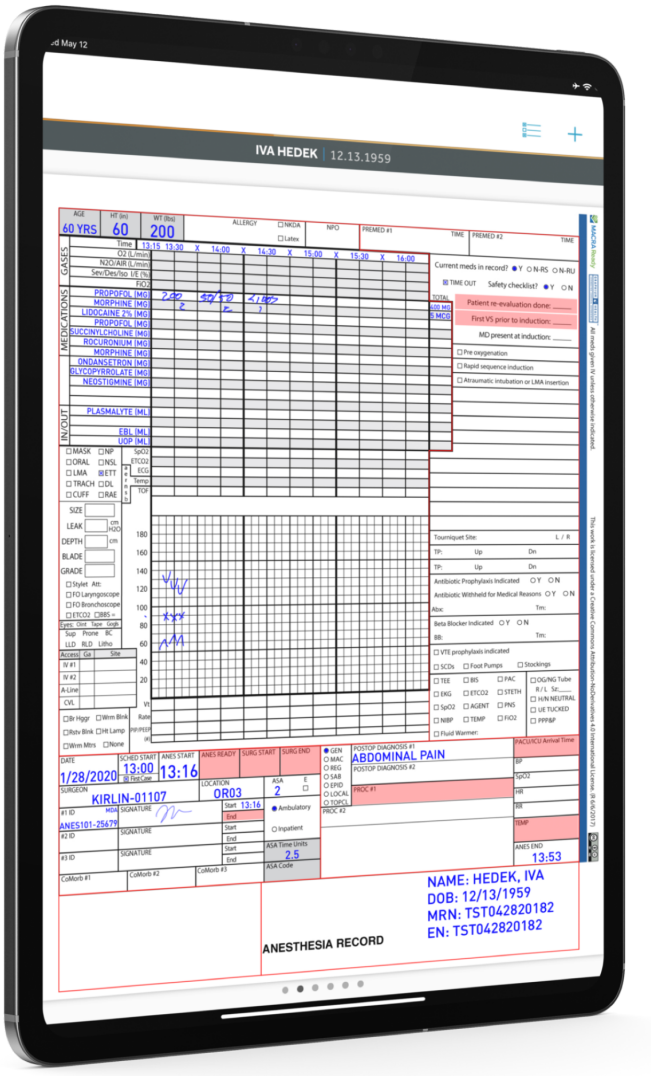
GRAPHIUM HEALTH

Wireless Assessment and Remediation



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3 Introduction

3.1 Project Background

GraphiumEMR is an IOS-based, mobile-first platform for anesthesia end users, and as such these users rely on robust WIFI and internet connectivity in order to quickly and reliably capture data at the point of care. We have many customers who have implemented Cisco network infrastructure at their hospital and surgery center facilities. Experience has shown us that various connectivity issues can manifest for IOS device users as they traverse these facilities, and that an optimal IOS/Cisco configuration, in particular, can be elusive. The purpose of this document is to provide specific recommendations to IT staff at such facilities based on a real Graphium implementation at a Cisco facility in order that they may further optimize their respective environments for Graphium and other IOS end users.

3.2 Audience

This document is intended for use by any/all IT personnel responsible for implementing and/or maintaining wireless network infrastructure in an environment where IOS devices are being used.

3.3 Scope

The scope of this document is to provide an overview of past findings related to a Graphium implementation at a Cisco-based hospital, and outline the changes necessary to remediate them.

4 Assessment

Complaints were being registered by the staff using the iPads with the Graphium software. The program was losing data because of what appeared to be a roaming issue. The complaints were coming from two different areas of the hospital ´ Endoscopy and PACU. As a result, the focus was in these areas. Many findings and issues will be identified in this section. These will be further explained in later sections.

