



Mesh Network Components

This chapter describes the mesh network components.

The Cisco wireless mesh network has four core components:

- Cisco Aironet 1500 series mesh access points



Note Cisco Aironet 1505 and 1510 mesh access points are not supported because of their End-of-Life status.

- Cisco Wireless LAN Controller (hereafter referred to as **controller**)
- Cisco Prime Infrastructure
- Mesh software architecture

This chapter contains the following sections:

- [Mesh Access Points, page 1](#)
- [Cisco Wireless LAN Controllers, page 40](#)
- [Cisco Prime Infrastructure, page 40](#)
- [Architecture, page 40](#)

Mesh Access Points

Licensing for Mesh Access Points on a 5500 Series Controller

To use both mesh and nonmesh access points with a Cisco 5500 Series Controller, only the base license (LIC-CT5508-X) is required from the 7.0 release and later releases. For more information about obtaining and installing licenses, see the *Cisco Wireless LAN Controller Configuration Guide* at http://www.cisco.com/en/US/products/ps10315/products_installation_and_configuration_guides_list.html.

Access Point Roles

Access points within a mesh network operate in one of the following two ways:

- 1 Root access point (RAP)
- 2 Mesh access point (MAP)

**Note**

All access points are configured and shipped as mesh access points. To use an access point as a root access point, you must reconfigure the mesh access point to a root access point. In all mesh networks, ensure that there is at least one root access point.

While the RAPs have wired connections to their controller, the MAPs have wireless connections to their controller.

MAPs communicate among themselves and back to the RAP using wireless connections over the 802.11a/n radio backhaul. MAPs use the Cisco Adaptive Wireless Path Protocol (AWPP) to determine the best path through the other mesh access points to the controller.

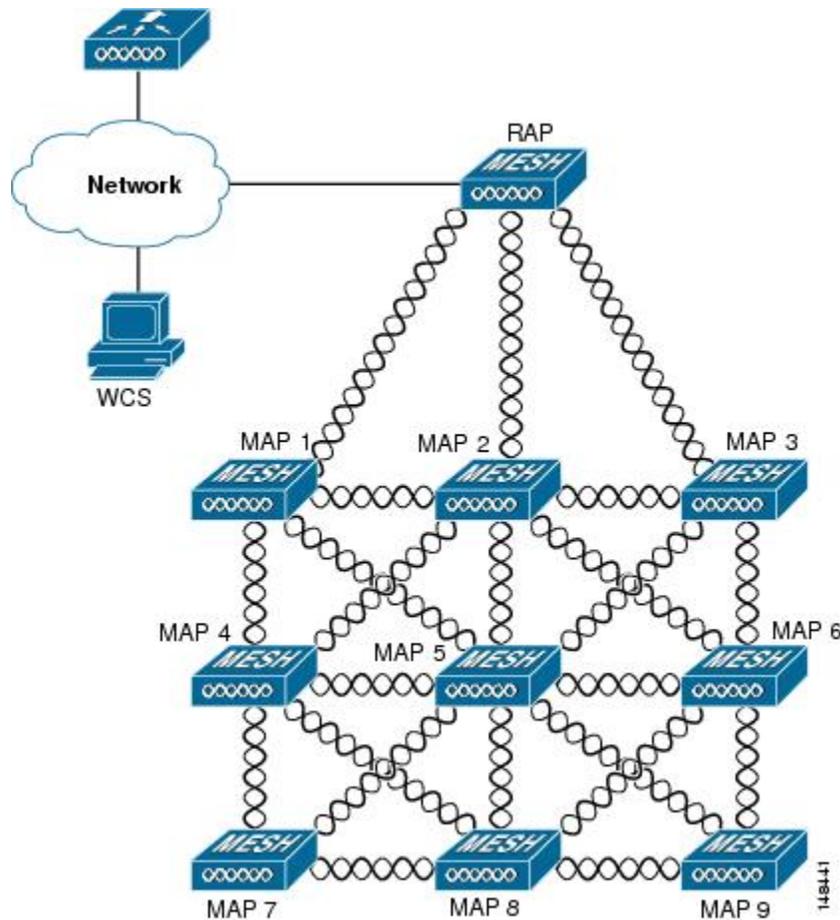
Bridge mode access points support CleanAir in mesh backhaul at 5GHz frequency and provides only the interference device report (IDR) and Air Quality Index (AQI) reports.

**Note**

The RAP or MAP does not generate Bridge Protocol Data Unit (BPDU) itself. However, the RAP or MAP forwards the BPDU to upstream devices if the RAP or MAP received the BPDU from its connected wired or wireless interface across the network.

This figure shows the relationship between RAPs and MAPs in a mesh network.

Figure 1: Simple Mesh Network Hierarchy



Network Access

Wireless mesh networks can simultaneously carry two different traffic types. They are as follows:

- Wireless LAN client traffic
- MAP Ethernet port traffic

Wireless LAN client traffic terminates on the controller, and the Ethernet traffic terminates on the Ethernet ports of the mesh access points.

Access to the wireless LAN mesh for mesh access points is managed by the following authentication methods:

- MAC authentication—Mesh access points are added to a database that can be referenced to ensure they are provided access to a given controller and mesh network.
- External RADIUS Authentication—Mesh access points can be externally authorized using a RADIUS server such as Cisco ACS (4.1 and later) that supports the client authentication type of Extensible Authentication Protocol-FAST (EAP-FAST) with certificates.

Network Segmentation

Membership to the wireless LAN mesh network for mesh access points is controlled by the bridge group names (BGNs). Mesh access points can be placed in similar bridge groups to manage membership or provide network segmentation.

Cisco Indoor Mesh Access Points

Indoor mesh is available on the following access points:

- 802.11a/b/g
 - 1130
 - 1240
- 802.11n
 - 1040
 - 1140
 - 1250
 - 1260
- 802.11n+CleanAir
 - 2600
 - 3500e
 - 3500i
 - 3600
- 802.11ac+CleanAir

**Note**

For more information about controller software support for access points, see the *Cisco Wireless Solutions Software Compatibility Matrix* at http://www.cisco.com/en/US/docs/wireless/controller/5500/tech_notes/Wireless_Software_Compatibility_Matrix.html.

Enterprise 11n mesh is an enhancement added to the CUWN feature to work with the 802.11n access points. Enterprise 11n mesh features are compatible with non-802.11n mesh but adds higher backhaul and client access speeds. The 802.11n indoor access points are two-radio Wi-Fi infrastructure devices for select indoor deployments. One radio can be used for local (client) access for the access point and the other radio can be configured for wireless backhaul. The backhaul is supported only on the 5-GHz radio. Enterprise 11n mesh supports P2P, P2MP, and mesh types of architectures.

You have a choice of ordering indoor access points directly into the bridge mode, so that these access points can be used directly as mesh access points. If you have these access points in a local mode (nonmesh), then you have to connect these access points to the controller and change the AP mode to the bridge mode (mesh).

This scenario can become cumbersome particularly if the volume of the access points being deployed is large and if the access points are already deployed in the local mode for a traditional nonmesh wireless coverage.

The Cisco indoor mesh access points are equipped with the following two simultaneously operating radios:

- 2.4-GHz radio used for client access
- 5-GHz radio used for data backhaul

The 5-GHz radio supports the 5.15 GHz, 5.25 GHz, 5.47 GHz, and 5.8 GHz bands.

Cisco Outdoor Mesh Access Points

Cisco outdoor mesh access points comprise of the Cisco Aironet 1500 series access points. The 1500 series includes 1552 11n outdoor mesh access points, 1522 dual-radio mesh access points, and 1524 multi-radio mesh access points. There are two models of the 1524, which are the following:

- The public safety model, 1524PS
- The serial backhaul model, 1524SB



Note

In the 6.0 release, the AP1524SB access point was launched in A, C, and N domains. In the 7.0 release, the AP1524SB access point was launched in the -E, -M, -K, -S, and -T domains.

Cisco 1500 series mesh access points are the core components of the wireless mesh deployment. AP1500s are configured by both the controller (GUI and CLI) and Cisco Prime Infrastructure. Communication between outdoor mesh access points (MAPs and RAPs) is over the 802.11a/n radio backhaul. Client traffic is generally transmitted over the 802.11b/g/n radio (802.11a/n can also be configured to accept client traffic), and public safety traffic (AP1524PS only) is transmitted over the 4.9-GHz radio.

The mesh access point can also operate as a relay node for other access points not directly connected to a wired network. Intelligent wireless routing is provided by the Adaptive Wireless Path Protocol (AWPP). This Cisco protocol enables each mesh access point to identify its neighbors and intelligently choose the optimal path to the wired network by calculating the cost of each path in terms of the signal strength and the number of hops required to get to a controller.

AP1500s are manufactured in two different configurations: cable and noncable.

- The cable configuration can be mounted to a cable strand and supports power-over-cable (POC).
- The noncable configuration supports multiple antennas. It can be mounted to a pole or building wall and supports several power options.

Uplinks support includes Gigabit Ethernet (1000BASE-T) and a small form-factor (SFP) slot that can be plugged for a fiber or cable modem interface. Both single mode and multimode SFPs up to 1000BASE-BX are supported. The cable modem can be DOCSIS 2.0 or DOCSIS/EuroDOCSIS 3.0 depending upon the type of mesh access point.

AP1500s are available in a hazardous location hardware enclosure. When configured, the AP1500 complies with safety standards for Class I, Division 2, Zone 2 hazardous locations.

**Note**

See the *Cisco Aironet 1520 Series Lightweight Outdoor Access Point Ordering Guide* for power, mounting, antenna, and regulatory support by model: http://www.cisco.com/en/US/prod/collateral/wireless/ps5679/ps8368/product_data_sheet0900aecd8066a157.html

The mesh access points, can operate, apart from the mesh mode, in the following modes:

- **Local mode**—In this mode, the AP can handle clients on its assigned channel or while monitoring all channels on the band over a 180-second period. During this time, the AP listens on each channel for 50 milliseconds for rogue client beacons, noise floor measurements, interference, and IDS events. The AP also scans for CleanAir interference on the channel.
- **FlexConnect mode**—FlexConnect is a wireless solution for branch office and remote office deployments. The FlexConnect mode enables you to configure and control access points in a branch or remote office from the corporate office through a WAN link without having to deploy a controller in each office. The FlexConnect mode can switch client data traffic locally and perform client authentication locally when the connection to the controller is lost. When connected to the controller, the FlexConnect mode can also tunnel traffic back to the controller.
- **Monitor mode**—In this mode, the AP radios are in the receive state. The AP scans all the channels every 12 seconds for rogue client beacons, noise floor measurements, interference, IDS events, and CleanAir intruders.
- **Rogue Detector mode**—In this mode, the AP radio is turned off, and the AP listens only to the wired traffic. The controller passes the APs that are configured as rogue detectors as well as lists of suspected rogue clients and AP MAC addresses. The rogue detector listens for ARP packets and can be connected to all broadcast domains through a trunk link.
- **Sniffer mode**—In this mode, the AP captures and forwards all packets on a channel to a remote device that decodes the packets with packet analyzer software such as Wireshark.
- **Bridge mode**—In this mode, the AP is configured to build a wireless mesh network where wired network cabling is not available.

**Note**

You can configure these modes using both the GUI and CLI. For configuration instructions, see the *Cisco Wireless LAN Controller Configuration Guide*.

**Note**

MAPs can only be configured in Bridge mode regardless of their wired or wireless backhaul. If the MAPs have a wired backhaul, you must change their AP role to RAP before you change the AP Mode.

