TOMORROW starts here.
Fundamentals of RF and WLAN building blocks

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Enterprise Business Group EMEAR
A good wireless network starts with a solid understanding of Radio Frequency coverage.

During this session we will talk about the principles that govern 802.11 protocols, including the new 802.11ac Gigabit WiFi. We will discuss antenna placement, antenna patterns and the importance of performing a site survey. Finally we will have an overview of the latest products available to build a WLAN network and the differences between APs.
Fundamentals of RF
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 50-60 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, and as such, it takes more power to move them greater distances.
This is why 2.4 GHz goes further vs. 5 GHz (given same amount of RF power).

Popular Radio Frequencies:
AM Radio 520-1610 KHz
Shortwave 3-30 MHz
FM Radio 88 to 108 MHz
Aviation 108-121 MHz
Weather Radio 162.40 MHz
GSM Phones 900 & 1800 MHz
DECT Phones 1900 MHz
Wi-Fi 802.11b/g/n 2.4 GHz
Wi-Fi 802.11a/n 5 GHz

Spark transmitter
Wi-Fi Radio Spectrum

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

As Wi-Fi popularity and usage increased, the regulatory bodies 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 with mechanisms in place to co-exist with licensed services such as (RADAR) RA dio D etection A nd R anging using (DFS) D ynamic F requency S election (method of automatic channel selection).

**Wi-Fi is an “unlicensed” service**

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

Even today, many portable devices in use are limited to 2.4 GHz only, including newer devices, but this is changing as newer 802.11ac (5-GHz) devices emerge.

**802.11b/g is 2.4 GHz**
**802.11a is 5 GHz**
**802.11n (can be either band) 2.4 or 5 GHz**
**802.11ac is 5GHz**

The 2.4 GHz spectrum in the US has 3 non-overlapping channels 1, 6 and 11.

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.
Wi-Fi Radio Spectrum 2.4 GHz

4 non-overlapping channels? NO
Wi-Fi Radio Spectrum 5 GHz Channels

Note: 5 GHz channels do not have the severe overlap that 2.4 GHz channels have but they use DFS to enable sharing of the band.
Example: ETSI Lower Band 5-GHz 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 “HT” High Throughput “802.11n clients use in addition to the control channel for higher throughput as they send data on BOTH channels
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 the signal needs to be at the receiver end to be properly decoded.

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

High-density modulation schemes such as 64-QAM "Quadrature Amplitude Modulation" is used by 802.11n to get additional throughput higher than what is found in 802.11a/b/g. This is one of the advantages of 802.11n.

Note: Newer 802.11ac modes can use up to 256-QAM.

802.11n can be used in either band.
Antenna Basics
Antenna Basics

- Antenna - a device which radiates and/or receives radio signals
- Antennas are usually designed to operate at a specific frequency
- Some antennas have more than one radiating element (example Dual Band)
- 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 the “i” is for isotropic dipole which is a computer modeled “perfect” 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
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.
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 (erected in 1932)
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.

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 in a given direction for gain.

(Inside view of the Cisco AIR-ANT1949 - 13.5 dBi Yagi)
Antennas Identified by Color

Cisco Antenna Color Coding

Black indicates 2.4 GHz

Blue indicates 5 GHz

Orange indicates 2.4 & 5 GHz
(used on AP-1600, 2600, 3600, & 3700)

Cisco antennas & cables are color coded – Black or no markings indicate 2.4 GHz
Identifying RF Connectors

**RP-TNC Connector**
Used on most Cisco Access Points

**“N” Connector**
Used on the 15xx Mesh and outdoor APs

**“RP-SMA” Connector**
Used on some Linksys Products

**“SMA” Connector**
“Pig tail” type cable assemblies
Most Common 802.11n Antennas
Indoor Access Points (1262 and 3502e) <First Generation AP’s>

These are **Single Radiating Element** antennas designed for Access Points that have **single band 2.4 or 5 GHz connectors** (black or blue color)

<table>
<thead>
<tr>
<th>Product ID</th>
<th>Description</th>
<th>Gain</th>
</tr>
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<tbody>
<tr>
<td>AIR-ANT2451NV-R=</td>
<td>2.4 GHz 3 dBi/5 GHz 4 dBi 802.11n dual band omni antenna (6)</td>
<td>3 dBi / 4 dBi</td>
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<tr>
<td>AIR-ANT2460NP-R=</td>
<td>2.4 GHz 6 dBi 802.11n directional antenna (3)</td>
<td>6 dBi</td>
</tr>
<tr>
<td>AIR-ANT5160NP-R=</td>
<td>5 GHz 6 dBi 802.11n directional antenna (3)</td>
<td>6 dBi</td>
</tr>
<tr>
<td>AIR-ANT2422SDW-R=</td>
<td>2.4 GHz 2.2 dBi Short white dipole antenna (1)</td>
<td>2.2 dBi</td>
</tr>
<tr>
<td>AIR-ANT5135SDW-R=</td>
<td>5 GHz 3.5 dBi Short white dipole antenna (1)</td>
<td>3.5 dBi</td>
</tr>
<tr>
<td>AIR-ANT2450NV-R=</td>
<td>2.4 GHz 5 dBi 802.11n Omni wall mount antenna (3)</td>
<td>4 dBi</td>
</tr>
<tr>
<td>AIR-ANT5140NV-R=</td>
<td>5 GHz 4 dBi 802.11n Omni wall mount antenna (3)</td>
<td>4 dBi</td>
</tr>
</tbody>
</table>