4.1 Cisco Wireless LAN Controller (WLC)

After a better understanding of the user experience, the focus shifted to the WLCs and APs. Both WLCs are 5520s, and the APs are 3802i, so the hardware is quite good and recommended. Additionally, while the firmware wasn̊t the latest s̄table and recommended version, it was still

good. In the configuration itself, however, issues were found with the configuration upon inspection. Some of these were:

- Incorrect roaming configuration to optimize for Apple devices
- 2.4 GHz and 5 GHz enabled on the SSID used for the iPad devices
- Lower data rates enabled

4.2 Endoscopy Area

The Endoscopy area is rather compact and has a main thoroughfare where most users would be walking, thereby concentrating the traffic in that area. Initial assessment of the area showed a considerable amount of Co-Channel Interference (CCI), Adjacent Channel Interference (ACI), and a lack of usage of UNII-1 channels in the 5 GHz band. Mitigating these issues initially became paramount to have any real chance of addressing roaming problems. Outside of those issues, there was plenty of coverage and there was more than enough good signal. This indicates that a full survey would not be necessary at this point as there were too many known issues to mitigate prior.

4.3 PACU Area

The PACU area is more open than the Endoscopy area, and didn't necessarily have a consistent thoroughfare like Endoscopy. Initial testing showed the Radio Frequency (RF) environment to be clean, thus making this area ideal for initial issue isolation and troubleshooting. Like Endoscopy, there was plenty of coverage and more than enough good signal. Again, a full survey would not be necessary here until progress was made resolving the known issues.

5 Remediation Efforts

As discussed, several different issues were found during the initial investigation. Therefore, it was important to address these one by one and perform validation testing after each one to attempt to isolate the results. A list of these efforts is below.

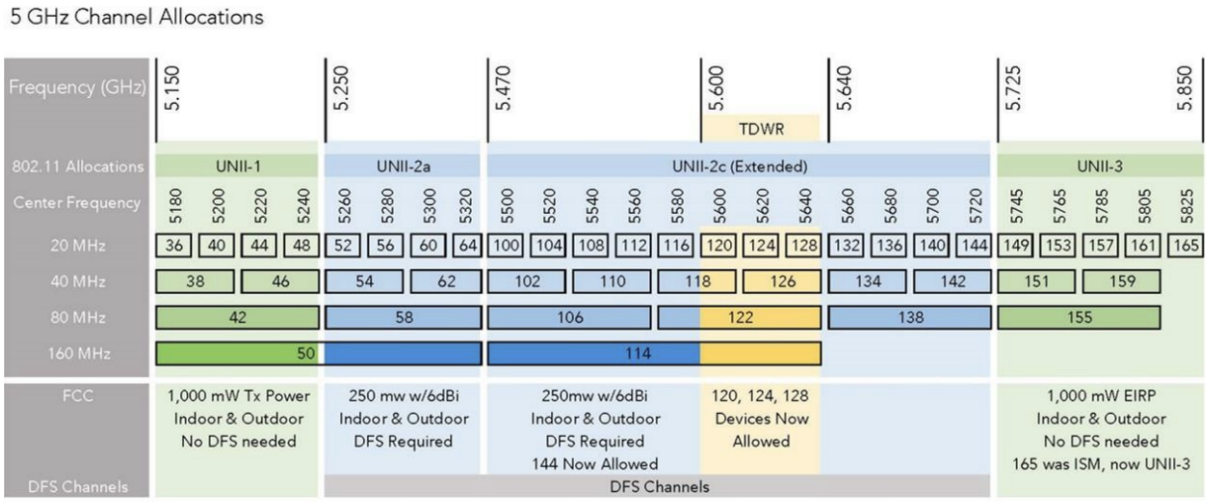
5.1 5 GHz

Only The SSID being used for the iPads, mobiledevices, was set to use both the 2.4 GHz band as well as the 5 GHz band. 2.4 GHz is rife with interference, only has 3 available channels which makes channel planning and the avoidance of CCI and ACI far more difficult, and is generally less effective than 5 GHz. 5 GHz is more resistant to interference from non-WiFi sources, has a

few multiples of more available channels, is capable of faster speeds and higher capacity, and is preferred by modern devices. Therefore, and especially in a hospital WiFi environment, every effort should be made to disable 2.4 GHz and only utilize 5 GHz. While this in itself is a larger discussion, the option was available to disable 2.4 GHz on mobiledevices, so this was done.

5.2 Channel Preferences

Below you will find an image showing the channel breakdown of the 5 GHz band.



