

CABLE MODEM REGISTRATION PROCESS

THROUGH THE EYES OF A DOCSIS PROTOCOL ANALYZER

By Brady Volpe

In this article, we are going to closely examine the cable modem registration process, break it down into its fundamental parts, and understand how it should work. We will then look at the registration process as seen from the RF plant using a DOCSIS Protocol Analyzer (DPA). Finally, we will discuss some common non-RF DOCSIS and IP problems that can be readily identified with a DPA.

CABLE MODEM REGISTRATION

All cable modems are simple devices, which mean they are easy to troubleshoot once you understand how they work. The subscriber buys a cable modem registers it with their local cable system, connects the RF coax and plugs in the power. The following are steps the cable modem should follow:

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 is sent by the Cable Modem Termination System (CMTS). A critical piece of information is 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 RF 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 configuration file. This is all achieved by using the Dynamic Host Configuration Protocol (DHCP). 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 configuration 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 and 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, encryption 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 respond with a Registration Response indicating a successful registration. If the CMTS does not like the cable modem's settings, 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 subscribers 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.

STRAIGHTFORWARD MATERIAL

Let us summarize the 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 (figure 1) from the perspective of a DOCSIS Protocol Analyzer.

No. -	Time	Source	Destination	Protocol	Info
1	0.000000	00:eo:6f:58:79:52	00:50:57:00:2b:e6	DOCSIS MGMT	Initial Ranging Request SID = 0
2	0.000817	00:50:57:00:2b:e6	00:eo:6f:58:79:52	DOCSIS MGMT	Ranging Response: SID = 3, Upstream Channel = 1 (U0)
3	0.406312	00:eo:6f:58:79:52	00:50:57:00:2b:e6	DOCSIS MGMT	Ranging Request: SID = 3
4	0.406862	00:50:57:00:2b:e6	00:eo:6f:58:79:52	DOCSIS MGMT	Ranging Response: SID = 3, Upstream Channel = 1 (U0)
5	0.808250	00:eo:6f:58:79:52	00:50:57:00:2b:e6	DOCSIS MGMT	Ranging Request: SID = 3
6	0.808798	00:50:57:00:2b:e6	00:eo:6f:58:79:52	DOCSIS MGMT	Ranging Response: SID = 3, Upstream Channel = 1 (U0)
11	1.300374	0.0.0.0	255.255.255.255	DHCP	DHCP Discover - Transaction ID 0xfffffdd5
12	1.307727	192.168.16.3	255.255.255.255	DHCP	DHCP Offer - Transaction ID 0xfffffdd5
13	1.317187	0.0.0.0	255.255.255.255	DHCP	DHCP Request - Transaction ID 0xfffffdd5
14	1.324316	192.168.16.3	255.255.255.255	DHCP	DHCP ACK - Transaction ID 0xfffffdd5
17	1.361174	192.168.1.52	192.168.1.100	TIME	TIME Request
20	1.390904	192.168.1.100	192.168.1.52	TIME	TIME Response
21	1.497676	00:eo:6f:58:79:52	00:50:57:00:2b:e6	DOCSIS MGMT	Ranging Request: SID = 3
22	1.498229	00:50:57:00:2b:e6	00:eo:6f:58:79:52	DOCSIS MGMT	Ranging Response: SID = 3, Upstream Channel = 1 (U0)
23	1.530124	192.168.1.52	192.168.1.100	TFTP	Read Request, File: boot_bploff.cfg, Transfer type: oc
24	1.534811	192.168.1.100	192.168.1.52	TFTP	Data Packet, Block: 1 (last)
25	1.544125	192.168.1.52	192.168.1.100	TFTP	Acknowledgement, Block: 1
26	1.548113	00:eo:6f:58:79:52	00:50:57:00:2b:e6	DOCSIS MGMT	Registration Request SID = 3
27	1.549170	00:50:57:00:2b:e6	00:eo:6f:58:79:52	DOCSIS MGMT	Registration Response SID = 3 (okay/success)
30	13.444230	192.168.1.100	192.168.1.52	ICMP	Echo (ping) request
31	13.452100	192.168.1.52	192.168.1.100	ICMP	Echo (ping) reply
32	14.455987	192.168.1.100	192.168.1.52	ICMP	Echo (ping) request
33	14.464962	192.168.1.52	192.168.1.100	ICMP	Echo (ping) reply
34	15.461659	192.168.1.100	192.168.1.52	ICMP	Echo (ping) request
35	15.469824	192.168.1.52	192.168.1.100	ICMP	Echo (ping) reply
40	16.466559	192.168.1.100	192.168.1.52	ICMP	Echo (ping) request
41	16.474662	192.168.1.52	192.168.1.100	ICMP	Echo (ping) reply
42	16.496675	00:eo:6f:58:79:52	00:50:57:00:2b:e6	DOCSIS MGMT	Ranging Request: SID = 3
43	16.497234	00:50:57:00:2b:e6	00:eo:6f:58:79:52	DOCSIS MGMT	Ranging Response: SID = 3, Upstream Channel = 1 (U0)
52	31.495888	00:eo:6f:58:79:52	00:50:57:00:2b:e6	DOCSIS MGMT	Ranging Request: SID = 3
53	31.496434	00:50:57:00:2b:e6	00:eo:6f:58:79:52	DOCSIS MGMT	Ranging Response: SID = 3, Upstream Channel = 1 (U0)

