

Maximizing the Capacity and Reliability of a DOCSIS Network

A Technical Paper prepared for SCTE•ISBE by

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Introduction

With the arrival of DOCSIS® 3.1 operators have a fantastic new asset in their arsenal to provide industry leading broadband experiences. However, with great power comes great responsibility (and complexity). As we build and upgrade our DOCSIS networks, we need to also take the time to maximize their configurations to effectively utilize the new advances in technology, while also increasing resiliency and reliability. To get the most out of a DOCSIS network today, operators need to balance capacity and reliability to bring high-quality customer experience and services. As you maximize the DOCSIS network, you will build a strong foundation. With a strong foundation you can provide a solid framework for future DOCSIS technologies and services. This framework will ease future deployments to improve services.

Building the Mindset

Before you start the process of maximizing your DOCSIS network, you need to build a mindset of capacity building and customer experience. Understanding the future capacity goals for the next 2-3 years can be a huge benefit. Coming in with an understanding of hardware upgrades, plant upgrades, cable modem deployment plans, future packaging, network traffic CAGR, licensing and capital plans provides the information necessary for making strategic choices.

Upgrades, CCAP hardware or Cable Plant, will enable new features or capabilities that can provide solutions for capacity needs. With DAA, FMA, and FDX significant hardware and plant upgrades are coming. These will come with high capital costs and will take time to deploy. Understanding the timelines for upgrades can provide insights for current network changes.

Cable Modem deployment plans need to include the roadmap for the continual upgrade cycle to the latest cable modem version. As an example, plans to upgrade your return plant to 204 MHz should also include a plan to start pre-seeding high-split capable cable modems years in advance. This will provide a higher initial gain when the upgrade takes place. In addition, old generations of CPE may have compatibility issues with a change of return plant and have the need to be removed prior.

Understanding CAGR, or traffic growth, and future customer packages will help operators recognize what future congestion and overhead needs will be. With this forecast, you need to build in the remaining costs of licensing. With all this information you can prioritize the next changes in your network.

Finally, you must always keep customer experience top-of-mind. Beyond the congestion risks, this also includes other performance indicators like latency and packet loss risks.

DOCSIS Network Configuration Options

There are many options for configuration of the DOCSIS access network. I will discuss these options in five sections: downstream, upstream, global, cable modem distribution, and data analytics applications.

1. Downstream Channel Configuration

With OFDM channel deployment in full swing, many lessons have been learned during these deployments. From personal experience, there are many items to consider. Also, we have additional work we can proceed with on the SC-QAM channels to aid with the transition to DOCSIS 3.1 capable CM.

1.1. Preparing for your first OFDM deployment

Before you turn on your first OFDM channels, you need to ensure your operational staff is ready for this new technology. Do they have meters, training, and other tools need to troubleshoot impairments within this carrier? A prepared staff will provide you great feedback to the success of your deployment.

1.2. Deployment Options for OFDM

The CableLabs specification provides many options for OFDM configurations. CCAP vendors have been continuously been adding feature through their firmware upgrades over the past 2-3 years, but it is not yet in a full-feature set. Due to this limitation, you may have access to some or all these features.

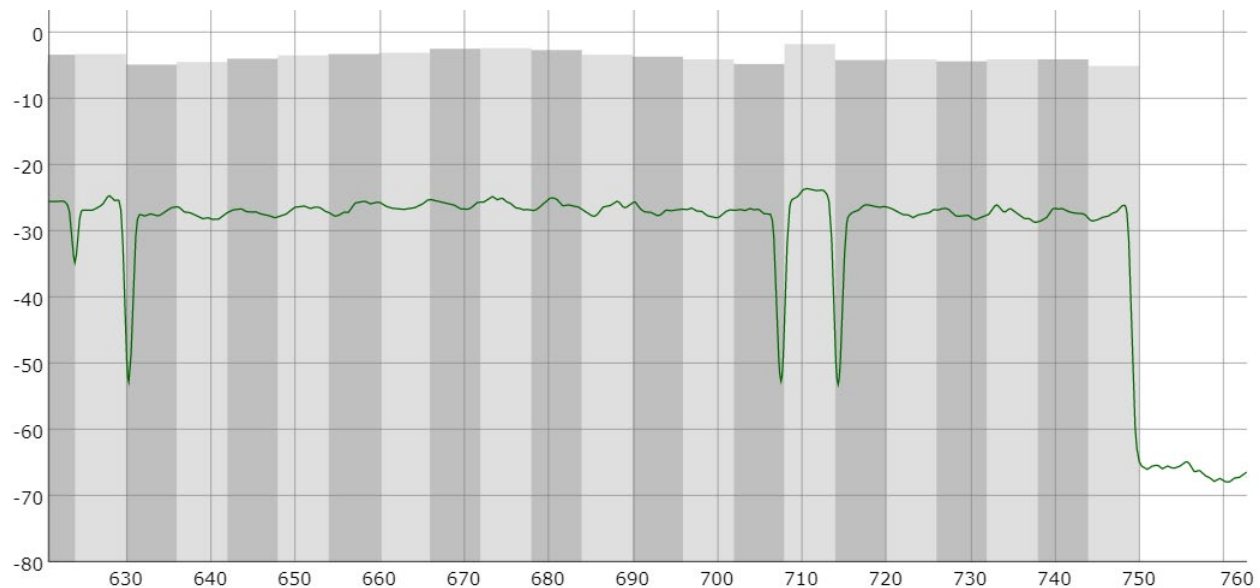


Figure 1 - OFDM Channel Spectrum with an Exclusion Band

1.2.1. Channel Width (Start and End Frequencies)

As you choose the starting and ending frequency, you will need to be aware of all plant attributes in between these end points. Also, be aware for every 6 MHz you deploy of OFDM may impact your highest output level of your downstream port on your CCAP chassis. The minimum size of an OFDM channel is 24 MHz with a maximum channel size of 192 MHz.

1.2.2. Subcarrier Spacing

Subcarrier spacing can be modified between 25 and 50 kHz. This choice provides one side that favors efficiency or one side that support more robustness to impulse noise. I recommend 50 kHz to gain resiliency over capacity until you understand spectrum performance.

1.2.3. Primary Channel Capability

Primary channels are utilized for cable modem registration, station maintenance, and CM STATUS messages. For OFDM, the DOCSIS specification provides additional CM STATUS messages that are critical for DS Profile switching. If CM are unable to communicate their CM STATUS message reliably, they will be unable to manage the change RF plant conditions that can occur with 192 MHz over one

channel. Another downside with a primary channel is that cable modems do not impair it until they can no longer receive and replay to station maintenance. This requires the cable modem register, which can cause a constant cycling cable modem since cable modems prefer to go back to their previous primary channel. Most OFDM deployments happening in the higher spectrum which likely has not been used for cable modems services before. This will bring unknown states about the reliability of this spectrum which has an add risk of roll-off. With this is mind, you may want to disable the primary channel capability and remain relying on SC-QAM channels for primary channel functions.

