

PLANNING GUIDE

12 ENGINEERING YOUR RF COMMUNICATIONS

Before diagramming network layouts, the wise course is to

- anticipate the correct amount of signal loss for your fade margin calculation (as defined below).
- recognize all permanent and transient RF signals in the environment.
- identify obstructions to line of sight reception.

12.1 ANTICIPATING RF SIGNAL LOSS

The C/I (Carrier-to-Interference) ratio defines the strength of the intended signal relative to the collective strength of all other signals. Canopy modules typically do not require a C/I ratio greater than

- 3 dB or less at 10-Mbps modulation and -65 dBm for 1X operation. The C/I ratio that you achieve must be even greater as the received power approaches the nominal sensitivity (-85 dBm for 1X operation).
- 10 dB or less at 10-Mbps modulation and -65 dBm for 2X operation. The C/I ratio that you achieve must be even greater as the received power approaches the nominal sensitivity (-79 dBm for 2X operation).
- 10 dB or less at 20-Mbps modulation.

12.1.1 Understanding Attenuation

An RF signal in space is attenuated by atmospheric and other effects as a function of the distance from the initial transmission point. The further a reception point is placed from the transmission point, the weaker is the received RF signal.

12.1.2 Calculating Free Space Path Loss

The attenuation that distance imposes on a signal is the free space path loss. [PathLossCalcPage.xls](#) calculates free space path loss.

12.1.3 Calculating Rx Signal Level

The Rx sensitivity of each module is provided at http://motorola.canopywireless.com/prod_specs.php. The determinants in Rx signal level are illustrated in [Figure 37](#).

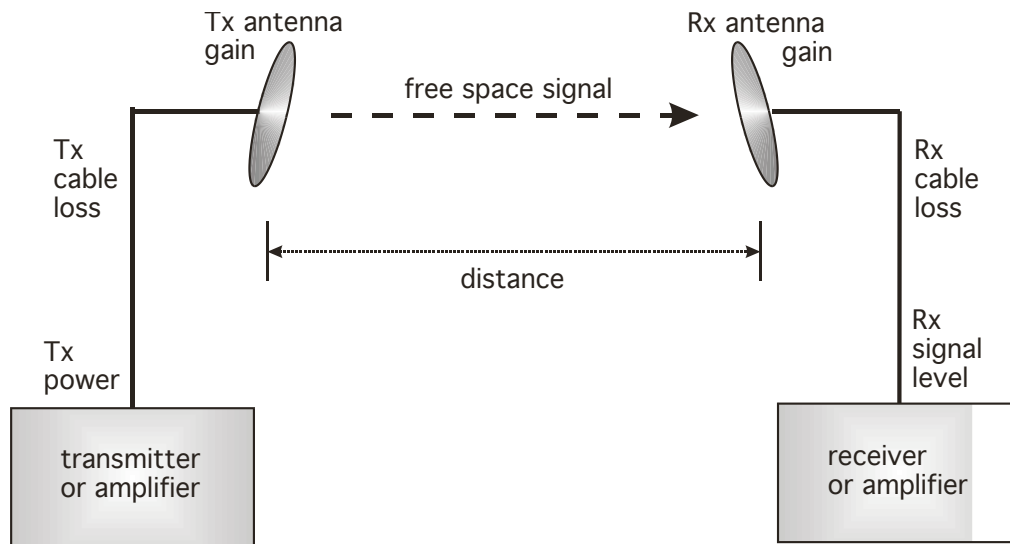


Figure 37: Determinants in Rx signal level

Rx signal level is calculated as follows:

$$\text{Rx signal level dB} = \text{Tx power} - \text{Tx cable loss} + \text{Tx antenna gain} - \text{free space path loss} + \text{Rx antenna gain} - \text{Rx cable loss}$$

**NOTE:**

This Rx signal level calculation presumes that a clear line of sight is established between the transmitter and receiver and that no objects encroach in the Fresnel zone.

12.1.4 Calculating Fade Margin

Free space path loss is a major determinant in Rx (received) signal level. Rx signal level, in turn, is a major factor in the system operating margin (fade margin), which is calculated as follows:

$$\text{system operating margin (fade margin) dB} = \text{Rx signal level dB} - \text{Rx sensitivity dB}$$

Thus, fade margin is the difference between strength of the received signal and the strength that the receiver requires for maintaining a reliable link. A higher fade margin is characteristic of a more reliable link.

12.2 ANALYZING THE RF ENVIRONMENT

An essential element in RF network planning is the analysis of spectrum usage and the strength of the signals that occupy the spectrum you are planning to use. Regardless of how you measure and log or chart the results you find (through the Spectrum Analyzer in SM and BHS feature or by using a spectrum analyzer), you should do so

- at various times of day.
- on various days of the week.
- periodically into the future.

As new RF neighbors move in or consumer devices in your spectrum proliferate, this will keep you aware of the dynamic possibilities for interference with your network.

12.2.1 Mapping RF Neighbor Frequencies

Canopy modules allow you to

- use an SM or BHS (or a BHM reset to a BHS), or an AP that is temporarily transformed into an SM, as a spectrum analyzer.
- view a graphical display that shows power level in RSSI and dBm at 5-MHz increments throughout the frequency band range, regardless of limited selections in the **Custom Radio Frequency Scan Selection List** parameter of the SM.
- select an AP channel that minimizes interference from other RF equipment.

The SM measures only the spectrum of its manufacture. So if, for example, you wish to analyze an area for both 2.4- and 5.7-GHz activity, take both a 2.4- and 5.7-GHz SM to the area. To enable this functionality, perform the following steps:



CAUTION!

The following procedure causes the SM to drop any active RF link. If a link is dropped when the spectrum analysis begins, the link can be re-established when either a 15-minute interval has elapsed or the spectrum analyzer feature is disabled.

Procedure 2: Analyzing the spectrum

1. Predetermine a power source and interface that will work for the SM or BHS in the area you want to analyze.
2. Take the SM or BHS, power source, and interface device to the area.
3. Access the Tools web page of the SM or BHS.
RESULT: The Tools page opens to its Spectrum Analyzer tab. An example of this tab is shown in [Figure 143](#).
4. Click **Enable**.
RESULT: The feature is enabled.
5. Click **Enable** again.
RESULT: The system measures RSSI and dBm for each frequency in the spectrum.

6. Travel to another location in the area.
7. Click **Enable** again.
RESULT: The system provides a new measurement of RSSI and dBm for each frequency in the spectrum.
NOTE: Spectrum analysis mode times out 15 minutes after the mode was invoked.
8. Repeat Steps 6 and 7 until the area has been adequately scanned and logged.

===== end of procedure =====

As with any other data that pertains to your business, a decision today to put the data into a retrievable database may grow in value to you over time.



RECOMMENDATION:

Wherever you find the measured noise level is greater than the sensitivity of the radio that you plan to deploy, use the noise level (rather than the link budget) for your link feasibility calculations.

12.2.2 Anticipating Reflection of Radio Waves

In the signal path, any object that is larger than the wavelength of the signal can reflect the signal. Such an object can even be the surface of the earth or of a river, bay, or lake. The wavelength of the signal is approximately

- 2 inches for 5.2- and 5.7-GHz signals.
- 5 inches for 2.4-GHz signals.
- 12 inches for 900-MHz signals.

A reflected signal can arrive at the antenna of the receiver later than the non-reflected signal arrives. These two or more signals cause the condition known as multipath. When multipath occurs, the reflected signal cancels part of the effect of the non-reflected signal so, overall, attenuation beyond that caused by link distance occurs. This is problematic at the margin of the link budget, where the standard operating margin (fade margin) may be compromised.

12.2.3 Noting Possible Obstructions in the Fresnel Zone

The Fresnel (pronounced *fre-NEL*) Zone is a theoretical three-dimensional area around the line of sight of an antenna transmission. Objects that penetrate this area can cause the received strength of the transmitted signal to fade. Out-of-phase reflections and absorption of the signal result in signal cancellation.

The foliage of trees and plants in the Fresnel Zone can cause signal loss. Seasonal density, moisture content of the foliage, and other factors such as wind may change the amount of loss. Plan to perform frequent and regular link tests if you must transmit through foliage.

12.2.4 Radar Signature Detection and Shutdown

With Release 8.1, Canopy meets ETSI EN 301 893 v1.2.3 for Dynamic Frequency Selection (DFS). DFS is a requirement in certain countries of the EU for systems like Canopy to detect interference from other systems, notably radar systems, and to avoid co-channel operation with these systems. All 5.4 GHz modules and all 5.7 GHz Connectorized modules running Release 8.1 have DFS. Other modules running Release

8.1 do not. With Release 8.1, Canopy SMs and BHSs as well as Canopy APs and BHMs will detect radar systems.

When an AP or BHM enabled for DFS boots, it receives for 1 minute, watching for the radar signature, without transmitting. If no radar pulse is detected during this minute, the module then proceeds to normal beacon transmit mode. If it does detect radar, it waits for 30 minutes without transmitting, then watches the 1 minute, and will wait again if it detects radar. If while in operation, the AP or BHM detects the radar signature, it will cease transmitting for 30 minutes and then begin the 1 minute watch routine. Since an SM or BHS only transmits if it is receiving beacon from an AP or BHM, the SMs in the sector or BHS are also not transmitting when the AP or BHM is not transmitting.

