Does not prevent equipment loss in cases of direct lightning strikes!

Lightning Arrestors

- ❖ An in-line RF device that must be connected to Earth ground
- ❖ Dissipates static electricity in the air
- ❖ When objects near RF antennas are struck, electrical current is induced

Wi-Fi: Under the Hood

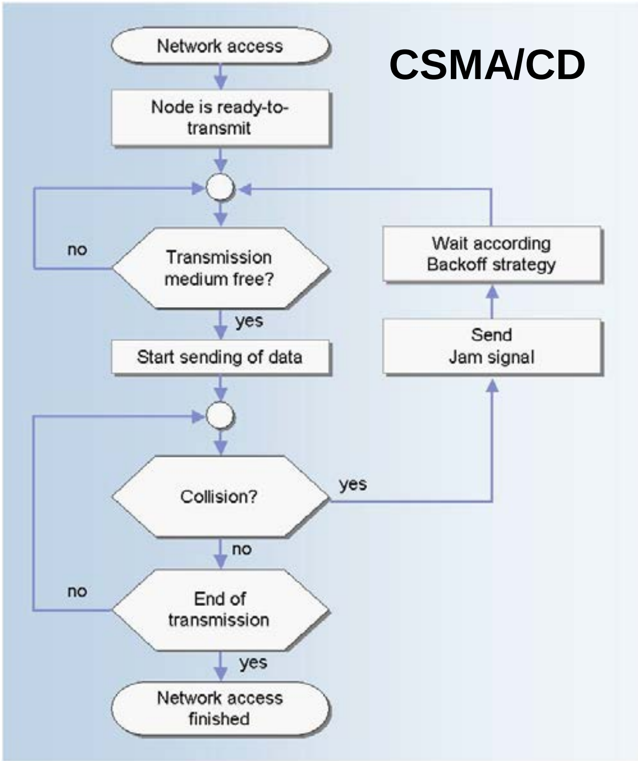
Medium Access

It's About Coordination

Medium access is the process of determining which device is allowed to transmit

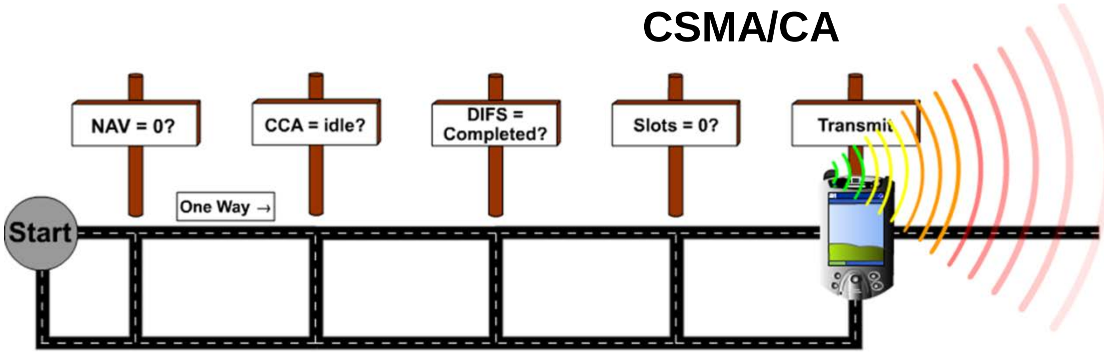
- **Devices that transmit simultaneously cause collisions and subsequent retransmissions**
- **Wi-Fi systems use a listen-before-talk mechanism called CSMA/CA to coordinate who transmits when.**

Collision Avoidance



Ethernet networks use CSMA/CD because they can hear network collisions over the Ethernet cable

Because Wi-Fi radios can either transmit or receive, but not both at the same time, they cannot hear when their transmissions collide with those of another radio.