1.2.4. PLC Frequency Selection

The Physical Layer Link Channel (PLC) is a requirement for a CM to receive its channel information. This channel selection is critical for CM's usage of the OFDM channel. From my testing we have found that the PLC carrier can be place almost anywhere in the OFDM channel. It is critical that the PLC remains free of noise. Be aware of recent 600 and 700 MHz wireless spectrum deployments when you are planning this channel placement.

1.2.5. Next Codeword Pointer

The next codeword pointer (NCP) is a critical piece for the cable modem to perform forward error correction within the OFDM channel. You can choose it to modulation at QPSK, 16-QAM, or 64-QAM. It should be modulated below your lowest OFDM modulation to keep this critical data clean.

1.2.6. Cyclic Prefix

This setting allows for greater protection from micro-reflection in your cable plant. The higher the sample rate the more protection you will receive. This will cause a loss of capacity as you increase the samples. Depending on your placement of the OFDM channel you may want greater protection from micro-reflections. From our experience 2.5 μ sec cyclic prefix (512 samples) provides enough protect for majority of deployments.

1.2.7. Downstream Profiles

Downstream profiles are your greatest assets to increase capacity and resiliency of an OFDM channel. With multiple profiles, you can gain diverse groupings of different capabilities for each fiber-node. With downstream profile A, you want to select the minimum modulation you want for a flat OFDM profile. Typically, you will want to run 256-QAM if your currently SC-QAM channels are running the same. Any additional downstream profiles should be utilized to address noise or additional capacity needs. Based on your average downstream MER data from the fiber-node value you can assign higher level of modulation to additional DS profiles. Ideally analysis from PMA (Profile Management Application) would give the best DS profile configuration for maximized capacity.

1.2.8. Exclusion Bands

In order to maximize your OFDM channel width you may have to build it around existing SC-QAM channels. The use of exclusion bands allows you to create gaps within the spectrum of the OFDM channel. Be aware that you will be required to pad 1 MHz on each side of the exclusion band. Also, the OFDM channel must have 22 MHz or greater of contiguous spectrum before the first exclusion. Exclusion bands are great, but they do cause overhead to the full potential of the OFDM carrier. Your long-term strategy should include ways to not have exclusion bands within your OFDM channels.

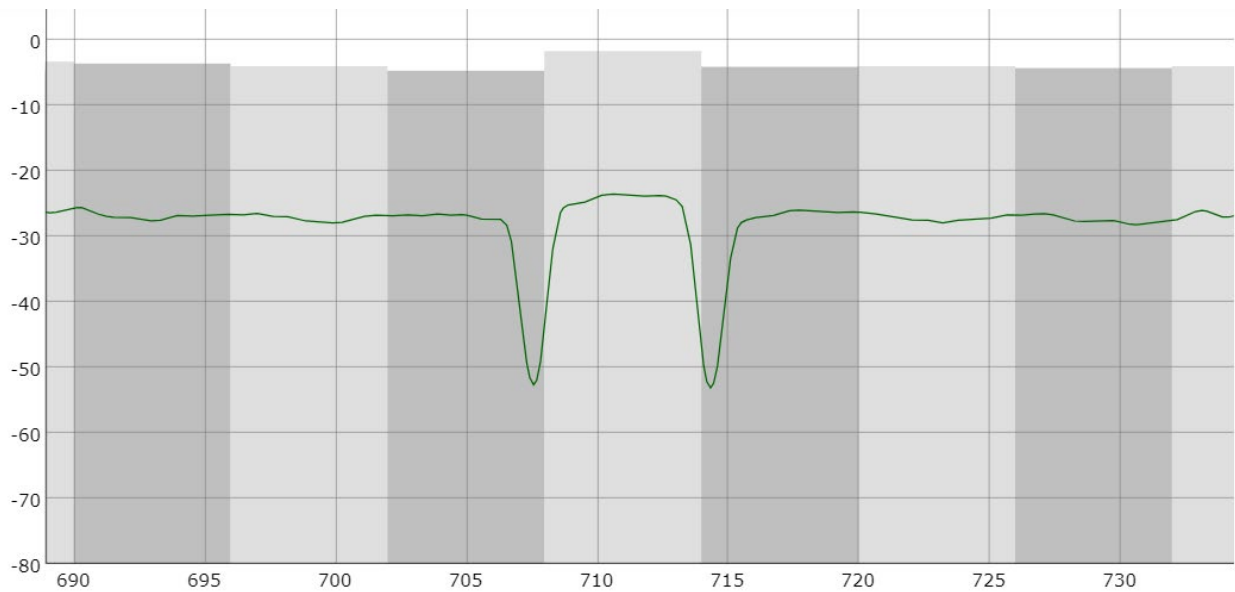


Figure 2 - OFDM Channel Exclusion Band

1.2.9. Variable Bit Loading

Once you have your DS profiles setup you can further adjust the spectrum by changing the modulation for parts of the OFDM channel. If you have a noisier section of frequency you can lower the modulation in the section only in place of change the whole OFDM channel. This can be very useful to mitigate roll-off or other channel impairments without sacrificing the capacity of the good spectrum of your OFDM channel.

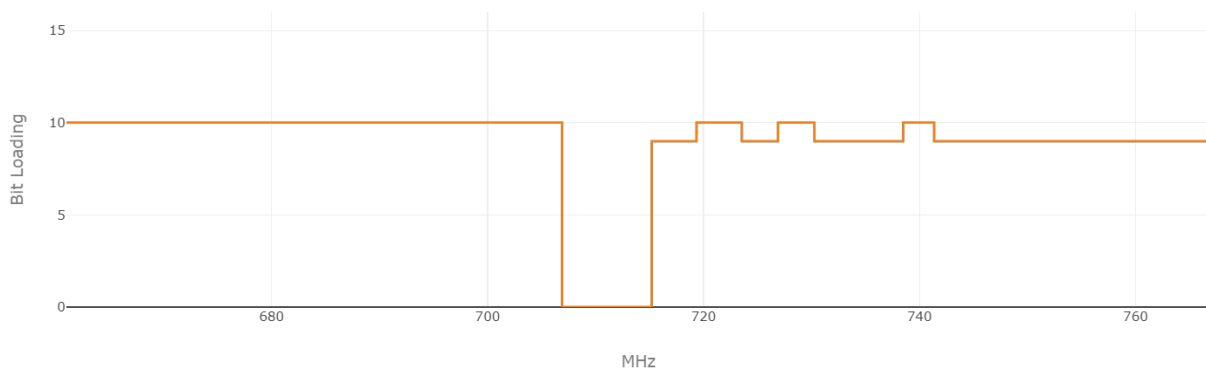


Figure 3 - Variable Bit Loading Example

1.3. Legacy Downstream Channel (SC-QAM) Configuration

For the first time in the history of DOCSIS we have created a channel type in the downstream that is not backwards capable. We have now started the transition of a DOCSIS network that is working towards the removal of old SC-QAM channels. This transition will take many years but will result in higher capacity per MHz. You can use the below features to help you transition capacity and to lengthen the timeframe of SC-QAM capacity without adding more channels.

