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Advanced Troubleshooting in a DOCSIS© 3.0 Plant

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Section 1 – Overview

This paper will present a brief overview of DOCSIS 3.0 and DOCSIS 3.0 terminology. Next the paper will review key differences between DOCSIS 2.0 and DOCSIS 3.0, including a high level overview of DOCSIS 3.0 architecture. Then it will examine two advanced DOCSIS 3.0 impairments called Partial Service and Impaired Service. Details on what these are, how to identify them and how to troubleshoot them will be thoroughly covered.

Section 2: DOCSIS 3.0 Primer

DOCSIS is effectively a transparent Ethernet bridge over a hybrid fiber/coax (HFC) network. There are two (2) functional components in a DOCSIS network, the cable modem (CM) on the subscriber side and the CMTS in the headend or hub site. The CMTS communicates with the CMs on one or more 6 MHz wide (8 MHz in Euro-DOCSIS deployments), 64- or 256-QAM (quadrature amplitude modulation) digitally encoded RF signals on the downstream path of an HFC network between 108 and 1 GHz. The CMs communicate with the CMTS using one or more quadrature phase shift keying (QPSK), 8-, 16-, 32-, or 64-QAM digitally encoded RF signals, also transmitted on an upstream HFC frequency between 5 to 85MHz. The digital data, transported via digitally modulated carriers, contains Media Access Control (MAC) information which enables the CMs to coexist with other CMs by using a Time Division Multiple Access (TDMA) scheme or synchronous code division multiple access (S-CDMA). In essence, the CMTS is the system scheduler which coordinates the power level, frequency, transmit time, and pre-equalization of all CM signals on the DOCSIS network.

By virtue of the fact that CMs and the CMTS are able to communicate digital data with each other over the HFC network for the purpose of "command-and-control" processes, they are also able to transmit packets containing other non-DOCSIS MAC related data. This is what fundamentally facilitates the ability to send Ethernet traffic bi-directionally over an HFC network. The CMTS-CM DOCSIS network transports IP based traffic in the same method that is used to communicate MAC protocol between the devices. Now that the IP traffic can traverse the HFC network, end users are also able to utilize this network for the purpose of transmitting content destined for the multitude of available data network services such as email, web browsing, IP video, and voice over IP telephony (VoIP).

In summary, each user is assigned a unique cable modem, which conforms to the DOCSIS standard. The CMTS works as a system scheduler enabling many cable modems to reside on the same RF network. TDMA and/or S-CDMA is employed in cable modem communications so that each modem is allocated a certain finite time over which it may transmit and receive IP data. IP data destined for a particular user is sent to that user's modem by the CMTS one or more downstream RF channel. This is the way an Ethernet network is able to be transparently bridged from a data backbone to a subscriber's home or business location.

Section 3: Terminology

A number of new terminologies have been developed for hybrid fiber/coaxial and DOCSIS networks along with re-use of terminology from other communications networks. In order to help the reader with the many acronyms and initialisms throughout this document, this section is provided as a terminology primer and reference. The major terminologies covered are as followed.[1]

Bonded Channel Set An identified set of upstream or downstream channels among which a stream of packets is distributed.

Bonding Group A list of channels providing a means to identify the specific channels bonded together.

Cable Modem Service Group In the HFC plant topology, the complete set of downstream and upstream channels within a single CMTS that a single Cable Modem could potentially receive or transmit on. In most HFC deployments, a CM-SG corresponds to a single Fiber Node. Usually, a CM-SG serves multiple CMs.

Cable Modem Termination System Cable modem termination system, located at the cable television system head-end or distribution hub, which provides complementary functionality to the cable modems to enable data connectivity to a wide-area network.

Channel Bonding A logical process that combines the data packets received on multiple independent channels into one higher-speed data stream. Channel bonding can be implemented independently on upstream channels or downstream channels.

Codeword An element of an error-correcting code used to detect and correct transmission errors.

Customer Premises Equipment Equipment at the end user's premises; may be provided by the end user or the service provider.

DOCSIS 2.0 Mode A CM operates in this mode when: 1) Multiple Transmit Channel (MTC) Mode is disabled; 2) the Enable 2.0 Mode configuration setting in the REG-RSP is set to 1 (Enable) explicitly or by default; and 3) it operates on an upstream channel using the burst descriptors associated with IUC 9, 10, and 11 as opposed to IUC 5 and 6. A CM is enabled for DOCSIS 2.0 Mode when the Enable 2.0 Mode configuration setting in the REG-RSP is set to 1 (Enable). A CM may be enabled for DOCSIS 2.0 Mode but may not be operating in DOCSIS 2.0 Mode. When a CM has MTC Mode enabled, the CM is not considered to be in DOCSIS 2.0 Mode even if some of the upstream channels it is using are operating with post-1.1 DOCSIS physical layer mechanisms. Therefore, "DOCSIS 2.0 Mode" does not have relevance for a CM operating in MTC Mode.

