Dynamic Radio Management

Introduction

Wireless LANs are becoming very common in the enterprise for their productivity and cost savings benefits. Usage has grown to require higher user capacities and higher Radio Frequency (RF) density. As wireless LANs grow larger, network performance becomes a critical factor in managing the network. Usually a site survey is necessary for installing and configuring large WLAN networks. However site surveys are not sufficient in addressing how the WLAN network will perform over time.

The performance of an 802.11 wireless LANs depends on how many clients are sharing the network. Larger numbers of clients require a denser deployment of Access Points (APs). However as APs are packed into a smaller area, they are more likely to interfere with each other and reduce the overall performance of the network.

Performance also depends on propagation of RF signals. RF signal propagation is affected by other APs, people, and other objects in the coverage area. The RF propagation changes as people and objects move through the coverage area. Wireless APs and clients have to constantly adapt to the changing RF environment—generally dropping the connection rate in noisier environments.

When deploying dense WLAN networks, network administrators face two main challenges:

- Dense deployment that can cause RF interference with neighboring APs residing on the same or neighboring channels
- RF interference and impedance from changing environments such as the movement of people, the position of objects in the office, as well as other RF sources such as Bluetooth devices, microwave ovens or cordless phones

Co-Channel Interference in Dense Deployments

Wireless LANs are increasingly becoming mission critical to business operations. They need to be engineered to address larger numbers of users and provide consistent coverage and capacity. This would require denser AP deployments. A dense deployment requires coordinated channel selection and power management amongst the APs.

As APs are deployed in dense environments with overlapping RF coverage, it is almost impossible to avoid co-channel interference between APs on the same channel. Co-channel interference causes collisions between RF transmissions, which reduces effective throughput. In Voice over WLAN applications, co-channel interference increases jitter and latency, which can result in audible static during conversations. For example, co-channel interference is more common in the 2.4 GHz band (802.11b and 802.11g) where there are only three non-overlapping channels (1, 6, and 11) in North America.

Other Sources of RF Interference

RF quality can also be affected by interference caused by other RF sources and propagation characteristics of the RF signal through and around objects.

Other devices operating in either the 2.4 GHz band or the 5GHz band can interfere with WLAN communications. These types of devices include fluorescent lights and other wireless technologies such as Bluetooth or cordless phones. Microwave equipment including microwave ovens can interfere in different ways with WLAN devices depending on how they use the RF spectrum. Many of these RF sources work in the unlicensed 2.4 GHz and 5.0 GHz bands.

An RF transmission through any object will cause interference in the form of reflection and refraction. The amount of reflection or refraction will depend on the geometric and material properties of the object. Metal objects will tend to reflect the signal, while wood, concrete or water will tend to absorb and refract (bend) the RF signal.

Refraction generally causes loss in signal power, while reflection causes a change in signal direction. Refraction will cause a device to receive a signal at a reduced power level, thereby reducing the Signal-to-Noise Ratio (SNR). A large power reduction can cause a WLAN client to lose data and potentially its wireless link to the AP.

Signal reflection can cause the wireless device to receive the same signal with a small time delay. This multi-path interference can cause data transmission errors and if significant, can cause a wireless device to lose its link with the AP. The changes to the RF environment will occur dynamically. In the simplest case, people walking around an office, or doors being open or shut, can change the RF coverage. Most industries are prone to dynamic RF changes, but some can be critically prone, such as:

- **Hospitals**—lots of equipment movement, including lead-lined curtains, and the movement of patients and guests
- **Education**—students, and personnel the number one source of absorption
- **Public Places**—caused mostly by people, but include indoor signage from stores, mobile kiosks, booths for convention centers, other wireless devices not controlled by the network administrator, etc.
- **Warehousing**—addition and removal of inventory, and the equipment used to move the inventory

Benefits of Dynamic Radio Management (DRM)

DRM on Summit® WM WLAN controllers from Extreme Networks® allows Altitude 350 APs to exchange RF information and dynamically adapt to changes in the RF environment. It allows the WLAN to be installed in dense deployments while minimizing interference issues. DRM provides the following benefits which include:

- Highly available RF data rates: With the smart exchanges between Altitude 350 APs, the WLAN helps ensure the highest performance for the entire wireless network.
- RF redundancy: With a dense deployment, DRM provides dynamic redundancy should an AP fail (e.g. power loss). Altitude APs can detect the loss of an adjacent AP and therefore increase coverage dynamically to eliminate "dead spots".
- Operational savings: With RF management, network administrators do not need to plan out the channel assignment and the signal strength for every AP. Also, with a dense deployment, site surveys are, in most cases, not required.