1.3.1. Primary and DSG Channel Reduction

Primary channels are necessary for all cable modem registration, but we don't require a primary channel on every SC-QAM channel. With the movement towards bonding capable CMs has provided us the opportunity to remove this service from some channels. By removing this feature from a DOCSIS channel, you can gain additional capacity by reducing the overhead cause by cable modem registration, station maintenance, and CM STATUS messages. In addition to primary channel reduction, we can also reduce the DSG services to the primary channels. We have seen a gain of ~5% capacity (1.84 Mbps) on a SC-QAM channel that has the primary and DSG channel features disabled. This value will change vendor-to-vendor I have seen about 1-2 Mbps on different platforms or configurations.

If you are moving towards a R-PHY DAA solution you may already have noticed a requirement to reduce your primary channels. My vendor is only offering five primary channels for a fiber-node. My experience with integrated CCAP platforms a reduction to eight primary channels can easily be supported.

2. Upstream Channel Configuration

Upstream channel configuration has gained the option of OFDMA channel type. A lot of companies are also exploring Mid (5-85 MHz) and High (5-200 MHz) split return cable plants. In addition to these changes we also have some great upstream features to mitigate noise issues and maintain high upstream capacities.

2.1. Modifying Cable Plant Split

Gaining higher splits of the forward and return spectrum can enable a powerful way to expand your upstream capacity. In the 5-42 MHz plant, you have about 27 MHz of usage upstream frequency but when you expand to 85 MHz you gain an additional 43 MHz of usable spectrum. This provides 159% more upstream spectrum for DOCSIS capacity. This also enables new spectrum for OFDMA which enables higher capacity per MHz than SC-QAM. Additionally, high-split will bring an addition of 119 MHz of capacity (or a 600% gain). With each split change, be very aware of all equipment to ensure it supports the forward and return plant changes.

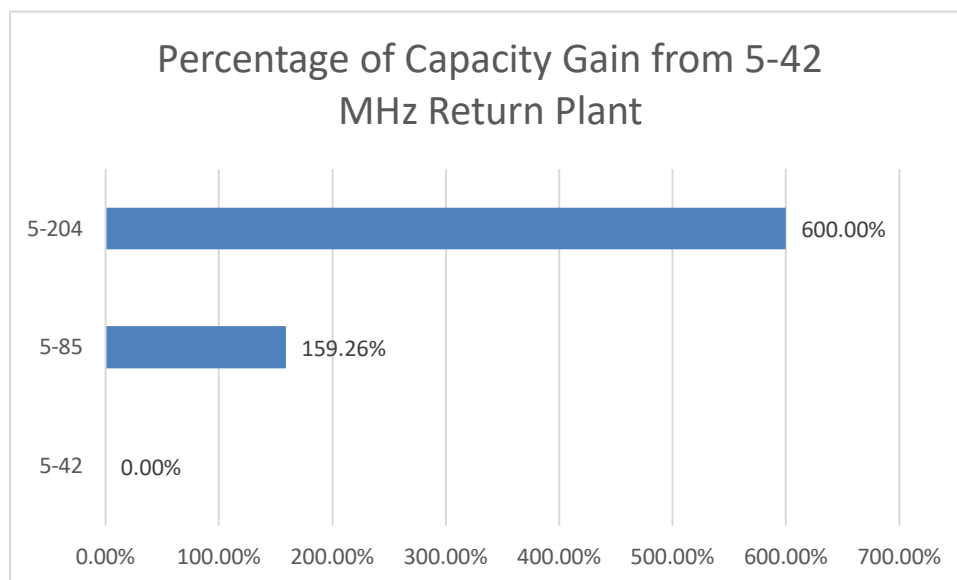


Figure 4 - Return Plant Upgrade Gains

2.2. Deployment of OFMDA

OFDMA channels provide higher orders of modulation and less channel spacing than the traditional SC-QAM channel. This provides high upstream capacities and high noise resiliency. The challenge for most operators will be where to place this new carrier since is not backwards capable. In addition, likely all available upstream spectrum of already taken by SC-QAM channels to meet current capacity needs. I expect most operators will wait for return plant upgrades before implementing an OFDMA channel.

2.2.1. Spectrum Choice

First you need to understand where you are going to place the OFDMA carrier before you look at options for this channel. There are four possible choices:

1. “Dirty” Deployment – Deploying OFDMA in the 5-20 MHz. This would provide more MHz of spectrum used by CMs, but this would be at low modulations.
2. SC-QAM Sacrifice Deployment – Turn off existing SC-QAM channel(s) to free up spectrum for OFDMA. This would provide more capacity for DOCSIS 3.1 CMs but would sacrifice DOCSIS 3.0 or later CMs capacity. CM distribution would have a large factor to how many channels you can sacrifice.
3. High Frequency Deployment – Deploying OFDMA in new high frequency is the ideal way to deploy this new channel. This provides an addition to your current upstream deployment. In order to deploy this way, cable plant split must be modified to have more upstream frequency capacity (85 or 204 MHz).
4. Hybrid Deployment – This deployment would include multiple options from the previous three choices.

2.2.2. Channel Width

The minimum size for a 2K FFT in 10 MHz that can be a challenge to find in a 5-42 MHz plant. You can expand this channel size up to 95 MHz of usable spectrum with 500 kHz of guard bands on each side.

2.2.3. Interval Usage Code

Interval Usage Code (IUC) allows us to manage multiple modulation levels within the same OFDMA modulation profile. You set IUC 13 to the lowest modulation you want to run within the OFDMA channel. Then you can add additional IUCs to offer multiple modulation levels within the same channel similarly to DS profiles for OFDM channels.

2.2.4. Exclusion Bands

We can also utilize exclusion bands for OFDMA channels. This can assist with managing OFDMA spectrum within your SC-QAM channels. This allows you to create gaps in the OFDMA band to fit other channels within. Be aware the guard band size changes based on the SC-QAM channels you have next to the OFDMA channel.

Table 1 - Minimum Guard Band for A OFDMA Exclusion Band

SC-QAM Channel Width	Minimum Guard Band
1.6 MHz	550 kHz
3.2 MHz	300 kHz
6.4 MHz	0 kHz

2.2.5. Variable Bit-loading

This provides a method to deploy OFDMA channel in different quality of spectrum and maintain maximum capacity. This becomes very useful when running OFDMA in the noisier areas of the upstream spectrum with some clean spectrum. It has all the same benefits that variable bit-loading offers to an OFDM channel.

2.3. Legacy Upstream Channels (SC-QAM)

The current SC-QAM channels are still very much important to offer upstream capacity for DOCSIS 3.0 or later CMs. We have far less options than the new OFDMA channels but if configured correctly you can offer the capacity needed for legacy CMs.

2.3.1. Channel Width

There are three common channel widths for SC-QAM channels: 1.6, 3.2, and 6.4 MHz. To maximize capacity the wider the channel the better. The downside is the noise resistance decreases with a wider channel. If you deploy 3.2 MHz wide channels you can fit two inside the same space as one 6.4 MHz wide channel. This will increase your costs and increase the maximum TX level for your CMs.

2.3.2. Modulation Profiles

There are also three common modulation orders: QPSK, 16-QAM, and 64-QAM. 64-QAM provides the highest level of capacity for SC-QAM channels; OFDMA is required to modulate higher. The higher the modulation level the greater capacity but the higher required SNR level as well.