**Note:** do *NOT* use on units with **ORANGE** label (1600, 2600 & 3600)
**Most Common 802.11n Antennas**

Indoor Access Points (1600, 2600, 3600 & 3700) <2nd Generation AP’s>

These are **Dual Radiating Element antennas** (use with Orange labels)

<table>
<thead>
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<th>Gain</th>
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<tr>
<td>AIR-ANT2524DB-R</td>
<td>2.4 &amp; 5 GHz -- Dual Band Dipole Dipole Ant., Black, RP-TNC connector (1)</td>
<td>2 dBi (2.4 GHz)</td>
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<tr>
<td>AIR-ANT2524DB-R</td>
<td></td>
<td>4 dBi (5 GHz)</td>
</tr>
<tr>
<td>AIR-ANT2524DG-R</td>
<td>2.4 &amp; 5 GHz -- Dual Band Dipole Dipole Ant., Gray, RP-TNC connector (1)</td>
<td>2 dBi (2.4 GHz)</td>
</tr>
<tr>
<td>AIR-ANT2524DG-R</td>
<td></td>
<td>4 dBi (5 GHz)</td>
</tr>
<tr>
<td>AIR-ANT2524DW-R</td>
<td>2.4 &amp; 5 GHz -- Dual Band Dipole Dipole Ant., White, RP-TNC connector (1)</td>
<td>2 dBi (2.4 GHz)</td>
</tr>
<tr>
<td>AIR-ANT2524DW-R</td>
<td></td>
<td>4 dBi (5 GHz)</td>
</tr>
<tr>
<td>AIR-ANT2566P4W-R</td>
<td>2.4 &amp; 5 GHz -- Dual Band Directional (Patch) Directional Ant., RP-TNC connectors (4)</td>
<td>6 dBi (2.4 GHz)</td>
</tr>
<tr>
<td>AIR-ANT2566P4W-R</td>
<td></td>
<td>6 dBi (5 GHz)</td>
</tr>
<tr>
<td>AIR-ANT2524V4C-R</td>
<td>2.4 &amp; 5 GHz -- Dual Band Ceiling Mount Ceiling Mount Omni Ant., RP-TNC connectors (4)</td>
<td>2 dBi (2.4 GHz)</td>
</tr>
<tr>
<td>AIR-ANT2524V4C-R</td>
<td></td>
<td>4 dBi (5 GHz)</td>
</tr>
<tr>
<td>AIR-ANT2544V4M-R</td>
<td>2.4 &amp; 5GHz -- Dual Band Wall Mount Omni Wall Mount Omni Ant., RP-TNC connectors (4)</td>
<td>4 dBi (2.4 GHz)</td>
</tr>
<tr>
<td>AIR-ANT2544V4M-R</td>
<td></td>
<td>4 dBi (5 GHz)</td>
</tr>
</tbody>
</table>

Use on antennas with Orange label *if using (1600) only use 3 antennas (4th unused)
Understanding and Interpreting Antenna Patterns
Low gain dipoles radiate everywhere think “light bulb”
Understanding Antenna Patterns

Patch (Directional)

A low gain Patch Antenna
Understanding Antenna Patterns
Patch (Higher Gain Directional)

A High Gain 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
Elevation plane has nulls due to high gain 14 dBi but this 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 Antenna Patterns
### Sector (Higher Gain Directional)

<table>
<thead>
<tr>
<th>Antenna Type</th>
<th>90-degree sector</th>
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</thead>
<tbody>
<tr>
<td>Operating Frequency Range</td>
<td>2400–2500 MHz</td>
</tr>
<tr>
<td>Nominal Input Impedence</td>
<td>50Ω</td>
</tr>
<tr>
<td>2:1 VSWR Bandwidth</td>
<td>2400–2500 MHz</td>
</tr>
<tr>
<td>Gain (including 1.5 m cable)</td>
<td>14 dBi</td>
</tr>
<tr>
<td>Polarization</td>
<td>Linear, vertical</td>
</tr>
<tr>
<td><strong>Azimuth 3-dB Beamwidth</strong></td>
<td>90 degrees</td>
</tr>
<tr>
<td><strong>Elevation 3-dB Beamwidth</strong></td>
<td>8.5 degrees</td>
</tr>
<tr>
<td>Cable Length and Type</td>
<td>5 ft. (1.5 m)</td>
</tr>
<tr>
<td></td>
<td>LMR-195 Coaxial</td>
</tr>
<tr>
<td>Connector Type</td>
<td>RP-TNC Male</td>
</tr>
<tr>
<td>Environment</td>
<td>Outdoor</td>
</tr>
<tr>
<td>Length</td>
<td>35.9 in. (91.2 cm)</td>
</tr>
<tr>
<td>Width</td>
<td>6.4 in. (16.3 cm)</td>
</tr>
<tr>
<td>Depth</td>
<td>4.03 in. (10.23 cm)</td>
</tr>
<tr>
<td>Weight (with Hardware Kit)</td>
<td>7.5 lb. (3.4 kg)</td>
</tr>
<tr>
<td>Operating Temperature Range</td>
<td>-22°F to 158°F</td>
</tr>
<tr>
<td></td>
<td>(-30°C to 70°C)</td>
</tr>
<tr>
<td>Storage Temperature Range</td>
<td>-40°F to 185°F</td>
</tr>
<tr>
<td></td>
<td>(-40°C to 85°C)</td>
</tr>
<tr>
<td>Wind Rating</td>
<td>100 mph (161 kph)</td>
</tr>
</tbody>
</table>
The Richfield Ohio (Aironet) Facility
Qualifying Cisco and 3rd Party Antennas

Satimo software compatible with Stargate-64 System. Basic measurement tool is 8753ES Network Analyzer.