Cisco Aironet 1552 Mesh Access Point

The Cisco Aironet 1550 Series Outdoor Mesh Access Point is a modularized wireless outdoor 802.11n access point designed for use in a mesh network. The access point supports point-to-multipoint mesh wireless connectivity and wireless client access simultaneously. The access point can also operate as a relay node for other access points that are not directly connected to a wired network. Intelligent wireless routing is provided by the Adaptive Wireless Path Protocol (AWPP). This enables the access point to identify its neighbors and

intelligently choose the optimal path to the wired network by calculating the cost of each path in terms of signal strength and the number of hops required to get to a controller.

The 1550 series access points leverage 802.11n technology with integrated radio and internal/external antennas. The 1552 outdoor platform consists of Multiple Input Multiple Output (MIMO) WLAN radios. It offers 2x3 MIMO with two spatial streams, Beamforming, and comes with integrated spectrum intelligence (CleanAir).

CleanAir provides full 11n data rates while detecting, locating, classifying, and mitigating radio frequency (RF) interference to provide the best client experience possible. CleanAir technology on the outdoor 11n platform mitigates Wi-Fi and non-Wi-Fi interference on 2.4-GHz radios.

The 1550 series access points have two radios—2.4-GHz and 5-GHz MIMO radios. While the 2.4-GHz radios are used primarily for local access, the 5-GHz radios are used for both local access and wireless backhaul in mesh mode.

**Note**

The wIPS submode is not supported on the Cisco 1552 Series Mesh Access Points.

**Note**

The 2.4-GHz radios cannot be used for backhaul in 1552 APs.

The 2-GHz b/g/n radio has the following features:

- Operates in the 2.4-GHz ISM band.
- Supports channels 1-11 in the United States, 1-13 in Europe, and 1-13 in Japan.
- Has two transmitters for 802.11b/g/n operation.
- You can configure the output power for 5 power levels.
- The radio has three receivers that enable maximum-ratio combining (MRC).

The 5-GHz a/n radio has the following feature:

- Operates in the UNII-2 band (5.25 to 5.35 GHz), UNII-2 Extended/ETSI band (5.47 to 5.725 GHz), and the upper ISM band (5.725 to 5.850 GHz).
- Has two transmitters for 802.11a operation.
- Power settings can change depending on the regulatory domain. You can configure the output power for 5 power levels in 3 dB steps.
- The radio has three receivers that enable maximum-ratio combining (MRC).

The 1550 series access points have the following features:

- Supports modularity of the 1520 series and allows flexibility in radio configuration
- Fully interoperable with the 1520 series access points
- Can also interoperate with legacy clients and offers enhanced backhaul performance
- Multicast VideoStream and HotSpot 2.0 are supported when the AP is configured in Local mode.
- AP1552 is QoS capable of supporting quality VoWLAN calls.
- Band Select, which notifies a connected client to roam from 2.4 GHz to 5 GHz, is supported.

- DTLS support allows AP1552 to encrypt data in all supported AP modes except Bridge mode.
- You can enable CleanAir on the 5-GHz radio by navigating to **Wireless > Radios > 802.11a > Configure** on the controller GUI.
- If AP1552 is in Bridge mode, CleanAir Advisor becomes operational. CleanAir Advisor generates CleanAir reports and identifies interference. The event driven RRM is disabled. Therefore, the radio does not change the transmission power level or channel.

The models can be classified as models with external antennas and models with built-in antennas. The 1552C model is configured with an integrated DOCSIS/EuroDOCSIS 3.0 cable modem. The DOCSIS 3.0 cable modem provides 8 DS and 4 US (8x4), 304x108 Mbps. The EuroDOCSIS 3.0 cable modem provides 4 US and 4 DS (4x4), 152x108 Mbps. While a DOCSIS 2.0 cable modem could provide throughput of up to 40 Mbps only, a DOCSIS 3.0 cable modem can provide a DS throughput of 290 Mbps and a US throughput of 100 Mbps.

The 1552 Access Point is available in these models:

- [1552E, on page 8](#)
- [1552C, on page 9](#)
- [1552I, on page 10](#)
- [1552H, on page 10](#)
- [1552CU, on page 11](#)
- [1552EU, on page 11](#)

For more information about the Cisco 1550 Series Access Points, see <http://www.cisco.com/en/US/products/ps11451/index.html>.

1552E

The Cisco Aironet 1552E Outdoor Access Point is the standard model, dual-radio system with dual-band radios that are compliant with IEEE 802.11a/n (5-GHz) and 802.11b/g/n standards (2.4 GHz). The 1552E has three external antenna connections for three dual-band antennas. It has Ethernet and fiber Small Form Factor Pluggable (SFP) backhaul options, along with the option of a battery backup. This model also has a PoE-out port and can power a video surveillance camera. A highly flexible model, the Cisco Aironet 1552E is well equipped for municipal and campus deployments, video surveillance applications, mining environments, and data offload.

The 1552E model has the following features:

- Weighs 17.3 lbs (7.9 kg) excluding external antennas
- Two radios (2.4 GHz and 5 GHz)
- Three external dual-band omnidirectional antennas with 4 dBi in 2.4 GHz and 7 dBi in 5 GHz
- Vertical beamwidth: 29° at 2.4 GHz, 15° at 5 GHz
- Aligned console port
- Higher equivalent isotropically radiated power (EIRP)
- Multiple uplinks with Ethernet and fiber

- An optional Small Form Factor Pluggable (SFP) fiber module that can be ordered with the AP. The AP can use SFP fiber or copper module.
- 802.3af-compliant PoE-Out option to connect IP devices (such as video cameras)
- AC Powered (100 to 480 VAC)
- PoE-In using Power Injector
- Battery backup option (6 AH)



Note The 1552E model has no cable modem. The 1552E battery cannot be used for 1552H.

- AP1552E can be ordered with an Ethernet Passive Optical Network SFP as an add-on. The EPON SFP provides Gigabit data rates.



Note The EPON SFP feature must be ordered separately and installed.

1552C

Where service providers have already invested in a broadband cable network, the Cisco next-generation outdoor wireless mesh can seamlessly extend network connectivity with the Cisco Aironet 1552C access point by connecting to its integrated cable modem interface. The Cisco Aironet 1552C Outdoor Mesh Access Point is a dual-radio system with DOCSIS 3.0/EuroDOCSIS 3.0 (8x4 HFC) cable modem for power and backhaul. It has dual-band radios that are compliant with IEEE 802.11a/n (5 GHz) and 802.11b/g/n standards (2.4 GHz). The 1552C has an integrated, three-element, dual-band antenna and easily fits within the 30 cm height restriction for service providers. This model is suitable for 3G data offload applications and public Wi-Fi.

The 1552C model has the following features:

- Lightweight (14 lbs or 6.4 kg), low-profile AP
- Two radios (2.4 GHz and 5 GHz)
- DOCSIS/EuroDOCSIS 3.0 Cable Modem
- Aligned console port
- It supports cable modem backhaul
- Has an integrated 3-element array antenna with 2 dBi in 2.4 GHz and 4 dBi in 5 GHz
- Input module, power-over-cable supply (40 to 90 VAC)
- Stamped cover with two convenient holes to tighten the seizure screw for stringer connector (RF/Power Input) and to adjust the fuse pad to attenuate the signal



Note The 1552C model has no battery backup, no fiber SFP support, no PoE Out, no PoE In using Power Injector or Ethernet port, and no AC power option.

1552I

The Cisco Aironet 1552I Outdoor Access Point is a low-profile, lighter weight model. The smaller size and sleeker look helps it blend with the surrounding environment. The smaller power supply also makes it an energy efficient product. The 1552I does not have PoE-Out or a fiber SFP port.

The 1552I model has the following features:

- Lightweight (14 lbs or 6.4 kg), low-profile version
- Two radios (2.4 GHz and 5 GHz)
- Aligned console port
- AC powered (100 to 277 VAC)
- Stamped cover with no holes
- Supports street light power TAP



Note

The 1552I model has no battery backup, no fiber SFP support, no cable modem, and no PoE Out.

1552H

This access point is designed for hazardous environments like oil and gas refineries, chemical plants, mining pits, and manufacturing factories. The Cisco Aironet 1552H Outdoor Access Point is Class 1, Div 2/Zone 2 hazardous location certified. The features are similar to the 1552E model, with the exception of the battery backup.

The 1552H model has the following features:

- Weighs 14 lbs (6.4 kg)
- Two radios (2.4 GHz and 5 GHz)
- Hazardous Location (Haz Loc) version.
- Power-over-Ethernet (PoE) input using Power Injector
- Aligned console port
- Three dual-band external omnidirectional antennas
- AC entry module with terminal block
- AC powered (100 to 240 VAC, as per ATEX certification requirement)
- Fiber SFP backhaul option
- 802.3af-compliant PoE Out option to connect IP devices (such as video cameras)
- Battery backup option (special battery for hazardous locations)

For more information about Cisco Aironet 1552 mesh access point hardware and installation instructions, see http://www.cisco.com/en/US/products/ps11451/prod_installation_guides_list.html

1552CU

The 1552CU model has the following features:

- Two radios (2.4 GHz and 5 GHz)
- Aligned console port
- AC powered (40 to 90 VAC)
- Stamped cover with no holes
- External high-gain antennas (13 dBi in 2.4 GHz, 14 dBi in 5 GHz)
- Cable modem

1552EU

The 1552EU model has the following features:

- Two radios (2.4 GHz and 5 GHz)
- Aligned console port
- AC powered (90 to 480 VAC)
- PoE 802.3af
- External high-gain antennas (13 dBi in 2.4 GHz, 14 dBi in 5 GHz)
- Battery
- AP1552EU can be ordered with an Ethernet Passive Optical Network SFP as an add-on. The EPON SFP provides Gigabit data rates.



Note The EPON SFP feature must be ordered separately and installed.

Cisco 1522 Mesh Access Point

The AP1522 mesh access point (part numbers: AIR-LAP1522AG-X-K9, AIR-LAP1522HZ-X-K9, AIR-LAP1522PC-X-K9) includes two radios: a 2.4-GHz and a 4.9- to 5.8-GHz radio. The 2.4-GHz (802.11b/g) radio is for client access and the 5-GHz (802.11a) radio is used as the backhaul. With the 7.0.116.0 release and later releases, 2.4 GHz is available for backhaul. This feature is applicable only to AP1522.

The 5-GHz radio is a 802.11a radio that covers the 4.9- to 5.8-GHz frequency band and is used as a backhaul. It can also be used for client access if the *backhaul client access* feature is enabled.



Note AP1522s with serial numbers *prior* to FTX1150XXXX do **not** support 5- and 10-MHz channels on the 4.9-GHz radio; however, a 20-MHz channel is supported.



Note Those AP1522s with serial numbers *after* FTX1150XXXX support 5-, 10-, and 20-MHz channels.

Cisco 1524PS Mesh Access Point

The AP1524PS mesh access point (part number: AIR-LAP1524PS-X-K9) includes three radios: a 2.4-GHz, a 5.8-GHz, and a 4.9-GHz radio. The 2.4-GHz radio is for client access (nonpublic safety traffic) and the 4.9-GHz radio is for public safety client access traffic only. The 5.8-GHz radio can be used as the backhaul for both public safety and nonpublic safety traffic.

The 4.9-GHz and 5.8-GHz radios are 802.11a subband radios that support a subset of specific 802.11a channels and include a subband specific filter designed to lessen interference from other 11a subband radios within the same mesh access point.

The 4.9-GHz subband radio on the AP1524 supports public safety channels within the 5-MHz (channels 1 to 10), 10-MHz (channels 11 to 19), and 20-MHz (channels 20 to 26) bandwidths.

- The data rates supported within the 5-MHz bandwidth are 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mbps. The default rate is 6 Mbps.
- The data rates supported within the 10-MHz bandwidth are 3, 4.5, 6, 9, 12, 18, 24, and 27 Mbps. The default rate is 12 Mbps.

Cisco 1524SB Mesh Access Point

The AP1524SB mesh access point (part number: AIR-LAP1524SB-X-K9) includes three radios: one 2.4-GHz radio and two 5-GHz radios.