When an SM or BHS with DFS boots, it scans to see if an AP or BHM is present (if it can detect a Canopy beacon). If an AP or BHM is found, the SM or BHS receives on that frequency for 1 minute to see if the radar signature is present. For an SM, if no radar pulse is detected during this 1 minute, the SM proceeds through normal steps to register to an AP. For a BHS, if no radar pulse is detected during this 1 minute, it registers, and as part of registering and ranging watches for the radar signature for another 1 minute. If the SM or BH does detect radar, it locks out that frequency for 30 minutes and continues scanning other frequencies in its scan list.

Note, after an SM or BHS has seen a radar signature on a frequency and locked out that frequency, it may connect to a different AP or BHM, if color codes, transmitting frequencies, and scanned frequencies support that connection.

For all modules, the module displays its DFS state on its General Status page. You can read the DFS status of the radio in the General Status tab of the Home page as one of the following:

- Normal Transmit
- Radar Detected Stop Transmitting for n minutes, where n counts down from 30 to 1.
- Checking Channel Availability Remaining time n seconds, where n counts down from 60 to 1. This indicates that a 30-minute shutdown has expired and the one-minute re-scan that follows is in progress.

DFS can be enabled or disabled on a module's Radio page: Configuration > Radio > DFS.

Operators in countries with regulatory requirements for DFS must not disable the feature and must ensure it is enabled after a module is reset to factory defaults.

Operators in countries without regulatory requirements for DFS will most likely not want to use the feature, as it adds no value if not required, and adds an additional 1 minute to the connection process for APs, BHMs, and SMs, and 2 minutes for BHSs.



RECOMMENDATION:

Where regulations require that radar sensing and radio shutdown is enabled, you can most effectively share the spectrum with satellite services if you perform spectrum analysis and select channels that are distributed evenly across the frequency band range.

A connectorized 5.7-GHz module provides an **Antenna Gain** parameter. When you indicate the gain of your antenna in this field, the algorithm calculates the appropriate sensitivity to radar signals, and this reduces the occurrence of false positives (wherever the antenna gain is less than the maximum).

12.3 USING JITTER TO CHECK RECEIVED SIGNAL QUALITY

The General Status tab in the Home page of the Canopy SM and BHS displays current values for **Jitter**. This is an index of overall received signal quality. Interpret the jitter value as indicated in [Table 32](#).

Table 32: Signal quality levels indicated by jitter

Signal Modulation	Correlation of Highest Seen Jitter to Signal Quality		
	High Quality	Questionable Quality	Poor Quality
1X operation (2-level FSK)	0 to 4	5 to 14	15
2X operation (4-level FSK)	0 to 9	10 to 14	15

In your lab, an SM whose jitter value is constant at 14 may have an incoming packet efficiency of 100%. However, a deployed SM whose jitter value is 14 is likely to have even higher jitter values as interfering signals fluctuate in strength over time. So, *do not* consider 14 to be acceptable. Avoiding a jitter value of 15 should be the highest priority in establishing a link. At 15, jitter causes fragments to be dropped and link efficiency to suffer.

Canopy modules calculate jitter based on both interference and the modulation scheme. For this reason, values on the low end of the jitter range that are significantly higher in 2X operation can still be indications of a high quality signal. For example, where the amount of interference remains constant, an SM with a jitter value of 3 in 1X operation can display a jitter value of 7 when enabled for 2X operation.

However, on the high end of the jitter range, *do not* consider the higher values in 2X operation to be acceptable. This is because 2X operation is much more susceptible to problems from interference than is 1X. For example, where the amount of interference remains constant, an SM with a jitter value of 6 in 1X operation can display a jitter value of 14 when enabled for 2X operation. As indicated in [Table 32](#), these values are unacceptable.

12.4 USING LINK EFFICIENCY TO CHECK RECEIVED SIGNAL QUALITY

A link test, available in the Link Capacity Test tab of the Tools web page in an AP or BH, provides a more reliable indication of received signal quality, particularly if you launch tests of varying duration. However, a link test interrupts traffic and consumes system capacity, so *do not* routinely launch link tests across your networks.

12.4.1 Comparing Efficiency in 1X Operation to Efficiency in 2X Operation

Efficiency of at least 98 to 100% indicates a high quality signal. Check the signal quality numerous times, at various times of day and on various days of the week (as you

checked the RF environment a variety of times by spectrum analysis before placing radios in the area). Efficiency less than 90% in 1X operation or less than 60% in 2X operation indicates a link with problems that require action.

12.4.2 When to Switch from 2X to 1X Operation Based on 60% Link Efficiency

In the above latter case (60% in 2X operation), the link experiences worse latency (from packet resends) than it would in 1X operation, but still greater capacity, if the link remains stable at 60% Efficiency. Downlink Efficiency and Uplink Efficiency are measurements produced by running a link test from either the SM or the AP. Examples of what action should be taken based on Efficiency in 2X operation are provided in [Table 33](#).

Table 33: Recommended courses of action based on Efficiency in 2X operation

Module Types	Further Investigation	Result	Recommended Action
Advantage AP with Advantage SM	Check the General Status tab of the Advantage SM. ¹ See Checking the Status of 2X Operation on Page 93.	Uplink and downlink are both $\geq 60\%$ Efficiency. ²	Rerun link tests.
	Rerun link tests.	Uplink and downlink are both $\geq 60\%$ Efficiency.	Optionally, re-aim SM, add a reflector, or otherwise mitigate interference. In any case, continue 2X operation up and down.
Advantage AP with Canopy SM	Check the General Status tab of the Canopy SM. ¹ See Checking the Status of 2X Operation on Page 93.	Uplink and downlink are both $\geq 60\%$ Efficiency. ²	Rerun link tests.
	Rerun link tests.	Uplink and downlink are both $\geq 60\%$ Efficiency.	Optionally, re-aim SM, add a reflector, or otherwise mitigate interference. In any case, continue 2X operation up and down.
		Results are inconsistent and range from 20% to 80% Efficiency.	Monitor the Session Status tab in the Advantage AP.
	Monitor the Session Status tab in the Advantage AP.	Link fluctuates between 2X and 1X operation. ³	Optionally, re-aim SM, add a reflector, or otherwise mitigate interference. Then rerun link tests.
	Rerun link tests.	No substantial improvement with consistency is seen.	On the General tab of the SM, disable 2X operation. Then rerun link tests.
	Rerun link tests.	Uplink and downlink are both $\geq 90\%$ Efficiency.	Continue 1X operation up and down.

NOTES:

1. Or check Session Status page of the Advantage AP, where a sum of greater than 7,000,000 bps for the up- and downlink indicates 2X operation up and down (for 2.4- or 5.x-GHz modules).
2. For throughput to the SM, this is equivalent to 120% Efficiency in 1X operation, with less capacity used at the AP.
3. This link is problematic.

12.5 CONSIDERING FREQUENCY BAND ALTERNATIVES

For 5.2-, 5.4-, and 5.7-GHz modules, 20-MHz wide channels are centered every 5 MHz. For 2.4-GHz modules, 20-MHz wide channels are centered every 2.5 MHz. This allows the operator to customize the channel layout for interoperability where other Canopy equipment is collocated.

Cross-band deployment of APs and BH is the recommended alternative (for example, a 5.2-GHz AP collocated with 5.7-GHz BH).



IMPORTANT!

Regardless of whether 2.4-, 5.2-, 5.4-, or 5.7-GHz modules are deployed, channel separation between modules should be at least 20 MHz for 1X operation or 25 MHz for 2X.

12.5.1 900-MHz Channels

900-MHz Single AP Available Channels

A single 900-MHz AP can operate with the 8-MHz wide channel centered on any of the following frequencies:

(All Frequencies in MHz)

906	909	912	915	918	922
907	910	913	916	919	923
908	911	914	917	920	924

900-MHz AP Cluster Recommended Channels

Three non-overlapping channels are recommended for use in a 900-MHz AP cluster:

(All Frequencies in MHz)

906	915	924
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This recommendation allows 9 MHz of separation between channel centers. You can use the Spectrum Analysis feature in an SM, or use a standalone spectrum analyzer, to evaluate the RF environment. In any case, ensure that the 8-MHz wide channels you select *do not* overlap.

12.5.2 2.4-GHz Channels

2.4-GHz BH and Single AP Available Channels

A BH or a single 2.4-GHz AP can operate in the following channels, which are separated by only 2.5-MHz increments.

(All Frequencies in GHz)

2.4150	2.4275	2.4400	2.4525
2.4175	2.4300	2.4425	2.4550
2.4200	2.4325	2.4450	2.4575
2.4225	2.4350	2.4475	
2.4250	2.4375	2.4500	

The channels of *adjacent* 2.4-GHz APs should be separated by at least 20 MHz.

**IMPORTANT!**

In the 2.4-GHz frequency band, an SM can register to an AP that transmits on a frequency 2.5 MHz higher than the frequency that the SM receiver locks when the scan terminates as successful. This establishes a poor-quality link. To prevent this, select frequencies that are at least 5 MHz apart.

2.4-GHz AP Cluster Recommended Channels

Three non-overlapping channels are recommended for use in a 2.4-GHz AP cluster:

(All Frequencies in GHz)

2.4150 2.4350 2.4575

This recommendation allows 20 MHz of separation between one pair of channels and 22.5 MHz between the other pair. You can use the Spectrum Analysis feature in an SM or BHS, or use a standalone spectrum analyzer, to evaluate the RF environment. Where spectrum analysis identifies risk of interference for any of these channels, you can compromise this recommendation as follows:

- Select 2.4375 GHz for the middle channel
- Select 2.455 GHz for the top channel
- Select 2.4175 GHz for the bottom channel

In any case, ensure that your plan allows at least 20 MHz of separation between channels.