Downstream In cable television, the direction of transmission from the head-end to the subscriber.

Downstream Bonded Service Flow A downstream Service Flow assigned to a Downstream Bonding Group.

Downstream Bonding Group A subcomponent object of a MAC Domain that distributes packets from an assigned set of Downstream Bonding Service Flows to an associated set of Downstream Channels of that MAC Domain.

Downstream Channel Physical layer characteristics and MAC layer parameters and functions associated to a DOCSIS forward channel.

Downstream Interface As a term, refers to either a Downstream Channel (DC) or a Downstream Bonding Group (DBG). A DI is not a separate object in the object model.

[1] DOCSIS 3.0 MAC and Upper Layer Protocols Interface Specification, CM-SP-MULPIv3.0-I13-100611

Downstream M-CMTS Channel An object representing the M-CMTS DEPI session (see [DEPI]) that carries the DOCSIS MAC-Layer contents of a single Downstream RF Channel.

Downstream RF Channel The CMTS object representing the physical transmission of the MAC-Layer contents of a DOCSIS downstream RF signal at a single center frequency. A DRF object implements the functions of: FEC Encoding, MPEG2 Convergence, QAM modulation, and Physical RF transmission.

Downstream Service Group The complete set of Downstream Channels (DCs) from a single CMTS that could potentially reach a single Cable Modem. A DS-SG corresponds to a broadband forward carrier path signal from one CMTS. In an HFC deployment, a DS-SG corresponds to the downstream fiber transmission from one CMTS to one or more Fiber Nodes.

Edge Quadrature Amplitude Modulator In the M-CMTS architecture, a network element that terminates DEPI sessions and implements the physical Downstream RF Channel for those sessions. The EQAM terminates Downstream M-CMTS Channels and forwards their DOCSIS MAC-Layer contents to downstream RF Channels.

Fiber Node In HFC, a point of interface between a fiber trunk and the coaxial distribution.

Forward Error Correction FEC enables the receiver to detect and fix errors to packets without the need for the transmitter to retransmit packets.

Group Delay The difference in transmission time between the highest and lowest of several frequencies through a device, circuit or system.

Individual MAC Address An IEEE 6-byte MAC address with the first transmitted bit (the group bit) set to 0, indicating that the address refers to a single MAC host. For the Ethernet MAC addresses of DOCSIS, the group bit is the least significant bit of the first byte of the MAC address.

Logical (Upstream) Channel A MAC entity identified by a unique channel ID and for which bandwidth is allocated by an associated MAP message. A physical upstream channel may support multiple logical upstream channels. The associated UCD and MAP messages completely describe the logical channel.

MAC Domain A subcomponent of the CMTS that provides data forwarding services to a set of downstream and upstream channels.

Media Access Control The part of the data link layer that supports topology-dependent functions and uses the services of the Physical Layer to provide services to the logical link control (LLC) sublayer.

Modular Cable Modem Termination System A CMTS composed of discrete functional blocks linked together using Gigabit Ethernet links.

Non-primary Downstream Channel A Downstream Channel received by a cable modem which is not its Primary Downstream Channel.

Receive Channel Configuration The CMTS send the RCC encoding in the REG-RSP message. The RCC contains TLVs to initially configure a CM's Receive Channels (RCs) and Receive Modules (RMs).

Primary-Capable Downstream Channel A Downstream Channel which carries SYNC messages, MDD messages containing ambiguity resolution TLVs, as well as UCD and MAP messages for at least one upstream channel in each of the MD-CM-SG that the downstream channel reaches.

Primary Downstream Channel A Primary-Capable Downstream Channel on which the DOCSIS 3.0 CM has achieved SYNC lock and successfully received an MDD message containing ambiguity resolution TLVs.

Transmit Channel Configuration TLV settings in Registration and DBC MAC Management Messages that define operations such as addition, deletion, change, replacement, or re-ranging of one or more upstream channels in the Transmit Channel Set of a cable modem.

Upstream The direction from the subscriber location toward the head-end.

Upstream Bonding Group A subcomponent object of a MAC Domain that collects and resequences/reassembles Upstream Segments from a UBSF from an administered set of UCs.

Upstream Bonded Service Flow An upstream Service Flow assigned to an Upstream Bonding Group.

Upstream Channel Physical layer characteristics and MAC layer parameters and functions associated to a DOCSIS reverse channel.

Upstream Channel Bonding The ability of the cable modem and cable modem termination system to support allocating traffic for a single Service Flow across two or more upstream channels.

