Understanding RF Fundamentals and the Radio Design of Wireless Networks

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Session Agenda - Objectives

- What is radio how did we get here?
- Basic 802.11 Radio Hardware & Terminology
- 802.11 Antenna Basics – Single & Diversity Antennas
- Interpreting antenna patterns – Cisco Richfield Facility
- Diversity, Multipath, 802.11n RF characteristics
- Choosing the right Access Point
What is radio?
How did we end up on these frequencies?
Basic understanding of Radio...

Battery is DC Direct Current

Typical home is AC Alternating Current

How fast the AC current goes is its “frequency”
AC is very low frequency 60 Hz (Cycles Per Second)

Radio waves are measured in kHz, MHz and GHz

The lower the frequency the physically longer the radio wave – Higher frequencies have much shorter waves as such take more power to move them greater distances. This is why 2.4 GHz goes further then 5 GHz (given same amount of RF power)

Popular Radio Frequencies:
AM Radio 1100 kHz (1.100 MHz)
Shortwave 3-30 MHz
FM Radio 88-108 MHz
Weather Radio 162.40 MHz
Cellular Phones 800-900 MHz
WiFi 802.11a 5 GHz
WiFi 802.11b/g 2.4 GHz

Vintage RF Transmitter
A radio needs a proper antenna

As the frequency goes up the radiating element gets smaller

Cisco antennas are identified by color
Blue indicates 5 GHz
Black indicates 2.4 GHz

Antennas are custom made for the frequency to be used. Some antennas have two elements to allow for both frequencies in one antenna housing

Omni-Directional antennas like the one on the left, radiate much like a raw light bulb would everywhere in all directions

Directional antennas like this “Patch” antenna radiate forward like placing tin foil behind the light bulb or tilting the lamp shade

Note: Same RF energy is used but results in greater range as its focused at the cost of other coverage areas
Complex Modulation Schemes

Radio technology has a lot in common with that old twisted pair phone line that started out at 300 baud and then quickly increased

In order to get faster data rates, (throughput) into the radio signal, complex modulation schemes as QPSK or 64 bit QAM is used.

Generally speaking, the faster the data rate the more powerful signal needs to be at the receiver to be decoded.

Take-away here is that 802.11n is a method of using special modulation techniques and *not* specific to a frequency like 2.4 or 5 GHz

802.11n can be used in either band

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<th>Number of spatial streams</th>
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Example of 802.11n Modulation Coding Schemes

QAM or Quadrature Amplitude Modulation is one of the fastest modulation types actually sending two signals that are out of phase with each other and then somehow “putting all the pieces back together” for even greater throughput.

This is one of the advantages of 802.11n
The radio spectrum in the US

Source US Department of Commerce
http://www.ntia.doc.gov/osmhome/allochrt.PDF
Wi-Fi Radio Spectrum

The first frequencies available for Wi-Fi use was in the 2.4 GHz range.

As Wi-Fi popularity and usage increased the FCC allocated additional spectrum in the 5 GHz band.

The spectrum we use today is also used by Amateur (Ham Radio) and other services such as radio location (radar).

There is more bandwidth in 5 GHz and mechanisms are in place to co-exist with services such as radar.

Wi-Fi is “unlicensed” so it doesn’t show up in the overall spectrum allocation as a service.

But it has beginnings in the ISM (industrial Scientific Medical) band where it was not desirable or profitable to license such short range devices.
Wi-Fi Radio Spectrum

The 2.4 GHz spectrum has only (three non-overlapping channels 1,6 and 11 (US)

There are plenty of channels in the 5 GHz spectrum and they do not overlap

2.4 GHz and 5 GHz are different portions of the radio band and usually require separate antennas

Most if not all 5 GHz devices also have support for 2.4 GHz however there are still many 2.4 GHz only devices.

Even today many portable devices in use are limited to 2.4 GHz only including newer devices but this is changing

802.11b/g is 2.4 GHz
802.11a is 5 GHz
802.11n (can be either band) 2.4 or 5 GHz
Basic 802.11 RF terminology and Hardware identification
Common RF terms

- **Attenuation** – a loss in force or intensity – As radio waves travel through objects or in media such as coaxial cable attenuation occurs.

- **BER** – Bit Error Rate - the fraction of bits transmitted that are received incorrectly.

