



Mesh Network Components

This chapter describes the mesh network components.

The Cisco wireless mesh network has four core components:

- Cisco Aironet 15X0 series mesh access points



Note Cisco Aironet 1520 series 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, on page 1](#)
- [Cisco Wireless LAN Controllers, on page 18](#)
- [Cisco Prime Infrastructure, on page 18](#)
- [Architecture, on page 18](#)

Mesh Access Points

Licensing for Mesh Access Points on a 5508, 5520 and 8540 Series Cisco Comptroller

To use both mesh and non-mesh access points with a Cisco 5500 and 8500 Series Controller, only the base license 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 802.11 a/n/g 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.

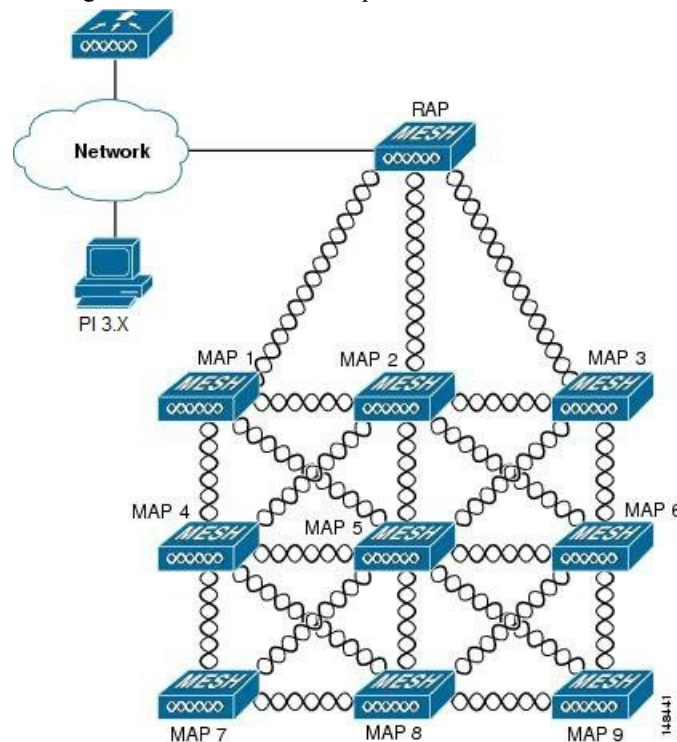
Bridge mode access points support CleanAir in mesh backhaul and provides only the interference device report (IDR) and Air Quality Index (AQI) reports.



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.

Figure 1: Simple Mesh Network Hierarchy

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



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

The following access point platforms are supported in this release:

- Cisco Aironet 1600 Series Access Points
- Cisco Aironet 1700 Series Access Points
- Cisco Aironet 2600 Series Access Points
- Cisco Aironet 2700 Series Access Points
- Cisco Aironet 3500 Series Access Points
- Cisco Aironet 3600 Series Access Points
- Cisco Aironet 3700 Series Access Points
- Cisco Aironet 1530 Series Access Points
- Cisco Aironet 1550 Series Access Points
- Cisco Aironet 1560 Series Access Points
- Cisco Aironet 1570 Series Access Points
- Cisco Industrial Wireless 3700 Series Access Points



Note In 8.4 release the following AP s will be supported.

- 1700
- 2700
- 3700



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/ac mesh is an enhancement added to the CUWN feature to work with the 802.11n/ac access points. Enterprise 11ac mesh features are compatible with non-802.11ac mesh but adds higher backhaul and client access speeds. The 802.11ac 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. If Universal Backhaul Access is enabled, the 5-GHz and 2.4-GHz radios in rel 8.2 can be used for local (client) access as well as a backhaul. Enterprise 11ac mesh supports P2P, P2MP, and mesh types of architectures.

The 802.11ac provides enterprise-class reliability and wired network like performance. It supports three spatial streams and 80 MHz wide channels for a maximum data rate of 1.3 Gbps. This is three times the maximum data rate of today's high-end enterprise 802.11n access point.

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 (non-mesh), 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 non-mesh wireless coverage.

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

- From rel 8.2 2.4 GHz radio used for data backhaul and client access if UBA is enable
- 5-GHz radio used for data backhaul and client access if Universal Backhaul Access is enabled

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 1572 11ac outdoor access points, 1552 and 1532 11n outdoor mesh access points, and the 1560 11ac wave 2 series. 1532 dual radio mesh access points .