The 2.4-GHz radio is for client access (nonpublic safety traffic). The two 5-GHz radios serve as serial backhauls: one uplink and one downlink. The AP1524SB is suitable for linear deployments.



Note

In the 6.0 release, the 5-GHz radios in the -A domain could be operated only in the 5.8-GHz band with 5 channels. In the 7.0 release, these radios cover the whole 5-GHz band.

Each 5-GHz radio backhaul is configured with a different backhaul channel. There is no need to use the same shared wireless medium between the north-bound and south-bound traffic in a mesh tree-based network.

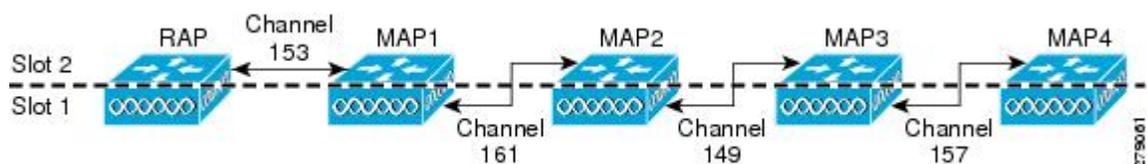
On the RAP, the radio in slot 2 is used to extend the backhaul in the downlink direction; the radio in slot 1 is used only for client access and not mesh.

On the MAP, the radio in slot 2 is used for the backhaul in the uplink direction; the radio in slot 1 is used for the backhaul in the downlink direction.

You only need to configure the RAP downlink (slot 2) channel. The MAPs automatically select their channels from the channel subset. The available channels for the 5.8-GHz band are 149, 153, 157, 161, and 165.

This figure shows an example of channel selection when the RAP downlink channel is 153.

Figure 2: Channel Selection Example



Fall Back Mode

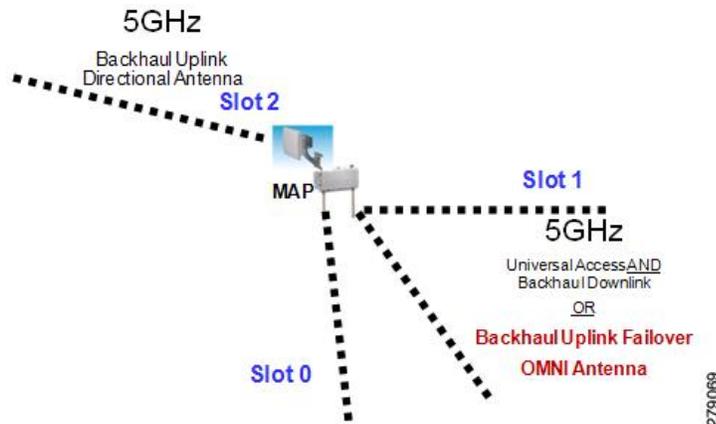
Slot 1 in a 5-GHz radio in a MAP can act as an uplink radio for the backhaul in any one of the following scenarios:

- Slot 2 radio fails.
- Antenna for slot 2 radio goes bad.
- Slot 2 radio is unable to find the uplink because of a bad RF design.
- Interference and long-term fades disturb the uplink to the extent that the slot 2 radio loses its uplink connection.

When a slot 1 radio takes over a slot 2 radio, it is called Fall Back Mode. The slot 2 radio is made inactive on a noninterfering channel. The hardware is reduced to AP1522 (two radios). The slot 1 radio (omni antenna) is extended to the uplink. A period of 15 minutes is set on a timer to attempt a rescan to find a parent on the slot 2 radio again. The timer is similar to the default BGN timer.

This figure shows an example of the Fall Back Mode.

Figure 3: Fall Back Mode



The antenna ports are labeled on the AP1524SB and are connected internally to the radios in each slot. The AP1524SB has six ports with three radio slots (0, 1, 2) as described in [Table 1: AP1524SB Antenna Ports](#), on page 13.

Table 1: AP1524SB Antenna Ports

Antenna Port	Radio Slot	Description
1	1	5 GHz—Used for backhaul and universal access. Universal access is configured only on slot 1. Note Omni antenna is required.
2	0	2 GHz—Used for client access.
3	0	2 GHz—Used for client access.

Antenna Port	Radio Slot	Description
4	0	2 GHz—Used for client access.
5	—	Not connected.
6	2	5 GHz—Used for backhaul. Note Directional antenna is required.

**Note**

Depending on the product model, the AP1524SB could have either 5-GHz radios or 5.8-GHz subband radios installed in slot 1 and slot 2. Regardless of the radios installed, the AP1524SB running controller software release 6.0 is restricted to the UNII-3 channels (149, 153, 157, 161, and 165) in slot 1 and slot 2.

Ethernet Ports

AP1500s support four Gigabit Ethernet interfaces.

- Port 0 (g0) is a Power over Ethernet (PoE) input port—PoE (in)
- Port 1 (g1) is a PoE output port—PoE (out)
- Port 2 (g2) is a cable connection
- Port 3 (g3) is a fiber connection

You can query the status of these four interfaces in the controller CLI and Cisco Prime Infrastructure.

In the controller CLI, the **show mesh env summary** command is used to display the status of the ports.

- The Up or Down (Dn) status of the four ports is reported in the following format:
 - port0(PoE-in):port1(PoE-out):port2(cable):port3(fiber)
- For example, *rap1522.a380* in the display below shows a port status of *UpDnDnDn*. This indicates the following:
 - PoE-in port 0 (g0) is Up, PoE-out port 1 (g1) is Down (Dn), Cable port 2 (g2) is Down (Dn), and Fiber port 3 (g3) is Down (Dn).

```
(controller)> show mesh env summary
AP Name      Temperature (C/F)  Heater  Ethernet  Battery
-----
rap1242.c9ef    N/A              N/A     UP         N/A
rap1522.a380    29/84            OFF     UpDnDnDn  N/A
rap1522.4da8    31/87            OFF     UpDnDnDn  N/A
```

Multiple Power Options

For the 1550 Series

Power options include the following:

- Power over Ethernet (PoE)-In
 - 56 VDC using a Power Injector (1552E and 1552H)
 - PoE-In is not 802.3af and does not work with PoE 802.3af-capable Ethernet switch
- AC Power
 - 100 to 480 VAC (47-63 Hz)—Connecting AC or Streetlight Power (1552E)
 - 100 to 240 VAC—Connecting AC or Streetlight Power (1552H)
- External Supply
 - 12 VDC—Connecting DC Power Cable (All Models)
- Internal Battery Backup (1552E and 1552H)
- Power over Cable (PoC)
 - 40 to 90VAC—Connecting Cable PoC (1552C)
- PoE-Out 802.3af compliant to connect IP devices such as Video Cameras (1552E and 1552H)
 - (PoE-Out) is not available when using Power Injector (PoE-In) as the power source
- 802.3af compliant PoE-Out to connect IP devices such as video cameras (1552E and 1552H)

This port also performs Auto-MDIX, which enables to connect crossover or straightthrough cables.

The 1550 series access points can be connected to more than one power source. The access points detect the available power sources and switch to the preferred power source using the following default prioritization:

- AC power or PoC power
- External 12-VDC power
- Power injector PoE power
- Internal battery power

[Table 2: Power Options in 1552 Models](#), on page 16 lists the power options available for the 1552 access point models.

Table 2: Power Options in 1552 Models

Power Option	1552E	1552H	1552C	1552I
AC	100 to 480 VAC 80W	100 to 240 VAC 80W	Not Applicable	100 to 277 VAC 50W
Power over Cable	Not Applicable	Not Applicable	40-90 V (quasi-square wave) 45W	Not Applicable
PoE (using Power Injector)	56V +/- 10%	56V +/- 10%	Not Applicable	Not Applicable
DC (nominal 12 VDC)	11.4 – 15V	11.4 – 15V	11.4 – 12.6V	11.4 – 15V
Battery Backup	80W-hr	35W-hr	Not Applicable	Not Applicable

For the 1520 Series

Power options include the following:

- 100 to 480 VAC streetlight power
- 12 VDC
- Power-over-cable power supply (40 to 90 VAC)
- PoE using a separate power injection system (48 VDC)
 - For more information about the power injection, its specifications, and installation, see http://www.cisco.com/en/US/docs/wireless/access_point/1520/power/guide/1520pwrinj.html
- Internal battery backup power
- 802.3af-compliant PoE-Out to connect IP devices (such as video cameras)

This port also performs Auto-MDIX, which allows to connect crossover or straightthrough cables.

Battery Backup Module (Optional)

Battery backup six-ampere hour module is available for the following:

- AIR-1520-BATT-6AH for AP1520s
- AIR-1550-BATT-6AH for only the AIR-CAP-1552E-x-K9 model

The integrated battery can be used for temporary backup power during external power interruptions.

The battery run time for AP1520s is as follows:

- 3-hour access point operation with up to 3 radios at 77oF (25oC) with PoE output port off

- 2-hour access point operation with up to 3 radios at 77oF (25oC) with PoE output port on

The battery run time for AP1550s is as follows:

- 2-hour access point operation using two radios at 77oF (25oC) with PoE output port off
- 1.5-hour access point operation using two radios at 77oF (25oC) with PoE output port on

The battery pack is not supported on the access point cable configuration.



Note

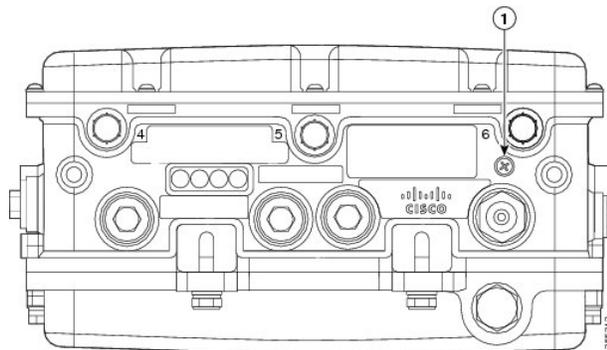
For a complete listing of optional hardware components for AP1520s such as mounting brackets, power injectors, and power tap adapters, see http://www.cisco.com/en/US/prod/collateral/wireless/ps5679/ps8368/product_data_sheet0900aecd8066a157.html

Reset Button

A 1500 series access point has a reset button located on the bottom of the unit. The reset button is recessed in a small hole that is sealed with a screw and a rubber gasket. The reset button can be used to perform the following functions:

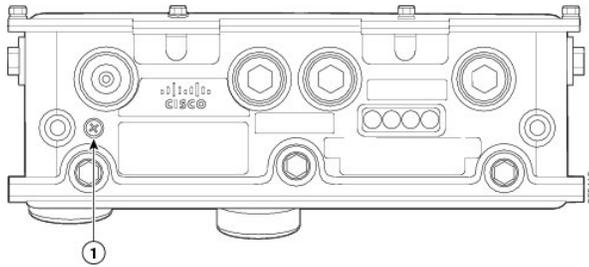
- Reset the access point—Press the reset button for less than 10 seconds, and the LEDs turn off during the reset and then reactivate when the reset is complete.
- Disable battery backup power—Press the reset button for more than 10 seconds, and the LEDs turn off, then on, and then stay off.
 - You can also disable the battery remotely by entering the following command:
config mesh battery-state disable AP_name
- Switch off LEDs—Press the reset button for more than 10 seconds, and the LEDs turn off, then on, and then stay off.