- **Channel Bonding** – act of combining more than one channel for additional bandwidth

- **dBd** – abbreviation for the gain of an antenna system relative to a dipole

- **dBi** – abbreviation for the gain of an antenna system relative to an isotropic antenna

- **dBm** – decibels milliwatt -- abbreviation for the power ratio in decibels (dB) of the measured power referenced to one milliwatt of transmitted RF power.

- **Isotropic antenna** – theoretical “ideal” antenna used as a reference for expressing power in logarithmic form.

- **MRC** – Maximal Ratio Combining a method that combines signals from multiple antennas taking into account factors such as signal to noise ratio to decode the signal with the best possible Bit Error Rate.

- **Multipath** – refers to a reflected signal that combines with a true signal resulting in a weaker or some cases a stronger signal.

- **mW** – milliwatt a unit of power equal to one thousandth of a watt (usually converted to dBm)

- **Noise Floor** – The measure of the signal created from the sum of all the noise sources and unwanted signals appearing at the receiver. This can be adjacent signals, weak signals in the background that don’t go away, electrical noise from electromechanical devices etc.

- **Receiver Sensitivity** – The minimum received power needed to successfully decode a radio signal with an acceptable BER. This is usually expressed in a negative number depending on the data rate. For example the AP-1140 Access Point requires an RF strength of at least negative -91 dBm at 1 MB and an even higher strength higher RF power -79 dBm to decode 54 MB

- **Receiver Noise Figure** – The internal noise present in the receiver with no antenna present (thermal noise).

- **SNR** – **Signal to Noise Ratio** – The ratio of the transmitted power from the AP to the ambient (noise floor) energy present.

- **TxBF** – Transmit beam forming the ability to transmit independent and separately encoded data signals, so-called streams, from each of the multiple transmit antennas
Identifying RF connectors

RP-TNC Connector
Used on most Cisco Access Points

“N” Connector
Used on the 1520 Mesh and 1400 Bridge

“RP-SMA” Connector
Used on some Linksys Products

“SMA” Connector
“Pig tail” type cable assemblies
Identifying different cable types

- **LMR- 400 Foil & shield**

- **Leaky Coax**
  - shield cut away on one side

- **LMR – 1200**

- **½ inch Heliax (Hardline)**
This is a chart depicting different types of Times Microwave LMR Series coaxial cable.

Cisco uses Times Microwave cable and has standardized on two types: Cisco Low Loss (LMR-400) and Cisco Ultra Low Loss (LMR-600).

LMR-600 is recommended when longer cable distances are required.

Larger cables can be used but connectors are difficult to find and install.
Antenna Cables

LMR-400 is 3/8 inch Cisco Low Loss
LMR-600 is ½ inch Cisco Ultra Low Loss

Trivia: LMR Stands for Land Mobile Radio
Antenna Cables - Plenum

If the cable is ORANGE in color it is usually Plenum Rated.

Plenum is the air-handling space that is found above drop ceiling tiles or below floors.

Because of fire regulations this type of cable must burn with low smoke.

The 3 Ft white cable attached to most Cisco antennas is plenum rated.

Our outdoor cable (black) is not Plenum.

Plenum cable is more expensive.
802.11 Antenna basics
Antenna basics

- Antenna - a device which radiates and/or receives radio signals
- Antennas are usually designed to operate at a specific frequency. Wide-Band antennas can support additional frequencies but it’s a trade-off and usually not with the same type of performance.
- Antenna Gain is characterized using dBd or dBi
  Antenna gain can be measured in decibels against a reference antenna called a dipole and the unit of measure is dBd (d for dipole)
  Antenna gain can be measured in decibels against a computer modeled antenna called an “isotropic” dipole <ideal antenna> and the unit of measure is dBi (i for isotropic dipole) (computer modeled ideal antenna)
- WiFi antennas are typically rated in dBi.
  dBi is a HIGHER value (marketing folks like higher numbers)
  Conventional radio (Public safety) tend to use a dBd rating.
  To convert dBd to dBi simply add 2.14 so a 3 dBd = 5.14 dBi
  Again… dBd is decibel dipole, dBi is decibel isotropic.
How does a Omni-directional dipole radiate?