12.5.3 5.2-GHz Channels

Channel selections for the AP in the 5.2-GHz frequency band range depend on whether the AP is deployed in cluster.

5.2-GHz BH and Single AP Available Channels

A BH or a single 5.2-GHz AP can operate in the following channels, which are separated by 5-MHz increments.

(All Frequencies in GHz)

5.275	5.290	5.305	5.320
5.280	5.295	5.310	5.325
5.285	5.300	5.315	

The channels of *adjacent* APs should be separated by at least 20 MHz. However, 25 MHz of separation is advised.

5.2-GHz AP Cluster Recommended Channels

Three non-overlapping channels are recommended for use in a 5.2-GHz AP cluster:

(All Frequencies in GHz)

5.275 5.300 5.325

12.5.4 5.4-GHz Channels

Channel selections for the AP in the 5.4-GHz frequency band range depend on whether the AP is deployed in cluster.

5.4-GHz BH and Single AP Available

A BH or single 5.4-GHz AP can operate in the following channels, which are separated by 5-MHz.

(All Frequencies in GHz)

5495	5515	5535	5555	5575	5595	5615	5635	5655	5675	5695
5500	5520	5540	5560	5580	5600	5620	5640	5660	5680	5700
5505	5525	5545	5565	5585	5605	5625	5645	5665	5685	5705
5510	5530	5550	5570	5590	5610	5630	5650	5670	5690	

The channels of *adjacent* APs should be separated by at least 20 MHz.

5.4-GHz AP Cluster Recommended Channels

The fully populated cluster requires only three channels, each reused by the module that is mounted 180° opposed. In this frequency band range, the possible sets of three non-overlapping channels are numerous. As many as 11 non-overlapping 20-MHz wide channels are available for 1X operation. Fewer 25-MHz wide channels are available for 1X operation, where this greater separation is recommended for interference avoidance.

5.4-GHz AP Cluster Limit Case

In the limit, the 11 channels could support all of the following, vertically stacked on the same mast:

- 3 full clusters, each cluster using 3 channels
- a set of 4 APs, the set using the 2 channels that no AP in any of the 3 full clusters is using



IMPORTANT!

Where regulations require you to have Dynamic Frequency Selection (DFS) enabled, analyze the spectrum, then spread your channel selections as evenly as possible throughout this frequency band range, appropriately sharing it with satellite services.

12.5.5 5.7-GHz Channels

Channel selections for the AP in the 5.7-GHz frequency band range depend on whether the AP is deployed in cluster.

5.7-GHz BH and Single AP Available ISM/U-NII Channels

A BH or a single 5.7-GHz AP enabled for ISM/U-NII frequencies can operate in the following channels, which are separated by 5-MHz increments.

(All Frequencies in GHz)			
5.735	5.765	5.795	5.825
5.740	5.770	5.800	5.830
5.745	5.775	5.805	5.835
5.750	5.780	5.810	5.840
5.755	5.785	5.815	
5.760	5.790	5.820	

The channels of *adjacent* APs should be separated by at least 20 MHz. However, 25 MHz of separation is advised.

5.7-GHz AP Cluster Recommended ISM/U-NII Channels

Six non-overlapping ISM/U-NII channels are recommended for use in a 5.7-GHz AP cluster:

(All Frequencies in GHz)		
5.735	5.775	5.815
5.755	5.795	5.835

The fully populated cluster requires only three channels, each reused by the module that is mounted 180° offset. The six channels above are also used for backhaul point-to-point links.

As noted above, a 5.7-GHz AP enabled for ISM/U-NII frequencies can operate on a frequency as high as 5.840 GHz. Where engineering plans allow, this frequency can be used to provide an additional 5-MHz separation between AP and BH channels.

12.5.6 Channels Available for OFDM Backhaul Modules

Channel selections for BHs in the OFDM series are quoted in the user guides that are dedicated to those products. However, these BHs dynamically change channels when the signal substantially degrades. Since the available channels are in the 5.4- and 5.7-GHz frequency band ranges, carefully consider the potential effects of deploying these products into an environment where traffic in this range pre-exists.

12.5.7 Example Channel Plans for AP Clusters

Examples for assignment of frequency channels and sector IDs are provided in the following tables. Each frequency is reused on the sector that is at a 180° offset. The entry in the Symbol column of each table refers to the layout in [Figure 38](#) on Page 142.

**NOTE:**

The operator specifies the sector ID for the module as described under [Sector ID](#) on Page 439.

Table 34: Example 900-MHz channel assignment by sector

Direction of Access Point Sector	Frequency	Sector ID	Symbol
North (0°)	906 MHz	0	A
Northeast (60°)	915 MHz	1	B
Southeast (120°)	924 MHz	2	C
South (180°)	906 MHz	3	A
Southwest (240°)	915 MHz	4	B
Northwest (300°)	924 MHz	5	C

Table 35: Example 2.4-GHz channel assignment by sector

Direction of Access Point Sector	Frequency	Sector ID	Symbol
North (0°)	2.4150 GHz	0	A
Northeast (60°)	2.4350 GHz	1	B
Southeast (120°)	2.4575 GHz	2	C
South (180°)	2.4150 GHz	3	A
Southwest (240°)	2.4350 GHz	4	B
Northwest (300°)	2.4575 GHz	5	C

Table 36: Example 5.2-GHz channel assignment by sector

Direction of Access Point Sector	Frequency	Sector ID	Symbol
North (0°)	5.275 GHz	0	A
Northeast (60°)	5.300 GHz	1	B
Southeast (120°)	5.325 GHz	2	C
South (180°)	5.275 GHz	3	A
Southwest (240°)	5.300 GHz	4	B
Northwest (300°)	5.325 GHz	5	C

Table 37: Example 5.4-GHz channel assignment by sector

Direction of Access Point Sector	Frequency	Sector ID	Symbol
North (0°)	5.580 GHz	0	A
Northeast (60°)	5.620 GHz	1	B
Southeast (120°)	5.660 GHz	2	C
South (180°)	5.580 GHz	3	A
Southwest (240°)	5.620 GHz	4	B
Northwest (300°)	5.660 GHz	5	C

Table 38: Example 5.7-GHz channel assignment by sector

Direction of Access Point Sector	Frequency	Sector ID	Symbol
North (0°)	5.735 GHz	0	A
Northeast (60°)	5.755 GHz	1	B
Southeast (120°)	5.775 GHz	2	C
South (180°)	5.735 GHz	3	A
Southwest (240°)	5.755 GHz	4	B
Northwest (300°)	5.775 GHz	5	C

12.5.8 Multiple Access Points Clusters

When deploying multiple AP clusters in a dense area, consider aligning the clusters as shown in [Figure 38](#). However, this is only a recommendation. An installation may dictate a different pattern of channel assignments.

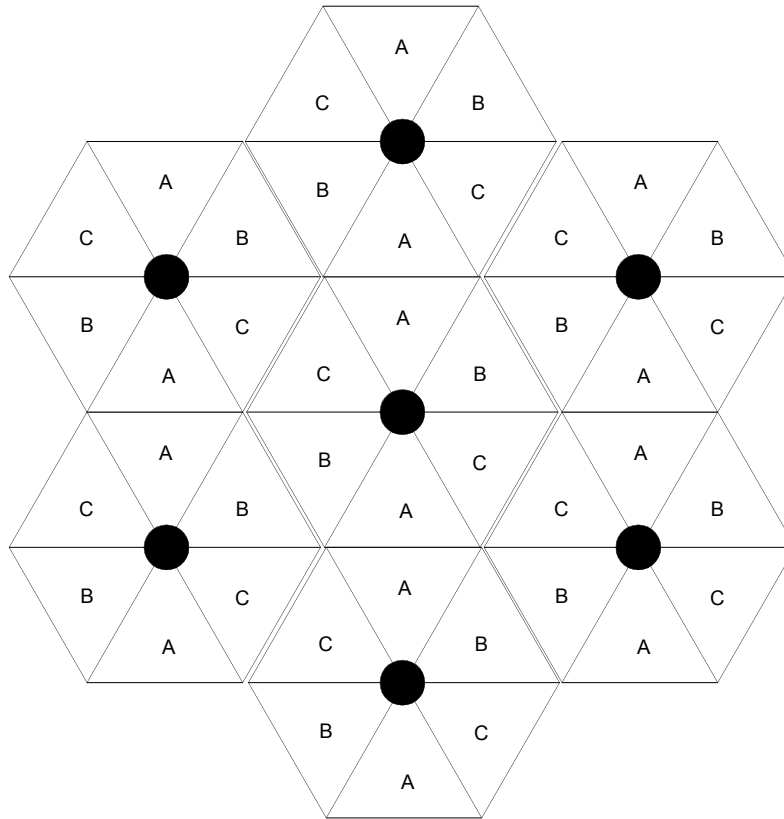


Figure 38: Example layout of 7 Access Point clusters

12.6 SELECTING SITES FOR NETWORK ELEMENTS

The Canopy APs must be positioned

- with hardware that the wind and ambient vibrations cannot flex or move.
- where a tower or rooftop is available or can be erected.
- where a grounding system is available.
- with lightning arrestors to transport lightning strikes away from equipment.
- at a proper height:
 - higher than the tallest points of objects immediately around them (such as trees, buildings, and tower legs).
 - at least 2 feet (0.6 meters) below the tallest point on the tower, pole, or roof (for lightning protection).
- away from high-RF energy sites (such as AM or FM stations, high-powered antennas, and live AM radio towers).
- in line-of-sight paths
 - to the SMs and BH.
 - that will not be obstructed by trees as they grow or structures that are later built.