Figure 4: Reset Button Location - Models AIR-CAP1552E-x-K9 and AIR-CAP1552H-x-K9



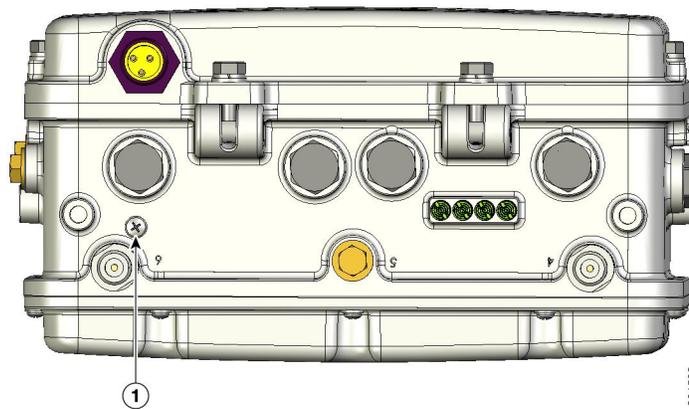
1	Reset button
---	--------------

Figure 5: Reset Button Location - Models AIR-CAP1552C-x-K9 and AIR-CAP1552I-x-K9



1	Reset button
---	--------------

Figure 6: Reset Button Location for 1520 Series



1	Reset button location
---	-----------------------

Resetting Access Point

To reset the access point, follow these steps:

-
- Step 1** Use a Phillips screwdriver to remove the reset button screw. Ensure that you do not lose the screw.
 - Step 2** Use a straightened paperclip, and push the reset button for less than 10 seconds. This step causes the access point to reboot (power cycle), all LEDs turn off for approximately 5 seconds, and then the LEDs reactivate.
 - Step 3** Replace the reset button screw, and use a Phillips screwdriver to tighten to 22 to 24 in. lbs (2.49 to 2.71 nm).
-

Monitoring the LED Status

The four-status LEDs on AP1500s are useful during the installation process to verify connectivity, radio status, access point status, and software status. However, once the access point is up and running and no further diagnosis is required, we recommend that you turn off the LEDs to discourage vandalism.

If your access point is not working as expected, see the LEDs at the bottom of the unit. You can use them to quickly assess the status of the unit.



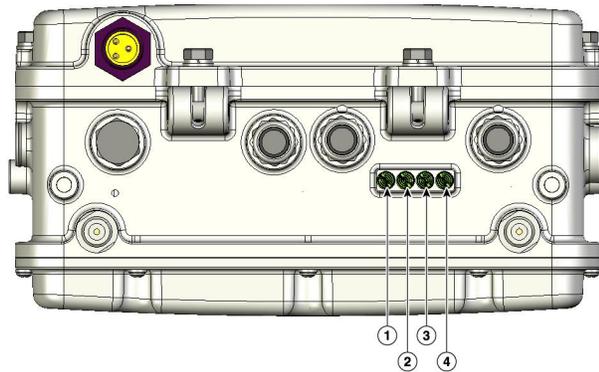
Note

LEDs are enabled or disabled using the `config ap led-state {enable | disable} {cisco_ap_name | all}` command.

There are four LED status indicators on AP1500s.

This figure shows the location of the AP1500 LEDs.

Figure 7: Access Point LEDs at the Bottom of the Unit



The table below describes each LED and its status.

1	Status LED—Access point and software status	3	RF-1 LED—Status of the radio in slot 0 (2.4-GHz) and slot 2 (5.8-GHz for 1524SB and 4.9-GHz for 1524PS)).
2	Uplink LED—Ethernet, cable, or fiber status	4	RF-2 LED—Status of the radio in slot 1 (5.8-GHz) and the radio in slot 3. ¹

¹ Slot 3 is disabled



Note

The RF-1 and RF-2 LEDs monitor two radios simultaneously but do not identify the affected radio. For example, if the RF-1 LED displays a steady red LED, one or both of the radios in slots 0 and 2 have experienced a firmware failure. To identify the failing radio, you must use other means, such as the access point CLI or controller GUI to investigate and isolate the failure.

[Table 3: Access Point LED Signals](#), on page 20 lists the access point LED signals.

Table 3: Access Point LED Signals

LED	Color ^{2 3}	Meaning
Status	Off	Access is point is not powered on.
	Green	Access point is operational.
	Blinking green	Download or upgrade of Cisco IOS image file is in progress.
	Amber	Mesh neighbor access point discovery is in progress.
	Blinking amber	Mesh authentication is in progress.
	Blinking red/green/amber	CAPWAP discovery is in progress.
	Red	Firmware failure. Contact your support organization for assistance.
Uplink	Off	No physical connector is present. The uplink port is not operational.
	Green	Uplink network is operational (cable, fiber optic, or Ethernet).
RF-1 Slot 0 2.4-GHz radio	Off	Radio is turned off.
	Green	Radio is operational.
	Red	Firmware failure. Contact your support organization for assistance.
RF-1 Slot 2 802.11a radio	Off	Radio is turned off.
	Green	Radio is operational.
	Red	Firmware failure. Contact your support organization for assistance.
RF-2 Slot 1 802.11a radio	Off	Radio is turned off.
	Green	Radio is operational.
	Red	Firmware failure. Contact your support organization for assistance.
RF-2 Slot 3	Disabled in this release.	—

- 2 If all LEDs are off, the access point has no power.
- 3 When the access point power supply is initially turned on, all LEDs are amber.

Serial Backhaul Access Point Guidelines for the Rest of the World (ROW)

In the 7.0 release, new 1524 SKUs are released, with both 802.11a radio units supporting the entire 5-GHz band from 4.9 GHz to 5.8 GHz. This release also opens the 5-GHz band for the -A domain as well on the existing hardware. The radios can also operate in UNII-2 (5.25 to 5.35 GHz), UNII-2 plus (5.47 to 5.725 GHz), and the upper ISM (5.725 to 5.850 GHz) bands.

The public safety band (4.94 to 4.99 GHz) is not supported for backhaul and for client access.

For information about the channels and maximum power levels of the AP1500 supported within the world's regulatory domains, see the *Channels and Maximum Power Settings for Cisco Aironet Lightweight Access Points* manual at:

- AP1520: http://www.cisco.com/en/US/docs/wireless/access_point/channels/lwapp/reference/guide/1520_chp.html

Table 4: Channels Supported Per Regulatory Domain, on page 21 provides a complete overview of channels supported in each domain. In addition to 5 channels in the upper ISM band, there are 4 channels in the UNII-2 band and 11 channels in the UNII-2 Plus band. For outdoor APs, there are 5 channels in the upper ISM band, 3 channels in the UNII-2 band, and 8 channels in the UNII-2 Plus band.

Table 4: Channels Supported Per Regulatory Domain

Channel ID	Frequency (MHz)	Regulatory Domains								
		-A	-C	-E	-K	-M	-N	-P	-S	-T
4940-5100 MHz										
184	4920							Yes		
188	4949							Yes		
22/192	4960							Yes		
26/196	4980							Yes		
8	5040							Yes		
12	5060							Yes		
5250-5350 MHz										
52	5260									
56	5280	DFS			DFS					
60	5300	DFS			DFS					
64	5320	DFS			DFS					

Channel ID	Frequency (MHz)	Regulatory Domains								
		-A	-C	-E	-K	-M	-N	-P	-S	-T
5470-5725 MHz										
100	5500	DFS		DFS	DFS	DFS				DFS
104	5520	DFS		DFS	DFS	DFS				DFS
108	5540	DFS		DFS	DFS	DFS				DFS
112	5560	DFS		DFS	DFS	DFS				DFS
116	5580	DFS		DFS	DFS	DFS				DFS
120	5580				DFS					DFS
124	5620				DFS					DFS
128	5640									DFS
132	5660	DFS		DFS		DFS				DFS
136	5680	DFS		DFS		DFS				DFS
140	5700	DFS		DFS		DFS				DFS
5725-5875 MHz										
149	5745	Yes	Yes			DFS	Yes		Yes	Yes
153	5765	Yes	Yes			DFS	Yes		Yes	Yes
157	5785	Yes	Yes			DFS	Yes		Yes	Yes
161	5805	Yes	Yes			DFS	Yes		Yes	Yes
165	5825	Yes	Yes				Yes		Yes	Yes
Note	Channels marked Yes/DFS are channels supported in that domain. Channels marked DFS are additional DFS-enabled channels and require checks for radar detection. This table is for up to 8 -Bi antennas. For higher gain antennas, see http://www.cisco.com/en/US/docs/wireless/access_point/channels/lwapp/reference/guide/1520_chp.html .									

With the expansion of the channel set, DFS-enabled channels are also supported. Radar detection and automatic channel reassignment in case of radar detection on RAP/MAPs are also supported. When there is a channel change, it is also propagated to the corresponding parent/child access point (if applicable) so that the channel change is synchronized between the parent and child so that there is no link downtime. For example, if radar is detected on the uplink radio of a child access point, the parent is informed so that it can change the channel

of the downlink radio. The parent in turn informs the child about the channel change, so that the child access point can set the new channel on its uplink radio as well and does not have to scan again to rejoin the parent on the new channel.

For countries in the Middle East such as Saudi Arabia and Kuwait, a new regulatory domain for outdoor APs, the -M domain, has been mandated. With this release, outdoor APs will now support this new -M domain. Earlier, these countries were part of the -E domain, which supported a channel set of 100 to 140. However, in the -M domain, channels 149 to 161 are also supported with the 100 to 140 band. Also, in the -M domain, channels 149 to 161 are DFS enabled, unlike other domains such as -A, -C, -N, and so on, where these channels are non-DFS. Radar detection is also enabled on these channels. Because the countries that are now part of the -M domain (that is, Saudi Arabia and Kuwait) were earlier part of the -E domain, both the -E domain and the -M domain APs are supported, when any of these countries is configured on the controller, which ensures backward compatibility with the existing -E domain APs in these countries. However, you will have to ensure that only a valid set of channels (the channels common to both the -E and the -M domains) is selected as part of the 802.11a DCA list, and that the backhaul channel deselection feature is enabled to ensure correct operation of the -E domain APs, as these APs can support 100 to 140 channels and not the extended list of 149 to 161 channels available in the -M domain.

Discontinuation of the 116 and 132 Channels from the UNII-2 Extended Band

With the 7.0 release, in AP1522 and AP1524SB platforms, in addition to the 5 channels in the upper ISM band, there are 3 channels in the UNII-2 band and 8 channels in the UNII-2 Extended band. There are 11 channels in the UNII-2 Extended band, but only 8 are applicable in the outdoors due to stringent dynamic frequency selection (DFS) conditions for Canada because Canada requires a channel availability check every 10 minutes compared to every 60 seconds in the USA. The 120 (5600 MHz), 124 (5620 MHz), and 128 (5640 MHz) channels have had to be dropped.

The Federal Communications Commission (FCC) has issued a guideline to protect Terminal Doppler Weather Radar (TDWR) systems operating in the 5600- to 5650-MHz band from interference. Also, the UNII-2 Wi-Fi operating channels are interfering with the TDWR band. Therefore, with the 7.0.116.0 release, the 116 and 132 channels are dropped in addition to the 120, 124, and 128 channels. The guidelines also require that you avoid operation in the TDWR band and operate at least 30 MHz away from the TDWR operation frequencies when devices are installed within 35 km (about 21 miles) or the line-of-sight of the TDWR sites.



Note

Your outdoor installation should be registered in the outdoor database. No fee is required to register your company. The TDWR location sites can be found on the Internet.



