# Optimizing The Home: MoCA and Wi-Fi

An Operational Practice prepared for SCTE/ISBE by

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# Introduction

Today's home network design is driven by increased coverage requirements and significantly higher capacity demands, which means - customers are no longer satisfied with limited wireless connectivity throughout a home and less than satisfactory download speeds. By infusing a Multi-Media over Coax Alliance (MoCA) backbone with 802.11ac Wi-Fi access points, Gigabit home services will soon be a widespread reality in residential and small business broadband services. Elevating broadband services to this level is absolutely necessary since customers are prone to targeting the service provider for problems with their broadband experience, when in reality it's quite possible that the customer's home network contributes to the problem. By going to the method of service delivery outlined in the following pages, and associated presentation, MoCA Wi-Fi solutions will improve customer satisfaction, reduce trouble calls and subsequent trouble tickets and truck-rolls. The main purpose of this operational practices paper is to establish a technical launching point for better understanding MoCA and 802.11ac systems, and also, to provide implementation considerations. First, MoCA is described, followed by 802.11ac and finally installation considerations are given.

MoCA 2.0, which is backward compatible with MoCA 1.1, provides a baseline mode of 400 Mbps, and an enhanced mode 800 Mbps by combining two 100 MHz channels. There is a "Turbo" option for one Gigabit in point-to-point connections. While many home networking solutions have provided expanded connectivity and somewhat increased throughput for the average residential customer, these solutions have not provided a reliable system with low packet loss or low latency. MOCA 2.0 supports a packet error rate of 1 in 100,000,000 ($10^{-8}$) with 3.6 millisecond latency and a wide spectral function from as low as 400 MHz up to 1675 MHz. Also, with the newer MoCA 2.5, many more enhancements are possible.

802.11ac is a 5 GHz Wi-Fi solution that provides 1.3 Gbps with Phase-I and 7 Gbps with Phase-II deployments. However, actual real-world deployments experience somewhat less throughout. For example, to obtain 1.3 Gbps, the access point and client must support 4 spatial streams and use an 80MHz bonded channel. Another way to describe a spatial stream is thinking of it as a radio signal. In some cases, each stream carries separate data to primarily improve throughput, and in other cases, multiple copies of the same data sent to improve reception. In reality, most devices still support, at most; two spatial streams and can operate with either the base channel size of 20 MHz, or possibly two bonded 20 MHz channels for a single 40 MHz channel. A word of clarification is required at this point – 802.11ac does not operate in the 2.4 GHz range, yet many 802.11ac Wi-Fi Access Points (AP) do support the 2.4 GHz band. As we will learn in this paper and accompanying presentation, there are several 5 GHz bands available, which help to improve the wireless performance significantly because currently there is very little congestion or co-channel interference in the 5 GHz Wi-Fi bands, which also improves data throughput. However, just these factors are not sufficient to completely revolutionize the end user experience. Coverage MUST be increased so there are virtually – no "dead spots" or "low speed zones" from the customer's perceptive. Hence, the MoCA backbone interconnecting multiple "ac" access points is the direction service providers should be considering. The cost of additional access points and modern dual or tri-band access points is potentially negligible when compared to cost of customer calls placed to technical support lines and unnecessary truck rolls to customer locations. The emphasis on "unnecessary" is because single AP installations are limited in terms of what can be done for these implementations, and especially if the AP is embedded within the cable modem.

## 1. MoCA

MoCA is an extremely efficient method of interconnecting devices via coaxial cable. The technology is overseen by the Multimedia over Coax Alliance, hence the term “MoCA”. MoCA 2.0, Media Access Control “MAC”, supersedes MoCA 1.1 with improved features. These features provide MAC efficiency for higher throughput and overall system performance, low latency, and offers seamless interoperability with MoCA 1.X legacy nodes.

Typical home coaxial cabling is configured as a branching topology. The point of connection from the outside plant via the Network Interface Device (NID) or Optical Network Unit (ONU), goes to the first splitter, which is called the *Root Node*. The maximum cable distance supported between the root and the last outlet is 300 feet with a specified loss of no more than 25dB. Additionally, MoCA uses a technique called “splitter jumping” to create a meshed network. The operation of splitter jumping means signals pass between devices by way of traversing splitter ports. This in contrast to the typical coaxial cabling methods where the goal is to distribute the all of the signals, data or video for example, over the entire network where the cable modem pulls off data and the set-top box (STB) pulls off video. Yet, the cable modem and STB have no need to communicate with each other. With MoCA, a person can watch content recorded in one part of the home, such as at the STB with the digital video recorder, and view the content somewhere else in the home.