Cisco Anechoic chamber using an 45 cm absorber all the way, around 1-6 GHz
Anechoic means “without echo”
Understanding 802.11ac
Why is 802.11ac important?

This section will guide you in understanding 802.11ac Wave-1 and Wave-2

802.11ac devices are started to emerge especially mobile devices so there is a customer need for improved performance

Cisco AP-3600 with .11ac module

New .11ac clients starting to emerge
So let’s talk about 802.11ac – Wave1

The Wi-Fi Alliance (WFA) is looking at Wave 1 today with the main features implemented being:

- **Channel Bonding 80 MHz** (mandatory)
- **Faster modulation 256-QAM** (optional)
- **Ability to receive 1, 2 & 3 Spatial Streams** tested
  - 2SS is mandatory for non-battery-powered APs
  - Only 1SS is mandatory for battery powered AP’s and clients
- **WFA’s focus is on 80 MHz, 1-3SS and 256-QAM** with WFA compliant products likely sporting a new Wi-Fi Certified logo

802.11ac is happening in stages
Referred to as “Wave-1 and Wave-2”
So let’s talk about 802.11ac - How is it like .11n?

802.11ac (Wave-1) introduces 256-QAM

Faster throughput happens when you can use more complex Modulation Coding Schemes (MCS)

802.11n 1-ss MCS up to 64-QAM
64-QAM uses 6 bits per symbol

802.11ac 1-ss MCS supports 256-QAM
256-QAM uses 8 bits per symbol (up to 4x faster)
How about Multi-User MIMO (MU-MIMO) 
Does it work? Any caveats?

- **802.11ac MU MIMO is like 802.11n MIMO, except instead of one client, there are up to four clients**
  - AP does pre-coding for all the clients within the Multi-User group simultaneously
  - In MU pre-coding, when AP beam-forms space-time streams to one client, it simultaneously null-steers those space-time streams to the rest.
  - All users’ MPDUs are padded to the same number of OFDM symbols

- **MU-MIMO is technically risky and challenging:**
  - Needs precise channel estimation (CSI) to maintain deep nulls
  - Precise channel estimation adds overhead
  - Rate adaptation is more difficult
  - Throughput benefits are sensitive to MU grouping

---

**WFA Wave 2 certification:**
- MU-MIMO

Null-steering: To send data to user 1, the AP forms a strong beam toward user 1, shown as the top-right lobe of the blue curve. At the same time the AP minimizes the energy for user 1 in the direction of user 2 and user 3. This is called "null steering" and is shown as the blue notches. Same logic applies to red and yellow beams.
So let's talk about 802.11ac - How is it like .11n?

What about channel bonding?
Wave-1 allows up to 80 MHz channel bonding

802.11n can bond up to 40 MHz

802.11ac can bond up to 80 MHz (Wave-1)
*up to 160 MHz (Wave-2)
Let’s talk about 802.11ac - How is it like .11n?

ETSI and Japan channel allocation plan

80 MHz bonding (Wave-1) 160 MHz (Wave-2)

Note: Efforts are underway globally to expand the number of channels in the 5 GHz band. China probably is progressing a bit quicker than others, but everyone sees the need.
So why is channel bonding so important?
MCS rates @ 1 Spatial Stream in Mbps

More than 1-SS requires that the client have more radios which draw more power.

The goal is to enable devices to have more throughput with less battery draw.

Most mobile devices will use 1-SS.

Tablets & laptops can use 2-SS or more.

New Phones such as the HTC One & Samsung S 4 have support for 802.11ac Wave-1.
802.11ac (Wave-2)
Up to 8 spatial streams.

802.11ac MCS rates (unlike 802.11n) don’t exceed 0-9 -- but rather it is 0-9 and then you call out how many Spatial Streams so a chart like this is quite extensive.

Depicted to the right are only streams 2 & 3 out of the 8 possible spatial streams.

1 stream (80MHz) is 433 Mbps
2 stream (80MHz) is 866 Mbps
3 stream (80MHz) is 1300 Mbps
Expected 802.11ac Client Throughput (take-away)

1 stream (80MHz) is 433 Mbps
2 stream (80MHz) is 866 Mbps
3 stream (80MHz) is 1300 Mbps

(Now let’s drop it to ~70% MAC efficiency)

What’s the real expected throughput?*

* Assumes 70% MAC efficiency

- Smartphones from **210 Mbps**
- Tablets from **460 Mbps**
- High End Laptops from **+680 Mbps**

802.11ac Performance Table
Since we are talking about the future (Wave-2) What are likely to be the minimum requirements?

(Wave-2) Minimum requirements for enterprise will likely include: 256-QAM, 3-SS and 160 MHz

- For Wave 2, initially it is expected that 160 MHz devices will appear with 1-3SS (typical) with perhaps 4-SS supported with likely data rates of 867-2600 Mbps.

- Likely data rates up to 3.5 Gbps PHY and over 2 Gbps MAC (IEEE approval late 2013)?

- Will require faster than GigE speeds requiring either 10GbE or perhaps two GbE cables / hybrid

Future proofing new installations (cabling considerations)

- A single GbE cable is fine for (Wave-1)

- Wave-2 will exceed GbE speeds so for now, it is recommended for new installs requiring Wave-2 that you pull two CAT6a cables until this standard is better defined.

- A pair of CAT6a cables allows you to fall back to using 2 GbE ports for some iterations of (Wave-2) if required. If the second cable isn’t needed it can be used to bring the console port back.