Table 2 - Recommended SNR Levels for Modulation Type

Modulation Type	Recommended SNR Level
64-QAM	27
16-QAM	23
QPSK	18

2.3.3. Dynamic Upstream Configuration Changes

Dynamic upstream configuration change feature goes by different names depending on your vendor of your CMTS/CCAP. This feature allows you to automatically change upstream channel configuration based on RF performance thresholds. Typically, you have access to average SNR level, Correctable FEC errors, and Uncorrectable FEC errors as thresholds. Based on these thresholds, you may want to change modulation, channel width, or even change the center frequency. By using this feature, you can quickly

mitigate a customer impacting noise events automatically. This is done at the cost of capacity, but this is better than a loss or degradation of service.

By using this feature, you can configure your upstream channels at the maximum possible setting and have the CCAP lower the modulation and channel width. This feature also comes with traps so you can report on these configuration changes to assist with PNM or incident activities.

Table 3 - Example of Dynamic Upstream Configuration States

State ID	Capacity (Mbps)	Modulation	Channel Width	Center Frequency	Degradation Trigger ID	Improvement Trigger ID
1	30	64-QAM	6.4	Default	1	N/A
2	20	16-QAM	6.4	Default	3	2
3	15	64-QAM	3.2	Default	1	2
4	15	64-QAM	3.2	High	1	2
5	15	64-QAM	3.2	Low	1	2
6	10	16-QAM	3.2	Default	3	2
7	10	16-QAM	3.2	High	3	2
8	10	16-QAM	3.2	Low	3	2
9	5	QPSK	3.2	Default	3	4
10	5	QPSK	3.2	High	3	4
11	5	QPSK	3.2	Low	N/A	4

3. Global Configuration Options

Global configuration brings together downstream and upstream features to provide options to run your DOCSIS network better. These features, for the most part, are vendor specific, so I will cover a couple of the bigger features that most vendors have or should have.

3.1.1. Cable Modem Load-balancing

Cable Load-balancing is a powerful tool to ensure traffic on each channel is operating at similar traffic levels as the other channels within the fiber-node. With different configuration of load-balancing you can dramatically change traffic loading between channels. This also supports load-balancing bonded and non-bonded CMs. The closer the channels are at the same traffic levels the more load-balancing you will need to perform. Each load-balancing event comes with a risk of a CM reset event. You need to balance the need of per channel capacity with the risk of a CM reset event.

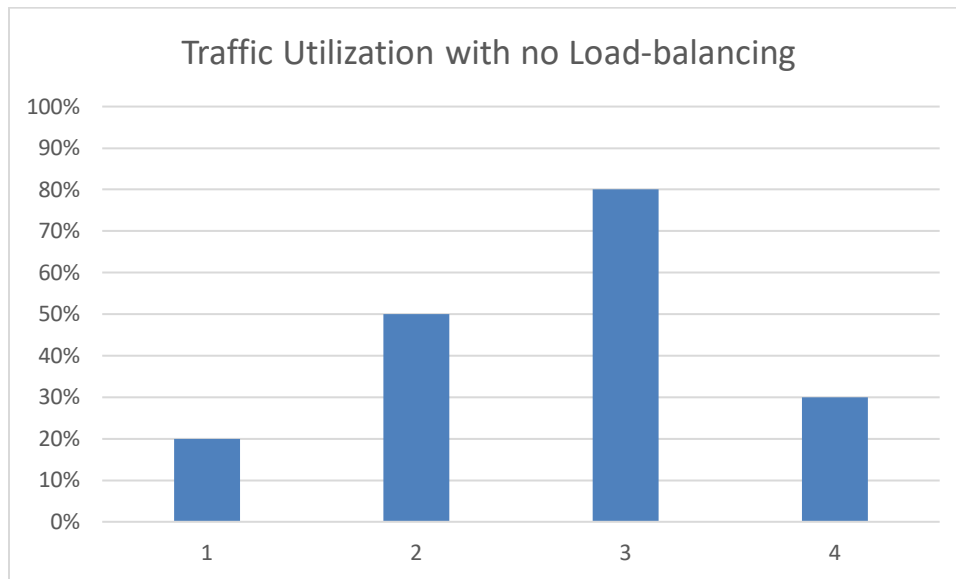


Figure 5 - Traffic Utilization without using load-balancing

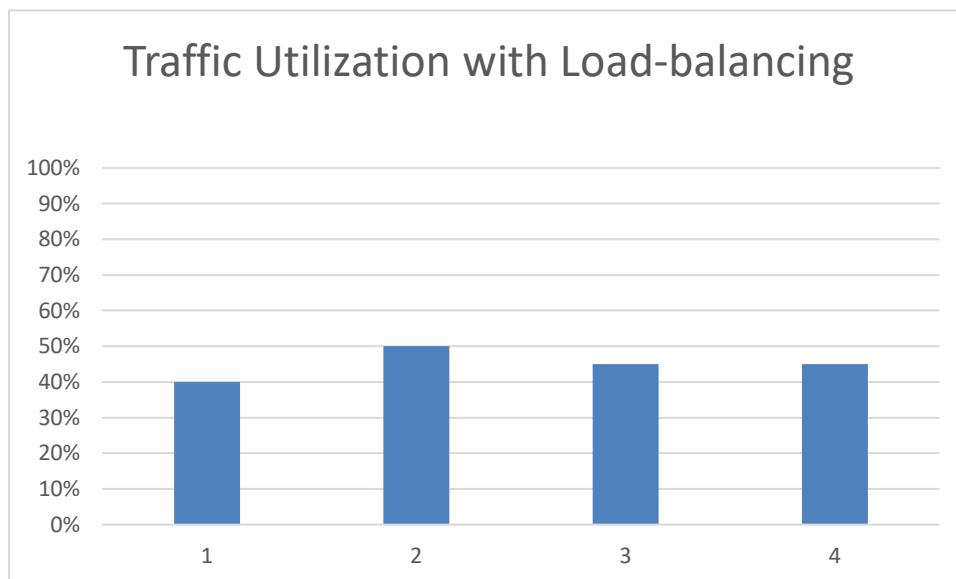


Figure 6 - Traffic Utilization after load-balancing

3.1.2. Transitional MAC Scheduler

From my experience MAC schedulers try to balance bonded CMs over all their bonded channels. This was a great system for MAC domains that are only SC-QAMs. As you turn up OFDM/OFDMA interfaces with a low distribution of DOCSIS 3.1 capable CMs a different MAC scheduler is needed. On a traditional MAC scheduler, a DOCSIS 3.1 CM will end up consuming SC-QAM bandwidth with lots of remaining OFDM capacity remaining. This becomes a more pressing issue on high utilization on SC-QAM channel within a fiber-node. Moving to a MAC scheduler that prioritizes the DOCSIS 3.1 CMs to use OFDM/OFDMA channels over the SC-QAM channels becomes a better configuration. This MAC

scheduler should ideally be one you can switch to and back to a traditional scheduler on a per fiber-node's need. With changing CM distribution over the coming years, you may find the need to go back to the traditional MAC scheduler again.