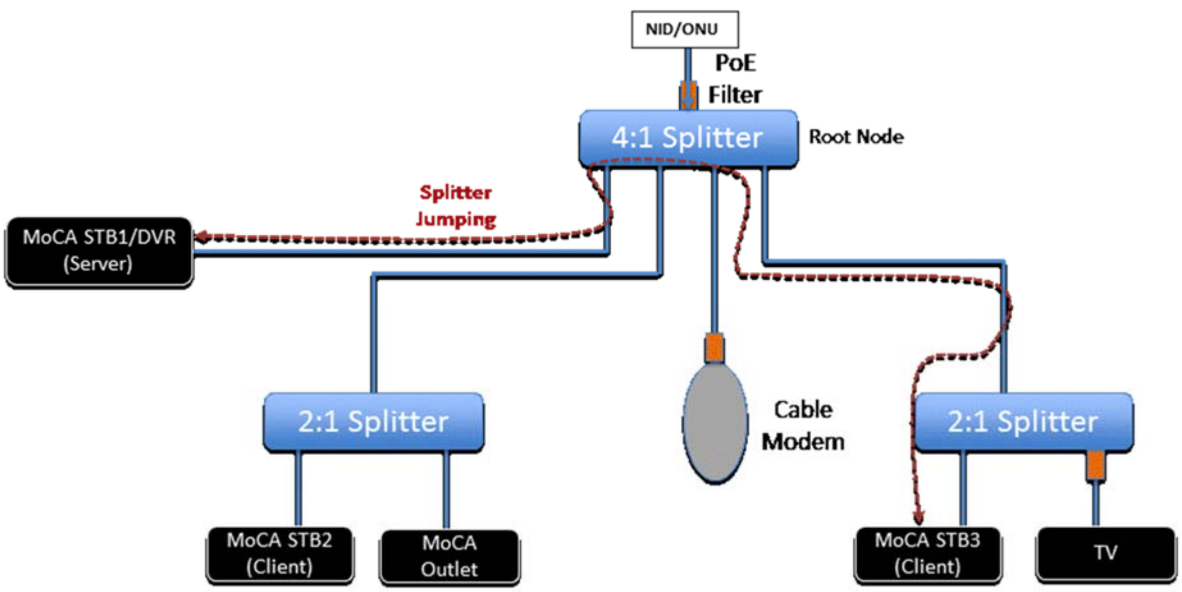



**Figure 1 – MoCA Network**

MoCA nodes communicate with each other over various channels provide spectrum for signals to traverse across one or more splitters. Signal path transmission between MoCA nodes may include superposition of several individual paths. Each signal path may have a different magnitude and delay resulting in an aggregate signal with frequency nulls, high attenuation, and significant delay spread. However, a MoCA Network uses orthogonal frequency division multiplexing (OFDM) similar to Wi-Fi and DOCSIS 3.1, and thus is designed to operate efficiently under these challenging channel conditions.

The previously mentioned channels actually comprise various frequency bands and operate at above HFC plant QAM channels. The next section covers each of the main MoCA bands The following provides a high-level overview of common MoCA channels and their associated characteristics:

***Extended band D*** occupies between 1125 MHz and 1675 MHz. Primary Channels are 100 MHz wide and are centered on a 25 MHz grid. Bonded-pair channels are 225 MHz wide with a fixed 25 MHz gap between the bonded pair of channels. Additionally, one can increase throughout by bonding channels as shown in Figure 2, or, operate two independent networks at shown in Figure 3.

