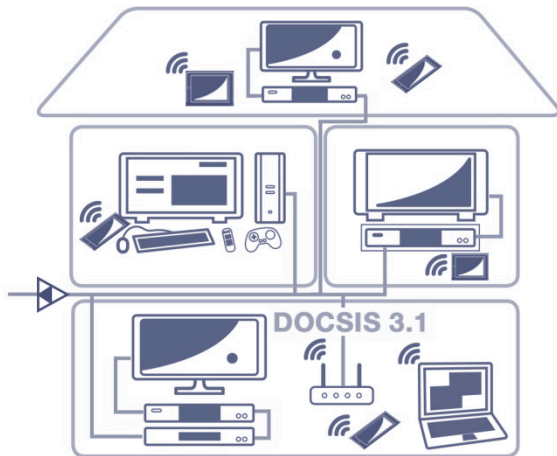


# How to Improve In-Home Performance Thresholds for DOCSIS 3.1

## DOCSIS 3.1 White Paper

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When international telecommunications standard Data Over Cable Service Interface Specification (DOCSIS) 3.1 was initiated in late 2013, it targeted greater capacity and increased speed for HFC Broadband networks, while remaining compatible with earlier technologies. Delivering DOCSIS services, whether it is 64 QAM upstream (3.0) or orthogonal frequency division multiplexing (OFDM) 1024 (3.1), is often possible with minimal investment and network changes. However, to maximize delivery quality with the highest data speeds requires an in-home network resilient to interference and noise contributors. Where is your threshold for the next generation of services?



There are several obstacles to delivering DOCSIS technologies, including the common effects of loose connectors, signal level discrepancies and ingress/egress. In addition, the peripheral wireless technology of long term evolution (LTE) shows its presence in homes within the same spectrum (regionally specific) with which broadband cable systems are present. Negative effects with respect to ingress and egress from coaxial cable shielding deficiencies and/or loose connectors with the presence of LTE transmissions can generate service calls, degrade the customer experience and are increasingly monitored regularly.

Network architectures are evolving to fewer homes per node creating increased capacity per subscriber, thus delivering higher speeds. Fewer homes per node will create a performance improvement due to the reduced return path noise funneling. There is also strong consideration for expanded bandwidth in both the upstream and downstream creating additional spectral efficiency. The actual bandwidth considerations vary geographically around the globe, and any modification to the network frequency allocation split between the forward and return path can come with a significant capital and operational cost.

To achieve capacity demands with the exploding adoption of data services, there is a natural evolution to deploy more complex modulation techniques over DOCSIS platforms. This has always been a leading indication that the overall network performance needs to improve. From QPSK to 16 / 32 / 64 QAM presented additional challenges over the past years that delivered common phrases, such as drop hardening, home integrity check, proactive network maintenance and line conditioning. DOCSIS 3.1 utilizing OFDM modulation techniques and LDPC (Low Density Parity Check) error correction offers additional capacity per subscriber for a robust performing network, but maximizing the return on investment may require some efforts within the transmission medium. The question that cannot be avoided today – can we consistently reach the DOCSIS 3.1 threshold while meeting the growing capacity demands?

This white paper details common network issues that plague operational budgets and serve as obstacles to delivering the most recent DOCSIS technology standards. It will also suggest network enhancements and daily installation tactics to improve network performance. Finally, reliable network performance improvements along with proactive network maintenance (PNM) efforts and monitoring systems create the in-home service integrity that drives customer satisfaction up and reduces churn.