DRM

DRM provides dynamic power management and channel selection upon boot up, maximizing the performance of the WLAN. DRM mitigates the need for extensive and costly site surveys when simple coverage is not the only requirement. DRM provides two methods of power control for the enterprise. They are called Standard Power Control and Shaped Power Control. Both methods provide the best possible service while minimizing interference between APs operating on the same channel. The following sections describe the two power control modes.

Standard Power Control

DRM Standard RF Power Control provides the best possible service to wireless clients while minimizing interference between APs operating on the same channel. DRM Standard Power Control dynamically adjusts power to service the furthest client from the AP. DRM creates a consistent footprint of the cell while minimizing the traffic present over the entire cell. This feature provides the basis for clients (PCs or Wi-Fi handsets) to accurately determine when to roam from AP to AP.

The goal of DRM RF Power Control is to provide the best possible service to clients associated with the AP. With the increasing number of 802.11 devices present in the market, and the limited number of channels to choose from, it is critical for APs to limit their transmit range to the maximum required to service its clients. Limiting this range maximizes the ability to reuse channels. This feature then maximizes the number of 802.11 transmitting devices that can successfully operate in an environment.

The following sections describe how DRM Standard RF Power Control works.

Maximizing RF Footprint

DRM Standard Power Control transmits 802.11 management frames at full power creating a maximum-sized RF cell. Management frames include beacons, association and disassociation frames, and probe request and responses. Clients use these messages to evaluate the RF environment, establish connections to APs, and determine when to roam to a new AP. All of these operations are critical to the operation of a wireless client.

The diagram in Figure 1 shows clients at different distances from the AP. Both clients measure the signal strength from the AP using beacons or probe responses. This gives the client an accurate view of the RF signal quality it can obtain from the AP.

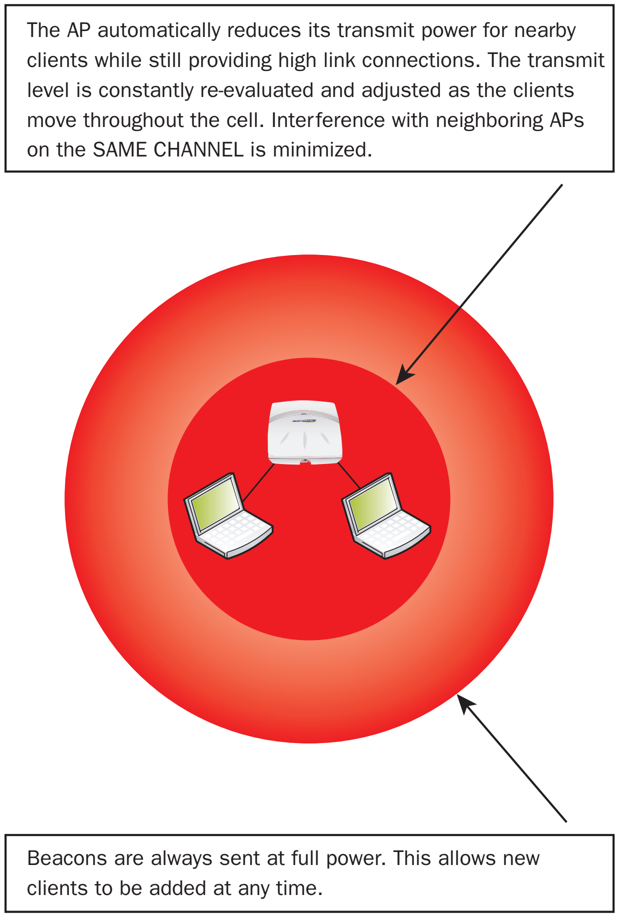

Figure 1: Dynamic Radio Management Standard Power Mode

Minimizing Interference

Data traffic in a wireless network makes up the majority of transmissions causing interference. A client associated to an AP that is very close does not need the AP to transmit at full power in order to obtain a great connection. Reducing power of the data traffic not only provides excellent performance to the client but also reduces the amount of interference this traffic may cause to other APs.