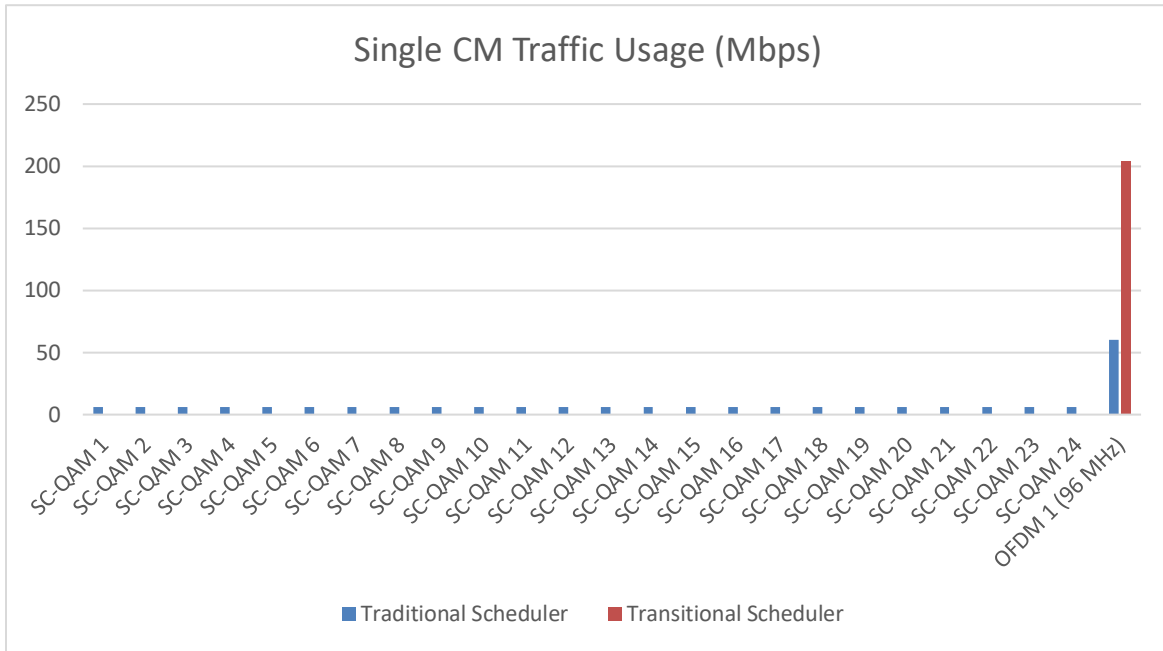


Figure 7 - MAC Scheduler Differences – Single CM

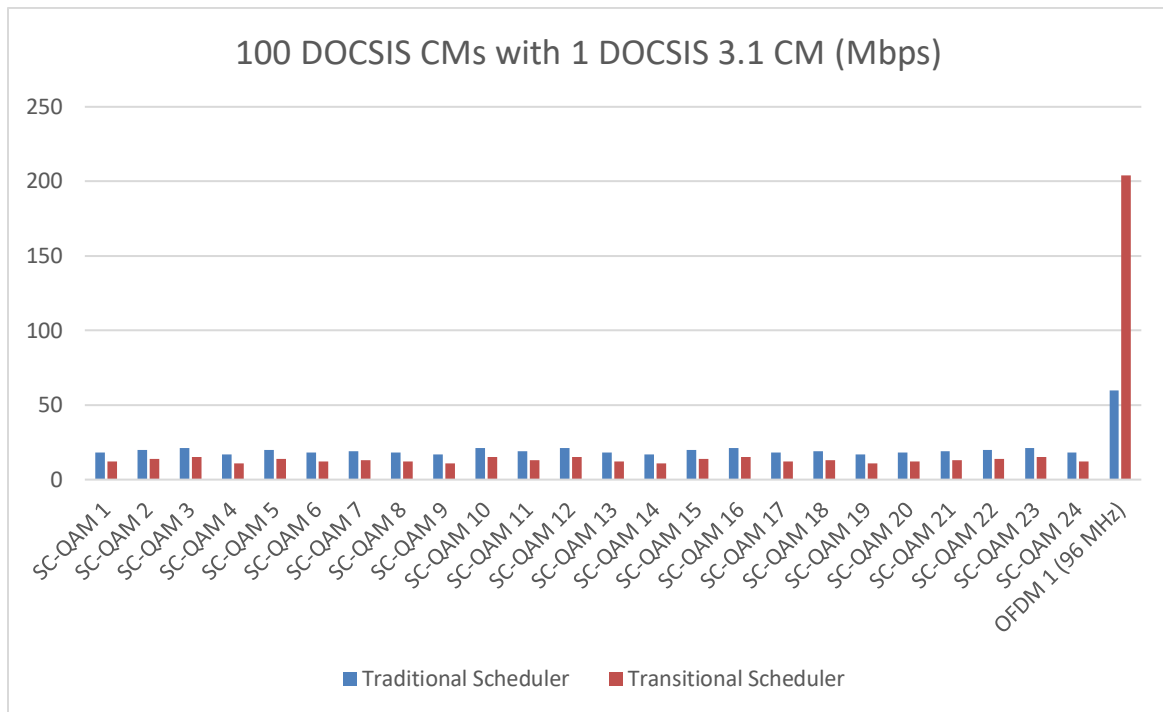


Figure 8 - MAC Scheduler Differences – 100 CMs with 1 DOCSIS 3.1 CM (Mbps)

