Wireless Technology

Topic Objective

In this topic, you will describe how radio technology relates to Wireless LANs.

What's Covered

Propagation Essentials

Sine Waves

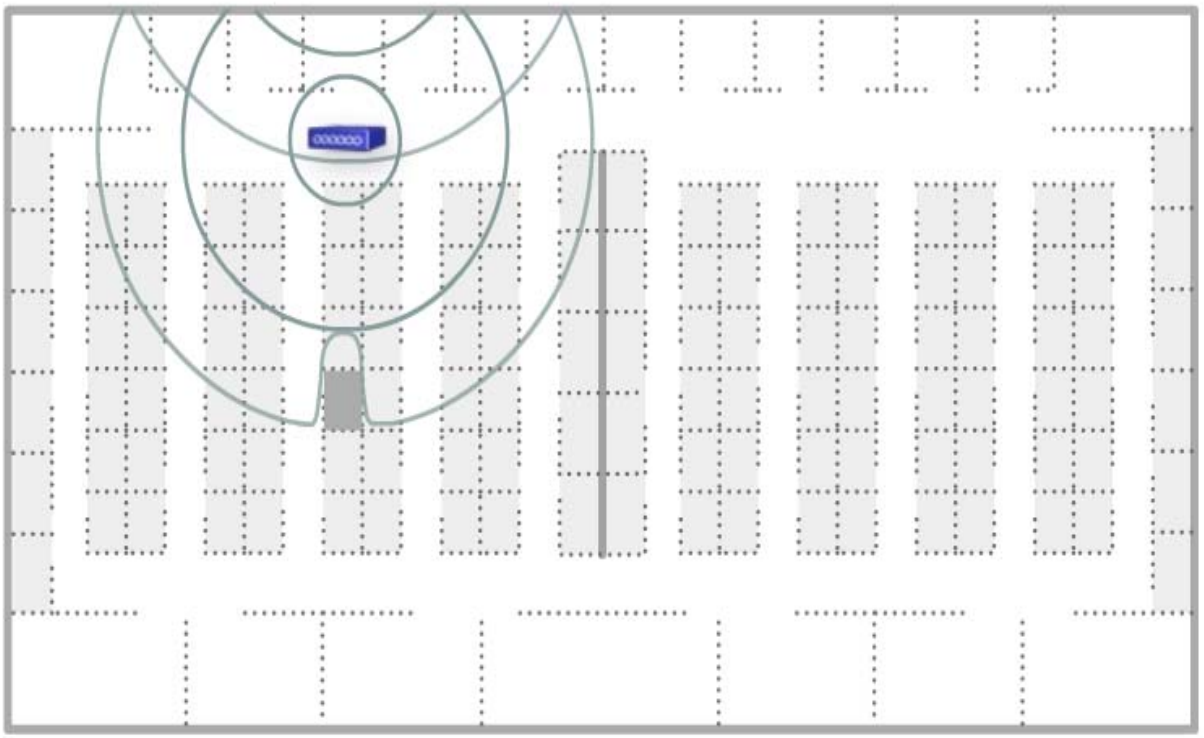
Carrier Waves

Power Gain and Losses

Fresnel Zones

The Concept of RF Theory

RF Propagation



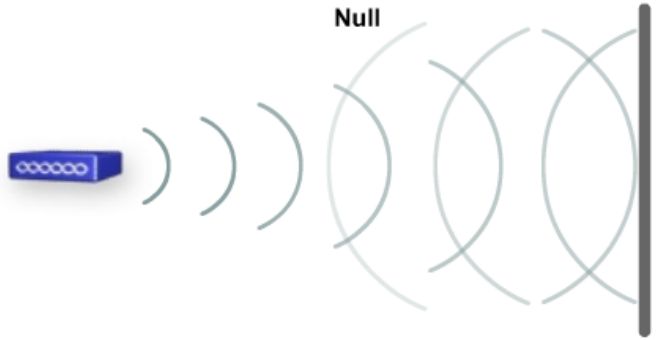
May Cause:

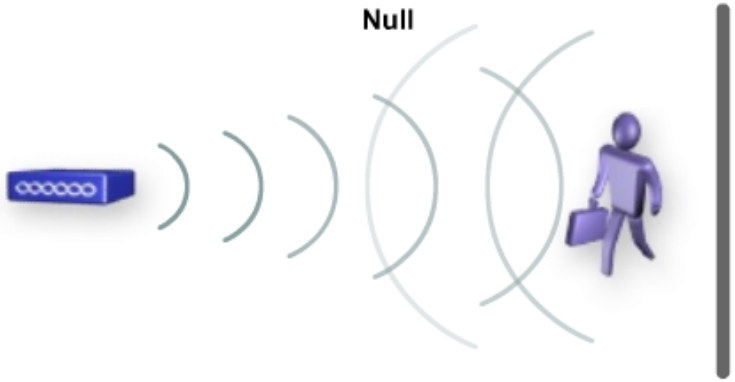
- **Reflection**
- **Refraction**
- **Diffraction**
- **Scattering**
- **Absorption.**

Propagation is the process by which a disturbance, such as the motion of electromagnetic waves, is transmitted through a medium, such as air.

Reflection

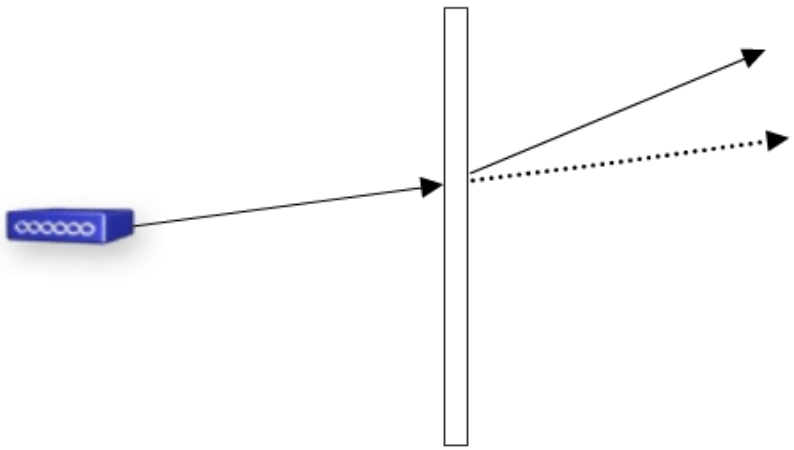
RF reflection occurs when radio waves strike a surface and are redirected back, usually back toward the point of origin.

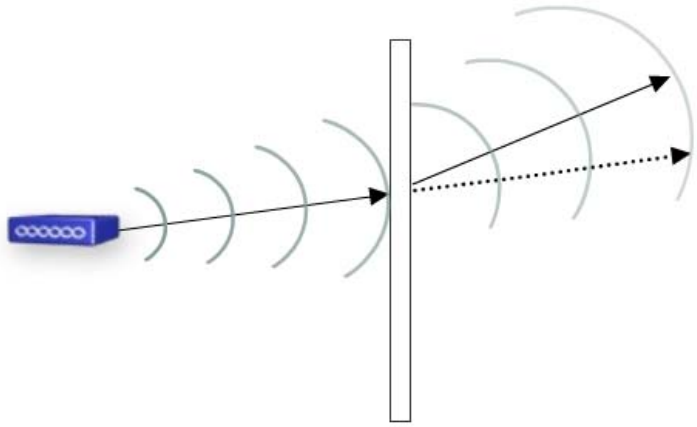




Refraction

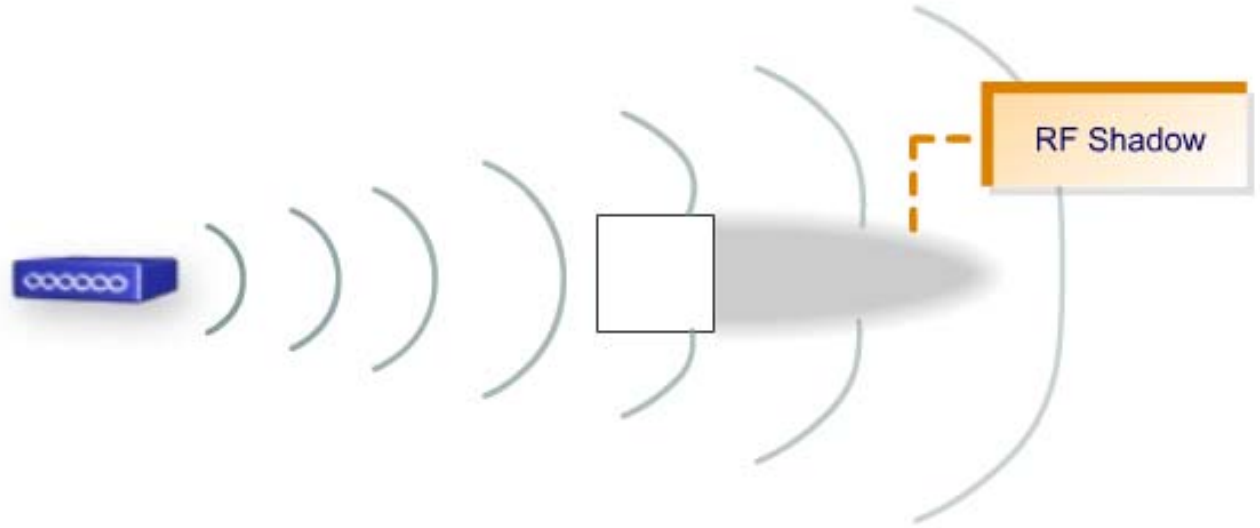
Refraction is the turning or bending of any wave, such as a radio wave, when it passes from one medium into another of different density.





Diffraction

Diffraction is the change in the directions and intensities of a group of waves after passing by an obstacle or through an aperture whose size is approximately the same as the wavelength of the waves.

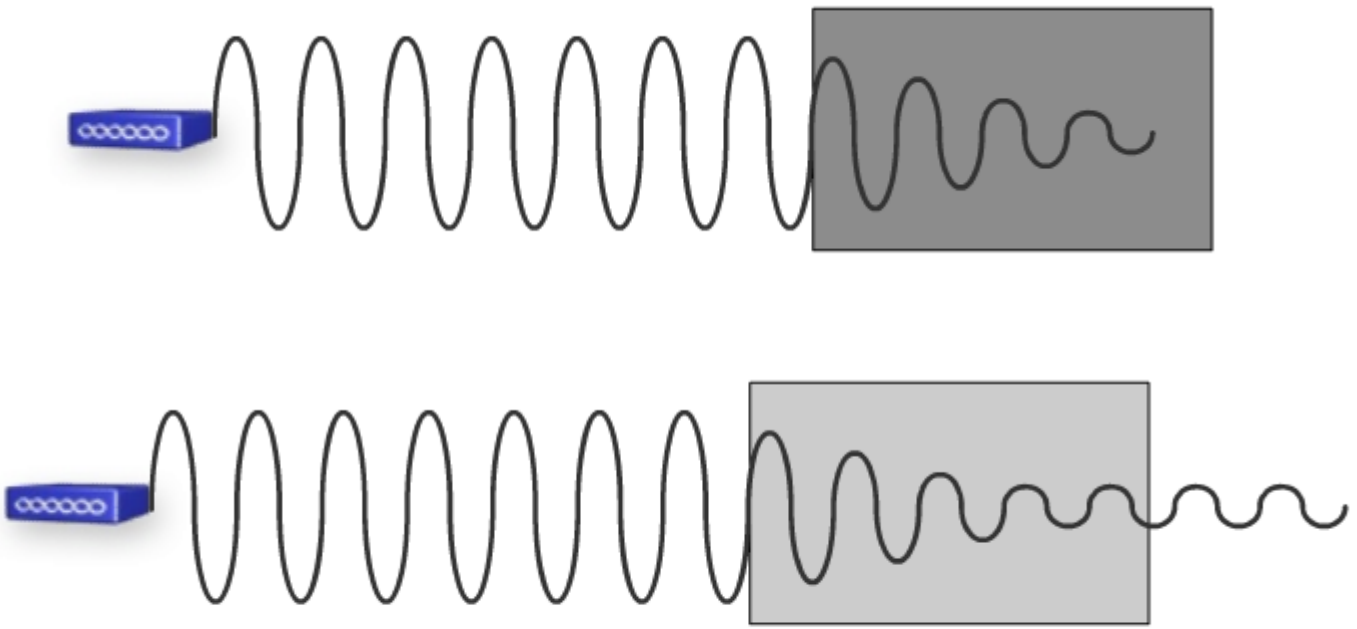


Diffusion (scattering)

RF diffusion, or scattering, is the scattering of the radio wave by reflection from a rough surface.

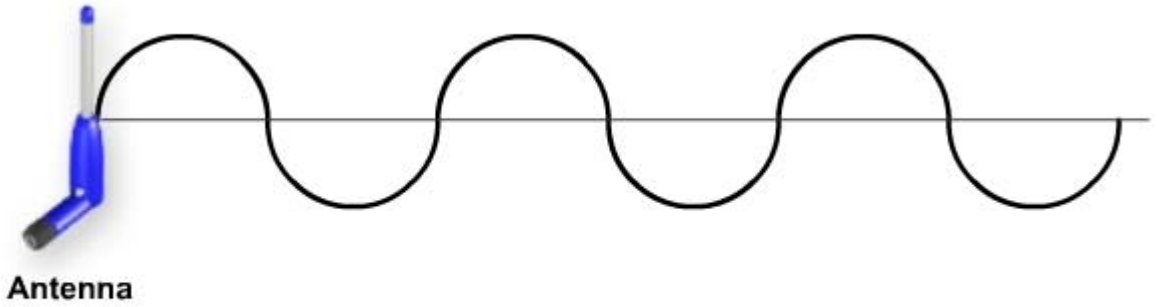
Absorption

Absorption is the process in which incident radiated energy is retained without reflection or transmission on passing through a medium.



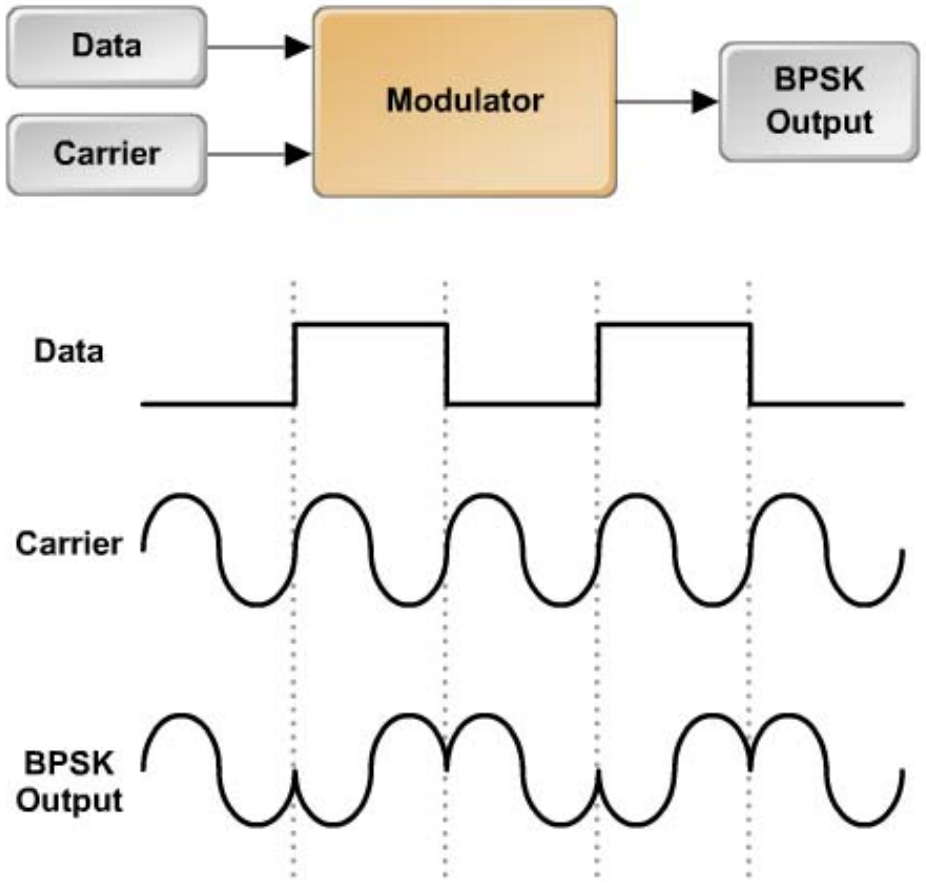
Building materials vary from 2 dB to 20 dB per layer

Sine Waves

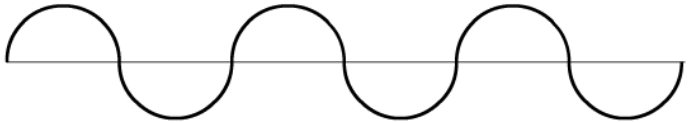


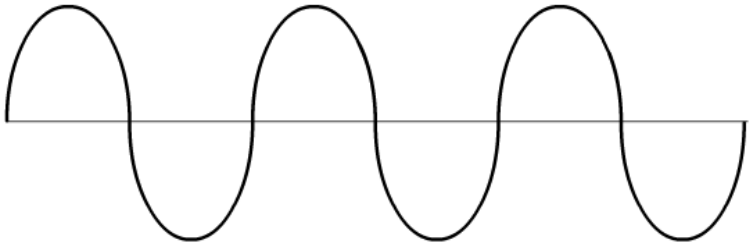
Carrier Waves

A carrier wave is an electromagnetic wave that can be modulated in frequency, amplitude, or phase to transmit speech, music, images, or other signals.

