MANAGING THE EVOLUTION TO DOCSIS 3.1

PART 2

OPERATIONAL CONSIDERATIONS FOR A SMOOTH TRANSITION

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INTRODUCTION

The rapid development and release of the DOCSIS 3.1 specification has members of the broadband market accelerating their plans to bring its exciting new capabilities online. In addition to facilitating the increases in broadband throughput needed to satisfy the growing service demands of residential and business subscribers, DOCSIS 3.1 also provides a platform for HFC network operators to keep pace with increasing fiber-based competition. As vendors ready new equipment, service providers have begun creating phased evolution plans to ensure a successful migration from DOCSIS 3.0 to DOCSIS 3.1. In addition to the required technology evolution steps, there are numerous operational issues that must be considered so that this transition does not degrade current services, or in any way interfere with subscriber satisfaction.

Based on years of DOCSIS experience dating back to the original development of the specification, leadership on the DOCSIS 3.1 board, and experience gleaned from the DOCSIS 3.0 transition, ARRIS has identified several operational considerations associated with the DOCSIS 3.1 transition. This paper will review several unique requirements of DOCSIS 3.1 and discuss multiple paths on which service providers may choose to embark as they ready their networks while minimizing operational disruption along the way. In the pages that follow, readers will learn:

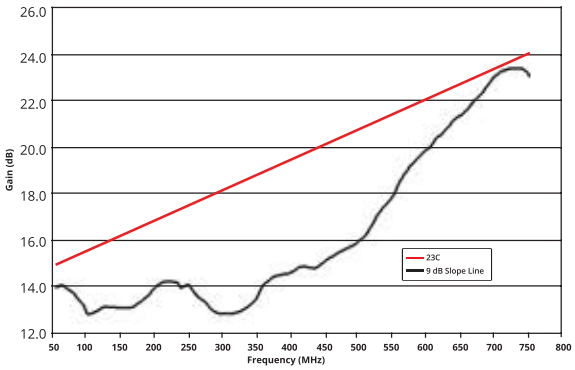
- How the spectrum requirements of DOCSIS 3.1 can lead to new operational challenges for service providers
- New perspectives on the DOCSIS 3.1 migration that can help service providers mitigate these operational challenges, including:
  - Strategies for networks with limited capacity
  - Methods of phasing in new equipment purchases
  - New ways to improve broadband service quality for average users and “super users”
  - Opportunities to synchronize the DOCSIS 3.1 migration with the evolution to IP Video services
  - Techniques for evolutionary bandwidth expansion

THE OPERATIONAL CHALLENGES OF DOCSIS 3.1

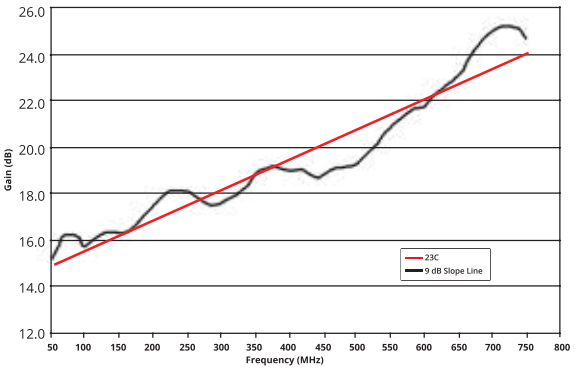
The promise of DOCSIS 3.1 as a means of expanding network capacity and supporting service growth is well documented. But as service providers prepare to migrate to this new specification, they must also understand the operational challenges that lie ahead. These include managing the transition of the DOCSIS 3.0 cable modems that are currently deployed, planning for changes to the outside plant spectrum split, and factoring in the changing upstream and downstream traffic dynamics being caused by the rapid increase in streaming video. Most importantly, service providers must evaluate their upstream and downstream spectrum to understand its utilization, availability and usability in the DOCSIS 3.1 world.

