

Radio Resource Management under Unified Wireless Networks

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Introduction

Along with the marked increase in the adoption of Wireless LAN (WLAN) technologies, deployment issues have risen. The 802.11 specification was originally designed primarily with home, single-cell use in mind. Decisions about the channel and power settings for a single AP were trivial. However, as pervasive WLAN coverage is now a user expectation, the determination of the settings for each Access Point (AP) necessitates a thorough site survey. Thanks to the shared nature of the 802.11 bandwidth, the applications now run over the wireless segment push customers to more capacity-oriented deployments.

The addition of capacity to a WLAN is an issue unlike that of wired networks, where the common practice is to throw bandwidth at the problem. Additional APs are required in order to add capacity. However, if the APs are configured incorrectly, the APs can actually lower system capacity due to interference and other factors. As large-scale, dense WLANs are now quite standard, administrators are continuously challenged with these RF configuration issues. Often, these issues can increase operating costs, and, if handled improperly, lead to WLAN instability and a poor end user experience.

With a finite spectrum and a limited number of non-overlapping channels with which to play, and given the innate desire of RF to bleed through walls and floors, the design process for a WLAN of any size can be a daunting task. Even given a flawless site survey, RF is ever-changing. What might be an optimal AP channel and power schema one moment, can prove to be less-than-functional the next.

The Cisco Radio Resource Management (RRM) allows the Cisco Unified WLAN Architecture to continuously analyze the existing RF environments, and automatically adjust the AP power and channel configurations in order to help mitigate co-channel interference, signal coverage problems, and so on. RRM also reduces the need to perform exhaustive site surveys, increases system capacity, and provides automated self-healing functionality to compensate for RF dead zones and AP failures.

This document details the functionality and operation of RRM and provides an in-depth discussion of the algorithms behind this feature.

Prerequisites

Requirements

Cisco recommends that you have knowledge of these topics:

- Lightweight Access Point Protocol (LWAPP)
- Common WLAN/RF design considerations (knowledge comparable to that of the Planet 3 Wireless CWNA certification)

Note: Client Aggressive Load-Balancing and Rogue Detection/Containment (and other Cisco Intrusion Detection System [IDS]/Cisco IOS® Intrusion Prevention System [IPS] features) are not functions of RRM and are beyond the scope of this document.

Components Used

This document is not restricted to specific software and hardware versions.

Conventions

Refer to Cisco Technical Tips Conventions for more information on document conventions.

Radio Resource Management: Concepts

Key Terms

Readers must fully understand these terms, which are used throughout this document:

- **Signal** Any airborne RF energy.
- **dBm** An absolute, logarithmic mathematical representation of the strength of an RF signal. dBm is directly correlated to milliwatts, but is commonly used to easily represent output power in the very low values common in wireless networking. For example, the value of -60 dBm is equal to 0.000001 milliwatts.
- **Received Signal Strength Indicator (RSSI)** An absolute, numeric measurement of the strength of the signal. Not all 802.11 radios report RSSI the same. For the purposes of this document, RSSI is assumed to directly correlate with received signal as indicated in dBm.
- **Noise** Any signal that cannot be decoded as an 802.11 signal. This can either be from a non-802.11 source (such as a microwave or Bluetooth device) or from an 802.11 source whose signal has been

invalidated due to collision or any other retarding of the signal.

- Noise floor The existing signal level (expressed in dBm) below which received signals are unintelligible.
- Signal-to-Noise Ratio (SNR) The ratio of signal strength to noise floor. This value is a relative value and as such is measured in decibels (dB).
- Interference Unwanted RF signals in the same frequency band that can lead to a degradation or loss of service. These signals can either be from 802.11 or non-802.11 sources.

An Overview of RRM

Before the discussion of how RRM algorithms work, it is important to understand the basic workflow involved when an RRM system collaborates to form an RF Grouping. It is also imperative to understand where RF computations happen. This is an outline of the steps that the Cisco Unified Solution goes through in order to learn, group, and compute all RRM features:

1. Controllers, whose APs must have an RF configuration computed as a single group, are provisioned with the same RF Group Name. An RF Group Name is an ASCII string each AP uses in order to determine if the other APs they hear are a part of the same system.
2. APs periodically send out neighbor messages that share information about themselves, their controllers, and their RF Group Name. These neighbor messages can then be authenticated by other APs that share the same RF Group Name.
3. APs that can hear these neighbor messages and authenticate the messages based on the shared RF Group Name, pass this information up to their connected controllers. The neighbor messages consist primarily of controller IP addresses and information on the AP that transmits the message.
4. The controllers, which can now identify the other controllers that are part of the RF Group, form a logical group to share the RF information. Subsequently, the controllers elect a Group Leader.
5. Equipped with detailed information about the RF environment for every AP in the RF Group, a series of RRM algorithms are run at the RF Group Leader. The algorithms are designed to optimize AP configurations related to these functions (with the exception of the Coverage Hole Detection and Correction Algorithm, which are run at the local controller to the APs):

- ◆ Dynamic Channel Assignment (DCA)
- ◆ Transmit Power Control (TPC)

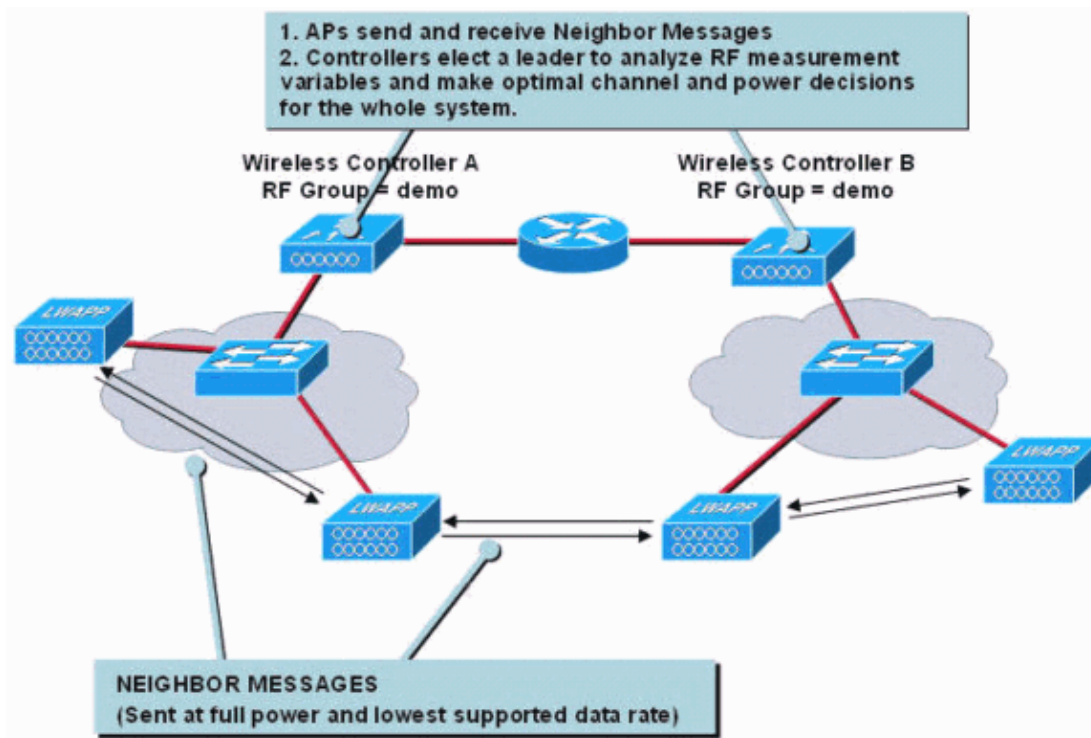
The RRM feature uses these ports on the wireless LAN controllers (WLCs):

- For 802.11b/g, ports 12124 and 12134 are used.
- For 802.11a, ports 12125 and 12135 are used.

Note: RRM, which includes RF Grouping, is a separate function from inter-controller mobility, which includes Mobility Grouping. The only similarity is the use of a common ASCII string assigned to both group names during the initial controller configuration wizard. The common ASCII string is assigned for a simplified setup process and can be changed later.

A graphical representation of the steps outlined is displayed in Figure 1:

Figure 1: Neighbor messages from APs give WLCs a system-wide RF view for channel and power adjustments.



Functionality

Performed at/by:

RF Grouping Coverage Hole

WLCs elect the Group Leader

Dynamic Channel Assignment

Group Leader

Transmit Power Control

Group Leader

Coverage Hole Detection and Correction

WLC

RF Grouping Algorithm

RF Groups are clusters of controllers who not only share the same RF Group Name, but whose APs hear each other.

AP logical allocation, and thus controller RF Grouping, is determined by APs that receive other AP neighbor messages. These messages include a multitude of information about the transmit of AP and its WLC (along with additional information detailed in Table 1), and are authenticated by a hash.