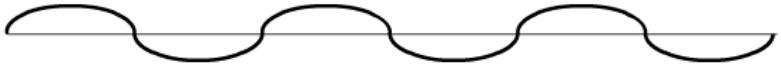


Power Gain and Loss



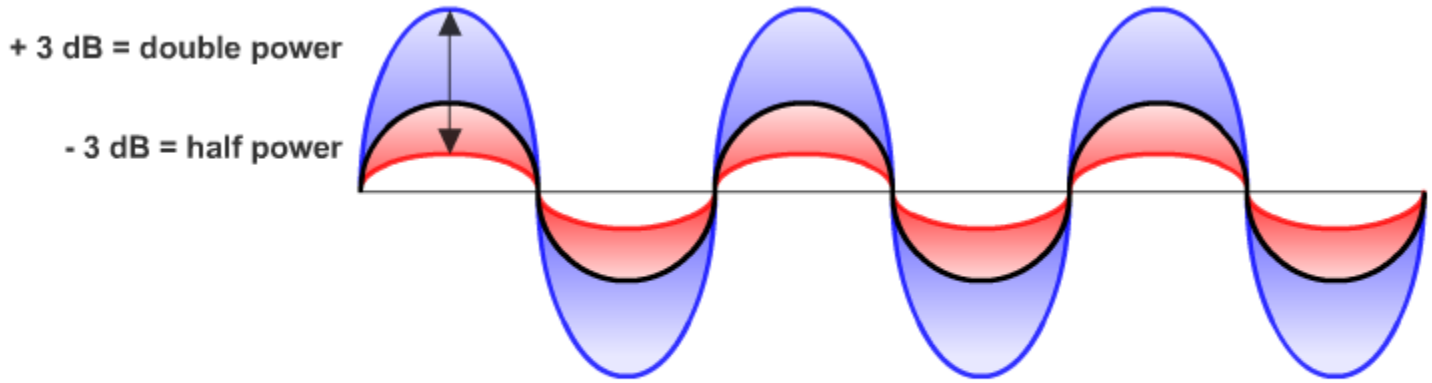


Power Gain



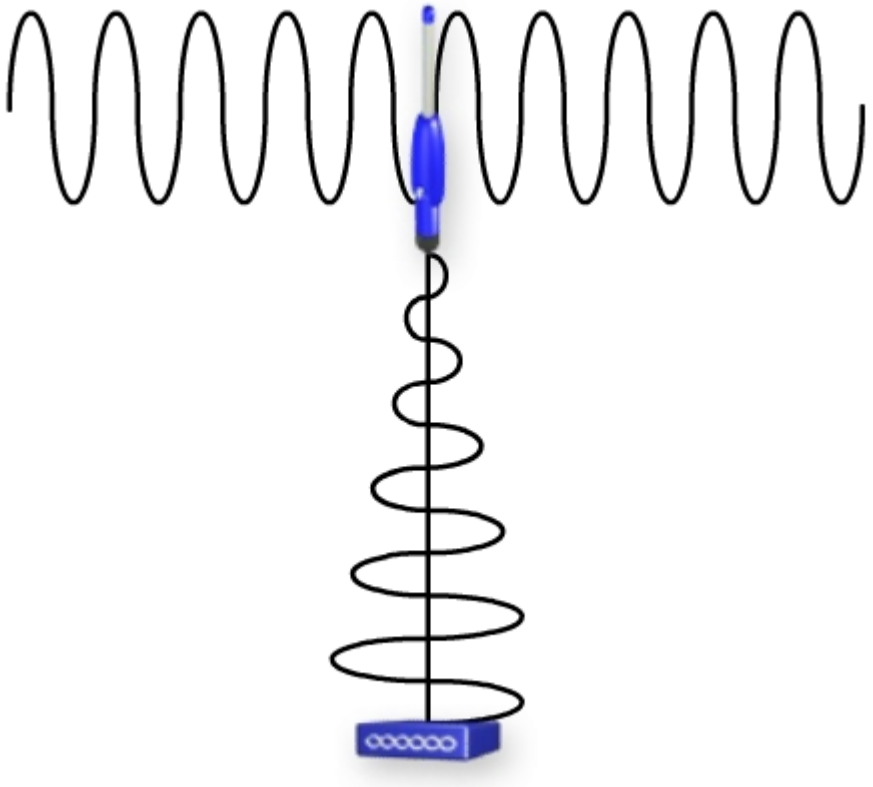
Power Loss

Power Gain and Loss

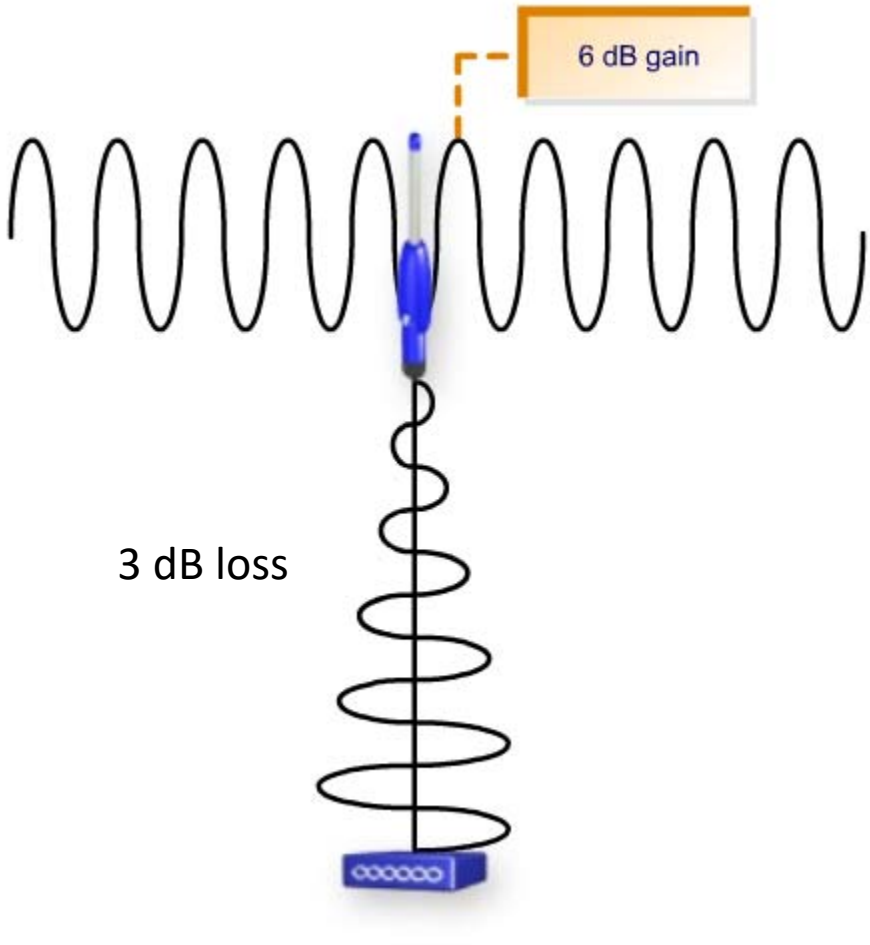


Antennas and Amplifiers produce gain
Cables and Connectors produce loss

Power Gain and Losses

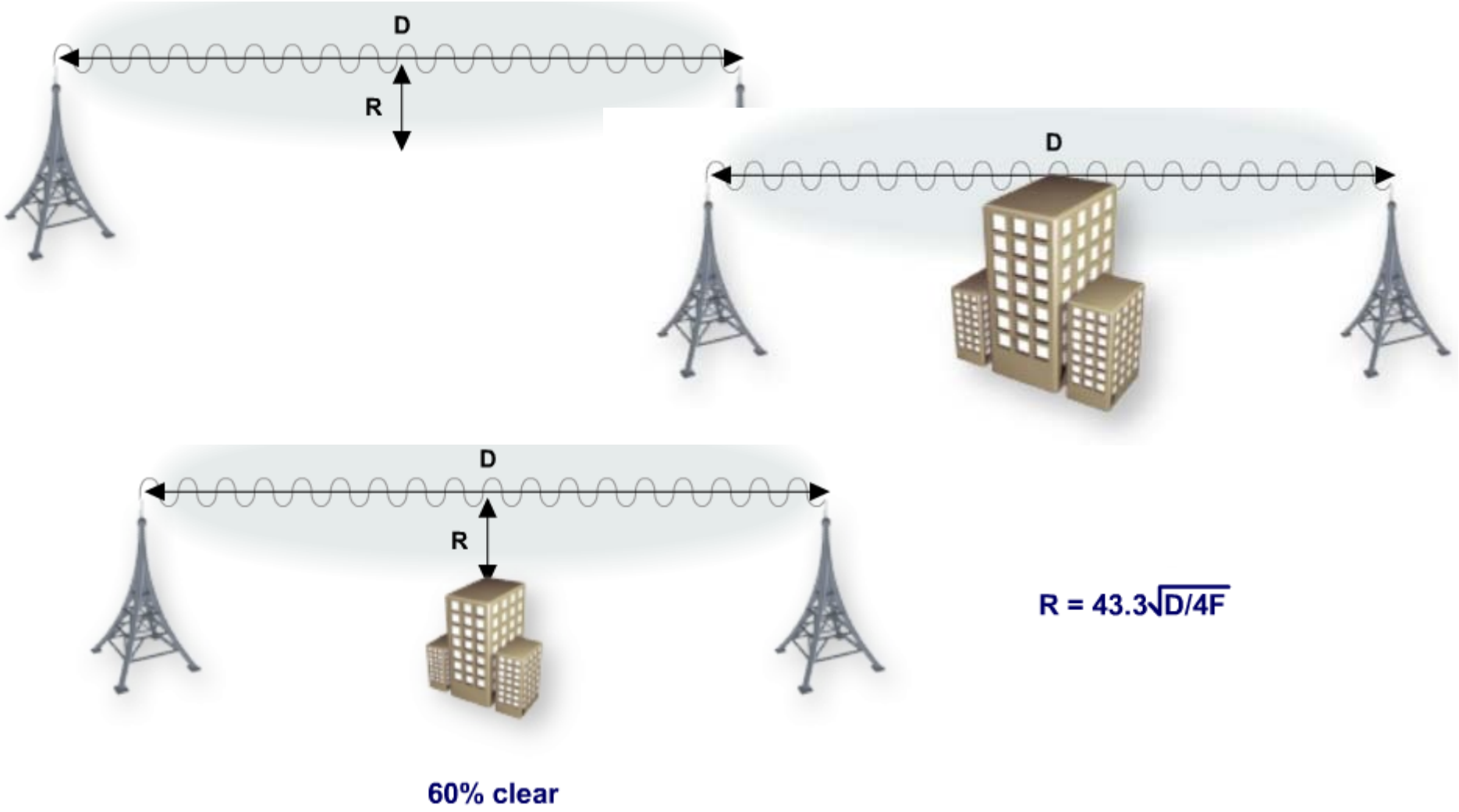


Power Gain and Losses in RF



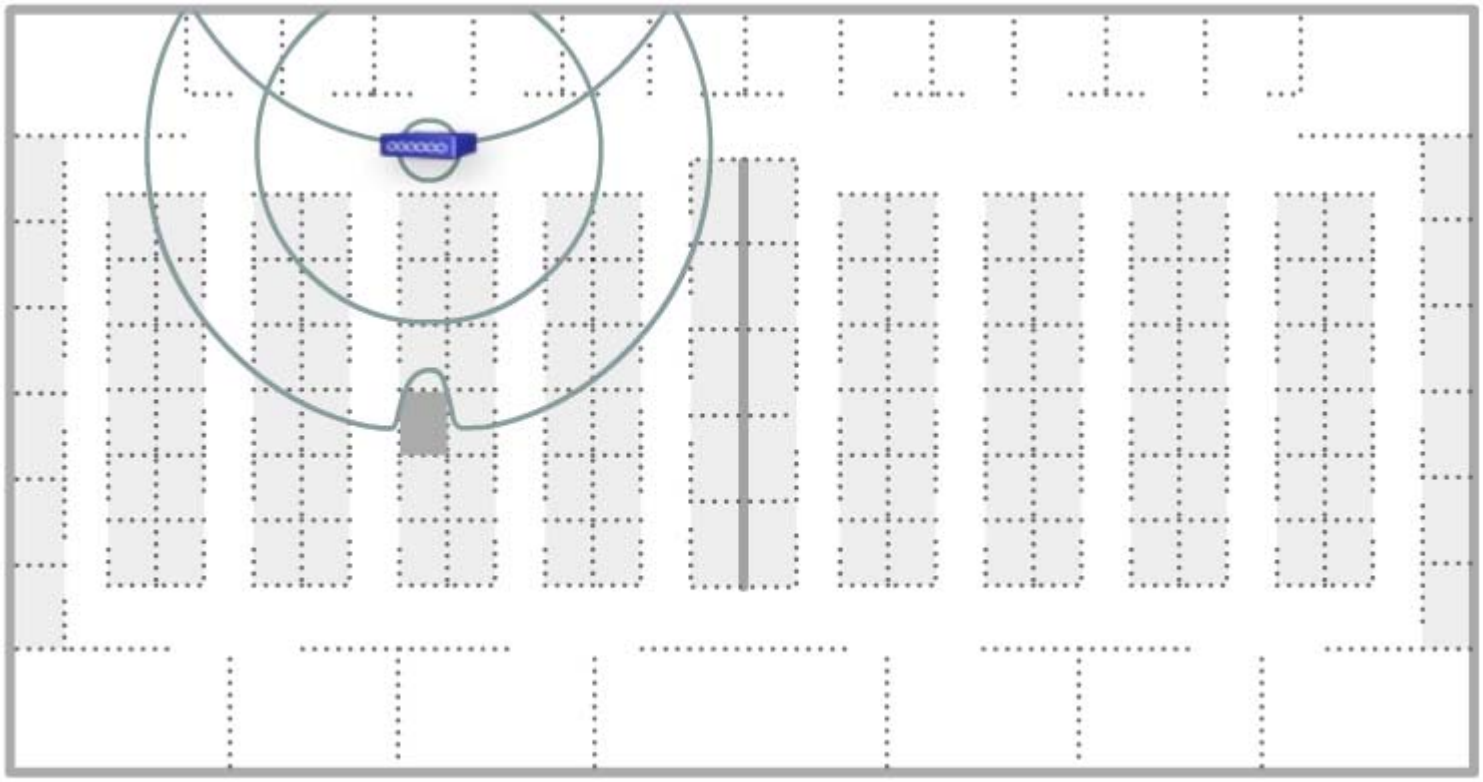
100 mW x 1/2 x 4 = 200 mW

Calculating Fresnel Zone



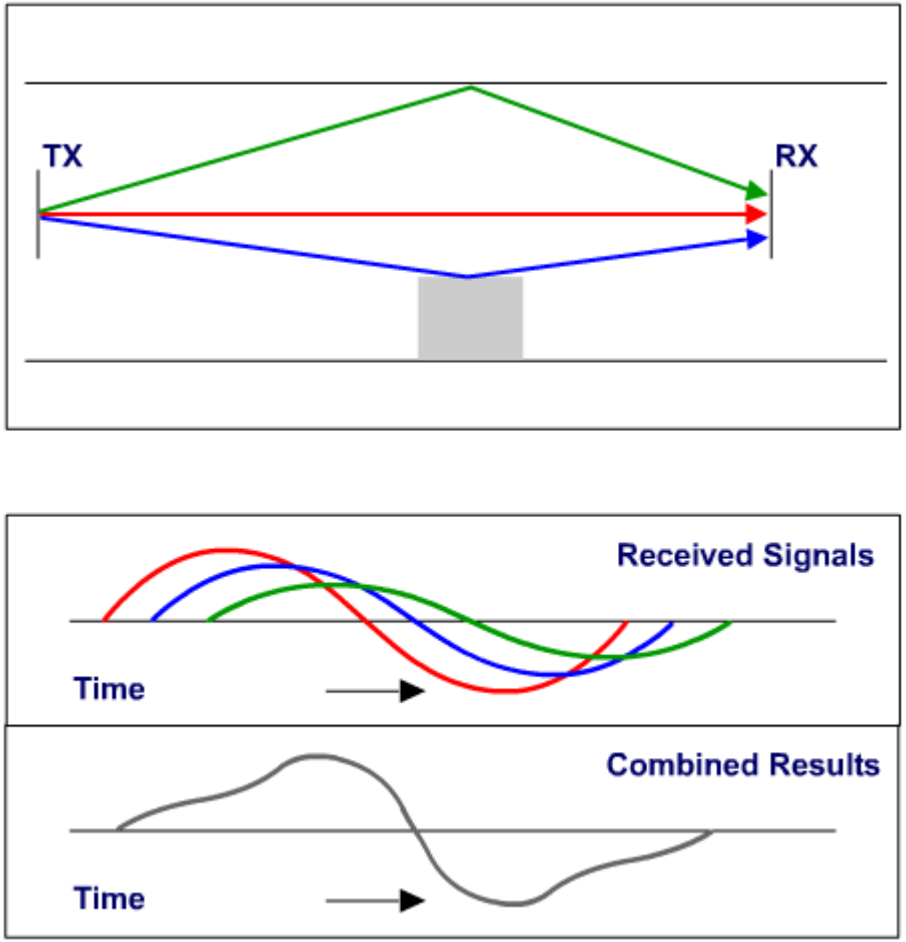
$$R = 43.3\sqrt{D/4F}$$

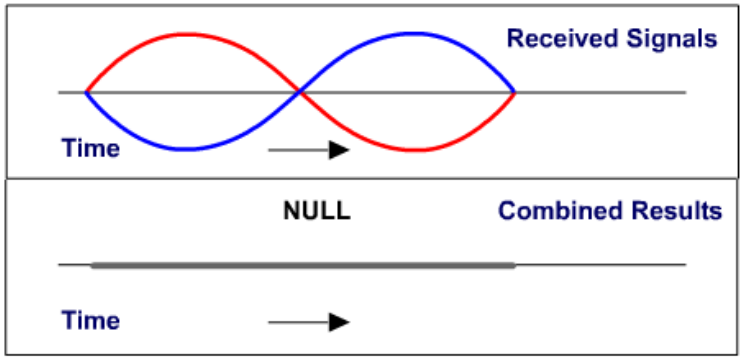
RF Theory Applied to WLANs



RF theory is the underlying principle that determines how a radio signal can be transmitted and received.