Transitioning to DOCSIS 3.1 requires that a dedicated block of downstream spectrum be made available for its exclusive use. Unlike the upstream, where DOCSIS 3.1 and legacy traffic can be time division multiplexed and therefore spectrum is shared, DOCSIS 3.1 downstream traffic must remain isolated from legacy traffic. For service providers, this requires that new spectrum be made available exclusively for DOCSIS 3.1, and service groups must be well planned and managed to ensure that downstream channels do not overlap. To make this new spectrum available, service providers must choose between spectrum reclamation and plant upgrades.

RF POWER COMPARISON WITH AMPLIFIER SIGNATURE CORRECTION



ORIGINAL SYSTEM

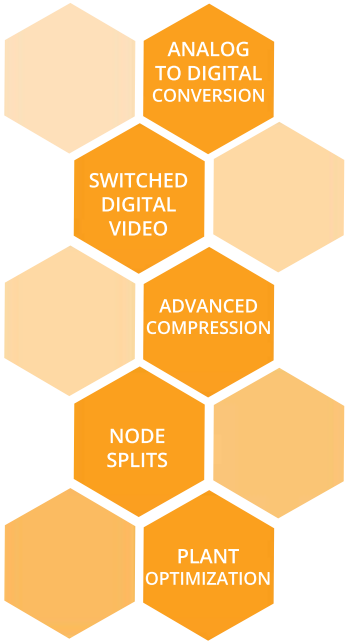


SIGNATURE CORRECTED SYSTEM

Figure 1

There are several, well known means of reclaiming spectrum. Whether they are converting channels from analog to digital, deploying switched digital video (SDV), utilizing more efficient compression techniques, performing node splits or optimizing plant characteristics, service providers can sometimes find the spectrum they need to begin the DOCSIS 3.1 journey in their own back yard. However, if there is no room to spare in their current plant, service providers will have to deploy new spectrum. This means migrating their networks from today's 750 or 850 MHz capabilities to 1 or 1.2 GHz. In addition to the equipment costs associated with this upgrade, there are several operational considerations as well.

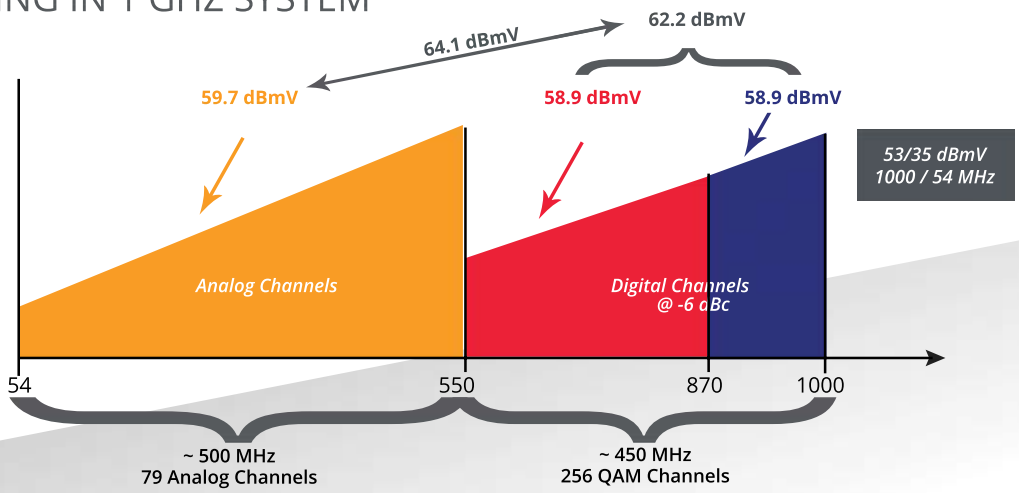
SPECTRUM RECLAMATION OPTIONS



As *Figure 2* shows, since attenuation is larger at higher frequencies, the system composite power at 1GHz can be twice that at 870 MHz. At high frequencies, there may be potential variations in frequency response, which is largely due to the type and condition of the taps used in the plant. While 1 GHz taps have been available for some time, some exhibit a non-linear increase in insertion loss above 750 MHz, with temperature conditions increasing this variability. For these reasons, system frequency response and RF levels must be analyzed and well understood before expanding plant bandwidth. Service providers may need to deploy signature correction and even increase the output levels for certain actives to ensure that power levels across the plant are ready to support the new, higher frequencies. In doing so, service providers can accurately understand where plant maintenance is required and proactively rectify any issues. The benefits of signature correction can be seen in *Figure 1.*