Field Description

Description

Radio Identifier

APs with multiple radios use this to identify which radio is being used to transmit Neighbor Messages

Group ID

A Counter and MAC Address of the WLC

WLC IP Address

Management IP Address of the RF Group Leader

AP s Channel

Leader Native channel on which the AP services clients

Neighbor Message Channel

Channel on which the neighbor packet is transmitted

Power

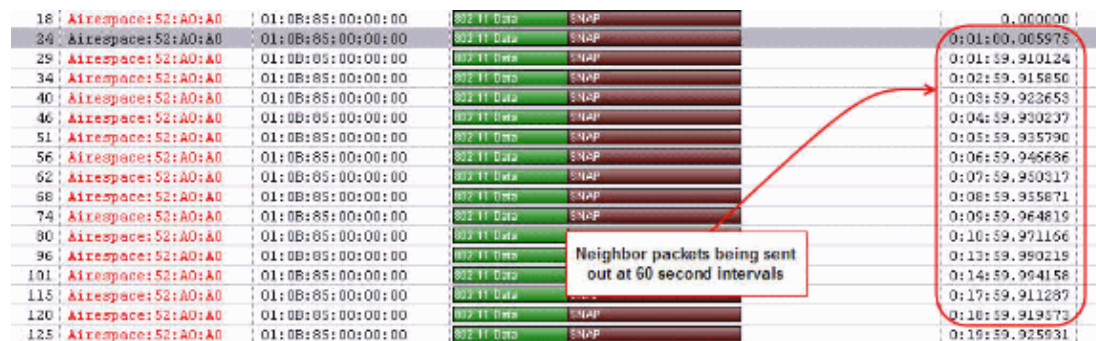
Not currently used

Antenna Pattern

Not currently used

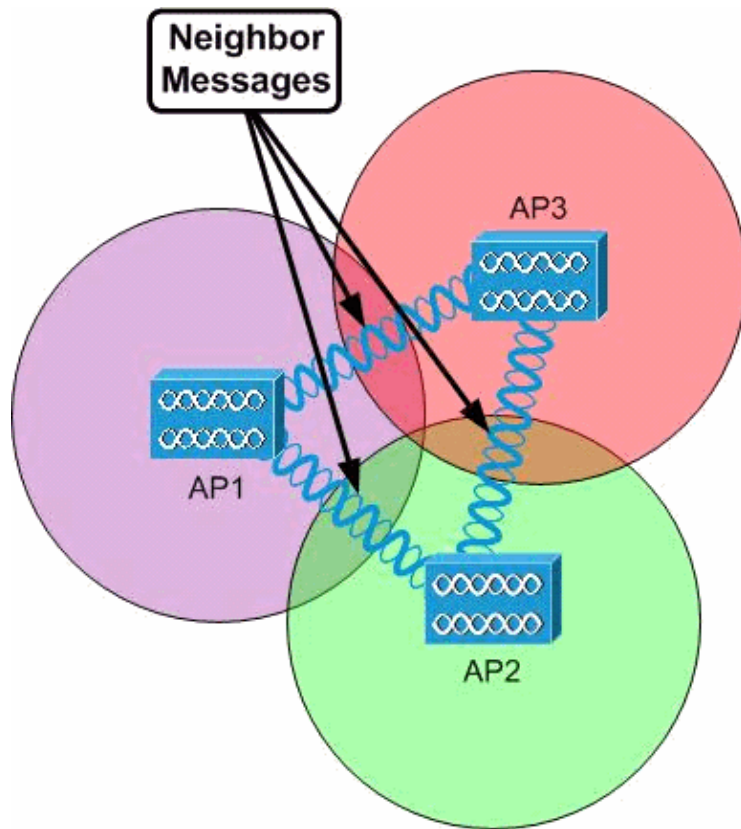
When an AP receives a neighbor message transmitted every 60 seconds, on all serviced channels, at maximum power, and at the lowest supported data rate the AP sends the frame up to its WLC in order to determine whether the AP is a part of the same RF Group. This is verified with the embedded hash. An AP that sends undecipherable neighbor messages an indication that a foreign RF Group Name is used or if an AP sends no neighbor messages at all, is determined to be a rogue AP.

Figure 2: Neighbor messages are sent every 60 seconds to the multicast address of 01:0B:85:00:00:00.



Given all controllers share the same RF Group Name, in order to form an RF Group, a WLC needs to only have a single AP hear one AP from another WLC. Figures 3 through 8 provide further details.

Figure 3: APs send and receive neighbor messages which are then forwarded to their controller(s) to form an RF Group.



Neighbor messages are used by receiving APs and their WLCs in order to determine how to create inter-WLC RF Groups, as well as to create logical RF sub-Groups. Logical RF sub-Groups consist of only those APs that can hear each other's messages. The RRM configurations of these logical RF sub-Groups are performed at the RF Group Leader. However, the configurations are created independently because the APs do not have inter-RF sub-Group wireless connectivity. This is illustrated in Figures 4 and 5:

Figure 4: All the APs are logically connected to a single WLC, but two separate logical RF sub-Groups are formed because APs 1, 2, and 3 and APs 4, 5, 6 cannot hear neighbor messages from each other.

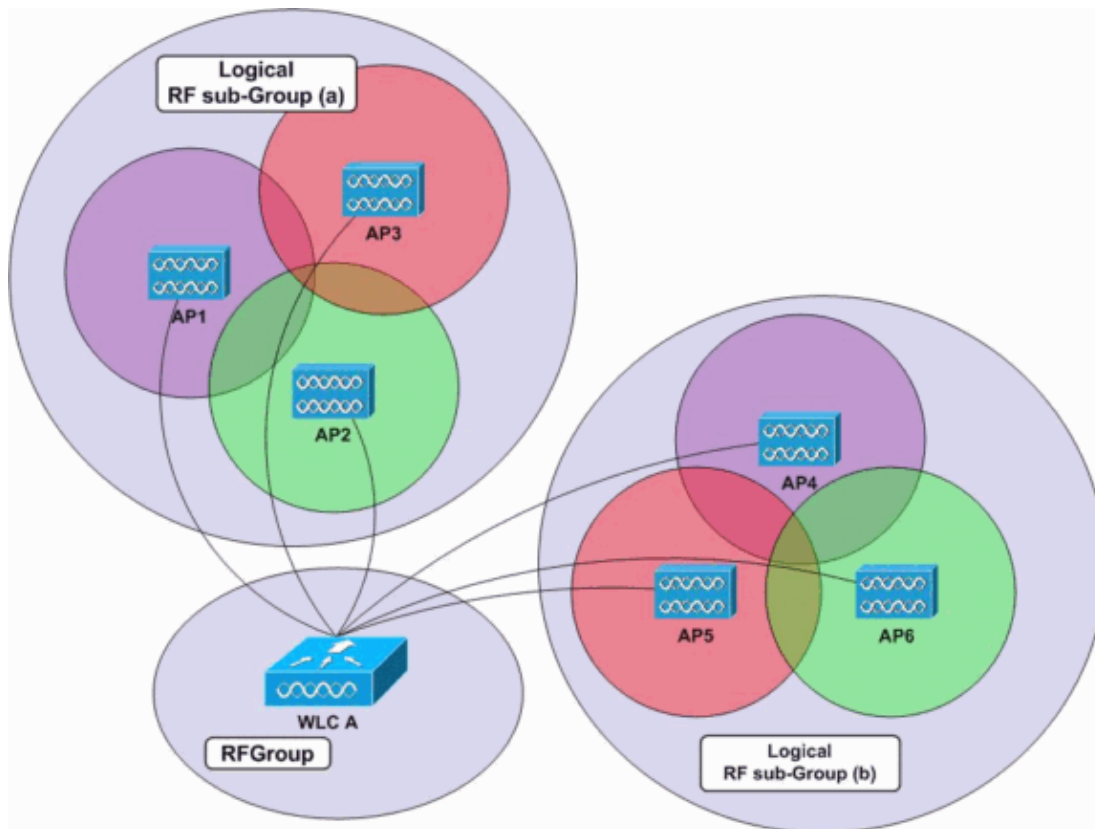
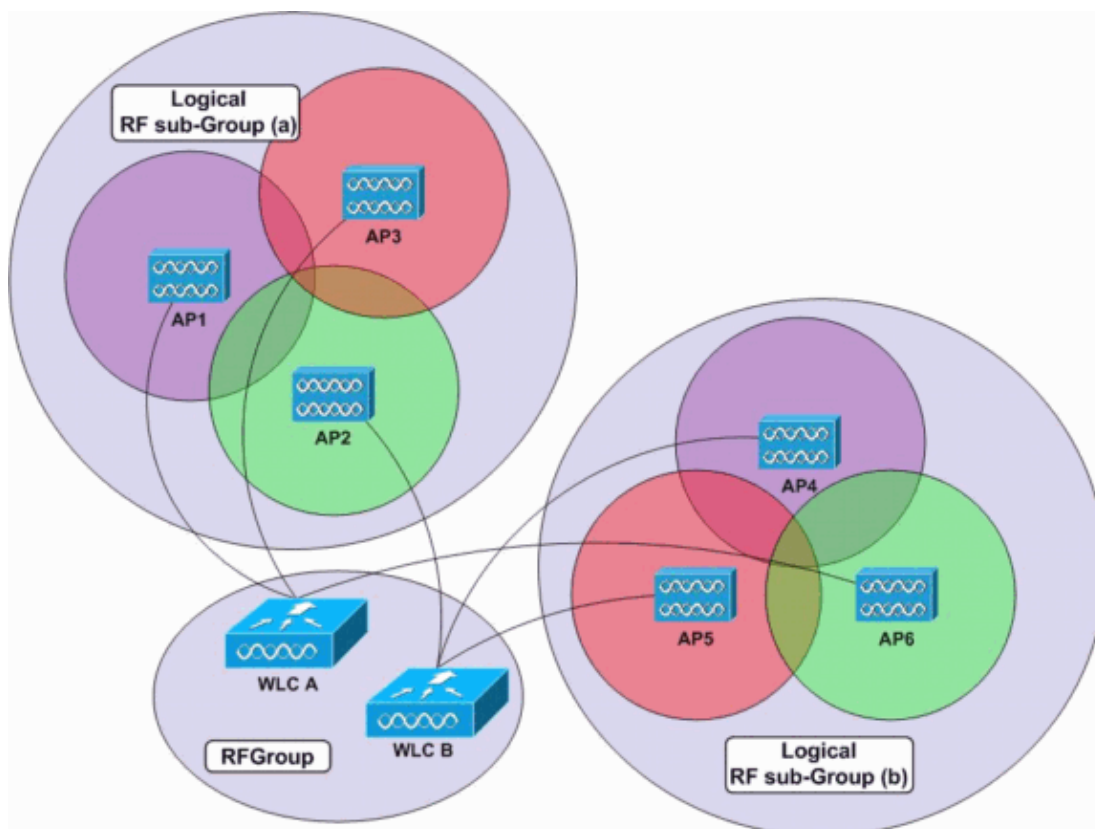
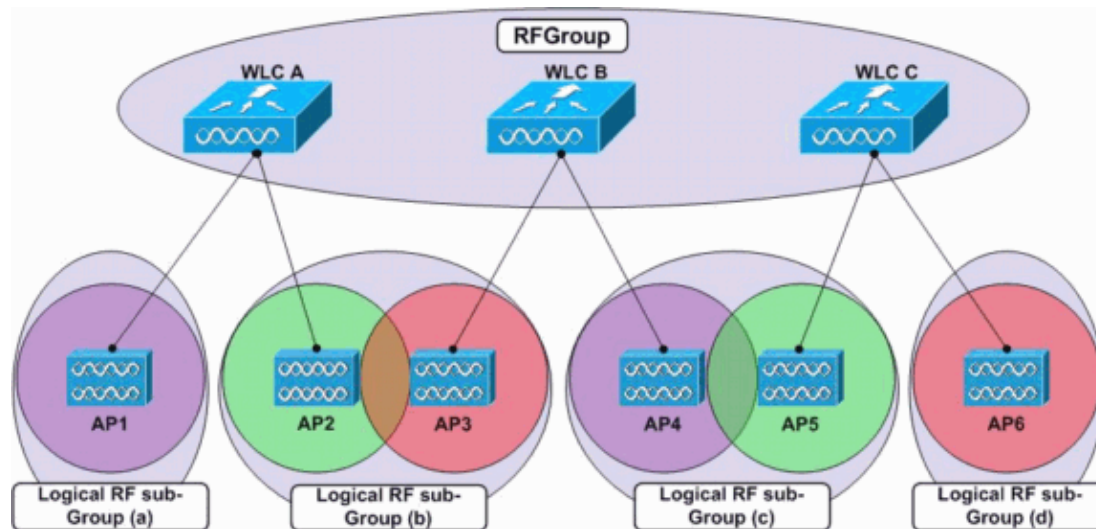