The radio signal leaves the center wire using the ground wire (shield) as a counterpoise to radiate in a 360 degree pattern.
Antenna theory (Dipole & Monopole)

A dipole does not require a ground plane as the bottom half is the ground (counterpoise).

A Monopole requires a ground plane – (conductive surface)

808 Ft Broadcast Monopole WSM 650 AM) Grand Ole Opry (erected in 1932)
Antenna theory (dipole & monopole)

Monopoles were added to our antenna line primarily for aesthetics and require a metal surface to radiate.

Do not use Monopoles on AP-1240 or Access Points without metal surface plane.
How does a directional antenna radiate?

Although you don’t get additional RF power with a directional antenna it does concentrate the available energy into a given direction resulting in greater range - much like bringing a flashlight into focus.

Also a receive benefit - by listening in a given direction, this can limit the reception of unwanted signals (interference) from other directions for better performance.

A dipole called the “driven element” is placed in front of other elements. This motivates the signal to go forward into a given direction for gain.

(inside view of the Cisco AIR-ANT1949 13.5 dBi Yagi)
Antennas identified by color

Blue indicates 5 GHz
Black indicates 2.4 GHz
Orange indicates Dual Band 2.4 & 5 GHz

Orange indicates Dual Band 2.4 & 5 GHz
AP-3600e antenna considerations

Orange stripe indicates 2.4 & 5 GHz dual band antenna

Do not use single band antennas unless you choose to use the AP-3600 as a single band device (disabling the other radio) otherwise use dual band antennas.
Patch Antenna a look inside

Patch antennas can have multiple radiating elements that combine for gain. Sometimes a metal plate is used behind the antenna as a reflector for more gain.

9.5 dBi Patch, AIR-ANT5195-R
### Most common **2.4 GHz** antennas for Access Points (single and diversity)

<table>
<thead>
<tr>
<th>Antenna</th>
<th>Description</th>
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<tbody>
<tr>
<td>AIR-ANT4941</td>
<td>2.2 dBi Swivel-mount Dipole; most popular mounts directly to radio, low gain, indoor</td>
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<tr>
<td>AIR-ANT5959</td>
<td>2 dBi Diversity Ceiling-mount Omni</td>
</tr>
<tr>
<td>AIR-ANT1729</td>
<td>6 dBi Wall-mount Patch</td>
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<tr>
<td>AIR-ANT1728</td>
<td>5.2 dBi Ceiling-mount Omni</td>
</tr>
<tr>
<td>AIR-ANT3549</td>
<td>9 dBi Wall-mount Patch</td>
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</tbody>
</table>
Most common **5 GHz** antennas for Access Points (single and diversity)

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</thead>
<tbody>
<tr>
<td>AIR-ANT5135D-R</td>
<td>3.5 dBi Omni-directional Antenna; mounts directly to radio, low gain, indoor</td>
</tr>
<tr>
<td>AIR-ANT5145V-R</td>
<td>4.5 dBi Omni-directional Diversity Antenna; unobtrusive, ceiling mount, low gain, indoor</td>
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<tr>
<td>AIR-ANT5160V-R</td>
<td>6 dBi Omni-directional Antenna; ceiling or mast mount, indoor/outdoor</td>
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<tr>
<td>AIR-ANT5170P-R</td>
<td>7 dBi Patch Diversity Antenna; directional, small profile, wall mount, indoor/outdoor</td>
</tr>
<tr>
<td>AIR-ANT5195-R</td>
<td>9.5 dBi Patch Antenna; directional, small profile, wall mount, indoor/outdoor</td>
</tr>
</tbody>
</table>
Understanding and interpreting antenna patterns
Understanding antenna patterns
Dipole (Omni-directional)

Low gain dipoles radiate everywhere think “light bulb”
Understanding antenna patterns
Monopole (Omni-Directional) MIMO

When three monopoles are next to each other – the radiating elements interact slightly with each other – The higher gain 4 dBi also changes elevation more compared to the lower gain 2.2 dBi Dipole.
Understanding antenna patterns
Patch (Directional)
Understanding antenna patterns
Patch (Higher Gain Directional)

Four element Patch Array
Understanding antenna patterns

Sector (Higher Gain Directional)

Elevation plane has nulls due to high gain 14 dBi

AIR-ANT2414S-R
14 dBi Sector 2.4 GHz
Understanding antenna patterns
Sector (Higher Gain Directional)

Elevation plane has nulls due to high gain 14 dBi but antenna was designed with “Null-Fill” meaning we scaled back the overall antenna gain so as to have less nulls or low signal spots on the ground.