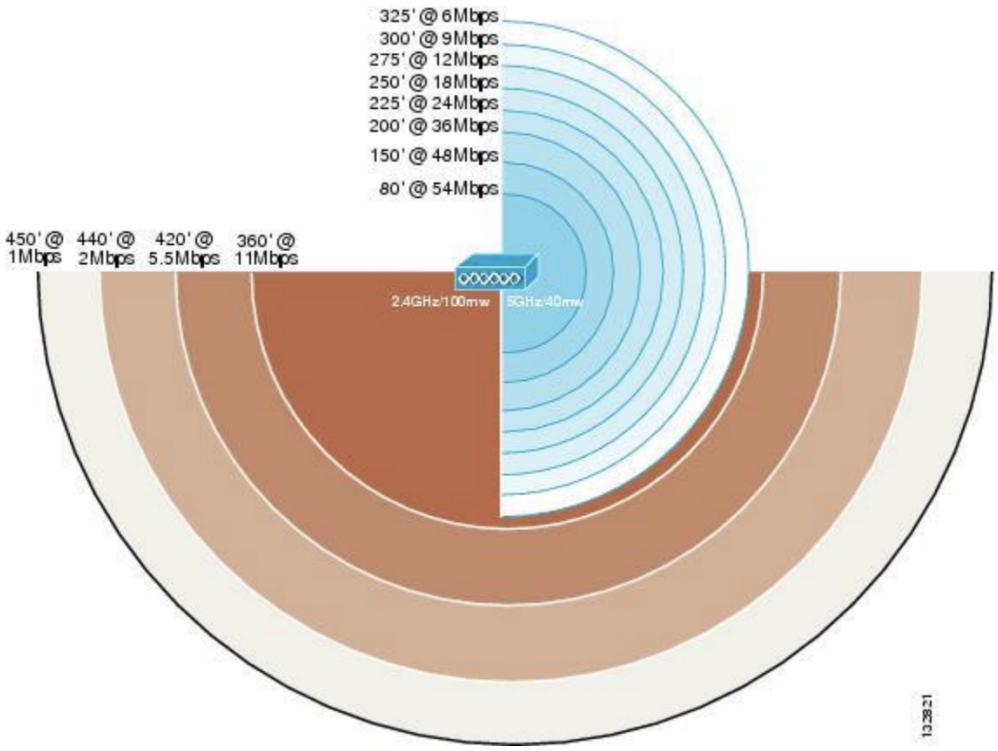
Note the 802.11 Allocations, called UNII-x. 20 MHz channel width (which is recommended) is in use in this environment, so that is the channel breakdown relevant to this discussion.

5.3 Disabling Lower Data Rates

Lower data rates were found to be in use throughout the WLAN. This is not best practice, nor is it ever desired.

Data rates vary by band and are configurable within the wireless controller. Cisco allows different options with each data rate, such as disabling them, or making them mandatory, or optional (called supported). Setting a data rate to mandatory means that if a client does not support that rate, the controller will not allow that client to associate with the Access Point.

The figure below was created by Cisco and it shows Free Space Path Loss (FSPL) - which is the propagation of RF signal with nothing but air preventing it ´ of an AP in both the 2.4 GHz and 5 GHz bands. This figure illustrates the data rates and the distances they can achieve. The data represented is in a “perfect” environment and is not meant to be taken literally. With that said, it does a great job of illustrating that as the data rates get lower, the distances at which a user can connect are greater.



The current configuration is allowing the use of the lower data rates. These lower data rates allow for a bit more coverage, but they also hurt the capacity and efficiency of the wireless network. Because of the different modulation techniques used by each different data rate, the lower data rates require more bandwidth for management. This “clogs” the wireless environment by taking up bandwidth. If these lower data rates are disabled (such as 6 Mbps, 9 Mbps, & 12 Mbps in the 5 GHz band at minimum), it frees up bandwidth. Further, this results in clients roaming faster and more effectively as they will not hang on to an AP until the last minute as they would on the lower data rates. This results in mobility that is much more effective.

5.4 Apple iPad Firmware (iOS version)

The iOS of the iPads was found to be an older version ´ 12.4 in many cases. After upgrading the iOS to 13.1, testing indicated immediate improvements with roaming. Since roaming is ultimately decided by the client device, this makes sense.