- CAT5e cables may be used or one of each for cost savings but not for 10GbE.
Building your network
Choosing the architecture and controller
Cisco Unified Access = Deployment Flexibility

**AUTONOMOUS AP**
- Limited control plane on AP
- Distributed data plane
- Intended for static installations
- Point-to-point/work group bridge

**CLOUD MANAGED**
- Centralized control plane
- Distributed data plane
- Common LAN and WLAN OS
- LAN and WLAN feature consistency
- No controller at remote sites
- Optimized for distributed enterprise or branch deployments

**FLEXCONNECT**
- Centralized control plane
- Distributed data plane
- Data center hosted controller
- No controller at remote sites
- Optimized for distributed enterprise or branch deployments

**CENTRALIZED**
- Centralized control plane
- Centralized data plane
- Premise-based controller
- Controller at every location
- Optimized for campus deployment

**CONVERGED ACCESS**
- Centralized control plane
- Distributed data plane
- Common LAN and WLAN OS
- LAN and WLAN feature consistency
- Optimized for high performance
- Optimized for campus and branch

- Aironet Access Points
- Catalyst switches
- Identity Services Engine
- Prime Infrastructure
- MR Access Points
- MS switches
- MX security
- Dashboard
- Aironet Access Points
- FlexConnect capable controllers
- Catalyst switches
- Identity Services Engine
- Mobility Services Engine
- Prime Infrastructure
- Aironet Access Points
- Centralized controllers
- Catalyst switches
- Identity Services Engine
- Mobility Services Engine
- Prime Infrastructure
- Aironet Access Points
- Catalyst 3850 Switch
- Identity Services Engine
- Mobility Services Engine
- Prime Infrastructure
Integrated WLAN Controllers
Cisco Wireless Services Module 2

**Key Features**

- Supported on Catalyst 6500 Series Switches
- Scalability: up to 1000 APs (Single Controller)
- DTLS-Encryption for Control- and Data-Layer
- Up to 20 Gbps backplane connection
- Interoperable with other Service Modules (especially 1st Generation WiSMs)

**Scalability-Numbers**

<table>
<thead>
<tr>
<th>Maximum #</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td># of APs</td>
<td>1'000</td>
</tr>
<tr>
<td># of Clients</td>
<td>15'000</td>
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<tr>
<td># of FlexConnect-Groups</td>
<td>100</td>
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<tr>
<td># of APs per FlexConnect-Group</td>
<td>50</td>
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<tr>
<td># of Rogue APs</td>
<td>4'000</td>
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<td># of Rogue Clients</td>
<td>5'000</td>
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<tr>
<td># of RFID-Tags</td>
<td>10'000</td>
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<tr>
<td># of APs per RRM-Group</td>
<td>2'000</td>
</tr>
<tr>
<td># of AP-Groups</td>
<td>500</td>
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</table>
Standalone WLAN Controllers
Cisco 2500 Series Wireless Controllers

**Key Features**
- Scalability: up to 75 APs
- 4x 1GE RJ45 (2x PoE)
- DTLS-Encryption for Control- and Data-Layer
- 1000 Mbps backplane capacity

### Scalability-Numbers

<p>| | |</p>
<table>
<thead>
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<tr>
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<td>Maximum # of FlexConnect-Groups</td>
<td>20</td>
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<tr>
<td>Maximum # of APs per FlexConnect-Group</td>
<td>25</td>
</tr>
<tr>
<td>Maximum # of Rogue APs</td>
<td>2'000</td>
</tr>
<tr>
<td>Maximum # of Rogue Clients</td>
<td>2'500</td>
</tr>
<tr>
<td>Maximum # of RFID-Tags</td>
<td>500</td>
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<tr>
<td>Maximum # of APs per RRM-Group</td>
<td>500</td>
</tr>
<tr>
<td>Maximum # of AP-Groups</td>
<td>50</td>
</tr>
</tbody>
</table>

Some feature are not supported
Examples:
- No Wired-Guest

Please consult documentation!
Standalone WLAN Controllers
Cisco 5500 Series Wireless Controllers

Key Features

- Scalability: Up to 500 APs
- 8x 1GE SFP (LAG possible)
- DTLS-Encryption for Control- and Data-Layer
- Non-blocking backplane capacity

### Scalability-Numbers

<table>
<thead>
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<th>Maximum # of APs</th>
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<td>Maximum # of Rogue APs</td>
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<td>Maximum # of Rogue Clients</td>
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<tr>
<td>Maximum # of RFID-Tags</td>
<td>5'000</td>
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<tr>
<td>Maximum # of APs per RRM-Group</td>
<td>1'000</td>
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<tr>
<td>Maximum # of AP-Groups</td>
<td>500</td>
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**Key Features**

- Scalability: Up to 6000 APs
- 2x 10GE SFP
- DTLS-Encryption for Control- and Data-Layer

### Scalability-Numbers

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<td>Maximum # of Clients</td>
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<td>Maximum # of Rogue APs</td>
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<td>Maximum # of Rogue Clients</td>
<td>32'000</td>
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<tr>
<td>Maximum # of RFID-Tags</td>
<td>50'000</td>
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<tr>
<td>Maximum # of APs per RRM-Group</td>
<td>6'000</td>
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<tr>
<td>Maximum # of AP-Groups</td>
<td>6'000</td>
</tr>
</tbody>
</table>

### Limited feature support!

Examples:
- No Wired Guest
- No Guest Anchor

Please consult documentation!
**Key Features**

- FlexConnect- and Monitor-Mode-Deployments ONLY
- Up to 100 branch locations and 100 APs per branch (H-REAP-Groups)

