DOCSIS TROUBLESHOOTING

By Brady Volpe,.

In my December 2004 article, I introduced DOCSIS Protocol Analyzers. The article just scratched the surface of how a DOCSIS Protocol Analyzer (DPA) is used in bottom-to-top tool to troubleshoot complex DOCSIS network problems from the RF plant to the IP network layers (see figure 1). In this article, we are going to get medieval on the cable modem registration process, break it down into it fundamental parts, and understand how it should work – and more in importantly, what to look for when it doesn't with a DPA.


Figure 1. DOCSIS Troubleshooting Pyramid

CABLE MODEM REGISTRATION

All cable modems are pretty simple devices, which mean they are pretty easy to troubleshoot once you understand how they should work. So your subscriber buys a cable modem at their favorite electronics store, (hopefully) registers it with their local cable system, connects the RF coax and plugs in the power. The following steps are what the cable modem should do:

1. Downstream Frequency Search: The cable modem scans the downstream looking for 64- or 256-QAM digital carriers. Once a digital carrier is found, it looks for information on that signal that would be sent by the Cable Modem Termination System (CMTS). A critical piece of information would be the Upstream Channel Descriptor (UCD), which contains information that the cable modem will need, such as the upstream frequency and bandwidth to use in order to communicate with the CMTS.

2. Ranging: Once the cable modem has found the digital signal from the CMTS (remember, there are digital video signals on the downstream), the cable modem will listen for a special message from the CMTS called a MAP. The MAP will give the cable modem an opportunity to transmit upstream data for the first time [initial maintenance]. Since the cable modem doesn't know what power transmit power to use, it will start at its lowest power (8 dBmV). If the CMTS does not respond, it will increase its transmit power by 3 dB and try again. The message being sent is called a Range Request. The cable modem keeps increasing the transmit power of the Range Request until the CMTS is able to detect the Range Request. Once the CMTS detects the Range Request it analyzes the power, frequency and timing of the Range Request and sends back a Range Response to the cable modem which includes adjustments to the power, frequency and timing, as necessary.

   The CMTS does this Ranging [station maintenance] for every cable modem in the DOCSIS network at least once every 30 seconds. This ensures that all cable modems are transmitting at the proper power, frequency and timing.

3. DHCP: Now that the cable modem has ranged with the CMTS, it has established a communications link. It must now obtain additional information about the network, get an Internet Protocol (IP) address and get the name of a very important configuration filename. This is all achieved by using the Dynamic Host Configuration Protocol. This is a four step process in which the cable modem sends a DHCP Discover to a DHCP server connected to the IP network attached to the CMTS. If the cable modem has been provisioned on the server, the DHCP server will send the modem an IP address, the IP addresses of other important network servers and the ever important confuration filename.

4. Time of Day: Although a requirement for DOCSIS 1.0 networks, the time of day (ToD) server, which provides a timestamp to cable modems during registration is actually no longer required in DOCSIS 1.1 later revisions. Almost all modems will in fact boot without a functioning ToD server.

5. TFTP: Next the cable modem must download the configuration file whose name it was given during the DHCP process. It does this by sending a Trivial File Transfer Protocol (TFTP) Read Request to the IP address of the TFTP server, also given during the DHCP process. If the filename exists on the TFTP
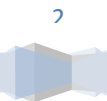
server, the file is downloaded to the cable modem. This file will provide the cable modem with settings such as the maximum subscriber data download and upload speeds, QoS settings, DOCSIS 1.1 settings, encryptions settings, etc.

6. Finally, the cable modem will send a Registration Request to the CMTS along with a list of the modem's configuration settings. If the CMTS approves of the modem's settings it will responds with Registration Response indicating a successful (okay) registration. If the CMTS does not like the cable modem's settings, then the CMTS has the ability to reject the cable modem with a registration rejection and the cable modem will not be able to come online and transmit data.

7. (Optional) BPI / BPI+: Baseline Privacy Infrastructure (BPI) is being implemented by many cable systems, both as a means to encrypt and protect subscriber data while it is on the RF network and as a way to prevent non-paying users from getting broadband service with hacked cable modems. The BPI registration process, when enabled, occurs immediately after the cable modem registers with the CMTS. BPI is a four step process at which time public and private keys are exchanged between the cable modem and CMTS, along with key expiration times.
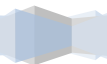
SIMPLE STUFF

So that was pretty simple right? Okay, the first time around it might sound a little over-whelming, but let's summarize it as a six step (seven with optional BPI) process:

1.   Downstream Search

2.   Ranging

3.   DHCP

4.   ToD

5.   TFTP

6.   Registration

7.   BPI (Optional)

This is what the process looks like. Now let's see a cable modem registering from the perspective of a DPA.

Figure 2. Cable Modem Registration

Obviously Step number 1, the Downstream Search is a passive process conducted by the cable modem. This is not something that would be observable by a DOCSIS Protocol Analyzer. The first thing that can be seen by the DPA is Step 2, Ranging.
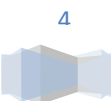
Frame number 1 at time 0.00000 sec., from Source MAC address 00:eo:6f:58:79:52 (the cable modem) communications to the Destination MAC address at 00:50:57:00:2b:e6 a DOCSIS protocol management message that is of type Initial Ranging Request. So this is the first time the CMTS (and the DPA) is able to hear a message from the cable modem. Since Service ID (SID) of the cable modem is equal to zero (0), this is also an indicator that the cable modem has not been assigned a SID by the CMTS, so it is using the default SID=0. Frame number 2 is the Range Response from the CMTS which contains adjustments for the cable modem in order to adjust it's transmitting power, frequency and timing (these values are observable by examining the details of any of the captured data above). The cable modem must make two more Range Requests in frame number 3 and 5, with corresponding Range Responses in frames 4 and 6 before it is transmitting at the proper levels. Now it can move on to Step 3, DHCP.