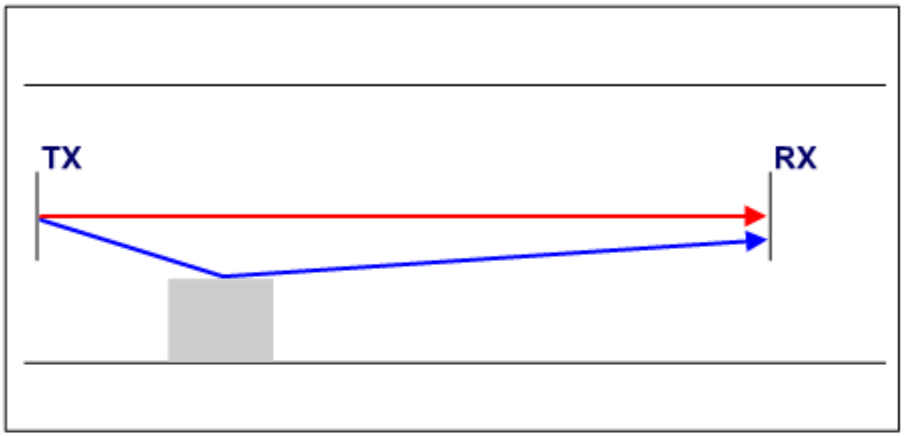
Multipathing: An Example of RF theory

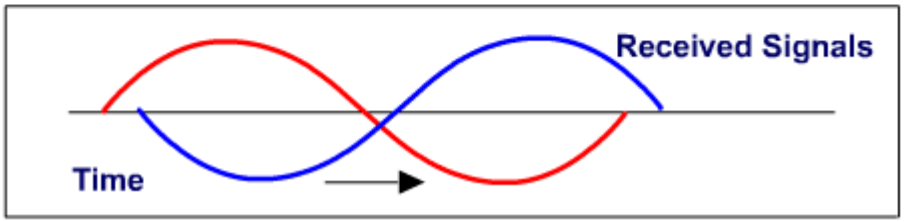




Multipathing: An Example of RF theory

Changing the location of the transmitter or receiver will cause the null spot to move.

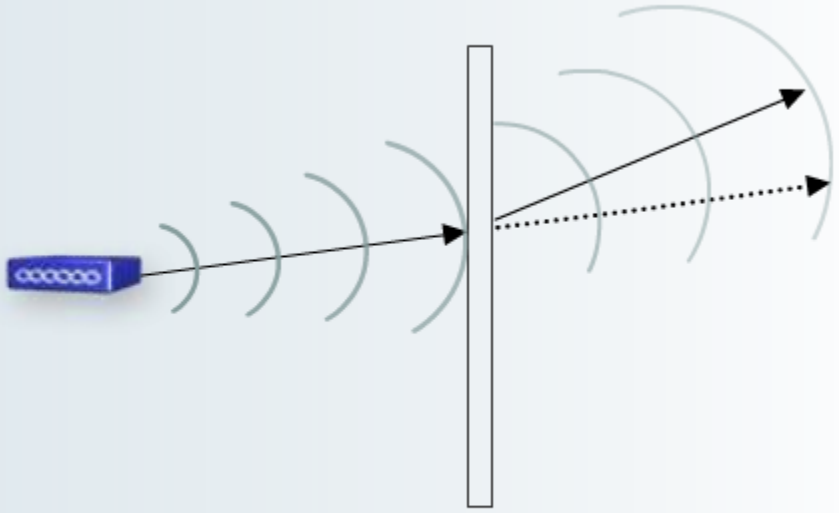




Q/A

Which type of RF propagation is illustrated here?

- A. Scattering
- B. Reflection
- C. Refraction
- D. Diffraction



Q/A

Sine wave	The movement of a wave through a medium.
Carrier wave	A wave that can change in frequency, amplitude, or phase to create a signal.
Propagation	A process in which radio waves strike a surface and are redirected back, usually back toward the point of origin.
Absorption	A waveform of a constant frequency and amplitude.
Reflection	The apparent bending and spreading of waves when they meet an obstruction.
Diffraction	A process in which incident radiated energy is retained without reflection or transmission on passing through a medium.

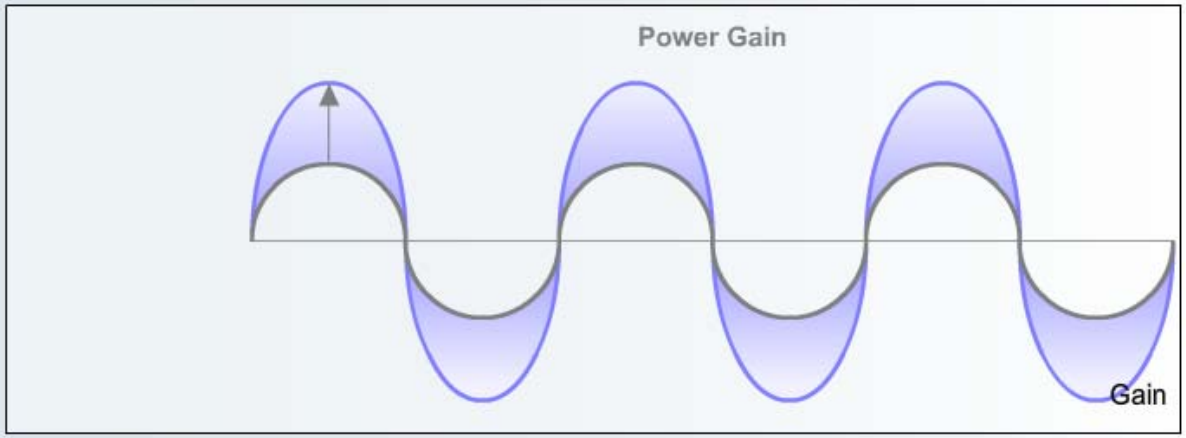
Q/A

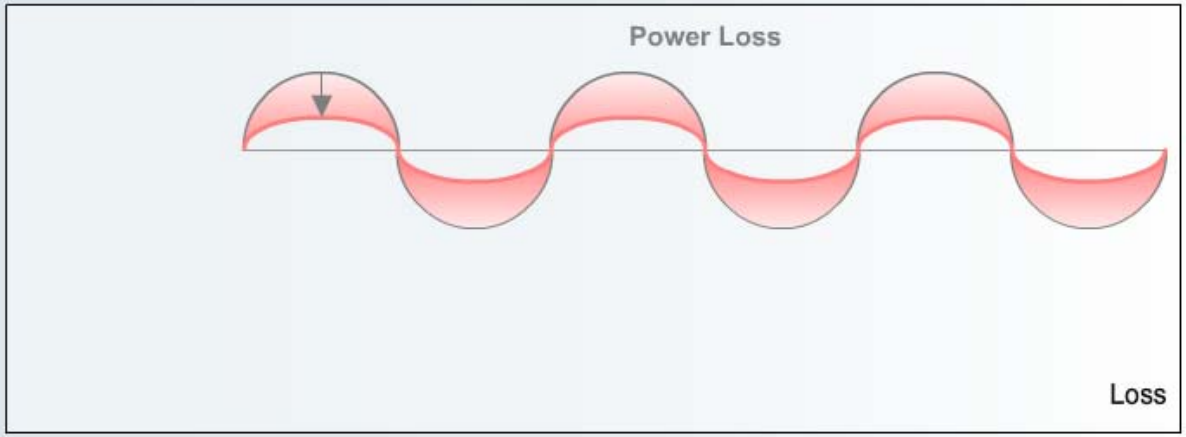
As the distance between two antennas increase, the Fresnel zone will

- A. increase
- B. decrease
- C. not change

Q/A

- Amplifiers
- Connectors
- Antennas
- Cables





Unlicensed Frequency Bands

Band	Frequency Range
900 MHz band	The 900 MHz band extends from 902. to 928. MHz (only in North America, Australia, and New Zealand). The band has a 26 MHz range.
2.4 GHz band	The 2.4 GHz band extends from 2.4000 to 2.4835 GHz (in Japan it extends to 2.495 GHz). The band has an 83.5 MHz range.
5 GHz band	The 5 GHz band extends from 5.150 to 5.350 MHz and from 5.725 to 5.825 MHz, with some countries supporting middle bands between 5.350 and 5.725 MHz. The number of countries that permit 802.11a and the available spectrum varies widely, and the list is changing quickly.

2.4 GHz Frequency—Channel Regulations

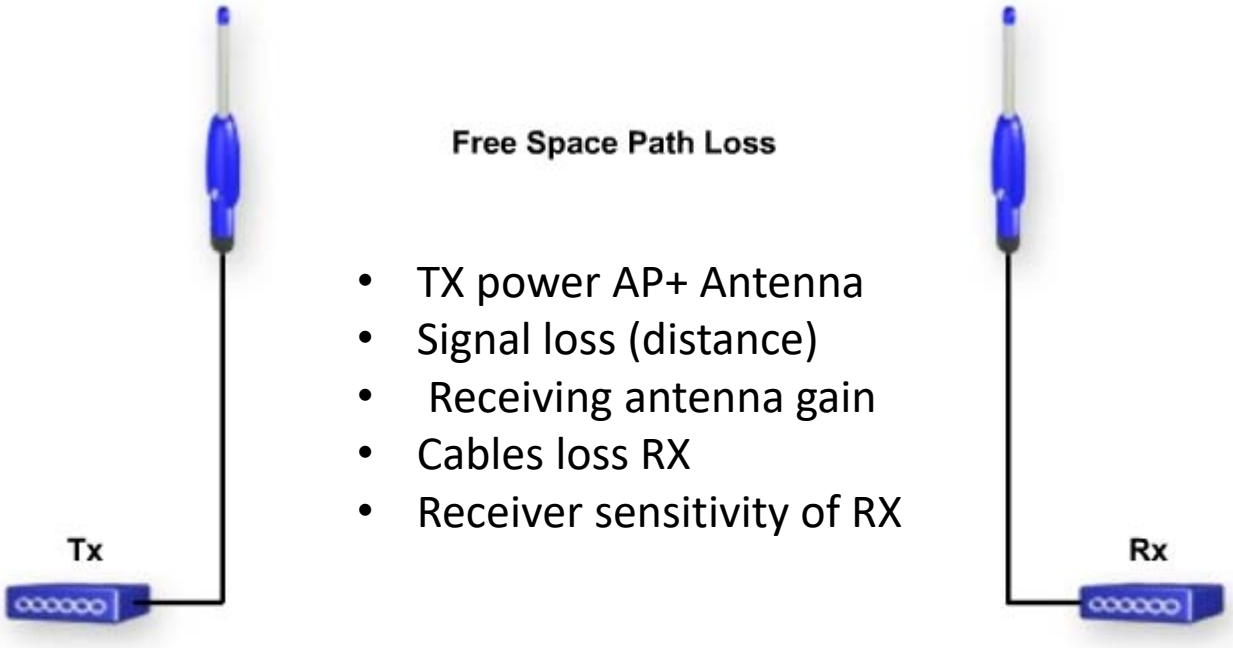
Channel ID	Frequency	United States		Europe, Middle East, and Africa (-E)		Israel (-I)		Japan (-J)	
	(MHz)	802.11b	802.11g	802.11b	802.11g	b	a	802.11b	802.11g
1	2412	X	X	X	X			X	X
2	2417	X	X	X	X			X	X
3	2422	X	X	X	X			X	X
4	2427	X	X	X	X			X	X
5	2432	X	X	X	X	X	X	X	X
6	2437	X	X	X	X	X	X	X	X
7	2442	X	X	X	X	X	X	X	X
8	2447	X	X	X	X	X	X	X	X
9	2452	X	X	X	X			X	X
10	2457	X	X	X	X			X	X
11	2462	X	X	X	X			X	X
12	2467			X	X			X	X
13	2472			X	X			X	X
14	2484							X	
Maximum Power (mW)		100	30	50	30	50	30	30	30

5 GHz Frequency—Channel Regulations 802.11a

5 GHz WLAN Frequency Bands

Frequency Band	Max. Power	Country	Frequency (GHz)	Channels
UNII-1	30 mW	US, Japan	5.15-5.25	4
		Europe		
UNII-2	200 mW	US	5.25–5.35	4
UNII-3	800 mW	US	5.725–5.825	4
HiperLAN	200 mW	Europe	5.25–5.35	8
HiperLAN II	1 W	Europe	5.470–5.725	11

Loss Budget



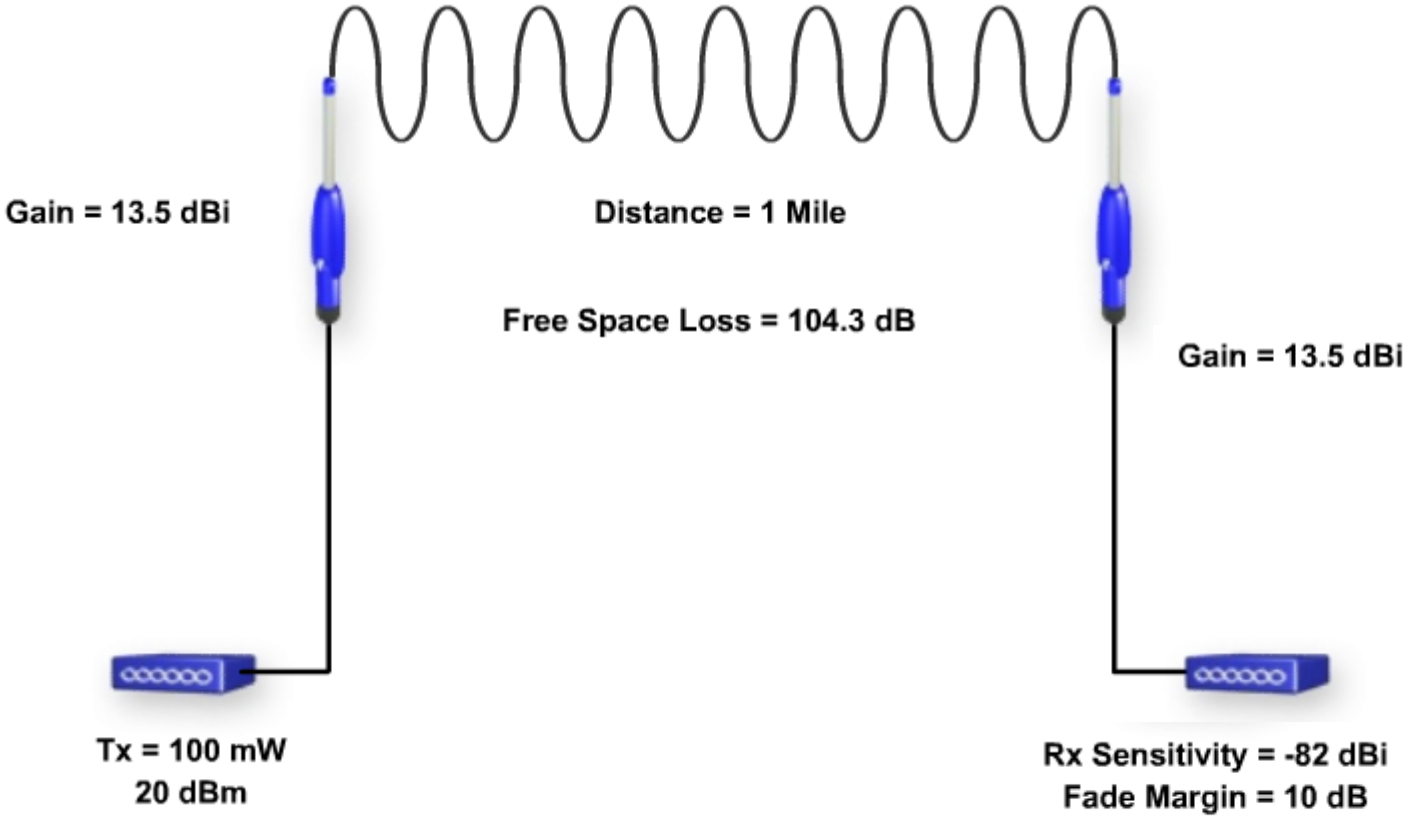
- TX power AP+ Antenna
- Signal loss (distance)
- Receiving antenna gain
- Cables loss RX
- Receiver sensitivity of RX

Rx Level= Free Space Path Loss

Loss Budget = - Rx Sensitivity - Rx Level - Fade margin

Loss Budget is the amount of signal loss that can occur in a transmission while still allowing a link to operate.

Loss Budget Example



Rx Level = Tx Pwr - Cbl Loss + Ant Gain - FSPL + Ant Gain - Cbl Loss

20.0 - 0.0 + 13.5 - 104.3 + 13.5 - 0.0 = -57.3

Loss Budget = - Rx Sensitivity - Rx Level - Fade margin

-(-82) - 57.34 - 10 = 14.7

Q/A

Which of the following is not an unlicensed RF band?

- A. 900 MHz
- B. 1.2 GHz
- C. 2.4 GHz
- D. 5.0 GHz

900 MHz	Supported by numerous countries and spectrum range greatly varies.
2.4 GHz	Governed by IEEE standards 802.11b and 802.11g.
5 GHz	Used mostly only in North America.