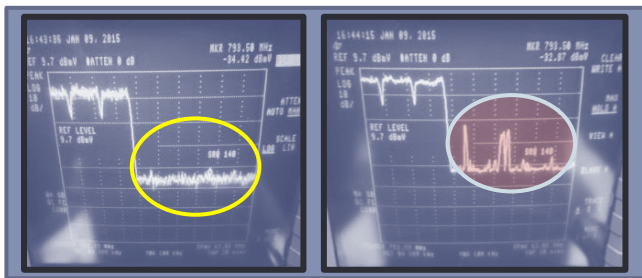
### The In-Home Network Threshold

Experience over the past few decades has proven that in-home architectural issues, typical installation errors and in-home connectivity components contribute significantly to overall network performance falling below acceptable threshold levels. These issues have been inherited from legacy operators, the in-home DIY's, and common craft errors that are simply human nature.

There is a threshold of performance for every major electronic component in the network. Installation errors, as well as the increased number of passive devices, affect performance – making it challenging to effectively deliver to the DOCSIS 3.1 standard.

Improving the network performance for increased data capacity is also challenged by the growing number of customer premise equipment (CPE) devices online. Furthermore, these CPE devices, in the form of modems, routers and set-top devices, often come with self-installation kits where subscribers frequently perform installations themselves. This results in a higher number of service calls in this sector due to installation errors.

In addition, multiple wireless devices using LTE frequencies in close proximity to the coax network are increasing the risk of interference as noted in the diagram below. This diagram shows the cable



TV spectrum where the LTE spectrum coexists. The left side of the diagram shows no interference with tight F Connectors on the CPE devices. The right shows LTE phone transmissions when a standard connector is in a loose state with a high resistance to ground. Note that the cable TV spectrum where LTE coexists has been left vacant, in this case perhaps to avoid interference issues in the short term. As data demands increase with service adoption and competitive offerings, the desire to deploy more sophisticated modulation techniques over DOCSIS platforms indicates the need for overall network performance improvements or raising the threshold for DOCSIS 3.1 performance.

### Common Sources of In-Home Network Performance Issues

The in-home network radio frequency (RF) performance plays a lead role in delivering services that meet service quality demands. There

are three main areas impacting today's in-home network performance:

1. Quantity of Products – With the increasing number of revenue generating units (RGUs) per home comes additional components in the form of connectors, passive splitters, drop amplifiers, coaxial cables, as well as modems and set-top devices. Additional RGUs typically require passives for the installation that reduce signal carrier strength, allowing infiltration of noise. It also increases the total cost of ownership (TCO) with the increase in service calls, a systemic problem that is difficult to track for a single component. There is a cumulative effect situation whereby more devices installed create additional noise, thus a greater funneling effect of noise in the return path.
2. Quality of Products – The quality of the components used to connect multiple home devices impacts performance with respect to electrical integrity and component reliability. RF ingress and egress from components that have poor RF shielding effectiveness enable interference and noise that funnels in the return path to the head-end or Cable Modem Termination System (CMTS). This RF noise degrades performance, increases error rates and diminishes the integrity of data flow.
3. Quality of Installation – The greater the number of components requiring installation, the greater the chance for installation errors. For example, when connectors are left loose or are improperly installed, the RF performance is negatively impacted. Again, with the increase in self-installations comes an increase of craft errors resulting in service calls. Loose connections are also very susceptible to moisture ingress. Loose connectors, resulting in the loss of continuity, can significantly degrade signal return loss and insertion loss creating reflections that generate data transmission errors hindering performance.

Perhaps the most common service call condition is noted with loose connectors. Over 50 percent of all indoor connectors are less than finger tight. Often a connector may be loose with no continuity to ground such that the connector post and nut are floating or un-coupled. This causes very high resistance and generates immediate signal level degradation, as well as ingress and egress. Details for this area are noted further in this paper.

Another common source of in-home performance degradation is low signal level. The overall signal level as a result of increased passives and associated passive loss may not be sufficient to deliver adequate performance, thus the need for amplification.

Removing these obstacles combined with architectural improvements creates a path to and beyond the current DOCSIS 3.1 threshold requirement to competitively deliver services that exceed consumer demand. The TCO with simple network investments have been proven in recent years to provide a pathway for successful technology deployment.