DRM continuously monitors the position of its clients and dynamically adjusts power to accommodate the furthest client. Figure 2 shows the transmit power for data frames is raised to support the client furthest away.

The diagram in Figure 2 shows the inner ring (data frame transmit power) reaching just past the furthest client. Transmitting at a power level that provides the furthest client with the best service yields the best overall system performance.

If the furthest client moves closer to the AP or roams to another AP, DRM will automatically adjust the power to provide the best results for the changing environment.

Clients that are continuously moving (Wi-Fi phones for example) require an RF environment that will adapt quickly to its needs. DRM monitors every client for movement and accurately adjusts power to support them. This process is done continuously to support all clients whether stationary or moving.

Now consider this deployment for a system of four APs deployed in a region where there are only three non-overlapping channels such as in North America.

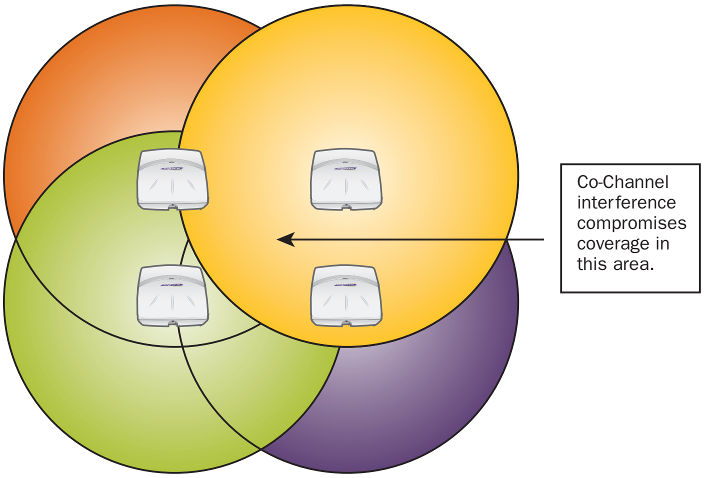

Figure 2: Non-DRM APs and Area of Co-Channel Interference

Now consider the case for DRM's standard RF mode. The data transmit (Tx) range from each AP is kept as low as possible give the active clients adequate coverage. The area of co-channel interference in the middle of the APs is now reduced to just co-channel interference for beacons. Beacons are regular traffic but are only sent on a typical interval of every 0.1 seconds. Also, for co-channel interference from beacons to occur in the center area, the beacons from the co-channel APs would have to be exactly synchronized. Given the infrequency of the beacons and the probability of an exact synchronization between co-channel APs, it is fair to say that the dynamic RF ability of DRM's standard mode helps significantly clean up the co-channel interference in the center of this example diagram (see Figure 3).

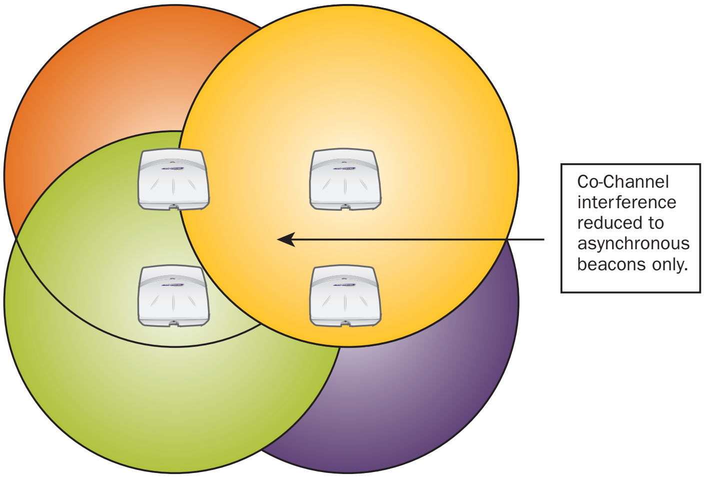

Figure 3: Reduction of Co-Channel Interference Using DRM-Enabled APs

Supporting New Clients

A key characteristic of DRM Power Control is how it handles new clients. When a client first associates, DRM increases the transmit power for data frames to full power. This is done because DRM does not know the status of the client when it first associates. DRM then evaluates the client's needs and adjusts the transmit power to support it. If the client is far away, DRM provides more power to support it. If the client is very close, the transmit power for data traffic is reduced significantly to minimize interference.