Q/A

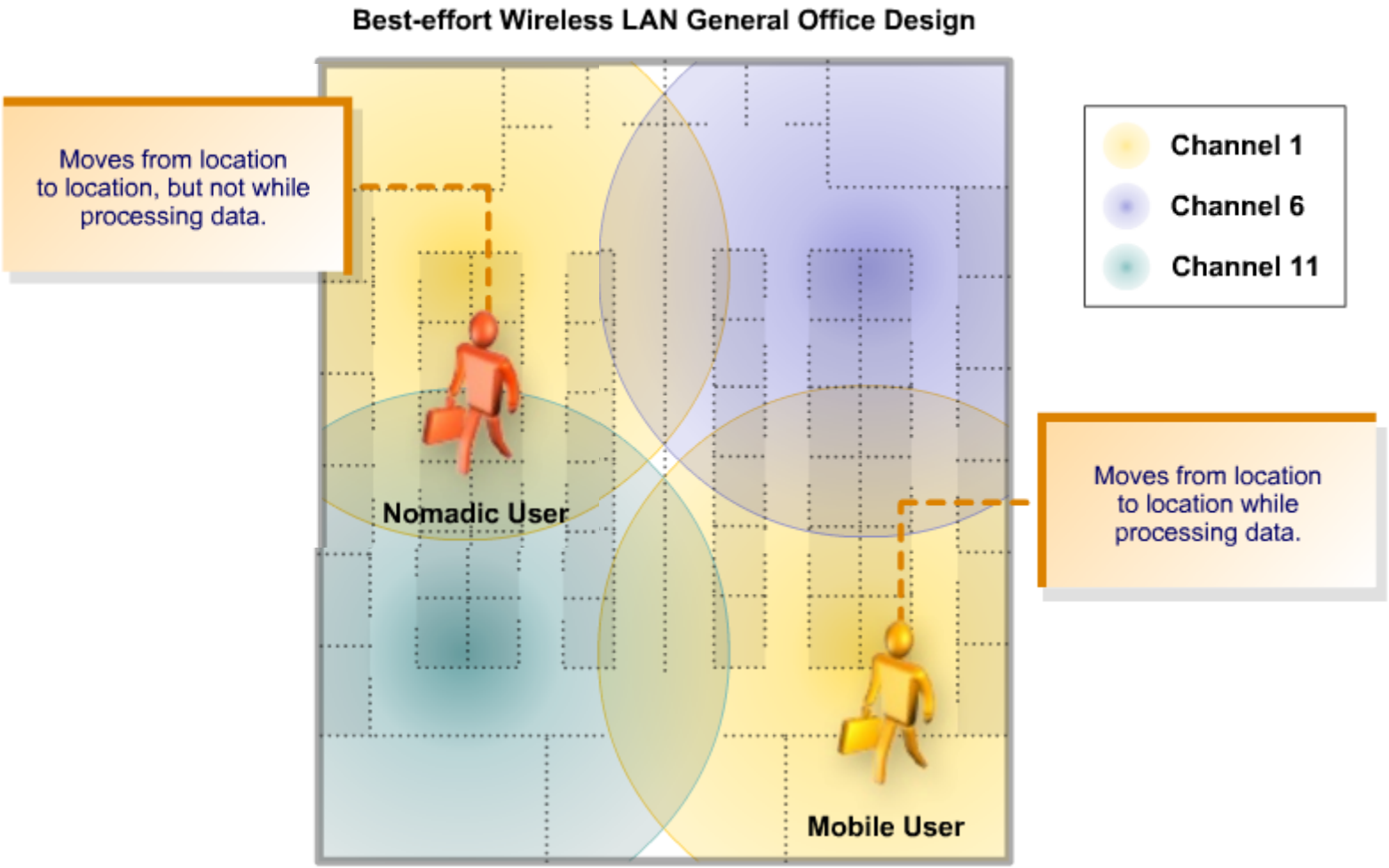
The EIRP is estimated by adding the _____ and _____.

- A. antenna gain and the radio transmitter power.
- B. antenna loss and the radio transmitter power.
- C. antenna gain and dBm.
- D. antenna loss and dBm.

What's Covered

- Typical Applications
- Client Density
- AP Cell Size
- Rate Shifting
- Radio Choice
- Throughput Considerations
- Cisco Recommendations
- Identify Key Criteria for Best-effort WLANs

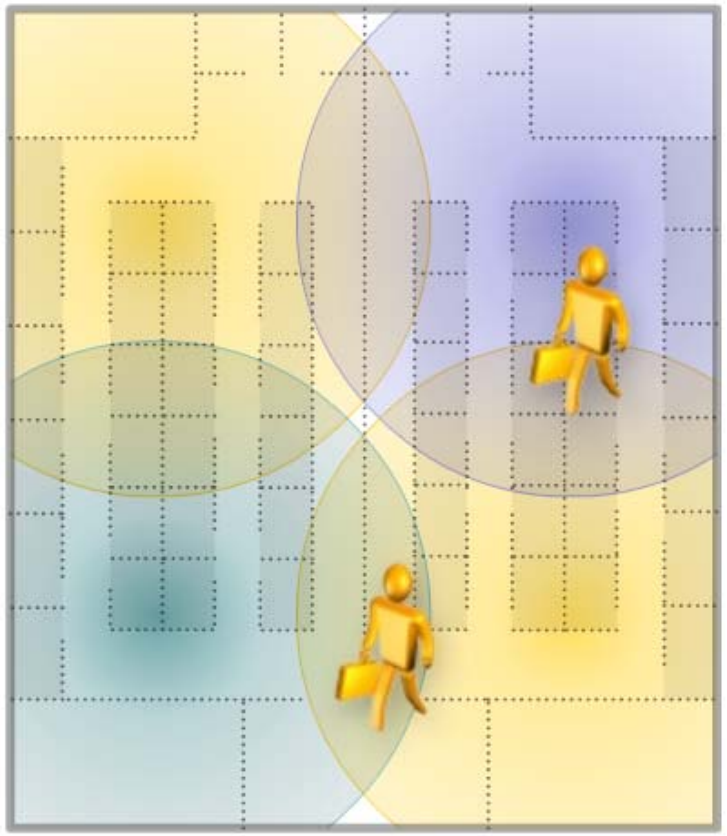
What is a Best-effort WLAN?



Best-effort WLANs:

- Allow for mobility and roaming.
- Can have significant delays in frame response.
- Are appropriate for applications that can tolerate delays, such as:
  - Data collection.
  - Internet access.
  - General office applications.
- Are not appropriate for delay-sensitive applications, such as:
  - VoIP or video.
  - VPN over wireless.
  - Client/server or Citrix-based applications.

Best-effort Wireless LAN General Office Design

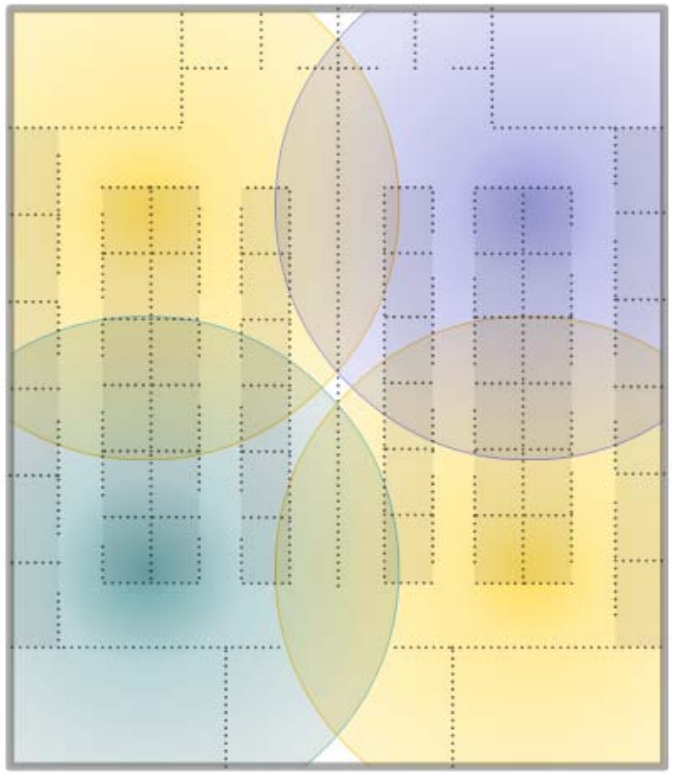


Determining Cell Density

Cell density is the maximum number of users per cell.

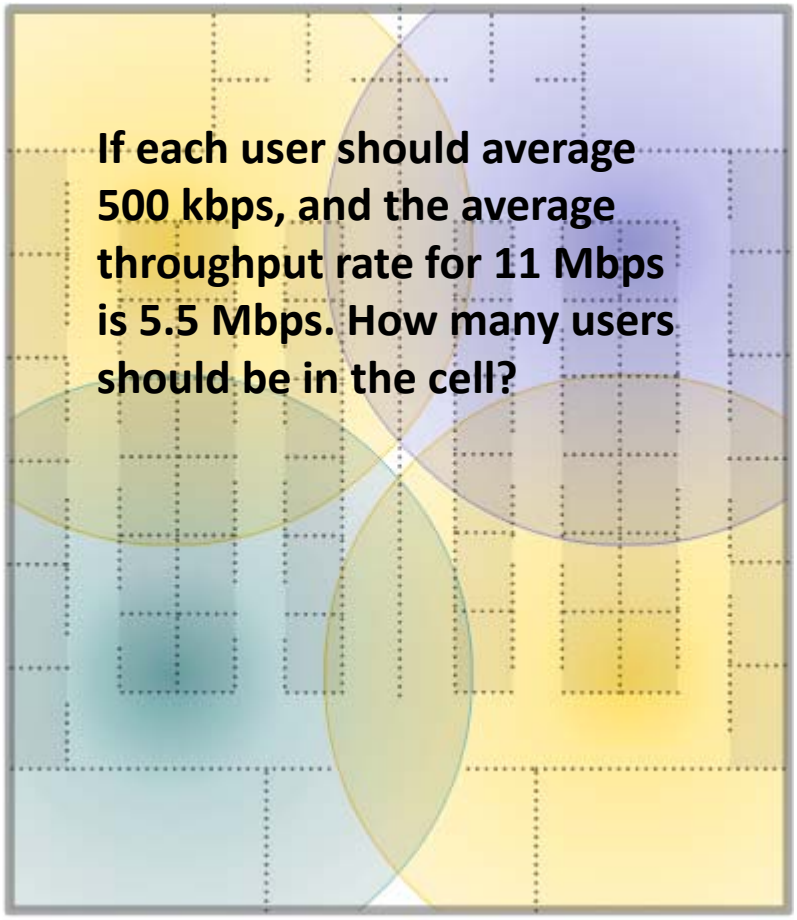
To determine cell density:

- Determine throughput per user.
- Divide AP throughput by per-user throughput.
- Consider that latency does not need to be factored in for best-effort WLANs.

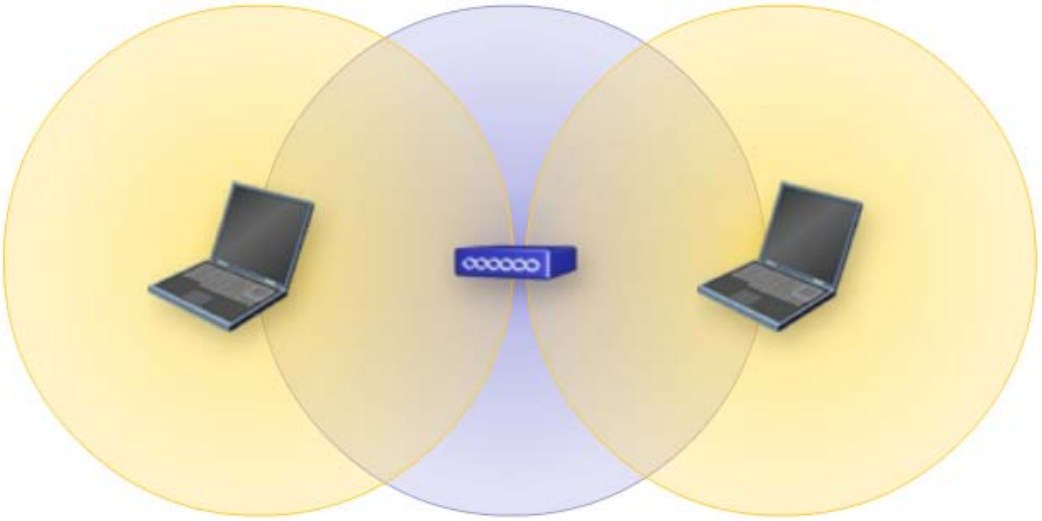


$$\frac{\text{AP throughput}}{\text{Per-user throughput}} = \text{Maximum active transmissions per cell}$$

Client Density Example



Determining Cell Size



Cell size is the area of coverage provided by an access point.

Cell Size is limited by the device with the weakest RF characteristics.

Cell size is determined by:

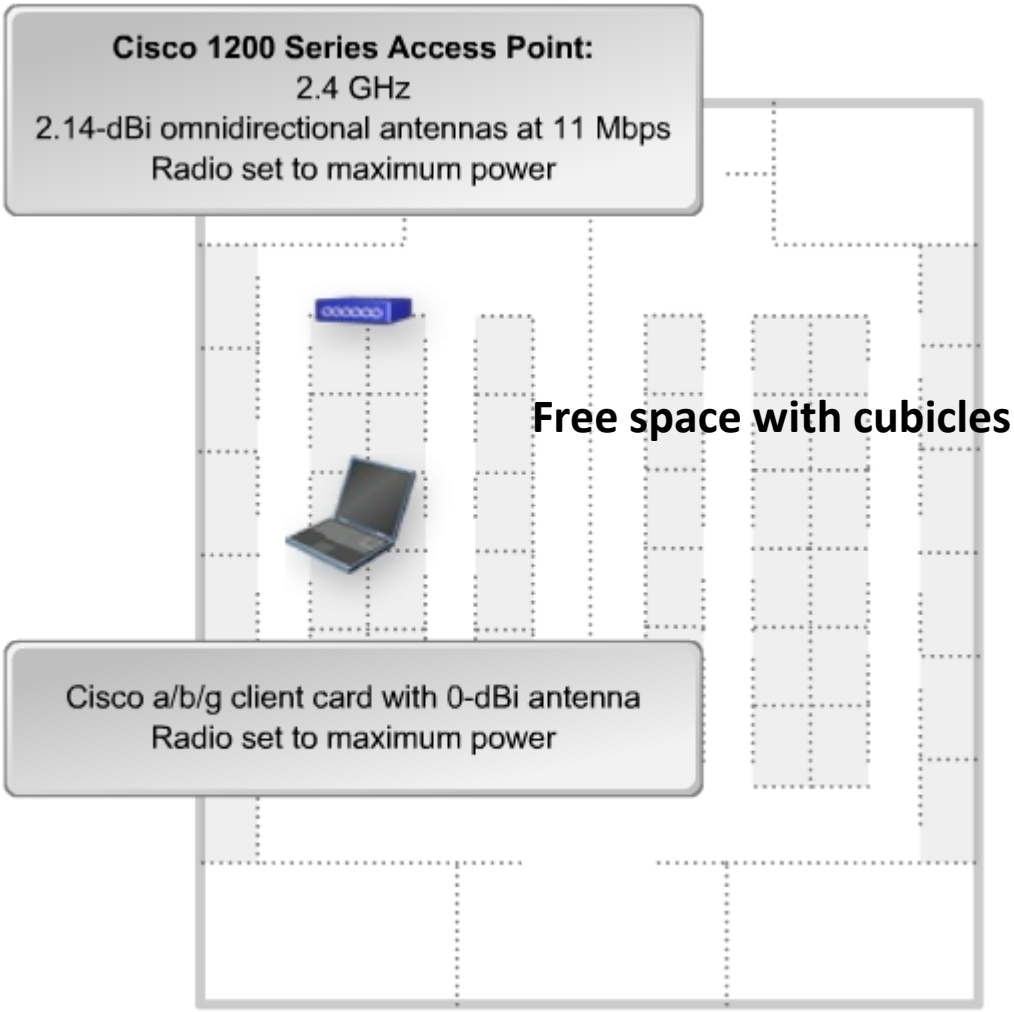
- Power.
- Antenna.
- Data rate.
- Frequency.
- Environment.

General Rules

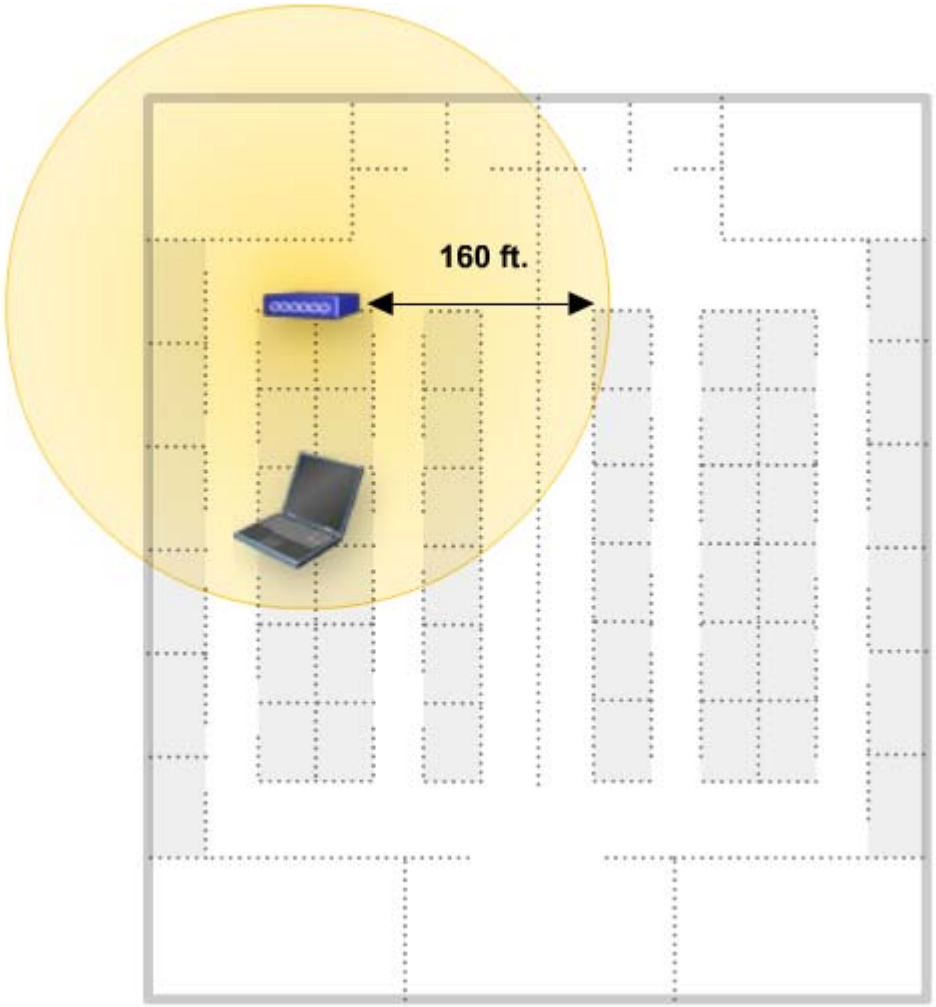
In general:

- Higher data rate equals smaller cell size.
- Higher frequency equals smaller cell size.
- More antenna gain equals larger cell size.
- Higher power equals larger cell size.
- RF interference in the environment equals smaller cell size.