AIR-ANT2414S-R
14 dBi Sector 2.4 GHz
Understanding multipath and diversity and some RF characteristics of 802.11n
Understanding Multipath
Multipath can change signal strength

As radio signals bounce off metal objects they often combine at the receiver.

This often results in either an improvement “constructive” or a “destructive” type of interference.

Note: Bluetooth type radios that “hop” across the entire band can reduce multipath interference by constantly changing the angles of multipath as the radio wave increases and decreases in size (as the frequency constantly changes) however throughput using these methods are very limited but multipath is less of a problem.
Understanding Multipath

Multipath reflections can cause distortion

As the radio waves bounce they can arrive at slightly different times and angles causing signal distortion and potential signal strength fading.

Different modulation schemes fair better – 802.11a/g uses a type of modulation based on symbols and is an improvement over the older modulation types used with 802.11b clients.

802.11n with more receivers can use destructive interference (multipath) as a benefit but it is best to reduce multipath conditions.
Antenna placement considerations

- AP antennas need placements that are away from reflective surfaces for best performance.
- Avoid metal support beams, lighting and other obstructions.
- When possible or practical to do so, always mount the Access Point (or remote antennas) as close to the actual users as you reasonably can.
- Avoid the temptation to hide the Access Point in crawl spaces or areas that compromise the ability to radiate well.
- Think of the Access Point as you would a light or sound source, would you really put a light there or a speaker there?

Never mount antennas near metal objects as it causes increased multipath and directionality.
Understanding Diversity (SISO)

802.11a/b/g diversity has just one radio

Non-802.11n diversity Access Points use two antennas sampling each antenna choosing the one with the least multi-path distortion

Cisco 802.11a/b/g Access Points start off favoring the right (primary antenna port) then if multi-path or packet retries occur it will sample the left port and switch to that antenna port if the signal is better.

Note: Diversity Antennas should always cover the same cell area
Understanding Diversity (MIMO)
MRC Maximal Ratio Combining (three radios)

- Receiver benefit as each antenna has a radio section
- MRC is done at Baseband using DSP techniques
- Multiple antennas and multiple RF sections are used in parallel
- The multiple copies of the received signal are corrected and combined at Baseband for maximum SNR (Signal to Noise) benefit
- This is a significant benefit over traditional 802.11a/b/g diversity where only one radio is used
Simple example of Beam-forming

By changing the timing (phase) of the two transmitters, you can create a stronger signal (constructive interference) so the client can hear it better.

Constructive = Good

Destructive = Bad

Sometimes this happens by accident (multi-path)

Client Link doesn’t only help at the edge of the network but by pushing the signal at the client - it permits easier decoding maintaining higher data rate connectivity (rate over range) on the downlink side.
Understanding 802.11 MIMO terminology

MIMO (Multiple-Input-Multiple-Output)

Some RF components of 802.11n include:

**MRC** – Maximal Ratio Combining a method that combines signals from multiple antennas taking into account factors such as signal to noise ratio to decode the signal with the best possible Bit Error Rate.

**TxBF** – Transmit beam forming – The ability to transmit independent and separately encoded data signals, so-called “streams” from each of the multiple transmit antennas.

**Channel Bonding** – Use of more than one frequency or channel for more bandwidth.

**Spatial Multiplexing** – A technique for boosting wireless bandwidth and range by taking advantage of multiplexing which is the ability within the radio chipset to send out information over two or more transmitters known as “spatial streams”.