5.5 Switch Port Configuration

At this point, enough productive changes had been made to focus on any remaining issues. When watching the roaming paths, it became apparent that some APs were not involved. To investigate this, an inspection of the network infrastructure was warranted. The switch ports were found to be inconsistently configured, and all switch ports should have uniform configurations throughout (except in unique cases). Once the outliers were correlated to the specific APs, these outlier port configurations matched the APs not involved in the roaming paths that should have been. The switch ports were configured to allow the correct VLANs and to eliminate any superfluous additions. This change added the missing APs back into the environment and stopped them from dropping client traffic if their corresponding APs were targeted by a client device attempting to roam. There were still 5 ports with connected APs ´ one on each floor ´ that didn̓t match any other port configuration. These were incorrectly configured for any appropriate use in a WLAN.

5.6 AirPrint

These 5 outlier APs were configured as they were to make Apple's "AirPrint" work. This is what the iPads use to discover printers and in turn allows the software to print to a nearby printer. Each of these APs was put into the relevant wired floor VLAN (e.g. - 2nd floor wired VLAN for the 2nd floor) instead of being in the correct WiFi management VLAN that is home to the WLCs and all other APs.

This was done at some point in the past to make the WLC "network aware" of the 5 floor VLANs. Because the printers are in those 5 networks, and because those networks didn̓t have a wireless function, the WLC had no knowledge of them and in turn did not know how to find them or the devices therein.

So, a virtual interface was created for each of these 5 VLANs on the WLCs. This made the WLCs aware of them, and after configuring appropriate forwarding of multicast traffic, this allowed any wireless clients to query those networks for printers.
Once this functionality was confirmed, those 5 APs were configured correctly and put back into the WLANs as they should be.

5.7 Cisco Radio Resource Management (RRM)

This function "acts as a built-in RF engineer to consistently provide real-time RJ management" (Cisco̓s own words). Essentially, this feature will dynamically adjust power, channel assignments, and more based on its analysis of the WiFi environment. RRM was previously configured to scan and adjust every 10 minutes. This means that an interference event could occur, and it could be a full 10 minutes before any mitigation attempts were made. The option to change this to "pre event" meaning that RRM will scan and adjust at the occurrence of any "event" – was available and not service affecting. So, as a final tuning adjustment, this was activated.

6 Survey Results and Analysis

At the conclusion of the 7 major remediation efforts, roaming was working effectively, and enough issues were resolved to move on to a survey to look for further tuning needs.

6.1 Heat Map

In this section, you will find a heat map of the environment. This visual heat map shows only the strength of the RF signal for the indicated area. As a reference, there are three different categories in which to group the signal strength. These are:

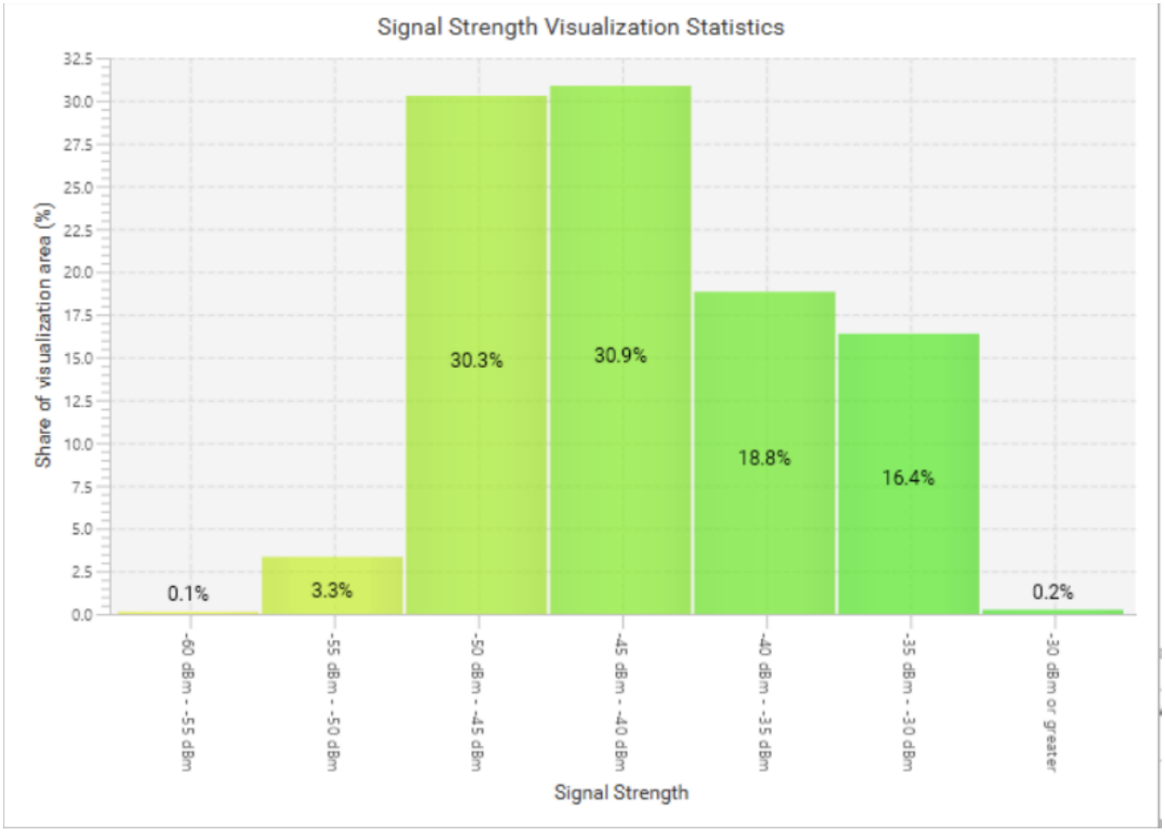
“Want” -67dBm and up. This is considered a good, usable signal for data, voice, and video requirements. Indicated by any shade of green. Though anything -72dBm and above is considered sufficient for data coverage, in a hospital environment -67dBm is a far better and healthier standard.