### Discovery to Solution

To control and increase in-home performance requires a focus and evaluation of the components in place today. It is vital to be cognizant of the current performance of all components, specifically the integrity of the F Connectors, coaxial cable, passives, such as splitters, and F-81 line splices. Let's review these individual components.

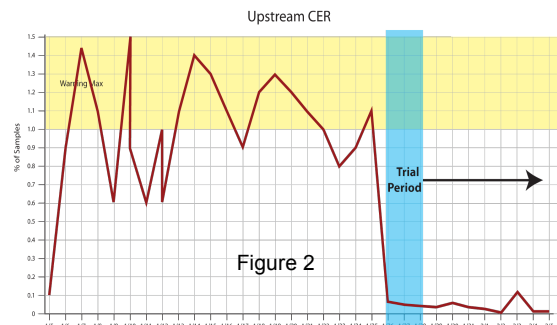
### F Connectors

By far the most critical component in the home is the F Connector. It is also the highest volume component in the network. For example, there are approximately 250 million CPE devices deployed in the North American networks that contain over 3 billion F Connectors. The F Connector is also the most common failure point, responsible for a significant operational cost burden that is magnitudes above the initial capital cost. The high operational burden has become a focus of attention to improve the technology and quality while reducing the associated installation craft errors. The technology of the F Connector has progressed over the years from a hex crimp design to a 360 degree compression design. Furthermore, the physical design enhancements have created connector technology with a dynamic range that covers varying braid content from 60 percent coverage through quad shield with

performance parameters exceeding recommended industry standards in some cases.

Proven field observations surrounding craft errors on connectors that generate service calls have caused further advancements over the past ten years. However, it is common to find older technology connector devices within the walls, i.e., located behind wall plates. With connector improvements over the past decade, service offerings are placing more stringent requirements on this component within the in-home network.

With over 50 percent of the indoor connections less than finger tight or loose, this problem has gained high visibility with respect to the loss of continuity to ground, which greatly affects the current network performance. The effects several years ago with one-way analog networks had minimal to no impacts. This is not the case today. Loss of continuity occurs in loose connections whereby the connector hex nut is physically separated or intermittently disconnected from the connector post that extends within the grounding braid in the coaxial cable. The loss of continuity creates an impedance mismatch, ingress / egress, high insertion loss and reflections that impede the data transfer and generate service calls. In fact, a

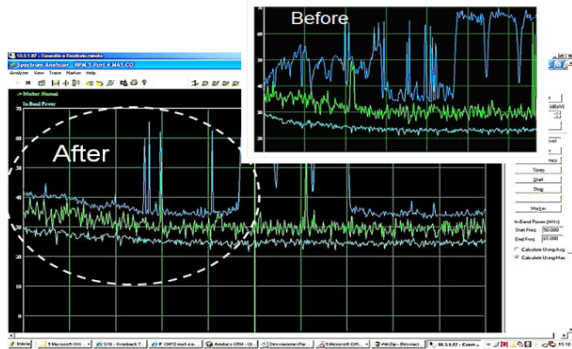


single connector without continuity to ground can result in service calls at numerous homes within the optical service area or “node.”

Today, it is essential to select an F Connector that easily installs on all common cables in every environment and seals out moisture 100 percent of the time to minimize network impairments and service calls. While there are many components contributing to in-home performance issues, the connector is often most vulnerable due to subscriber self-installs, device movement and common vibrations. To address this operational burden, extensive research and monitoring of in-home networks worldwide resulted in the

development of a connector that has technology integrated to maintain continuity to ground when loose. When left loose, the continuity connector performs near that of a fully tightened connector minimally impeding network performance. It has been widely adopted by the largest global operators and recognized as an enabler to better customer experiences and lower operational costs. It has become a standard migration and is in millions of homes.

The figure below is a graph exhibiting a single loose connector with no continuity to ground. It



shows “Before” effecting 200 homes in the return path and the “After” resulting noise reduction when the single suspect connector was tightened.