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/ac radio backhaul. Client traffic is generally transmitted over the 802.11b/g/n radio (802.11a/n/ac can also be configured to accept client traffic).

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.

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.

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.
- **Flex+Bridge Mode**—In this mode, both the Flexconnect and Bridge mode configuration options are available on the access point.

- 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.
- Flex+Bridge Mode—In this mode, both the Flexconnect and Bridge mode configuration options are available on the access point.



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 / Flex+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.



Note For complete details and specification of all models of outdoor Mesh AP please visit this links below:

- http://www.cisco.com/c/en/us/products/collateral/wireless/aironet-1530-series/data_sheet_c78-728356.html
- http://www.cisco.com/c/en/us/products/collateral/wireless/aironet-1550-series/data_sheet_c78-641373.html
- http://www.cisco.com/c/en/us/td/docs/wireless/access_point/1550/installation/guide/1550hig/1550_ch1.html
- http://www.cisco.com/c/en/us/td/docs/wireless/access_point/1550/installation/guide/1550hig/1550_ch1.html
- <http://www.in.cisco.com/c/cec/prods-industry/selling-en/products/wireless/ap.html>
- <http://www.cisco.com/c/en/us/support/wireless/aironet-1572eac-outdoor-access-point/model.html>
- <http://www.cisco.com/c/dam/en/us/products/collateral/wireless/aironet-1570-series/datasheet-c78-732348.pdf>

Battery Backup Module (Optional)

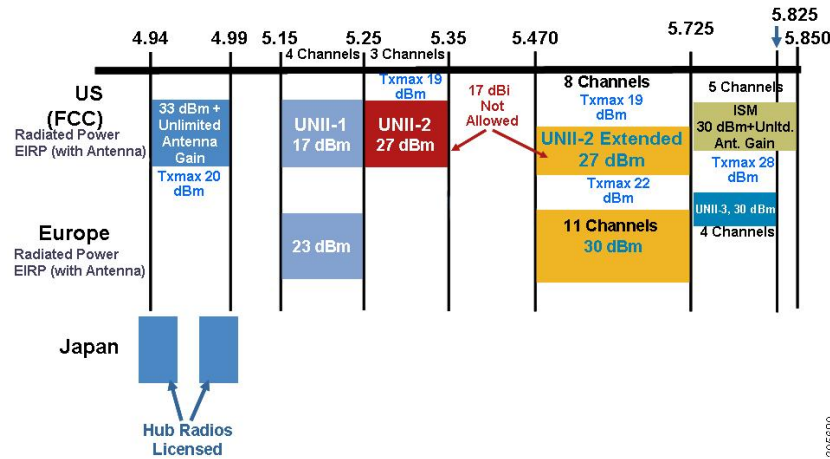


Note For a complete listing of optional hardware components for AP1520s such as mounting brackets, power injectors, and power tap adapters, see http://www.cisco.com/en/US/prod/collateral/wireless/ps5679/ps8368/product_data_sheet0900aecd8066a157.html

Frequency Bands

Both the 2.4-GHz and 5-GHz frequency bands are supported on the indoor and outdoor access points.

Figure 2: Frequency Bands Supported By 802.11a Radios on AP1500s



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 1: Frequency Band](#), on page 7).

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 1: Frequency Band

Frequency Band Terms	Description	Model Support
UNII-1 ¹	Regulations for UNII devices operating in the 5.15- to 5.25-GHz frequency band. Indoor operation and outdoor APs using the -B reg domain.	All 11n/ac Indoor APs and the 1572.
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.	All 11n/ac indoor APs, 1532, 1552, 1562 and 1572.

Frequency Band Terms	Description	Model Support
UNII-2 Extended	Regulations for UNII-2 devices operating in the 5.470 to 5.725 frequency band.	All 11n/ac indoor APs, 1532, 1552, 1562 and 1572.
ISM ²	Regulations for UNII devices operating in the 5.725 to 5.850 GHz frequency band.	All 11n/ac indoor APs, 1532, 1552, 1562 and 1572.

¹ UNII refers to the Unlicensed National Information Infrastructure.

² ISM refers to Industrial, Scientific and Medical.



Note 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 3: 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 beam-widths.