### Scalability-Numbers

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum # of APs</td>
<td>200</td>
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<tr>
<td>Maximum # of Clients</td>
<td>3'000</td>
</tr>
<tr>
<td>Maximum # of FlexConnect-Groups</td>
<td>100</td>
</tr>
<tr>
<td>Maximum # of APs per FlexConnect-Group</td>
<td>100</td>
</tr>
<tr>
<td>Maximum # of Rogue APs</td>
<td>800</td>
</tr>
<tr>
<td>Maximum # of Rogue Clients</td>
<td>1'500</td>
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<tr>
<td>Maximum # of RFID-Tags</td>
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<tr>
<td>Maximum # of APs per RRM-Group</td>
<td>400</td>
</tr>
<tr>
<td>Maximum # of AP-Groups</td>
<td>200</td>
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</tbody>
</table>

### Limited feature support!

Examples:
- No Data-Layer DTLS
- No Guest Anchor
- No Mesh-Support

Please consult documentation!

### VMWare Requirements

- ESX/ESXi 4.x or 5.x
- Mind. 1 vCPU
- Mind. 2 GB RAM
- Mind. 8 GB Storage
- Mind. 2 VMNICS
“FlexConnect” WLAN Controllers
Cisco Flex 7500 Series Controllers

**Key Features**

- Scalability: up to 6000 APs
- FlexConnect- and Monitor-Mode-Deployments ONLY
- 2x10 GE SFP+ Connector (active/standby)
- Up to 1000 branch locations and 50 APs per branch (H-REAP-Groups)
- Up to 1 Gbps centralized Dataplane

<table>
<thead>
<tr>
<th>Scalability-Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum # of APs</td>
</tr>
<tr>
<td>Maximum # of Clients</td>
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<tr>
<td>Maximum # of FlexConnect-Groups</td>
</tr>
<tr>
<td>Maximum # of APs per FlexConnect-Group</td>
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<td>Maximum # of Rogue APs</td>
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<td>Maximum # of Rogue Clients</td>
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<tr>
<td>Maximum # of RFID-Tags</td>
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<tr>
<td>Maximum # of APs per RRM-Group</td>
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<tr>
<td>Maximum # of AP-Groups</td>
</tr>
</tbody>
</table>

**Limited feature support!**

Please consult documentation!
Converged Access
Cisco 5760 Series Wireless Controller

**Key Features**
- Scalability: up to 1000 APs
- Hardware based on UADP Asic (Unified Access Data Plane)
- 60 Gbps throughput
- Supports flexible Netflow v9
- Supports dACLs
- MQC-based QoS-Configuration

<table>
<thead>
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<tbody>
<tr>
<td>Maximum # of APs</td>
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<tr>
<td>Maximum # of Clients</td>
<td>12'000</td>
</tr>
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</table>

Today this products offers limited feature support!
- Please make yourself familiar with the Converged Access Solution
- Please consult documentation!
Converged Access
Cisco Catalyst 3650 Series Switches

**Key Features**
- Scalability: up to 25 APs
- Hardware based on UADP Asic (Unified Access Data Plane)
- 160 Gbps Stacking capacity
- 40 Gbps Uplink capacity
- Supports flexible Netflow v9
- Supports dACLs
- MQC-based QoS-Configuration

---

**Scalability-Numbers**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Maximum # of APs</td>
<td>25</td>
</tr>
<tr>
<td>Maximum # of Clients</td>
<td>1'000</td>
</tr>
</tbody>
</table>

---

Today this products offers limited feature support!

- Please make yourself familiar with the Converged Access Solution
- Please consult documentation!
**Converged Access**

Cisco Catalyst 3850 Series Switches

**Key Features**

- Scalability: up to 50 APs
- Hardware based on UADP Asic (Unified Access Data Plane)
- 480 Gbps Stacking capacity
- 40 Gbps Uplink capacity
- Supports flexible Netflow v9
- Supports dACLs
- MQC-based QoS-Configuration

**Scalability-Numbers**

<p>| | |</p>
<table>
<thead>
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<tbody>
<tr>
<td>Maximum # of APs</td>
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</tr>
<tr>
<td>Maximum # of Clients</td>
<td>2'000</td>
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</table>

**Today this products offers limited feature support!**

- Please make yourself familiar with the Converged Access Solution
- Please consult documentation!
Choosing the right Access Point Model
Integrated or External antennas?
# Indoor AP Portfolio

<table>
<thead>
<tr>
<th></th>
<th>802.11n</th>
<th>3 Spatial Streams</th>
<th>802.11ac</th>
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<tr>
<td><strong>Ruggedized</strong></td>
<td>AP1600e</td>
<td>AP2600e</td>
<td>AP3700e/p</td>
</tr>
<tr>
<td></td>
<td>AP3500e/p</td>
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<td></td>
</tr>
<tr>
<td></td>
<td><strong>AP3600e</strong></td>
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<tr>
<td><strong>Carpeted</strong></td>
<td>AP702W</td>
<td>AP2600i</td>
<td>AP3700i</td>
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<tr>
<td></td>
<td>AP700</td>
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<td>AP3500i</td>
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<td><strong>OEAP600</strong></td>
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</table>

* AP3600 only

**APx00 Modules**
- WSSI
- 3G
- 11ac*

*Presentation_ID
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Cisco Public
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 or for areas with more challenging RF-environment.
Cisco Aironet 1600e Series Access Point