Note: Cisco 802.11n Access Points utilize two transmitters and three receivers per radio module.
Technical Elements of 802.11n

- MIMO
- 40Mhz Channels
- Packet Aggregation
- Backward Compatibility
Aspects of 802.11n

- **MIMO (Multiple Input, Multiple Output)**
  - Performed by Transmitter (Talk Better)
  - Ensures Signal Received in Phase
  - Increases Receive Sensitivity
  - Works with non-MIMO and MIMO Clients

- **40Mhz Channels**

- **Packet Aggregation**

- **Backward Compatibility**

**Beam Forming**
- With Beam Forming
  - Transmissions Arrive in Phase, Increasing Signal Strength

- Without Beam Forming
  - Transmissions Arrive out of Phase and signal is weaker

**Maximal Ratio Combining**

**Spatial Multiplexing**
Aspects of 802.11n

MIMO (Multiple Input, Multiple Output)

Without MRC
Multiple Signals Sent; One Signal Chosen

With MRC
Multiple Signals Sent and Combined at the Receiver Increasing Fidelity

Performed by Receiver (Hear Better)
Combines Multiple Received Signals
Increases Receive Sensitivity
Works with non-MIMO and MIMO Clients

Beam Forming Maximal Ratio Combining Spatial Multiplexing
Aspects of 802.11n

MIMO (Multiple Input, Multiple Output)

Information Is Split and Transmitted on Multiple Streams

Transmitter and Receiver Participate
Concurrent Transmission on Same Channel
Increases Bandwidth
Requires MIMO Client

Beam Forming
Maximal Ratio Combining
Spatial Multiplexing
### Aspects of 802.11n

<table>
<thead>
<tr>
<th>MIMO</th>
<th>40Mhz Channels</th>
<th>Packet Aggregation</th>
<th>Backward Compatibility</th>
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#### 40Mhz Channels

**Moving from 2 to 4 Lanes**

40-MHz = 2 aggregated 20-MHz channels—takes advantage of the reserved channel space through bonding to gain more than double the data rate of two 20-MHz channels.
Aspects of 802.11n

Carpooling Is More Efficient Than Driving Alone

Without Packet Aggregation

802.11n Overhead

Data Unit Packet

Data Unit Packet

Data Unit Packet

With Packet Aggregation

802.11n Overhead

Data Unit Packet

Packet

Packet

Packet
Aspects of 802.11n

- MIMO
- 40Mhz Channels
- Packet Aggregation
- Backward Compatibility

Backward Compatibility

2.4GHz  11n Operates in Both Frequencies  5GHz

802.11ABG Clients Interoperate with 11n AND Experience Performance Improvements
Understanding MCS rates and Channel Bonding

40MHz 802.11n channel

Channel Bonding:
Wider channels means more bandwidth per AP

2.402 GHz 20 MHz channel 2.483 GHz

MCS rates 0-15 apply
Regardless of channel Bonding.

When you bond a channel
You have a control channel
You have a data (extension) Channel

Legacy clients use control Channel for communication
2.4 GHz, 40 MHz Bandwidths

### Tip:
Channel bonding in 2.4 GHz should be avoided in enterprise deployments use 5 GHz as there are no overlapping channels to worry about.
Example UNII-3 Channel Bonding

In 40-MHz you define the control channel this is the channel that is used for communication by Legacy .11a clients.

The Extension channel is the bonded channel that High Throughput “HT” 802.11n clients use in addition to the control channel for higher throughput as they send data on BOTH channels.
Channel Bonding - Subcarriers

802.11n uses both 20-MHz and 40-MHz channels.

The 40-MHz channels in 802.11n are two adjacent 20-MHz channels, bonded together.

When using the 40-MHz bonded channel, 802.11n takes advantage of the fact that each 20-MHz channel has a small amount of the channel that is reserved at the top and bottom, to reduce interference in those adjacent channels.

When using 40-MHz channels, the top of the lower channel and the bottom of the upper channel don't have to be reserved to avoid interference. These small parts of the channel can now be used to carry information. By using the two 20-MHz channels more efficiently in this way, 802.11n achieves slightly more than doubling the data rate when moving from 20-MHz to 40-MHz channels.
Understanding Guard Interval

The guard interval that is part of each OFDM symbol is a period of time that is used to minimize inter-symbol interference.

This type of interference is caused in multipath environments when the beginning of a new symbol arrives at the receiver before the end of the last symbol is done.