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 14-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 2: External 2.4- and 5-GHz Antennas, on page 10 lists the supported external 2.4- and 5-GHz antennas for AP1500s.

Table 2: External 2.4- and 5-GHz Antennas

Part Number	Model	Gain (dBi)
AIR-ANT2450V-N	2.4-GHz compact omnidirectional ³	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 ⁴	8.0
AIR-ANT5140V-N	5-GHz right-angle omnidirectional	4.0
AIR-ANT5114P-N	5-GHz patch2	14.0
AIR-ANT2547V-N	2.4 – 5-GHz dual-band omnidirectional	4 dBi at 2.4 GHz and 7 dBi at 5 GHz

³ The compact omnidirectional antennas mount directly on the access point.

⁴ The compact omnidirectional antennas mount directly on the access point.

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 3: Horizontal and Vertical Beamwidth for Cisco Antennas, on page 11 summarizes the horizontal and vertical beamwidth for Cisco antennas.

Table 3: Horizontal and Vertical Beamwidth for Cisco Antennas

Antenna	Horizontal Beam-width (degrees)	Vertical Beam-width (degrees)
AIR-ANT5180V-N	360	16
AIR-ANT5114P-N	25	29
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.

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 and 2.4 GHz are fixed and labeled.

Antenna Configurations for 1552

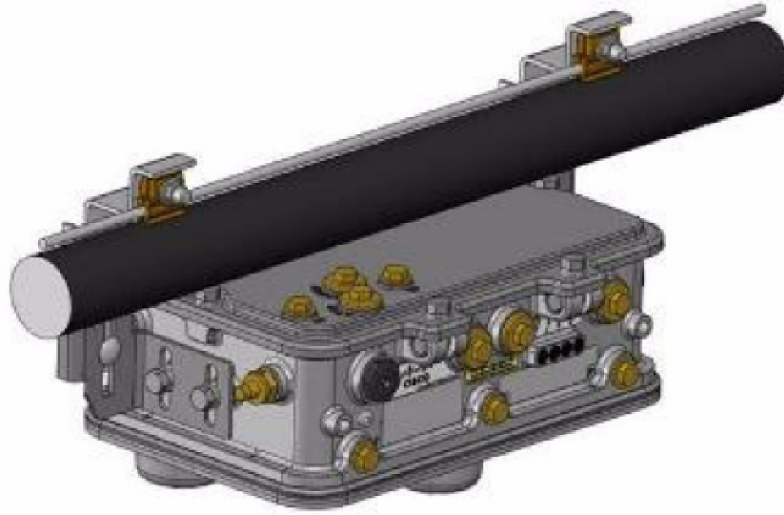
The 1552 access point supports the following two types of antennas designed for outdoor use with radios operating in the 2.4-GHz and 5-GHz frequency:

- 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.

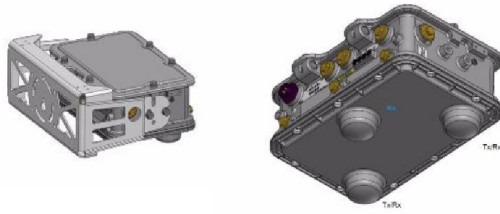
The 1552 models C and I access points are equipped with three new integrated dual-band antennas, with 2 dBi gain at 2.4 GHz and 4 dBi gain at 5 GHz. The antenna works in cable strand mount and low cost, low profile applications.

Figure 4: 1552C Cable Mount



331444

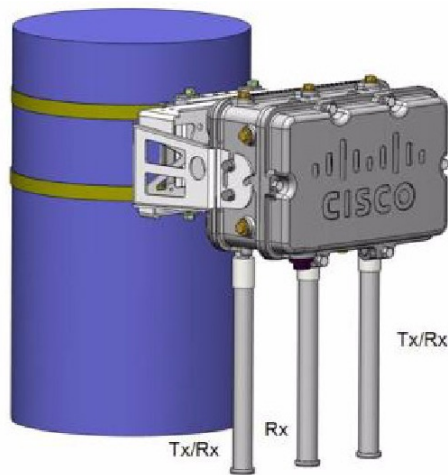
Figure 5: 1552I Pole/Wall Mount



331445

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.