**NOTE:**

Visual line of sight does not guarantee radio line of sight.

12.6.1 Resources for Maps and Topographic Images

Mapping software is available from sources such as the following:

- <http://www.microsoft.com/streets/default.asp>
 - Microsoft Streets & Trips (with Pocket Streets)
- <http://www.delorme.com/software.htm>
 - DeLorme Street Atlas USA
 - DeLorme Street Atlas USA Plus
 - DeLorme Street Atlas Handheld

Topographic maps are available from sources such as the following:

- <http://www.delorme.com/software.htm>
 - DeLorme Topo USA
 - DeLorme 3-D TopoQuads
- <http://www.usgstopomaps.com>
 - Timely Discount Topos, Inc. authorized maps

Topographic maps with waypoints are available from sources such as the following:

- <http://www.topografix.com>
 - TopoGrafix EasyGPS
 - TopoGrafix Panterra
 - TopoGrafix ExpertGPS

Topographic images are available from sources such as the following:

- <http://www.keyhole.com/body.php?h=products&t=keyholePro>
 - keyhole PRO
- <http://www.digitalglobe.com>
 - various imagery

12.6.2 Surveying Sites

Factors to survey at potential sites include

- what pre-existing wireless equipment exists at the site. (Perform spectrum analysis.)
- whether available mounting positions exist near the lowest elevation that satisfies line of site, coverage, and other link criteria.
- whether you will always have the right to decide who climbs the tower to install and maintain your equipment, and whether that person or company can climb at any hour of any day.

- whether you will have collaborative rights and veto power to prevent interference to your equipment from wireless equipment that is installed at the site in the future.
- whether a pre-existing grounding system (path to Protective Earth $\downarrow$) exists, and what is required to establish a path to it.
- who is permitted to run any indoor lengths of cable.

12.6.3 Assuring the Essentials

In the 2.4-, 5.2-, 5.4-, and 5.7-GHz frequency band ranges, an unobstructed line of sight (LOS) must exist and be maintainable between the radios that are involved in each link.

Line of Sight (LOS) Link

In these ranges, a line of sight link is both

- an unobstructed straight line from radio to radio.
- an unobstructed zone surrounding that straight line.

Fresnel Zone Clearance

An unobstructed line of sight is important, but is not the *only* determinant of adequate placement. Even where the path has a clear line of sight, obstructions such as terrain, vegetation, metal roofs, or cars may penetrate the Fresnel zone and cause signal loss. [Figure 39](#) illustrates an ideal Fresnel zone.

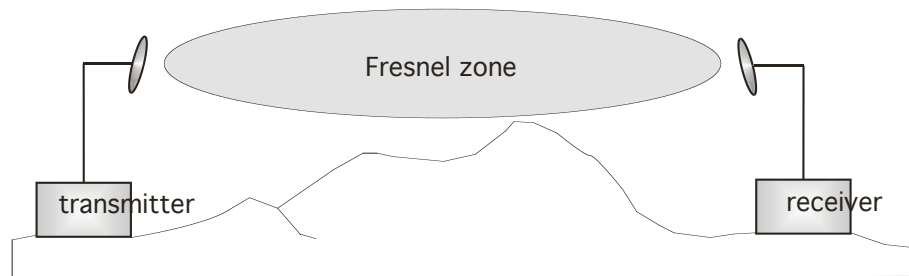


Figure 39: Fresnel zone

[FresnelZoneCalcPage.xls](#) calculates the Fresnel zone clearance that is required between the visual line of sight and the top of an obstruction that would protrude into the link path.

Non-Line of Sight (NLOS) Link

The Canopy 900-MHz modules have a line of sight (LOS) range of 40 miles (more than 64 km) and greater non-line of sight (NLOS) range than Canopy modules of other frequency bands. NLOS range depends on RF considerations such as foliage, topography, obstructions.

12.6.4 Finding the Expected Coverage Area

The transmitted beam in the vertical dimension covers more area beyond than in front of the beam center. [BeamwidthRadiiCalcPage.xls](#) calculates the radii of the beam coverage area.

12.6.5 Clearing the Radio Horizon

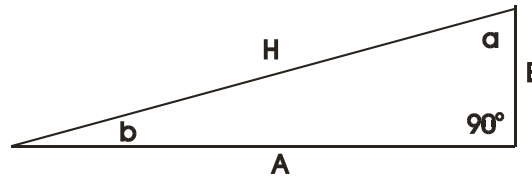
Because the surface of the earth is curved, higher module elevations are required for greater link distances. This effect can be critical to link connectivity in link spans that are greater than 8 miles (12 km). [AntennaElevationCalcPage.xls](#) calculates the minimum antenna elevation for these cases, presuming no landscape elevation difference from one end of the link to the other.

12.6.6 Calculating the Aim Angles

The appropriate angle of AP downward tilt is derived from both the distance between transmitter and receiver and the difference in their elevations. [DowntiltCalcPage.xls](#) calculates this angle.

The proper angle of tilt can be calculated as a factor of both the difference in elevation and the distance that the link spans. Even in this case, a plumb line and a protractor can be helpful to ensure the proper tilt. This tilt is typically minimal.

The number of degrees to offset (from vertical) the mounting hardware leg of the support tube is equal to the angle of elevation from the lower module to the higher module (<B in the example provided in [Figure 40](#)).



LEGEND

- b** Angle of elevation.
- B** Vertical difference in elevation.
- A** Horizontal distance between modules.

Figure 40: Variables for calculating angle of elevation (and depression)

Calculating the Angle of Elevation

To use metric units to find the angle of elevation, use the following formula:

$$\tan b = \frac{B}{1000A}$$

where

B is expressed in meters

A is expressed in kilometers.

To use English standard units to find the angle of elevation, use the following formula:

$$\tan b = \frac{B}{5280A}$$

where

B is expressed in feet

A is expressed in miles.

The angle of depression from the higher module is identical to the angle of elevation from the lower module.

12.7 COLLOCATING CANOPY MODULES

A BH and an AP or AP cluster on the same tower require a CMM. The CMM properly synchronizes the *transmit start* times of all Canopy modules to prevent interference and desensing of the modules. At closer distances without sync from a CMM, the frame structures cause self interference.

Furthermore, a BH and an AP on the same tower require that the effects of their differing *receive start* times be mitigated by either

- 100 vertical feet (30 meters) or more and as much spectral separation as possible within the same frequency band range.
- the use of the frame calculator to tune the **Downlink Data** parameter in each, so that the receive start time in each is the same. See [Using the Frame Calculator Tool \(All\)](#) on Page 440.

Canopy APs and a BHS can be collocated at the same site only if they operate in different frequency band ranges.

Where a single BH air link is insufficient to cover the distance from an AP cluster to your point of presence (POP), you can deploy two BHSSs, connected to one another by Ethernet, on a tower that is between a BHM collocated with the AP cluster and another BHM collocated with the POP. This deployment is illustrated in [Figure 41](#).

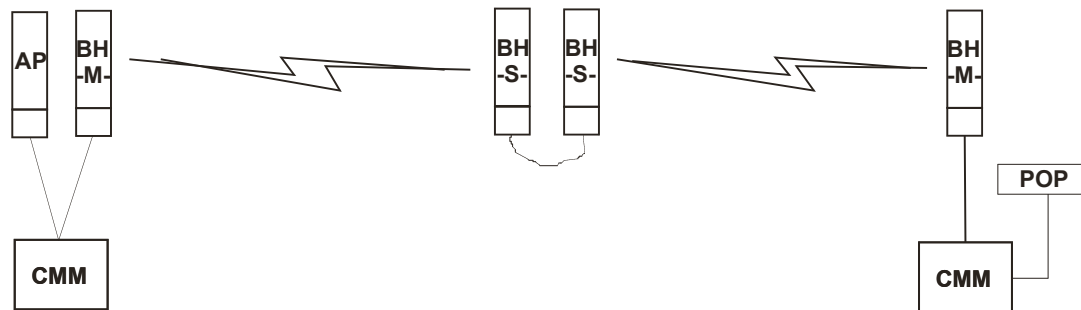


Figure 41: Double-hop backhaul links

However, the BHSs can be collocated at the same site *only if* one is on a different frequency band range from that of the other or one of the following conditions applies:

- They are vertically separated on a structure by at least 100 feet (30 m).
- They are vertically separated on a structure by less distance, but either
 - an RF shield isolates them from each other.
 - the uplink and downlink data parameters and control channels match (the **Downlink Data** parameter is set to **50%**).

The constraints for collocated modules in the same frequency band range are to avoid self-interference that would occur between them. Specifically, unless the uplink and downlink data percentages match, intervals exist when one is transmitting while the other is receiving, such that the receiving module cannot receive the signal from the far end.

The interference is less a problem during low throughput periods and intolerable during high. Typically, during low throughput periods, sufficient time exists for the far end to retransmit packets lost because of interference from the collocated module.

12.8 DEPLOYING A REMOTE AP

In cases where the subscriber population is widely distributed, or conditions such as geography restrict network deployment, you can add a Remote AP to

- provide high-throughput service to near LoS business subscribers.
- reach around obstructions or penetrate foliage with non-LoS throughput.
- reach new, especially widely distributed, residential subscribers with broadband service.
- pass sync to an additional RF hop.

In the remote AP configuration, a Canopy AP is collocated with a Canopy SM. The remote AP distributes the signal over the last mile to SMs that are logically behind the collocated SM. A remote AP deployment is illustrated in [Figure 42](#).