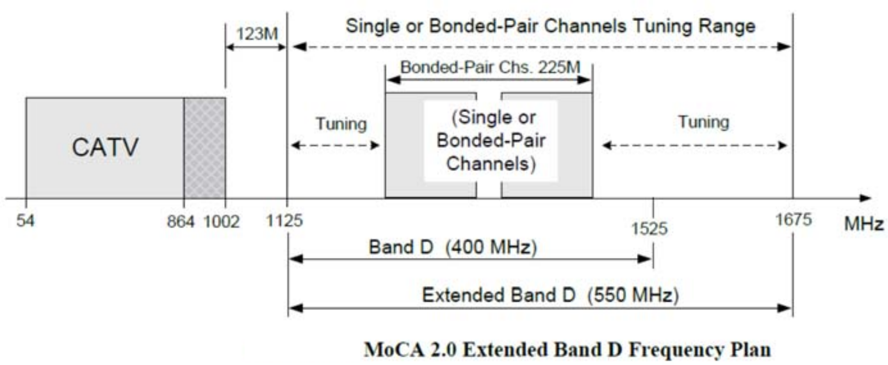



**Figure 2 - MoCA 2.0 Extended D-Band Bonded Channels**

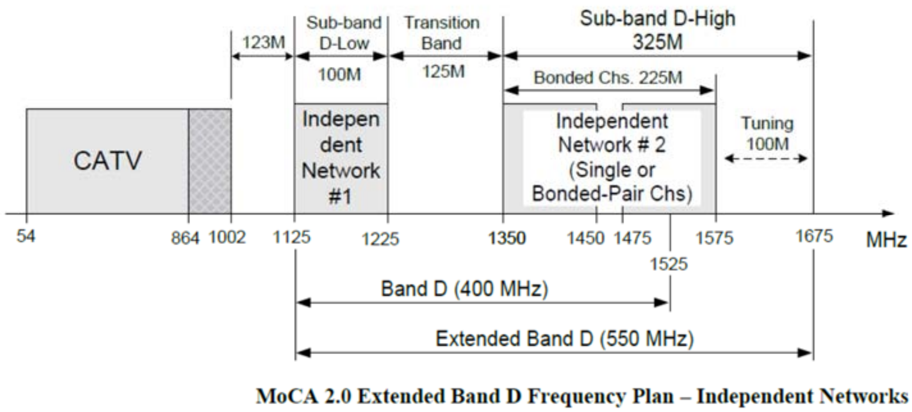



**Figure 3 - MoCA 2.0 Extended D-Band Dual Networks**

Below are the primary "D" channels blocks used in MoCA 2.0:

- Sub-band D-Low (DL): 1125 to 1225 MHz edge to edge (100 MHz wide)
- Sub-band D-High (DH): 1350 to 1675 MHz edge to edge (325 MHz wide)
- Guard-band between sub-bands: 1225 to 1350 MHz (125 MHz wide)

This spectrum allows:

- Single channel or bonded-pair channels operation in extended band D
- Two independent networks on shared coaxial medium

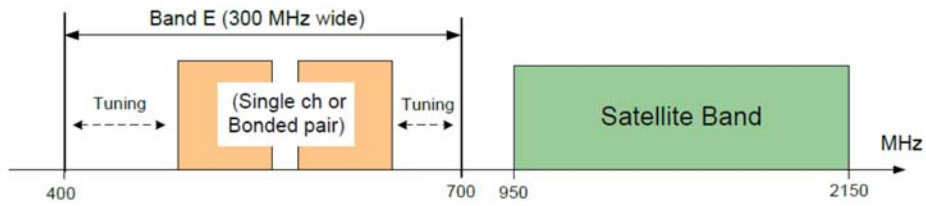
 

- Network 1: Single, non-bonded-pair, channels operating in sub-band **D-Low**
- Network 2: Single channel or 2 bonded-pair channels in sub-band **D-High**

- Mixed Mode operation anywhere within the extended band D

***Band E*** occupy frequencies between 400 MHz and 700 MHz.

Just like Extended-D, MoCA 2.0 single channels in this band are 100 MHz wide and centered on a 25 MHz grid and can tune in 25 MHz increments. Bonded-pair channels are 225 MHz wide and have a fixed 25 MHz gap between them where both the Primary Channel and Secondary Channels are centered on the 25 MHz grid.