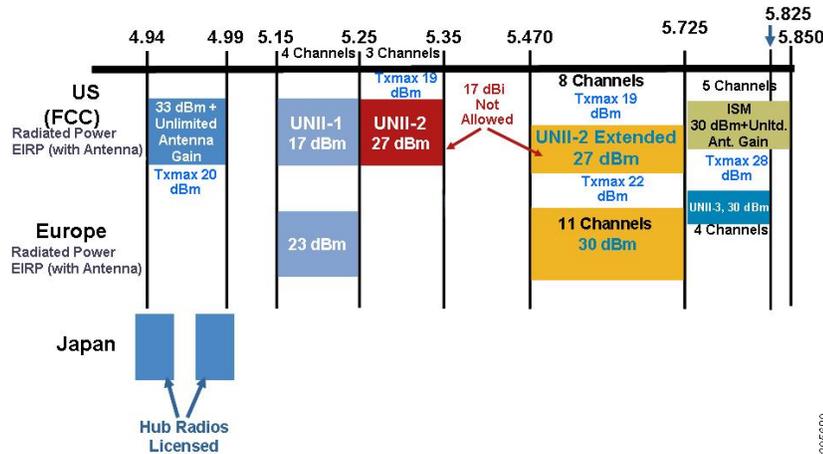
Note

The FCC, the National Telecommunications and Information Administration (NTIA), and the Federal Aviation Administration (FAA) are continuing to investigate and eliminate cases of interference to TDWRs. For more information about FCC guidelines for outdoor installations, see http://www.cisco.com/en/US/prod/collateral/routers/ps272/data_sheet_c78-647116_ps11451_Products_Data_Sheet.html.

Frequency Bands

Both the 2.4-GHz and 5-GHz frequency bands are supported on the indoor and outdoor access points. Additionally, the 4.9-GHz public safety band is supported on AP1524PS.

Figure 8: Frequency Bands Supported By 802.11a Radios on AP1520s



The 5-GHz band is a conglomerate of three bands in the USA: 5.150 to 5.250 (UNII-1), 5.250 to 5.350 (UNII-2), 5.470 to 5.725 (UNII-2 Extended), and 5.725 to 5.850 (ISM). UNII-1 and the UNII-2 bands are contiguous and are treated by 802.11a as being a continuous swath of spectrum 200-MHz wide, more than twice the size of the 2.4-GHz band (see [Table 5: Frequency Band](#), on page 24).

The 4.9 GHz is a public safety channel within the 5-MHz (channels 1 to 10), 10-MHz (channels 11 to 19), and 20-MHz (channels 20 to 26) bandwidths.

The -D domain, which is the country domain for India, supports the following:

- 20-MHz channels—169 (5.845 GHz) and 173 (5.865 GHz)
- 40-MHz channels—The channel pair 169/173 (5.855 GHz)



Note

The frequency depends on the regulatory domain in which the access point is installed. For additional information, see the Channels and Power Levels document at http://www.cisco.com/en/US/docs/wireless/access_point/channels/lwapp/reference/guide/lw_chp2.html.

Table 5: Frequency Band

Frequency Band Terms	Description	Model Support
UNII-1 ⁴	Regulations for UNII devices operating in the 5.15- to 5.25-GHz frequency band. Indoor operation only,	1130, 1240, and all 11n Indoor APs

Frequency Band Terms	Description	Model Support
UNII-2	Regulations for UNII devices operating in the 5.25- to 5.35-GHz frequency band. DFS and TPC are mandatory in this band.	1130, 1240, all 11n indoor APs, 1522, 1524SB, and 1552 (except -A domain)
UNII-2 Extended	Regulations for UNII-2 devices operating in the 5.470 to 5.725 frequency band.	1130, 1240, all 11n indoor APs, 1522, 1524SB, 1552
ISM ⁵	Regulations for UNII devices operating in the 5.725 to 5.850 GHz frequency band.	1130, 1240, all 11n indoor APs, 1522, 1524 (AP1524PS and AP1524SB), 1552

⁴ UNII refers to the Unlicensed National Information Infrastructure.

⁵ ISM refers to Industrial, Scientific and Medical.



Note

The 1552 access points support only the ISM band in the -A domain. The 1552 access points support the UNII-2 and UNII-2 Extended bands. The DFS algorithms work as expected. The DFS algorithms can be implemented in the ETSI and other domains, but not in the -A domain. The product certification is pending the FCC approval and it might take up to 4 months to get the product certified. After the product is certified, Cisco will provide new software that will allow the UNII-2 and UNII-2 Extended bands to be used for the 1552 access points in the -A domain.

For regulatory information, see http://www.cisco.com/en/US/prod/collateral/wireless/ps5679/ps5861/product_data_sheet0900aecd80537b6a.html.

Dynamic Frequency Selection

Previously, devices employing radar operated in frequency subbands without other competing services. However, controlling regulatory bodies are attempting to open and share these bands with new services like wireless mesh LANs (IEEE 802.11).

To protect existing radar services, the regulatory bodies require that devices wishing to share the newly opened frequency subband behave in accordance with the Dynamic Frequency Selection (DFS) protocol. DFS dictates that to be compliant, a radio device must be capable of detecting the presence of radar signals. When a radio detects a radar signal, it is required to stop transmitting to for at least 30 minutes to protect that service. The radio then selects a different channel to transmit on but only after monitoring it. If no radar is detected on the projected channel for at least one minute, then the new radio service device may begin transmissions on that channel.

The AP performs a DFS scan on the new DFS channel for 60 seconds. However, if a neighboring AP is already using that new DFS channel, the AP does not perform the DFS scan.

The process for a radio to detect and identify a radar signal is a complicated task that sometimes leads to incorrect detects. Incorrect radar detections can occur due to a large number of factors, including due to uncertainties of the RF environment and the ability of the access point to reliably detect actual on-channel radar.

The 802.11h standard addresses DFS and Transmit Power Control (TPC) as it relates to the 5-GHz band. Use DFS to avoid interference with radar and TPC to avoid interference with satellite feeder links.

**Note**

DFS is mandatory in the USA for 5250 to 5350 and 5470 to 5725 frequency bands. DFS and TPC are mandatory for these same bands in Europe.

Figure 9: DFS and TPC Band Requirements

	Frequency (MHz)
1	5150 – 5250
2	5250 – 5350
	5470 – 5725
3	5725 – 5850

Antennas

Overview

Antenna choice is a vital component of any wireless network deployment. There are two broad types of antennas:

- Directional
- Omnidirectional

Each type of antenna has a specific use and is most beneficial in specific types of deployments. Because antennas distribute RF signal in large *lobed* coverage areas determined by antenna design, successful coverage is heavily reliant on antenna choice.

An antenna gives a mesh access point three fundamental properties: gain, directivity, and polarization:

- Gain—A measure of the increase in power. Gain is the amount of increase in energy that an antenna adds to an RF signal.
- Directivity—The shape of the transmission pattern. If the gain of the antenna increases, the coverage area decreases. The coverage area or radiation pattern is measured in degrees. These angles are measured in degrees and are called beamwidths.



Note Beamwidth is defined as a measure of the ability of an antenna to focus radio signal energy toward a particular direction in space. Beamwidth is usually expressed in degrees HB (Horizontal Beamwidth); usually, the most important one is expressed in a VB (Vertical Beamwidth) (up and down) radiation pattern. When viewing an antenna plot or pattern, the angle is usually measured at half-power (3 dB) points of the main lobe when referenced to the peak effective radiated power of the main lobe.



Note An 8-dBi antenna transmits with a horizontal beamwidth of 360 degrees, causing the radio waves to disperse power in all directions. Therefore, radio waves from an 8-dBi antenna do not go nearly as far as those radio waves sent from a 17-dBi patch antenna (or a third-party dish) that has a more narrow beamwidth (less than 360 degrees).

- **Polarization**—The orientation of the electric field of the electromagnetic wave through space. Antennas can be polarized either horizontally or vertically, though other kinds of polarization are available. Both antennas in a link must have the same polarization to avoid an additional unwanted loss of signal. To improve the performance, an antenna can sometimes be rotated to alter polarization, which reduces interference. A vertical polarization is preferable for sending RF waves down concrete *canyons*, and horizontal polarization is generally more preferable for wide area distribution. Polarization can also be harnessed to optimize for RF bleed-over when reducing RF energy to adjacent structures is important. Most omnidirectional antennas ship with vertical polarization as their default.

Antenna Options

A wide variety of antennas are available to provide flexibility when you deploy the mesh access points over various terrains. 5 GHz is used as a backhaul and 2.4 GHz is used for client access.

[Table 6: External 2.4- and 5-GHz Antennas, on page 27](#) lists the supported external 2.4- and 5-GHz antennas for AP1500s.

Table 6: External 2.4- and 5-GHz Antennas

Part Number	Model	Gain (dBi)
AIR-ANT2450V-N	2.4-GHz compact omnidirectional ⁶	5
AIR-ANT-2455V-N	2.4-GHz compact omnidirectional	5.5
AIR-ANT2480V-N	2.4-GHz omnidirectional	8.0
AIR-ANT5180V-N	5-GHz compact omnidirectional ⁷	8.0
	4.9-GHz compact omnidirectional ⁸	7.0
AIR-ANT5140V-N	5-GHz right-angle omnidirectional	4.0
AIR-ANT58G10SSA-N	5-GHz sector	9.5

Part Number	Model	Gain (dBi)
AIR-ANT5114P-N	4.9- to 5-GHz patch2	14.0
AIR-ANT5117S-N	4.9- to 5-GHz 90-degree sector2	17.0
AIR-ANT2547V-N	2.4- to 5-GHz dual-band omnidirectional	4 dBi at 2.4 GHz and 7 dBi at 5 GHz

- ⁶ The compact omnidirectional antennas mount directly on the access point.
⁷ The compact omnidirectional antennas mount directly on the access point.
⁸ Use of the 4.9-GHz band requires a license and may be used only by qualified Public Safety operators as defined in section 90.20 of the FCC rules.

See the *Cisco Aironet Antenna and Accessories Reference Guide* on Cisco antennas and accessories at http://www.cisco.com/en/US/prod/collateral/wireless/ps7183/ps469/product_data_sheet09186a008008883b.html

The deployment and design, limitations and capabilities, and basic theories of antennas as well as installation scenarios, regulatory information, and technical specifications are addressed in detail.

[Table 7: Horizontal and Vertical Beamwidth for Cisco Antennas](#), on page 28 summarizes the horizontal and vertical beamwidth for Cisco antennas.

Table 7: Horizontal and Vertical Beamwidth for Cisco Antennas

Antenna	Horizontal Beamwidth (degrees)	Vertical Beamwidth (degrees)
AIR-ANT5180V-N	360	16
AIR-ANT58G10SSA-N	60	60
AIR-ANT5114P-N	25	29
AIR-ANT5117S-N	90	8
AIR-ANT2547V-N	360	30

N-Connectors

All external antennas are equipped with male N-connectors.

AP1552 E/H have three N-connectors to connect dual-band antennas.

AP1552 C/I have no N-connectors as they come with inbuilt antennas.

AP1522 has three separate N-connectors to attach two 2.4-GHz antennas and one N-connector for a 5- GHz antenna.

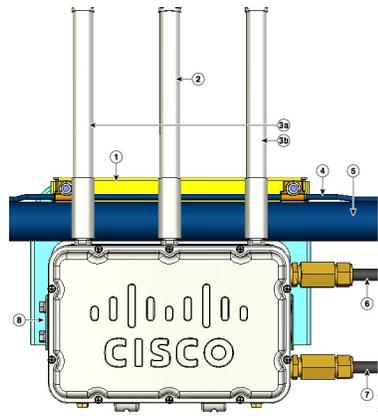
AP1524PS and AP1524SB have five N connectors to attach three 2.4-GHz antennas and two N connectors for 5-GHz/4.9-GHz bands.

Each radio has at least one TX/RX port. Each radio must have an antenna connected to at least one of its available TX/RX ports.

Antenna locations for 5.8 GHz, 4.9 GHz, and 2.4 GHz are fixed and labeled.

This figure shows antenna placement for a two-radio cable mesh access point.