Upstream Channel Descriptor The MAC Management Message used to communicate the characteristics of the upstream physical layer to the cable modems.

Upstream Service Group The complete set of Upstream Channels (UCs) within a single CMTS potentially reachable by the transmission of a single Cable Modem. In an HFC deployment, a USSG corresponds to the physical combining of the upstream reverse carrier path signal from one or more Fiber Nodes reaching a single CMTS.

Section 4: Key Topics to Know

1. **Primary Downstream Channel**

   A Primary Downstream Channel carries SYNC messages, MDD messages, UCD and MAP messages which are required by each cable modem for registration on the DOCSIS network as well as obtaining the necessary information to be able to transmit data on the upstream channel(s) of the DOCSIS network. A Primary Downstream Channel is almost always associated with the line card of a CMTS itself, but a Primary Downstream Channels can also be configured on edge-QAMs (eQAMs) for M-CMTS architectures.

2. **Non-primary Downstream Channel**

   A non-primary Downstream Channel is a DOCSIS downstream channel that is not defined as “Primary”. The non-primary downstream channel is used for transporting user data. Since it does not carry the MAC overhead of SYNC, UCD, MAP, etc. it is more efficient by nearly 25% in transporting user data. Non-primary channels do occasionally transmit MDD messages (see next #3 below).

3. **MAC Domain Descriptor (MDD)**

   MDD messages are periodically transmitted on all Downstream Channel(s) of DOCSIS 3.0 CMTSs. The MDD message contains the Downstream Channel ID of the Primary Downstream Channel for the CMTS sending the MDD message. The value of the MDD occurs when a cable modem locks onto a Secondary Downstream Channel, the cable modem will read the MDD and know immediately where to tune to in order to lock on to the Primary Downstream Channel. The MDD can also be used for load balancing cable modems in a DOCSIS 3.0 network. The MDD also contains additional information for the cable modem, such as available downstream channels, available upstream channels, upstream frequency range and more.

4. **Downstream Bonding Group (DBG)**

   The term “Downstream Bonding Group” is intended to refer to a set of two or more downstream channels that are available to a cable modem. DBGs may either be statically provisioned by an operator or dynamically determined by the CMTS for load balancing purposes. The adjacency restrictions on DBGs are limited to within a 60 MHz bandwidth per the DOCSIS specification.

5. **MAC Domain Downstream Service Group (MD-DS-SG)**

   The term “MAC Domain Downstream Service Group” (MD-DS-SG) refers to the set of downstream channels from the same MAC Domain that reaches a fiber node. In most cases, an operator will configure all downstream channels reaching a fiber node to the same MAC Domain. Often times, MD-DS-SGs are configured such that they are shared by many cable modems that have different upstream channels, or more specifically, MAC Domain

Upstream Service Groups (see next section). This is similar to DOCSIS 1.x and 2.0 where a single downstream would service multiple upstreams.

6. MAC Domain Upstream Service Group (MD-US-SG)

The term "MAC Domain Upstream Service Group" (MD-US-SG) refers to the set of upstream channels from the same MAC Domain that is reached by a single CM. The MD-US-SG set of channels is available to many cable modems, but the downstream channels to those cable modems may be different (this is the axiom of section 5 above). Further, even though a MD-US-SG may be available to a particular cable modem, it does not mean that the cable modem will be able to use each of the channels in the SG (service group). Impairments in the upstream may prevent the CMTS from receiving all signals on all channels transmitted by the CM available. This is not a problem for DOCSIS 3.0. The protocol is resilient enough so that the modem will stay online with as many upstream channels as possible. Only throughput will suffer.

7. Upstream Bonding Group (UBG)

Upstream Bonding Group or UBG is the total set of available RF transmit channels available to a cable modem. The available number of transmit channels may be greater than those allocated by the MD-US-SG because other modems may be using some channels. UBGs also will consist of physical RF channels and logical channels. There can only be one channel associated with the center frequency of an RF channel. However a physical channel can support multiple logical channels. Logical channels can be used for A-TDMA modes of operation in addition to S-CDMA mixed with non-S-CDMA modes of operation.

8. Early Authentication and Encryption (EAE)

EAE is enabled via a configuration in the CMTS and is then communicated to the CM in the MDD message. If the CM receives an MDD message with EAE enabled, the CM will initiate EAE during the registration process just after ranging and just before DHCP. EAE helps prevent unauthorized CMs from accessing IP provisioning servers and provides confidentiality/privacy for IP provisioning messages between the CM and CMTS. If there is a problem with the BPI+ certificates in a cable modem or the x.509 certificates or configuration in the CMTS, EAE could be a root cause. However, enabling EAE greatly improves the overall security of a DOCSIS network, thus reducing the probability of theft of service.