**MoCA 2.0 Band E Frequency Plan with Single or Bonded-Pair Channels Example**

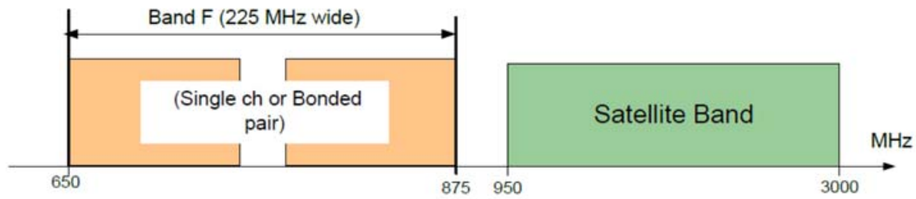
**Figure 4 - MoCA 2.0 E-Band**

This spectrum allows:

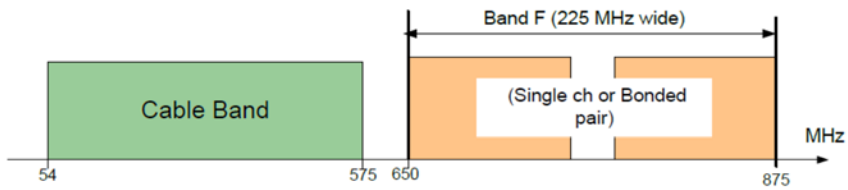
- MoCA 2.0 single channel or bonded-pair channels operation in Band E
- Mixed-mode operation (MoCA 1/MoCA 2.0) in Band E

***Band F*** occupies frequencies between 650 MHz and 875 MHz. This band is really two separate bands: F*sat* (for satellite) and F*cbl* (for cable). Both have the same channel plan but differ in some of the other requirements.




MoCA 2.0 Band $F_{SAT}$ Frequency Plan with Bonded-Pair Channels Example




MoCA 2.0 Band $F_{CBL}$ Frequency Plan with Bonded-Pair Channels Example

**Figure 5 - MoCA 2.0 F-Band**

And just like “D” and “E”, MoCA 2.0 single channels are 100 MHz wide and centered on a 25 MHz grid, which can tune in 25 MHz increments. Bonded-pair channels are 225 MHz wide and have a fixed 25 MHz gap between them where both the primary channel and secondary channels are centered on the 25 MHz grid.

This spectrum allows:

- MoCA 2.0 single channel or bonded-pair channels operation in Band F
- Mixed-mode operation (MoCA 1/MoCA 2.0) in Band F

## 2. 802.11ac

Wi-Fi has evolved to “Gigabit” heights, yet many still think about a single AP solution for most homes, and especially if this single AP uses only the 2.4 GHz band, there is no way to achieve Gigabit speeds throughout the home, especially given the congestion that currently plagues the 2.4 MHz band.