Default mode for 802.11n is 800 nanoseconds. If you set a shorter interval it will go back to long in the event retries occur.
### MCS index of 802.11n rates

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<td>43 1/3</td>
<td>90</td>
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<td></td>
<td></td>
<td>144 4/9</td>
<td>300</td>
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</table>
### 802.11n Operation

Throughput improves when all things come together

<table>
<thead>
<tr>
<th>Scenario</th>
<th>AP Configuration</th>
<th>Client Configuration</th>
<th>Throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>802.11a/g AP (non-MIMO)</td>
<td>802.11a/g client (non-MIMO)</td>
<td>24 Mbps</td>
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<tr>
<td>2</td>
<td>802.11n AP (MIMO)</td>
<td>802.11a/g client (non-MIMO)</td>
<td>54 Mbps</td>
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<tr>
<td>3</td>
<td>802.11n AP (MIMO)</td>
<td>802.11n client (MIMO)</td>
<td>300 Mbps</td>
</tr>
</tbody>
</table>

- MRC
- TxBF
- Spatial Multiplexing

- Channel Bonding
Access Point Models and Features
Cisco Indoor .11n Access Point Positioning

Teleworker

Business-Ready Wireless

Rich Media

Mission-Critical

OfficeExtend AP 600

AP 1040

AP 3500
AP 1260
AP 1140

802.11n WiFi
# Cisco Aironet 802.11n Access Point Feature Comparison Matrix

<table>
<thead>
<tr>
<th>Feature</th>
<th>3600 Series</th>
<th>3500 Series</th>
<th>1260 Series</th>
<th>1140 Series</th>
<th>1040 Series</th>
<th>600 Series</th>
<th>1550 Series</th>
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<tbody>
<tr>
<td><strong>Data Rate</strong></td>
<td>450 Mbps</td>
<td>300 Mbps</td>
<td>300 Mbps</td>
<td>300 Mbps</td>
<td>300 Mbps</td>
<td>300 Mbps</td>
<td>300 Mbps</td>
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<tr>
<td><strong>Radio Design</strong></td>
<td>4X4:3</td>
<td>2X3:2</td>
<td>2x3:2</td>
<td>2x3:2</td>
<td>2X2:2</td>
<td>2X2:2</td>
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<td><strong>CleanAir</strong></td>
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<td>✔</td>
<td></td>
<td></td>
<td></td>
<td>✔</td>
<td></td>
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<td><strong>ClientLink</strong></td>
<td>ClientLink 2.0</td>
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<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
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<td><strong>BandSelect</strong></td>
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<td>✔</td>
<td>✔</td>
<td>✔</td>
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<td><strong>VideoStream</strong></td>
<td>✔</td>
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<td>✔</td>
<td>✔</td>
<td>✔</td>
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<td><strong>Rogue AP Detection</strong></td>
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<td>✔</td>
<td>✔</td>
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<td><strong>Wireless Mesh</strong></td>
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<td>✔</td>
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<td><strong>Data Uplink (Mbps)</strong></td>
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<td>802.3af</td>
<td>802.3af</td>
<td>802.3af</td>
<td>802.3af</td>
<td>100 to 240 VAC, 50-60 Hz</td>
<td>By Model Number: See AP AAG</td>
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<tr>
<td><strong>Temperature Range in Celsius</strong></td>
<td>(i) -0 to 40°C (e) -20 to 55°C</td>
<td>(i) -0 to 40°C (e) -20 to 55°C</td>
<td>-20 to 55°C</td>
<td>-0 to 40°C</td>
<td>-0 to 40°C</td>
<td>0 to 40°C</td>
<td>-40 to 131°C</td>
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* Planned for 7.2 Release
### New AP-3600 supported HT Data Rates

<table>
<thead>
<tr>
<th>MCS</th>
<th>Coding</th>
<th>Modulation</th>
<th>Streams</th>
<th>Signal BW = 20 MHz</th>
<th>40 MHz</th>
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<td>64-QAM</td>
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</tbody>
</table>

**New**

3 Spatial Stream MCS Rates
Integrated antenna? – External antenna?

Carpeted areas

Integrated antenna versions are designed for mounting on a ceiling (carpeted areas) where aesthetics is a primary concern.