Example


Cisco 1200 Series Access Point:
2.4 GHz
2.14-dBi omnidirectional antennas at 11 Mbps
Radio set to maximum power
Free space with cubicles
Cisco a/b/g client card with 0-dBi antenna
Radio set to maximum power

Example

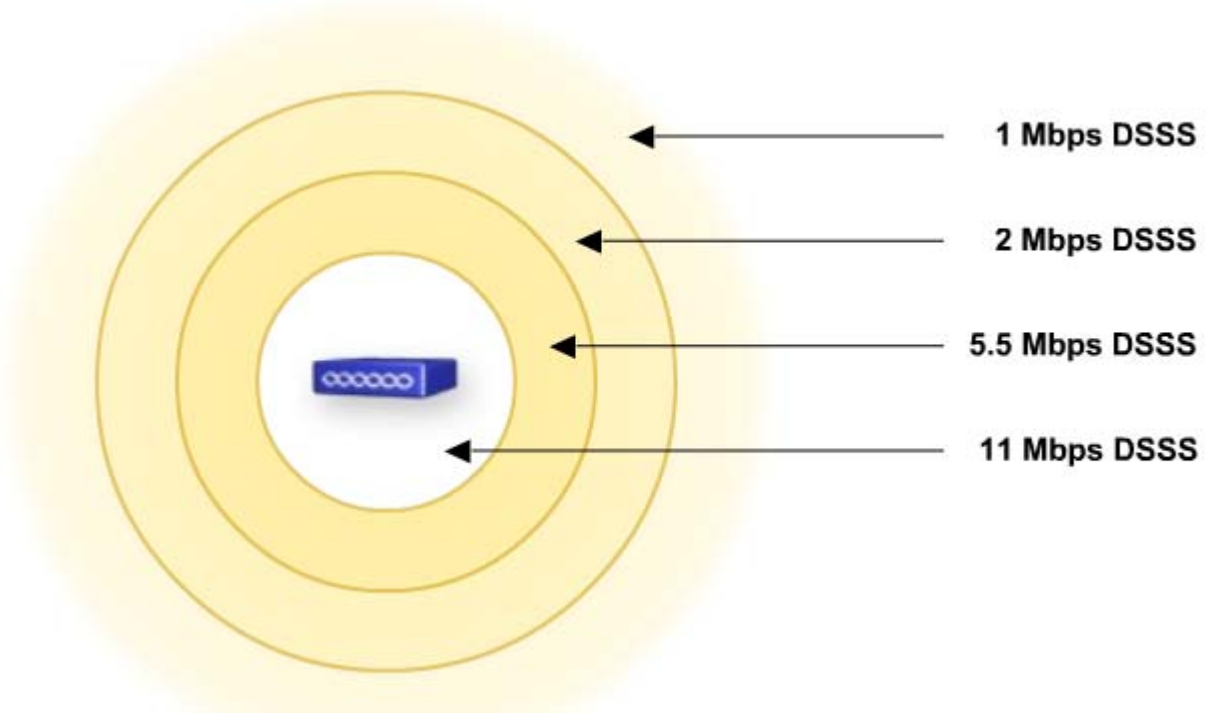


Best-effort Receiver Thresholds

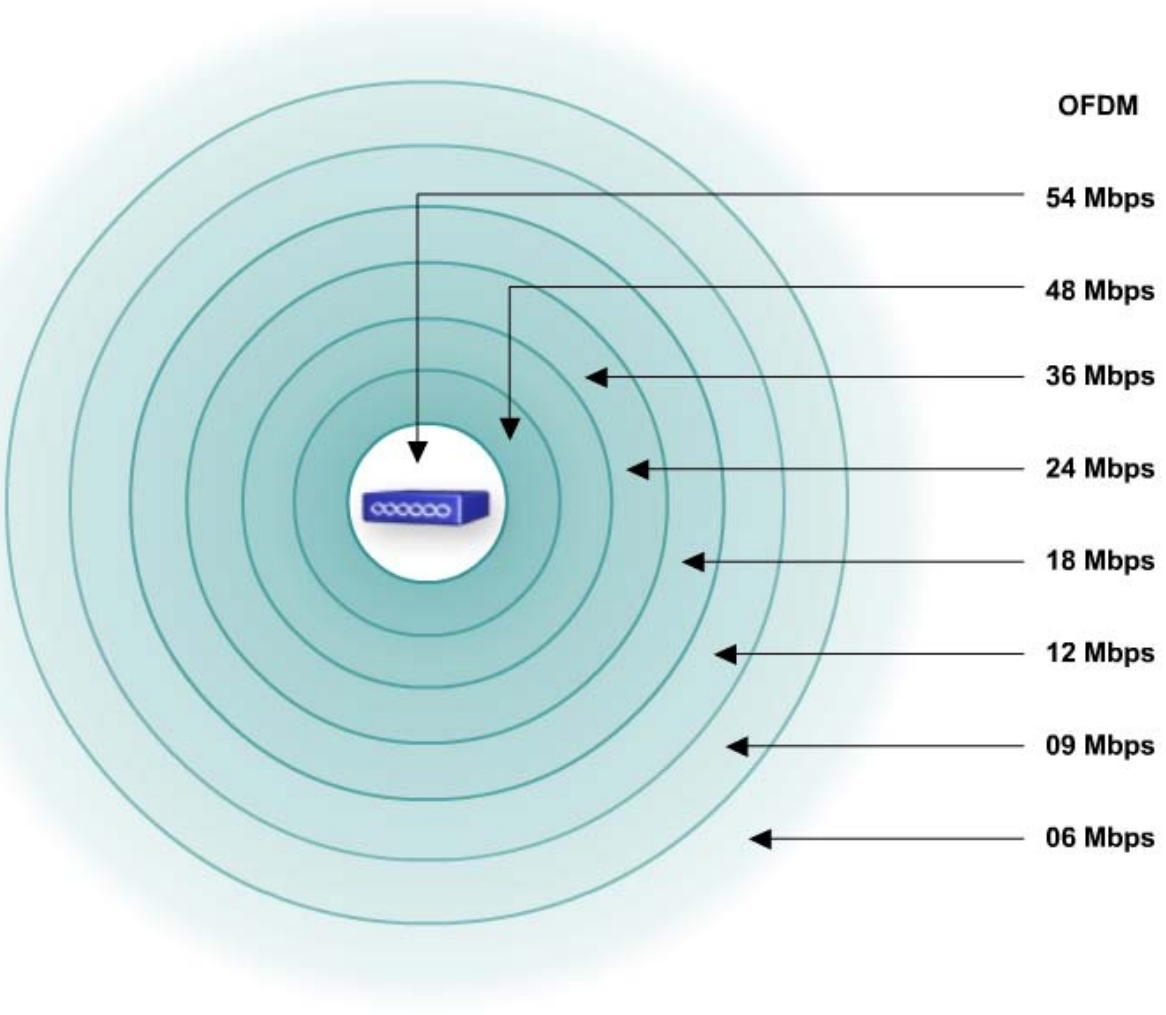
802.11g 2.4 GHz

Data Rate	RX Threshold (RT) (dBm)	Recommended Minimum RT (dBm)	RX Signal-to-Noise Ratio (S/N)	Recommended Minimum S/N
54	-71	-61	25	35
48	-72	-62	22	31
36	-73	-63	18	28
24	-77	-67	12	22
12/11	-82	-72	10	20
6/5.5	-89	-79	8	18
2	-91	-91	6	16
1	-94	-84	4	14

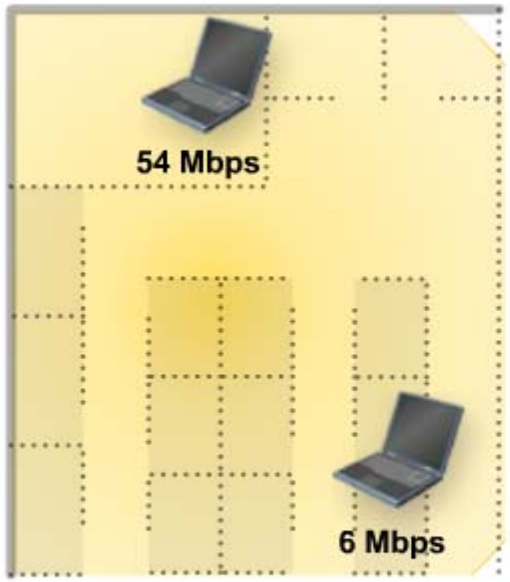
Rate Shifting: 802.11b



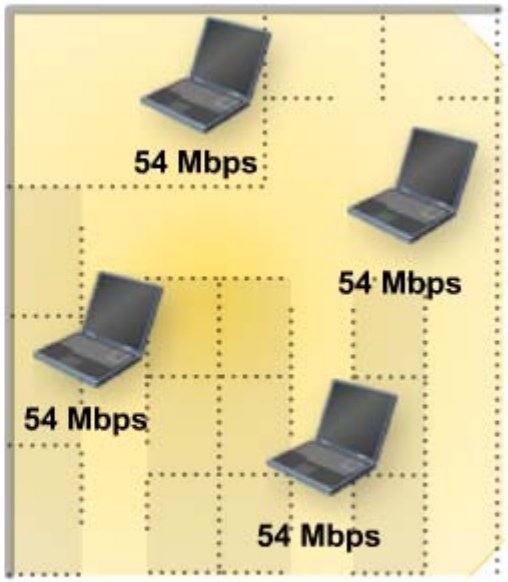
Rate Shifting: 802.11a/g



Rate Shifting Design Considerations



Rate Shifting



No Rate Shifting

Cell size will be determined by the lowest data rate in any particular technology.

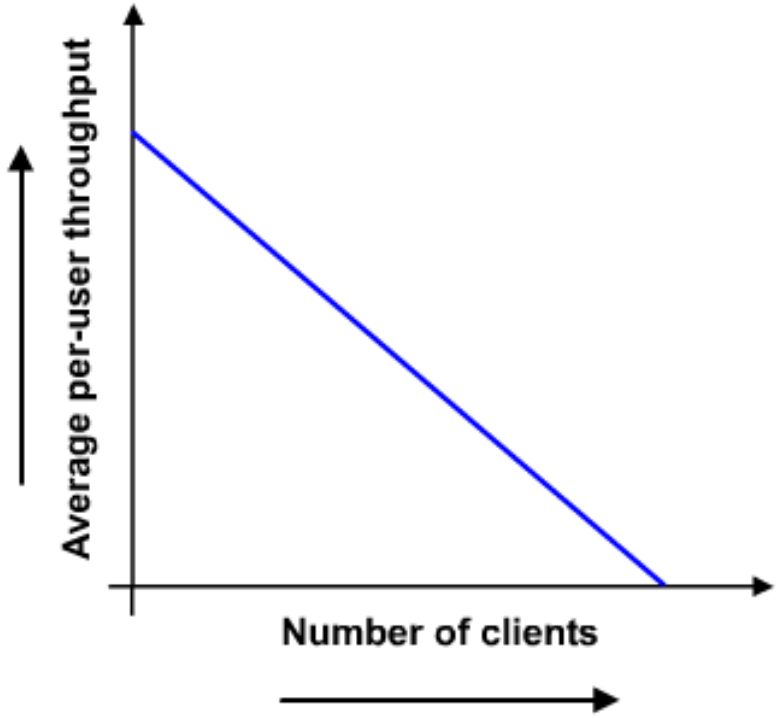
Client Application and Hardware Con.

Industry	Radio Technology		
	802.11b	802.11g	802.11a
Hospitality	X	X	
Manufacturing	X	X	
Healthcare	X	X	X
Higher Education	X	X	X
Enterprise Office	X	X	X
Financial Institutions	X	X	X
Retail	X	X	
Transportation	X		
Warehousing	X		

Determining Throughput

Throughput = data rate – protocol overhead

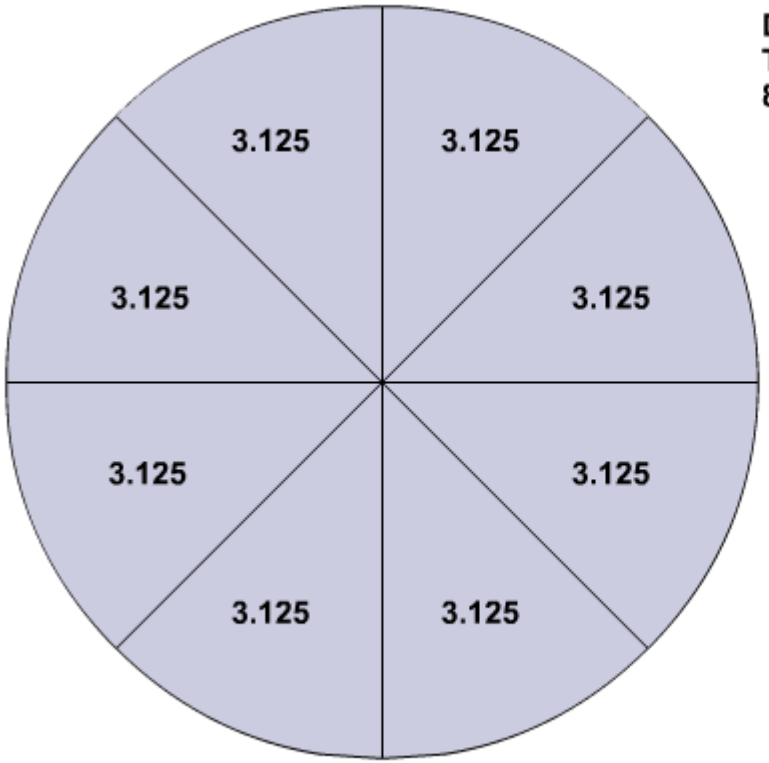
802.11a/b/g throughput = ~1/2 data rate
(without legacy support in mixed-mode operation)



Maximum Throughput Values

Cell Type	Maximum Throughput
802.11b	In an 802.11b cell, the maximum throughput will be approximately 6 Mbps.
802.11g in protected mode	In an 802.11g cell with at least one 802.11b client associated, the maximum throughput will be approximately 8 to 13 Mbps.
802.11g not in protected mode	In an 802.11g cell with no 802.11b clients associated, the maximum throughput will be approximately 22 Mbps.
802.11a	In an 802.11a cell, the maximum throughput will be approximately 25 Mbps.

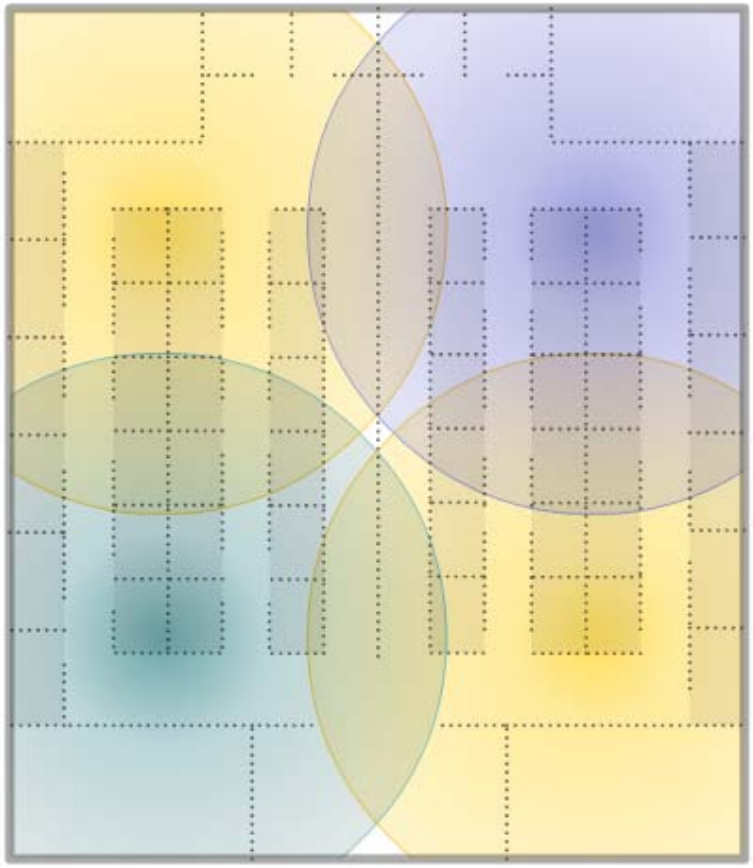
Client Throughput



Data rate = 54 Mbps
Total throughput = 25 Mbps
8 Clients

When designing a best-effort WLAN:

1. Determine client types and 802.11 format.
2. Establish throughput requirements.
3. Determine if the applications are latency sensitive.
4. Determine cell density.