“Don’t Want”-82dBm through -68dBm. This is not good. This signal is good enough to be seen by wireless clients, but not good enough to actually use. This signal region wreaks havoc for user devices. Indicated by any shading of gray.

“Don’t Care”-83dBm and down. This signal has no bearing on the usability at all. Indicated by white. Also represents the absence of signal data.

* Please note that this is a partial survey, conducted in such a way to only hit focal areas that were relevant to the reported issues. The white area is not indicating a problem, but rather an area that simply wasn't captured.

Next is a breakdown of the signal by percentages in the area surveyed. Both images indicate there is no issue with having enough coverage. There is good signal in every location.



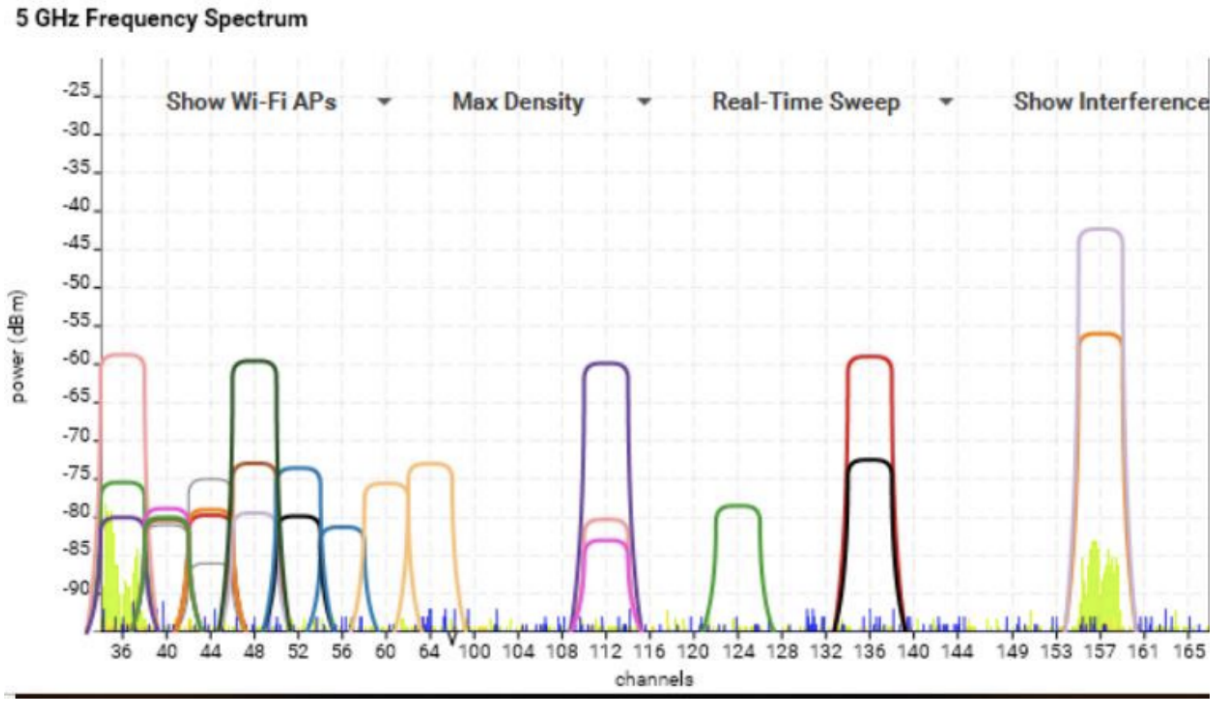
6.2 Interference

We aren't seeing much outside interference at all on the 5 Ghz band which is great and expected in that band. What we are seeing is some Co-Channel and Adjacent Channel interference. Co-Channel Interference (CCI) is caused when there exists more than one source on the same channel. Adjacent Channel Interference (ACI) is similar, but when there is a source of signal just beside the intended channel. As the signal strength increases, so does the overlap and this causes a disruption.

The below image shows a breakdown of the channels in use by any source, and is a great example of the environment overall. It was difficult to find any non-hospital WiFi on the 5 GHz band. But in this specific instance you can see one and it is the Wireless Network Interface Card (Wireless NIC) of a client device.

Radio	SSIDs	Tech.	Data Rt.	Ch.	Si...
Cisco (66:2*)	[redacted]	a n ac ax	18-288.9M	157	-41
Cisco (ab:6*)		a n ac	18-288.9M	157	-55
Cisco (7d:e*)		a n ac	18-288.9M	64	-57
Cisco (d5:6*)		a n ac	18-288.9M	36	-59
Cisco (52:4*)		a n ac	18-288.9M	48	-60