9. Alternate Provisioning Mode (APM)

The MDD message tells the cable modem what type of IP address (DHCP) provisioning it will go through. The MDD has four options; IPv4 only, IPv6 only, APM and DPM. Alternative Provisioning Mode (APM) tells the CM to try and provision using IPv6 first. If IPv6 provisioning is unsuccessful, either because IPv6 Address acquisition or the TFTP configuration file download fails, the CM abandons IPv6 provisioning and attempts provisioning using IPv4. APM is preferred over “IPv6 only” as it provides a fall-back mechanism to IPv4 and the modem will ultimately come online, though it may take some additional time.

10. **Dual-stack Provisioning Mode (DPM)**

Dual-stack Provisioning Mode (DPM) is another configurable by the CMTS engineer and then communicated by the MDD message to the CM. In this case, the CM attempts to acquire both IPv6 and IPv4 addresses through DHCPv6 and DHCPv4 almost simultaneously. For the acquisition of time-of-day and the download of a configuration file the CM prioritizes the use of the IPv6 address over the IPv4 address. If the CM cannot obtain an IPv6 address, or if it cannot download a configuration file using IPv6, it tries downloading it using IPv4. In this mode, the CM can acquire IPv4 and the IPv6 addresses, if successfully acquired. The benefit of DPM over APM is that the modem will acquire an IPv6 or IPv4 or both addresses in a faster time period since it is dual-provisioning. This is especially crucial during a system-wide outage when thousands of modems are coming back online. The downside of DPM is that if cable modems are able to obtain both IPv6 and IPv4 address, there will be significant overhead of used addresses and duplicate TFTP downloads. This will also have repercussions during a system wide outage if the provisioning servers are unable to keep up with the extra utilization by the CMs.

Section 5: DOCSIS 2.0 vs. 3.0

Migrating to DOCSIS 3.0 is likely a business decision to address competitive pressure or a technical decision to alleviate existing bandwidth restraints resulting in many required node splits. In either case, the migration will require training on the part of field, headend, CMTS and IT staff. Fortunately many lessons learned in DOCSIS 1.x and 2.0 will be directly transferable to DOCSIS 3.0. There will be some new challenges moving forward due to RF channel bonding and integration with components, depending on the architecture deployed. First the architectures will be assessed.

Integrated CMTS

A DOCSIS Integrated CMTS architecture, or I-CMTS, is one that we are more accustomed to based upon DOCSIS 1.x and 2.0 architectures. That is a pizza box or chassis-based CMTS whereby all components necessary for DOCSIS 3.0 operation are integrated. The first CMTS vendor to gain full DOCSIS 3.0 qualification was CASA Systems, who provides a complete DOCSIS 3.0 CMTS and edge QAM (eQAM) in a 1RU platform. The benefits of the I-CMTS architecture are its ease of deployment since all components are integrated. Seemingly there should be fewer points of failure since cabling and interfaces between external components are eliminated.