POWER LOADING IN 1 GHZ SYSTEM

Figure 2



Some steps that may be taken to achieve the high SNR values needed for the high order modulations of DOCSIS 3.1 include performing needed maintenance on connectors, taps and amplifiers; tightening any loose connections; installing new faceplates and replacing outdated equipment. Finally, it is critical that plant technicians are well trained on the unique dynamics of extended bandwidth, and equipped with tools and techniques that support the new higher frequencies. These include not only diagnosis and repair capabilities, but ongoing visibility into dynamic plant characteristics as well.

EASING THE TRANSITION TO DOCSIS 3.1 DEPLOYMENT

In order to efficiently and effectively migrate to DOCSIS 3.1, it is critical that service providers develop a transition plan that considers several of today's pressing operational realities. These include minimizing the cost impact of new equipment, providing high throughput for heavy bandwidth users, improving service levels across all service groups, creating a seamless coexistence between legacy and new equipment and aligning DOCSIS 3.1 deployment with other service expansion plans. As they begin on the journey to DOCSIS 3.1, service providers should evaluate several options for making this transition, and choose the path that best aligns with their network realities and operational goals.

Starting Point 1: Seeding the Network with DOCSIS 3.1 CPE

Because activating DOCSIS 3.1 will require new customer premises equipment and an isolated block of downstream spectrum, service providers may find it prudent to first seed the market with DOCSIS 3.1 modems that run in legacy DOCSIS 3.0 mode. Once a significant percentage of DOCSIS 3.1 modems are up and running, service providers can make the required spectrum available and activate the advanced DOCSIS 3.1 feature set on these devices to unlock new capacity. This helps reduce the up front deployment costs, while giving service providers time to reclaim or deploy new spectrum.

STARTING POINT #1

Ideal for:

- Networks with limited available bandwidth
- Making new equipment investments over time
- Providing additional time for spectrum expansion

Starting Point 2: Maximizing Support for Super Users

Service providers who want to deploy DOCSIS 3.1 capacity as soon as possible may instead choose to begin with "super users" - those who are consuming the most average or peak bandwidth on their networks. These users include small to medium business (SMB) customers, bandwidth-intensive residential customers, and heavy users of high-resolution streaming media. By carving out a dedicated block of spectrum for new DOCSIS 3.1 modems, service providers can begin transitioning these users off of the spectrum being used by light and moderate DOCSIS 3.0 subscribers. This enables a significant amount of spectrum, which was once required for a large number of single carrier DOCSIS 3.0 channels, to be reclaimed and applied to more efficient DOCSIS 3.1 OFDM channels. In doing so, service providers can provide super users with the additional bandwidth they need, while ensuring that the rest of subscribers do not experience performance degradation. This approach also provides an evolutionary strategy for bandwidth expansion.

If enough downstream spectrum exists, a 96 or 192 MHz block of spectrum is optimal for this configuration, with all super users receiving downstream service via DOCSIS 3.1 OFDM channels. If only a small block of new downstream spectrum exists, as little as 24-48 MHz, a small number of new DOCSIS 3.1 OFDM channels can be bonded with legacy DOCSIS 3.0 channels to give super users their own dedicated spectrum and allow them to borrow additional capacity from light and moderate users when it is available. As new network bandwidth is deployed or reclaimed, service providers can increase the number of DOCSIS 3.1 downstream channels to accommodate super users' growing bandwidth needs, without degrading performance for light and moderate users.