- ❖ Four parameters must be considered before a Wi-Fi device transmits
  - ✓ Physical Carrier Sense (CCA)
  - ✓ Virtual Carrier Sense (NAV)
  - ✓ Backoff
  - ✓ Interframe Spacing
- ➢ These mechanisms allow Wi-Fi radios to be proactive at avoiding collisions

Modulation

Modulation Examples

Radio wave must change its shape in some way to transmit data

✓Amplitude (power) Modulation (AM)
✓ Frequency Modulation (FM)
✓ Phase Modulation (PM)

Buzzword:
Modulation

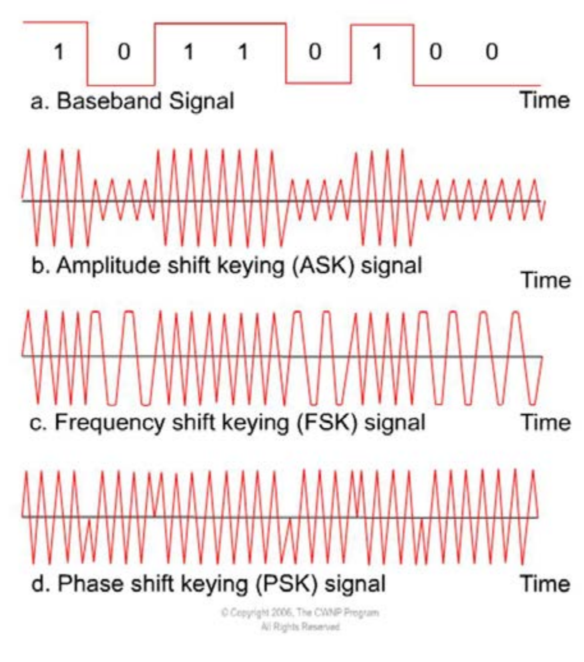
- **Original Data**

…could be "Modulated" using:

- **ASK**
- **FSK**
- **PSK**

Wi-Fi systems use highly-complex and *incompatible* modulation schemes (HR/DSSS, OFDM, HT-OFDM) that do not illustrate well, hence the simplified example below.

<u>Modulation</u> is digital communication (binary data bits) over analog waveforms



Mixed Mode Environments

Languages

❖ Modulations are like languages, and Wi-Fi now has three primary types:

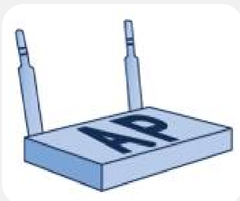
- ❖HR/DSSS
- ❖OFDM
- ❖HT-OFDM

❖ Each modulation is incompatible, so newer stations have to be bi- or tri-lingual for "backwards compatibility"

❖ Legacy (older) clients cannot demodulate (understand) newer modulations, so newer stations have to use older modulations to tell older clients when it is OK to transmit (speak).

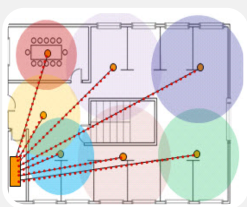
Wi-Fi Site Surveys

Purposes of a Site Survey

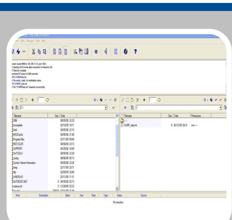


Determine proper AP placement based on customer requirements

Find RF interference sources; eliminate when possible



Identify throughput, coverage, and mobility requirements for the Wi-Fi network deployment



Identify the types of applications that will be used on the Wi-Fi network

Site Survey Procedures

Wi-Fi Network Deployment Life Cycle

1. Gather functional requirements from all stakeholders
2. Project planning
3. Wi-Fi network design, including *Predictive RF Site Survey*
4. Pre-deployment audit to verify RF coverage plan, including *Manual RF Site Survey*
5. Wi-Fi network deployment
6. Post-deployment audit (coverage, throughput, security), including *Manual RF Site Survey*
7. Final RF node adjustments
8. Automated maintenance and management (WNMS)