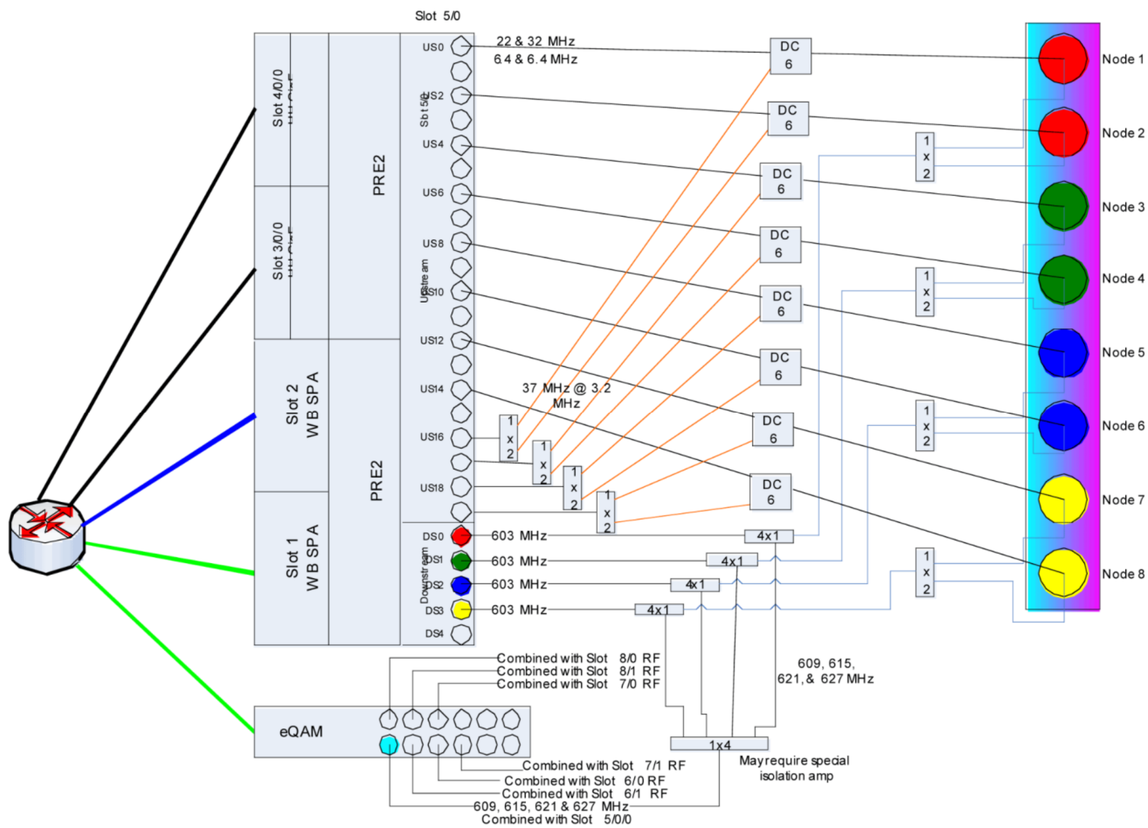
Modular CMTS

A DOCSIS Modular CMTS, or M-CMTS, is one in which DOCSIS 3.0 channel bonding is achieved by using a conventional CMTS and extending it with an eQAM, DOCSIS DTI time source, and Gigabit Ethernet (GigE) interfaces. The conventional CMTS line card provides a Local or Primary downstream, which contains all of the DOCSIS MAC layer protocol information necessary for DOCSIS-to-cable modem communication. The basics of this information contain timing Sync messages, Upstream Channel Descriptors (UCDs), Upstream Bandwidth Allocation Map (MAP) messages, Ranging messages, etc. The CMTS line card also provides the inputs for the upstream channels returning from the cable modems, which are then bound by the CMTS. The CMTS will usually have a specialized interface on it with a GigE connector that communicates directly with an eQAM. The eQAM provides the additional downstream bonded channels transmitted to the cable modems. Extremely accurate timing is maintained between the CMTS and the eQAM via a DOCSIS DTI timing reference. The eQAM and the CMTS can be remotely located and multiple DTI timers used and synchronized via GPS to ensure stable clock references. This enables the eQAMs to be located in hub sites where local video distribution is occurring while the CMTS remains at the headend or visa-versa. The modularity of the M-CMTS architecture is extremely advantageous in large systems. eQAMs can be repurposed for DOCSIS or video as demand calls. The system scales well from four bonded channels, to eight and more as necessary.

Challenges that come with the M-CMTS architecture are on both the RF and IP fronts. In the RF realm, there is a vast amount of RF combining that must occur between the CMTS and the eQAM as seen in Figure 1. At a minimum, headends / hubsites will require significant re-cabling. During this time, one must consider the potential for isolation issues that may occur between different downstreams and upstreams as combining is created for different node combinations. Isolation issues which occur at the source will not be resolvable at the subscriber premise.

In the IP realm, multiple potential failure points are introduced with M-CMTS architecture. GigE interfaces are introduced between the CMTS to the eQAM, the CMTS to the back office, and the DTI timers to both the CMTS and the eQAMs. One should ensure that each interface has a redundancy and that the redundant path is fully tested under load prior to any actually live network failure. Often, redundant paths are planned and installed but fail to perform adequately under full line rates during an actual failover.

Figure 1[2]



From a headend / hub perspective, cable management, isolation, and IP connectivity become much more complicated as will be discussed in the following slides.

Channel Bonding

Channel bonding in DOCSIS 3.0 networks is a logical process that combines the data packets received on multiple independent channels into one higher-speed data stream. Channel bonding can be implemented independently on upstream channels or downstream channels.[3] This is the primary new feature in DOCSIS 3.0 that allows at least four times the data through-put as in previous revisions.

Bonding simply means that logically the CMTS recognizes that there are four or more RF signals within a 60 MHz passband (greater if more than four channels are bound) that are collectively transporting data to or from the same end user. The CMTS takes over responsibility for managing how this data is directed to each individual RF channel by assessing its service class and priority as

[2] The Need for Speed -DOCSIS 3.0 Downstream Bonding Issues, John Downey and Brady Volpe, Communications Technology Magazine, March 1, 2009

[3] DOCSIS 3.0 Physical Layer Specification, CM-SP-PHY-I03-070223

well as the assumed channel performance. So one can quickly understand that an impaired bonded channel can quickly degrade overall system throughput and loading on a DOCSIS 3.0 CMTS.