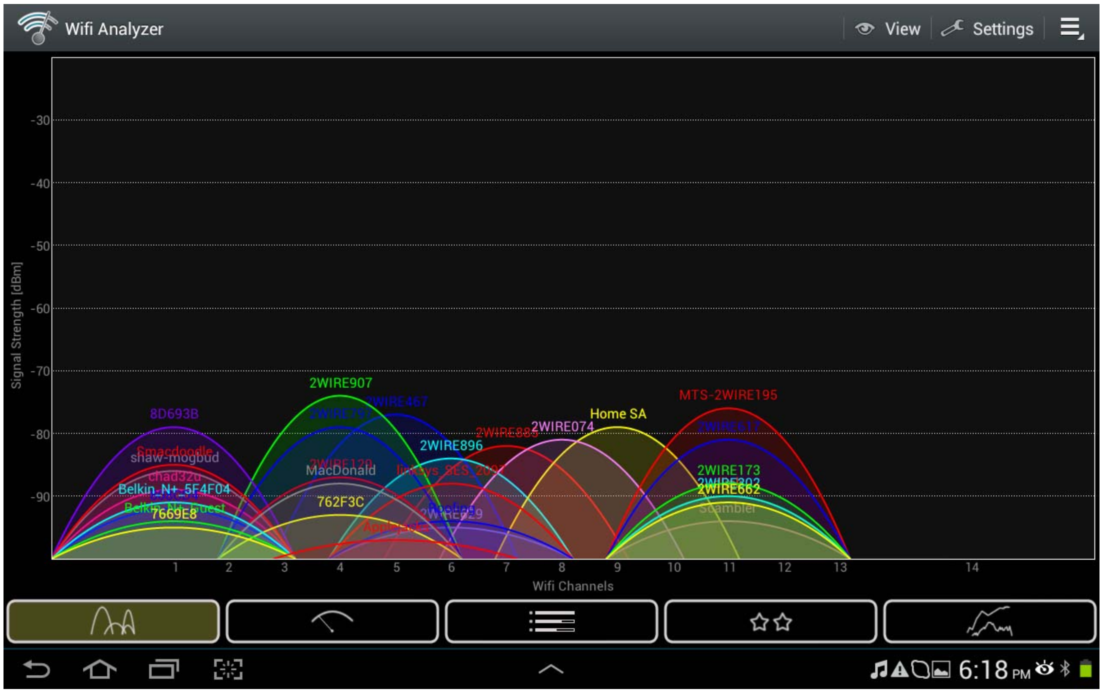



**Figure 6 - Crowded 2.4 GHz Spectrum**

Yet, even with 802.11ac, coverage and throughput is still affected by; distance from the AP, building materials and the number of users in a given coverage area, which is known as a Basic Service Set (BSS). And, as with any RF signal, the further one is from a transceiver – the lower the signal-to-noise ratio (SNR), and the more difficult it is for RF receivers to distinguish between the transmitted signal and the noise floor. The latter means that as one moves away from say an AP, data throughput is reduced. True, 802.11ac supports many benefits over legacy standards, which is part of the reason why so many still embrace the single AP implementation.

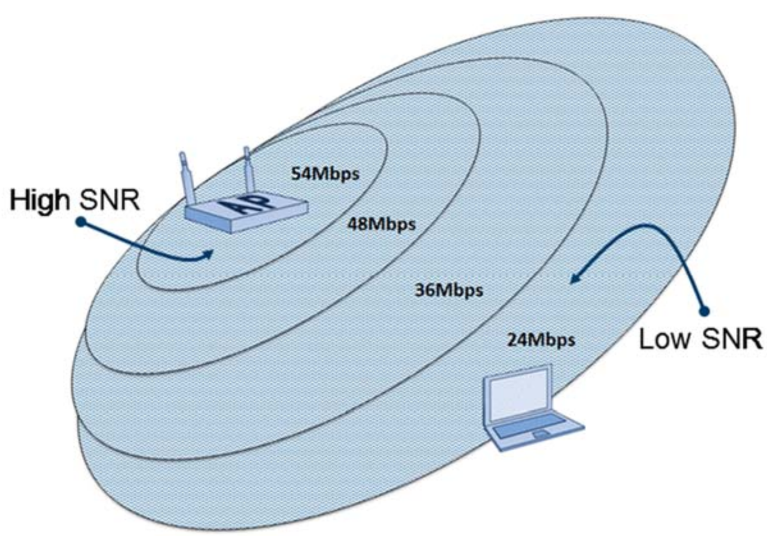



**Figure 7 - Wi-Fi Data Rate vs. Distance**

In addition, 802.11ac is strictly a 5 GHz technology working in the Unlicensed National Information Infrastructure ("UNII"). This is notable because the 2.4GHz spectrum, or Industrial Scientific & Medical ("ISM") band is severely crowded, and, limited to three non-overlapping channels; 1, 6, & 11. While there are eleven channels available, the three channels listed are the only channels that are able to maintain 25 MHz of channel separation. When one moves off either these channels, then the potential for adjacent channel interference can become a factor. Whereas, the UNII band currently has 12 channels, and will have even more in the very near future. The reason for pointing out the 802.11ac channel plan in the accompanying presentation, is because having more channels to choose from, further reduces the likelihood, if not eliminates, co-channel interference that currently plagues many Wi-Fi installs. Simply stated; only having three non-overlapping channels in ISM/2.4GHz band limits what installers can do, versus having 12+, or soon 30+ channels in UNII/5GHz band to choose from.

Consider this - if there are 2, 3 or 4 APs throughout a structure, the chances of being close to one is MUCH greater, and, the corresponding SNR in a BSS generally produces a higher throughout the entire structure. Another point of clarification; having 2, 3, or 4 APs does not necessarily equate to twice, three times or quadruple the cost. Ideally, a single strategically located AP controller manages simpler APs everywhere else in the structure. These "simple" APs are transceivers, which convert Wi-Fi frames to Ethernet frames, without advanced services such as routing, filtering and DHCP. Outside of this type of solution, there are many types MoCA bridges that convert MoCA to Ethernet.

