DOCSIS Codeword Errors & Their Effect on RF Impairments

The Volpe Firm, Inc.
3000 Old Alabama Rd.
Suite 119-434
Alpharetta, GA 30022
Volpefirm.com
+1.404.954.1233
4/1/2013

Commissioned by:
ZCorum
Corporate Headquarters
4501 North Point Parkway
Suite 125
Alpharetta, GA 30022
Toll Free: 800-909-9441
Fax: 678-507-5001
info@ZCorum.com

Monitoring DOCSIS Codeword Errors Improve Subscriber QoE

DOCSIS codeword errors is terminology that you may or may not be familiar with. No matter which camp you're in it is important to know that monitoring codeword errors will enable you to improve your subscriber's quality of experience (QoE). How is this possible? DOCSIS codeword errors are the most effective metric to determine if a data issue; like slow web pages, slow gaming, poor voice quality, etc., is an RF plant problem or if it is a data network problem. If you work in the field you know how critical this information can be. DOCSIS codeword errors are the deciding factor if you have an RF impairment or if you do not have an RF impairment. Period.

What are DOCSIS Codeword Errors?

When a subscriber is using a device, such as a PC or iPad, and transmits data over a DOCSIS cable modem, an error protection algorithm called Reed-Solomon (R-S) forward error correction (FEC), kicks in. There are two functions to the R-S FEC protocol, the encoder and the decoder. The cable modem and CMTS act as both interchangeably depending on data direction.

The encoder takes the subscriber traffic, puts it into a fixed chunk of data called a codeword and appends two calculated bytes of data for error correction. The decoder then receives the codeword plus the extra two bytes of error correction data. If the decoder finds that any bits in the codeword were corrupted due to RF impairments it will use the two bytes of correction data to attempt to fix the corrupted bits. If the bits can be repaired, then the decoder reports back with a correctable codeword, because the codeword was saved thanks to the forward error correction. This means the subscriber never knew that any RF impairment occurred.

On the other hand, if the decoder is not able to repair the corrupted bits, the decoder reports an uncorrectable codeword. This means the subscriber's device (PC, iPad, etc.) must re-transmit the data if possible and their QoE will start to diminish as uncorrectable codewords increase. This is especially true for real-time services such as gaming.

If the number of uncorrectable codewords is high then the subscriber may notice their Internet traffic is slow. If the subscriber is using voice-over-Internet Protocol (VoIP) offered by the cable operator, Skype, Vonage, etc. then it is not possible to retransmit real-time voice traffic. So voice and video calls will be impacted. The rule of thumb is uncorrectable codeword errors should be kept under 1% for VoIP or the subscriber QoE will be impacted. At 3% they start to become very annoying to subscribers and at 5% you will start to get complaints from subscribers as their QoE is very poor.

How To See DOCSIS Codeword Errors

The best ways to monitor DOCSIS codeword errors are through Simple Network Management Protocol (SNMP) or Internet Protocol Detail Records (IPDR) systems. These let you track correctable and uncorrectable errors on a per-cable modem basis over time.

The following figure shows one such monitoring system from ZCorum that allows you to track upstream uncorrectable codeword errors over the past seven (7) days.

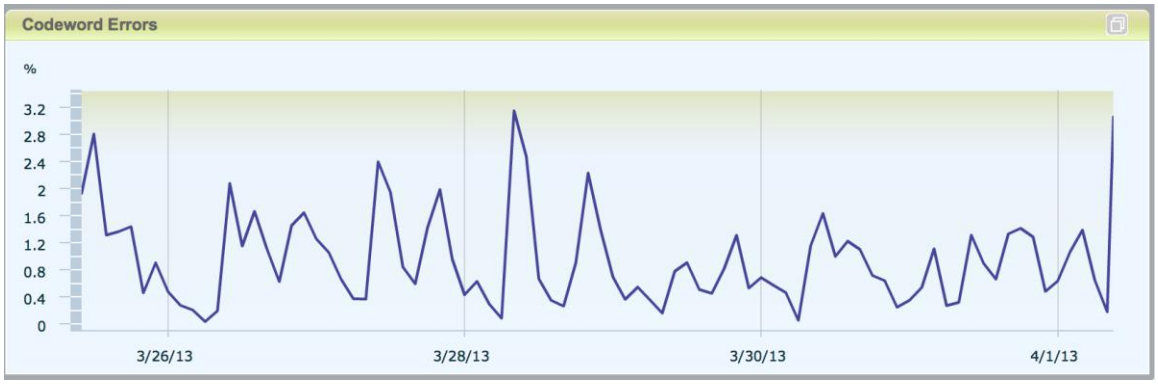


Figure 1: High Levels of Uncorrectable Upstream Codeword Errors C4/0/U1

The benefit of this particular view is that we can see a common trend on upstream interface C4/0/U1 of the CMTS. Daily peaks and valleys between 1% and 3% of uncorrectable codeword errors are present across all cable modems in the upstream. This gives the average uncorrectable codeword error rate for all modems, which shows a systemic problem. Now we must start looking at individual modems to see which ones are being impacted the most.

