

Guide to Managing Cable Network Traffic Congestion

Addressing Capacity and Congestion with Cable Modem Termination System (CMTS) “Tweaks”

A Technical Paper prepared for SCTE•ISBE by

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1. Introduction

With unprecedented demand on local broadband networks, operators are under pressure to prepare for congestion and capacity issues before they happen. During the Spring of 2020, most systems experienced the equivalent of one year's growth in 2-3 weeks. The industry "weathered this storm", but we must be prepared for continued demand. Some suggestions will be given to help alleviate and mitigate congestion now and also provide ideas on how to address capacity concerns into the future on cable operator DOCSIS plants.

2. Top Seven Steps

1. Decreasing subscribers per service group (SG) is one of the most obvious choices, but it can be achieved in a multitude of ways.
 - ✓ Increase the amount of SGs and add more licensing/channels.
 - ✓ Decrease service groups (SG) down to one fiber node (FN).
 - ✓ Utilize upstream (US) segmentation. Maybe the node supports multiple downstream (DS) optical receivers and US transmitters or the US utilizes baseband digital reverse (BDR) and can be converted from 1 to 2 US segments.
 - ✓ The last option would be a physical node split, but if utilizing distributed access architectures (DAA) like Remote-PHY, possibly a 1x1 RPD can be replaced with a 2x2 or some other variant.
2. Verifying no **uncorrectable** Forward Error Correction (Uncorr FEC) and "clean" plant should be part of everyone's proactive maintenance plans, but sometimes relegated to the bottom of the list.
 - ✓ Uncorr FEC is basically dropped packets. Regardless of modulation error ratio (MER), signal-to-noise ratio (SNR), carrier-to-noise ratio (CNR), correctable FEC (fixed packets); Uncorr FEC is the most important to your end-customer.
 - ✓ **Note:** Uncorr FEC is not only caused by bad plant issues. It could be from bad timing (time offsets and MAP Advance), poor port-to-port isolation leading to signal "bleed-over", modulation profile settings, and a myriad of other contributors.
3. Increasing capacity without physical node splits or SG changes may be the first goal and can be achieved with a few ideas.
 - ✓ Use the highest US and DS modulation along with the largest channel widths as possible. This may have no cost increase since licensing may be based on channel only and not the rate/speed.
 - ✓ Utilize DOCSIS 3.1 where possible. ***Note:** More speed does not necessarily mean less latency! D3.1 US may exhibit even more latency with ping tests.

- This brings up an all too familiar question, “How many D3.1 CPE are needed to justify exchanging ATDMA chs for OFDMA spectrum?” Is it 10%, 25%, 50%, even higher? If 10% of your users are using 85% of your capacity, they either have D3.1 CMs already or you could identify those “heavy users” with subscriber traffic management (STM) and then give them a D3.1 CM. Assuming it’s not that bad and 10% use 50% of your US, that could be the justification to drop 2 ATDMA chs and use that spectrum for more efficient D3.1 OFDMA. There are some advantages to dropping from 4 to 2 ATDMA chs. D3.0 CMs get back 3 dB more max Tx power and less DS overhead in the form of MAPs. Two ATDMA chs give 54 Mbps aggregate US speed and one could offer a 20 Mbps service and lower. All other US offerings >20 Mbps would use D3.1.
- ✓ Allocate more spectrum for high speed data (HSD) services. This may entail using spectrum once thought to be questionable such as: roll-off, known ingress areas like CB, LTE, Aeronautic band, and the very low end of the US spectrum. DS may require you to “steal” from video spectrum. Analog video reclamation should be an easy sell but converting MPEG-2 video to MPEG-4, over the top (OTT) video is the ultimate endgame and takes more consideration and planning.
- ✓ Utilize/exploit “Powerboost”™. More speed could translate to “actual” vs “perceived”. Powerboost is a term/feature (name trademarked by Comcast) used for faster speeds that can affect perceived speed (DS & US). A command may need to be configured on the CMTS for DS Powerboost activation along with a very large DS Max Burst setting, like 50 MB in the cm file.
- ✓ Figure 1 below depicts an example of a D3.1 CM with 510 Mbps max rate, 600 Mbps peak rate, and 70 MB DS max burst. This can achieve approximately 6 seconds of Powerboost.