## 3. Implementation

This next section provided general guidelines for effectively taking a customer from legacy topologies to the previously described heights of improved customer experience. Keep in mind, the upfront work needed to make Gigabit home services a reality, is carefully pre-testing a number of solutions, and negotiating with vendors to reduce the capital expenditures (CAPEX) per install overall. Over time, possibly several months, this cost should become negligible due to the potential for reduced customer complaints.

The following is a high-level installation and testing overview for making Gigabit broadband a reality. Steps 1-5 outline MoCA tips, with steps 5-9 outlining Wi-Fi tips:

**STEP-1:** *Assess the current cabling of the customer's home.* This is crucial because MoCA will demand more from coaxial cabling than existing services. Far too often, tract-home builders use whatever they can get, in abundance, and at the lowest cost. Also, in some instances, the coax is basically "old" and deteriorating; exposed braid, corroded connectors and excessive macro bends. These factors alone, can be attributed to lack-luster performing broadband services, but will definitely become an issue when setting up the MoCA backbone. When in doubt; pull out the old and install new. Yes, this may lead to longer installs, but a reduction in daily installs will be of little concern when compared to a reduction in calls placed by the customer to technical support immediately after installs.

**STEP-2:** *Determine the splitter arrangement* since MoCA uses splitter jumping, which provides for 2-way transmission over the coax cabling within the home. Now, the distance from what will become the root splitter to MoCA device becomes more than just a home-run, or possibly adding a line amp to extend the cable's reach. In fact, line amps CANNOT be installed downstream of the root splitter with MoCA due to splitter jumping. Also, the installer must maintain 300 feet, or less, between the NID/ONU and the root, and no more than 300 feet, or 25 dB of loss, from the Root Splitter to MoCA devices.

**STEP-3:** *Replace suspect cabling and splitters*, as they need to be able to support the higher frequencies used in various MOCA channel plans. Also, remove the endless cascades of splitters and install higher port density splitters. Note, the "cascade-effect" in many instances, is due to the customers becoming "Wikipedia Aware" and installing their own creative solutions. Also, keep in mind that older splitters will not support the needed cross port communication that MoCA uses, and again, may not support the higher frequencies.

**STEP-4:** *Install a Point of Entry (POE) filter* to prevent MoCA signals from leaving the customer location, which would otherwise be destined for the HFC plant without it. Additionally, POE filters, help to better manage the MoCA backbone signal level, overall. Lastly, some customers are reticent of getting rid their museum piece VCR, among other devices, thus installing a POE filter between the wall plate and the device will help to eliminate unwanted ingress signals, which emanate from the "classic" device.

**STEP-5:** *Attach MoCA devices and test*. Ensure devices have power from the backbone or AC adapter, as might be the case for customer owned APs. There are a number of MoCA testers available that can be sued to verify Ethernet connectivity characteristics and overall MoCA performance. And MOST IMPORTANT – have the customer check their wired Ethernet devices such as computers and printers as the testing progresses.

**STEP-6:** *Meet with the customer and discuss their wireless needs***.** Determine the number of devices and possibly which Wi-Fi standard these devices use. More than half of the time, the customer will not know this, so start asking probing questions; "When did you but *X*?" or if not sure with multi-purpose devices; "what do you do with it?". In the final analysis, you may simply need to setup the wireless network and ensure devices can connect 5 GHz channels. If some do not, then they are probably working legacy 2.4 GHz channels and a dual band 5GHz and 2.4 GHz AP configuration will be required. Also, find out how many people will home later in the day. What works with one-person home, may not work as well with two, three or more people, and their associated devices.

**STEP-7**; *Characterize the RF environment*; there are several options available from software based tools that provide Wi-Fi signal detection, which are loaded onto laptops or tablets. What these simpler analyzers do is detect Wi-Fi signal levels, measured in "dbm", on each of the 11 channels in the ISM and the 12 channels commonly found in the UNII bands. Also, use of handheld test equipment is highly recommended since they will also check for not only detectable Wi-Fi signal, but also low level Wi-Fi signals and interference. Optimally – *both should be used*.