Figure 10: 1522C Two Radio Cable Mesh Access Point Configuration (Hinged-Side Facing Forward)



1	Clamp bracket with cable clamps (part of strand mount kit, ordered separately)	5	Cable bundle
2	5-GHz antenna ⁹ (Tx/Rx)	6	Fiber-optic connection ²
3a	2.4-GHz antennas ¹⁰ (Tx/Rx)	7	Cable POC power input ¹¹
3b	2.4-GHz antennas (Rx)2	8	Strand mount bracket (part of strand mount kit, ordered separately)
4	Strand support cable		

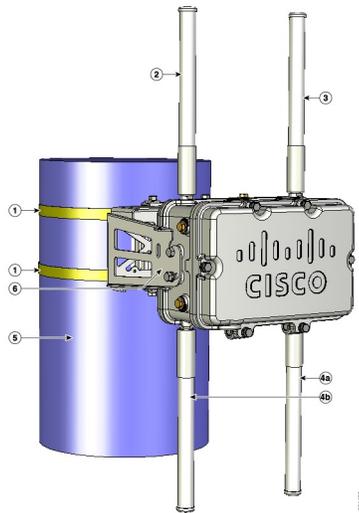
⁹ Illustration shows antenna for an access point with two radios.

¹⁰ Liquid tight connector not shown.

¹¹ Stinger connector shown is user-supplied.

This figure shows antenna placement for a two-radio fiber mesh access point.

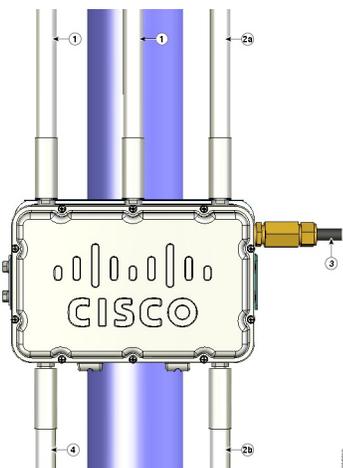
Figure 11: AP 1522 Two Radio Fiber Mesh Access Point Configuration (Hinged-Side Facing Backward)



1	Stainless steel mounting straps (part of pole mount kit)	4b	2.4 GHz antennas (Tx/Rx)
2	2.4-GHz antenna (Rx)	5	Pole (wood, metal, or fiberglass), 2 to 16 in. (5.1 to 40.6 cm) diameter
3	5-GHz antenna (Tx/Rx)	6	Mounting bracket (part of pole mount kit)
4a	2.4 GHz antennas (Rx)		

This figure shows antenna placement for a three-radio fiber mesh access point.

Figure 12: AP1524SB and AP1524PS Mesh Access Point Pole Mount Configuration (Hinged-Side Facing Forward)



1	2.4-GHz antenna (Rx)	3	Fiber-optic connection
2a	5-GHz antenna (Tx/Rx)	4	5-GHz/4.9-GHz antenna (Tx/Rx)
2b	2.4-GHz antenna (Tx/Rx)		

Antenna Configurations for 1552

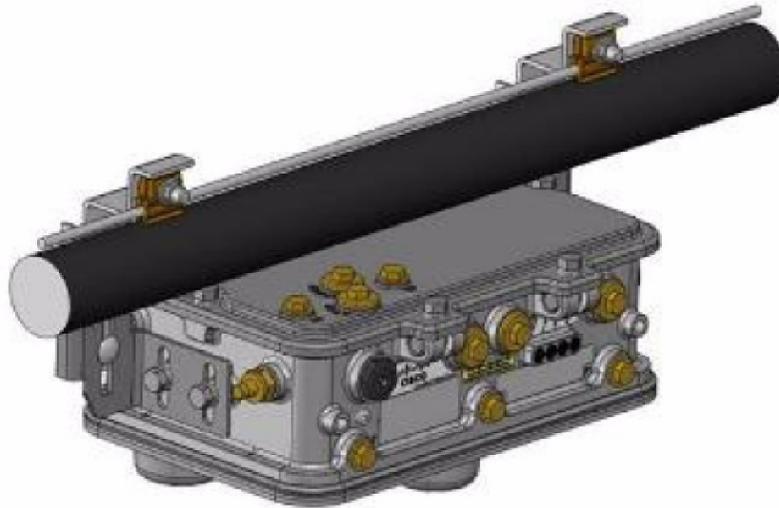
The 1552 access point supports the following two types of antennas designed for outdoor use with radios operating in the 2.4-GHz and 5-GHz frequency:

- Cisco Aironet Low Profile Dual-Band 2.4/5 GHz Dipole Antenna Array (CPN 07-1123-01), an integrated array of three dual-band dipole antennas
- Cisco Aironet Dual-Band Omnidirectional Antenna (AIR-ANT2547V-N), referred to as “stick” antennas

Two types of mounting configurations are available: the cable strand mount and the pole mount.

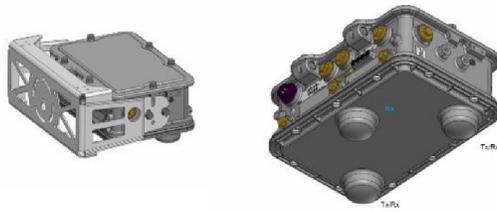
The 1552 models C and I access points are equipped with three new integrated dual-band antennas, with 2 dBi gain at 2.4 GHz and 4 dBi gain at 5 GHz. The antenna works in cable strand mount and low cost, low profile applications.

Figure 13: 1552C Cable Mount



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Figure 14: 1552I Pole/Wall Mount

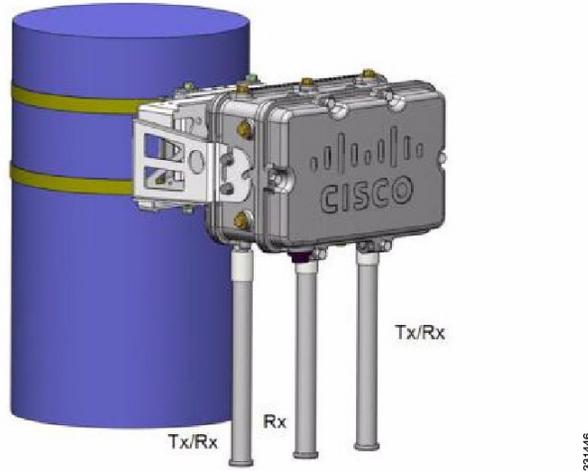


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The 1552 E and H access points are equipped with three N-type radio frequency (RF) connectors (antenna ports 4, 5, and 6) on the bottom of the unit for external antennas to support multiple input multiple output (MIMO) operation as shown in the figure below. When using the optional Cisco Aironet AIR-ANT2547V-N

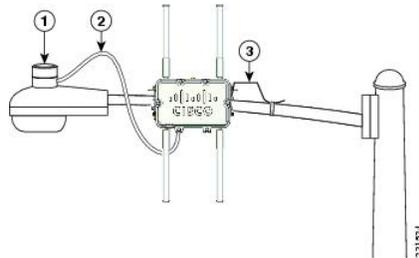
Dual-Band Omnidirectional Antenna, the 2.4- and 5-GHz antennas connect directly to the access point. These antennas have 4 dBi gain at 2.4 GHz and 7 dBi gain at 5 GHz.

Figure 15: 1552 E Pole/Wall Mount



This figure shows one of the recommended installations of an outdoor AP1500.

Figure 16: Outdoor Pole-top Installation of a Mesh Access Point



1	Outdoor light control	3	6-AWG copper grounding wire
2	Streetlight power tap adapter		

The AP1500 series was designed building on the long experience we have had in deploying outdoor access points over the past few years. This includes consideration for resistance to lightning effects. The AP1500 series employs some lightning arrestor circuitry on the Ethernet & Power ports. On input Ethernet port, Gas Discharge Tubes (GDT) are used on the Power Entry Module (PEM) to mitigate lightning effect. On the AC Power, GDTs are also used along with fuses to mitigate a high-current condition. For the DC power, a fuse is used to mitigate a high-current condition.

While not a common practice, users may want to consider adding additional lightning protection at the antenna ports for added protection.

Client Access Certified Antennas (Third-Party Antennas)

You can use third-party antennas with AP1500s. However, note the following:

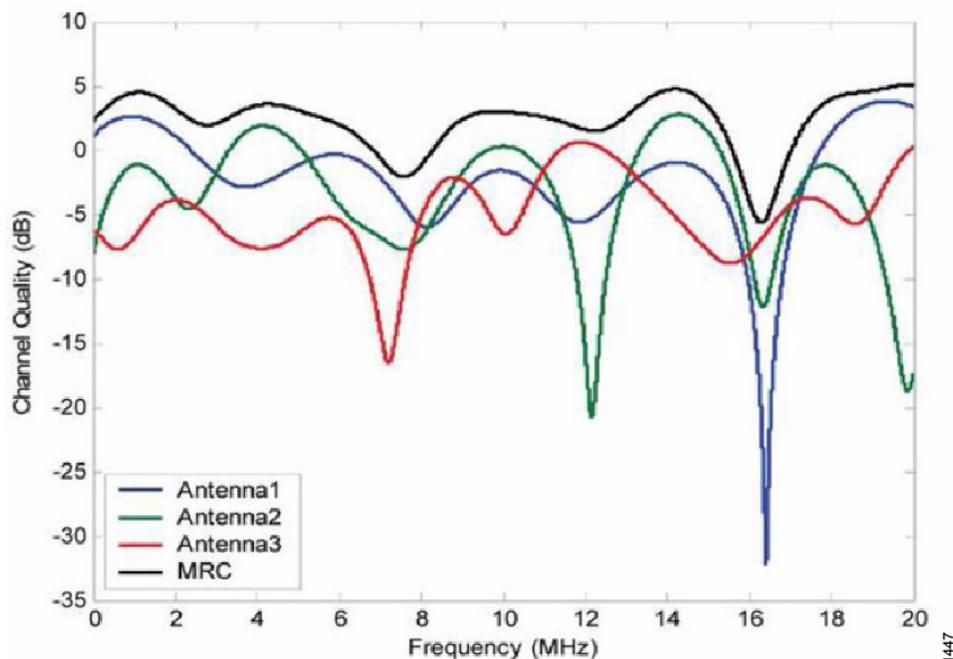
- Cisco does not track or maintain information about the quality, performance, or reliability of the noncertified antennas and cables.
- RF connectivity and compliance is the customer's responsibility.
- Compliance is only guaranteed with Cisco antennas or antennas that are of the same design and gain as Cisco antennas.
- Cisco Technical Assistance Center (TAC) has no training or customer history with regard to nonCisco antennas and cables.

Maximum Ratio Combining

To understand how this works, consider a single transmitter 802.11a/g client sending an uplink packet to an 802.11n access point with multiple transceivers. The access point receives the signal on each of its three receive antennas.

Each received signal has a different phase and amplitude based on the characteristics of the space between the antenna and the client. The access point processes the three received signals into one reinforced signal by adjusting their phases and amplitudes to form the best possible signal. The algorithm used, called maximum ratio combining (MRC), is typically used on all 802.11n access points. MRC only helps in the uplink direction, enabling the access point to "hear" the client better.

Figure 17: Reinforcement of Received Signal via MRC Algorithm



For the 1520 Series

AP1520 radios have a much higher transmit power, better receiver sensitivity, and broader outdoor temperature range as compared to AP1510 and AP1505 mesh access points.

- The 5-GHz radio (802.11a) is a Single-in-Single-Out (SISO) architecture and the 2.4-GHz radio (802.11b/g) is 1x3 Single-in-Multiple-Out (SIMO) architecture.
- The 2.4-GHz radio has one transmitter and three receivers. Output power is configurable to 5 levels. With its 3 receivers enabling maximum-ratio combining (MRC), this radio has better sensitivity and range than a typical SISO 802.11b/g radio for OFDM rates.

When operating with data rates higher than 12 Mbps, you can increase gain on a 2.4-GHz radio to 2.7 dB by adding two antennas and to 4.5 dB, by adding three antennas. For information about RX sensitivities and MRC gain, see [Table 8: RX Sensitivities and MRC Gain, on page 35](#).