Figure 5: APs in the same logical RF sub-Group can share a single WLC, can each be on a separate WLC, or can be on a mix of WLCs. RRM functionality is performed on a system-wide level, so as long as APs can hear each other, their controllers are automatically grouped. In this example, WLCs A and B are in the same RF Group, and their APs are in two different logical RF sub-Groups.



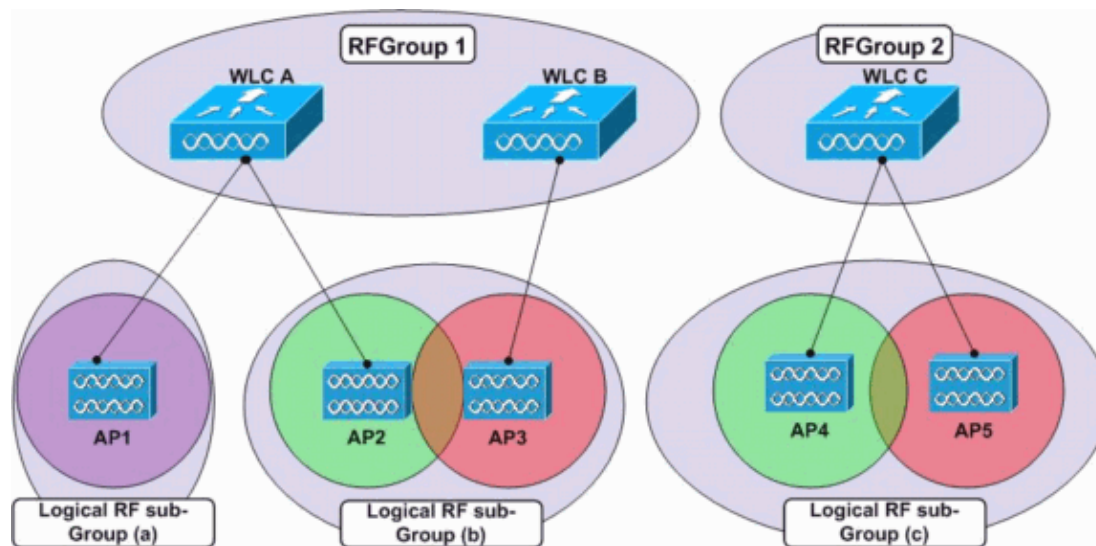
In an environment with many WLCs and many APs, not all APs must hear each other in order for the whole system to form a single RF Group. Each controller must have at least one AP hear another AP from any other WLC. As such, RF Grouping can occur across many controllers, regardless of the localized view of neighboring AP of each controller and thus, WLCs. This is illustrated in Figure 6:

Figure 6: In this example, the APs connected to WLCs A and C are not able to hear neighbor messages from each other. WLC B can hear both WLC A and C and can then share the other s information with them so that a single RF Group is formed. Discrete logical RF sub-Groups are created for each group of APs that can hear the neighbor messages of each other.



In a scenario where multiple controllers are configured with the same RF Group Name, but their respective APs cannot hear the neighbor messages of each other, two separate top-level RF Groups are formed. This is illustrated in Figure 7:

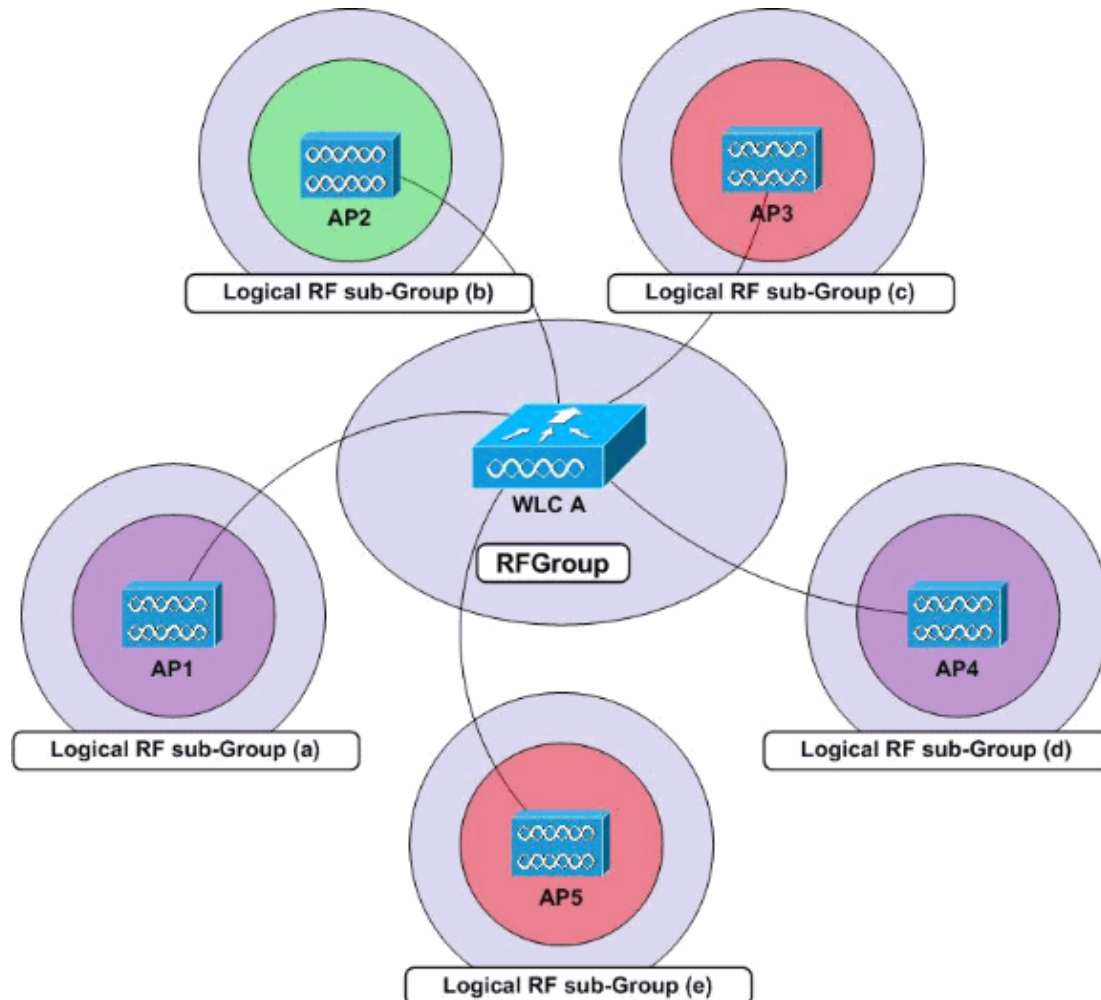
Figure 7: Although the WLCs share the same RF Group Name, their APs cannot hear each other. Two separate RF Groups are formed.