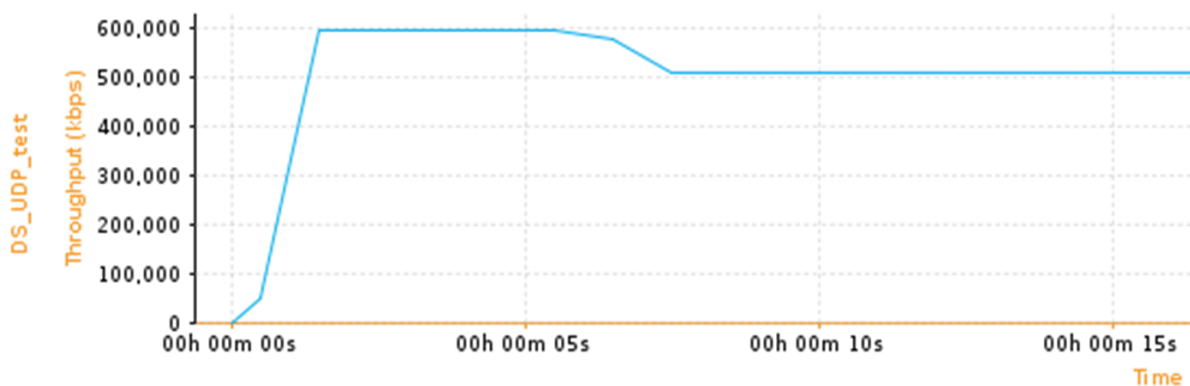


Figure 1 – DS Powerboost Example

- **Note:** DOCSIS 3.0 CMs support a TLV for per-CM Peak Rates.
- Utilize to alleviate typical 10% over-provisioning, which is usually done to negate differences between layer 2 & 3 speed reporting.

- Can exploit US Max Traffic Burst for US “Powerboost” as well. US Powerboost may help alleviate perception of lower speed. This can also be exploited to apply a peak-rate and less over-provisioning, which is typically done today at 10% just to “ring the bell”.
 - The “jury is still out” whether this can negatively affect OTT video and other adaptive bit rate (ABR) applications with buffer loading.
- ✓ An US Powerboost can be achieved as well. If for example we wanted to provide a 500x50 Mbps offering, most would typically set for 550x55 Mbps. Instead, we could use Powerboost to allow: 500x50 max rate, 550x60 peak rate, and 50x10 MB DS/US max burst. This should provide ~ 8 secs of US and DS Powerboost.

4. Eliminate Overhead

- ✓ More USs in a MAC domain creates more DS MAP overhead at ~.4 Mbps per US. Increasing US channel size and eliminating too many US channels will help. Another way to get less US channels per MAC domain would be to create more MAC domains. This can be achieved easily when the SG consists of two fiber nodes (FNs).
- ✓ Also, moving to every 4th DS as Primary could save 54 Mbps per 24-ch DS bonding group (BG). The trade-off is less aggregate capacity for D2.0 CMs.
- ✓ Remove “stale” service flows. Some inactive VoIP flows may not be torn down according to their T8 timer and can be done automatically with the CMTS command, `cable service flow activity-timeout 300`. Add this CMTS global command so flows with no activity > 300 seconds (5 minutes) are torn down if the CM/eMTA does not do it automatically.
- ✓ Understand WIFI, VPN, etc. encapsulation overhead along with potential “bottlenecks”.
- ✓ US acks are used for DS TCP flows. D3.0 & 3.1 CMs support and have ack suppression on by default helping to alleviate US acks. For very fast DS TCP flows (i.e. 1 Gbps), this helps alleviate US overhead from the acks required (typically 20 Mbps decreases to ~7 Mbps). The pitfall to this is each ack is now more important and ack suppression is not very active or efficient when the DS flow is slow (IE < 10 Mbps). So, having many OTT video sessions simultaneous across one CM may not benefit from ack suppression since each flow is 3-10 Mbps.

5. Control Abusers and Denial of Service (DoS) Attacks

- ✓ Cloning – DMIC, BPI+, “Hotlist”.
 - The CMTS can control the same mac address on a chassis and identify potential cloned devices. It can also control CPE “appearing” behind multiple CMs, but it has not visibility across multiple chassis. Some

external devices may have this visibility like the DHCP server and better suited for cloning identification.

- If a cloned device is identified, you can disable CM ranging and registration by implementing the Cisco “hotlist” command.

```
(config)#cab privacy hotlist ?
cm                Add cm hotlist
manufacturer     Add manufacturer hotlist

(config)#cab privacy hotlist cm ?
H.H.H            CM mac address H.H.H
```

- **Note:** The CM could still be ranging “all the time”, but it will not even show init(r1) on the CMTS. Some could argue that it’s better to let it register and give it a cm file with network access disabled.

✓ Over-Use/Abuse

- Deep Packet Inspection (DPI) can be used to at least identify “heavy” users.
- Subscriber Traffic Management (STM) takes rate limiting and monitoring down to the least common denominator, which is bytes. There is no bias towards ports, applications, etc. It solely looks at total bytes over a certain time frame and can dynamically drop the CM’s QoS to a lower rate for a given time period.

✓ Arp Attacks, IGMP Joins?

- Arp Filters, Access Lists (ACLs), subscriber-based rate limiting (SBRL).

✓ Expiring Certificates

- Allow/Deny Lists. Cablelabs’ certifications are expiring by end of 2020 and some CM certifications could render it unusable.