**Key Features**

- 2.4 GHz, IEEE 802.11b/g/n
- 5 GHz, IEEE 802.11a/n
- 3 receivers / 3 senders / 2 spatial streams (3x3:2 MIMO)
- Extended range for 300 Mbps per Band
- Dual-Band Antenna-Connectors for both frequencies (max. 6dBi gain)
- Worldclass integrated features using custom-designed silicon: Cisco ClientLink 2.0
- Controller-based and Autonomous
- Nice formfactor and design adapted from AP1140 → same mounting-brackets
Cisco Aironet 2600e Series Access Point

**Key Features**

- 2.4 GHz, IEEE 802.11b/g/n
- 5 GHz, IEEE 802.11a/n
- 4 receivers / 3 senders / 3 spatial streams (3x4:3 MIMO)
- Extended range for 450 Mbps per Band
- Dual-Band Antenna-Connectors for both frequencies (max. 6dBi gain)
- Worldclass integrated features using custom-designed silicon:
  - Cisco CleanAir
  - Cisco ClientLink 2.0
- Controller-based and Autonomous
- Nice formfactor and design adapted from AP1140 → same mounting-brackets

Cisco CleanAir enables the network to make intelligent decisions on the appearance of Non-WiFi-Interferers depending on their impact – providing higher network availability to today’s mission critical Wireless-Networks.
Cisco Aironet 3500e Series Access Point

**Key Features**

- 2.4 GHz, IEEE 802.11b/g/n
- 5 GHz, IEEE 802.11a/n
- Distinguished Antenna-Connectors for each frequency-band (max. 6dBi gain)
- Worldclass Spectrum Intelligence integrated with specific HW: → Cisco CleanAir
- Controller-based and Autonomous
- Nice formfactor and design adapted from AP1140 → same mounting-brackets

Cisco CleanAir enables the network to make intelligent decisions on the appearance of Non-WiFi-Interferers depending on their impact – providing higher network availability to today's mission critical Wireless-Networks
Cisco Aironet 3500p Series Access Point

**Key Features**

- Designed with custom configuration settings and narrow-bandwidth, high-gain external antennas to provide very targeted coverage for high-density deployments.
- 2.4 GHz, IEEE 802.11b/g/n
- 5 GHz, IEEE 802.11a/n
- Supports AIR-ANT25137NP-R high-gain “Stadium Antenna”
- Worldclass Spectrum Intelligence integrated with specific HW: → Cisco CleanAir
- Controller-based and Autonomous
- Nice formfactor and design adapted from AP1140 → same mounting-brackets

**Please note:**

Because of the unique antenna and power settings, FCC regulations require the Cisco Aironet 3500p Access Point to be installed by a certified professional.
 Cisco Aironet 3600e Series Access Point

**Key Features**

- Modul-Slot for additional radios
- 2.4 GHz, IEEE 802.11b/g/n
- 5 GHz, IEEE 802.11a/n
- 4 receivers / 4 senders / 3 spatial streams (4x4:3 MIMO)
- Large range for 450 Mbps per Band
- Dual-Band Antenna-Connectors for both frequencies (max. 6dBi gain)
- Worldclass integrated features using custom-designed silicon:
  - Cisco CleanAir
  - Cisco ClientLink 2.0
- Controller-based and Autonomous
- Nice formfactor and design adapted from AP1140 → same mounting-brackets

Cisco CleanAir enables the network to make intelligent decisions on the appearance of Non-WiFi-Interferers depending on their impact – providing higher network availability to todays mission critical Wireless-Networks.
Cisco Aironet 3700e Series Access Point

**Key Features**

- Modul-Slot for additional radios
- 2.4 GHz, IEEE 802.11b/g/n
- 5 GHz, IEEE 802.11a/n/ac
- 4 receivers / 4 senders / 3 spatial streams (4x4:3 MIMO)
- Large range for 1.3 Gbps
- Dual-Band Antenna-Connectors for both frequencies (max. 6dBi gain)
- Worldclass integrated features using custom-designed silicon:
  - Cisco CleanAir
  - Cisco ClientLink 3.0
- Controller-based and Autonomous (later)
- Nice formfactor and design adapted from AP1140 → same mounting-brackets

---

Cisco CleanAir enables the network to make intelligent decisions on the appearance of Non-WiFi-Interferers depending on their impact – providing higher network availability to todays mission critical Wireless-Networks.

---

Works with 802.3af, but will fall back to 3x3:3 MIMO. 802.3at, EPoE or UPoE recommended!
Cisco Aironet 3700p Series Access Point

Key Features

- Modul-Slot for additional radios
- 2.4 GHz, IEEE 802.11b/g/n
- 5 GHz, IEEE 802.11a/n/ac
- 4 receivers / 4 senders / 3 spatial streams (4x4:3 MIMO)
- Large range for 1.3 Gbps
- Supports special high-gain Stadium-Antenna
- Worldclass integrated features using custom-designed silicon:
  → Cisco CleanAir
  → Cisco ClientLink 3.0
- Controller-based and Autonomous (later)
- Nice formfactor and design adapted from AP1140 → same mounting-brackets

Please note:

Because of the unique antenna and power settings, FCC regulations require the Cisco Aironet 3700p Access Point to be installed by a certified professional.
Cisco Aironet 700W Series Access Point

**Key Features**

- Wall-Mount AP
- Integrated Switch

- More details will be added closer to FCS

**Please note:**

AP700W will become available only in H1CY14

**Disclaimer:**

Information about future developments is subject to change.
Cisco Aironet 700 Series Access Point