RF Grouping occurs at the controller level. This means that once APs report information to their controllers on the other APs they hear, and the controllers to which those APs are connected, each respective WLC communicates directly with the other WLCs to form a system-wide grouping. Within a single system-wide group, or RF Group, many subsets of APs can have their RF parameters set independently of each other. For instance, consider a scenario where one central WLC has individual APs at remote sites. In this case, each AP

has its RF parameters set separately of the others. While each AP belongs to the same controller RF Grouping, each individual AP in this example is in its own logical RF sub-Group. This is illustrated in Figure 8:

Figure 8: The RF parameters of each AP are set independently of the others because the APs are unable to hear the neighbor messages of each other.



APs each compile and maintain a list of up to 34 neighboring APs per radio. This list is then reported up to their respective controllers. Each WLC maintains a list of 24 neighbors per AP radio from the neighbor messages sent by each AP. Once at the controller level, this per-AP, per-radio neighbor list of up to 34 APs is pruned. The ten APs with the weakest signals are dropped. WLCs then forward each AP neighbor list up to the RF Group Leader, the WLC elected by the RF Group in order to perform all RRM configuration decision-making. The RF Group Leader is discussed in more detail in the Group Leader section of this document.

RF Grouping works per radio type. The grouping algorithm runs separately for the 802.11a and 802.11b/g radios, which means it runs per AP and per radio, such that each AP radio is responsible for populating a list of neighbors. In order to limit flapping, whereby APs can frequently be added and pruned from this list. WLCs add neighbors to their lists if the neighbors are heard at -80 dBm or greater. The neighbors are removed only once their signals dip less than -85 dBm.

Note: RRM supports a maximum of 20 controllers and 1000 APs per RF Group.

The Group Leader

The RF Group Leader is the elected controller in the RF Group that performs analysis of AP RF data. The RF Group Leader is also responsible for the configuration of most of the AP power and channel settings, which excludes Coverage Hole Detection and Correction. The Coverage Hole Detection and Correction algorithm is based on client SNR. Therefore, this is the only RRM function performed at each local controller.

Each controller determines which WLC has the highest Group Leader priority based on the Group Identifier information element in each neighbor message. The Group Identifier information element advertised in each neighbor message is comprised of a counter value and a controller MAC address. Each controller maintains a 16-bit counter that starts at 0 and increments events such as an exit from an RF Group or a WLC reboot. Each WLC prioritizes the Group Identifier values from its neighbors based first on this counter value and then, in the event of a counter value tie, on the MAC address. Each WLC selects the one controller (either a neighboring WLC or itself) with the highest Group Identifier value, after which each controller confers with the others in order to determine which single controller has the highest Group Identifier. This WLC is subsequently selected by the RF Group as the RF Group Leader.

In the event that the RF Group Leader goes offline, the entire group is disbanded and existing RF Group members rerun the Group Leader selection process to select a new leader.

Once an RF Group Leader is elected, every ten minutes that leading controller polls each WLC in the group for AP statistics, as well as all received neighbor message information. From this information, the Group Leader is able to understand the system-wide RF environment and can then use the DCA and TPC algorithms to continuously adjust AP channel and power configurations. The Group Leader runs these algorithms every ten minutes. However, as with the Coverage Hole Detection and Correction algorithm, changes are only made if determined necessary. This document provides details on each of these algorithms in the sections to come.

Note: You cannot override the RF Group election and make a particular WLC the elected leader for a group of controllers. You can disable the grouping so that a single controller can perform its RRM calculations irrespective of the RRM information in other WLCs in the network.

Dynamic Channel Assignment Algorithm

The DCA algorithm, run at the RF Group Leader, is applied on a per-RF-Group basis in order to determine optimal AP channel settings for all the RF Group APs. Each set of APs that can hear the neighbor messages of each other, referred to as a logical RF sub-Group in this document, has its channel configuration performed independently of other logical RF sub-Groups. This is because signals do not overlap. With regard to the DCA process, the leader considers a handful of AP-specific metrics during the determination of necessary channel changes. These metrics are:

- **Load Measurement** Every AP measures the percentage of total time occupied by transmission or receipt of 802.11 frames.
- **Noise** APs calculate noise values on every serviced channel. This process also takes into account the effects of adjacent signals on each channel value.
- **Interference** APs report on the percentage of the medium taken up by interfering 802.11 transmissions, which can be caused by overlapping signals from foreign APs, as well as non-neighbors.
- **Signal Strength** Every AP hears neighbor messages on all serviced channels and records the RSSI values at which these messages are heard. This AP signal strength information is the most important metric considered in the DCA calculation of channel energy.

Note: When all APs boot up for the first time (new, out-of-the-box APs), they transmit on the first non-overlapping channel in the band(s) supported (channel 1 for 11b/g and channel 36 for 11a). When APs

power cycle, the APs use their previous channel settings. DCA adjustments subsequently occur as needed.

The values described are then used by the Group Leader in order to determine if another channel schema will result in at least a bettering of the worst performing AP by 5dB (SNR) or more. Weighting is given to APs on their operating channels such that channel adjustments are made locally, which dampens changes in order to prevent a domino effect, whereby a single change would trigger system-wide channel alterations. AP utilization information is derived from the load measurement report of each AP. Preference is given to APs based on the determined utilization, so that a less-used AP has a higher likelihood of a channel change compared to a heavily utilized neighbor if a change is needed.

Note: Whenever the channel of an AP is changed, clients are briefly disconnected. Clients can either reconnect to the same AP on this new channel, or roam to a nearby AP. This depends on the client roaming behavior. Fast, secure roaming, offered by both Cisco Centralized Key Management (CCKM) and Proactive Key Caching (PKC), continues to work during such failover roams if the client is compatible.

Transmit Power Control Algorithm

The TPC algorithm, run at an un-modifiable ten-minute interval, is used by the RF Group Leader to determine APs RF proximities and adjust each band's transmit power level downward, as necessary. This is performed in order to limit excessive cell overlap and co-channel interference.

Note: The TPC algorithm is only responsible for the downward adjustment of power levels. Increased transmission power is a part of the Coverage Hole Detection and Correction algorithm function, also explained in this document.

Each AP reports an RSSI-ordered list of all neighboring APs. Provided an AP has three or more neighboring APs, the RF Group Leader applies the TPC algorithm on a per-band, per-AP basis in order to adjust AP power transmit levels downward such that the third loudest neighbor AP is heard at a signal level of -65dBm (default value) or lower.

Power changes are only made when the third loudest neighbor of a given AP is heard at a signal level higher than the default value of -65 dBm.

Note: When all APs boot up for the first time, the APs transmit at their maximum power levels. Also, if the APs do not see each other with a -65dBm (default value), they push the power level up to the maximum in order to achieve this. If you go to the Controller CLI and issue the **show ap auto-rf 802.11b<AP NAME>** command, there is a **Nearby APs** section near the bottom of the command output. In this section, you find the dBm listing. If this dBm listing has values more than -65, then the AP transmit power is at the maximum. This is tweakable to an extent. You can issue the **Config advanced 802.11b tx-power-control-thresh <-50 to -80>** command. This command is discussed later in this document.

Note: When APs sustain a power cycle, the APs use their previous power setting. TPC adjustments subsequently occur as needed. See Table 5 for supported AP transmit power levels.

Note: Table 4 provides an example of the logic used in the TPC algorithm.

Coverage Hole Detection and Correction Algorithm

The Coverage Hole Detection and Correction algorithm is primarily aimed at the determination of coverage holes based on the quality of client signal levels. Its second goal is to increase the transmit power of the APs to which those clients are connected. Because this algorithm is concerned with client statistics, it is run independently on each controller and not system-wide on the RF Group Leader.

The algorithm determines if a coverage hole exists when the clients' SNR levels pass below a given SNR threshold. The SNR threshold is considered on an individual AP basis and is based primarily on each AP's transmit power level. The higher the AP power levels, the more noise the APs tolerate as compared to the client signal strength, which means a lower tolerated SNR value.

Note: The AP does not reduce its power level if a client is associated to it with an SNR of 10db or less. If the AP reduces its power level in this case, it might result in a coverage hole. Normally, a good SNR is between 15–35db. When a client is at a poor SNR, the AP raises its power level to compensate for the coverage gap. The same applies if a client is associated with a poor RSSI (signal strength) value.