Q/A

What factors affect cell density in a best-effort WLAN? (choose 3)

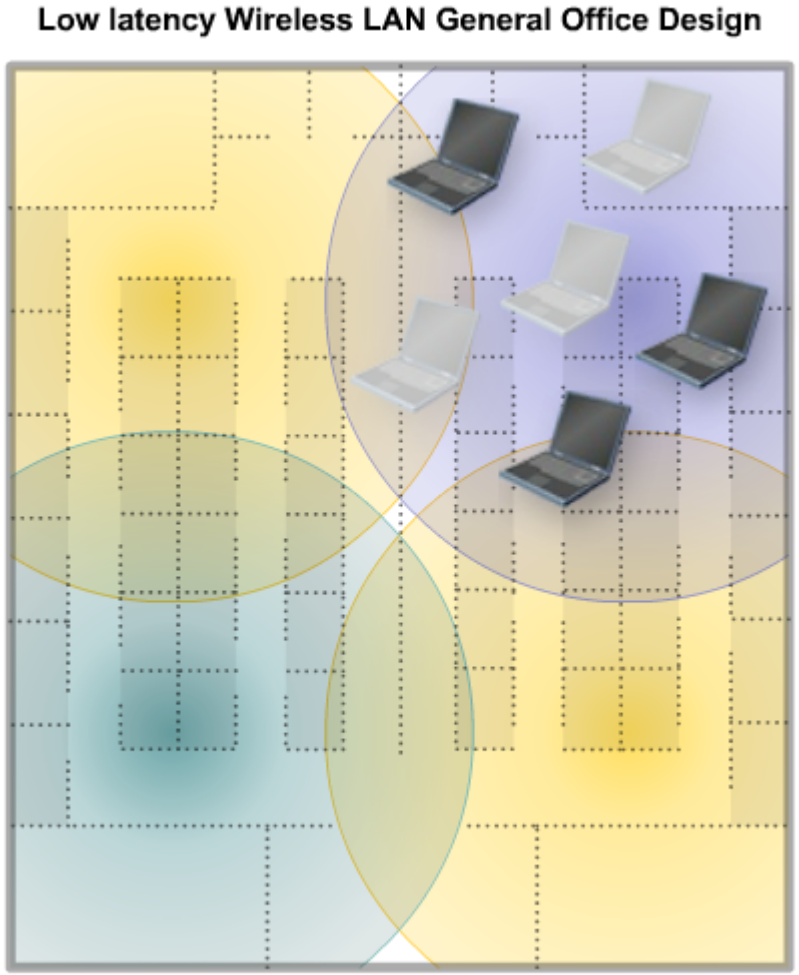
- [ ] A. Cell Size
- [ ] B. Data Rate
- [ ] C. Data latency
- [ ] D. Throughput

Q/A

When designing a customer WLAN where there will be a mix of 802.11b and 802.11g clients, what should client density be based on?

- A. Maximum 802.11b throughput and the number of 802.11g clients
- B. Maximum 802.11b throughput and the number of 802.11b clients
- C. Maximum 802.11g throughput and the number of 802.11b clients
- D. Maximum 802.11g throughput with 802.11g clients

Low Latency WLAN



A low latency network is a network that employs latency-sensitive applications, such as wireless voice over IP (VoIP), video streaming, video on demand, VPN over wireless, and client/server-based applications, such as Enterprise Resource Planning (ERP) or Citrix-based solutions.

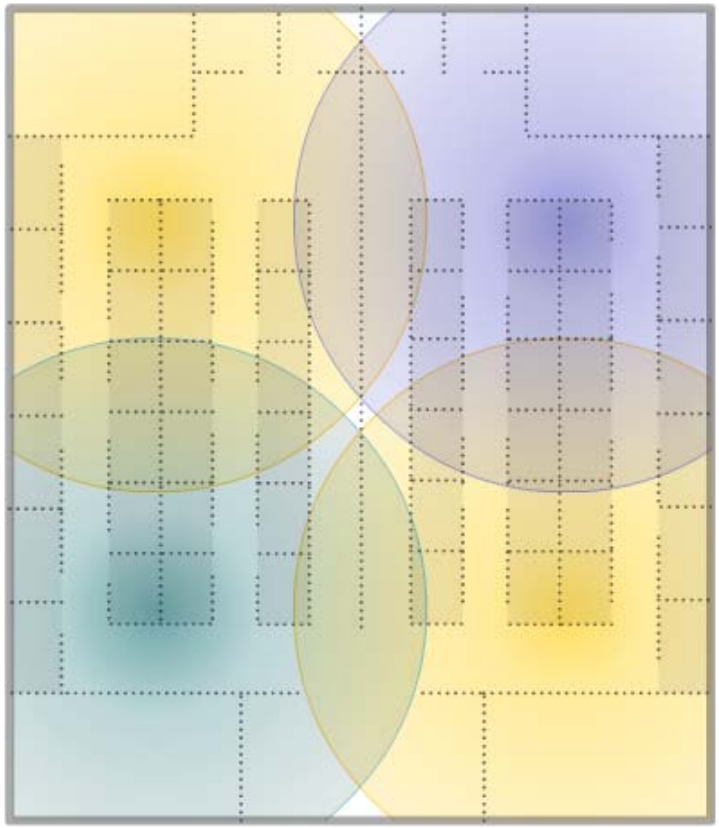
Latency Requirements

Cisco Aironet client latency:

- Is 400 ms-600 ms (at Layer 2).
- Increases when 802.1x authentication is enabled:
  - LEAP adds 200 ms-1.2 seconds.
- Must be < 150 ms end to end for latency-sensitive applications.
- Can be reduced to < 100 ms with Cisco Fast Secure Roaming.

To determine cell density:

- Determine throughput per user.
- Divide AP throughput by per-user throughput.
- Take half the data rate of the AP, in general.



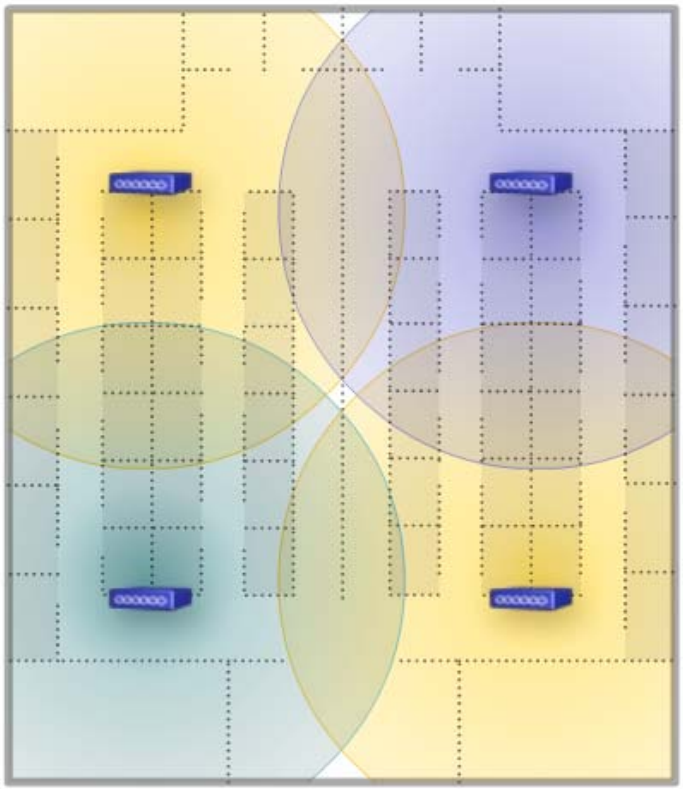
$$\frac{\text{AP throughput}}{\text{Per-user throughput}} = \text{Maximum active transmissions per cell}$$

Density Considerations

General network capacity guidelines include:

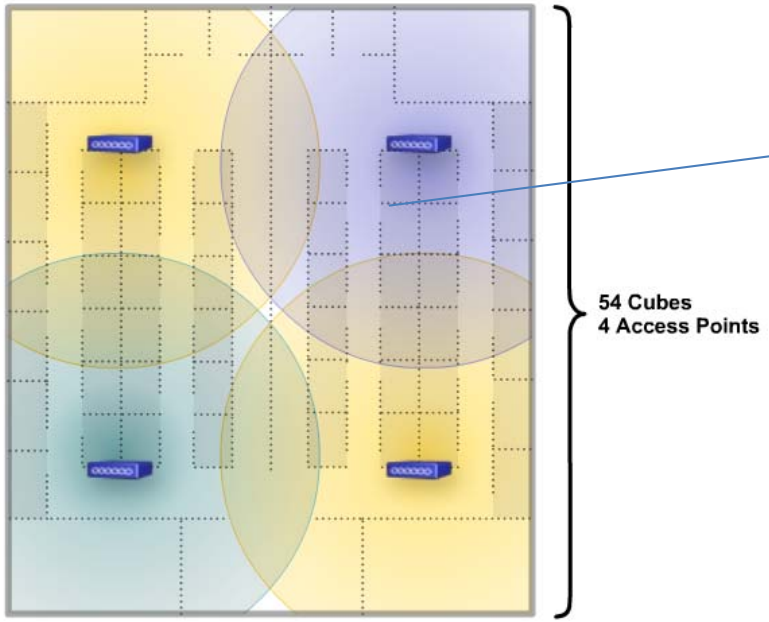
- Having no more than seven concurrent G.711 calls per cell.
- Having no more than eight concurrent G.729 calls per cell.
- Using no more than 20 to 25 802.11b endpoints per AP.

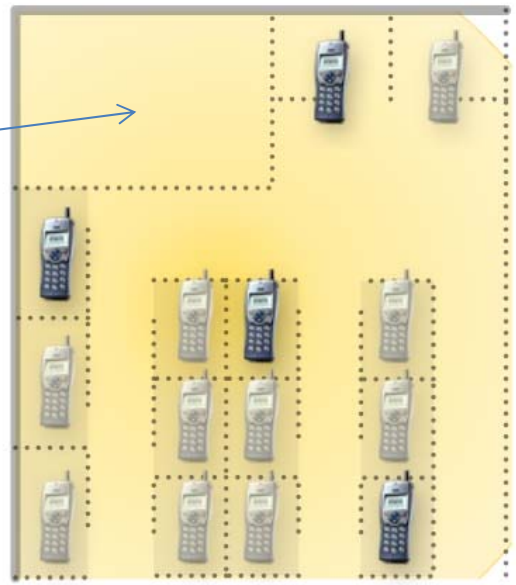
Client Density Example



Use a 3:1 ratio to determine how many phones are in an area vs. how many are in use.

Client Density Example

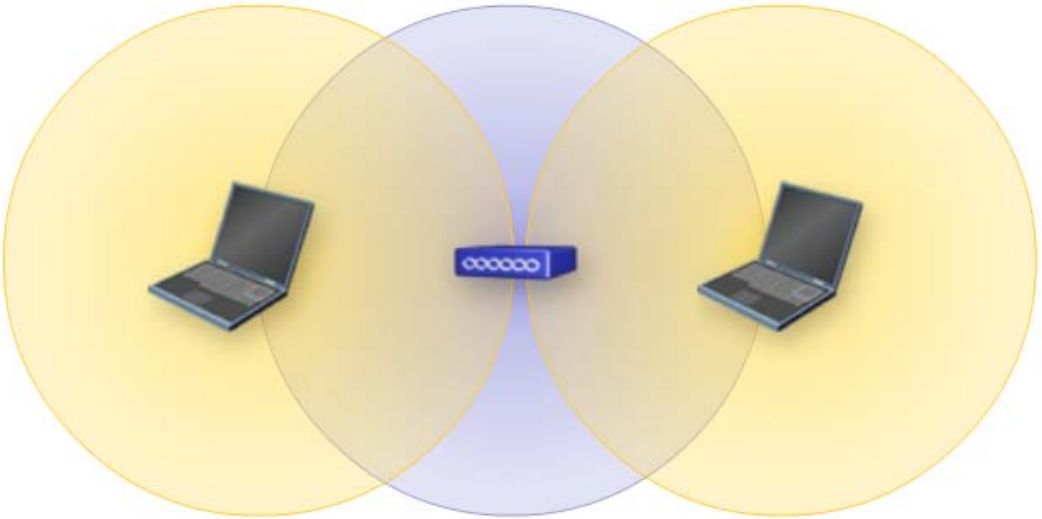




Recommended client density allows for up to 21 G.711 phones per cell.

14 phones does not exceed the limit.

Determining Cell Size



Cell Size is limited by the device with the veakest RF characteristics.

Cell size is determined by:

- Power.
- Antenna.
- Data rate.
- Frequency.
- Environment.

In general:

- A higher data rate means a smaller cell size.
- A higher frequency means a smaller cell size.
- More antenna gain means a larger cell size.
- Higher power means a larger cell size.
- RF interference in the environment means a smaller cell size.

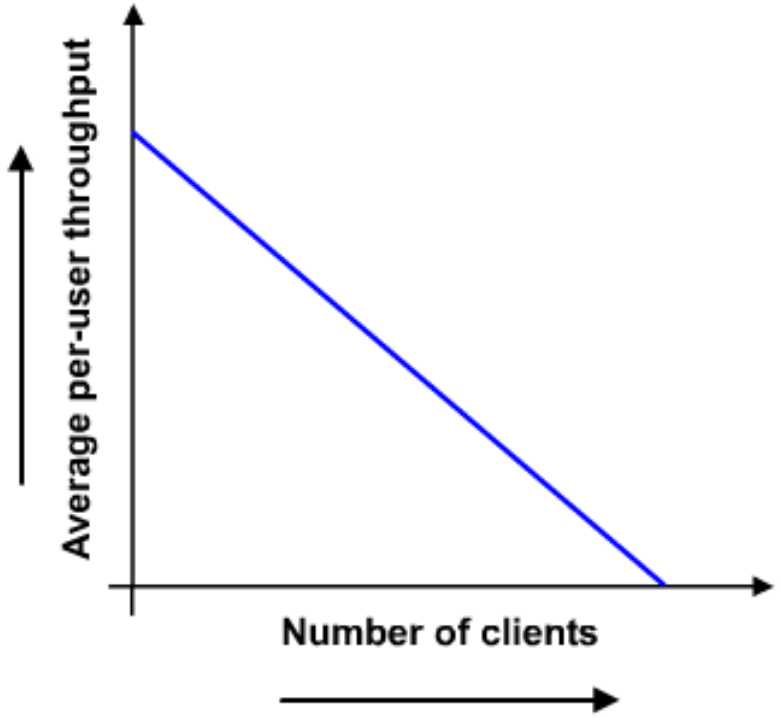
Low Latency Receiver Thresholds

Data Rate (Mbps)	RX Threshold (RT) (dBm)	Recommended Minimum RT (dBm)	RX Signal-to-Noise Ratio (S/N)	Recommended Minimum S/N
54	-71	-56	25	40
48	-72	-57	22	36
36	-73	-58	18	33
24	-77	-62	12	27
12/11	-82	-67	10	25
6/5.5	-89	-74	8	23
2	-91	-76	6	21
1	-94	-79	4	19

Determining Throughput

Throughput = data rate – protocol overhead

802.11a/b/g throughput = ~1/2 data rate
(without legacy support in mixed-mode operation)



To design a low latency WLAN:

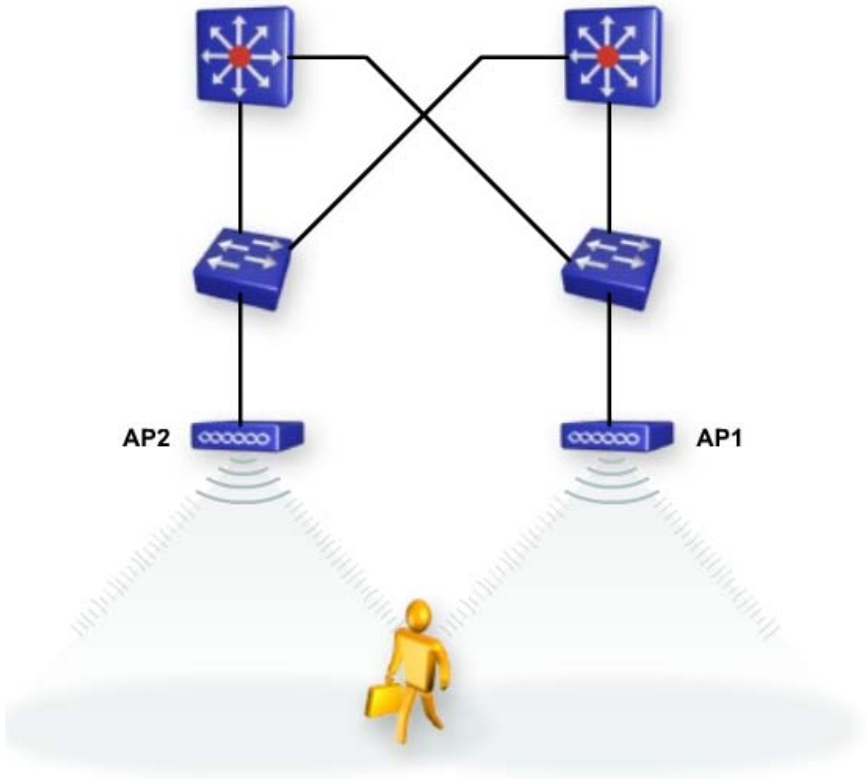
- Determine client type and 802.11 format.
- Determine throughput requirements and latency sensitivity.
- Determine the maximum number of concurrent clients.
- Determine the number of best-effort and active low latency clients.
- Cell density is determined for each technology separately.