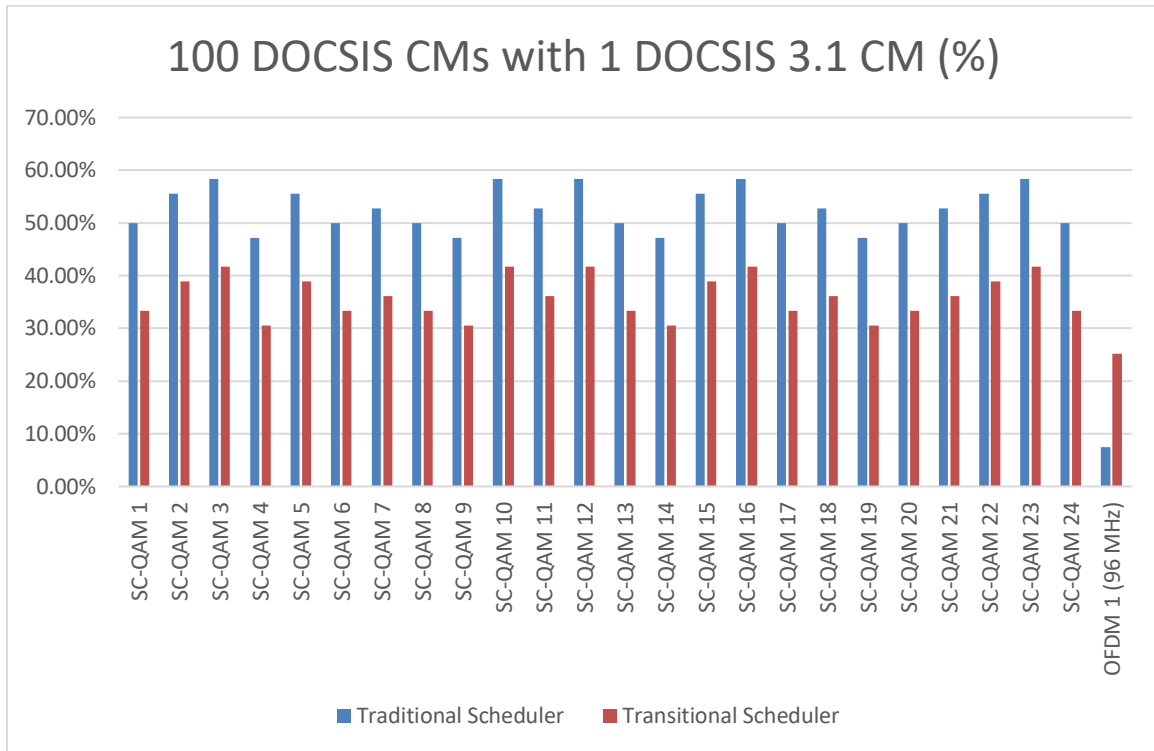


Figure 9 - MAC Scheduler Differences – 100 CMs with 1 DOCSIS 3.1 CM (%)

4. Cable Modem Distribution

With the introduction of new DOCSIS channel types (OFDM/OFDMA) we have created a barrier of non-capability in order to further gain capacity and resiliency. With cable plant upgrades such as mid-split will also create these barriers of non-capability. With upcoming future technologies such as Full-duplex DOCSIS, 1.8 and 3 GHz cable plants will also continue this trend.

At Shaw, we started production testing of 85 MHz return plant in 2014. During this time, Shaw also selected a cable modem for our customer that would support 85 MHz. Shaw didn't immediately deploy 85 MHz in mass deployment, but tests showed the benefit of additional upstream capacity. In 2018, Shaw started our deployment of upstream channel deployment above 42 MHz. Based on the results of traffic offloading to the higher frequency upstream channels we can see a correlation of 5-85 MHz supporting cable modems to effectiveness of traffic offloading.

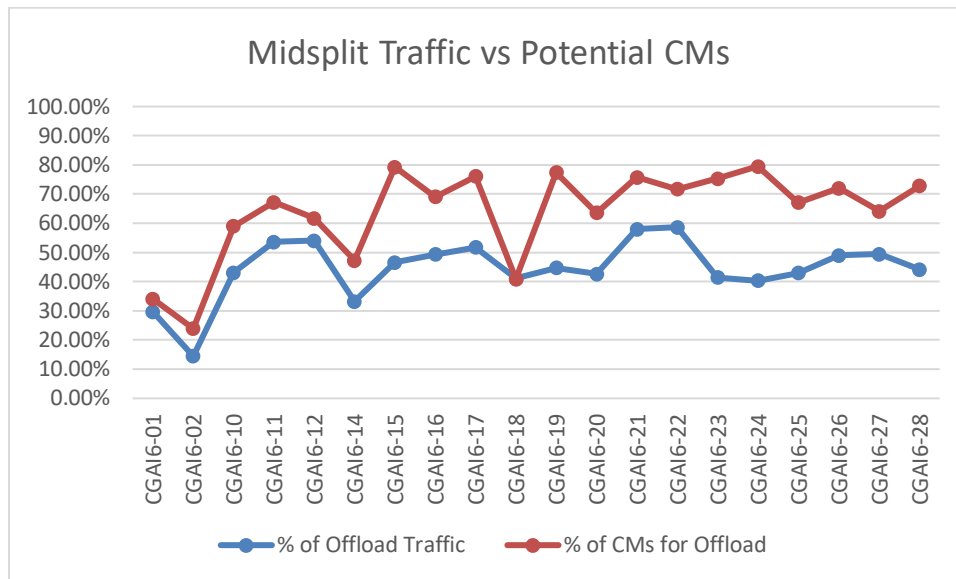


Figure 10 - Impacts of CM Distribution of New 85 MHz of Return Plant

5. Data Analysis Applications

CableLabs has been providing data analysis tool designs to provide DOCSIS network designers additional tools to maximize capacity and resiliency of the network. These applications can be a great benefit to you and your customer experience.

5.1. Proactive Network Maintenance

Proactive Network Maintenance (PNM) is a powerful tool to identify oncoming negative RF issues. It can also identify current outstanding RF issues. This is a great way to monitor your cable plant from every cable modem in your DOCSIS network. By doing this, you can maintain higher capacity levels due to good plant conditions. PNM commonly looks at pre-equalization, in-channel frequency response, full band capture, and time domain reflectometry data. In DOCSIS 3.1 items like RxMER for OFDM/OFDMA channels have been added to PNM. This addition within PNM drives the support for additional tool called PMA.

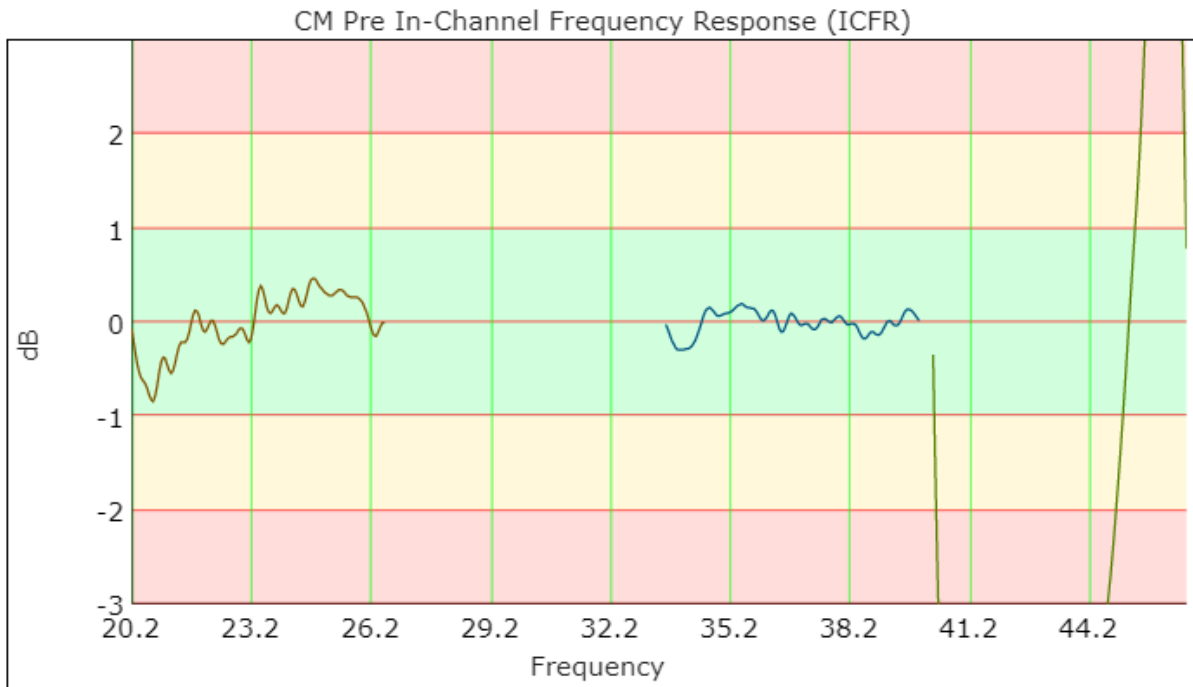


Figure 11 - In-channel Frequency Response Showing An Impairment Caused By In-home Drop Amplifier In A 85 MHz Return Plant