Table 8: RX Sensitivities and MRC Gain

Modulation Rate	Typical sensitivity (dBm)			MRC gain	
	One antenna	Two antennas MRC	Three antennas MRC	Two antennas	Three antennas
1	-92.0	-92.0	-92.0	0.0	0.0
2	-91.0	-91.0	-91.0	0.0	0.0
5.5	-90.3	-90.3	-90.3	0.0	0.0
11	-90.0	-90.0	-90.0	0.0	0.0
6	-90.3	-90.3	-90.3	0.0	0.0
9	-90.3	-90.3	-90.3	0.0	0.0
12	-89.0	-89.5	-90.0	0.5	1.0
18	-88.0	-89.5	-90.0	1.5	2.0
24	-84.3	-87.0	-88.3	2.7	4.0
36	-81.3	-84.0	-85.8	2.7	4.5
48	-77.3	-80.0	-81.8	2.7	4.5
54	-76.0	-78.7	-80.5	2.7	4.5

For the 1550 Series

In the 1552 series mesh access point, MRC gain is different than the 1520 series mesh access points. The 1520 series access points do not have 802.11n functionality. In the 2.4-GHz band, it has only one transmitter and up to three receivers. Therefore, it is SIMO (Single in Multiple out) in 2.4 GHz. In the 5-GHz band, it

has only one transmitter and one receiver. Therefore, it is SISO (Single in Single out) in the 5-GHz band. The MRC gain is important only for the 2.4-GHz radio in the 1552 access points. The MRC is not available for the 5-GHz radio. The 2.4-GHz radio has one Tx and up to three Rx antennas depending on the AP configuration.

In the 1522 access points, users have an option to use one, two, or three 2.4-GHz Rx antennas. With this option, users get around 3 dB MRC gain with 2 Rx antennas and a 4.5-dB MRC gain with 3 Rx antennas for data rates of 24 Mbps or higher.

For the 1552 access points, both the 2.4- and 5-GHz radios are 2x3 MIMO. Therefore, they have two transmitters and three receivers. Because the antennas are dual band and there is no option to have less than three Rx antennas, the MRC is added to the RX sensitivity always as it is embedded into the baseband chipset.

The number for typical Rx sensitivity in our customer data sheet assume 3 Rx antennas for both the 1520 and the 1550 series access points.

With the chipset used in the AP1520 series radios, there was a start-of-packet problem at lower data rates that wiped out the gain. Therefore, the MRC gain became useful from a data rate of 12 Mbps onwards in the 1520 series access points. This problem has been corrected in the current chipset used in the 1552 access points. The MRC gain has improved for lower data rates as well in the 1552 access points. You get a 4.7-dB improvement in sensitivity with the 2x3 MIMO radio over a 1x1 SISO implementation.

[Table 9: AP1552 11a/g MRC Gain, on page 36](#) and [Table 10: AP1552 11n MRC Gain, on page 36](#) list the MRC gain for the AP1552 11a/g and AP1552 11n respectively.

Table 9: AP1552 11a/g MRC Gain

11a/g MCS (Mbps)	Modulation	MRC Gain from 3 RXs (dB)
6	BPSK 1/2	4.7
9	BPSK 3/4	4.7
12	QPSK 1/2	4.7
18	QPSK 3/4	4.7
24	16QAM 1/2	4.7
36	16QAM 3/4	4.7
48	64QAM 2/3	4.7
54	64QAM 3/4	4.7

Table 10: AP1552 11n MRC Gain

No. of Spatial Streams	11n MCS	Modulation	MRC Gain from 3 RXs (dB)
1	MCS 0	BPSK 1/2	4.7
1	MCS 1	QPSK 1/2	4.7
1	MCS 2	QPSK 3/4	4.7

No. of Spatial Streams	11n MCS	Modulation	MRC Gain from 3 RXs (dB)
1	MCS 3	16QAM 1/2	4.7
1	MCS 4	16QAM 3/4	4.7
1	MCS 5	64QAM 2/3	4.7
1	MCS 6	64QAM 3/4	4.7
1	MCS 7	64QAM 5/6	4.7
2	MCS 8	BPSK 1/2	1.7
2	MCS 9	QPSK 1/2	1.7
2	MCS 10	QPSK 3/4	1.7
2	MCS 11	16QAM 1/2	1.7
2	MCS 12	16QAM 3/4	1.7
2	MCS 13	64QAM 2/3	1.7
2	MCS 14	64QAM 3/4	1.7
2	MCS 15	64QAM 5/6	1.7

**Note**

With two spatial streams, the MRC gain is halved, that is the MRC gain is reduced by 3 dB. This is because the system has $10 \log(3/2 \text{ SS})$ instead of $10 \log(3/1 \text{ SS})$. If there were to have been 3 SS with 3 RX, then the MRC gain would have been zero.

Cisco 1500 Hazardous Location Certification

The standard AP1500 enclosure is a ruggedized, hardened enclosure that supports the NEMA 4X and IP67 standards for protection to keep out dust, damp and water.

Hazardous Certification (Class 1, Div 2, and Zone 2)

To operate in occasional hazardous environments, such as oil refineries, oil fields, drilling platforms, chemical processing facilities, and open-pit mining, special certification is required and the certification is labeled as Class 1, Div 2, or Zone 2.

**Note**

For USA and Canada, this certification is CSA Class 1, Division 2. For Europe (EU), it is ATEX or IEC Class 1, Zone 2.

Cisco has Hazardous Certified SKUs for USA and EU: AIR-LAP1522HZ-x-K9, AIR-LAP1524HZ-x-K9, and AIR-LAP1552H-x-K9. These SKUs are modified, as per the certification requirements. The hazardous locations certificate requires that all electrical power cables be run through conduit piping to protect against accidental damage to the electrical wiring that could cause a spark and possible explosion. Access points for hazardous locations contain an internal electrical mounting connect that receives discrete wires from a conduit interface coupler entering from the side of the housing. After the electrical wiring is installed, a cover housing is installed over the electrical connector to prevent exposure to the electrical wiring. The outside of the housing has a hazardous location certification label (CSA, ATEX, or IEC) that identifies the type of certifications and environments that the equipment is approved for operation.

**Note**

Power entry module for CSA (USA and Canada) is Power Entry Module, Groups A, B, C, and D with T5v(120° C) temp code. Power Entry Module for ATEX (EU) is Power entry module Groups IIC, IIB, IIA with T5 (120° C) temp code.

Hazardous Certification (Div 1 > Div 2 and Zone 1 > Zone 2)

Class 1, Division 1/Zone 1 is for environments with full-time ignitable concentrations of flammable gases, vapors, or liquids. To meet the requirements of the Div 1 > Div 2 and Zone 1 > Zone 2 locations, we recommend a TerraWave Solutions CSA certified protective Wi-Fi enclosure (see [Table 11: TerraWave Enclosures, on page 38](#)).

Table 11: TerraWave Enclosures

Access Points	Enclosure Part No	Description
Indoor Mesh Access Points (Cisco Aironet 1040, 1130, 1140, 1240, 1250, 1260, 3500e, and 3500i series access points)	Example: TerraWave XEP1242 for 1240 series.	18 x 12 x 8 Protective Wi-Fi Enclosure that includes the Cisco 1242 Access Point
Outdoor Mesh Access Points (1522, 1524, 1552)	Example: TerraWave Part Number: XEP1522	18 x 12 x 8 Protective Wi-Fi Enclosure that includes the Cisco 1522 Access Point

For more information about the TerraWave enclosures, see http://www.tessco.com/yts/partner/manufacturer_list/vendors/terrawave/pdf/terrawavehazardouesenclosuresjan08.pdf

[Table 12: Hardware Features at a Glance, on page 39](#) lists the hardware features across different AP1500 models at a glance.

Table 12: Hardware Features at a Glance

Features	1552E	1552H	1552C	1552I	152X (1522, 1524SB, 1524PS)
Number of radios	2	2	2	2	2 (1522), 3 (1524)
External Antennas	Yes	Yes	—	—	Yes
Internal Antennas	—	—	Yes	Yes	—
CleanAir 2.4-GHz radio	Yes	Yes	Yes	Yes	—
CleanAir 5-GHz radio	—	—	—	—	—
Beam Forming (ClientLink)	Yes	Yes	Yes	Yes	—
Fiber SFP	Yes	Yes	—	—	Yes
802.3af PoE out port	Yes	Yes	—	—	Yes
DOCSIS 3.0 Cable Modem	—	—	Yes	—	—
DOCSIS 2.0 Cable Modem	—	—	—	—	Yes
HazLoc Class 1 Div 2/Zone 2	—	Yes	—	—	Yes
Battery backup option	Yes	Yes	—	—	Yes
Power options	AC, DC, Power Injector	AC, DC, Power Injector	40 to 90 VAC Power over Cable	AC, DC	AC, DC, 40 to 90 VAC Power over Cable
Heater	—	—	—	—	Yes (1522C)
Console Port Ext. Access	Yes	Yes	Yes	Yes	Yes Note You need to open the access point.

**Note**

PoE-in is not 802.3af and does not work with PoE 802.3af-capable Ethernet switch. It requires Power Injector.

Cisco Wireless LAN Controllers

The wireless mesh solution is supported on Cisco 2500, 5500, and 8500 Series Wireless LAN Controllers.

For more information about the Cisco 2500, 5500, and 8500 Series Wireless LAN Controllers, see http://www.cisco.com/en/US/products/ps6302/Products_Sub_Category_Home.html.

Cisco Prime Infrastructure

The Cisco Prime Infrastructure provides a graphical platform for wireless mesh planning, configuration, and management. Network managers can use the Prime Infrastructure to design, control, and monitor wireless mesh networks from a central location.

With the Prime Infrastructure, network administrators have a solution for RF prediction, policy provisioning, network optimization, troubleshooting, user tracking, security monitoring, and wireless LAN systems management. Graphical interfaces make wireless LAN deployment and operations simple and cost-effective. Detailed trending and analysis reports make the Prime Infrastructure vital to ongoing network operations.

The Prime Infrastructure runs on a server platform with an embedded database, which provides scalability that allows hundreds of controllers and thousands of Cisco mesh access points to be managed. Controllers can be located on the same LAN as the Prime Infrastructure, on separate routed subnets, or across a wide-area connection.

Architecture

Control and Provisioning of Wireless Access Points

Control and provisioning of wireless access points (CAPWAP) is the provisioning and control protocol used by the controller to manage access points (mesh and nonmesh) in the network. In release 5.2, CAPWAP replaced lightweight access point protocol (LWAPP).

**Note**

CAPWAP significantly reduces capital expenditures (CapEx) and operational expenses (OpEx), which enables the Cisco wireless mesh networking solution to be a cost-effective and secure deployment option in enterprise, campus, and metropolitan networks.

CAPWAP Discovery on a Mesh Network

The process for CAPWAP discovery on a mesh network is as follows:

- 1 A mesh access point establishes a link before starting CAPWAP discovery, whereas a nonmesh access point starts CAPWAP discovery using a static IP for the mesh access point, if any.
- 2 The mesh access point initiates CAPWAP discovery using a static IP for the mesh access point on the Layer 3 network or searches the network for its assigned primary, secondary, or tertiary controller. A maximum of 10 attempts are made to connect.

**Note**

The mesh access point searches a list of controllers configured on the access point (primed) during setup.

- 3 If Step 2 fails after 10 attempts, the mesh access point falls back to DHCP and attempts to connect in 10 tries.
- 4 If both Steps 2 and 3 fail and there is no successful CAPWAP connection to a controller, then the mesh access point falls back to LWAPP.
- 5 If there is no discovery after attempting Steps 2, 3, and 4, the mesh access point tries the next link.

Dynamic MTU Detection

If the MTU is changed in the network, the access point detects the new MTU value and forwards that to the controller to adjust to the new MTU. After both the access point and the controller are set at the new MTU, all data within their path are fragmented into the new MTU. The new MTU size is used until it is changed. The default MTU on switches and routers is 1500 bytes.