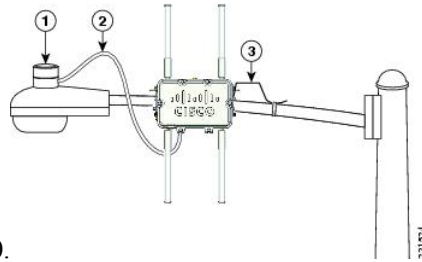
Figure 6: 1552 E Pole/Wall Mount



331446

Figure 7: Outdoor Pole-top Installation of a Mesh Access Point

This figure shows one of the recommended installations of an outdoor



AP1500.

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:

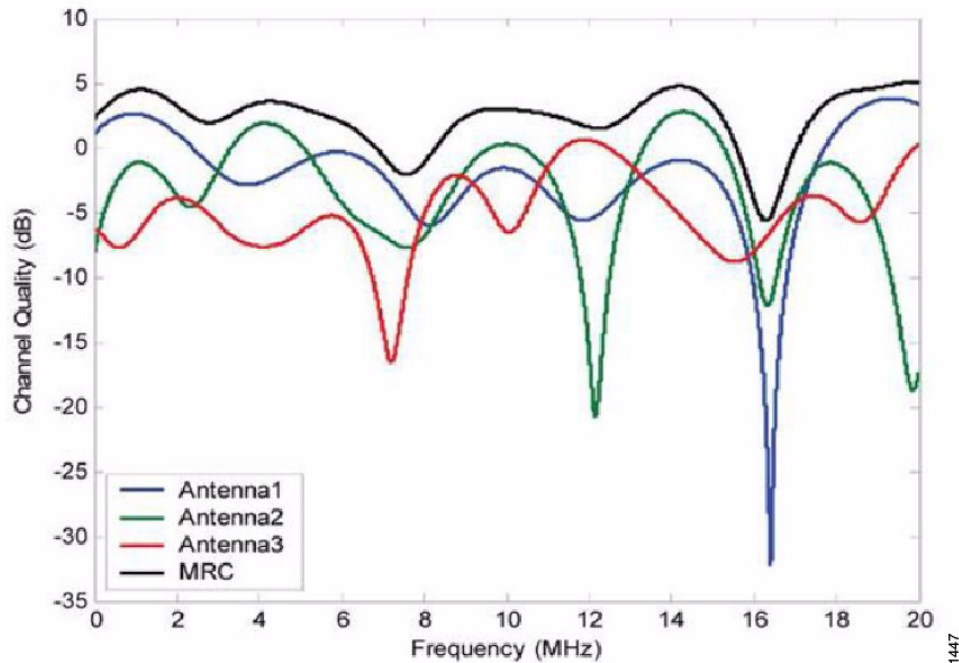
- Cisco does not track or maintain information about the quality, performance, or reliability of the noncertified antennas and cables.
- RF connectivity and compliance is the customer’s responsibility.
- Compliance is only guaranteed with Cisco antennas or antennas that are of the same design and gain as Cisco antennas.
- Cisco Technical Assistance Center (TAC) has no training or customer history with regard to non Cisco 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 8: Reinforcement of Received Signal via MRC Algorithm



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 4: AP1552 11a/g MRC Gain, on page 15 and Table 5: AP1552 11n MRC Gain, on page 15 list the MRC gain for the AP1552 11a/g and AP1552 11n respectively.

Table 4: 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 5: 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
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 SKU for USA and EU: AIR-LAP1552H-x-K9. This SKU is 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 6: TerraWave Enclosures, on page 17](#)).

Table 6: TerraWave Enclosures

Access Points	Enclosure Part No	Description
Indoor Mesh Access Points	Example: TerraWave XEP1242 for 1240 series.	18 x12 x8 Protective Wi-Fi Enclosure that includes the Cisco 1242 Access Point
Outdoor Mesh Access Points (1552)	Example: TerraWave Part Number: XEP1522	18 x 12 x8 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 7: Hardware Features at a Glance, on page 17 lists the hardware features across different AP1500 models at a glance.

Table 7: Hardware Features at a Glance

Features	1552E	1552H	1552C	1552I
Number of radios	2	2	2	2
External Antennas	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	—	—
802.3af PoE out port	Yes	Yes	—	—
DOCSIS 3.0 Cable Modem	—	—	Yes	—
HazLoc Class 1 Div 2/Zone 2	—	Yes	—	—
Battery backup option	Yes	Yes	—	—
Power options	AC, DC, Power Injector	AC, DC, Power Injector	40 to 90 VAC Power over Cable	AC, DC
Console Port Ext. Access	Yes	Yes	Yes	Yes



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, 3504, 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.