Deployment of continuity connectors is increasing, resulting in fewer service calls. In the diagram, tracking code word error rates (CER) improved when loose connectors were replaced with continuity connectors that were also left loose. The results were conclusive, immediate performance improvements were noted for the upstream CER and service calls were reduced.

### Coaxial Cable

The older coaxial cables installed should be verified as performing adequately. Networks are demanding performance to 1.2 GHz and the installed coax may only have adequate performance at a frequency specified below 1 GHz. The ingress effects caused by poor or damaged coaxial cable and poor or loose coaxial connectors within the home can generate service calls and service disruption affecting numerous subscribers.

### Passive Devices

When it comes to passive devices, specific parameters (electrical, bandwidth and physical) are designed into every solution. These

parameters, however, have changed over the years to evolve with the network demands. This section observes various passive devices and their performance threshold parameters.

### Passive Splitters

Splitters may perform to adequate specifications per their specified bandwidth. These specifications include insertion loss and return loss, yet, the bandwidth requirements may have since expanded and these components may not perform well beyond 1 GHz, or even to lower frequencies in the typical frequency range of 5 MHz to 860 MHz. Due to the inadequate performance at higher and lower frequencies than originally designed to, the bandwidth edges in which the network operates will be significantly degraded.

### Passive Line Splices

F-81 splices, such as those located in wall plates, may be older and specified to a limited operating frequency. With an amount often exceeding five in every home in wall plates and splices (that ALL look alike with different specifications), it is difficult to identify the weaker links. Return loss and center-conductor contacts are often not specified to current operating frequencies again hindering performance for impedance, return loss and insertion loss.

### Passives in General

Shielding effectiveness is another area of older or poor-quality passives that may not be obvious during routine visits. It is not frequently desirable for technicians to replace poor coax within the walls of homes due to the operational cost burden. However, the network parameters and certification techniques within the home are starting to demand this.

Operators are now providing a home checklist of performance parameters for the service technicians and installers prior to closing out the service call or installation. The home integrity checklist is becoming key such that vital parameters surrounding signal integrity and data performance are met or exceeded. These key parameters within the checklist are a subset of the proactive network maintenance systems or standard operational practices (SOP) and have an overall positive impact on the future home services and cumulative network performance improvement.



Finally, with the increasing amount of CPE devices and televisions per household, signal levels may require amplification due to the required increase in passives.

The initial network build may not have considered the high level of passive loss or the loss increase due to higher bandwidth. The signal levels at the CPE devices may not be adequate to offer acceptable performance. The situation may need amplification.

#### **Passive MoCA Filters**

There is also a rising deployment of “whole-house” DVR services and the adoption of these services continues to grow. This uses a technology standard known as MoCA (Multimedia over Coax Alliance). MoCA operates at a much higher frequency and must be blocked via a low pass filter at the point of entry to the home. Since the strict “in-home” MoCA network provides secure transmission from DVR to client devices throughout the home, it is a requirement to contain these signals in the subscriber’s home network and prevent connecting the DVR with neighboring homes. Unfortunately, these low-pass MoCA filters add additional insertion loss attenuating the primary signals as well.

#### **Drop Amplifiers**

Drop amplifiers continue to be used to counter the effects of passive loss. Technicians must be sure to use the amplifier gain wisely and not cover other issues within the drop plant, such as excessive loss due to poor quality passives or damaged devices. These issues could include damaged coax, loose connectors or passives that simply do not meet current bandwidth requirements. Secondly, the bandwidth of the drop amplifiers themselves and the location within the in-home network is critical to the overall system performance. Finally, we should consider a passive port on the amplifier, also known as a bypass port. This maintains VoIP and data transmission via the DOCSIS modem when there is no power in the home and ensures that the DOCSIS carrier remains above the noise floor.