This SNR threshold varies based on two values: the AP transmit power and the controller Coverage profile value. The threshold is defined by the transmit power (represented in dBm) of each AP, minus the constant value of 17dBm, minus the user-configurable Coverage profile value. The Coverage value is defaulted to 12 dB. The client SNR threshold value is the absolute value, or the positive number, that results from this equation:

Coverage Hole SNR Threshold Equation:

Client SNR Cutoff Value (|dB|) = [AP Transmit Power (dBm) - Constant (17 dBm) - Coverage Profile (dB)]

Once the average SNR of a single client dips below this SNR threshold for at least 60 seconds, the AP transmit power of that client is increased to the appropriate level in order to mitigate the SNR violation, and correct the coverage hole. Only one client need violate this threshold in order to trigger a correction.

Each controller runs the Coverage Hole Detection and Correction algorithm for each radio on each of its APs every three minutes. The default value of 180 seconds can be changed, as described in the Monitor Intervals (60 to 3600 secs) section of this document. It is important to note that volatile environments can cause the TPC algorithm to turn the power down at subsequent algorithm runs.

An example of the logic involved in the triggering of the Coverage Hole Detection and Correction algorithm is provided in the Coverage Hole Detection and Correction Algorithm Workflow Example section of this document.

Note: The Coverage Hole Detection and Correction algorithm is also responsible for the detection of lapses in coverage due to AP failure and powering up nearby APs as needed. This allows the network to heal around service outages.

Radio Resource Management: Configuration Parameters

After a discussion of RRM algorithms, the next step is to learn how to view and adjust all necessary parameters. This section details the RRM configuration operations and outlines basic reporting settings.

The very first step involved in the configuration of RRM is to ensure each WLC has the same RF Group Name. This can be achieved through the controller web interface. Choose Controller > General and input a common Group Name value. IP connectivity between WLCs in the same RF Group is a necessity, as well.

Figure 9: RF Groups are formed based on the user-specified RF-Network Name, also called the RF Group Name in this document. All WLCs that are required to participate in system-wide RRM operations must share this same string.

The screenshot displays the Cisco WLC GUI with the 'CONTROLLER' tab selected. The left sidebar shows various configuration categories, with 'General' highlighted. The main content area shows the 'General' configuration page with various settings and their values:

Setting	Value
802.3x Flow Control Mode	Disabled
LWAPP Transport Mode	Layer 3
LAG Mode on next reboot	Disabled
Ethernet Multicast Mode	Disabled
Aggressive Load Balancing	Disabled
Peer to Peer Blocking Mode	Disabled
Over The Air Provisioning of AP	Disabled
AP Fallback	Enabled
Apple Talk Bridging	Disabled
Fast SSID change	Disabled
Default Mobility Domain Name	mobility-demo
RF-Network Name	rrm-demo
User Idle Timeout (seconds)	3600
ARP Timeout (seconds)	300
Web Radius Authentication	PAP

All of the configuration explanations and examples in this document are performed through the WLC GUI. Within the WLC GUI, go to Wireless and choose the Network option for the WLAN standard of choice on the left side. Next, choose the Auto RF& button in the upper right side of the screen. The subsequent configuration explanations and examples reference the resulting page (**Wireless > 802.11a or 802.11b/g Network > Auto RF...**).

Group Settings through the WLC GUI

These are the Group settings available through the WLC GUI:

- **Group Mode** The Group Mode setting allows RF Grouping to be disabled. When this feature is disabled, the WLC cannot group with other controllers in order to perform system-wide RRM functionality. When disabled, all RRM features are implemented locally on each controller. RF Grouping is enabled by default and the MAC addresses of other WLCs in the same RF Group are listed to the right of the Group Mode checkbox.
- **Group Update Interval** The group update interval value indicates how often the RF Grouping algorithm is run. This is a display-only field and cannot be modified.

- **Group Leader** This field displays the MAC Address of the WLC that is currently the RF Group Leader. Because RF Grouping is performed per-AP, per-radio, this value can be different for the 802.11a and 802.11b/g networks.
- **Is this controller a Group Leader** When the controller is the RF Group Leader, the value of this field is **yes**. If the WLC is not the leader, the previous field indicates which WLC in the group is the leader.
- **Last Group Update** The RF Grouping algorithm runs every 600 seconds (ten minutes). This field only indicates the time (in seconds) since the algorithm last ran and not necessarily the last time a new RF Group Leader was elected.

Figure 10: The RF Group s status, updates, and membership details are highlighted at the top of the Auto RF page.

802.11b/g Global Parameters > Auto RF		RF Group Members
RF Group		MAC Address
Group Mode	<input checked="" type="checkbox"/> Enabled	00:0b:85:33:1b:40
Group Update Interval	600 secs	00:0b:85:40:7b:60
Group Leader	00:0b:85:40:7b:60	
Is this Controller a Group Leader	Yes	
Last Group Update	221 secs ago	

RF Channel Assignment Settings through the WLC GUI

These are the RF Channel Assignment settings available through the WLC GUI:

- The Channel Assignment method allows the DCA algorithm to be configured in one of three ways:
 - ◆ **Automatic** This is the default configuration. When RRM is enabled, the DCA algorithm runs every 600 seconds, or ten minutes and, if necessary, channel changes are made at this interval. This is a display-only field and cannot be modified.
 - ◆ **On Demand** This prevents the DCA algorithm from being run. The algorithm can be manually triggered if the **Invoke Channel Update Now** button is clicked.

Note: If **On Demand > Invoke Channel Update Now** is selected when channel changes are necessary, the DCA algorithm is run, and the new channel plan is applied at the next 600-second interval.
 - ◆ **Off** This option disables all DCA functions, and is not recommended. This is typically disabled during a manual site survey and for the configuration of channel settings for each AP. Though unrelated, this is often performed when a fix is made to the TPC algorithm as well.
- **Avoid Foreign AP Interference** This field allows the co-channel interference metric to be included in DCA algorithm calculations. This field is enabled by default.
- **Avoid Cisco AP Load** This field allows the utilization of APs to be considered in the determination of which APs channels require changes. AP Load is a frequently a changing metric and its inclusion is not always desired in the RRM calculations. As such, this field is disabled by default.
- **Avoid non-802.11b Noise** This field allows each AP s heard noise to be a contributing factor to the DCA algorithm. This field is enabled by default.
- **Signal Strength Contribution** Neighboring AP signal strengths are always included in DCA calculations. This is a display-only field and cannot be modified.
- **Channel Assignment Leader** This field displays the MAC Address of the WLC that is currently the RF Group Leader. Because RF Grouping is performed per-AP, per-radio, this value can be different for the 802.11a and 802.11b/g networks.
- **Last Channel Assignment** The DCA algorithm runs every 600 seconds, or ten minutes. This field only indicates the time in seconds since the algorithm last ran and not necessarily the last time a new

channel assignment was made.

Figure 11: Dynamic Channel Assignment Algorithm Configuration

RF Channel Assignment	
Channel Assignment Method	<input checked="" type="radio"/> Automatic Every 600 sec <input type="radio"/> On Demand Invoke Channel Update now <input type="radio"/> OFF
Avoid Foreign AP interference	<input checked="" type="checkbox"/> Enabled
Avoid Cisco AP load	<input type="checkbox"/> Enabled
Avoid non-802.11b noise	<input checked="" type="checkbox"/> Enabled
Signal Strength Contribution	Enabled
Channel Assignment Leader	00:0b:85:40:7b:60
Last Channel Assignment	3 secs ago

Tx Power Level Assignment Settings through the WLC GUI

These Tx Power Level Assignment settings are available through the WLC GUI:

- The Power Level Assignment method allows the TPC algorithm to be configured in one of three ways:
 - ◆ **Automatic** This is the default configuration. When RRM is enabled, the TPC algorithm runs every ten minutes, or 600 seconds and, if necessary, power setting changes are made at this interval. This is a display-only field and cannot be modified.
 - ◆ **On Demand** This prevents the TPC algorithm from being run. The algorithm can be manually triggered with the **Invoke Channel Update Now** button.
- **Note:** If **On Demand > Invoke Power Update** is selected, assuming power changes are necessary, the TPC algorithm is run and new power settings are applied at the next 600-second interval.
- ◆ **Fixed** This option disables all TPC functions, and is not recommended. This is typically disabled during a manual site survey and for the configuration of AP power settings individually. Though unrelated, this is often performed when the DCA algorithm is disabled as well.
- **Power Threshold** This value, expressed in dBm, is the cut-off signal level at which the TPC algorithm adjusts the power levels downward, such that this value is the strength at which the third strongest neighbor of an AP is heard. In certain rare occasions where the RF environment has been deemed too hot, in the sense that the APs in a probable high-density scenario transmit at higher-than-desired transmit power levels, you can issue the **config advanced 802.11b tx-power-thresh** command to allow downward power adjustments. This way, you enable the APs to hear their third neighbor with a greater degree of RF separation enabling the neighboring AP to transmit at a lower power level. This has been an un-modifiable parameter until software release 3.2. The new configurable value ranges from -50dBm to -80dBm and can only be changed from the controller CLI.

