Getting a grip on DOCSIS

Network reliability equals increased revenue

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Data-Over-Cable System Interface Specification (DOCSIS) is the vehicle for cable operators to obtain immediate revenue-generating opportunities such as broadband data, voice-over-IP, IP video-on-demand, and countless emerging IP-based technologies. These growth channels rely on cable operators obtaining and retaining subscribers. Subscriber satisfaction with new services is a direct function of DOCSIS network reliability. Improving DOCSIS network reliability requires new skills and new test equipment, in addition to the skills and test equipment the industry possesses today.

This article provides a working knowledge of DOCSIS networks, the types of impairments that exist in DOCSIS networks, and strategies employed in identifying the impairments in the physical plant.

DOCSIS working model

Developed by CableLabs, DOCSIS is the specification which provides a standard for bridging Ethernet data over a hybrid fiber/coaxial (HFC) network. The DOCSIS specification defines the method by which DOCSIS-based devices operate on the RF plant. Fundamentally, there are three layers of communication which must be understood in order to analyze a DOCSIS network:

1. The physical layer (PHY), which defines how DOCSIS-based devices transmit data on RF carriers on the RF plant,

2. The DOCSIS communication language, or protocol, that defines how DOCSIS-based devices communicate with each other, and

3. The method that Internet Protocol (IP) packets are transported over the DOCSIS network, arriving at their intended destination in a timely manner and without errors.

This model is best illustrated as a bottom-up architecture in Figure 1. The base of the pyramid represents the physical layer of DOCSIS. This is where data is modulated and up-converted to an RF carrier for transport across the HFC plant. The second level of the pyramid is the DOCSIS Media Access Control (MAC) layer. This represents the inter-communications between DOCSIS-based devices that enable cable modems (CMs) to communicate with the cable modem termination systems (CMTSs). Finally, the top level of the pyramid represents the layer at which Ethernet data is transported. This layer is used both by subscribers for data access and by cable modems during registration (explained later).

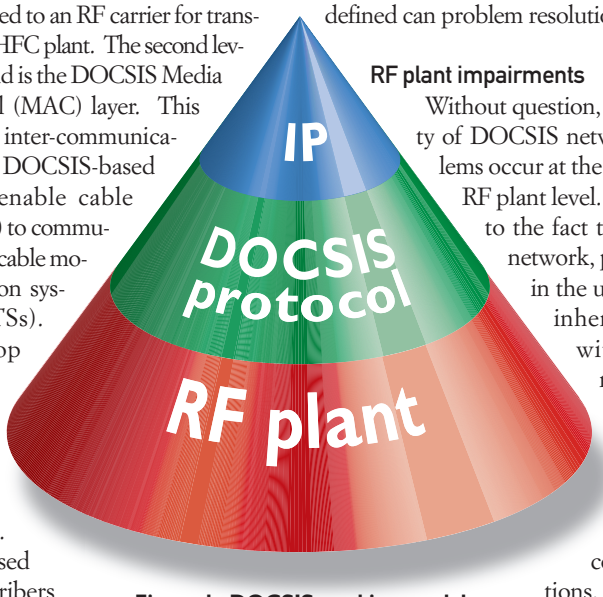

Figure 1: DOCSIS working model.

Troubleshooting DOCSIS

In assessing and improving DOCSIS network reliability, it is critical that all three layers of the DOCSIS working model are analyzed. Impairments that occur in the RF plant may appear to be DOCSIS- or IP-related problems; similarly, problems in the DOCSIS MAC or IP protocols may appear as RF impairments. This creates an enormous troubleshooting dilemma, which often results in significant time and money spent attempting to resolve a problem which does not exist. Here lies the enigma behind many DOCSIS network problems–locating the source of the problem!

In order to solve the enigma, we must first describe the origin of many common DOCSIS network problems. This is best done with a bottom-up approach, discussing impairments at each layer of the DOCSIS pyramid and how to best identify the impairment. Only after the problem has been defined can problem resolution begin.

RF plant impairments

Without question, the majority of DOCSIS network problems occur at the physical or RF plant level. This is due to the fact that the RF network, particularly in the upstream, is inherently rich with mechanisms that will prevent or impair DOCSIS communications. Some very common and well-known RF impairments are:

- Linear impairments such as Micro-reflections; amplitude and group delay distortion; and amplitude slope or tilt.
- Non-linear impairments such as common path distortion (CPD); and return laser clipping.
- Transient impairments such as ingress noise; and impulse noise.

Individually, these impairments may impact DOCSIS reliability and can be difficult to identify using conventional test equipment. Collectively, these impairments create an environment where it is impossible to identify the source of network failures with certainty. Why is this so?