RF Site Survey Life Cycle

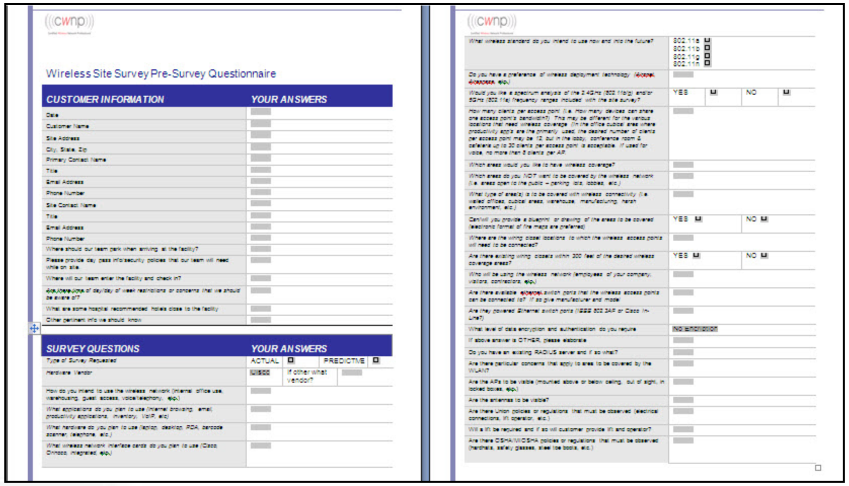
- ✓ Gather business requirements (1)
- ✓ Gather proper documentation (1)
- ✓ Perform a spectrum analysis (4)
- ✓ Perform a protocol analysis (4)
- ✓ The dreaded walkabout to determine AP placement (4, 6)
- ✓ Deliver the completed RF site survey documentation (3, 4, 6)

Manual RF Site Surveys

- ❖ Manual RF Site Surveys are audit mechanisms, not design mechanisms.
- ❖ Two manual audits per project:
  - ❖ Pre-deployment RF Site Survey
  - ❖ Post-deployment RF Site Survey

Gather Stakeholder Requirements

- **Gathering functional requirements from all stakeholders**
  - **Interview managers to determine business requirements**
  - **Interview network managers to determine the functional goals of the Wi-Fi network**
  - **Interview the facilities manager to determine facility-specific considerations**
  - **Interview employees to see what their data usage habits are**
  - **Interviews can be face-to-face or written questionnaires**


Wireless Site Survey Pre-Survey Questionnaire

CUSTOMER INFORMATION	YOUR ANSWERS

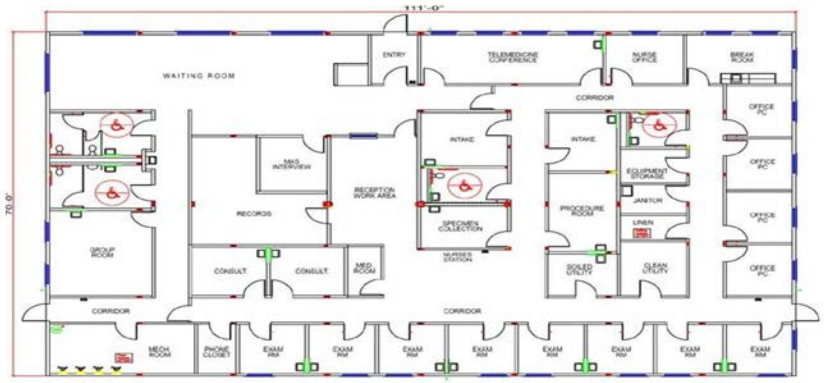
SURVEY QUESTIONS	YOUR ANSWERS

The easiest way to cause your project to come to a screeching halt at an inopportune time is to skip a stakeholder in the beginning.

