BY BRADY VOLPE, THE VOLPE FIRM
FORMALLY OF SUNRISE TELECOM

Contemporary troubleshooting of Data over Cable Service Interface Specifications (DOCSIS®) requires a combination of RF and IP disciplines. DOCSIS begins at the RF domain where digital signals are modulated and transported across the Hybrid-Fiber Coaxial (HFC) network between two end points. Theses devices consist of a Cable Modem Termination System (CMTS) and cable modem(s). The transmission of digital data forms an IP network, which relies on many common networking devices, such as Dynamic Host Control Protocol (DHCP), Trivial File Transfer Protocol (TFTP), and Time of Day (ToD). Impairments and communications breakdown can and do happen at both the RF and IP domains.

The challenge for today's broadband warrior is to rapidly determine where the root cause of the impairment lies, because all too often IP impairments look just like RF impairments and vice-versa. Adopting a holistic approach to diagnosing issues is critical as the combination of RF and IP become commonplace. In this article we will focus on the interaction of RF and IP impairments and the importance of considering these before assuming network problems are singularly RF-related, a typical approach in the cable industry.

CABLE MODEM REGISTRATION & FAILURES

An example of this interaction, which will later be extended to Voice-over-Internet Protocol (VoIP,), is cable modem registration. Understanding the basic cable modem registration process is key to understanding fundamental DOCSIS operation as well as RF and IP interaction in a DOCSIS network.

The first step of registration is downstream lock and cable modem upstream power ranging (Figure 1). If this step is successful, one can assume the RF network is working. Next, the IP network is exercised with a number of DHCP, ToD and TFTP transactions. These transactions give the cable modem critical information to operate on the network. A failure during this part of the process often involves IP network related elements; though can involve RF impairments as well.

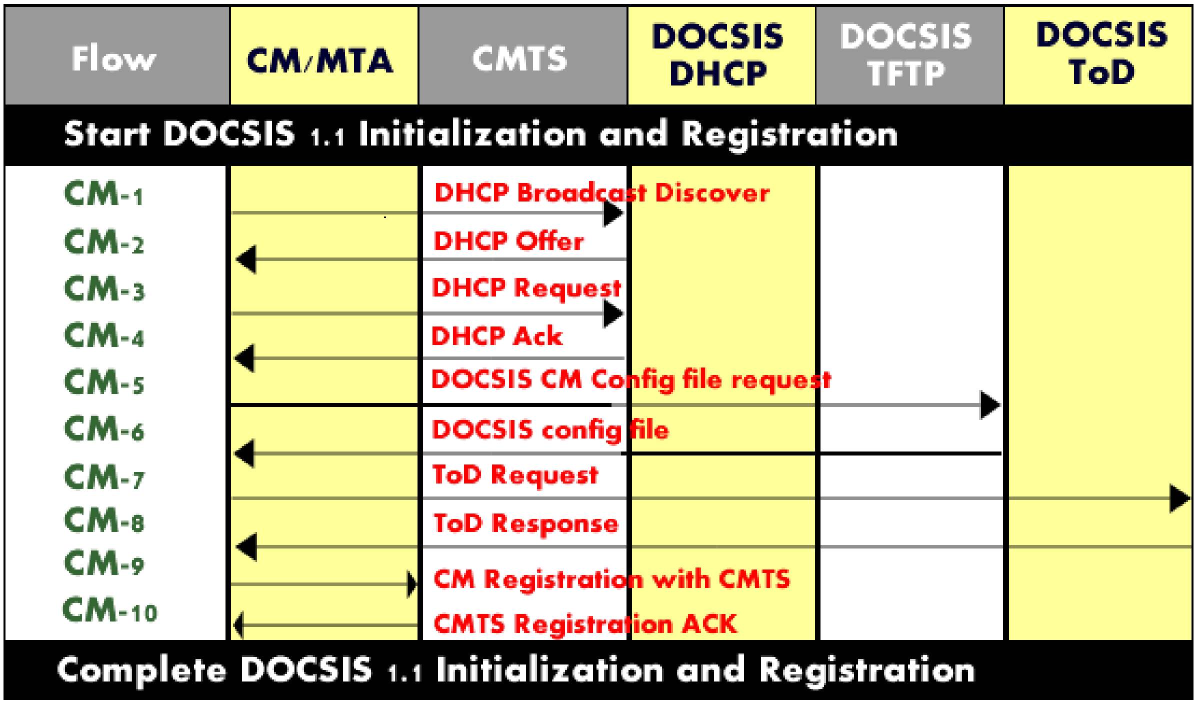

Figure 1

If there is a problem with any network server the cable modem or eMTA may not get the required information for registration, and service is disrupted. The most common failure modes for cable modem registration failures are:

1. Modem downstream lock failure → Signal too low, too high, signal quality too poor (low MER), or total channel power > +30 dBmV

2. Downstream lock okay, modem attempts to register, then resets → Too much upstream loss, upstream RF impairments, device is un-provisioned, DHCP or TFTP server problems/conflicts

3. Mixed mode modulation → (QPSK Ranging / 16-QAM Data) QPSK ranging punches through noise, but 16-QAM gets corrupted by ingress, so IP traffic (DHCP, TFTP, etc.) is lost

The above items should be the first line of "Have we checked these parameters?" from both the RF and IP front. Additionally, technicians are often told they have T3 or T4 timeouts by back-office specialists. A T3 timeout usually indicates downstream packet loss and a T4 timeout usually indicates upstream packet loss, both RF impairments.

VOIP IMPAIRMENTS

There is probably no single IP technology that is having so significant of an impact on DOCSIS and broadband networks as Voice-over-Internet Protocol (VoIP). The three primary impairments that degrade voice quality in VoIP networks are packet loss, latency and jitter.

Packet loss is the complete loss of a packet or frame of voice data due to impairment. The impairment could be RF noise damaging the packet so badly the CMTS is unable to recover it, or an IP switch that is over-utilized and forced to discard excessive packets. This represents an identical impairment with two completely different root causes which can occur independently or concurrently.

Latency is almost never caused by the HFC network, but is a function of the IP devices' routing and switching times. Excessive delay, greater than 150 milliseconds, makes conversations uncomfortable. Jitter is the variation of arrival time between packets in the network. Like latency, jitter is not impacted by the HFC network, but is created by IP network routers and switches. Both jitter and latency become worse as network utilization increases, and their effect accumulates.

Figure 2 summarizes the relationship between Mean Opinion Score (MOS) and three primary impairments of packet loss, latency and jitter. Toll quality MOS is considered to be 4.0 or higher. Subscribers begin to hear noticeable degradation to speech quality when MOS falls to 3.5 or lower. If problems related to packet loss, latency or jitter persist, cable operators risk losing customers to DSL services.

	Good	Noticeable	Objectionable
MOS	**4.0**	**3.5**	**3.1**
R-Factor	**90**	**80**	**70**
% Lost Packets	**0.5 %**	**1%**	**2%**
Latency	**100 mSec**	**180 mSec**	**250 mSec**
Jitter	**20 mSec**	**40 mSec**	**50 mSec**

Figure 2

CALL QUALITY E MODEL

MOS is a historical measurement of voice quality based on the subjective perception of a panel of listeners grading a series of calls. Today, calls are tested with an objective method using an equation based upon the E Model, an ITU-T G.107 standard which produces an R-factor score from the following equation: R Factor = Ro – Is – Id – Ie + A. In this equation, "Ro" is the SNR of the system; "Is" are tones and quantization distortion occurring concurrently with speech; "Id" is the network's delay impairment; "Ie" are network equipment impairments, and "A" is the advantage factor of the network.

The E Model takes into account a number of impairments, most importantly packet loss, latency and jitter. Figure 3 illustrates the correlation between R-factor and MOS. Most handheld test equipment providing VoIP test capabilities gives both R-factor and MOS numbers. It is important to differentiate the R-Factor and/or MOS numbers for the upstream and downstream paths of the HFC network because only one path may be impaired. A MOS of 4.0 can exist in the downstream with a MOS of 2.0 in the upstream. The E Model helps technicians compare one subscriber with another to quickly locate and fix network problems.

User Opinion	R Factor	MOS
Very satisfied (Toll Grade)	90 – 100	4.3 – 5.0
Satisfied	80 – 90	4.0 – 4.3
Some users satisfied	70 – 80	3.6 – 4.0
Many users dissatisfied	60 - 70	3.1 – 3.6
Nearly all users dissatisfied	50 – 60	2.6 – 3.1
Not recommended	0 – 50	1.0 – 2.6

Figure 3

SUMMARY

Today's HFC broadband workforce continues to face emerging challenges in sustaining DOCSIS networks. New services and technologies will continue to be deployed everyday with the pressure to sustain them never ending. A thorough understanding of potential impairments on both the RF and IP portions of the network can speed repair, reduce operating expenses, and improve customers' Quality of Experience. Conquer-and-divide troubleshooting methods on RF and IP impairments must be employed in order to realize these improvements. The Conquer-and-divide troubleshooting method works through close collaboration between the back-office technical personnel and field ops, whereby all aspects of the network, both RF and IP, are analyzed prior to a truck roll.