In a DOCSIS network, there is one master controller, the CMTS, communicating with hundreds or thousands of

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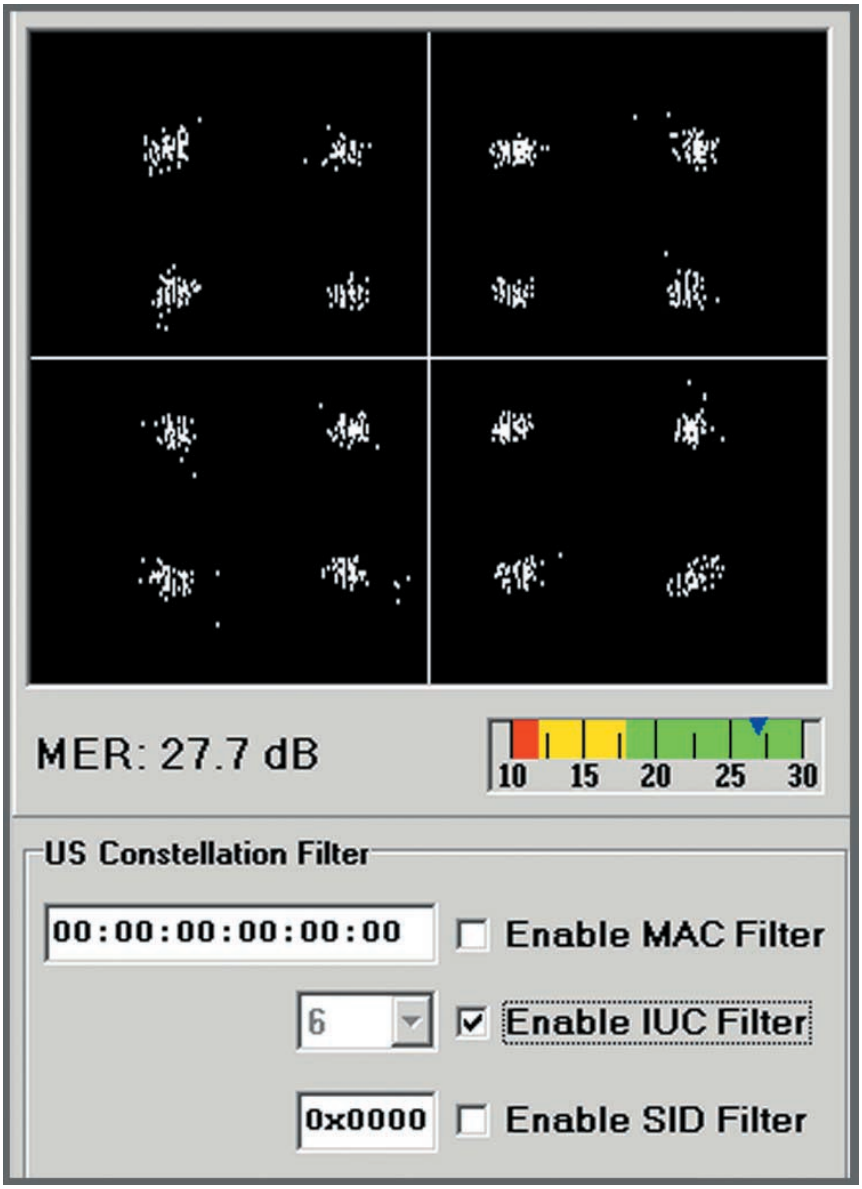

Figure 2: Upstream MER of a single cable modem.

cable modems. The cable modems all transmit signals to the CMTS by time-sharing the upstream channel, also called Time Division Multiple Access (TDMA). This means that the modems transmit data for a very brief period of time–on the order of micro-seconds–and turn their transmitters off.

Conventional spectrum analyzers and vector signal analyzers enable the technician to determine the carrier-to-noise (CNR) level and modulation error ratio (MER), respectively, of the cable modems collectively. While these measurements provide a qualitative index of overall network performance, they fail to provide the performance of individual cable modems.

Analyzing individual cable modem performance requires a new breed of test equipment called DOCSIS Protocol Analyzers. These analyzers demodulate individual cable modem transmissions and provide not only a quantitative measurement of the signal's quality, but also provide information designating the source of the transmission. A DOCSIS protocol analyzer can filter on a specific cable modem and provide signal quality measurements, as shown in Figure 2.

Armed with this capability, a cable technician can look at the signal performance of a single cable modem experiencing performance issues and determine whether or not the performance issues are due to RF impairments, without ever leaving the headend or hub site.

Figure 2 depicts a cable modem transmitting in 16-QAM, with MAC address 00:E0:6F:29:27:AC, which exhibits a 24.0 dB MER. Because 16-QAM transmissions only require 18 dB MER, the technician can be certain that this modem is operating properly in the RF plant. If, on the other hand, the MER of this particular modem was, for example, 16 dB, then the technician would know that the modem is experiencing impairments from the RF plant.

The technician now knows whether the source of the network impairment is a problem in the RF plant is a communications related problem, not involving the RF plant. In the case of RF plant impairments, traditional test equipment can be used for impairment location and resolution. For non-RF plant related impairments, the DOCSIS protocol analyzer must be used for analysis of the RF modulated data.

DOCSIS protocol impairments

CableLabs and tComLabs are the only two organizations responsible for certifying and qualifying cable modems and cable modem termination systems as DOCSIS compliant. This expensive and time-consuming testing process attempts to test each device against the DOCSIS specification under a number of possible real-world conditions in the laboratory. However, DOCSIS certification does not always guarantee that all DOCSIS-based devices conform to the DOCSIS specification.