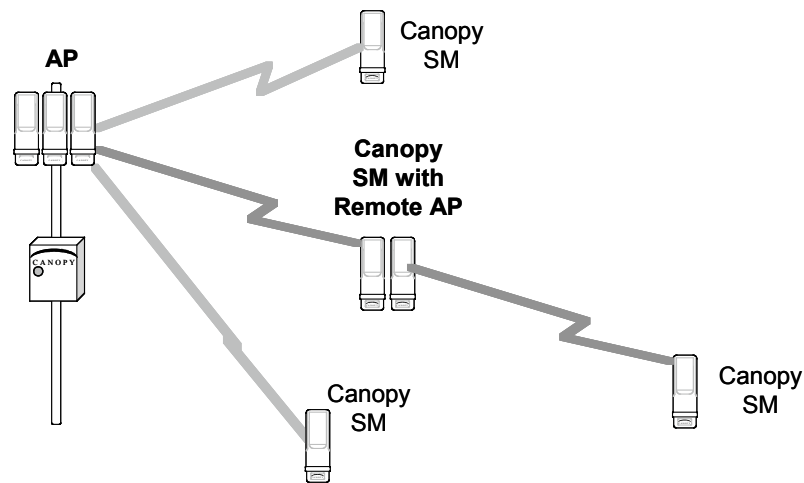


Figure 42: Remote AP deployment

The collocated SM receives data in one frequency band, and the remote AP must redistribute the data in a different frequency band. Base your selection of frequency band ranges on regulatory restrictions, environmental conditions, and throughput requirements.

**IMPORTANT!**

Each relay hop (additional daisy-chained remote AP) adds latency to the link as follows:

- approximately 6 msec where hardware scheduling is enabled.
- approximately 15 msec where software scheduling is enabled.

12.8.1 Remote AP Performance

The performance of a remote AP is identical to the AP performance in cluster. Throughputs, ranges, and patch antenna coverage are identical. Canopy Advantage and Canopy modules can be deployed in tandem in the same sector to meet customer bandwidth demands.

As with all equipment operating in the unlicensed spectrum, Motorola *strongly* recommends that you perform site surveys before you add network elements. These will indicate that spectrum is available in the area where you want to grow. Keep in mind that

- non-LoS ranges heavily depend on environmental conditions.
- in most regions, not all frequencies are available.
- your deployments must be consistent with local regulatory restrictions.

12.8.2 Example Use Case for RF Obstructions

A remote AP can be used to provide last-mile access to a community where RF obstructions prevent SMs from communicating with the higher-level AP in cluster. For example, you may be able to use 900 MHz for the last mile between a remote AP and the outlying SMs where these subscribers cannot form good links to a higher-level 2.4-GHz AP. In this case, the short range of the 900-MHz remote AP is sufficient, and the ability of the 900-MHz wavelength to be effective around foliage at short range solves the foliage penetration problem.

An example of this use case is shown in [Figure 43](#).

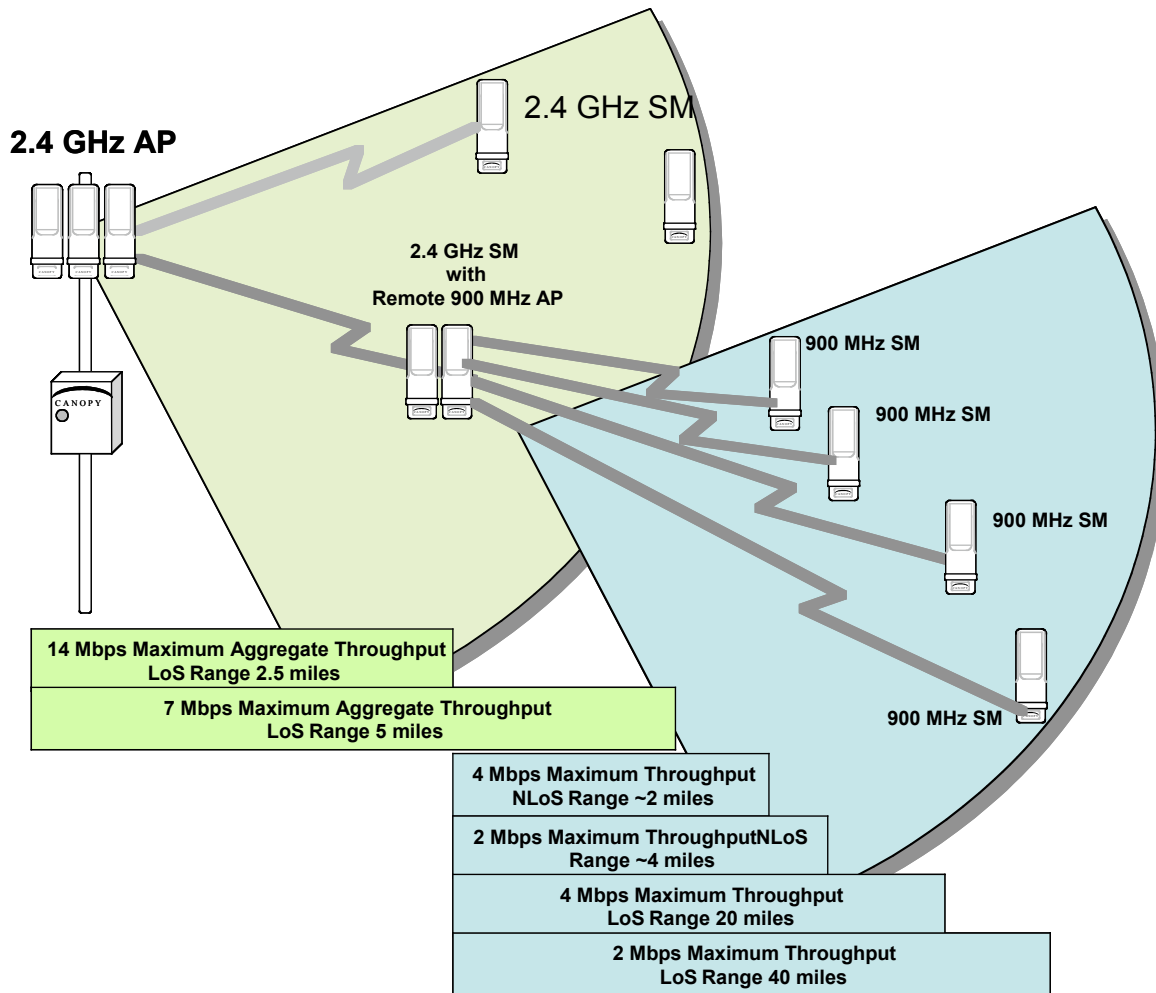


Figure 43: Example 900-MHz remote AP behind 2.4-GHz SM

The 2.4 GHz modules provide a sustained aggregate throughput of up to 14 Mbps to the sector. One of the SMs in the sector is wired to a 900-MHz remote AP, which provides NLoS sustained aggregate throughput⁵ of

- 4 Mbps to 900-MHz SMs up to 2 miles away in the sector.
- 2 Mbps to 900-MHz SMs between 2 and 4 miles away in the sector.

12.8.3 Example Use Case for Passing Sync

All Canopy radios support the remote AP functionality. The BHS and the SM can reliably pass the sync pulse, and the BHM and AP can reliably receive it. Examples of passing sync over cable are shown under [Passing Sync in an Additional Hop](#) on Page 97. The sync cable is described under [Cables](#) on Page 59.

⁵ NLoS ranges depend on environmental conditions. Your results may vary from these.

The sync is passed in a cable that connects Pins 1 and 6 of the RJ-11 timing ports of the two modules. When you connect modules in this way, you must also adjust configuration parameters to ensure that

- the AP is set to properly receive sync.
- the SM will not propagate sync to the AP if the SM itself ceases to receive sync.

Perform [Procedure 35: Extending network sync](#) on Page 369.

12.8.4 Physical Connections Involving the Remote AP

The SM to which you wire a remote AP can be either an SM that serves a customer or an SM that simply serves as a relay. Where the SM serves a customer, wire the remote AP to the SM as shown in [Figure 44](#).

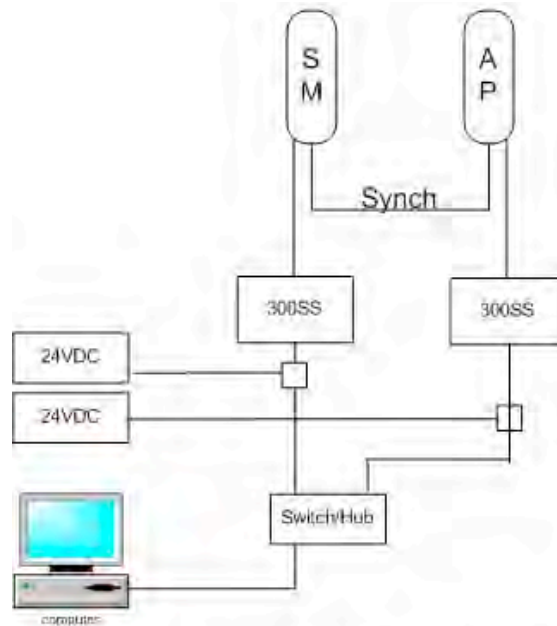


Figure 44: Remote AP wired to SM that also serves a customer

Where the SM simply serves as a relay, you must use a straight-through RJ-45 female-to-female coupler, and wire the SM to the remote AP as shown in [Figure 45](#).