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RF Domain

DRM adjusts power to APs that are part of its network. Another AP is defined as being part of this network if the SSID matches the SSID of this AP. If the APs support multiple SSIDs, then the APs are considered part of the same network if any of the SSIDs match. If APs are configured to suppress their SSIDs, none of the APs can determine which APs are part of the same network. To overcome this issue, DRM has introduced the concept of an RF Domain. The RF Domain creates a set of APs that are part of the same wireless network. To establish an RF Domain, each AP that is to be included must have a new field added to its configuration—the RF domain. This field is a text string that is transmitted with each 802.11 beacon. Clients cannot use this information to associate or compromise security. Its purpose is to create a set of APs that DRM will include in its power control.

Shaped Power Control

DRM provides a second enterprise-class power control mode called Shaped Power Control. In this mode, DRM APs will reduce power to minimize interference between other APs operating on the same channel. When DRM reduces power in this mode, it reduces power of all 802.11 frames including the management frames. This shrinks the size of the cell for both management and data frames.

This mode does not adjust the power to provide better service to distant clients. If a client moves to a position that provides marginal service from the AP it is associated to, DRM assumes that the client will realize this and roam to a better AP.

It is important to make sure that the APs configured for Shaped Power Control mode are operating on the same plane as the clients. The APs are adjusting power to avoid interfering with each other and are not taking into account the location of clients. If the APs are mounted on high ceilings (For example: 50 feet above an exhibit hall floor) and the APs reduce power to avoid interfering with other APs, the coverage on the exhibit hall floor may be severely impacted.

The trade-off for using Shaped Power Control vs Standard Power Control is whether increasing the transmit power for data frames to support distant clients will impact the performance of neighboring APs operating on the same channel. How well Shaped Power Control will work depends on the type of client.

VoWLAN

For VoWLAN, it is highly recommended to use Shaped Coverage with minimum and maximum power settings pre-configured. By setting to Shaped Coverage, WiFi handsets will interpret the beacon strength to be the same as the data strength. This is very important.

Minimum power should be set to the results of the site survey. Maximum power must be set to full power. This configuration will help ensure that for any wireless event, cell coverage will always be within the defined specifications of the site survey.

DRM Power Control Summary

- DRM Standard Power Control transmits management frames at full power creating a full size cell that clients use to analyze the environment.
  - This provides a consistent view of the RF environments to all clients
  - Clients can make accurate association decisions
- DRM Standard Power Control reduces the transmit power of data frames if there are other APs present in the environment operating on the same channel.
  - Reducing the transmit power of data frames minimizes co-channel interference
  - Increases the ability to reuse channels
- DRM Standard Power Control continuously monitors this situation and will raise power if the other AP is removed from service, changes channel or fails.
  - DRM can provide the best possible service to a changing RF environment
  - DRM Standard Power Control setting is especially effective and more secure by minimizing the cell at the periphery of the wireless network
- DRM will lower power if a new AP is brought online on the same channel in its environment
- When clients associate, DRM Standard Power raises the transmit power of data frames to the maximum, monitors the position of the client, and then adjusts the transmit power to provide the best possible service.
- When client movement is detected, DRM Standard Power Control will increase data frames to full power, reevaluate the position of the client, and adjust power again to best service the client.
- DRM continuously monitors and adjusts the transmit power for data frames to accommodate a very dynamic RF environment.
- The results of DRM RF Power Management are:
  - Minimized interference
  - Maximum performance for clients
  - Maximized ability to reuse channels
  - Overall better system performance
- DRM Shaped Power Control reduces the transmit power of all 802.11 frames including management frames.
  - This shrinks the entire cell minimizing interference with other APs
- DRM Shaped Power Control does not adjust power to support distant clients.
  - Once the cell size is established, client associations do not affect it
  - DRM Shaped Power Control will adjust the cell size when new APs are brought online or removed from service
  - Most effective for teal time applications such as VoWLAN
- DRM Shaped Power Control minimizes the co-channel interference between APs.

Automatic Channel Selection with DRM

When DRM is enabled for both the WLAN controller and for a specific AP then the AP may then participate in a dynamic channel selection procedure. If a radio within the AP is configured to use a channel called 'auto' then the automatic channel selection procedure occurs under the following conditions:

- When DRM is enabled globally for the system
- When DRM is enabled for a specific AP
- When the 'ReSync DRM' button is selected from the UI

The DRM channel selection algorithm automatically selects channels to minimize interference and optimize performance. The algorithm requires no central authority and works equally well in both sparse and dense deployments. DRM devices work in concert with each other selecting the best possible channel and cell size for any environment.