Figure 1. Cable Modem Registration

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 (the CMTS) 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 Identifier (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. 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 important information about the modem that the CMTS will inspect. Frame 27 shows the Registration Response from the CMTS with the words (okay/success) at time 1.549170 sec. 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...**

SO WHAT CAN GO WRONG DURING REGISTRATION?

Of the non-RF problems we see in the field affecting subscribers, about 90% are IP-related and 10% are DOCSIS protocol related

Here is a short list of very common problems:

1. Sticky fingers – Cable modems with MAC addresses provisioned incorrectly, or the USB MAC address provisioned instead of the HFC MAC address.
2. DHCP:
 - 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. Cable modems that will only accept a certain number of IP addresses from the DHCP server
3. TFTP usually suffers from missing or incorrectly named configuration files.
4. Worms and Virii – Subscribers on your network who become infected by worms or viruses have the potential generate large amounts of “broadcast” traffic on the DOCSIS network. This broadcast traffic can overwhelm the limited input buffers of the cable modems and cause them to behave erratically.
5. DOCSIS Protocol problems – cable modems whose firmware are not DOCSIS compliant will usually be rejected by the CMTS during registration. If not, they can cause greater havoc once online.

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.

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, such as in the example of figure 2. Frame 19 shows a cable modem in the middle of Step 5, TFTP, when it receives an Error Code: 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.

No. ↓	Time	Source	Destination	Protocol	Info
8	0.355024	192.168.1.100	192.168.1.100	DHCP	DHCP ACK Transaction ID: 0x11111111
9	0.354688	00:e0:6f:58:79:52	ff:ff:ff:ff:ff:ff	ARP	Who has 192.168.1.100? Tell 192.168.1.52
10	0.355847	00:50:57:00:2b:e6	00:e0:6f:58:79:52	ARP	192.168.1.100 is at 00:50:57:00:2b:e6
11	0.364688	192.168.1.52	192.168.1.100	TIME	TIME Request
12	3.355313	192.168.1.52	192.168.1.100	TFTP	Read Request, File: bot_bpioff.cfg, Transfer type: octet
13	4.354188	192.168.1.52	192.168.1.100	TFTP	Read Request, File: bot_bpioff.cfg, Transfer type: octet
14	6.398501	00:e0:6f:58:79:52	00:50:57:00:2b:e6	DOCSIS MGMT	Ranging Request: SID = 3
15	6.397048	00:50:57:00:2b:e6	00:e0:6f:58:79:52	DOCSIS MGMT	Ranging Response: SID = 3, Upstream Channel = 1 (U0)
16	6.353926	192.168.1.52	192.168.1.100	TFTP	Read Request, File: bot_bpioff.cfg, Transfer type: octet
17	6.364980	00:50:57:00:2b:e6	ff:ff:ff:ff:ff:ff	ARP	Who has 192.168.1.52? Tell 192.168.1.10
18	6.373926	00:e0:6f:58:79:52	00:50:57:00:2b:e6	ARP	192.168.1.52 is at 00:e0:6f:58:79:52
19	6.375544	192.168.1.100	192.168.1.52	TFTP	Error Code, Code: File not found, Message: File not found
20	7.382788	192.168.1.52	192.168.1.100	TFTP	Read Request, File: bot_bpioff.cfg, Transfer type: octet
21	7.387056	192.168.1.100	192.168.1.52	TFTP	Error Code, Code: File not found, Message: File not found
22	8.394538	192.168.1.52	192.168.1.100	TFTP	Read Request, File: bot_bpioff.cfg, Transfer type: octet
23	9.398421	192.168.1.100	192.168.1.52	TFTP	Error Code, Code: File not found, Message: File not found
24	11.003901	192.168.1.52	192.168.1.100	TFTP	Read Request, File: bot_bpioff.cfg, Transfer type: octet
25	11.007625	192.168.1.100	192.168.1.52	TFTP	Error Code, Code: File not found, Message: File not found
26	16.014276	192.168.1.52	192.168.1.100	TFTP	Read Request, File: bot_bpioff.cfg, Transfer type: octet
27	16.018177	192.168.1.100	192.168.1.52	TFTP	Error Code, Code: File not found, Message: File not found

Figure 2. Cable Modem Registration Failure

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For more information:

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