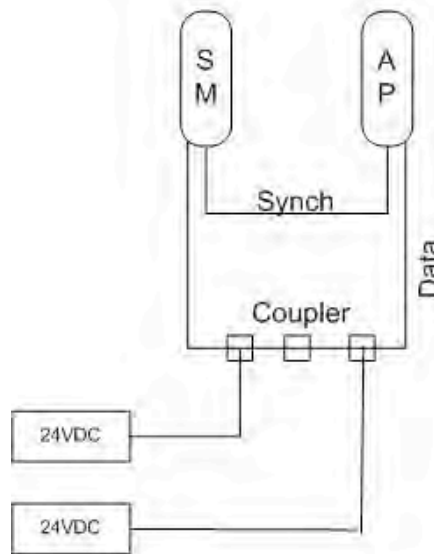


Figure 45: Remote AP wired to SM that serves as a relay

12.9 DIAGRAMMING NETWORK LAYOUTS

12.9.1 Accounting for Link Ranges and Data Handling Requirements

For aggregate throughput correlation to link distance in both point-to-multipoint and point-to-point links, see

- [Link Performance and Encryption Comparisons](#) on Page 63.
- all regulations that apply in your region and nation(s).

12.9.2 Avoiding Self Interference

For 5.2-, 5.4-, and 5.7-GHz modules, 20-MHz wide channels are centered every 5 MHz. For 2.4-GHz modules, 20-MHz wide channels are centered every 2.5 MHz. This allows you to customize the channel layout for interoperability where other Canopy equipment is collocated.



CAUTION!

Regardless of whether 2.4-, 5.2-, 5.4-, or 5.7-GHz modules are deployed, channel separation between modules should be at least 20 MHz for 1X operation or 25 MHz for 2X.

Physical Proximity

A BH and an AP on the same tower require a CMM. The CMM properly synchronizes the *transmit start* times of all Canopy modules to prevent interference and desensing of the modules. At closer distances without sync from a CMM, the frame structures cause self interference.

Furthermore, a BH and an AP on the same tower require that the effects of their differing *receive start* times be mitigated by either

- 100 vertical feet (30 meters) or more and as much spectral separation as possible within the same frequency band range.
- the use of the frame calculator to tune the Downlink Data % parameter in each, so that the receive start time in each is the same. See [Using the Frame Calculator Tool \(All\)](#) on Page 440.

Spectrum Analysis

You can use an SM or BHS as a spectrum analyzer. See [Mapping RF Neighbor Frequencies](#) on Page 131. Through a toggle of the **Device Type** parameter, you can temporarily transform an AP into an SM to use it as a spectrum analyzer.

Power Reduction to Mitigate Interference

Where any module (SM, AP, BH timing master, or BH timing slave) is close enough to another module that self-interference is possible, you can set the SM to operate at less than full power. To do so, perform the following steps.



CAUTION!

A low setting of the **Transmitter Output Power** parameter can cause a link to a distant module to drop. A link that drops for this reason can be re-established by only Ethernet access.

Procedure 3: Invoking the low power mode

1. Access the Radio tab of the module.
2. In the **Transmitter Output Power** parameter, reduce the setting.
3. Click **Save Changes**.
4. Click **Reboot**.
5. Access the Session Status tab in the Home web page of the SM.
6. Assess whether the link achieves good **Power Level** and **Jitter** values.
NOTE: The received **Power Level** is shown in dBm and should be maximized. **Jitter** should be minimized. However, better/lower jitter should be favored over better/higher dBm. For historical reasons, **RSSI** is also shown and is the unitless measure of power. The best practice is to use **Power Level** and ignore **RSSI**, which implies more accuracy and precision than is inherent in its measurement.
7. Access the Link Capacity Test tab in the Tools web page of the module.
8. Assess whether the desired links for this module achieve
 - uplink efficiency greater than 90%.
 - downlink efficiency greater than 90%.
9. If the desired links fail to achieve any of the above measurement thresholds, then
 - a. access the module by direct Ethernet connection.
 - b. access the Radio tab in the Configuration web page of the module.
 - c. in the **Transmitter Output Power** parameter, increase the setting.
 - d. click **Save Changes**.
 - e. click **Reboot**.

===== end of procedure =====

12.9.3 Avoiding Other Interference

Where signal strength cannot dominate noise levels, the network experiences

- bit error corrections.
- packet errors and retransmissions.
- lower throughput (because bandwidth is consumed by retransmissions) and high latency (due to resends).

Be especially cognitive of these symptoms for 900-MHz links. Where you see these symptoms, attempt the following remedies:

- Adjust the position of the SM.
- Deploy a band-pass filter at the AP.
- Consider adding a remote AP closer to the affected SMs. (See [Deploying a Remote AP](#) on Page 147.)

Certain other actions, which may seem to be potential remedies, *do not* resolve high noise level problems:

- *Do not* deploy an omnidirectional or vertically polarized antenna.
- *Do not* set the antenna gain above the recommended level.
- *Do not* deploy a band-pass filter in the expectation that this can mitigate interband interference.

13 ENGINEERING YOUR IP COMMUNICATIONS

13.1 UNDERSTANDING ADDRESSES

A basic understanding of Internet Protocol (IP) address and subnet mask concepts is required for engineering your IP network.

13.1.1 IP Address

The IP address is a 32-bit binary number that has four parts (octets). This set of four octets has two segments, depending on the class of IP address. The first segment identifies the network. The second identifies the hosts or devices on the network. The subnet mask marks a boundary between these two sub-addresses.

13.2 DYNAMIC OR STATIC ADDRESSING

For any computer to communicate with a Canopy module, the computer must be configured to either

- use DHCP (Dynamic Host Configuration Protocol). In this case, when not connected to the network, the computer derives an IP address on the 169.254 network within two minutes.
- have an assigned static IP address (for example, 169.254.1.5) on the 169.254 network.



IMPORTANT!

If an IP address that is set in the module is not the 169.254.x.x network address, then the network operator must assign the computer a static IP address in the same subnet.

13.2.1 When a DHCP Server is Not Found

To operate on a network, a computer requires an IP address, a subnet mask, and possibly a gateway address. Either a DHCP server automatically assigns this configuration information to a computer on a network or an operator must input these items.

When a computer is brought on line and a DHCP server is not accessible (such as when the server is down or the computer is not plugged into the network), Microsoft and Apple operating systems default to an IP address of 169.254.x.x and a subnet mask of 255.255.0.0 (169.254/16, where /16 indicates that the first 16 bits of the address range are identical among all members of the subnet).

13.3 NETWORK ADDRESS TRANSLATION (NAT)

13.3.1 NAT, DHCP Server, DHCP Client, and DMZ in SM

The Canopy system provides NAT (network address translation) for SMs in the following combinations of NAT and DHCP (Dynamic Host Configuration Protocol):

- NAT Disabled (as in earlier releases)
- NAT with DHCP Client and DHCP Server
- NAT with DHCP Client
- NAT with DHCP Server
- NAT without DHCP

NAT

NAT isolates devices connected to the Ethernet/wired side of an SM from being seen directly from the wireless side of the SM. With NAT enabled, the SM has an IP address for transport traffic (separate from its address for management), terminates transport traffic, and allows you to assign a range of IP addresses to devices that are connected to the Ethernet/wired side of the SM.

In the Canopy system, NAT supports many protocols, including HTTP, ICMP (Internet Control Message Protocols), and FTP (File Transfer Protocol). For virtual private network (VPN) implementation, L2TP over IPSec (Level 2 Tunneling Protocol over IP Security) is supported, but PPTP (Point to Point Tunneling Protocol) *is not* supported. See [NAT and VPNs](#) on Page 161.

DHCP

DHCP enables a device to be assigned a new IP address and TCP/IP parameters, including a default gateway, whenever the device reboots. Thus DHCP reduces configuration time, conserves IP addresses, and allows modules to be moved to a different network within the Canopy system.

In conjunction with the NAT features, each SM provides

- a DHCP server that assigns IP addresses to computers connected to the SM by Ethernet protocol.
- a DHCP client that receives an IP address for the SM from a network DHCP server.

DMZ

In conjunction with the NAT features, a DMZ (demilitarized zone) allows the assignment of one IP address behind the SM for a device to logically exist outside the firewall and receive network traffic. The first three octets of this IP address must be identical to the first three octets of the NAT private IP address.

NAT Disabled

The NAT Disabled implementation is illustrated in [Figure 46](#).