The DRM channel selection algorithm has the following properties:

- Fully distributed
- Requires no central authority
- Scales infinitely
- Accounts for non-DRM devices as well as DRM devices
- Compliant to all 802.11 standards
- Requires no connections between APs (i.e. only the APs that can hear each other participate in the process)

The channel selection process has several phases:

- Scanning (localized site survey)
- Selection (pick the best channel)
- Negotiate (request to operate on the selected channel)
- Operate (begin operation on the channel selected)

Scanning Phase

During the scanning phase, each AP scans all of the channels available in the regulatory domain. The APs search for other APs already operating on the channel, determine their signal strength, and locate other sources of non-802.11 interference. This information is used to determine the best channel for this AP to operate on.

In addition to listening for existing devices operating on the channel, the DRM APs notify other DRM APs that they are in the process of selecting a channel. This serves the following purpose:

- Synchronize all DRM APs during the channel selection process (only applies to situations where all APs are booting at the same time such as after a power failure).

Once the data is collected about existing APs operating on all channels in the environment and other DRM APs that are booting, DRM APs move onto the selection phase.

Selection Phase

This phase determines the best channel to operate on. The result is a list similar to the following:

- Channel 1: -32dbm
- Channel 6: -50dbm
- Channel 11: -29dbm

Each channel's loudest signal is captured. These signals are scanned and the channel with the quietest signal is selected. In the example above, Channel 6 would be selected because 50dbm is the weakest signal.

The selection process for the current release of DRM is more sophisticated. The information obtained in the scanning phase is fed into an algorithm to create a Channel Quality Index (CQI). The channel with the lowest CQI is then selected as the best channel. The CQI is computed using the following information:

- Loudest transmitting device operating on a channel
- Noise floor of the channel
- Other transmitting devices on the channel
- Transmitting devices on neighboring channels
- Transmitting devices on overlapping channels (Turbo-channels)

The CQI value is designed to take into account all forms of possible interference on a particular channel. If the noise floor is high on a channel, that channel's CQI is adjusted to look proportionally worse than a channel with no noise. If there are transmitters operating on adjacent channels, the overlapping channels' CQI is adjusted to take this into account.

Each channel's CQI is computed and the channel with the lowest CQI is chosen as the best channel.

Negotiation Phase

Once the channel has been selected, the negotiation process begins. The purpose of this process is to give the requested channel to the AP that needs it most. APs in dense areas get priority over other APs.

During the negotiation process, DRM APs communicate their selected channel and information about their denseness situation over the selected channel. The negotiation period lasts long enough for all APs that have selected the same channel to receive all of the other APs channel selection information. Once the negotiation period expires, all the APs determine if they are allowed to operate on the selected channel. The AP with the greatest need is allowed to operate on the selected channel. All other APs return to the scanning phase.

The APs that return to the scanning phase perform a minimal scan to detect any new APs operating on a channel. These are typically the APs that have just won the negotiation process. The channels are evaluated once more and the best channel is selected. A new negotiation round begins for this AP.

Operation Phase

Once an AP succeeds in acquiring its selected channel, it makes a quick check of that channel to make sure that nothing has changed during the negotiation process (i.e. a new AP appears nearby on the channel changing the CQI or signal strength measurement for that channel). If everything looks okay, the AP enables the channel and begins operation.

Channel Selection Time

The amount of time it takes to perform the first round of channel selection is approximately 60 seconds[1]. APs that lose in the negotiation phase return to the scanning phase. A new scan takes approximately 15 seconds after which a new round of negotiating takes place.

The distributed nature of this algorithm results in an optimum distribution of channels over a large number of APs. The maximum amount of time required to select channels is approximately three minutes. In a large and dense deployment of APs, many groups of APs pick channels simultaneously. Each round causes more and more APs to select appropriate channels in parallel. Even in dense deployments, an AP will acquire the selected channel after approximately three rounds of negotiating.

Dynamic Frequence Selection (DFS2)

In the United States, a new FCC ruling requires that WLAN systems operating in certain 5 GHz frequency bands must comply with Dynamic Frequency Selection (DFS2) to prevent WLAN communications from interfering with incumbent military and weather radar systems. WLAN systems must be capable of detecting radar and avoid the use of the channel if radar is detected.