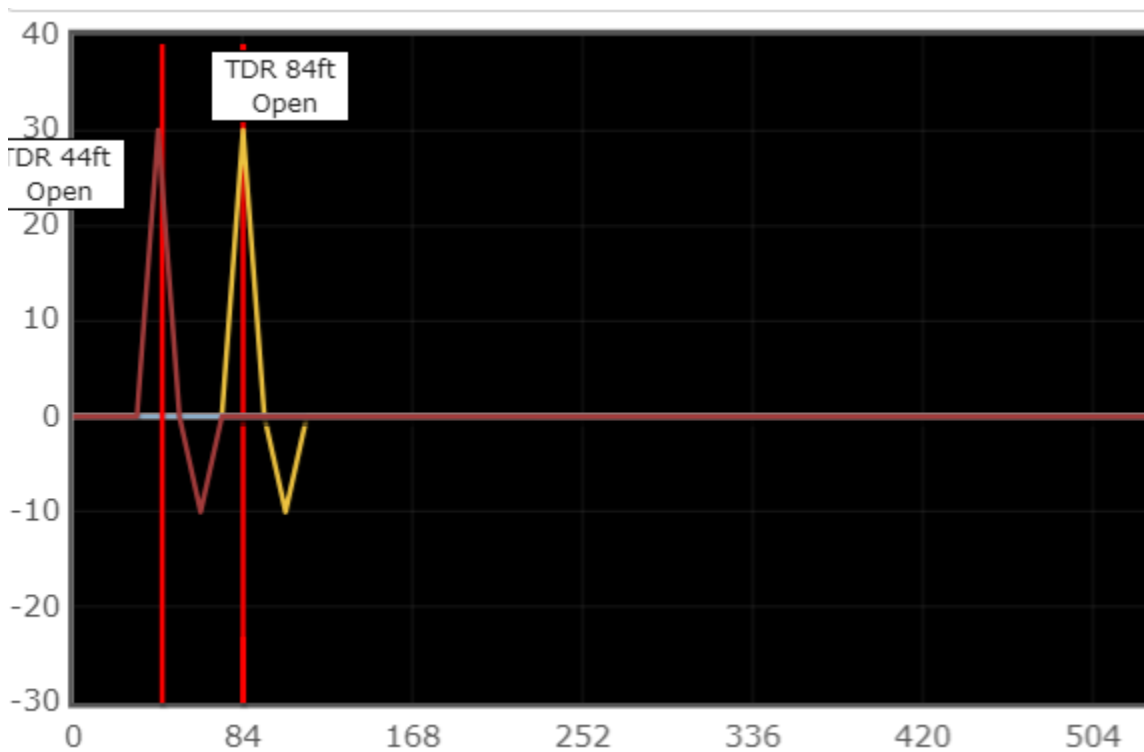


Figure 12 - Time Domain Reflectometry Showing A In-home Issue

5.2. Profile Management Application

Profile Management Application (PMA) is a tool to assist with OFDM/OFDMA channel configuration. This tool becomes increasingly more powerful as you are utilizing more profiles (IUC and DS Profile) and variable bit loading features within OFDM/OFDMA channel types. PMA utilizes the new PNM feature of RxMER to assess the capability of each CM on a fiber-node.

With testing at Shaw, we see the benefits of ~40% more capacity with this tool. We are configuring DS profile A as a default flat modulation (256-QAM) for the whole channel. Then every additional DS profile added to support a correlated group of CMs that share the same or similar spectrum characteristics to maximize their capacity for these conditions. The more correlated groups you have, the more DS profiles you require to gain this capacity. Based on our tests we believe DS profile A and seven additional DS profiles per OFDM channel will be needed to optimize your downstream capacity. We also see the need for many variable bit loading sections to further support the capacity of the OFDM channel.

PMA also brings additional channel resiliency into your network like other PNM features. The advantage is that it can be automated instead of a technician being onsite prior to any mitigation. The data from this tool can also provide correlated groups of cable modems with the same channel impairment. This data could also be found within your PNM tool if it performs analysis of the RxMER data too.

DOCSIS Network Deployment Example

Now that we have covered the available options, let's go over a fictional example of deployment of changes in a DOCSIS network. By going through this exercise, will provide an example of the thought process required to build a design change. It will also demonstrate the additional capacity or resiliency gains you can achieve with these options.

1. Starting Conditions

The baseline we will begin our deployment of new options will be the common 24x4 network. This means we will have 24 downstream SC-QAM channels plus four upstream SC-QAM channels. In order to keep this simple, I will display the rest of the setup in a few tables.

Table 4 - DOCSIS Device Configuration – Starting Conditions

Feature	Current Setting
Downstream	
SC-QAM Channel Count	24
SC-QAM Channel Modulation	256-QAM
SC-QAM Channel Frequency Range	300-444 MHz
SC-QAM Primary Channel	Enabled on all channels
SC-QAM DSG Service	Enabled on all channels
OFDM Channel Count	0
OFDM Frequency Range	-
OFDM DS Profile Count	-
OFDM DS Profile Modulation	-

Feature	Current Setting
OFDM Subcarrier Spacing	-
OFDM Primary Channel	-
OFDM Cyclic Prefix	-
OFDM PLC Channel	-
OFDM Exclusion Bands	-
OFDM Variable Bit Loading	None
Total Downstream Capacity (PHY Rate)	1029 Mbps
Upstream	
SC-QAM Channel Count	4
SC-QAM Modulation	64-QAM
SC-QAM Channel Width	2 x 6.4 MHz and 2 x 3.2 MHz
SC-QAM Center Frequencies	21.8, 25, 30.1, 36.8 MHz
OFDMA Channel Count	0
OFDMA Frequency Range	-
OFDMA Interval Usage Code(s)	-
OFDMA Exclusion Bands	-
OFDMA Variable Bit Loading	-
Total Upstream Capacity (PHY Rate)	92 Mbps
Global	
Dynamic Upstream Configuration Changes	Disabled
Cable Modem Load-balancing	Enable
MAC Scheduler	Default

On top of the DOCSIS network configuration, it should also be stated the current RF plant capabilities. We will start with are 750 MHz plant with a 5-42 MHz return. The current cable modem distribution for the internet services is 30% DOCSIS 2.0, 65% DOCSIS 3.0, and 5% DOCSIS 3.1. Our current top tier consumer product is 500 Mbps download with 30 Mbps upload speeds.

2. Deployment Senario

It's important to set a deployment goal to build towards. For this fictional deployment example, we are going to build a new top tier package. The product team has stated a desire to achieve at least 1 Gbps download with a 50 Mbps upload.

3. Deployment Plan

The first thing we need to maximize our capacity would be a DOCSIS 3.1 cable modem for this package. This will allow us to utilize OFDM and OFDMA channels to increase our capacity. If we don't use DOCSIS 3.1 features yet it would build a cable modem pool for this in the future. The first requirement will be a DOCSIS 3.1 cable modem.