RF Site Survey Documentation

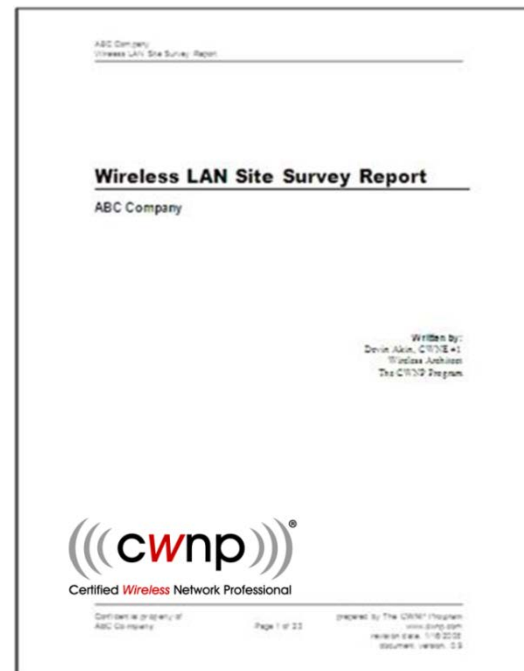
Gathering Documentation

- Floor plans of the building
- Facility access to all rooms within the scope of the project
- Network topology map and Ethernet cabling availability
- Power availability information (AC, PoE)
- Scope of work for the project
- A copy of the RF Site Survey document(s) for any currently installed Wi-Fi networks



RF Site Survey Deliverable(s)

- ❑ Typically a Microsoft Word or Adobe PDF formatted document that includes:
  - ✓ AP locations, configurations, and mounting considerations
  - ✓ Documentation exported from a predictive or manual RF Site Survey software tool
  - ✓ Deployment recommendations

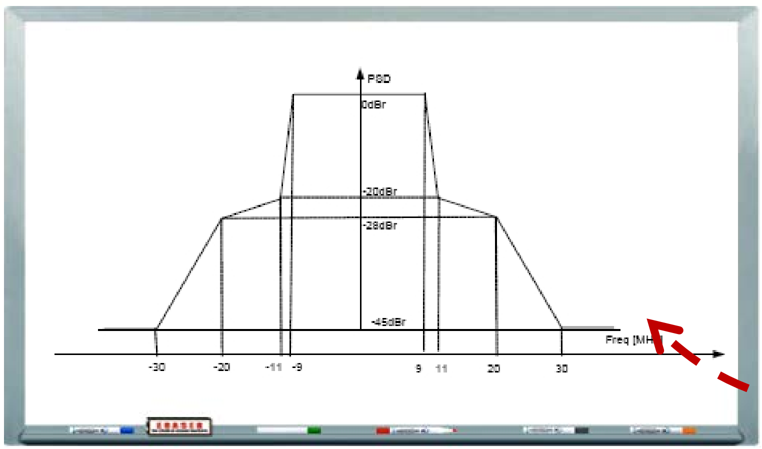

Wireless LAN Site Survey Report

ABC Company

cwnp

Certified Wireless Network Professional

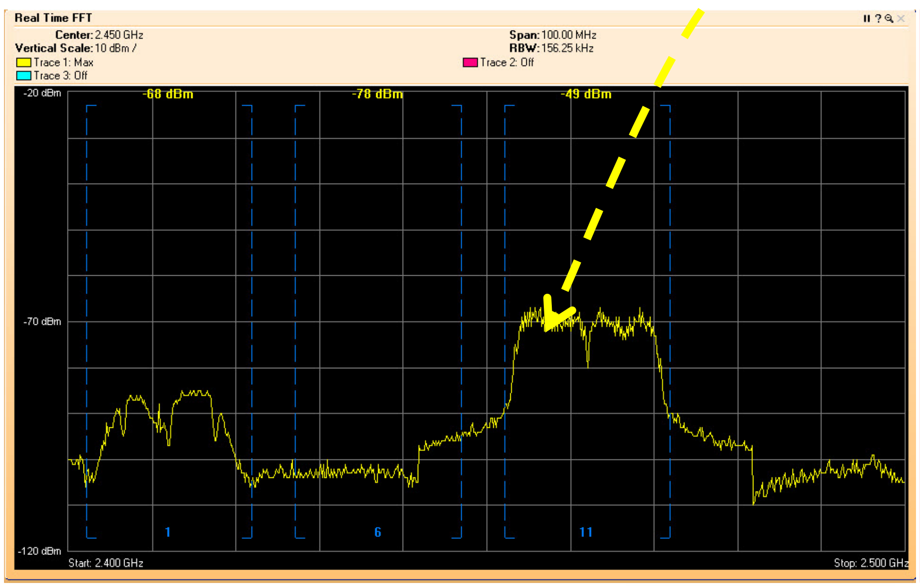
Perform a Spectrum Analysis



Spectrum Analyzer

- ❖ Physical layer hardware/software tool that analyzes radio frequency waveforms
- ❖ Used to discover sources of RF interference that could impact WLAN performance