Channel bonding between two different devices, such as the CMTS Primary downstream and eQAM downstreams is accomplished a through GigE interface, also called a Downstream External-Phy Interface (DEPI). The communications over the DEPI has its own DOCSIS specification called CM-SP-DEPI-I06, located www.cablelabs.com.

DEPI is an IP Tunnel that exists between the DOCSIS MAC in the M-CMTS Core and the DOCSIS PHY that exists in the EQAM. DEPI's job is to take either formatted DOCSIS frames or MPEG packets and transport them through a layer 2 or layer 3 network and deliver them to the EQAM for transmission.[4]

The base protocol that is used for the DEPI is the Layer 2 Tunneling Protocol Version 3, or L2TPv3 for short [RFC 3931]. L2TPv3 is an IETF protocol that is a generic protocol for creating a pseudowire. A pseudowire is a mechanism to transparently transport a layer 2 protocol over a layer 3 network. Examples of protocols supported by L2TPv3 include ATM, HDLC, Ethernet, Frame Relay, PPP, etc.[5]

Section 6: Partial Service

Defined

A modem is in a partial service mode of operation any time it is operating with a subset of the channels in the Receive Channel Set (RCS) and/or Transmit Channel Set (TCS) because a channel has become unusable, either due to an inability to acquire a channel or because communication on a channel was lost during normal operation.[6]

A typical bonded upstream service group will have up to four channels, that when aggregated together are capable of transmitting over 100 Mbps at 64-QAM modulation in a 6.4 MHz bandwidth. If only one upstream channel is out of service in the “partial service” scenario, it is possible that the end user will not notice any impact to performance. A three channel DOCSIS 3.0 modem would still be capable of over 80 Mbps. Therefore, in a DOCSIS 3.0 network, partial service is:

- Hard to detect after registration
- Most current test instruments will not identify it
- A throughput test may not identify it on a loaded plant

Two scenarios for partial service:

1. The channel was down when the modem came online
    a. Test equipment will show fewer channels bonded than expected
    b. Will likely not cause any noticeable performance issues, unless the service tier is very close to the maximum throughput performance with a full channel set
    c. The Errors for the channels that could not be acquired are reported to the CMTS in the REG-ACK

[4] Downstream External PHY Interface Specification, CM-SP-DEPI-I06-081209
[5] Downstream External PHY Interface Specification, CM-SP-DEPI-I06-081209
[6] DOCSIS 3.0 MAC and Upper Layer Protocols Interface Specification, CM-SP-MULPIv3.0-I13-100611

2. The channel becomes un-usable following TCC (Transmit Channel Configuration)
   a. The channel is already in the bonding group for this modem, and has become unusable. The CMTS will stop granting transmit opportunities on this channel until communication is reestablished via the ranging process. CMTS's may handle re-acquisition differently and may not re-acquire at all until the CM is rebooted! (it is a SHOULD requirement).
   b. Will cause temporary performance issues between the time that the channel becomes unusable and the time that the CMTS realizes that it is unusable (Range interval + Range timeout or about one minute). Following that time, the CMTS will refrain from granting timeslots on this channel, and performance degradation will stop.

Troubleshooting

When a technician is troubleshooting, partial service is one of the issues that can be experienced. It is unlikely that most technicians would go to the field specifically to troubleshoot partial service, as it is not particularly noticeable unless the end user is bumping up against the max transmit performance of the complete TCS.

The first indication to the technician that a portion of network is experiencing partial service is when the test instrument only bonds a portion of the Transmit Channel Set (TCS). As seen in the screen captures below, the technician expects to see 4 channels in the TCS, but the instrument only reports that there are 3 channels bonded.

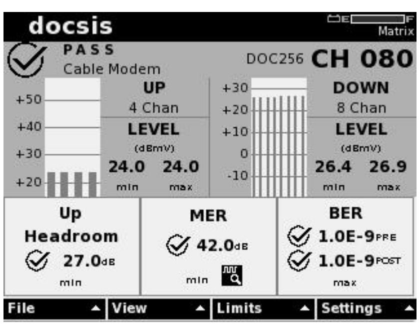


Fig 1: Full Service (4 Bonded Channels)

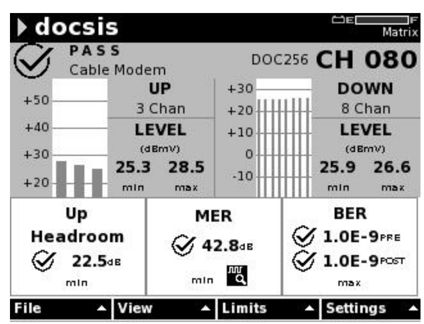


Fig 2: Partial Service (3 Bonded Channels)

In this situation, the CMTS is aware of the partial service, and would refrain from granting map opportunities on the channel that is unavailable. Therefore, unless the service level of the end user is above the capabilities of the 3 bonded channels (80+ Mb/s), the end user would likely not experience any degradation of service. (assuming that the other three channels are not experiencing performance issues)

When the technician determines that a partial service situation exists, the goal is to determine what is causing the partial service. To accomplish this, the technician should begin traversing the network toward the CMTS, testing at each test point (Ground Block, Tap, Amps, Node) until the point where the missing channel(s) return to service.