We could also look at cable plant upgrades to assist with additional spectrum. Looking at our current video deployment, we have spectrum available between 444-492, and 696-750 MHz. Also, on the return spectrum we have spectrum below 20 MHz available as well. Since we have unused spectrum for use, let's hold off at looking at cable plant upgrades.

In order to offer a 1 Gbps of speed it would be ideal to have 2 Gbps or more of capacity on the downstream. Since we have a lot of CMs that are not on DOCSIS 3.1 cable modems expanding SC-QAM would be a good idea first. This would provide additional growth for these cable modem and offer additional capacity for DOCSIS 3.1 CMs. We have eight channels worth of frequency right by our 24 SC-QAM channels. If we added these eight channels, it would increase our PHY rate by 343 Mbps to a total of 1372 Mbps. Now that leaves us with 54 MHz of free spectrum between 696-750 MHz. If we deploy OFDM in this space which is 54 MHz with 2 MHz of guard band leaving us 52 MHz of data spectrum. 52 MHz @ 256-QAM would provide 320 Mbps more. This would bring us to a total of 1692 Mbps which still doesn't provide us enough. Looking at the higher modulation orders on our OFDM channel will provide more capacity. Setting the channel to 1024-QAM bring the PHY rate to 400 which only get us 80 Mbps more (or a total of 1772 Mbps). Then going up to 4096-QAM get another 80 Mbps or 1852 Mbps in total. To achieve the capacity required for this package, additional spectrum is needed.

Looking at upstream, capacity let's examine what we can get out of it. The spectrum below 20 MHz is not a clean as our other channels. If we changed over to 4 x 6.4 MHz wide channels @ 64-QAM, we would have 123 Mbps in total capacity. This may be enough to services 50 Mbps service. Another option will be OFDMA, for which we need at least 10 MHz of spectrum. One option would be to turn down the lowest 3.2 MHz carrier and go below 20 MHz. This would deploy an OFDMA channel between 13.4 - 23.4 MHz @ 256-QAM to get the 10 MHz. This channel would provide 39 Mbps of capacity bring us to a total of 131 Mbps. Since we have reduced DOCSIS 3.0 upstream capacity the majority of our cable modems have lost capacity with an OFDMA channel.

Additional information was needed to determine the direction. Based on current upstream traffic levels, we can't lose SC-QAM capacity on the upstream so OFDMA is out as a choice. But a conversation with our video team has yielded an additional spectrum. After a channel reorganization it has yielded an additional 30 MHz of spectrum alongside of our possible OFDM channel. This would bring the OFDM capacity to 707 Mbps @ 1024-QAM. This bring the total of 32 SC-QAM + 82 MHz OFDM to 2079 Mbps. With the 123 Mbps of upstream capacity we could support a 1 Gig / 50 Mbps service with this configuration.

We could gain additional efficiency with a primary downstream channel reduction. This would reduce the DOCSIS overhead on the channels with this removed. Looking at the traffic levels of the DOCSIS 2.0 cable modems we can likely go down to 12 primary channels. This would provide 30 Mbps of data for customers bonded-capable CMs.

The requirement for dynamic upstream configuration changes on the upstream, where going below 20 MHz become increasingly important. Also, any upstream channel can benefit from this type of autonomous configuration system. By utilizing trigger events of SNR, uncorrectable, and correctable FEC errors, we can detect when RF impairments are occurring. Then by reducing modulation, channel-width are good first steps. Once the 6.4 MHz channel has been reduced to 3.2 MHz channel width, the center frequency can be moved around to avoid the noise issue. This configuration will also improve the customer experience.

4. Ending Conditions

After the above deployment plan is implemented, the new DOCSIS device configuration would be the following:

Table 5 - DOCSIS Device Configuration – Post Configuration

Feature	Current Setting
Downstream	
SC-QAM Channel Count	32
SC-QAM Channel Modulation	256-QAM
SC-QAM Channel Frequency Range	300-492 MHz
SC-QAM Primary Channel	Enabled on all channels
SC-QAM DSG Service	Enabled on all channels
OFDM Channel Count	1
OFDM Frequency Range	666-750 MHz
OFDM DS Profile Count	1
OFDM DS Profile Modulation	1024-QAM
OFDM Subcarrier Spacing	50 kHz
OFDM Primary Channel	No
OFDM Cyclic Prefix	2.5 μsec
OFDM PLC Channel	711 MHz
OFDM Exclusion Bands	None
OFDM Variable Bit Loading	None
Total Downstream Capacity (PHY Rate)	2079 Mbps
Upstream	
SC-QAM Channel Count	4
SC-QAM Modulation	64-QAM
SC-QAM Channel Width	4 x 6.4 MHz
SC-QAM Center Frequencies	16.7, 23.4, 30.1, 36.8 MHz
OFDMA Channel Count	0
OFDMA Frequency Range	-
OFDMA Interval Usage Code(s)	-
OFDMA Exclusion Bands	-
OFDMA Variable Bit Loading	-
Total Upstream Capacity (PHY Rate)	123 Mbps
Global	
Dynamic Upstream Configuration Changes	Enabled
Cable Modem Load-balancing	Enable
MAC Scheduler	Default

This configuration would be able to provide internet speeds of 1 Gbps download with a 50 Mbps upload. In addition, we gain resiliency on our upstream with dynamic upstream configuration changes. With the introduction of an OFDM channel, modems on these channels should have more reliable service as well.

Conclusion

As you upgrade and deploy new features on your DOCSIS network, you will gain capacity and the ability to add resiliency features. Ensure you have the correct mindset to design the DOCSIS network you want.

As MSOs move towards more DOCSIS 3.1 services, the need to manage the transition to OFDM/OFDMA carriers are a huge benefit. Features like transitional MAC scheduler ease the pressure of this transition. PNM/PMA applications enable resiliency and the ability to maximize our OFDM/OFDMA capacity.

Abbreviations

CAGR	Compound Annual Growth Rate
CCAP	Converged Cable Access Platform
CM	Cable Modem
CPE	Customer Premise Equipment
DAA	Distributed Access Architecture
DOCSIS	Data Over Cable Service Interface Specification
DS	Downstream
DSG	DOCSIS Set-top Gateway
FDX	Full-duplex DOCSIS
FEC	Forward Error Correction
FMA	Flexible Mac Architecture
FFT	Fast Fourier Transform
ICFR	In-Channel Frequency Response
IUC	Interval Usage Code
kHz	Kilohertz
MAC	Media Access Control
Mbps	Megabits Per Second
MHz	Megahertz
MSO	Multiple System Operator
NCP	Next Codeword Pointer
OFDM	Orthogonal Frequency-division Multiplexing
OFDMA	Orthogonal Frequency-division Multiple Access
PHY	Physical
PLC	Physical Link Channel
PMA	Profile Management Application
PNM	Proactive Network Maintenance
QPSK	Quadrature Phase Shift Keying
RxMER	Receive Modulation Error Ratio
SC-QAM	Single Carrier Quadrature Amplitude Modulation
SNR	Single-to-Noise Ratio
TDR	Time Domain Reflectometry
TX	Transmit

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CableLabs PMA Tool