RF transmitter types have unique RF signatures



Perform Protocol Analysis

Protocol Analyzer

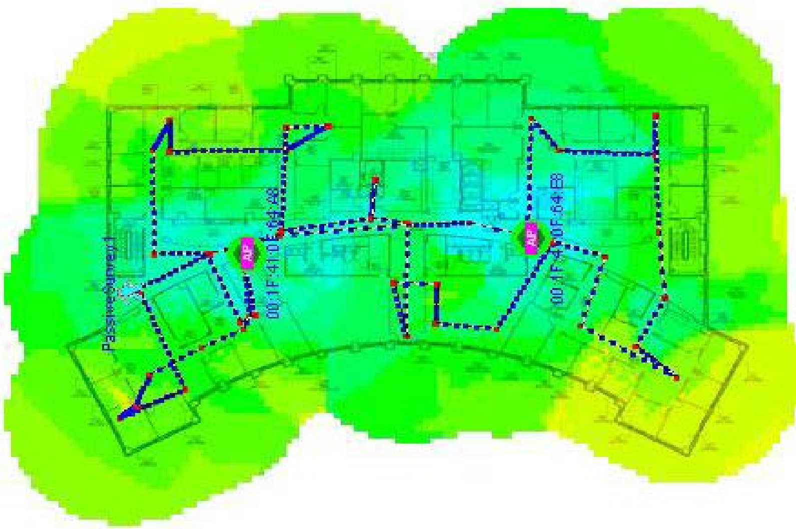
- Used to discover other Wi-Fi networks in the area for the purpose of proper channel planning in pre-deployment site surveys
- Scanning with Wi-Fi client utilities will not reveal enough information
- Used for troubleshooting link connectivity and throughput issues in post-deployment site surveys

Wireless Networks:	16	Ad Hoc Networks:	1
Access Points:	23	Clients:	59

Access Points

Node	Type	Channel	Frequency	Band	Encryption	Trust	Cur. Signal
Agere Sys:2D:EA:DE	AP	1	2412 MHz	802.11bg	WEP	Unknown	5
Airespace:03:0D:A0	AP	6	2437 MHz	802.11bg		Unknown	75
Airespace:03:1C:50	AP	1	2412 MHz	802.11bg		Unknown	41
Airespace:04:98:C0	AP	11	2462 MHz	802.11bg		Unknown	80
Aironet Wireless Comm:34:6...	AP	6	2437 MHz	802.11bg		Unknown	0
Aironet Wireless Comm:43:F...	AP	6	2437 MHz	802.11bg		Unknown	45
Belkinonents:66:33:24	AP	11	2462 MHz	802.11bg		Unknown	74
Belkinonents:CA:B0:5A	AP	3	2422 MHz	802.11bg		Unknown	30
Cisco-linksys:19:3C:77	AP	6	2437 MHz	802.11bg		Unknown	58
Cisco:3D:D7:A0	AP	11	2462 MHz	802.11bg		Unknown	57
Cisco:40:78:20	AP	6	2437 MHz	802.11bg		Unknown	35
Cisco:40:78:A0	AP	6	2437 MHz	802.11bg		Unknown	24
D-Link:97:6A:1B	AP	36	5180 MHz	802.11a		Unknown	14
D-link:AB:8A:6B	AP	9	2452 MHz	802.11bg	TKIP	Unknown	47
Linksys:75:AB:CB	AP	6	2437 MHz	802.11bg		Unknown	10
Linksys:B9:E3:42	AP	1	2412 MHz	802.11bg		Unknown	35
Lucent Tech:23:80:06	AP	5	2432 MHz	802.11bg	WEP	Unknown	42
Lucent Tech:23:9F:33	AP	6	2437 MHz	802.11bg	WEP	Unknown	40
Lucent Tech:F2:9B:94	AP	1	2412 MHz	802.11bg	WEP	Unknown	30
Netgear:CF:86:70	AP	11	2462 MHz	802.11bg		Unknown	65
Wistron Neweb:30:7F:99	AP	42	5210 MHz	802.11at		Unknown	32
Wistron Neweb:31:B6:3A	AP	42	5210 MHz	802.11at		Unknown	40
Zyxel Comm:B7:B5:A8	AP	1	2412 MHz	802.11bg		Unknown	48