Again, it's best to use SNMP and/or IPDR tools. Using another example from ZCorum, we can look at an individual cable modem as shown in the figure below:

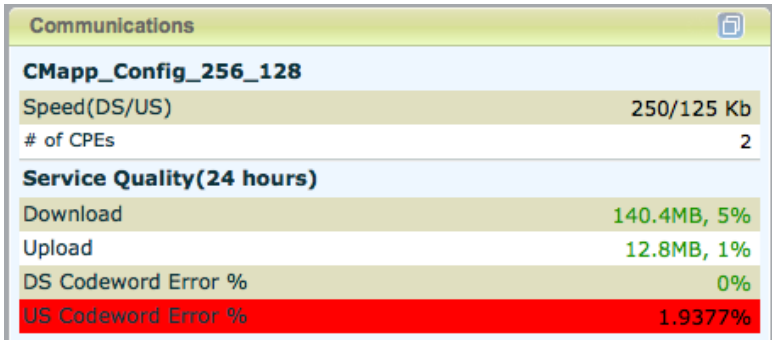


Figure 2: High Upstream Codeword Errors, Single Modem

It is very apparent on this particular cable modem that downstream (DS) codeword errors are not a problem, since there are no errors (0%), but upstream (US) codeword errors are quite high at nearly 2% (1.9377%). This subscriber will likely be experiencing somewhat reduced Internet browsing speeds because 2% of their traffic must be retransmitted. In addition, they will have poor VoIP calls. Their QoE is degraded and from a plant perspective we know that there are upstream RF problems.

Sources of Codeword Errors

We started off with the first metric that everyone should look at in a DOCSIS plant – uncorrectable codeword errors. This is one of the easiest ways to determine if packets are being dropped due to RF impairments. If there are no DOCSIS codeword errors, but subscribers are having problems then we can make the assumption that there are

impairments somewhere in the IP data network. It is a great way to determine if this is an RF problem or not.

Once an RF problem is detected, the typical causes of codeword errors must be reviewed in order to determine the problem. This next section will address the most basic causes and provide recommendations to identify and resolve them.

RF Levels at the Cable Modem that are too High or too Low

Downstream

The ideal downstream input to a cable modem is 0 dBmV for a DOCSIS QAM channel. If the downstream signal is too **low**, the cable modem receiver will not be able to demodulate the QAM channel, resulting in low SNR values (also known as modulation error ratio – MER). If the downstream signal is too **high**, the cable modem input will be over-driven, the same way when you turn your car stereo up too high and it sounds garbled.

The two threshold limits that are recommended for cable modem installation are as follows:

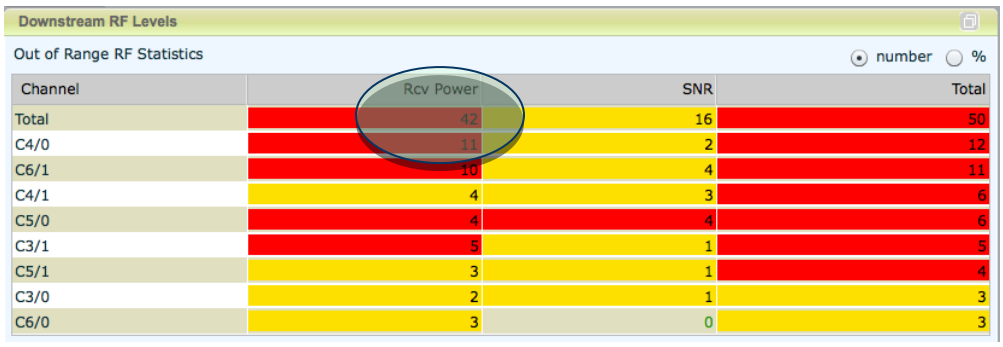
1. All general installations should be +/- 5 dBmV at the cable modem
2. For end of line or extreme cases allowance may be made for +/- 10 dBmV

Never exceed +/- 10 dBmV if you want a cable plant that is reliable. Yes, you have cable modems that are currently running at -18 to -20 dBmV, but do you have t3 errors on those cable modems? Do you have upstream correctable or uncorrectable codewords on those cable modems? While it may work it is not ideal.