Q/A

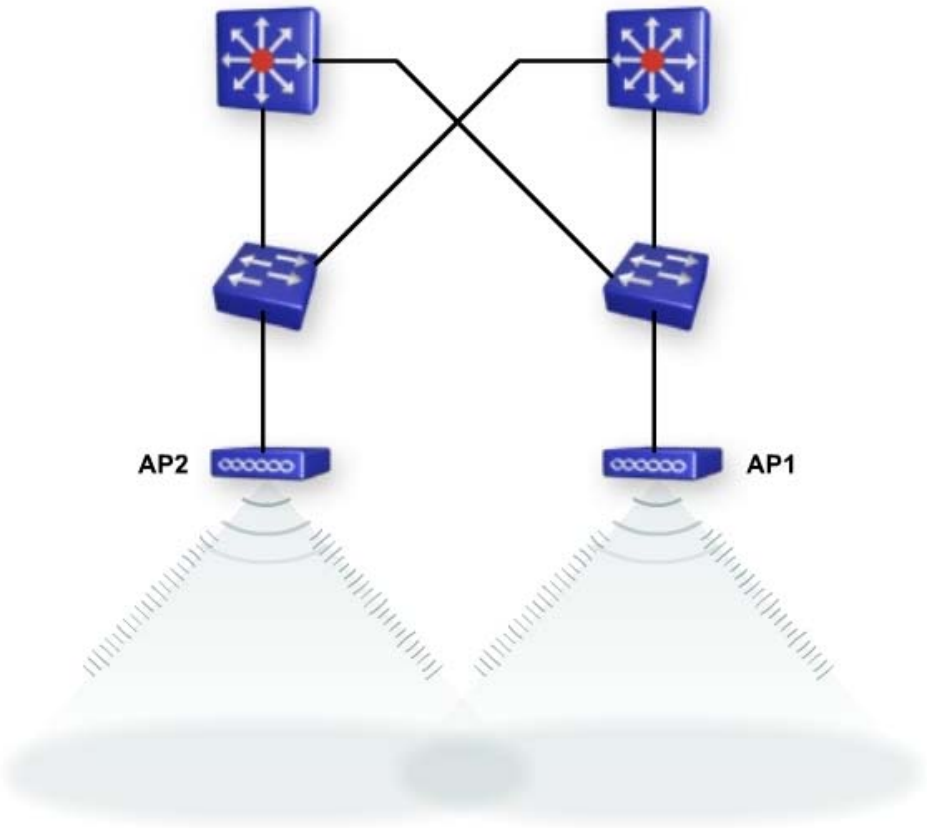
802.11b	22 Mbps
802.11g with b client	6 Mbps
802.11a	8 to 13 Mbps
802.11g without b client	25 Mbps

Roaming

Roaming is the ability to maintain network connectivity while moving from one access point to another.



Roaming Delay



Real-time applications require low delay for optimum quality.

VoIP WLAN Recommendations

In a voice over IP WLAN network, you should:

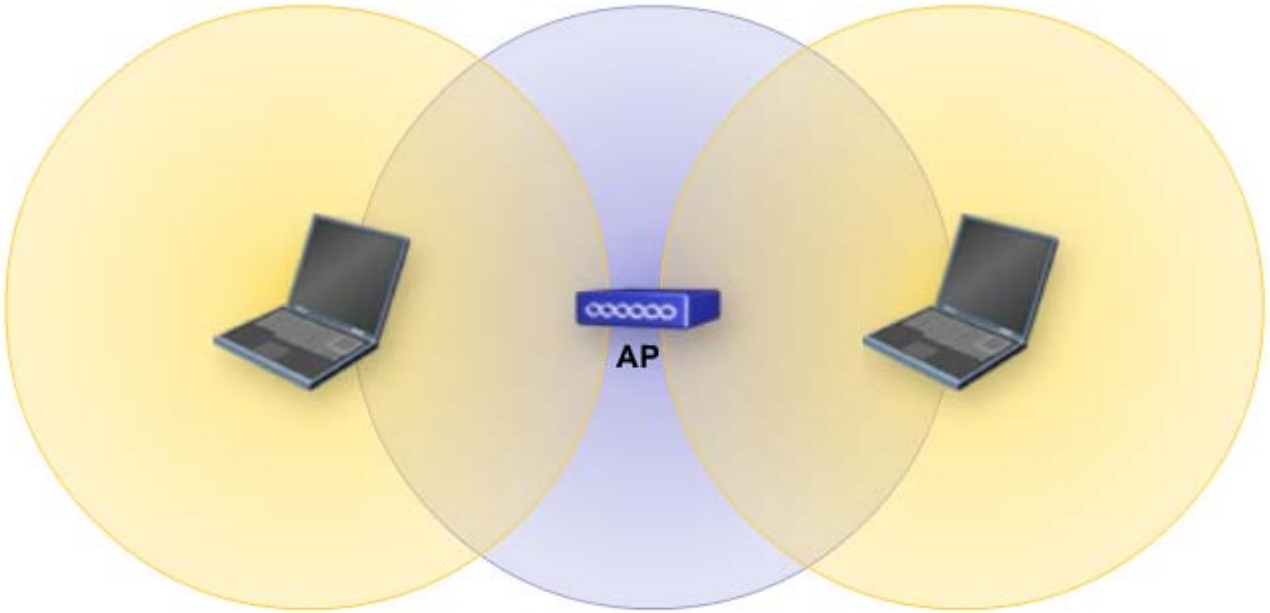
- Have no more than 450 to 600 phones per VLAN.
- Be sure not to cross building boundaries with a VLAN.
- Use Fast Secure Roaming when crossing a VLAN boundary.

Define WLAN infrastructure Devices

What's Covered

- Define 802.11 Access Points
- Types of Access Points
- Roles of Access Points
- What Is a Bridge?
- Roles of Bridges
- MRouters
- Wireless LAN Switch
- Wireless MESH Networks

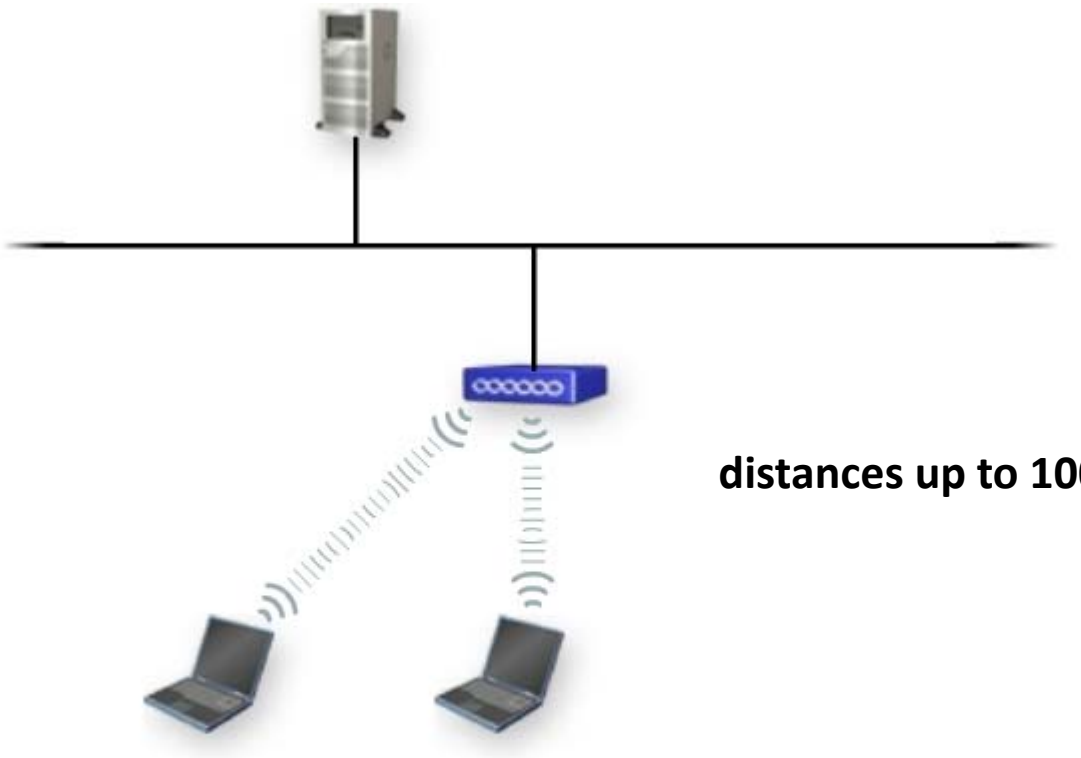
What is an Access Point?



Provide heightened security

Extend range of service

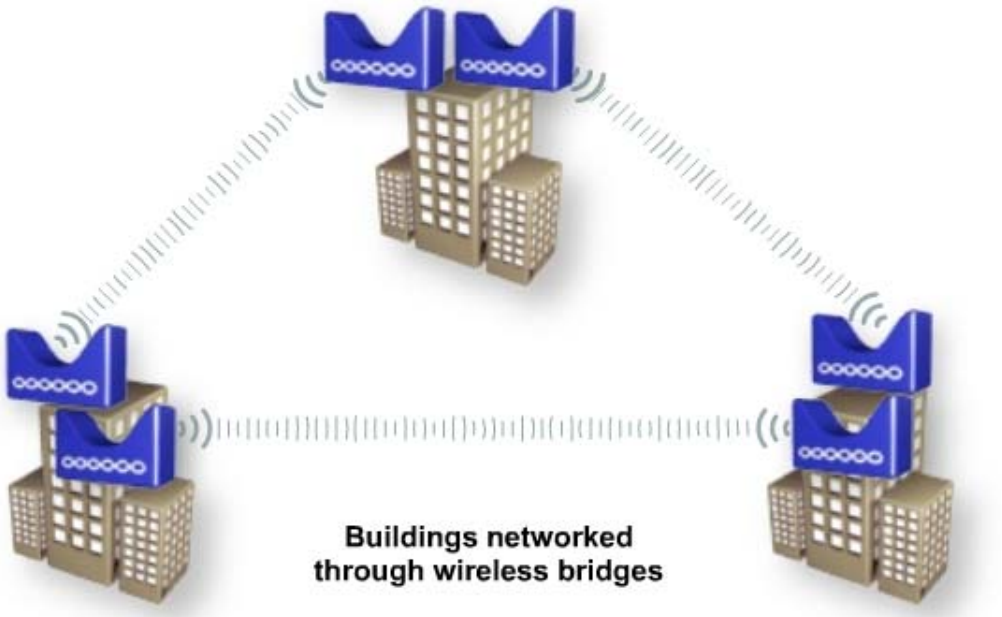
What does an Access Point do?



distances up to 1000 feet.

Provides access from anywhere in the facility

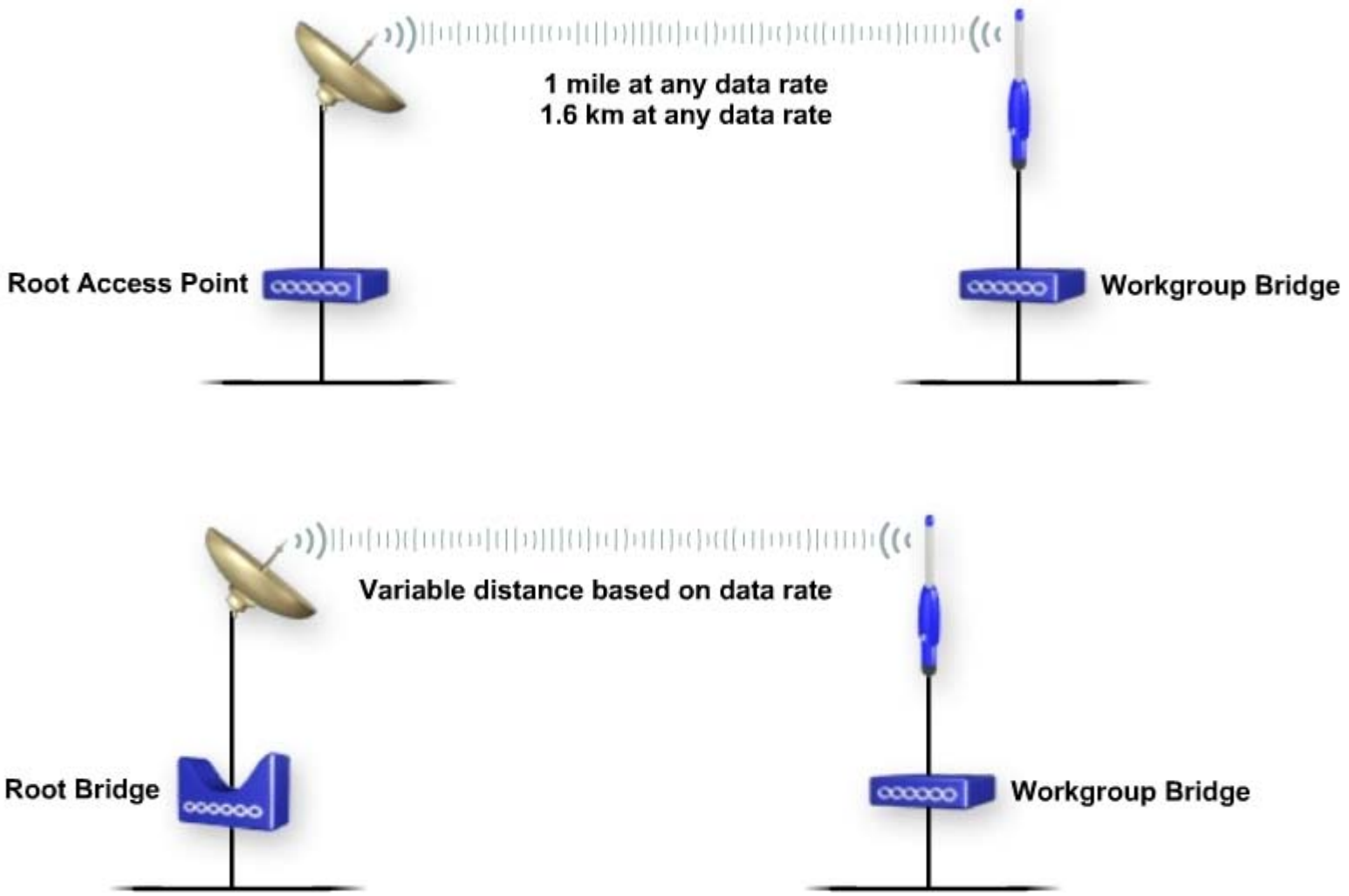
What is a LAN Bridge?



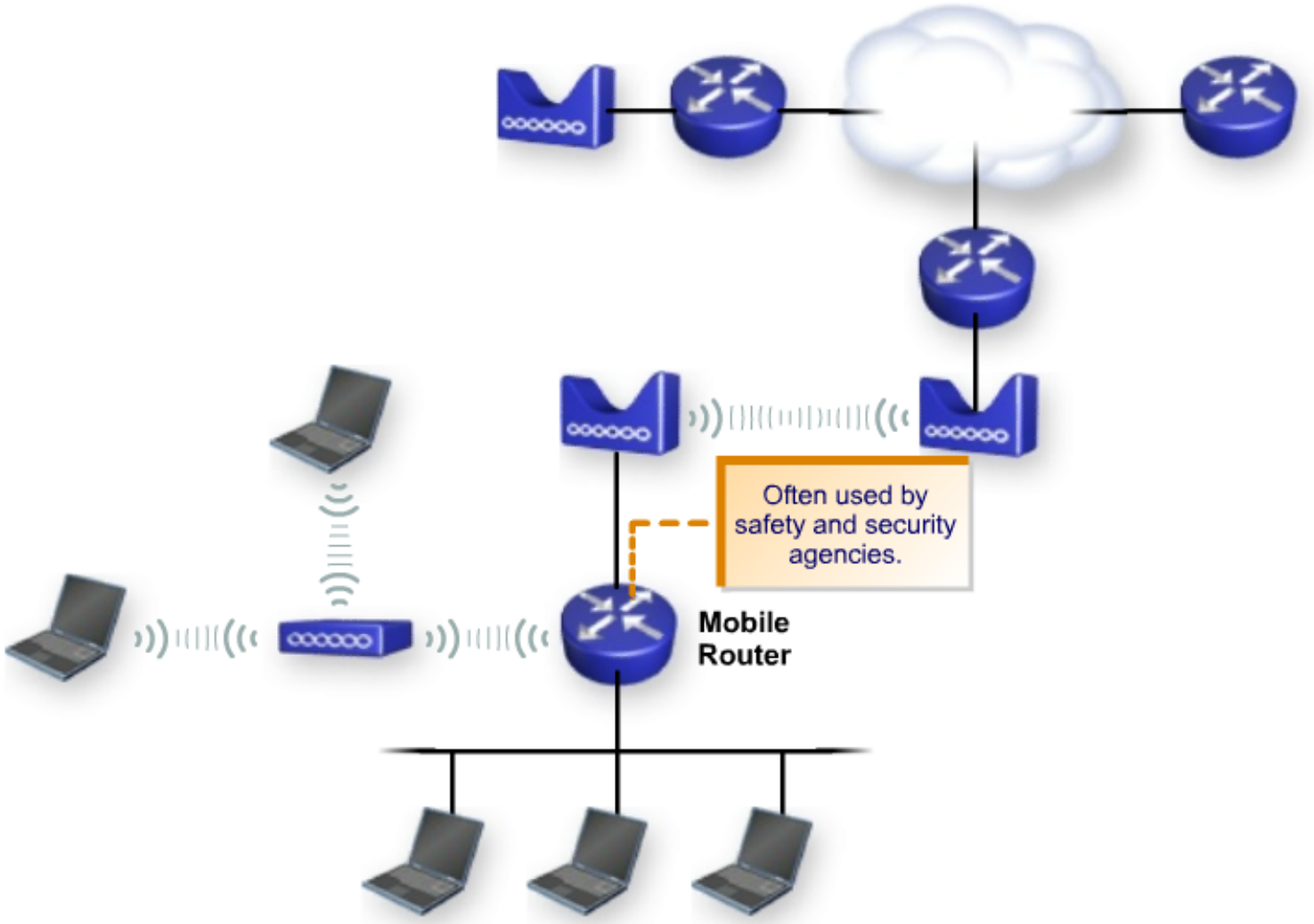
Cisco Aironet:

- 350 and 1310 Series can communicate with remote clients.
- 1400 Series is used for bridging only.
- Bridges have no routing capabilities.