XML Configuration File

Mesh features within the controller's boot configuration file are saved in an XML file in ASCII format. The XML configuration file is saved in the flash memory of the controller.

**Note**

The current release does not support binary configuration files; however, configuration files are in the binary state *immediately* after an upgrade from a mesh release to controller software release 7.0. After reset, the XML configuration file is selected.

**Caution**

Do not edit the XML file. Downloading a modified configuration file onto a controller causes a cyclic redundancy check (CRC) error on boot and the configuration is reset to the default values.

You can easily read and modify the XML configuration file by converting it to CLI format. To convert from XML to CLI format, upload the configuration file to a TFTP or an FTP server. The controller initiates the conversion from XML to CLI during the upload.

Once on the server, you can read or edit the configuration file in CLI format. Then, you can download the file back to the controller. The controller converts the configuration file back to XML format, saves it to flash memory, and reboots using the new configuration.

The controller does not support uploading and downloading of port configuration CLI commands. If you want to configure the controller ports, enter the relevant commands summarized below:

**Note**

The commands listed below are manually entered after the software upgrade to release 7.0.

- **config port linktrap** *{port | all}* **{enable | disable}**—Enables or disables the up and down link traps for a specific controller port or for all ports.
- **config port adminmode** *{port | all}* **{enable | disable}**—Enables or disables the administrative mode for a specific controller port or for all ports.
- **config port multicast appliance** *port* **{enable | disable}**—Enables or disables the multicast appliance service for a specific controller port.
- **config port power** *{port | all}* **{enable | disable}**—Enables or disables power over Ethernet (PoE) for a specific controller port or for all ports.

CLI commands with known keywords and proper syntax are converted to XML while improper CLI commands are ignored and saved to flash memory. Any field with an invalid value is filtered out and set to a default value by the XML validation engine. Validation occurs during bootstrap.

To see any ignored commands or invalid configuration values, enter the following command:

show invalid-config

**Note**

You can only execute this command before either the **clear config** or **save config** command. If the downloaded configuration contains a large number of invalid CLI commands, you might want to upload the invalid configuration to the TFTP or FTP server for analysis.

Access passwords are hidden (obfuscated) in the configuration file. To enable or disable access point or controller passwords, enter the following command:

config switchconfig secret-obfuscation **{enable | disable}**

Adaptive Wireless Path Protocol

The Adaptive Wireless Path Protocol (AWPP) is designed specifically for wireless mesh networking to provide ease of deployment, fast convergence, and minimal resource consumption.

AWPP takes advantage of the CAPWAP WLAN, where client traffic is tunneled to the controller and is therefore hidden from the AWPP process. Also, the advance radio management features in the CAPWAP WLAN solution are available to the wireless mesh network and do not have to be built into AWPP.

AWPP enables a remote access point to dynamically find the best path back to a RAP for each MAP that is part of the RAP's bridge group (BGN). Unlike traditional routing protocols, AWPP takes RF details into account.

To optimize the route, a MAP actively solicits neighbor MAP. During the solicitation, the MAP learns all of the available neighbors back to a RAP, determines which neighbor offers the best path, and then synchronizes with that neighbor. The path decisions of AWPP are based on the link quality and the number of hops.

AWPP automatically determines the best path back to the CAPWAP controller by calculating the cost of each path in terms of the signal strength and number of hops. After the path is established, AWPP continuously monitors conditions and changes routes to reflect changes in conditions. AWPP also performs a smoothing

function to signal condition information to ensure that the ephemeral nature of RF environments does not impact network stability.

Traffic Flow

The traffic flow within the wireless mesh can be divided into three components:

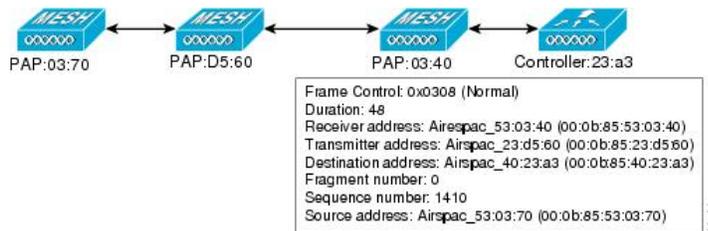
- 1 Overlay CAPWAP traffic that flows within a standard CAPWAP access point deployment; that is, CAPWAP traffic between the CAPWAP access point and the CAPWAP controller.
- 2 Wireless mesh data frame flow.
- 3 AWPP exchanges.

As the CAPWAP model is well known and the AWPP is a proprietary protocol, only the wireless mesh data flow is described. The key to the wireless mesh data flow is the address fields of the 802.11 frames being sent between mesh access points.

An 802.11 data frame can use up to four address fields: receiver, transmitter, destination, and source. The standard frame from a WLAN client to an AP uses only three of these address fields because the transmitter address and the source address are the same. However, in a WLAN bridging network, all four address fields are used because the source of the frame might not be the transmitter of the frame, because the frame might have been generated by a device *behind* the transmitter.

Figure 18: Wireless Mesh Frame, on page 43 shows an example of this type of framing. The source address of the frame is MAP:03:70, the destination address of this frame is the controller (the mesh network is operating in Layer 2 mode), the transmitter address is MAP:D5:60, and the receiver address is RAP:03:40.

Figure 18: Wireless Mesh Frame



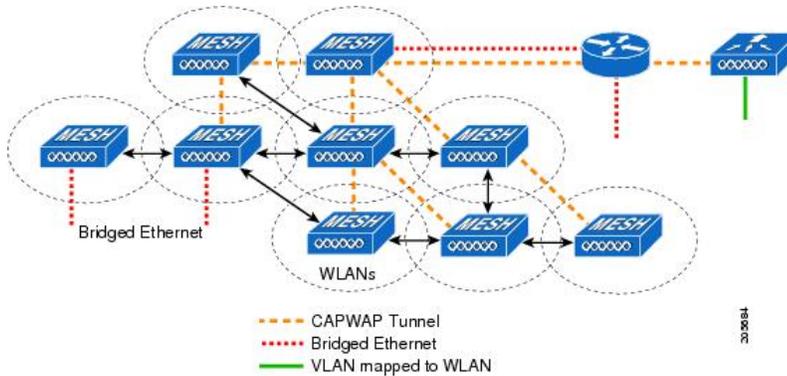
As this frame is sent, the transmitter and receiver addresses change on a hop-by-hop basis. AWPP is used to determine the receiver address at each hop. The transmitter address is known because it is the current mesh access point. The source and destination addresses are the same over the entire path.

If the RAP's controller connection is Layer 3, the destination address for the frame is the default gateway MAC address, because the MAP has already encapsulated the CAPWAP in the IP packet to send it to the controller, and is using the standard IP behavior of using ARP to find the MAC address of the default gateway.

Each mesh access point within the mesh forms an CAPWAP session with a controller. WLAN traffic is encapsulated inside CAPWAP and is mapped to a VLAN interface on the controller. Bridged Ethernet traffic

can be passed from each Ethernet interface on the mesh network and does not have to be mapped to an interface on the controller (see [Figure 19: Logical Bridge and WLAN Mapping](#), on page 44).

Figure 19: Logical Bridge and WLAN Mapping

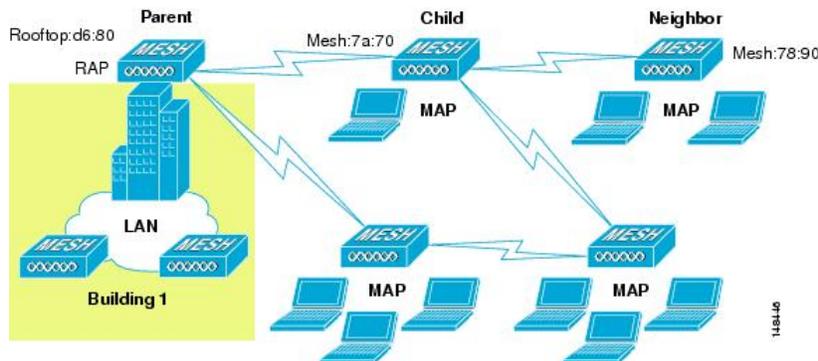


Mesh Neighbors, Parents, and Children

Relationships among mesh access points are as a parent, child, or neighbor (see [Figure 20: Parent, Child, and Neighbor Access Points](#), on page 44).

- A parent access point offers the best route back to the RAP based on its ease values. A parent can be either the RAP itself or another MAP.
 - Ease is calculated using the SNR and link hop value of each neighbor. Given multiple choices, generally an access point with a higher ease value is selected.
- A child access point selects the parent access point as its best route back to the RAP.
- A neighbor access point is within RF range of another access point but is not selected as its parent or a child because its ease values are lower than that of the parent.

Figure 20: Parent, Child, and Neighbor Access Points



Criteria to Choose the Best Parent

AWPP follows this process in selecting parents for a RAP or MAP with a radio backhaul:

- A list of channels with neighbors is generated by passive scanning in the *scan* state, which is a subset of all backhaul channels.
- The channels with neighbors are sought by actively scanning in the *seek* state and the backhaul channel is changed to the channel with the best neighbor.
- The parent is set to the best neighbor and the parent-child handshake is completed in the *seek* state.
- Parent maintenance and optimization occurs in the *maintain* state.

This algorithm is run at startup and whenever a parent is lost and no other potential parent exists, and is usually followed by CAPWAP network and controller discovery. All neighbor protocol frames carry the channel information.

Parent maintenance occurs by the child node sending a directed NEIGHBOR_REQUEST to the parent and the parent responding with a NEIGHBOR_RESPONSE.

Parent optimization and refresh occurs by the child node sending a NEIGHBOR_REQUEST broadcast on the same channel on which its parent resides, and by evaluating all responses from neighboring nodes on the channel.

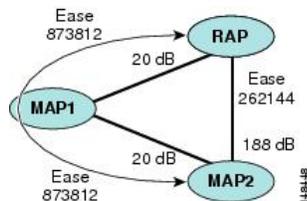
A parent mesh access point provides the best path back to a RAP. AWPP uses ease to determine the best path. Ease can be considered the opposite of cost, and the preferred path is the path with the higher ease.

Ease Calculation

Ease is calculated using the SNR and hop value of each neighbor, and applying a multiplier based on various SNR thresholds. The purpose of this multiplier is to apply a spreading function to the SNRs that reflects various link qualities.

Figure 21: Parent Path Selection, on page 45 shows the parent path selection where MAP2 prefers the path through MAP1 because the adjusted ease value (436906) though this path is greater then the ease value (262144) of the direct path from MAP2 to RAP.

Figure 21: Parent Path Selection



Parent Decision

A parent mesh access point is chosen by using the adjusted ease, which is the ease of each neighbor divided by the number of hops to the RAP:

$$\text{adjusted ease} = \min(\text{ease at each hop}) \text{ Hop count}$$

SNR Smoothing

One of the challenges in WLAN routing is the ephemeral nature of RF, which must be considered when analyzing an optimal path and deciding when a change in path is required. The SNR on a given RF link can change substantially from moment to moment, and changing route paths based on these fluctuations results in an unstable network, with severely degraded performance. To effectively capture the underlying SNR but remove moment-to-moment fluctuations, a smoothing function is applied that provides an adjusted SNR.

In evaluating potential neighbors against the current parent, the parent is given 20 percent of bonus-ease on top of the parent's calculated ease, to reduce the ping-pong effect between parents. A potential parent must be significantly better for a child to make a switch. Parent switching is transparent to CAPWAP and other higher-layer functions.

Loop Prevention

To ensure that routing loops are not created, AWPP discards any route that contains its own MAC address. That is, routing information apart from hop information contains the MAC address of each hop to the RAP; therefore, a mesh access point can easily detect and discard routes that loop.