Note: A change in the power threshold value does not affect the bandwidth performance of the AP. It still provides the best coverage closer to it, and lowers speeds farther away. This power threshold value simply detects other APs at a greater distance in order to allow the AP to decrease transmit power.

See the Verify Transmit Power Control Changes section of this document for further information.

- **Power Neighbor Count** The minimum number of neighbors an AP must have for the TPC algorithm to run. This is a display-only field and cannot be modified.
- **Power Update Contribution** This field is not currently in use.
- **Power Assignment Leader** This field displays the MAC Address of the WLC that is currently the RF Group Leader. Because RF Grouping is performed per-AP, per-radio, this value may be different for the 802.11a and 802.11b/g networks.
- **Last Power Level Assignment** The TPC algorithm runs every 600 seconds (10 minutes). This field only indicates the time (in seconds) since the algorithm last ran and not necessarily the last time a new power assignment was made.

Figure 12: Transmit Power Control Algorithm Configuration

Tx Power Level Assignment	
Power Level Assignment Method	<input checked="" type="radio"/> Automatic Every 600 sec <input type="radio"/> On Demand Invoke Power Update now <input type="radio"/> Fixed 1
Power Threshold	-65 dBm
Power Neighbor Count	3
Power Update Contribution	SNI.
Power Assignment Leader	00:0b:85:40:7b:60
Last Power Level Assignment	3 secs ago

Profile Thresholds: WLC GUI

Profile thresholds, called RRM Thresholds in Cisco Wireless Control System (WCS), are used principally for alarming. When these values are exceeded, traps are sent up to WCS or any other SNMP-based management system for easy diagnosis of network issues. These values are used solely as an alert, and have no bearing on the functionality of the RRM algorithms whatsoever, except for the Coverage value used in the Coverage Hole Detection and Correction algorithm.

Figure 13: Default alarming profile threshold values.

Profile Thresholds	
Interference (0 to 100%)	10
Clients (1 to 75)	12
Noise (-127 to 0 dBm)	-70
Coverage (3 to 50 dBm)	12
Utilization (0 to 100%)	80
Coverage Exception Level (0 to 100 %)	25
Data Rate (1 to 1000 Kbps)	1000
Client Min Exception Level (1 to 75)	3

- **Interference (0 to 100 percent)** The percentage of the wireless medium occupied by interfering 802.11 signals before an alarm is triggered.
- **Clients (1 to 75)** The number of clients per-band, per-AP a controller allows before an SNMP trap is generated.
- **Noise (-127 to 0 dBm)** The maximum allowable noise alarming value.
- **Coverage (3 to 50 dB)** The maximum tolerable level of SNR per client. This value is used in the generation of traps for both the Coverage Exception Level and Client Minimum Exception Level

thresholds.

- Utilization (0 to 100 percent) The alarming value that indicates the maximum desired percentage of the time an AP radio spends on both transmitting and receiving.
- Coverage Exception Level (0 to 100 percent) The maximum desired percentage of clients on an AP radio that operates below the defined desired Coverage threshold.
- Data Rate (1 to 1000 Kbps) This value is not currently in use.
- Client Min Exception Level Minimum desired number of clients tolerated per AP whose SNRs are below the defined Coverage threshold.

Noise, Interference, and Rogue Monitoring Channels

APs both provide client data service and periodically scan for full RRM (and IDS/IPS) functionality. The channels that the APs are permitted to scan are configurable.

In the Channel List, users can specify which channel ranges the APs periodically monitor in these ways:

- All Channels This setting directs APs to include every channel in the scanning cycle. This is primarily helpful for IDS/IPS functionality, which is outside the scope of this document and does not provide additional value in RRM processes when compared to the Country Channels setting.
- Country Channels APs scan only those channels explicitly supported in the regulatory domain configuration of each WLC. This means that APs periodically spend time listening on each and every channel allowed by the local regulatory body. This can include overlapping channels as well as the commonly used non-overlapping channels. This is the default configuration.
- DCA Channels This restricts the APs scanning to only those channels to which APs are assigned based on the DCA algorithm. This means that in the U.S., by default 802.11b/g radios only scan on channels 1, 6, and 11.

Note: The list of channels used by the DCA algorithm, for both channel monitoring and assignment, can be altered in WLC code version 4.0 or later. For example, in the U.S., by default the DCA algorithm uses only the 11b/g channels of 1, 6, and 11. In order to add channels 4 and 8, and remove channel 6 from this DCA list, these commands must be input in the controller CLI:

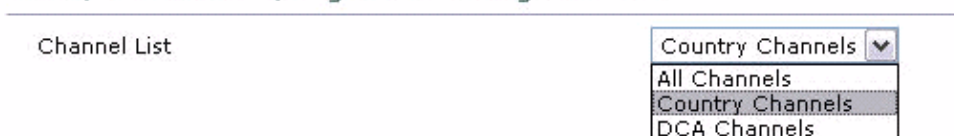
```
(Cisco Controller) >config advanced 802.11b channel add 4
(Cisco Controller) >config advanced 802.11b channel add 8
(Cisco Controller) >config advanced 802.11b channel delete 6
```

Note: This configuration is only an example and is not recommended.

If more channels are scanned, such as the case with the All Channels selection, the total amount of time spent servicing data clients is slightly lessened compared to when fewer channels are included in the scanning process. However, information on more channels can be gathered this way, as opposed to with the DCA Channels setting. The default setting of Country Channels must be used unless IDS/IPS needs to necessitate the All Channels selection, or if detailed information on other channels is not needed for both threshold profile alarming and RRM algorithm detection and correction. In this case, DCA Channels is the appropriate choice.

Figure 14: While Country Channels is the default selection, RRM monitoring channels can be set to either All or DCA Channels.

Noise/Interference/Rogue Monitoring Channels



Monitor Intervals (60 to 3600 secs)

All Cisco LWAPP-based APs deliver data to users while periodically going off-channel in order to take RRM measurements and perform other functions, such as IDS/IPS and location tasks. This off-channel scanning is completely transparent to users and only limits performance by up to 1.5 percent. In addition, the LWAPP has the built-in intelligence to defer scanning until the next interval upon detection of traffic in the voice queue in the last 100ms.

The adjustment of the Monitor Intervals changes how frequently APs take RRM measurements. The most important timer that controls the RF Groups formation is the Signal Measurement field. The value specified is directly related to the frequency at which the neighbor messages are transmitted, except in the case of the European Union (EU) and other 802.11h domains, where the Noise Measurement interval is considered as well.

Regardless of the regulatory domain, the entire scanning process takes 50 ms per radio, per channel, and runs at the default interval of 180 seconds. This interval can be changed if the Coverage Measurement value is altered. The time spent listening on each channel is a function of the non-configurable 50 ms scan time plus, the 10 ms it takes to switch channels and number of channels to be scanned. For example, in the U.S., all 11 802.11b/g channels, which includes the one channel on which data is delivered to clients, are scanned for 50 ms each within the 180-second interval. Therefore, in the U.S., for 802.11b/g, every 16 seconds, 50 ms is spent listening on each scanned channel ($180/11 = \sim 16$ seconds).

Figure 15: RRM monitoring intervals and the default values

Monitor Intervals (60 to 3600 secs)

Noise Measurement	180
Load Measurement	60
Signal Measurement	60
Coverage Measurement	180

Noise, Load, Signal, and Coverage Measurement intervals can be adjusted in order to provide more or less granular information to the RRM algorithms. These defaults must be maintained unless otherwise instructed by Cisco Technical Support.

Note: It is also important to note that if any of these scanning values are changed to exceed the intervals at which the RRM algorithms are run 600 seconds for both DCA and TPC and 180 seconds for Coverage Hole Detection and Correction RRM algorithms still run. However, the algorithms yield no new results because no new values are available.

Note: When WLCs are configured in order to bond multiple gigabit Ethernet interfaces using Link Aggregation (LAG), the Coverage Measurement interval is used to trigger the User Idle Timeout function. As such, with LAG enabled, User Idle Timeout is only performed as frequently as the Coverage Measurement interval dictates.

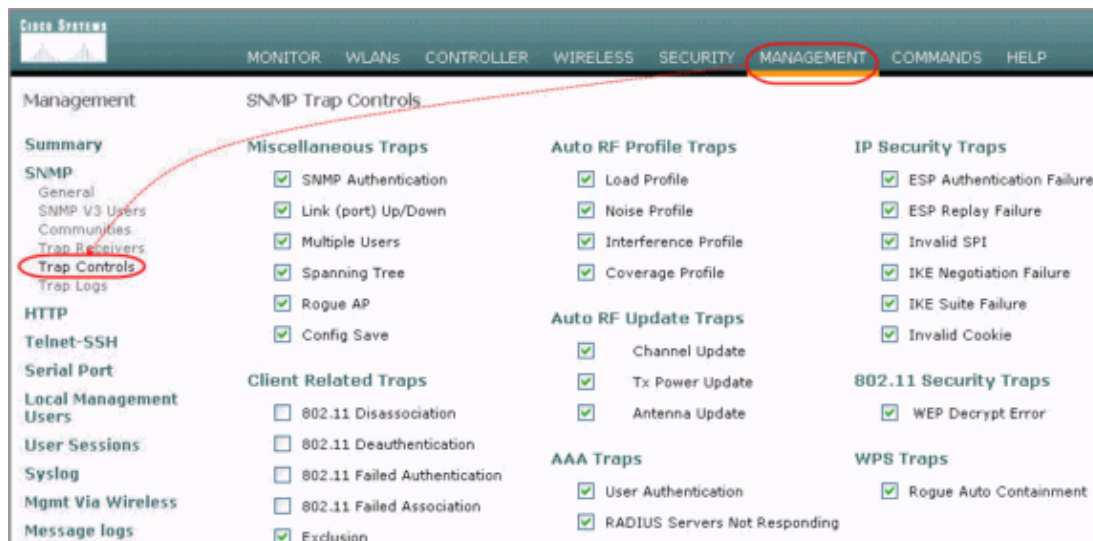
Factory Default

In order to reset the RRM values back to the default settings, click the **Set to Factory Default** button at the bottom of the page.