Cisco (4d:6*)		a n ac	18-288.9M	112	-61
Cisco (d0:8*)		a n ac	18-288.9M	136	-61
Cisco (d2:2*)		a n ac	18-288.9M	64	-71
Cisco (ed:4*)		a n ac	18-288.9M	136	-72
Cisco (ea:e*)		a n ac	18-288.9M	48	-73
Contec (57:7a)		a	6-54M	44	-73
Cisco (03:a*)		a n ac	18-288.9M	60	-74
Cisco (ba:e*)		a n ac	18-288.9M	36	-75
Cisco (d6:c*)		a n ac	18-288.9M	52	-78
Cisco (7d:e*)		a n ac	18-288.9M	124	-79
Cisco (21:e*)		a n ac	18-288.9M	40	-79
Cisco (a0:2*)		a n ac	18-288.9M	40	-79
Cisco (2d:8*)		a n ac	18-288.9M	36	-79
Cisco (fa:6*)		a n ac	18-288.9M	52	-80
Cisco (73:4*)		a n ac	18-288.9M	40	-80
Cisco (e4:a*)		a n ac	18-288.9M	44	-80
Cisco (97:8*)		a n ac	18-288.9M	48	-81
Cisco (87:4*)		a n ac	18-288.9M	56	-81
Cisco (ea:c*)		a n ac	18-288.9M	112	-81
Cisco (0a:e*)		a n ac	18-288.9M	44	-82
Cisco (d4:0*)		a n ac	18-288.9M	36	-83

However, in the next image you can see multiple sources of coverage on the same channels and these can cause the CCI we detected.



6.3 Channels

Referring to the same image, we see congestion in the UNII-1 band, and not much use elsewhere. Utilizing all available channels will improve the health of the WiFi environment, and that really cannot be overstated. There are some older devices that are still not compatible with UNII-2 Extended channels, so be mindful of that if you have any devices having trouble connecting.

6.4 AP Density

What we see in the channel analysis is also indicative of too much coverage. Looking at the APs heard at each location (next image), we find an overabundance of coverage. This is actually hurting the health of the environment and making roaming more difficult.

In some areas surveyed, we can see over 20 APs sourcing signal that can be detected by user devices.

6.5 Issues Summary

What we see here is confirmation that, of all of the other findings, there remains two major issues: Channel interference, and resulting data loss.