When the missing channel(s) have returned to service, it could mean one of two things:

1. The gross network issue has been passed, and the previously missing channel is in service and operating at peak performance.
2. A minor network issue has been passed, allowing the previously missing channel to return to service, but other network issues continue to impair the performance of the channel.

Because both of these results are possible, it is very important to take a closer look at all of the upstream channels once a partial service scenario is fixed. The sections that follow will discuss the process of isolating individual upstream channels in a bonded environment to determine performance of each.

Section 7: Impaired Service

Defined

A modem is in an impaired service mode of operation any time it is operating with one or more channels that are experiencing high counts of codeword errors due to one or more RF channel impairments. Further equipment malfunctions could be the root cause of impaired service, but is generally the exception and not the rule. Codeword errors could be present in either the upstream or the downstream direction. Codeword errors are errors that are either “correctable” or “uncorrectable” by the Foreword Error Correction (FEC), contained in each packet sent by a cable modem.

An impaired service is one where that channel is not bad enough to fail ranging, but impaired enough to cause data corruption and be identified through codeword errors.

Some fundamental statements can be made about impaired service:

- Impaired service impacts subscriber performance and quality of experience (QoE)
- It is easy to detect impaired service
- Throughput can be a good test for this, but not in all cases
- High volume Packetloss is the most effective test to detect impaired service, but may not identify impaired service if it is a function of time
- A question to discuss with your CMTS vendor is what should your station maintenance modulation profile be with respect to your data modulation profile?
    - Is it better or worse that the maintenance ranging is performed at a lower modulation to keep the channel in an impaired state or that it were in a higher modulation and caused the channel to transition into a partial service state?

Possible causes for impaired service are assumed to be physical layer issues first, which generate codeword errors. This should be the starting point prior to replacing equipment. Studies have shown that less than 1% of returned equipment (cable modems, eMTAs, set top boxes, etc.) have actually been identified as being defective (source: Arris). Further, if IP traffic congestion was the source of the problem, this would never result in codeword errors.

Customer complaints that would generate a ticket resulting in possible Impaired Service issues:

- VoIP issues (robo-voice, dropped words, dialing issues, dropped calls, etc.)
- VOD – cannot retrieve movie, cannot interact with Guide
- Gaming issues – latency, interactivity issues
- VPN issues – calling, two-way video, desktop sharing, VPN dropping, etc.
- File Sharing/Transfer/FTP Upstream – very slow upstream transfers

Troubleshooting

Once an impaired service situation is discovered, it is up to the technician to divide and conquer to find the cause of the impaired service. Ironically, this process has been both complicated and simplified due to the introduction of DOCSIS 3.0.

First, the process has been complicated through the introduction of channel bonding. With channel bonding there are multiple paths (channels) that a CM can use to simultaneously deliver data to the CMTS. While there have long been multiple upstream channels present within the plant, prior to DOCSIS 3.0 channel bonding, a CM could only be connected to and utilizing a single channel at any point in time. If a test instrument was experiencing impaired service, it was obvious what upstream channel (frequency) was impacted by the impairment.

Surprisingly, the process of individual carrier inspection has also been simplified with DOCSIS 3.0. In previous versions of DOCSIS a CM could only be connected to a single channel, and thus could only transfer data across that channel. Service layer testing and deep physical layer testing was only available for that single channel. In this scenario, it requires expert technicians to ensure that the test instrument is properly configured on the same upstream channel as the impaired modem. Additionally, in earlier versions of DOCSIS the process of analyzing multiple channels required that the instrument leave the current upstream channel and range and register on a separate channel to perform the testing.

That said, it is important to understand what it means to perform deep physical layer analysis on a DOCSIS upstream channel. The physical layer parameters that are traditionally associated with deep upstream analysis are:

- MER (per modem)
- In-Channel Response
- Group Delay
- Ingress Under the Carrier
- Impulse Detection

Traditionally, operators have access to this information in many ways. Some of the parameters are available from the CMTS's DOCSIS MIB. Others would be available by moving the carrier and using a field meter to transmit a constant carrier, and utilizing a digital analyzer in the headend to demodulate and analyze. All of the screen captures in this paper are taken from an integrated solution that captures in-band modem bursts from a specific field instrument, demodulates the burst, and returns the results to the field instrument for analysis.