The Summit WM controllers and Altitude APs support DFS2 and DRM concurrently. When DRM is enabled, DFS2 operates in the following manner:

- DFS2 and DRM manage the available channel list, i.e. if DFS2 finds a channel with radar signal then DRM knows it cannot use that channel for 30 minutes.
- If DFS2 must stop using a channel, it will momentarily be down while scanning for a new clean channel. During this time the surrounding APs will increase power to compensate.
- Upon radar signal detection, the AP will obtain a new channel from DRM and scan that channel for radar. Once the AP settles on a new clean channel, if Automatic Transmit Power Control (ATPC) is enabled, the transmit power will be recalculated. If ATPC is disabled, the transmit power will be preserved.

DRM Management

DRM is configured and monitored centrally. The configuration of DRM consists of:

a. Enable/disable DRM—global and per AP settings
b. Group DRM configuration
c. Enable/disable the avoidance of other WLANs
d. Override channel assignment
e. Restart DRM (resetting of channel and power)
f. Type of shaped coverage (standard versus shaped)
g. Max/Min RF power configuration

When DRM is enabled, both channel and transmit signal strength are automatically configured by DRM. Upon power-up, DRM will scan the WLAN network to select a channel and set its power to maximum. It will back-off its power to adjust for the presence of neighboring disabled DRM APs.

The DRM application is enabled globally on the WLAN controller. This means that a WLAN controller with the DRM software key will enable DRM on all APs with R2.1 or higher software. It is also possible to configure DRM on a per AP basis. Figure 4 shows the configuration page when DRM is enabled via software keys.

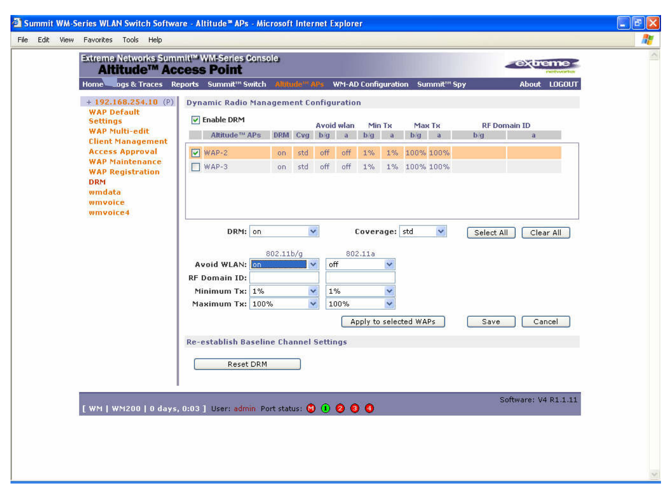

Figure 4: DRM Global Settings

[1] This number assumes that the regulatory domain does not require radar detection. For regulatory domains requiring radar detection, each pass though the negotiation phase requires a radar check that lasts 60 seconds. This significantly impacts the channel selection time for the 802.11a band due to the number of available channels. In an 802.11a environment with 19 channels and 17 APs, it can take up to 30 minutes to complete channel selection.

This page allows the parameters of DRM to be configured for the entire system. The following settings are available:

- **Enable DRM**—Controls whether DRM is enabled or disabled for the entire system. This setting overrides the setting on each individual AP.
- **DRM on/off**—Controls whether DRM is enabled or disabled for a specific AP.
- **Coverage**—Controls the selection of Standard or Shaped coverage mode for each AP.
- **Avoid WLAN**—Controls whether Tx power is backed off in the presence of other WLAN networks that are NOT part of the WLAN controller system (i.e. different SSID).
- **Minimum Tx**—Allows the user to set the absolute minimum Tx level the AP will use.
- **Maximum Tx**—Allows the user to set the absolute maximum Tx level the AP will use.

Reporting

The WLAN controller provides dynamic display of channel and transmit power setting for each radio on the AP (see Figure 5).

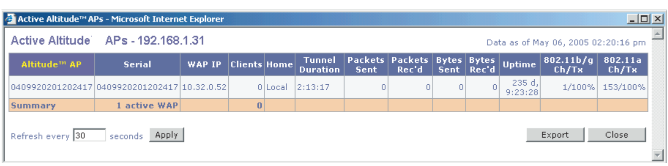

Figure 5: Altitude 350 Statistics GUI

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