A previously-certified cable modem can become non-conforming with a minor product change by either the equipment vendor or a manufacturing process change. These seemingly minor changes can have catastrophic impacts on equipment performance in DOCSIS networks.

When DOCSIS-based devices violate the DOCSIS protocol, network failures are sure to follow. Using conventional RF test equipment in identifying the source of DOCSIS protocol violations is difficult, if not impossible. Some diagnostic information is provided by the CMTS, but this usually only identifies that a problem exists and does not show the root cause of the problem.

In order to identify and isolate DOCSIS protocol violations, one must analyze the protocol in its native format–as RF modulated carriers in the RF plant. Additionally, DOCSIS commands have a format unlike any other in the communications industry, as defined by the DOCSIS specification. Cable operators must again turn to DOCSIS protocol analyzers in order to troubleshoot DOCSIS protocol-related problems–the very same way the DOCSIS vendor community develops and troubleshoots DOCSIS-based CMTSs and CMs.

The result is a DOCSIS network that is not operating properly. The technician has examined the RF plant and determined that the problems are not the result of RF impairments. Close analysis of DOCSIS communications between the CMTS and the cable modems experiencing problems will determine if equipment is functioning properly. A DOCSIS protocol analyzer captures DOCSIS protocol and a viewer which presents the DOCSIS protocol in a format that is readable by the human eye. This output is a powerful tool for both identifying the presence of DOCSIS violations and for settling disputes with vendors providing equipment that violates the DOCSIS specification.

IP layer impairments

IP layer impairments impact both the subscriber and the DOCSIS network. It is obvious that for a cable modem to register with a CMTS, both the RF plant and the DOCSIS MAC must be functioning properly. But the IP layer is also critical for cable modem registration. First, the cable modem must receive a unique network address from a Dynamic Host Configuration Protocol (DHCP) server. Additionally, the cable modem must download a configuration file from a Trivial File Transfer Protocol (TFTP) server. Both the DHCP and TFTP servers transmit data over the IP network.

After cable modem registration, the IP layer is used by subscribers to transfer and receive IP data such as e-mail, Web pages, and gaming sessions. Additionally, the IP layer is where VoIP calls reside. IP layer impairments such as server failures, network congestion, data delay and jitter, will provide a less than satisfactory user experience.

The IP layer also suffers from any RF or DOCSIS related impairments. For this reason, the IP layer resides at the top of the DOCSIS working model pyramid. Failures at any sub-layer directly translate to apparent failures at the IP layer. Failures at the IP layer translate to network reliability problems and subscriber complaints.

Achieving reliability

Improving DOCSIS network reliability is not a single action or investment. Rather, it is a conscious decision to implement a cradle-to-grave strategy to work the DOCSIS pyramid from the bottom to the top. This begins with investing in quality transmission equipment and using proven practices for installing, balancing and maintaining the HFC plant. Education and training play a strategic role in DOCSIS setup and maintenance, ensuring that the correct equipment is chosen and properly configured. Finally, investing in the proper test equipment, training technicians how to use the equipment, and actually putting the equipment to use, is the final step.

There are two principal ways to employ test equipment in order to improve DOCSIS network reliability–tactically and strategically. Tactical network testing is the usual practice, also referred to as "fire fighting." This occurs when a problem happens, usually a subscriber-generated complaint or a major outage. The required test equipment is located, the dust is blown off of it, and someone is identified who remembers where the power button is located. Testing commences, fingers point, speculations are sounded, and eventually the impairment is identified or the problem goes away, to surface again someday.

Strategic network analysis is a very different approach–also referred to as preventive maintenance. This second method, coupled with the proper test equipment, is the key to network reliability. At the physical layer (RF), most systems have in place one or more monitoring systems for measuring ingress levels, CNR, inter-modulation distortion levels, etc. This is critical for early identification of common problems.

DOCSIS protocol analyzers also serve as a critical element to achieving network reliability. DOCSIS protocol analyzers, when not being used for tactical purposes, can monitor downstream and upstream data communications of all DOCSIS devices. This information is archived to a database, which provides trend analysis information on cable modem MER, power, frequency, timing and equalization adjustments. User definable thresholds can be set which automatically notify appropriate personnel when device operation becomes critical due to any number of impairments in the DOCSIS pyramid.

This latter method provides a means of identifying potential network failures before they occur. The ability to replace a failing modem, upstream transmitter, or CMTS, long before the subscriber experiences an outage, this translates directly into improved network reliability, from the point-of-view of the subscriber. Problems will still occur, but they are resolved before the end user notices them.

Summary

Network reliability is the single greatest instrument to obtaining and retaining paying customers. It is the metric that will determine the successful deployment of advanced IP services beyond simple e-mail and Web browsing. No longer is it an option or a luxury–network reliability is a necessity for the cable industry to successfully capitalize on the video/voice/data triple play.

As with any new technology, for example fiber optics and digital video, the industry has learned new techniques and adopted new technologies in order to make the technology successful. DOCSIS is simply a new technology. The tools and training for implementing and stabilizing DOCSIS networks are available. It is now a matter of execution for cable operators to directly increase profitability. ■