Radio Resource Management: Troubleshooting

Changes made by RRM can easily be monitored if the necessary SNMP traps are enabled. These settings can be accessed from the **Management > SNMP > Trap Controls** heading in the WLC GUI. All other related SNMP trap settings detailed in this section are located under the **Management > SNMP** heading, where the links for **Trap Receivers, Controls, and Logs** are found.

Figure 16: Auto RF Channel and Power update traps are enabled by default.



Verify Dynamic Channel Assignment

After the RF Group Leader (and the DCA algorithm) has suggested, applied and optimized channel schema, monitor changes through the Trap Logs sub-menu. An example of such a trap is displayed in Figure 17:

Figure 17: The channel change log entries contain the radio MAC address and the new channel of operation.

162	Sun Mar 12 13:44:41 2006	Rogue : 00:14:bf:b6:01:de removed from Base Radio MAC : 00:0b:85:06:4f:f0 Interface no:0(802.11b/g)
163	Sun Mar 12 13:42:13 2006	RF Manager updated Channel for Base Radio MAC: 00:0b:85:23:7c:30 and slotNo: 1. New Channel is: 6
164	Sun Mar 12 13:39:29 2006	Rogue AP : 00:11:24:0e:28:43 detected on Base Radio MAC : 00:0b:85:06:4f:f0 Interface no:0(802.11b/g) with RSSI: -84 and SNR: 7

In order to view detailed statistics of how long APs retain their channel settings between DCA changes, issue this CLI-only command. It provides minimum, average, and maximum values of channel dwell time on a per-controller basis.

```
(Cisco Controller) >show advanced 802.11b channel

Automatic Channel Assignment
Channel Assignment Mode..... AUTO
Channel Update Interval..... 600 seconds
Channel Update Contribution..... SNI.
Channel Assignment Leader..... 00:0b:85:40:b2:60
Last Run..... 34 seconds ago
Channel Energy Levels
  Minimum..... -68 dBm
  Average..... -67 dBm
  Maximum..... -66 dBm
Channel Dwell Times
  Minimum..... 0 days, 00 h 51 m 09 s
```

```
Average..... 0 days, 07 h 24 m 21 s
Maximum..... 0 days, 19 h 13 m 56 s
```

Verify Transmit Power Control Changes

Current TPC algorithm settings, which includes the **tx-power-control-thresh** command described earlier, can be verified with these commands at the controller CLI (802.11b is displayed in this example):

```
(Cisco Controller) >show advanced 802.11b txpower
Automatic Transmit Power Assignment
  Transmit Power Assignment Mode..... AUTO
  Transmit Power Update Interval..... 600 seconds
  Transmit Power Threshold..... -65 dBm
  Transmit Power Neighbor Count..... 3 APs
  Transmit Power Update Contribution..... SNI.
  Transmit Power Assignment Leader..... 00:0b:85:40:7b:60
  Last Run..... 492 seconds ago
```

As indicated, a densely deployed area that results in increased cell-overlap, results in high collision and frame retry rates due to high co-channel interference. This effectively reduces the client throughput levels and might warrant the use of the newly introduced **tx-power-control-thresh** command. In such atypical or anomalous scenarios, the APs hear each other better than the clients hear them, assuming the signal propagation characteristics remain constant. The shrinkage of coverage areas and reduction of co-channel interference can effectively improve the client experience. However, this command must be exercised with careful analysis of the symptoms: high retry rates, high collision counts, lower client throughput levels and overall increased co-channel interference on the APs in the system (rogue APs are accounted for in the DCA). Internal testing shows that modification of the perceived RSSI of the third neighbor to -71dBm when troubleshooting such events is acceptable to begin with.

Much like the traps generated when a channel change occurs, TPC changes generate traps, which clearly indicate all necessary information associated with the new changes. Some sample traps are displayed in Figure 18:

Figure 18: The Tx Power trap log indicates the new power-level of operation for the specified radio.

21	Mon Mar 13 10:38:43 2006	RF Manager updated TxPower for Base Radio MAC: 00:0b:85:55:50:90 and slotNo: 1. New Tx Power is: 3
22	Mon Mar 13 10:38:43 2006	RF Manager updated TxPower for Base Radio MAC: 00:0b:85:55:c6:b0 and slotNo: 1. New Tx Power is: 4
23	Mon Mar 13 10:38:43 2006	RF Manager updated TxPower for Base Radio MAC: 00:0b:85:55:50:d0 and slotNo: 1. New Tx Power is: 5
24	Mon Mar 13 10:38:33 2006	RF Manager updated TxPower for Base Radio MAC: 00:0b:85:55:50:90 and slotNo: 0. New Tx Power is: 1
25	Mon Mar 13 10:38:33 2006	RF Manager updated TxPower for Base Radio MAC: 00:0b:85:55:43:b0 and slotNo: 0. New Tx Power is: 4
26	Mon Mar 13 10:38:33 2006	RF Manager updated TxPower for Base Radio MAC: 00:0b:85:55:50:d0 and slotNo: 0. New Tx Power is: 4

Transmit Power Control Algorithm Workflow Example

This example is a basic scenario and seeks to further explain the process by which the TPC algorithm analyses AP signal levels in the same vicinity. This example also explains how the algorithm adjusts transmit power downward in order to limit cell overlap.

Consider an environment where four APs can all hear each other's neighbor messages. This table of received signal strengths indicates the signal levels at which each AP hears the others.

Table 3 illustrates signal levels before the TPC algorithm is run and applied:

AP 1

AP 2

AP 3

AP 4

AP 2 at -46dBm

AP 3 at -47dBm

AP 2 at -43dBm

AP 2 at -48dBm

AP 3 at -53dBm

AP 4 at -52dBm

AP 4 at -57dBm

AP 3 at -51dBm

AP 4 at -71dBm

AP 1 at -49dBm

AP 1 at -59dBm

AP 1 at -58dBm

Table 3 clearly shows that APs 2, 3, and 4 do not have a third-loudest AP that operates at or less than -65dBm. As such, power output adjustments must be made in order to lower the strengths at which these APs receive at least one AP signal. With the analysis of the APs RSSIs, it is clear that the transmit power of AP 1 must be lowered. This change allows each AP to have at least one neighboring AP at or less than the -65dBm target. The results of this change are highlighted and shown in Table 4.

AP 1

AP 2

AP 3

AP 4

AP 2 at -46dBm

AP 3 at -47dBm

AP 2 at -43dBm

AP 2 at -48dBm

AP 3 at -53dBm

AP 4 at -52dBm

AP 4 at -57dBm

AP 3 at -51dBm

AP 4 at -71dBm

AP 1 at -69dBm

AP 1 at -65dBm

AP 1 at -68dBm

Coverage Hole Detection and Correction Algorithm Workflow Example

In order to illustrate the decision-making process used in the Coverage Hole Detection and Correction algorithm, this example first outlines the poor received SNR level of a single client, and how the system determines whether a change is needed. It also illustrates what that power change can be.

The Coverage Hole SNR Threshold Equation:

Client SNR Cutoff Value (dB) = [AP Transmit Power (dBm) - Constant (17 dBm) - Coverage Profile (dB)]

Note: This equation represents a situation where a client experience signal issues in a poorly covered area of a floor.

In such a scenario, these items can be true:

- A client has an SNR of 13dB.
- The AP to which it is connected is configured to transmit at 11 dBm (power level 4).
- This AP WLC has a Coverage profile threshold set to the default of 12 dB.

In order to determine if the client AP must be powered up, the numbers detailed are plugged into the Coverage Hole Threshold Equation. This is the result:

1. Client SNR cutoff = 11dBm (AP transmit power) - 17dBm (constant value) - 12dB (Coverage threshold) = |-18dB|.
2. Because a client SNR of 13dB is in violation of the present SNR cutoff of 18dB, the Coverage Hole Detection and Correction algorithm increase the AP transmit power to 17dBm.
3. When you use the Coverage Hole SNR Threshold Equation, it is evident that the new transmit power of 17dBm yields a Client SNR cutoff value of 12dB, which satisfies the client SNR level of 13 dBm.

This is the math for Step 3:

Client SNR cutoff = 17dBm (AP transmit power) - 17dBm (constant value) - 12dB (Coverage threshold) = |-12dB|.