**Key Features**

- 2.4 GHz, IEEE 802.11b/g/n
- 5 GHz, IEEE 802.11a
- 2 receivers / 2 senders / 2 spatial streams (3x3:2 MIMO)
- Simultaneous dual band, dual radio
- Available for controller-based (lightweight) setups. Autonomous support in future
- Small formfactor and design

Please note:

AP700 is smaller than other Cisco APs and therefore it uses its own, smaller mounting brackets
Cisco Aironet 1600i Series Access Point

**Key Features**

- 2.4 GHz, IEEE 802.11b/g/n
- 5 GHz, IEEE 802.11a/n
- 3 receivers / 3 senders / 2 spatial streams (3x3:2 MIMO)
- Extended range for 300 Mbps per Band
- Integrated Dual-Band Antenna-Connectors

Worldclass integrated features using custom-designed silicon:
  - Cisco ClientLink 2.0

- Controller-based and Autonomous
- Nice formfactor and design adapted from AP1140 → same mounting-brackets
Cisco Aironet 2600i Series Access Point

Key Features

- 2.4 GHz, IEEE 802.11b/g/n
- 5 GHz, IEEE 802.11a/n
- 4 receivers / 3 senders / 3 spatial streams (3x4:3 MIMO)
- Extended range for 450 Mbps per Band
- Integrated Dual-Band Antenna-Connectors
- Worldclass integrated features using custom-designed silicon:
  - Cisco CleanAir
  - Cisco ClientLink 2.0
- Controller-based and Autonomous
- Nice formfactor and design adapted from AP1140 → same mounting-brackets

Cisco CleanAir enables the network to make intelligent decisions on the appearance of Non-WiFi-Interferers depending on their impact – providing higher network availability to today’s mission critical Wireless-Networks.
Cisco Aironet 3500i Series Access Point

**Key Features**

- 2.4 GHz, IEEE 802.11b/g/n
- 5 GHz, IEEE 802.11a/n
- Dedicated and integrated antennas for each frequency-band
- Worldclass Spectrum Intelligence integrated with specific HW: Cisco CleanAir
- Controller-based and Autonomous
- Same nice formfactor and design as AP1140 → same mounting-brackets

Cisco CleanAir enables the network to make intelligent decisions on the appearance of Non-WiFi-Interferers depending on their impact – providing higher network availability to today’s mission critical Wireless-Networks.
Cisco Aironet 3600i Series Access Point

**Key Features**

- Modul-Slot for additional radios
- 2.4 GHz, IEEE 802.11b/g/n
- 5 GHz, IEEE 802.11a/n
- 4 receivers / 4 senders / 3 spatial streams (4x4:3 MIMO)
- Large range for 450 Mbps per Band
- Integrated Dual-Band Antenna
- Worldclass integrated features using custom-designed silicon:
  - Cisco CleanAir
  - Cisco ClientLink 2.0
- Controller-based and Autonomous
- Nice formfactor and design adapted from AP1140 → same mounting-brackets

Cisco CleanAir enables the network to make intelligent decisions on the appearance of Non-WiFi-Interferers depending on their impact – providing higher network availability to todays mission critical Wireless-Networks.
Cisco Aironet 3700i Series Access Point

**Key Features**

- Modul-Slot for additional radios
- 2.4 GHz, IEEE 802.11b/g/n
- 5 GHz, IEEE 802.11a/n/ac
- 4 receivers / 4 senders / 3 spatial streams (4x4:3 MIMO)
- Large range for 1.3 Gbps
- Integrated Dual-Band Antenna
- Worldclass integrated features using custom-designed silicon:
  - Cisco CleanAir
  - Cisco ClientLink 3.0
- Controller-based and Autonomous (later)
- Nice formfactor and design adapted from AP1140 → same mounting-brackets

Cisco CleanAir enables the network to make intelligent decisions on the appearance of Non-WiFi-Interferers depending on their impact – providing higher network availability to todays mission critical Wireless-Networks.

Works with 802.3af, but will fall back to 3x3:3 MIMO. 802.3at, EPoE or UPoE recommended!
Wireless Security & Spectrum Intelligence Module (WSSI)

**Key Features**

- Allows the AP to concurrently serve clients and scan all channels – always on

- Offloads CleanAir Monitoring & WIDS/WIPS Security capabilities to the Monitor Module

- Independent integrated antennas 0x4 (0 Tx antenna’s x 4 Rx Antenna’s)

- No configuration required! Module automatically scans all channels on 2.4 and 5 GHz bands

- Module powered from AP
  - AP-Power requires ~20W
    - Enhanced PoE
    - IEEE 802.3at
    - Power-Injector
    - Local Power-Supply

- Requires AP to be mounted with either:
  - Universal Mounting Brackets (Bracket-2; included)
  - Ceiling Mounting Brackets (Bracket-3)

This module eliminates the need for an extra cable pull and additional infrastructure costs, if full aWIPS scanning or CleanAir Spectrum Analyses is required!
IEEE 802.11ac Wave 1 Module

**Key Features**

- 5 GHz, IEEE 802.11ac (Wave 1)
- 3 receivers / 3 senders / 3 spatial streams (3x3:3 MIMO)
- 1.3 Gbps throughput
- Together with Host-AP the module supports b/g/n on 2.4 GHz and a/ac/n on 5 GHz
- Supports “Explicit Beamforming” as per the 802.11ac standard
- Module powered from AP
  - AP-Power requires ~20W
    - Enhanced PoE
    - IEEE 802.3at
    - Power-Injector
    - Local Power-Supply
- Requires AP to be mounted with either:
  - Universal Mounting Brackets (Bracket-2; included)
  - Ceiling Mounting Brackets (Bracket-3)

This field-upgradable IEEE 802.11ac module add-on to the AP3600 allows today investment protection for this emerging Wireless-Standard!