#### **Line Conditioning**

There are passive and active devices to enhance signal levels over a broad frequency spectrum in the forward and return path bands. These offer improvements by either filtering noise, blocking unwanted carriers that create interference, and switching the return path on and off to reduce the cumulative noise effects in the return path.

CPE devices require a signal level window to operate properly. When the signal levels exceed, fall below or both due to excessive tilt, the CPE fails to perform at optimum levels. Frequency-specific devices, such as equalizers, cable simulators, attenuators, gain devices (drop amplifiers), and high / low pass filters, groom signals for optimum CPE performance.

Another recent technology introduced is a noise mitigation technology that switches the return path on / off. The switching speed does not affect data transfer and the circuit is closed only when data is transmitted (or polled). To prevent noise funneling in the network, the circuit is in an open position when no upstream data is transferred. Major operators are currently conducting further studies on the positive effects surrounding network performance and customer satisfaction.

#### **Improving In-Home Network Performance Through Drop Hardening**

Drop hardening improves signal-to-noise ratio, reduces impulse noise, and minimizes ingress and egress, all of which decrease service calls. Initial service calls often create follow-up service calls, and approximately 20 percent of repeat / follow-up service calls result in customer churn. The operational cost of a service call almost always exceeds the capital cost, which is why the drop hardening procedure should be efficiently conducted at every visit.

Drop hardening involves three vital steps:

##### **Identifying Root Causes**

Root cause identification is important as it leads to product and process improvements. To control, stabilize and improve in-home performance requires a focus and evaluation of the components in place today. These vary greatly from one home to another as a result of the initial installation, architecture required at the time of installation(s), and the variation

of craft and component quality installed by operators and home owners. Today's advanced PNM systems can often direct technicians to root causes, identifying loose connectors, moisture damage, inadequate or damaged coax, and passive components to name a few. Knowing the root cause provides valuable insight to drop hardening / performance improvements.

**Benchmarking a Performance Threshold**

An SOP outlining architectural guidelines and test parameters ensures a uniform approach to reach the desired threshold. Signal levels at the CPE to include both forward and return should be in the desired range. DOCSIS levels from the cable modem should also be within the desired range as these vary greatly based on the passive loss variations in the return path. Signal to noise ratio (SNR) and modulation error ratio (MER) are also commonly tested.

Many of today's PNM systems are constantly monitoring all network devices via DOCSIS parameters. Using logic, the operator is directed to issue areas that when repaired provide a cumulative performance improvement for numerous subscribers. An integrity check can now be registered within the management system and monitoring continues automatically.

**Evolving the Quality of Components**

It is imperative to use quality components that meet or exceed current and future performance requirements. This involves upgrading devices with bandwidth limitations and ensuring that electrical / mechanical performance specifications are verified in accordance with network requirements. Bandwidth limitations may vary greatly within the home from "hidden" components, such as the coax within the walls to the simple splitters installed by the home owners to add additional devices (routers or TV's). The component quality must take into account the craft sensitivity of initial installations and reconnections commonly conducted by subscribers. It is essential that products meet or exceed mechanical and electrical performance recommendations not to exclude the areas of bandwidth (upper and lower frequency limits), RF shielding

effectiveness, return loss, insertion loss and stability in varying environmental conditions.

The current state of the in-home network will likely need to be enhanced or improved to meet the increasingly stringent demands. The transmission medium has often been neglected over time and the operational cost burden of service calls continuously results in reduced profit and a loss of subscribers. Regardless of the physical plant changes and the modulation schemes that provide us with increased data capacity, it is the daily, routine installation practices that can be the greatest contributor of success to network performance and the user experience.

Without following these best practices – investigating the drop plant to discover root causes of issues and selecting the best available technology within components planned for future requirements – service calls due to plant network issues will continue. Improving the drop plant significantly increases the likelihood of a successful DOCSIS 3.1 launch and a more profitable future.

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