Supported power output levels in the 802.11b/g band are outlined in Table 4. In order to determine the power level outputs for 802.11a, the **show ap config 802.11a <ap name>** CLI command is run:

Supported Power Levels

Tx Power (dBm)

Tx Power (mW)

1

20

100

2

17

50

3

14

25

4

11

12.5

5

8

6.5

6

5

3.2

7

2

1.6

8

-1

0.8

debug Commands

The **airewave-director debug** command can be used in order to further troubleshoot and verify RRM behavior. The top-level command-line hierarchy of the **debug airewave-director** command is displayed:

```
(Cisco Controller) >debug airewave-director ?

all          Configures debug of all Airewave Director logs
channel      Configures debug of Airewave Director channel assignment protocol
error        Configures debug of Airewave Director error logs
detail       Configures debug of Airewave Director detail logs
group        Configures debug of Airewave Director grouping protocol
manager      Configures debug of Airewave Director manager
message      Configures debug of Airewave Director messages
packet       Configures debug of Airewave Director packets
power        Configures debug of Airewave Director power assignment protocol
radar        Configures debug of Airewave Director radar detection/avoidance protocol
rf-change    Configures logging of Airewave Director rf changes
profile      Configures logging of Airewave Director profile events
```

These are a few important commands:

- **debug airewave-director all** When this command is issued, it invokes all RRM debugs which can help identify when RRM algorithms are run, what data they use, and what changes made. In this example, the **debug airewave-director all** command is run on the RF Group Leader in order to gain insight into the inner workings of the DCA algorithm and can be broken down into these four steps:

1. Collect and record the current statistics to be run through the algorithm:

```
Mon Mar 20 16:06:56 2006: Airewave Director:
Checking quality of current assignment for 802.11a
Mon Mar 20 16:06:56 2006: Airewave Director:
802.11a AP 00:15:C7:A9:3D:F0(1) ch 161 (before -86.91, after -128.00)
Mon Mar 20 16:06:56 2006: Airewave Director:
00:15:C7:A9:3D:F0(1)( 36, -76.00)( 40, -81.75)( 44, -81.87)( 48, -81.87)
Mon Mar 20 16:06:56 2006: Airewave Director:
00:15:C7:A9:3D:F0(1)( 52, -81.87)( 56, -81.85)( 60, -79.90)( 64, -81.69)
Mon Mar 20 16:06:56 2006: Airewave Director:
00:15:C7:A9:3D:F0(1)(149, -81.91)(153, -81.87)(157, -81.87)(161, -86.91)

!--- This command output has been condensed in order
!--- to show the DCA process only.
```

2. Suggest a new channel schema and store the recommended values:

```
Mon Mar 20 16:06:56 2006: Airewave Director:
Searching for better assignment for 802.11a
Mon Mar 20 16:06:56 2006: Airewave Director:
802.11a AP 00:15:C7:A9:3D:F0(1) ch 161 (before -86.91, after -128.00)
Mon Mar 20 16:06:56 2006: Airewave Director:
00:15:C7:A9:3D:F0(1)( 36, -76.00)( 40, -81.75)( 44, -81.87)( 48, -81.87)
Mon Mar 20 16:06:56 2006: Airewave Director:
00:15:C7:A9:3D:F0(1)( 52, -81.87)( 56, -81.85)( 60, -79.90)( 64, -81.69)
Mon Mar 20 16:06:56 2006: Airewave Director:
00:15:C7:A9:3D:F0(1)(149, -81.91)(153, -81.87)(157, -81.87)(161, -86.91)
```

3. Compare the current values against the suggested values:

```
Mon Mar 20 16:06:56 2006: Airewave Director:
Comparing old and new assignment for 802.11a
Mon Mar 20 16:06:56 2006: Airewave Director:
802.11a AP 00:15:C7:A9:3D:F0(1) ch 161 (before -86.91, after -86.91)
```

```

Mon Mar 20 16:06:56 2006: Airewave Director:
00:15:C7:A9:3D:F0(1)( 36, -76.00)( 40, -81.75)( 44, -81.87)( 48, -81.87)
Mon Mar 20 16:06:56 2006: Airewave Director:
00:15:C7:A9:3D:F0(1)( 52, -81.87)( 56, -81.85)( 60, -79.90)( 64, -81.69)
Mon Mar 20 16:06:56 2006: Airewave Director:
00:15:C7:A9:3D:F0(1)(149, -81.91)(153, -81.87)(157, -81.87)(161, -86.91)

```

4. If necessary, apply the changes in order for the new channel schema to take effect:

```

Mon Mar 20 16:06:56 2006: Airewave Director:
Before -- 802.11a energy worst -86.91, average -86.91, best -86.91
Mon Mar 20 16:07:00 2006: Airewave Director:
After -- 802.11a energy worst -86.91, average -86.91, best -86.91

```

- **debug airewave-director detail** This command can be issued in order to obtain a detailed, real-time view of RRM operation on the controller on which it is run. These are explanations of the relevant messages:

1. Keepalive messages are sent to group members in order to maintain the group hierarchy:

```

Sun Mar 19 23:14:34 2006: Airewave Director:
Sending keep alive packet to 802.11a group members

```

2. Load statistics are calculated on the neighbors reported:

```

Sun Mar 19 23:14:40 2006: Airewave Director:
Processing Load data on 802.11bg AP 00:13:5F:FA:2E:00(0)
Sun Mar 19 23:14:40 2006: Airewave Director:
Processing Load data on 802.11bg AP 00:0B:85:54:D8:10(1)
Sun Mar 19 23:14:40 2006: Airewave Director:
Processing Load data on 802.11bg AP 00:0B:85:23:7C:30(1)

```

3. This output displays how strongly the neighbor messages are heard and through which APs:

```

Sun Mar 19 23:14:40 2006: Airewave Director:
Neighbor packet from 00:0B:85:54:D8:10(1) received by 00:13:5F:FA:2E:00(0)rss
Sun Mar 19 23:14:40 2006: Airewave Director:
Neighbor packet from 00:0B:85:23:7C:30(1) received by 00:13:5F:FA:2E:00(0)rss

```

4. This output displays Noise and Interference statistics calculated at the reported radios:

```

Sun Mar 19 23:14:44 2006: Airewave Director:
Sending keep alive packet to 802.11bg group members
Sun Mar 19 23:15:40 2006: Airewave Director:
Processing Interference data on 802.11bg AP 00:0B:85:54:D8:10(1)
Sun Mar 19 23:15:40 2006: Airewave Director:
Processing noise data on 802.11bg AP 00:0B:85:54:D8:10(1)
Sun Mar 19 23:15:40 2006: Airewave Director:
Processing Interference data on 802.11bg AP 00:0B:85:54:D8:10(1)
Sun Mar 19 23:15:40 2006: Airewave Director:
Processing Interference data on 802.11bg AP 00:0B:85:23:7C:30(1)
Sun Mar 19 23:15:40 2006: Airewave Director:
Processing noise data on 802.11bg AP 00:0B:85:23:7C:30(1)
Sun Mar 19 23:15:40 2006: Airewave Director:
Processing Interference data on 802.11bg AP 00:0B:85:23:7C:30(1)

```

- **debug airewave-director power** This command must be run on the local WLC to the AP that is monitored for Coverage Hole corrections, as shown in this sample command output:

Watching Coverage Hole Algorithm run for 802.11a

```

Sun Mar 19 22:55:03 2006: Airewave Director:
Coverage Hole Check on 802.11a AP 00:0B:85:54:D8:10(0)
Sun Mar 19 22:55:03 2006: Airewave Director:
Found 0 failed clients on 802.11a AP 00:0B:85:54:D8:10(0)
Sun Mar 19 22:55:03 2006: Airewave Director:
Found 0 clients close to coverage edge on 802.11a AP 00:0B:85:54:D8:10(0)
Sun Mar 19 22:55:03 2006: Airewave Director:

```

```
Last power increase 549 seconds ago on 802.11a AP 00:0B:85:54:D8:10(0)
Sun Mar 19 22:55:03 2006: Airewave Director:
Set raw transmit power on 802.11a AP 00:0B:85:54:D8:10(0) to (20 dBm, level 1)
```

*!--- The output from this command is condensed for
!--- the purpose of this example.*

Watching Coverage Hole Algorithm run for 802.11b/g

```
Sun Mar 19 22:57:36 2006: Airewave Director:
Coverage Hole Check on 802.11bg AP 00:13:5F:FA:2E:00(0)
Sun Mar 19 22:57:36 2006: Airewave Director:
Found 0 failed clients on 802.11bg AP 00:13:5F:FA:2E:00(0)
Sun Mar 19 22:57:36 2006: Airewave Director:
Found 0 clients close to coverage edge on 802.11bg AP 00:13:5F:FA:2E:00(0)
Sun Mar 19 22:57:36 2006: Airewave Director:
Last power increase 183 seconds ago on 802.11bg AP 00:13:5F:FA:2E:00(0)
Sun Mar 19 22:57:36 2006: Airewave Director:
Set raw transmit power on 802.11bg AP 00:13:5F:FA:2E:00(0) to (20 dBm, level 1)
Sun Mar 19 22:57:36 2006: Airewave Director:
Set adjusted transmit power on 802.11bg AP 00:13:5F:FA:2E:00(0) to (20 dBm, level 1)
```

*!--- The output from this command is condensed for
!--- the purpose of this example.*

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