Some things to do in order to achieve the recommended signal levels are as follows:

- Change the tap value
- Replace Series 6 with Series 11 coax cable on long drops
- Run a separate dedicated drop to the cable modem (remove splitters)
- Check your connectors

It is also helpful to have a monitoring system that will tell you how many cable modems and which ones are outside of your +/- 10 dBmV receive power window. Again, taking an example from ZCorum's dashboard we can quickly tell that 42 modems are in need of adjustment to get them back into our required specifications:


Downstream RF Levels

Out of Range RF Statistics — number / %

Channel	Rcv Power	SNR	Total
Total	42	16	50
C4/0	11	2	12
C6/1	10	4	11
C4/1	4	3	6
C5/0	4	4	6
C3/1	5	1	5
C5/1	3	1	4
C3/0	2	1	3
C6/0	3	0	3

Figure 3: Total 42 Cable Modems Exceeding DS Receive (Rcv) Power (+/- 10 dBmV)

Upstream

Just as in the downstream, cable modems have an ideal transmit power range. This range is between 40 to 50 dBmV. If the cable modem is transmitting less than 40 dBmV the carrier-to-noise (CNR) may start to become a problem and degrade upstream SNR (MER). This will increase uncorrectable codeword errors. If the cable modem is transmitting higher than 50 dBmV, depending upon the modulation-profile and its exact transmit level, it may reach the CMTS at too low of an RF level. This will also result in uncorrectable codeword errors or even a cable modem that intermittently drops offline.

The key to establishing correct upstream transmit levels is proper balancing of the upstream plant. However, once the upstream is properly balanced, you may find that some cable modems still transmit too low. In this case there are upstream step attenuators that attenuate the return path, but do not attenuate the forward path. Install these at the tap, never in the home, to achieve maximal CNR performance. This is because more than 75% of ingress occurs between the home and the tap.

Other Impairments

Other impairments that cause codeword errors include the following:

- RF ingress – there are many types
  - Impulse noise
  - Additive white Gaussian Noise (AWGN)
  - AM radio, Citizen Band Radio, Ham radio, shortwave radio, etc.
  - CPD
- Group Delay
- Micro-reflections
- Frequency response ripple
- Laser clipping

Conclusion

There are many causes of RF impairments beyond what is covered here. However understanding and monitoring them is of tremendous value to you and your subscribers. You will be able to maintain a healthy DOCSIS plant by ensuring that your cable modems are receiving and transmitting at the correct RF power. And continuous monitoring of these metrics is intrinsically valuable so that correlation between a subscriber problem and an observed incident can be made. Always remember, uncorrectable codeword errors indicate that you have a problem, but at least you know you can diagnose the problem and take action to improve the subscriber QoE.

Biography

Brady Volpe, President and Founder of The Volpe Firm, Inc., is involved in providing technology consulting services and products to cable and telecom operators & vendors World-Wide. Mr. Volpe has over 20 years of broadband cable and telecommunications industry experience specializing in DOCSIS, MatLab Simulation and Design, VoIP, Video, IPTV, RF, Digital Design, IP Security, EPON, FTTx, SIP, Capacity Planning, Fiber Optic Transport and all things broadband.

Prior to the Volpe Firm, Mr. Volpe was R&D Director for JDSU, a leading provider of optical products and test and measurement solutions for the communications industry, were he was responsible for the development of communications test and measurement equipment & applications across 20 worldwide design centers. Mr. Volpe was also the VP of Engineering & Technology at Sunrise Telecom where under his leadership the company brought five new platform products to market. Previously, Mr. Volpe worked with Filtronic Sigtek, Inc. as Director Technical Marketing & Sales, where he developed and drove the industry debut of a DOCSIS protocol analyzer. The first portable DOCSIS analyzer for the broadband industry capable of analyzing both the upstream and downstream DOCSIS signals. Up to that time he was Director of Engineering State College, PA and Santa Clara, CA and Site Executive of Santa Clara, CA with C-COR Incorporated (now Arris) where he led engineering and telecommunications equipment development for all of the company's facilities.

A highly respected speaker and industry thought leader, Mr. Volpe is a frequent presenter at industry trade shows, conferences and regional seminars. He has published numerous articles in worldwide trade journals and authored several white papers on DOCSIS protocol and VoIP test and analysis. Mr. Volpe lends his expertise to industry associations and protocol bodies and is often sought out as an authority on DOCSIS, PacketCable, and VoIP. In addition, Mr. Volpe is a long time IEEE, SCTE and SCTE standards member. He holds patent number 7,885,195, "Test System With User Selectable Channel." His blog, bradyvolpe.com, now located at volpefirm.com, is the industry's most comprehensive DOCSIS tutorial and is used by a major MSO for training and educating their workforce.

Mr. Volpe earned his master's degree in electrical engineering, graduating with Honors (4.0) from John Hopkins University Applied Physics Laboratory in 2004. He received his bachelor's degree in electrical engineering from the Pennsylvania State University. Throughout his studies, Mr. Volpe focused on advanced telecommunications.

About ZCorum

ZCorum provides broadband Internet and communication solutions to telcos, cable companies, utilities, and municipalities, assisting in all facets of broadband implementation, integration, engineering and consulting, network monitoring and diagnostics. ZCorum also offers wholesale, private-labeled Internet services, including data and VoIP provisioning, email, Web hosting, and 24x7 support for end-users, enabling service providers to compete effectively in their local rural and suburban markets. ZCorum is headquartered in Alpharetta, GA. For more information, please visit www.ZCorum.com or contact Alex Rivera at 800-909-9441 ext. 5562 or arivera@zcorum.com.