Radio Resource Management

Introduction

Wireless connectivity is truly ubiquitous and Wi-Fi is one of the fastest growing wireless technologies of all time, everything has a Wi-Fi chipset and client installed and IoT is just getting warmed up. An analysts report back in 2011 said that the number of wireless stations vs wired stations on the internet will likely flip with wireless users exceeding wired nodes by 2015. We beat that estimate in 2014, and the future is clear, there will be more. Once upon a time we counted seats to evaluate capacity, however most users have more than one active device operating at all times. As I'm sitting here writing this, I count 3 devices between the laptop I am writing this on, my smartphone, and the tablet that is in hibernation mode at the moment. I'm not turning any of these off - and you probably aren't either. All of this persistent connectivity requires bandwidth and rescores, wireless spectrum is becoming even more precious than in previous times and the pressure on available spectrum doesn't look to be easing anytime soon. What has not changed significantly is the spectrum with which we have to work. All of this together makes managing what you have the primary mission of any wireless administrator or network operator.

Most of the pressure to date has been in the 2.4 GHz spectrum, however this will be spreading to a 5 GHz band near you soon (if it hasn't already). If this is your first foray into that deep and mystical world of the RF physical layer, fear not, the rules on this have changed pretty regularly so you're not behind but rather just in time! Most of the work will be done for you, but like any manager it's a good idea to to understand the goal of your team and their individual strengths. To that end, we'll discuss what RRM is, what it does, and how it does this. We will also discuss how to characterize your operating environment so you can ask RRM good questions.

Why is this important? Spectrum is the physical layer. Unlike wired networks - our spectrum is free to propagate in all directions. This means that if two cells overlap one another on the same channel, that they are sharing the spectrum normally reserved for each. Not only are users of each cell sharing the single channel of available spectrum, it's doubled the management traffic. The result is higher consumption of air time and less throughput. This is commonly known as co-channel interference. Assuming that all wireless devices are operating on your network and not on a neighbors, there is only two things that can be manipulated to adjust any given cell in response to co-channel interference:

- **Channel Plan**: adjusting the channel plan to facilitate the maximum separation of one AP from another

- **Power Levels**: power levels increase or decrease the size of the effective cell

Both of these are separate arguments but work together to produce an effective solution.

Cisco's Radio Resource Management (abbreviated RRM) allows Cisco's Unified WLAN Architecture to continuously analyze the existing RF environs, automatically adjusting each APs' power and channel configurations to help mitigate such things as co-channel interference and signal coverage problems. RRM 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 paper details the functionality and operation of RRM and provides an in-depth discussion of the algorithms behind the features

A Brief History of RRM in Cisco

RRM was introduced originally as a feature on AireSpace AP's and controllers, and became part of the Cisco CUWN with the acquisition of AireSpace in 2005.

In 2005 if you had 150 AP's in a network, that was a large Wi-Fi network. Today we routinely see RF installations with 3000-5000 and more AP's installed in campus deployments, stadium environments, conference centers, metro deployments, and hospitals. Much has changed in this short history - and as the questions have changed - so too have the answers that RRM must deliver. Since 2007, every release of CUWN (Cisco Unified Wireless Network) code has included several features related to RRM, as well as features designed to increase spectral efficiency and enhance RRM's effectiveness.

As AP spacing continues to decline, installations have migrated from simply providing Coverage models to demanding dense capacities for thousands of devices as the only edge technology. The investment in RRM as a core technology has kept pace. Smartphones and tablets with no wired connection have gone from being an accessory to being the main computing platform for users, and with this some growing pains as both the design methodologies and the network as a whole have had to adapt to different design goals, technologies and strategies.

Figure 1: Visual Timeline of Wi-Fi

Today, the wireless office is not just a cool idea - it is being implemented around the world as the only network connectivity possible between the diverse range of devices we require to do business and provide core services. Yes, Wi-Fi is mission critical.

RRM has kept pace as the technology has changed. We've gone form legacy single radio interfaces to 80 MHz 4 spatial stream 802.11ac in the last 5 years. Many of these changes have required new radios to take advantage of the advances in efficiency. We not only need to upgrade the core network but the clients as these changes impact our environments. When 802.11n entered the scene in 2003 we began to discuss the concept of an OBSS (Overlapping Base Service Set) and instead of modulating a single half duplex radio stream, we began modulating simultaneous spatial streams as well as linking existing 20 MHz channels together to increase the channel width and spatial efficiency.

Table 1: Current Wi-Fi Protocols and Capabilities Compared

Protocol	Date	Characteristics	Spatial Steams	20 MHz Channels
802.11	1997	1,2 Mbps, infra Red, spread and DSSS, 802.11FH 2.4 GHz	1	1
802.11b	1999	1,2,5.5,11 Mbps, DSSS 2.4 GHz	1	1
802.11a	1999	6,9,12,18,36,48,54 Mbps - OFDM - 5 Ghz	1	1
802.11g	2003	6,9,12,18,36,48,54 Mbps - OFDM - 5 Ghz	1	1
802.11n	2005	MCS 1-15-23 1-3 SS, OFDM, 20,40 MHz, 2.4 and 5 GHz	1-3	1-2
802.11ac	2012/15	1-8 SS MCS 1-9, OFDM, 20-40-80-160 MHz, 5 GHz	1-8	1-8

The client market was slow to embrace 802.11n as most people where just starting to rely on smartphones and functionality was slowly increasing - the majority of smartphone clients where strictly 2.4 GHz capable. As time went on, we saw more functionality and subsequent adoption. BYOD and the concept of everyone bringing their favorite platform to work created demand and as hardware technology improved, the market started changing to dualband smart devices. At the peak of this revolution 802.11AC makes it's debut, and we are off to the races. The good news is that the market is catching up and we largely have consensus for the devices that people rely on at least supporting 5 GHz (not perfectly, but then it never is).