Frames 11 through 14 show the DHCP process. First the cable modem sends a DHCP discover. This message is relayed to the DHCP server by the CMTS. The DHCP server responds with a DHCP Offer, providing the cable modem with all of the necessary details. The cable modem responds with a DHCP Request, confirming the information received which then acknowledged by the DHCP server via a DHCP ACK. Now the cable modem can move on to Step 4, ToD.

Frame 17 and 20 show the cable modem requesting a time of day stamp from the ToD server and then receiving the response from the ToD server. As stated before, the ToD process is no longer required in DOCSIS 1.1 and higher versions. If a modem does not immediately receive a ToD response it will automatically move on to Step 5, TFTP.

Unlike ToD, TFTP cannot fail. The filename provided during DHCP is now requested for download from the TFTP server by the cable modem, as shown in frame 23. The TFTP server will initiate a download to the cable modem, frame 24, and the modem will acknowledge the download if it is free of errors, frame 25.

Finally, the modem can register with the CMTS, Step 6. Frame 26 shows the Registration Request sent to the CMTS by the cable modem. This Registration Request contains very important information about the modem that the CMTS will inspect. Frame 27 shows the much anticipated Registration Response from the CMTS with the words (okay/success) at time 1.549170 sec. Yes, your eyes do not deceive you, the cable modem registered with the CMTS in under two seconds. Much of the time spent waiting for a cable to register with a CMTS is during Step 1, the Downstream Scan. Once the cable is locked to the downstream, the rest of the process is lightning fast – **unless you have problems with your DOCSIS or IP network…**

WHAT CAN MAKE A THING GO WRONG?

Often I'm asked, other than RF problems what type of things go wrong in DOCSIS networks that creates outages or performance issues for subscribers? These are normally loaded questions from RF guys in my SCTE lectures with their IT buddies sitting beside them. But they are quite legitimate questions. Of the non-RF problems we see in the field affecting subscribers, about 90% are IP-related and 10% are DOCSIS protocol related. This has changed from just a couple of years ago where we were seeing a much higher percentage of DOCSIS-related issues. What does this mean? Well, first of all, the certification and qualification process at
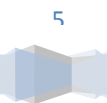
CableLabs has improved dramatically over the years and fewer bugs are slipping through the cracks. Secondly, the IP problems are under the control of the cable operator, which means once they identify them they have the power to quickly resolve them. The tricky part is figuring out whether the issue is an RF problem or IP problem, but that is why we are discussing DOCSIS Protocol Analyzers in the first place.

So about these 90% IP-related errors, here is a short list of very common ones that we see:

1. Sticky fingers – Cable modems with MAC addresses entered incorrectly, or the USB MAC address entered instead of the HFC MAC address entered during provisioning.

2. DHCP – This gets a special category because of the many potential pitfalls

    a. DHCP servers that run out of IP addresses

    b. DHCP servers that stop responding

    c. DHCP servers that respond only to certain line cards (domains) of the CMTS

    d. DHCP servers that refuse to respond to certain modems or modems with certain firmware revisions

    e. Modems that will only accept a certain number of IP addresses from the DHCP server

    f. Dozens more…

3. TFTP – Similar to DHCP, but simpler to resolve. The TFTP server can also suffer from sticky finger syndrome when upgrading systems or firmware, especially if a modem is asking for a file that does not exist on the TFTP server. Generally TFTP servers are robust because of their simplicity, but they are subject to hacking on the subscriber side. This forces the cable operator create a more complex TFTP server side, which in turn can turn a paying subscriber into an offline subscriber.

4. Worms and Virii – Subscribers on your network who become infected by worms, viruses, Trojans or other web garbage have the potential generate enormous amounts of "broadcast" traffic on the DOCSIS network. Broadcast traffic is IP data formatted in such a way that any cable modem on the network will listen to it. If the traffic becomes great enough, it will overwhelm the limited input buffers of the cable modems on your network. This means your subscribers will be dissatisfied with their performance in addition, when the modem is trying to register it be busy processing broadcast traffic when an important DHCP Offer comes by, so it may take a very long time to register. In one cable system it was taking an average of 12 hours for a cable modem to register due to the Sobig Worm.

SUMMARY

The cable modem registration process is a very straight forward process consisting of six basic steps. This process should be committed to memory and understood whether you are a line tech or a plant manager for the simple fact that DOCSIS is rapidly becoming the bread and butter of the cable industry. Once you have a solid foundation of the cable modem – CMTS intricacies, then you'll be ready to move on to Multi-Media Terminal Adapter (MTA), which is required for VoIP, but that is a 20 step registration process. First we must crawl before we walk.

We now have the tools, the knowledge of how the cable modems register, and a basic understanding of the most common problems. Identifying these problems when they occur is usually intuitive. Usually something unexpected occurs as in figure 3. Frame 19 shows a cable modem in the middle of Step 5, TFTP, when it receives an Error Cod: File not found to its TFTP read request in frame 12. This could have resulted in hours of RF troubleshooting or diverted by a simple file analysis with a DOCSIS protocol analyzer resulting in a quick diagnosis of the problem. You be the judge.

Figure 3. Cable Modem Registration Failure

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