The software analyzers are easy to use, and, provide results extremely quickly as a technician roams the structure. What one is looking for are neighboring Wi-Fi devices and non-Wi-Fi forms of interference. For the ISM band – this will be a busy place, thus, steering wireless device the UNII bands is highly recommend. Also, some customers use a variety of electronic devices which can lead to electromagnetic interface (EMI). Microwave ovens, baby monitors, home monitoring systems and wireless cameras are common issues in the 2.4 GHz band, which are better discovered using handheld test equipment since software based Wi-Fi analyzer tools won't see the signals. The handheld devices will find Wi-Fi networks that are not detectible to software spectrum analysis software, and also, characterize each room in the home. One manufacture provides a comprehensive Wi-Fi analysis using ALL Wi-Fi standards and associated data rates, and then, has the ability to send a "pdf" to any e-mail account with the results.

**STEP-8**: *Assess antenna placement and RF coverage*. One of the most significant limiting factors cable operators have today, is the fact that most Wi-Fi deployments rely on embedded APs within the cable modem. *It is currently infeasible to place the functionality of newer multi-radio chain 802.11n/802.11ac*

*APs into the size of a standard cable modem chassis*. *Notwithstanding the fact that a cable modem is a high power RF transceiver*!

What needs to occur for single AP solutions, is having the ability to change out AP antennas. For most considerations, the goal of going to a higher gain antenna *is not to increase power output and extend the coverage are, but to increase APs receive sensitivity, or basically stated – received signal level from Wi-Fi clients*. Without too much exception – APs out-power Wi-Fi clients, hands-down. For example, going from a 3 dBi antenna to a 6 dBi antenna will nearly double the transmit power and increase the coverage area, but, it will also nearly double the receive sensitivity. Keep in mind, the power needs to be closely monitored, and in most cases, reduced when going to a higher gain antenna. Take for instance a speaker at a conference. The speaker is using a PA system and everyone can hear him. But, if the speaker cannot hear questions – turning up his power to reach further out – will not help the situation. What needs to happen, is for the speaker to better hear the audience member at a louder level.

For multiple APs, it is much easier, as 802.11ac creates steering matrices for client devices and very little needs to be done with the AP. In fact, embedded antennas usually work just fine for "ac" APs.

**STEP-9:** *Meet with the customer and verify their wireless needs have been met.* This step is worth the time, without question. Deal with issues while the technician is still there. Also, note, here is a good time for an "upgrade" conversation with the customer who still has the desktop computer with a PCI Wi-Fi card, or the 8-year-old "DVD" player. As well, ensure security being used, such as WPA-2 or WPS, and that the security configuration is not preventing Wi-Fi clients from connecting.

# Conclusion

MoCA has numerous possibilities to improve customer intra-network and cable provided broadband experiences. There is now improved throughout if bonded MoCA channels are used. The IEEE standard 802.11ac has enumerable benefits as compared to legacy Wi-Fi. For example, the average Wi-Fi client ca accommodate two spatial streams on operate on 40MHz channel, which can easily yield 300 Mbps. Couple these two industries together and you get a more predictable broadband service delivery. Of course, no solution will ever serve ALL customers to their complete satisfaction, and performance metrics should be used. Because it makes no difference at the end of the day if you are feeding an IPv6 DOCSIS 3.1 network to a home riddled with older and much poorer-performing cabling and legacy Wi-Fi devices. Customer satisfaction is at the forefront of most cable operators these days, so the additional cost of better Wi-Fi solutions and slightly increased effort in installing them properly is not only aligned with this goal, but does so in one of the most critical areas for ensuring Gigabit speeds are indeed possible in the cable customers' premises.

# Abbreviations

| | |
|---|---|
| AP | access point |
| BSS | Basic Service Set |
| ISM | Industrial Scientific & Medical |
| HFC | hybrid fiber-coax |
| UNII | Unlicensed National Information Infrastructure |
| MHz | Mega-hertz |
| GHz | Giga-Hertz |

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|---|---|
| IEEE | Institute of Electronics and Electrical Engineers |
| MoCA | Multimedia over Coax Alliance |
| OFDM | Orthogonal frequency division multiplexing |

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