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 non mesh 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:

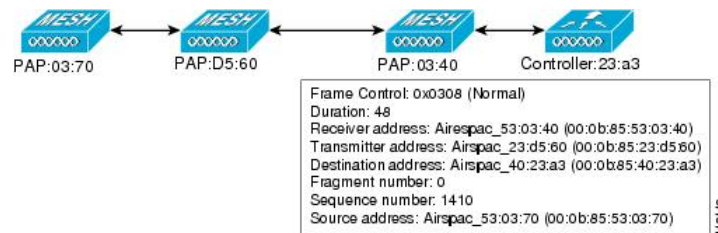
1. Overlay CAPWAP traffic that flows within a standard CAPWAP access point deployment; that is, CAPWAP traffic between the CAPWAP access point and the CAPWAP controller.
2. Wireless mesh data frame flow.
3. AWPP exchanges.

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 9: Wireless Mesh Frame, on page 21](#) 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 9: Wireless Mesh Frame

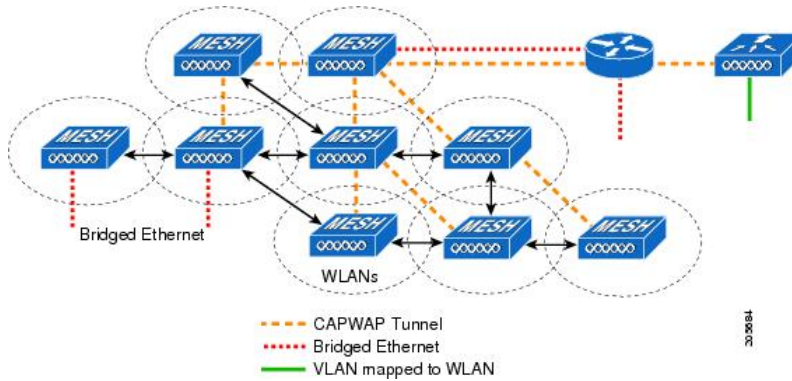


As this frame is sent, the transmitter and receiver addresses change on a hop-by-hop basis. AWPP is used to determine the receiver address at each hop. The transmitter address is known because it is the current mesh access point. The source and destination addresses are the same over the entire path.

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 a 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 10: Logical Bridge and WLAN Mapping, on page 22](#)).

Figure 10: Logical Bridge and WLAN Mapping

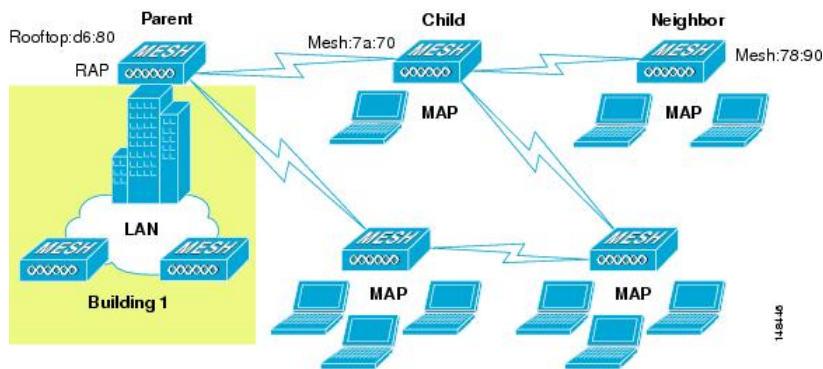


Mesh Neighbors, Parents, and Children

Relationships among mesh access points are as a parent, child, or neighbor (see [Figure 11: Parent, Child, and Neighbor Access Points, on page 22](#)).

- 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 11: 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.

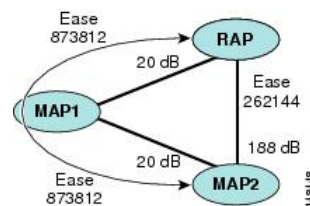
A parent mesh access point provides the best path back to a RAP. AWPP uses ease to determine the best path. Ease can be considered the opposite of cost, and the preferred path is the path with the higher ease.

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 12: Parent Path Selection, on page 23 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 12: 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:

adjusted ease = min (ease at each hop) 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.