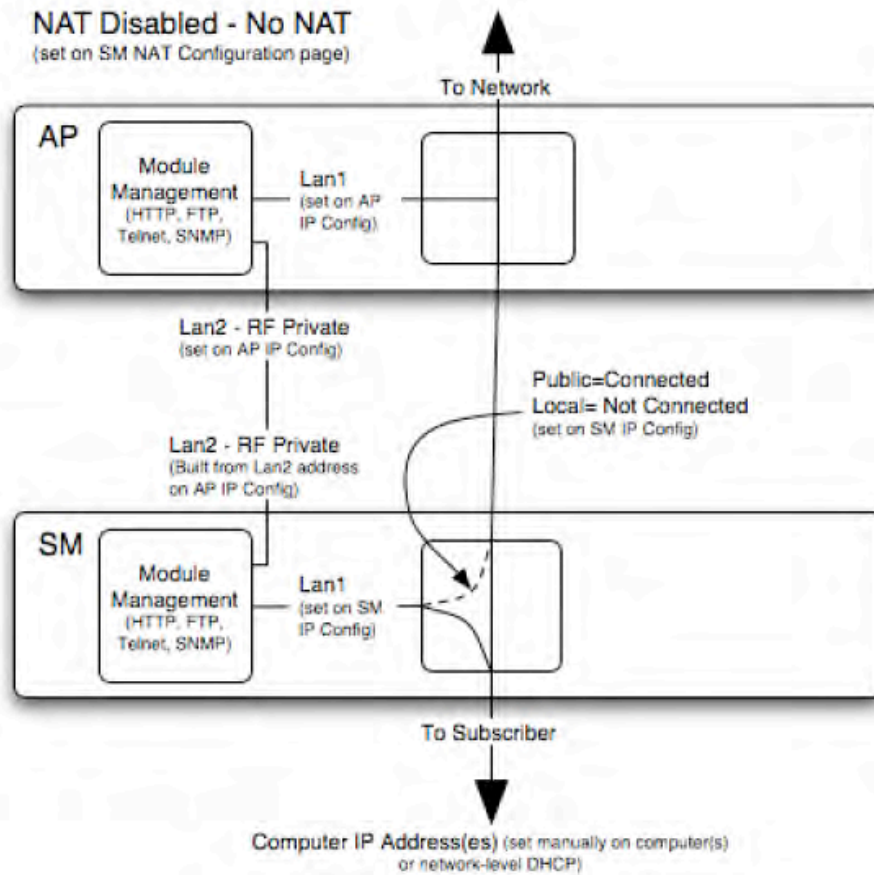


Figure 46: NAT Disabled implementation

NAT with DHCP Client and DHCP Server

The NAT with DHCP Client and DHCP Server implementation is illustrated in [Figure 47](#).

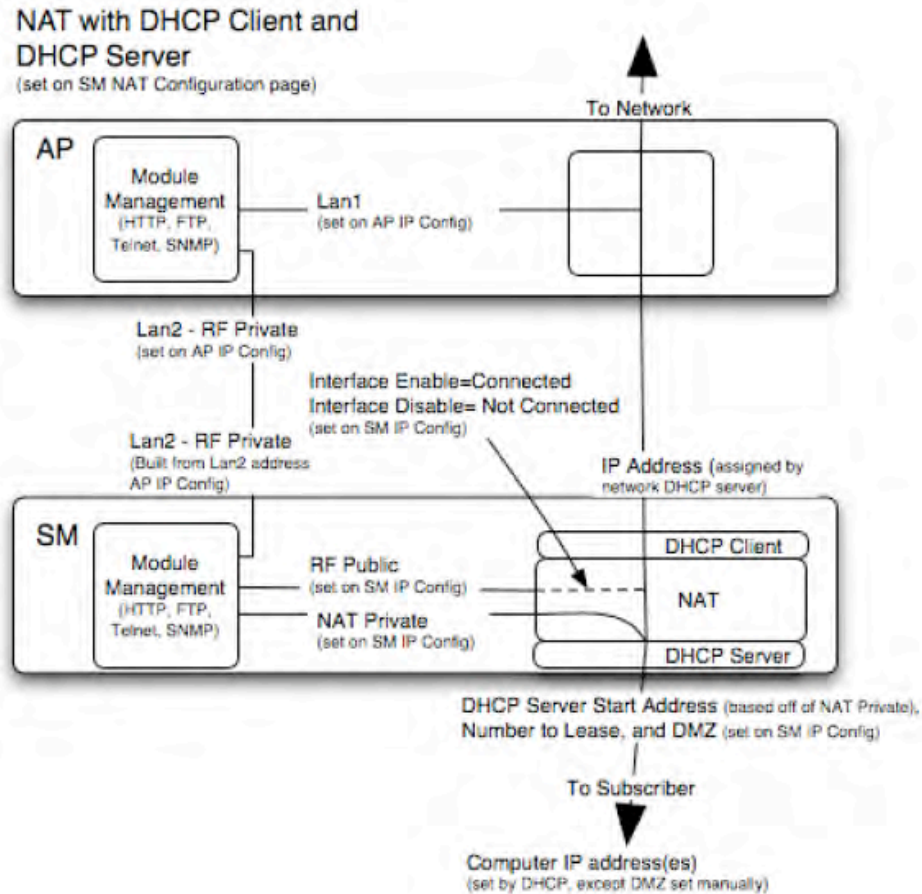


Figure 47: NAT with DHCP Client and DHCP Server implementation

NAT with DHCP Client

The NAT with DHCP Client implementation is illustrated in Figure 48.

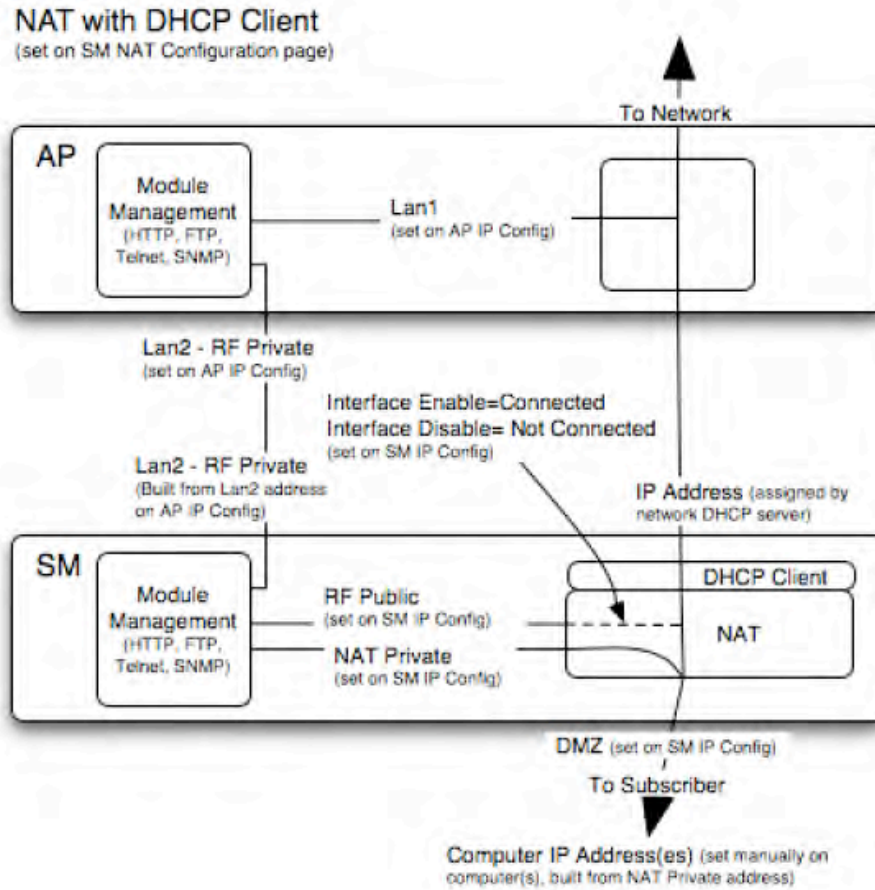


Figure 48: NAT with DHCP Client implementation

NAT with DHCP Server

The NAT with DHCP Server implementation is illustrated in Figure 49.

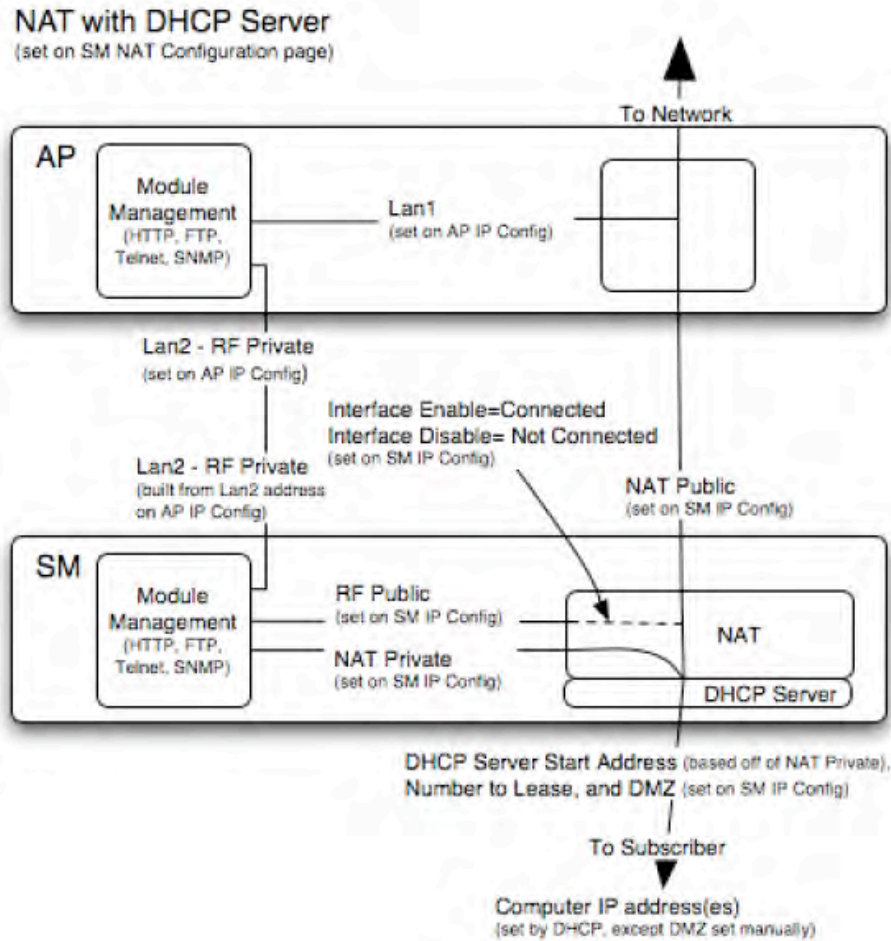


Figure 49: NAT with DHCP Server implementation

NAT without DHCP

The NAT without DHCP implementation is illustrated in Figure 50.