Site Survey Type - Manual

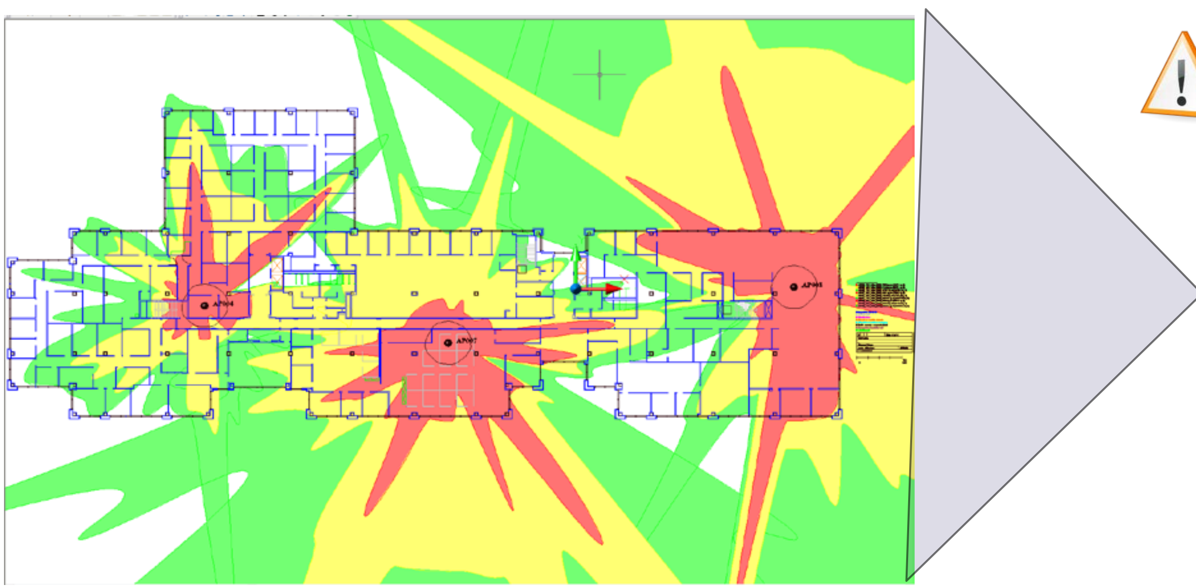


Ah…the dreaded walkabout. You' ve probably heard the horror stories...

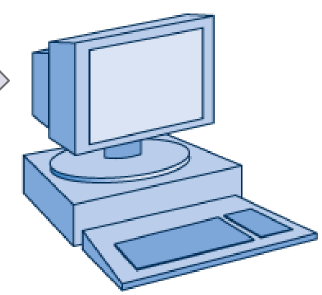
- **Measure RF properties of a site in order to determine optimum AP placement, output power, and channel planning**
- **Typically done with a mobile AP on a pole and a powered cart**
- **The AP is moved from one location to another while the Site Surveyor takes measurements with RF Site Survey software.**
- **Cost prohibitive in large environments**
- **Also called a "Physical" site survey**
- **Two types: Active, Passive**

Site Survey Type - Predictive

- **Often called "Virtual" site surveys because they are performed off-site with computer-aided modeling software. Software predicts how RF signals will travel from each AP.**
- **Require the use of imported vector or raster graphics**
- **Use databases of loss values for RF obstacles such as doors, walls, and windows**
- **Can accurately predict where to place APs for best coverage/throughput**
- **Output information is only as good as input information (it's a computer after all)**
- **When used in concert with a manual site survey, accuracy is significantly improved**



Predictive site surveys do not take into account RF interference sources



Thank You

Questions?