Rugged areas

Use for industrial applications where external or directional antennas are desired and or applications requiring higher temperature ranges.
When to use integrated antennas

- When there is no requirement for directional antennas and the unit will ceiling mounted
- Areas such as enterprise carpeted office environments where aesthetics are important
- When the temperature range will not exceed 0 to +40°C
When to use external antennas

Reasons to consider deploying a rugged AP

- When Omni-directional coverage is not desired or greater range is needed

- The environment requires a more industrial strength AP with a higher temperature rating of -20 to +55 C (carpeted is 0 to +40 C)

- The device is going to be placed in a NEMA enclosure and the antennas need to be extended

- You have a desire to extend coverage in two different areas with each radio servicing an independent area - for example 2.4 GHz in the parking lot and 5 GHz indoors

- Requirement for outdoor or greater range Bridging application (aiOS version)

- Requirement for WGB or mobility application where the device is in the vehicle but antennas need to be mounted external

Rugged AP in ceiling enclosure
When to use AP-1240 and AP-1250

Reasons to consider the AP-1240 or AP-1250

- The AP-1240 and AP-1250 support higher gain antennas - a benefit only if a high gain antenna already exists or is required
- Higher gain (up to 10 dBi) can improve WGB and Bridging distances
- Recommend the AP-1240 if there is no requirement for 802.11n support or the infrastructure is older 10/100 ports
- AP-1240 will work with older Cisco PoE switches (Cisco proprietary power)
- AP-1240 draws less power so better for solar applications
- AP-1240 supports Cisco Fiber injectors
- Tip: Higher than 10 dBi antenna gains are supported with the 1300 Series Bridge/AP
Which 802.11n Access Point is right?

- AP-3500i and AP-3500e have the very latest Cisco features such as **Clean Air** Cisco’s spectrum intelligence.

- AP-1140 and AP-1260 are of similar design **less Cisco Clean Air features** and can also run autonomous code (aiOS) for stand alone or Workgroup Bridge applications. Note: 3500 Series does not support the older aiOS modes.

- All the Access Points were designed to have similar coverage for ease of deployment.
## Coverage Comparison – 5GHz

<table>
<thead>
<tr>
<th></th>
<th>AP1140</th>
<th>AP1250</th>
<th>AP3500i</th>
<th>AP3500e</th>
</tr>
</thead>
</table>

![Coverage Map AP1140](image1)

![Coverage Map AP1250](image2)

![Coverage Map AP3500i](image3)

![Coverage Map AP3500e](image4)
Installation and deployment considerations
Effective Frequency Use 5GHz - 2.4GHz

Create a 5GHz Strategy

- 5 GHz Recommended for 802.11n
  More available spectrum—greater number of channels
  Benefits from 40MHz channels, although 20MHz still works well
  Many 11n devices only support 40MHz in 5GHz, although Cisco supports 40MHz in both 2.4GHz and 5GHz

- 2.4 GHz still benefits from MIMO and packet aggregation

![Diagram showing 2.4GHz 20MHz Channels and 5GHz 40MHz Channels]

Ideal for legacy apps (handhelds, scanners, med. applications)
5GHz Dynamic Frequency Selection

When Radar Is Present

APs Shift Channels—Results in Lower Available Channels and Loss of UNI 2 and UNI 2e Bands

<table>
<thead>
<tr>
<th>Available 40MHz Channels</th>
<th>No DFS Support</th>
<th>DFS Support</th>
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</thead>
<tbody>
<tr>
<td>4</td>
<td>11</td>
<td></td>
</tr>
</tbody>
</table>

5 GHz Frequency

- UNI 1
- UNI 2
- UNI 2 Ext.
- UNI 3
DFS and Available Bandwidth

- Full DFS support is required for complete use of channels in 5GHz
- Limited DFS support directly impacts available bandwidth
- Limited bandwidth restricts application support and negates investment in 11n

### Available Channels per Region

<table>
<thead>
<tr>
<th>Available Channels per Region</th>
<th>Theoretical</th>
<th>Cisco</th>
<th>Meru/Aruba</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11n 5GHz 20MHz</td>
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<td>21</td>
<td>8</td>
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<tr>
<td>11n 5GHz 40MHz</td>
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<td>4</td>
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<tr>
<td>Europe</td>
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<tr>
<td>11n 5GHz 20MHz</td>
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<td>4</td>
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<tr>
<td>11n 5GHz 40MHz</td>
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<td>9</td>
<td>2</td>
</tr>
</tbody>
</table>

* 40 MHz Channels in 5GHz

![Available Bandwidth in 5GHz for 11n Chart](chart.png)
Wall mounting which model to choose?