S.Str -Signal Strength - Indicates areas where signal strength is not sufficient.
#APs - Number of APs - Indicates where too many APs are present in a given area.
Data - Data - Indicates where too much data is clogging the wireless environment.
SNR - Signal to Noise Ratio - Indicates where the RF noise is too high and is impacting the signal.
RTT -Round Trip Time - Indicates areas where the RTT for pings is too high.
Loss - Data Loss - Indicates where the data is not returning and is a complete loss.
Ch.I - Channel Interference - Indicates where there are 2 or more radios transmitting on the same channel.

7 Recommendations

There are still some recommendations to further improve the wireless environment. It should be noted that the best recommendation is a redesign of the environment to bring this to a properly functioning medical grade wireless network. In the meantime, these recommendations will help.

7.1 Firmware

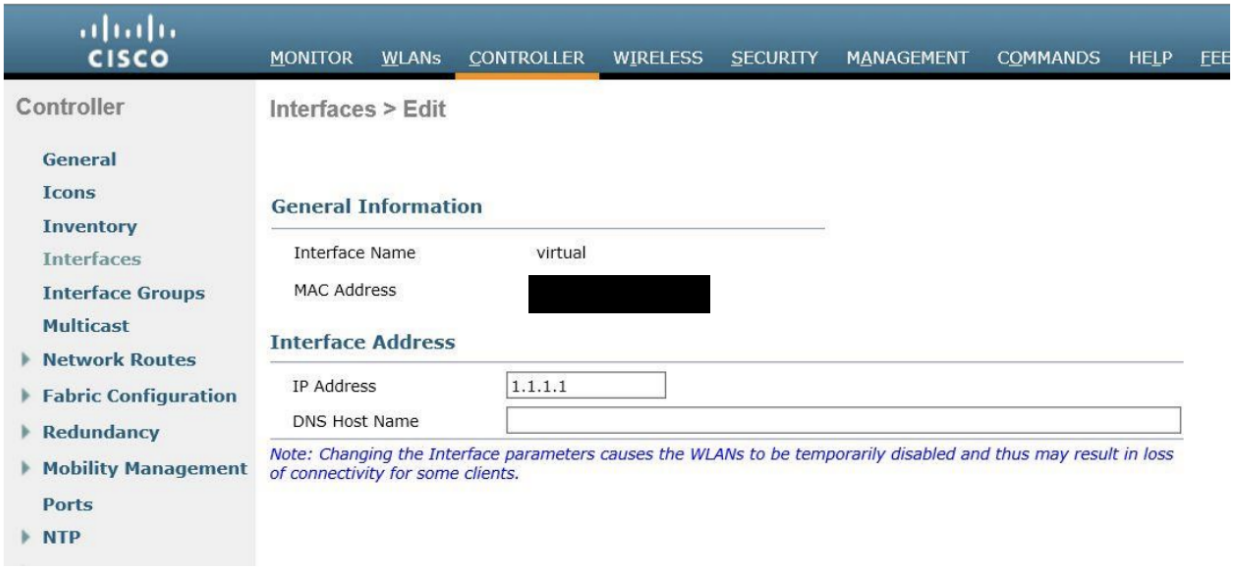
The Cisco 5520 WLCs are running version 8.5.140.0, and the APs are running version 8.1.102. Though this is not necessarily problematic, it is recommended to upgrade the firmware to the latest stable version of code. As of the writing of this document, that is 8.5.151.0. The newest version of code is 8.9.111.0, but it is never recommended to go to the newest firmware, especially in a hospital environment, as that version has not had enough time since its release to properly identify and address any bugs. The firmware upgrade will require both controllers to reboot, and is service affecting.

7.2 Disable 2.4 GHz, Optimize for 5 GHz

In a perfect world, we would just disable 2.4 GHz globally and be done with it thereby avoiding so many common interference sources. However, there are known devices at the hospital that still require 2.4 GHz. It is recommended to create an SSID just for 2.4 GHz devices and only broadcast this SSID on about half of the APs (2.4 GHz travels further than 5 GHz). For the remaining SSIDs, disable 2.4 GHz altogether. This change allows you to optimize the configuration for those WLANs for 5 GHz and will improve the overall health and effectiveness.