An effective DOCSIS 3.1 migration strategy for downstream channels includes the following steps:

1. Add a DOCSIS 3.1 OFDM channel above 860 MHz
2. Bond the SC-QAM and OFDM channels together
3. Reduce the number of SC-QAM channels
4. Make the OFDM channel wider
5. Add an OFDM channel above 1002 MHz
6. Move to a high-split architecture (204/258 MHz)
7. Add more OFDM channels above 1218 MHz

STARTING POINT #2

Ideal for:

- Networks with some available bandwidth
- Improving the service experience for super users
- Preventing average users from being "stepped on"
- Providing an evolutionary strategy for bandwidth expansion

As with the downstream, there are multiple options for managing upstream spectrum to accommodate super users. If there is not a significant demand for upstream traffic, all spectrum can remain allocated for DOCSIS 3.0 mode. However, if there is a need for upstream bandwidth expansion, there are two options. First, if a small block of upstream spectrum, as little as 24 MHz, is available for DOCSIS 3.1 traffic, it can be used to carry DOCSIS 3.1 OFDMA channels, which can be bonded together and used to support super users. If a large block of upstream spectrum is available, the OFDMA channels can be used without bonding. This expands bandwidth for super users by taking advantage of OFDM's multi-carrier technology, while isolating average users from the impacts of those with higher bandwidth needs.

The steps below present an effective DOCSIS 3.1 migration strategy for upstream channels:

1. Move to a mid-split architecture (85/108 MHz)
2. Add a DOCSIS 3.1 OFDMA channel, using frequency division and excluded subcarriers
3. Bond the SC-QAM and OFDMA channels together
4. Change to time division multiplexing between the SC-QAM and OFDM channels in overlapping spectrum
5. Move to a high-split architecture (204/258 MHz)
6. Increase OFDMA channel size
7. Add a 2nd OFDMA channel

Starting Point 3: Aligning the DOCSIS 3.1 Transition with IP Video

In addition to supporting increasing broadband traffic requirements, service providers are also looking to DOCSIS 3.1 to help enable the coming transition to IP video. By bringing their IP video and DOCSIS 3.1 deployment plans together, service providers can avoid replacing customer premises equipment multiple times and instead install DOCSIS 3.1 enabled gateways with all of the features needed for IP video. Such features include multiple tuners for IP video and high-speed data traffic, MoCA outputs for IP set-top boxes, and HDVR capabilities.

STARTING POINT #3

Ideal for:

- Networks with some available bandwidth
- Synchronizing DOCSIS 3.1 and IP Video investments
- Preventing broadband traffic from being "stepped on" by IP Video traffic
- Scaling bandwidth as IP Video traffic increases

In addition to synchronizing infrastructure investments, service providers can also align their spectrum utilization plans to maximize the gains of DOCSIS 3.1. Much like the approach for super users above, service providers can dedicate a small amount of downstream spectrum to DOCSIS 3.1 IP video traffic and bond it with legacy channels for added capacity, or use a larger area of dedicated spectrum if it is available. In this case, IP video traffic is isolated on DOCSIS 3.1 OFDM channels, while high-speed data traffic for all customers continues to be sent using DOCSIS 3.0 single carrier channels. This approach allows service providers to take advantage of the DOCSIS 3.1 higher spectral efficiencies, while gradually increasing spectrum as IP video traffic grows. As with the super users approach, upstream bandwidth can remain in the DOCSIS 3.0 realm or expanded to 5-85 or 5-204 MHz to accommodate higher traffic demand. This approach enables service providers to more fully utilize the highly scalable CCAP solutions they are deploying in the headend, many of which are architected to include a seamless transition to DOCSIS 3.1. It also reduces installation costs and capitalizes on the DOCSIS 3.1 capability of supporting more programs within the same channel bandwidth.