The point is that even if you update your network to the latest and greatest standard, the client market and what you have to support on your network remain somewhat variable and define how efficient you can use essentially the same spectrum. Backwards compatibility has always been a part of networking technologies, with wireless we are limited by airtime - and the efficiency we can gain in that finite airtime is affected by the technology in use as well as the number of clients you are supporting.

With 802.11n - we got an important boost, however it was barely keeping ahead of demand in most extreme cases and still falling behind in the worst examples. Not all devices supported more than a single spatial stream, or even bonded channels. The ability to use 40 MHz bonded channels was a waste of channel space unless your user base where all using laptops only.

Welcome to the 802.11ac evolution. Every client must support up to an 80 MHz channel in order to pass WFA certification, so that levels the playing field a bit. Spatial streams capabilities vary but tend to be matched to the size and power source of the device being implemented. Each spatial stream requires an additional radio and corresponding power requirements still limit but have improved what is possible. Battery efficiency/capacity plays a role in the design decisions with smaller entry level devices still supporting only 1 SS. However, all devices can benefit from the expanded channel widths and along with what's being called wave 2 implementations - we can now simultaneously address individual single and dual spatial stream devices from the same BSS radio to achieve Multi User - Multiple Input Multiple Output (MU-MIMO). Multi User - Multiple Input Multiple Output radios allow us to service multiple single spatial stream clients in the same time block by using spatial stream diversity. Add to this that most clients are now releasing with 802.11ac radios - the time has never been better to start taking control of airtime efficiency and seeing big gains that where simply not possible only a couple of years ago.

In most environments, we are seeing overwhelming client support for 802.11n as a minimum. There are still pockets of legacy clients out there, but most of these are limited to application specific devices such as scanners, printers or devices that are purpose built for a specific industry tasks (retail, logistics). BYOD has enabled users to stay up with the latest technology trends by placing them in a continuous update cycle. If your implementation still relies on legacy clients - it is in your best interest to update these devices as soon as is feasible. While the new technologies allow for backward compatibility, they require more airtime and contribute heavily to what we now consider spectrum waste. It may still work, but you will never see most of the benefits gained in the current specifications while supporting the older less efficient radios and designs. For most users, this means 802.11n and the news is pretty good there. A mixed 802.11n and 802.11ac deployment has a tremendous amount of capacity and if designed properly will continue to service client needs over a wide range of demands.

Obviously, not every one has the same use case in mind – and RRM is designed to be flexible in its implementation to fit multiple use cases today without an exhaustive user understanding of the underlying RF challenges. RRM can be applied intelligently to multiple use models through the use of RF Profiles. Many new features can be found under the heading of HDX (High Density Experience) features, however all of these features actually support allowing RRM to do its job better, and under a wider range of conditions. We will touch on some of these features in this document, as they apply to managing user architectures, however full documentation for these features should be referenced in their deployment guides located here: HDX High Density Experience deployment guide. Also refer to this document Air Time Fairness (ATF) deployment guide which covers additional protections which can be implemented for multiple roles ensuring airtime fairness for multiple deployment roles.

Most issues with RRM result from either too many (yes, too many) or not enough AP's/channels serving applications at a specific site. For the last few years trouble reports with RF are generally related to over saturation of the 2.4 GHz band. This should not be a surprise, increased density is mitigated by channel isolation and with only 3 channels that results in a much quicker need to reuse those channels which results in higher co-channel interference. The 2.4 GHz is largely considered a junk band for WI-Fi users now as many devices that do not use Wi-Fi as well as many IOT devices take advantage of this band for ease of implementation as well as favorable propagation to power characteristics. These devices generally do not have the same requirements as a data or voice client, so it works out ok for them. More of these devices are coming and this will continue to make 2.4 GHz less favorable for most infrastructure users.

There is a finite limit to the number of radios that can operate in close proximity, and with many new devices entering the market, exceeding an RF designs capacity is becoming much more common. While this is sometimes initially blamed on RRM, RRM can only manage the resources that it has to work with. Architecture and radio placement need to be considered as part of the overall design. It is likely not good enough to just assume that the site survey that was conducted even 5 years ago meets the needs of todays user base. The good news is that once deployment density and design decisions have been adjusted to accommodate the increased demands on our networks today, RRM manages the result quite well. Poor planning can lead to unintended results with RRM. Improved diagnostics and instrumentation have made this information clearer, easier to understand, and more available at all levels of the organization.

This document seeks to provide you, the architect or technician with the details of how and why RRM makes its decisions. Knowing this will lead to better design decisions and quicker issue resolution. Continuing focus on Cisco's RF Excellence will continue to bring value to the users experience. A proven track record of changes and continuous development to stay ahead of the curve means that RRM is well established to continue to manage RF for our continuously growing needs.