7.3 Virtual IP Address

Set a new Virtual IP of 192.0.2.1 instead of 1.1.1.1. The address of 1.1.1.1 used to be the standard assignment. And although this has always been a publicly routable IP address, it has recently been activated and is now a live address on the internet. Due to this, it is known to cause some strange issues. Therefore, it is best avoided. Note that this change will cause a brief loss of service for the entire WiFi environment. Below is an image of where this can be changed.



7.4 Switch Port Configuration

Ensure a uniform configuration for the switch ports with connected APs. A good example for this is shown below. Just change the interface and the description. All else should remain the same.

interface TwoGigabitEthernet1/0/4
description 2-EastWing-AP03
switchport access vlan 10
switchport mode access
auto qos trust dscp
service-policy input AutoQos-4.0-Trust-Dscp-Input-Policy
service-policy output AutoQos-4.0-Output-Policy

7.5 Data Rates

Most of the Tower data rates have been disabled, effectively shrinking cell size. Consider disabling the next rates up as well to further shrink the cell size. This will aid in roaming and will allow the WiFi to work more efficiently, resulting in higher capacity and user device speeds. This will be a helpful change, but be mindful that too much signal retraction can cause coverage holes.

7.6 SSIDs

A Service Set Identifier (SSID) is a unique identifier included on the header of 802.11 packets to indicate a specific wireless network. Each SSID requires a certain amount of airtime and bandwidth to advertise and manage itself. Increasing the number of SSIDs means more required airtime to be used for

administration. The table below shows the estimated calculations of the percentage of loss per SSID count on an individual Access Point. Three SSIDs is the maximum recommended number on any AP (or more accurately, on any radio).

Wi-Fi SSID Overhead Calculator

VARIABLES:	
Beacon Data Rate (Mbps	802.11b 1 Mbps
Beacon Frame Size (Byt	380
Beacon Interval (ms)	102.4

ASSUMPTIONS:
802.11b Long Preamble used for 1 Mbps; Short Preamble used for 2, 5.5, 11 Mb
802.11g short slot time is assumed, with no 802.11b clients within range
WMM is enabled and beacons are transmitted using Best Effort AC

Amount of Overhead:		0-10% Low	10-20% Medium	20-50% High	>50% Very High	

Number of APs on Channel*	Number of SSIDs 1	2	3	4	5	6	7	8	9	10
1	3.22%	6.45%	9.67%	12.90%	16.12%	19.35%	22.57%	25.80%	29.02%	32.25%
2	6.45%	12.90%	19.35%	25.80%	32.25%	38.70%	45.14%	51.59%	58.04%	64.49%
3	9.67%	19.35%	29.02%	38.70%	48.37%	58.04%	67.72%	77.39%	87.06%	96.74%
4	12.90%	25.80%	38.70%	51.59%	64.49%	77.39%	90.29%	100.00%	100.00%	100.00%
5	16.12%	32.25%	48.37%	64.49%	80.62%	96.74%	100.00%	100.00%	100.00%	100.00%
6	19.35%	38.70%	58.04%	77.39%	96.74%	100.00%	100.00%	100.00%	100.00%	100.00%
7	22.57%	45.14%	67.72%	90.29%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

There are more than this in use in the example WiFi environment. As the table below shows, a little more than 3.2% of airtime is lost with each additional SSID. When just 6 are being broadcast, it results in a loss of 19.35% of potential airtime. And that is before any clients are talking.

Though a maximum of three SSIDs is not always possible, it is strongly recommended that the total number of SSIDs be reduced as much as possible.

7.7 Summary of Recommendations

All of the issues found can be remedied with a proper redesign of the wireless network. Fortunately, the hardware is great, so new equipment would not be necessary. In the meantime, there are recommendations that will improve things. A summary of the recommendations discussed is below:

1. Upgrade the WLC firmware
2. Disable 2.4 GHz, and optimize for 5 GHz coverage
3. Change the Virtual IP address on the controller
4. Make the AP connected switch port configurations uniform
5. Disable lower data rates as much as possible
6. Reduce the number of SSIDs

After these have been resolved, it is our recommendation to have another on-site survey done to capture data within the new WiFi environment. This will validate the design, implementation, and the health of the new wireless network overall.

To reiterate, the best next step though a difficult and time consuming one is to redesign the entire wireless network to implement a proper medical grade wireless design.