Because the DOCSIS 3.0 modem has a bonded upstream, as seen in the following figure, it is critical to analyze each of the upstream channels in turn.

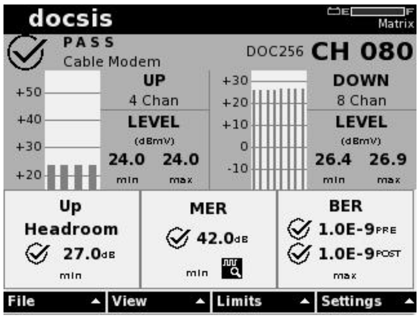
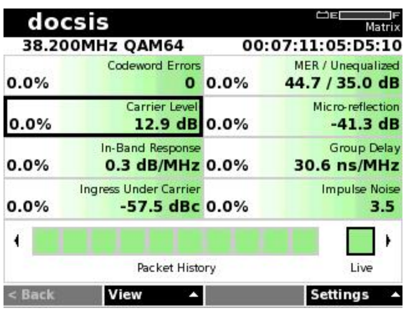
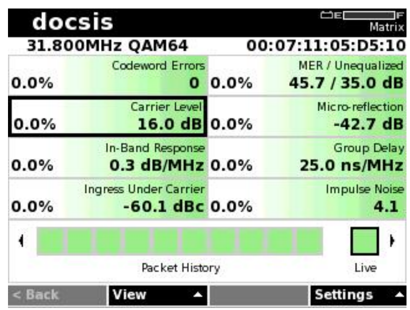
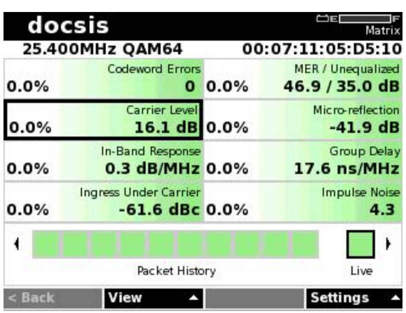


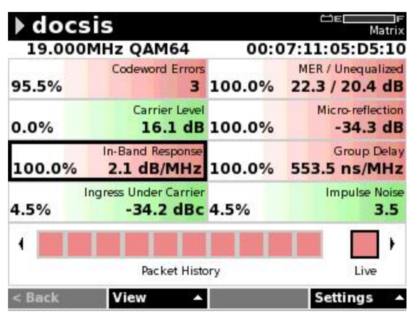
Fig 3: Range Summary with US Bonding

Selecting the upstream channels one by one, and gathering up to 10 packets at the headend specifically from the test instrument yields the following results.









Analysis of these measurements clearly indicates that there is a physical layer issue affecting the upstream channel at 19 MHz. This issue is causing codeword errors, and would be service impacting to the modem. It is very important to note that even if there were no codeword errors present, the deep analysis would show impairments that are being masked by the equalizers in the system.

When the technician determines the channel source of the impaired service, the goal is to determine what is causing the impaired service. To accomplish this, the technician should begin traversing the network toward the CMTS, testing at each test point (Ground Block, Tap, Amps, Node) until the point where the affected channel becomes clean. When the channel becomes clean, the technician has passed the impacting impairment.

Following the correction of the physical layer issue, the technician should repeat the test at the initial location to ensure that the issue is indeed resolved.

Section 8: Summary

For continued reading into the detailed potential issues and areas of concerns in deploying DOCSIS 3.0 the following articles should be read as an addendum to this one:

1. The Need for Speed - DOCSIS 3.0 Downstream Bonding Issues, CT Magazine, March 1, 2009 – go here: **http://www.cable360.net/ct/strategy/emergingtech/34304.html**
2. Speeding Upstream - DOCSIS 3.0 Tips, – go here: **http://bradyvolpe.com/docsis/speeding-upstream-part-i/**

These two articles investigate other areas of downstream and upstream DOCSIS 3.0 related concerns.

To wrap things up, this document should have provided a fundamental understanding of the differences between DOCSIS 2.0 and DOCSIS 3.0. A number of new terms, interfaces and hardware components were introduced, but are necessary for the day-to-day operation of DOCSIS 3.0. A detailed discussion covering Partial and Impaired Service was held, including how to identify and troubleshoot each. Readers should recognize that while DOCSIS 2.0 test equipment can still be used, DOCSIS 3.0 test equipment offers substantial advantages over legacy equipment and in some cases may be the only way to resolve advanced problems in a DOCSIS 3.0 network.

As a take-away, one should recognize that experiences from DOCSIS 1.x/2.0 deployments will be directly applicable to DOCSIS 3.0, however there will still be a learning curve and new hurdles with DOCSIS 3.0. These challenges will be well worth the value brought to the table by DOCSIS 3.0 in the highly competitive market place that we find ourselves in today.