This module is not supported in the AP3700!
Cisco Universal Small Cell 5310

**Key Features**

The Cisco USC 5310 is field-upgradeable and contains a dedicated third-generation (3G) small cell base station that can efficiently deliver mobile services indoors while offloading traffic from the outdoor macro network.

This approach:

- improves the mobile user experience
- reduces costs by eliminating the need for dedicated macro base station sites
- reducing the need to acquire new small cell real
- decreasing the backhaul infrastructure required to support small cell deployments.

Please note:

This module works in the licensed band, so you have to work with the local SP that owns the right to operate equipment in that frequency range!
A look at some installations that went wrong
Installations that Went Wrong

NEVER EVER MIX ANTENNA TYPES

same RF cell
watch polarity
Above ceiling installs that went wrong
Yes it Happens and When it Does it is Expensive to Fix and No One is Happy

Tip: Access Points like light sources should be in the clear and near the users
Above Ceiling Installs that Went Wrong
Huh?? You Mean it Gets Worse?
Other Installations that Went Wrong

Ceiling mount AP mounted on the wall up against metal pipe (poor coverage)
Installations that Went Wrong

Patch antenna shooting across a metal fence
Multipath distortion causing severe retries

Mount the box horizontal and extend the antennas down and not right up against the metal enclosure
Installs that Went Wrong

Sure is a comfy nest –

Glad this model runs pretty warm
Installations that Went Wrong - Mesh

GOOD INSTALL

Sways in wind =>

BAD INSTALL

Too much weight
Installations that Went Wrong - Mesh
Installations that Went Wrong - Mesh

Building aesthetics matters – Antennas obstructed
Basic 802.11 RF Terminology
Common RF Terms

- **Attenuation** – a loss in force or intensity – As radio waves travel 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.
- **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.
Installation and Deployment Considerations
Site Survey Prepares for 802.11n

- Recommended to optimize 11n deployment
- Survey reveals effects of building characteristics on the wireless spectrum
- Measure RF variations due to human activity and time of day
- Survey with client types that you plan to implement (11n, 11abg, VoIP, location tags)
- Spectrum intelligence to detect interference
Wall Mounting Access Point with Internal Antennas

Coverage is always more uniform when installed on the ceiling tile or grid area.

Note: Wall mounting may create unwanted coverage areas on the floor above or below - This is not desirable for voice as it may cause excessive roams and is directional as metal is behind the antennas (backside).
Antenna Patterns – Internal Access Points
Azimuth and Elevation Patterns for 2.4 GHz & 5 GHz
Access Points 3600 with Module installed

Designed Primarily for Ceiling (carpeted) installations

AP-3600 antenna system with module installed

This shows how the module antennas are extended into the radiation ground plane for best performance

Module antennas (top) extend next to the four dual band integrated antennas
Wall mounting AP-1260, 3500e & 3600e
Orientation of the Dipoles if Wall Mounting

If using advanced features like location or voice try to locate the AP on the ceiling, or when mounting the AP on a wall orient the dipoles in this configuration.

Because dipoles on a wall can easily get orientated wrong as people touch and move them. Better still might be to use a Patch antenna or use the Oberon wall bracket. Be aware walls can add directional properties to the signal as they can have wiring, metal 2x4 construction and the wall attenuates the signal behind the AP limiting a nice 360 degree coverage.

Note: The ceiling is usually higher and a better location for RF.
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
www.terrawave.com
AP Placement Above False Ceiling Tiles 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 antenna 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.
Integrated Ceiling Mount – Public Areas

Flush mount bracket part number is AIR-AP-BRACKET-3.

This is a Cisco factory bracket that can be specified at time of order.

Full strut on right provides support across two ceiling rails, making it ideal for safety in earthquake prone areas.
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.
Wall Mounting AP-1260e, 3500e & 3600e
Orientation of the Dipoles if Wall Mounting

When the antenna is upright, the signal is a uniform 360 degrees.

When the antenna is sideways the pattern is no longer a uniform 360 degree pattern it takes on the pattern above.

Middle is ok as it is receive only
These should be vertical UP or DOWN not horizontal polarity

This is ok for diversity receive only antenna (middle one) it is not recommended for transmitter antennas as the polarity is also wrong we prefer vertical polarity for best performance.
Wall Mounting AP-1260e, 3500e & 3600e
Orientation of the Dipoles if Wall Mounting

Vertical polarity

Dipoles pointing UP or Down are in vertical polarity. This is ideal for uniform coverage.

Horizontal polarity

Dipoles pointing sideways are in horizontal polarity. Note: Cisco recommends transmitting antennas use vertical polarity.
Example: Warehouse Design
As Stock Levels Change so Does Coverage

You can suspend an AP from the ceiling or use patch or Yagi on walls
Example: Warehouse Design
As Stock Levels Change so Does Coverage

Maximum Tx power
Patch or Yagi antennas

Easy power
Easy Ethernet drop

Null spots have to be corrected

Trucks loading docks
Example: Warehouse Design
As Stock Levels Change so Does Coverage

- Reduced Tx power (RRM)
- More APs (+ power drops)
- Omni directional antennas
- AP wire distance to nearest switch

![Diagram of warehouse design with trucks and APs layout]

- Trucks loading docks
- Difficult to deploy - Placement of APs can be cumbersome