Delivering Greater Density Using Distributed Access Architectures

In addition to the expected increase in I-CCAP densities over the next few years, there are several other potential solutions under discussion that provide additional solutions to head end restrictions in space and power as well as dealing with non-linear optical noise issues associated with lambda density and fiber run length challenges. Many solutions have been proposed but the industry is consolidating around some key technologies. Some of these such as Remote PHY and Remote CCAP leverage the increased density and distance associated with digital optics to move the PHY and MAC/PHY respectively to the fiber node while techniques. Additional solutions are also under development to provide more cost effective support for highly distributed smaller head ends.

DOCSIS 3.1 will permit MSOs to increase their spectral efficiencies using much higher-order modulations than those used in DOCSIS 3.0 today. As an example, it may be possible to push the DOCSIS 3.1 modulation levels to 16384 QAM in the future, which offers much higher bandwidth capacities than the 256 QAM levels used in DOCSIS 3.0 today. These higher-order modulation systems within DOCSIS 3.1 will undoubtedly require high SNR values within the HFC plants, and any plant modifications that improve SNRs will help MSOs capitalize on all of the benefits of DOCSIS 3.1. One particular area that may promise improvements in SNR is the use of distributed access architectures (both Remote PHY and Remote CCAP). Through

the use of digital optics (Ethernet) to transmit signals from head-ends to fiber nodes, distributed access architectures can effectively mitigate many of the SNR-degrading issues associated with nonlinear optical noise (commonly found within analog optical transport systems). For this reason, some operators may eventually evolve their HFC plants to support distributed access architectures. These techniques are discussed in a later white paper in this series focused on distributed access architectures.

CONCLUSION

As service providers move beyond calculating the benefits of DOCSIS 3.1 and begin preparing their plans for deployment, it is critical for them to consider several operational issues that have the potential to impact the early successes of this promising new specification. By examining the unique challenges that come with operating in a new area of spectrum, preparing their plants for DOCSIS 3.1 traffic, examining the needs of distinct user and service profiles, service providers can begin to formulate a migration strategy that creates a path to initial and long-term success.

RELATED READINGS

- **Migration Paths to Full CCAP Functionality white paper**
  (http://www.arrisi.com/dig_lib/white_papers/_docs/migration_paths_to_ccap.pdf)

  The cable industry has begun a multi-year migration toward a common platform for video and data. While CCAP defines a particular architecture, there are numerous ways to reach that converged endpoint. Drawing from the real-life experience that service providers have had to date, this paper recognizes the diversity and ongoing evolution of the headend and existing cable infrastructures; focusing on three paths to full CCAP.

- **Managing the Evolution to DOCSIS 3.1 Part 1: A Technical Migration Plan for Long-term Success**
  (http://www.arrisi.com/data1/content/d3-1_migration.asp)

  While the abundance of cutting-edge DOCSIS 3.1 features and technologies yield significant capacity improvements, they can also present a challenge in selecting the right migration path with the appropriate sequence of evolution steps. This paper reviews the DOCSIS 3.1 capacity gains over DOCSIS®3.0 systems, outlines best practices to maximize DOCSIS®3.1 throughput on HFC networks, and proposes a technical network evolution plan to carry service providers several decades into the future for long-term, sustained success.

MEET OUR EXPERT: Ayham Al-Banna

When it comes to DOCSIS-based cable access networks, Ayham Al-Banna is at the forefront of innovation and expertise. At ARRIS, his role is to define the architecture and guide the evolution of the company's CCAP and CMTS solutions, and he is the holder of several granted and pending patents in this area. But his influence truly transcends the cable industry. Through his work on the DOCSIS 3.1 PHY committee and its covert predecessor the Advanced MAC PHY committee, Ayham has helped shape this exciting new specification from the very beginning. And when he's not busy inventing the future,he's sharing his knowledge with his peers at IEEE events and industrial conferences, presenting new ideas to customers to help them architect better cable access networks, and inspiring the minds of tomorrow through his work as an Advisory Council member for Miami University and his adjunct teaching role at several other universities.