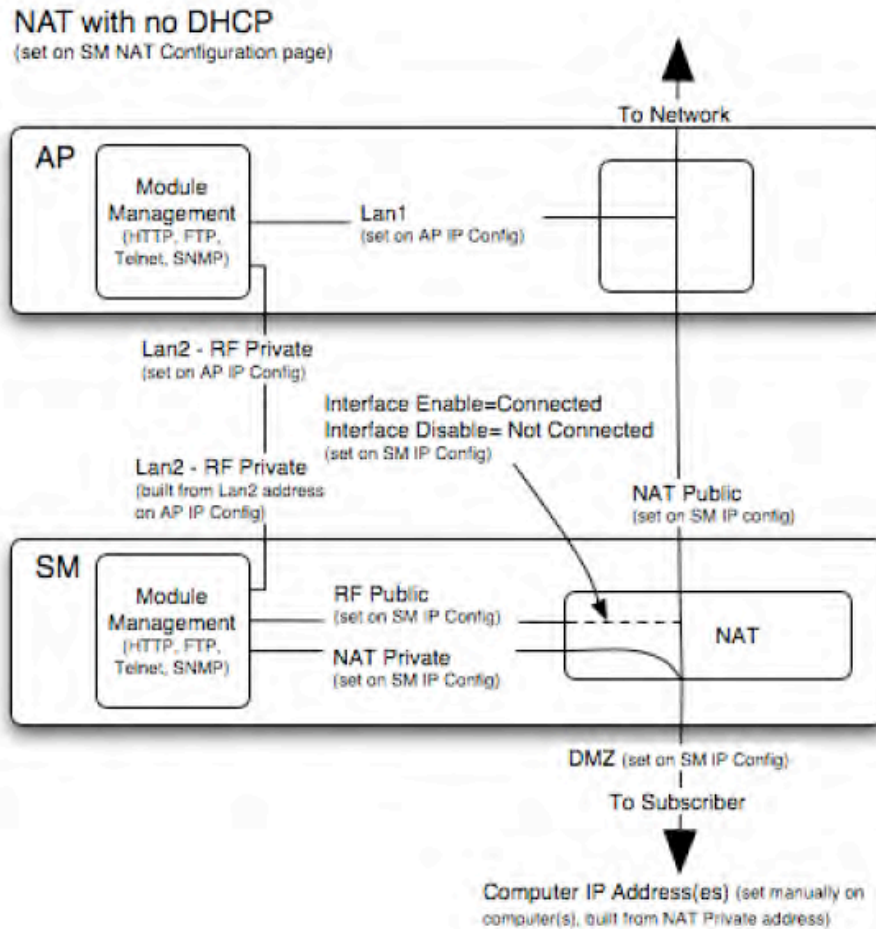


Figure 50: NAT without DHCP implementation

13.3.2 NAT and VPNs

VPN technology provides the benefits of a private network during communication over a public network. One typical use of a VPN is to connect remote employees, who are at home or in a different city, to their corporate network over the public Internet. Any of several VPN implementation schemes is possible. By design, NAT translates or changes addresses, and thus interferes with a VPN that is not specifically supported by a given NAT implementation.

With NAT enabled, SMs support L2TP over IPSec (Level 2 Tunneling Protocol over IP Security) VPNs, but *do not* support PPTP (Point to Point Tunneling Protocol) VPNs. With NAT disabled, SMs support all types of VPNs.

13.4 DEVELOPING AN IP ADDRESSING SCHEME

Canopy network elements are accessed through IP Version 4 (IPv4) addressing. A proper IP addressing method is critical to the operation and security of a Canopy network.

Each Canopy module requires an IP address on the network. This IP address is for only management purposes. For security, you should either

- assign an unroutable IP address.
- assign a routable IP address only if a firewall is present to protect the module.

You will assign IP addresses to computers and network components by either *static* or *dynamic* IP addressing. You will also assign the appropriate subnet mask and network gateway to each module.

13.4.1 Address Resolution Protocol

As previously stated, the MAC address identifies a Canopy module in

- communications between modules.
- the data that modules store about each other.
- the data that BAM or Prizm applies to manage authentication and bandwidth.

The IP address is essential for data delivery through a router interface. Address Resolution Protocol (ARP) correlates MAC addresses to IP addresses.

For communications to outside the network segment, ARP reads the network gateway address of the router and translates it into the MAC address of the router. Then the communication is sent to MAC address (physical network interface card) of the router.

For each router between the sending module and the destination, this sequence applies. The ARP correlation is stored until the ARP cache times out.

13.4.2 Allocating Subnets

The subnet mask is a 32-bit binary number that filters the IP address. Where a subnet mask contains a bit set to 1, the corresponding bit in the IP address is part of the network address.

Example IP Address and Subnet Mask

In [Figure 51](#), the first 16 bits of the 32-bit IP address identify the network:

	Octet 1	Octet 2	Octet 3	Octet 4
IP address 169.254.1.1	10101001	11111110	00000001	00000001
Subnet mask 255.255.0.0	11111111	11111111	00000000	00000000

Figure 51: Example of IP address in Class B subnet

In this example, the network address is 169.254, and 2^{16} (65,536) hosts are addressable.

13.4.3 Selecting Non-routable IP Addresses

The factory default assignments for Canopy network elements are

- unique MAC address
- IP address of 169.254.1.1, except for an OFDM series BHM, whose IP address is 169.254.1.2 by default
- subnet mask of 255.255.0.0
- network gateway address of 169.254.0.0

For each Canopy radio and CMMmicro, assign an IP address that is both consistent with the IP addressing plan for your network and cannot be accessed from the Internet. IP addresses within the following ranges are not routable from the Internet, regardless of whether a firewall is configured:

- 10.0.0.0 – 10.255.255.255
- 172.16.0.0 – 172.31.255.255
- 192.168.0.0 – 192.168.255.255

You can also assign a subnet mask and network gateway for each CMMmicro.

14 ENGINEERING VLANS

Canopy radios support VLAN functionality as defined in the 802.1Q (*Virtual LANs*) specification, except for the following aspects of that specification:

- the following protocols:
 - Generic Attribute Registration Protocol (GARP) GARV
 - Spanning Tree Protocol (STP)
 - Multiple Spanning Tree Protocol (MSTP)
 - GARP Multicast Registration Protocol (GMRP)
- priority encoding (802.1P) before Release 7.0
- embedded source routing (ERIF) in the 802.1Q header
- multicast pruning
- flooding unknown unicast frames in the downlink

As an additional exception, the Canopy AP *does not* flood downward the unknown unicast frames to the Canopy SM.

A VLAN configuration in Layer 2 establishes a logical group within the network. Each computer in the VLAN, regardless of initial or eventual physical location, has access to the same data. For the network operator, this provides flexibility in network segmentation, simpler management, and enhanced security.

14.1 SM MEMBERSHIP IN VLANS

With the supported VLAN functionality, Canopy radios determine bridge forwarding on the basis of not only the destination MAC address, but also the VLAN ID of the destination. This provides flexibility in how SMs are used:

- Each SM can be a member in its own VLAN, whose other members can be APs in other sectors. This case would allow movement of the SM from sector to sector without requiring a reconfiguration of the VLAN.
- Each SM can be in its own broadcast domain, such that only the radios that are members of the VLAN can see multicast traffic to and from the SM. In most cases, this can significantly conserve bandwidth at the SMs.
- The network operator can define a work group of SMs, regardless of the AP(s) to which they register.

Canopy point-to-multipoint modules provide the VLAN frame filters that are described in [Table 39](#).

Table 39: VLAN filters in point-to-multipoint modules

Where VLAN is active, if this parameter value is selected ...	then a frame is discarded if...		because of this VLAN filter in the Canopy software:
	<i>entering</i> the bridge/ NAT switch through...		
	Ethernet...	TCP/IP...	
any combination of VLAN parameter settings	with a VID not in the membership table		Ingress
any combination of VLAN parameter settings		with a VID not in the membership table	Local Ingress
Allow Frame Types: Tagged Frames Only	with no 802.1Q tag		Only Tagged
Allow Frame Types: Untagged Frames Only	with an 802.1Q tag, regardless of VID		Only Untagged
Local SM Management: Disable in the SM, or All Local SM Management: Disable in the AP	with an 802.1Q tag and a VID in the membership table		Local SM Management
	<i>leaving</i> the bridge/ NAT switch through...		
	Ethernet...	TCP/IP...	
any combination of VLAN parameter settings	with a VID not in the membership table		Egress
any combination of VLAN parameter settings		with a VID not in the membership table	Local Egress

14.2 PRIORITY ON VLANS (802.1p)

Canopy radios can prioritize traffic based on the eight priorities described in the IEEE 802.1p specification. When the high-priority channel is enabled on an SM, regardless of whether VLAN is enabled on the AP for the sector, packets received with a priority of 4 through 7 in the 802.1p field are forwarded onto the high-priority channel.

VLAN settings in a Canopy module can also cause the module to convert received non-VLAN packets into VLAN packets. In this case, the 802.1p priority in packets leaving the module is set to the priority established by the DiffServ configuration.

If you enable VLAN, *immediately* monitor traffic to ensure that the results are as desired. For example, high-priority traffic may block low-priority.

For more information on the Canopy high priority channel, see [High-priority Bandwidth](#) on Page 88.