Access Points vs. Bridges and Distance



Can use outdoor broadband wireless infrastructures across large areas

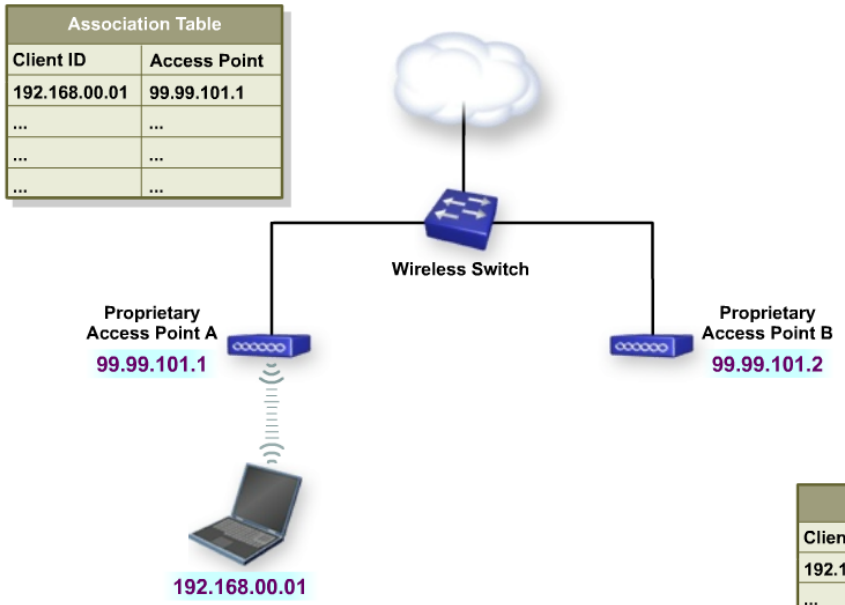


Wireless Router

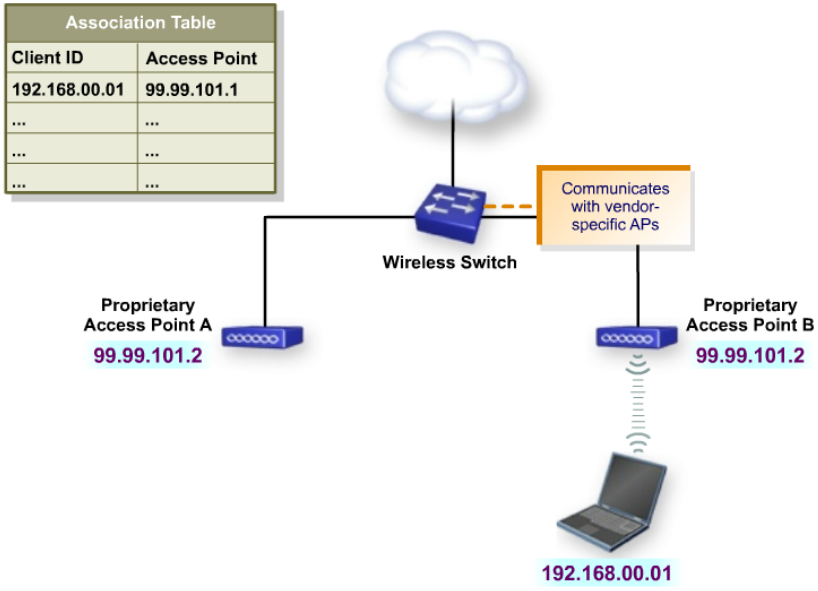
The Cisco 3200 Series router:

- Is a wireless mobile router with Cisco IOS software.
- Is ruggedized for harsh environments.
- Has a flexible form factor.
- Securely routes data, voice, and video.
- Permits transparent roaming.
- Is secure and scalable.

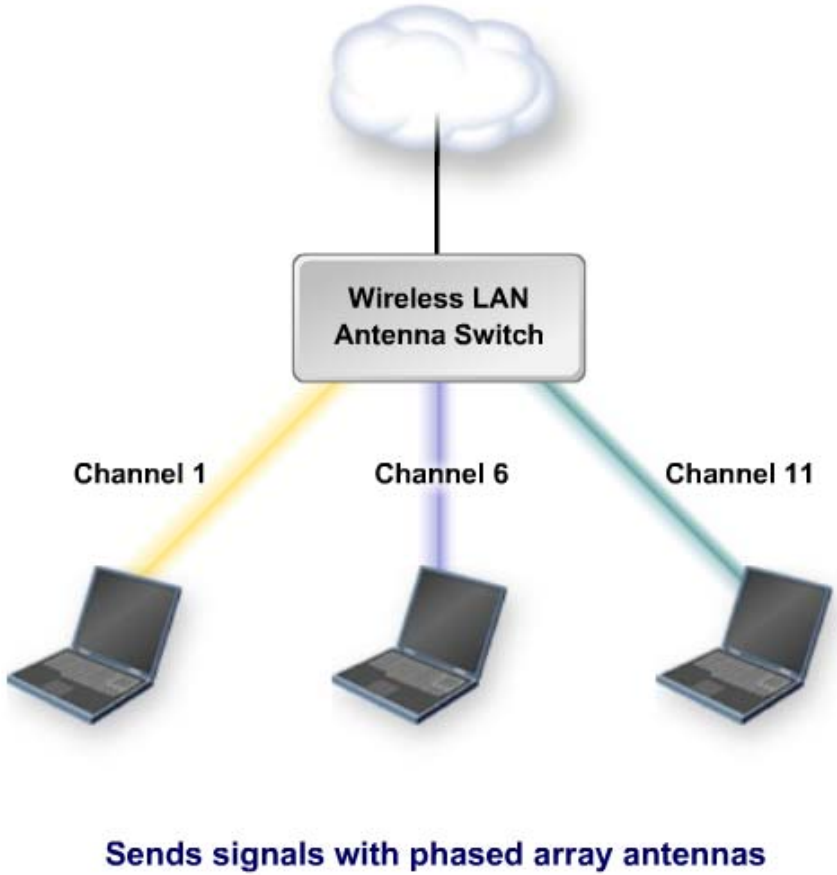
Wireless LAN Switch Functions



All of the 802.11 processing is done in the switch

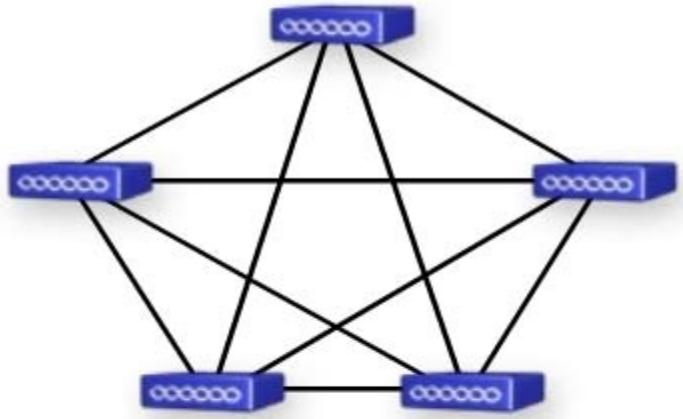


Components of a Wireless LAN Antenna Switch



A wireless LAN antenna switch combines the switching and RF functions into a single appliance.

Wireless MESH Networks



In a full-mesh network:

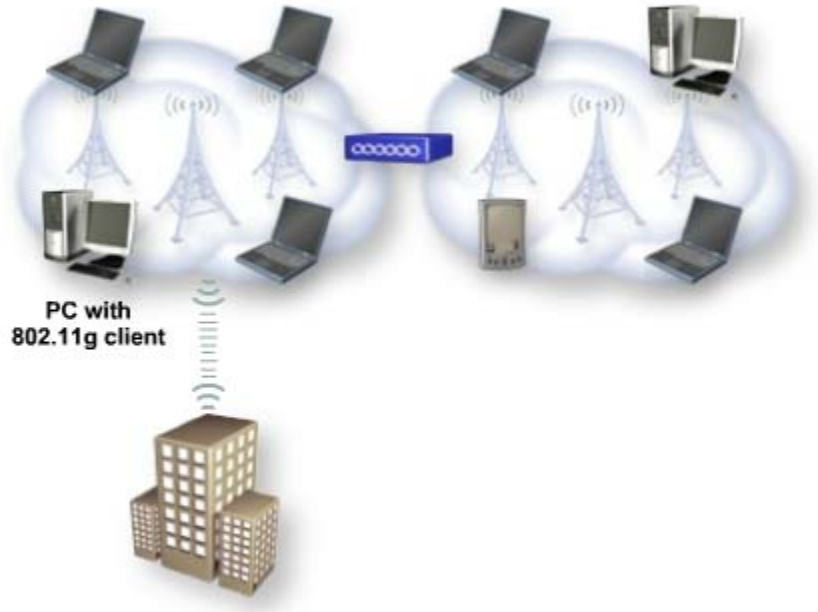
- All nodes have a connection to all other nodes.
- Protocols ensure:
  - Traffic does not loop.
  - Alternate paths are available for failover.

Identify types of Wireless client

What's Covered

- 802.11 Definition of a Station
- Various Radio Types
- Radio Card Converters and Adapters
- Cisco and Cisco Compatible Cards
- VoIP Wireless Clients
- Data Collection Terminals
- Embedded Radios

What is an 802.11 Station?



Contains a MAC and physical layer interface to the wireless medium

CardBus
(802.11a/b/g)

PCMCIA - PC
(8002.11b)

USB
(802.11a/b/g)

Compact Flash
(802.11b)

PCI
(802.11 a/b/g)

SD

MiniPCI
(802.11 b/g)

WLAN client devices:

- Are 802.11 stations.
- Can send or receive data via:
  - Infrastructure mode.
  - Ad hoc mode.

VoIP Wireless Client Characteristics

VoIP wireless clients:

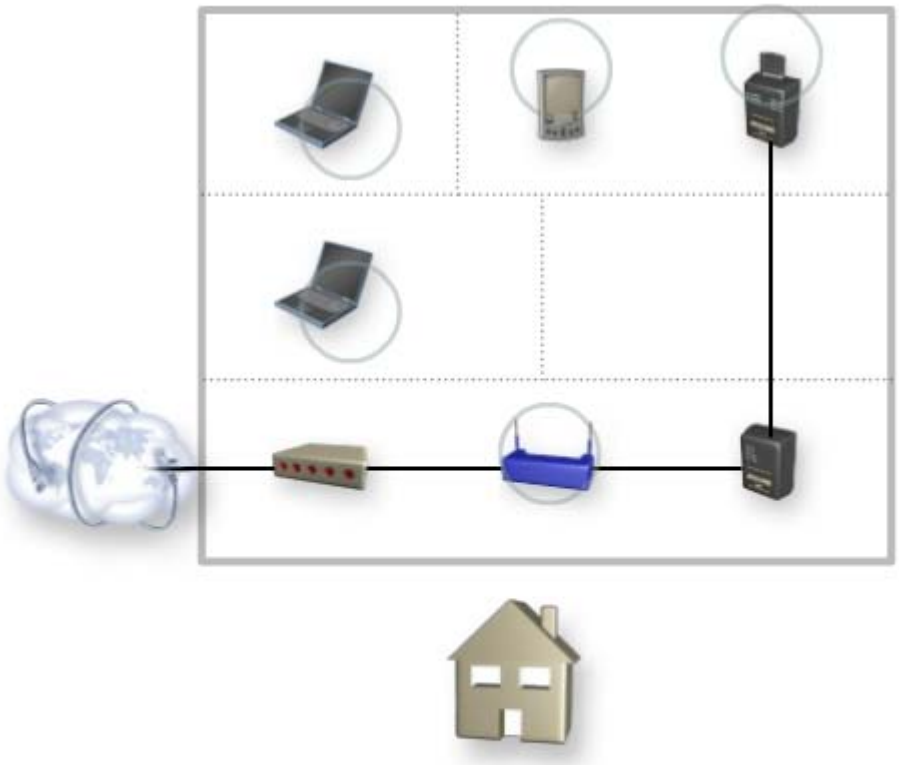
- Can be any WLAN client with VoIP functionality.
- Are often designed to look and work like a phone.
- Are typically 802.11b clients.

Data collection devices

Data collection devices:

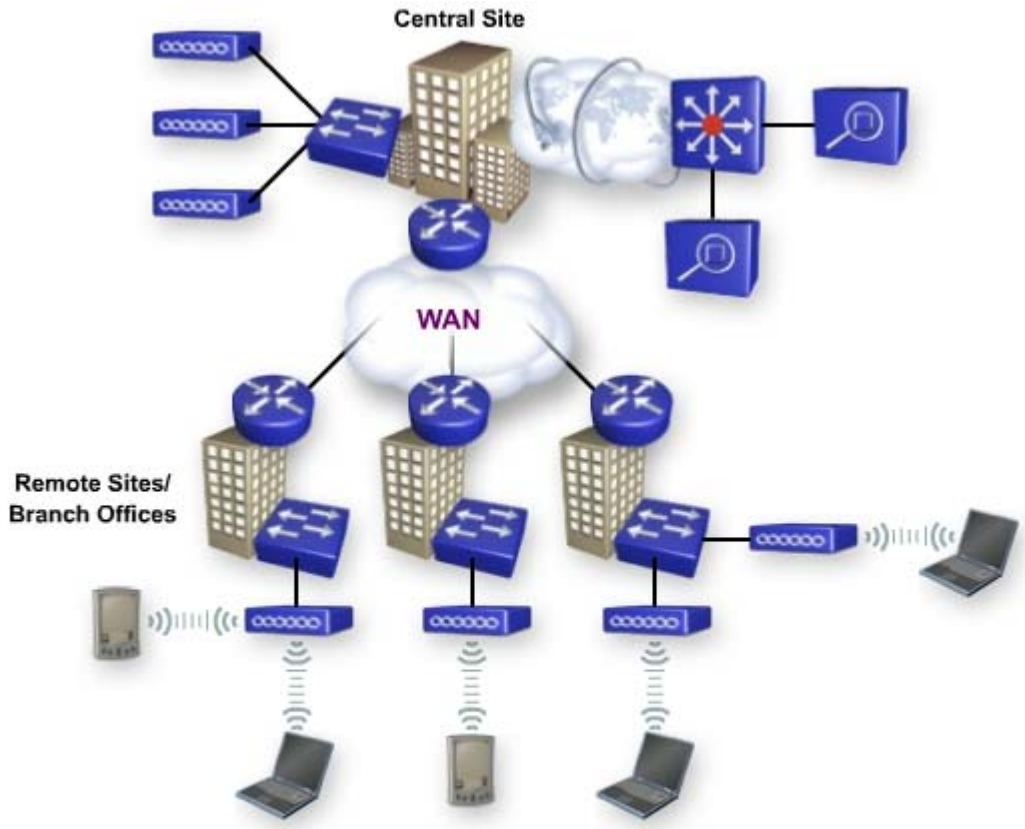
- Check the stock, receiving, and point of sale.
- Provide real-time updates to databases.
- Do not usually support 802.11a/g.
- Operate at 2-11 Mbps.

Definition of SOHO Devices



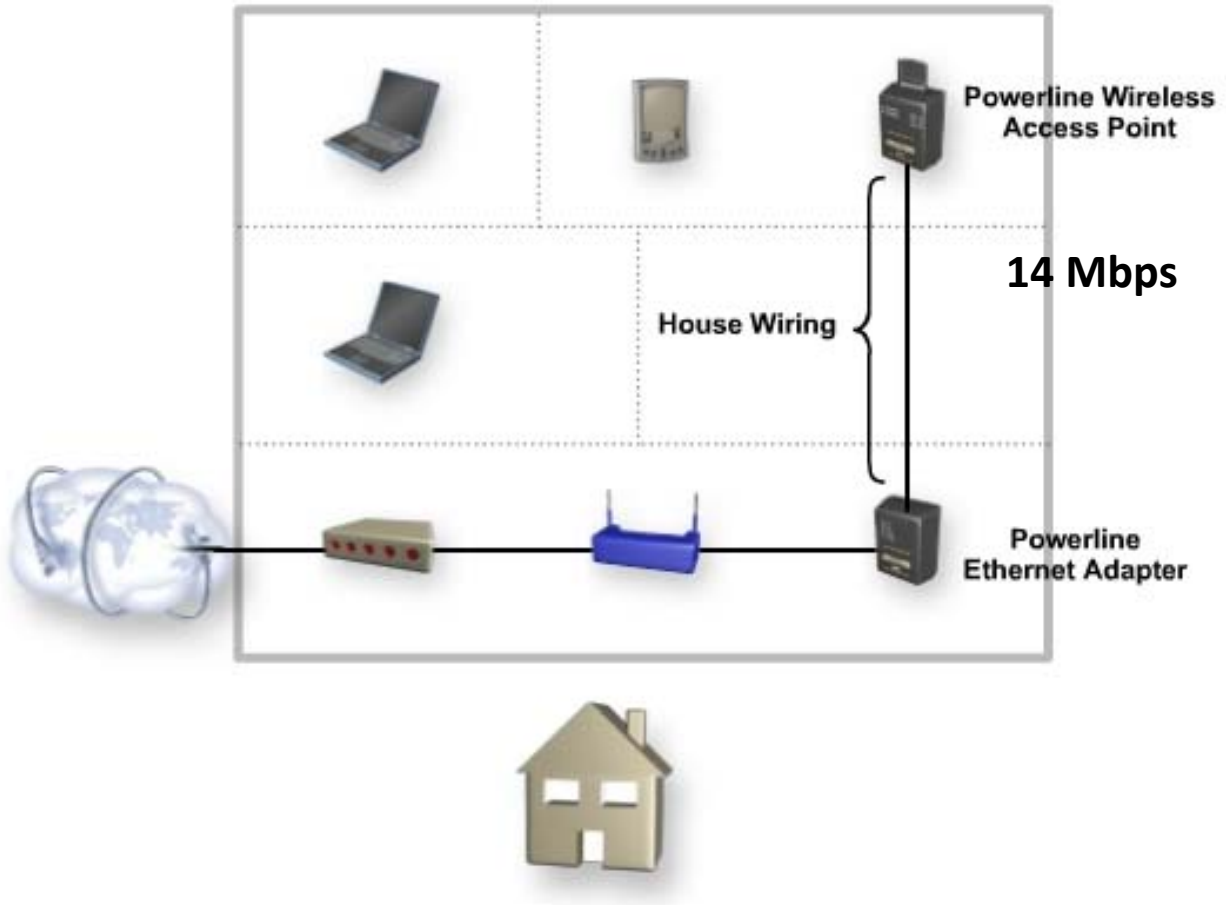
Easy to install and manage

Definition of enterprise Devices



Architecture for Voice, Video and Integrated Data

Powerline Networking



Enterprise Wireless Gateways

SOHO Wireless Routers