Wall mounting is acceptable for small deployments such as hotspots, kiosks, etc but radiation is better on ceiling.

Best for enterprise deployments as coverage is more uniform especially for advanced features such as voice and location.

AP-1140 and AP-3500i

AP-1260 and AP-3500e
Aironet 1140 / 3500e (style case)
Third party wall mount option is available

This optional wall mount best positions the Access Point dipoles for optimum performance – Recommended for Voice applications If you MUST mount the Access Point on a wall.

Ceiling is a better location as the AP will not be disturbed or consider using patch antennas on wall installations

Oberon model 1029-00 is a right angle mount
http://www.oberonwireless.com/WebDocs/Model1029-00_Spec_Sheet.pdf
Access Points (Internal Antenna Models)

Designed Primarily for Ceiling (carpeted) Installations

Access Point has six integrated 802.11n MIMO antennas

4 dBi @ 2.4 GHz
3 dBi @ 5 GHz

Note: Metal chassis and antennas were designed to benefit ceiling installations as the signal propagates downward in a 360 degree pattern for best performance
Antenna Patterns
Azimuth and Elevation Patterns for 2.4 GHz & 5 GHz

2.4 GHz Azimuth

2.4 GHz Elevation

5 GHz Azimuth

5 GHz Elevation
What about mounting options?

Different mounting options for ceiling APs

Cisco has options to mount to most ceiling rails and directly into the tile for a more elegant look.

Locking enclosures and different color plastic “skins” available from third party sources such as [www.oberonwireless.com](http://www.oberonwireless.com) [www.terrawave.com](http://www.terrawave.com)
Clips adapt Rail to “T” bracket.
Attaching to fine line ceiling rails

If the ceiling rail is not wide enough or too recessed for the “T” rail this can be addressed using the optional clips

Part Number for ceiling clips is AIR-ACC-CLIP-20=
This item is packaged in 20 pieces for 10 Access Points
AP Placement in Plenum Areas

- When placing the Access Point above the ceiling tiles (Plenum area) Cisco recommends using rugged Access Points with antennas mounted below the Plenum area whenever possible.

- Cisco antennas have cables that are plenum rated so the antenna can be placed below the Plenum with cable extending into the plenum.

- If there is a hard requirement to mount carpeted or rugged Access Points using dipoles above the ceiling – This can be done however uniform RF coverage becomes more challenging especially if there are metal obstructions in the ceiling.

- Tip: Try to use rugged Access Points and locate the antennas below the ceiling whenever possible.
Installation above the ceiling tiles

An optional rail above the tiles may be used

Note: The AP should be as close to the tile as practical

AP bracket supports this optional T-bar box hanger item 2 (not supplied) Such as the Erico Caddy 512 or B-Line BA12.
Installation above the ceiling tiles
Mount AP close to the tiles and away from objects

Try to find open ceiling areas away from metal obstructions (use common sense)

Installing Access Points above the ceiling tiles should be done only when mounting below the ceiling is not an option.

Such mounting methods can be problematic for advanced RF features such as voice and location as they depend on uniform coverage.

Tip: Mount antennas either below ceiling tile or the AP as close to the inside of the tile as possible
Plenum installs that went wrong
Yes it happens and when it does its bad…

When a dipole is mounted against a metal object you lose all Omni-directional properties.

It is now essentially a directional patch suffering from acute multipath distortion problems.

Add to that the metal pipes and it is a wonder it works at all.

Tip: Access Points like light sources should be near the users – Perhaps the AP is here for “Pipe Fitter Connectivity”?

Dipole antennas up against a metal box and large metal pipes Multipath everywhere
Plenum installs that went wrong
Huh?? You mean it gets worse?
Installations that went wrong

Ceiling mount AP up against pipe hmmm

A little ICE to keep the packets cool
Installations that went wrong

Patch antenna shooting across a metal fence

Mount the box and antennas downward Please
Installations that went wrong

Sure glad this model runs a bit on the warm side --- “Chirp Chirp”

Mount the box and antennas downward Please
Minimize the Impact of Multipath

- Temptation is to mount on beams or ceiling rails
- This reflects transmitted as well as received packets
- Dramatic reduction in SNR due to high-strength, multipath signals

Minimize Reflections When Choosing Locations