6. Optimize CMTS Efficiency

- ✓ Load Balancing
- ✓ D3.1 Graceful Profile Management & US/DS Resiliency/Partial Mode

7. Implement Cache Servers

- ✓ **Note:** Netflix, YouTube and other OTT video providers may drop video quality to save bandwidth and/or temporarily halt 4K video offerings.
- ✓ Allowing a new gaming version of Fortnite or Call of Duty to be stored on a cache server closer to your end-users mitigates WAN traffic and overload.

3. CMTS & Cable Interface Suggestions

- **CM Insertion Interval** - CM ranging opportunities

✓ (config-if)#cab insertion-interval auto 120 1000 or (60 480)

- ✓ The Cisco scheduler has dedicated time every 60 ms for initial maintenance (IM). The number of CMs online and traffic utilization will automatically make the insertion interval change between those two numbers. Verify with the show controller command:
 - ```
cbr8#sh contr c1/0/2 upstream | in Insertion
 Ranging Insertion Interval automatic (120 ms)
 Ranging Insertion Interval automatic (120 ms)
 Ranging Insertion Interval automatic (120 ms)
 Ranging Insertion Interval automatic (120 ms)
 Ranging Insertion Interval automatic (120 ms)
```
- ✓ **Note:** The value reported could be an average between a changing insertion interval and report a value that is not an increment of 60 as one would expect.
- ✓ It may be worth experimenting with this Insertion Interval. The cBR-8 defaults are 120 1000, but we have had success in the past with the old uBR10K defaults of 60 480. We have also used “fixed” settings (lowest of 100 ms and highest of 2000 ms) to address maintenance windows. The lower number creates more opportunities for CM registration at the expense of user traffic capacity.
- ✓ A new CM will start ranging typically around 6 to 9 dBmV in 3 dB steps until the CMTS “sees” it, which is about -20 dBmV at the CMTS. Once the CMTS “sees” it, the CM will report inti(r1) as they are doing initial maintenance (IM). This is contention time and CMs will back-off when, and if, they collide. Explained below.
- ✓ **Note:** The CM should quickly go from broadcast IM to unicast station maintenance (SM) for final ranging and report init(r2). This does not have to be in 3 dB steps anymore.
- **US Range & Data Backoff & Init Technique** - Used to minimize collisions in the US
  - ✓ 

```
cable upstream x range-backoff 3 6
```

    - This can be experimented with in case CMs collide at init(r1) and have to back-off. The code allows a CM to back-off randomly between 2<sup>0</sup> (1) to 2<sup>3</sup> (8) insertion intervals (above command) for first collision. Second time collision, randomly back-off between 2<sup>3</sup> (8) and 2<sup>6</sup> (64) insertion opportunities.
    - In the case of a CMTS reboot, the insertion interval would be the lowest of every 120 msec and a bunch of CMs would be in inti(r1). Assuming collisions are happening, they would back-off randomly that first time between 1-8 opportunities, this means between 1\*120 and 8\*120 = a back-off anywhere from 120 msec to .96 sec.
    - **Tip:** Look for CMs stuck in init(r1) as they could cause issues by “eating up” limited IM opportunities and cause high Uncorr FEC counters.
  - ✓ 

```
cable upstream x data-backoff 3 5
```

- This is for contention Request collision back-off. The good thing about faster US service flow speeds, is usually after an initial contention Request, the subsequent bandwidth (BW) Requests end up being “piggybacked” within the actual data traffic and no more possibility of collisions. We have seen good results lately in some markets using values of 4 and 6.

**Side Note:** More US utilization coupled with applications not using unsolicited grant service (UGS) such as Vonage, Skype, Zoom, Wi-Fi calling and other BE VoIP, will increase the probability of Request collisions. This could also be exacerbated by DS OTT video and its TCP acks that must be sent on the US.

I suspect customers with audio-only will have more contention requests since video would increase the US throughput requirements and piggybacking should occur more often.

**Warning:** These collisions could lead to laser clipping and dropped packets. This is not the case for distributed access architectures (DAA) like remote-PHY since the fiber link is digital and there would be no laser clipping.

The following Cisco CMTS commands can be used to verify BW Requests whether they are contention or piggybacked. It cannot tell when contention requests actually contend/collide. The first one is intended for a specific CM. Refer to your CMTS vendor for similar commands.

```
cbr8#sh int cx/y/z sid n count ver | inc BW
BWReqs {Cont,Pigg,RPoll,Other} : 8306, 3243, 0, 0
```

This second command will show per US.

```
cbr8#sh contr cx/y/z up n | in Request|Bytes
Bandwidth Requests = 2776290
Piggyback Requests = 1077964
Invalid BW Requests= 195
Bytes Requested = 256264277
Bytes Granted = 1626995783
```

If for example 500 homes were in a SG/FN and 10% are doing some sort of teleconferencing and 40% of them are doing audio-only and half of them actually have collisions. This gives  $500 \cdot .1 \cdot .4 \cdot .5 = 10$  potential request collisions.  $10 \cdot \log(10) =$  a 10-dB potential power spike. To add power perfectly, signals need to be the same frequency, amplitude, and phase. At the US laser input, signals will be the same freq and power, but phase is based on timing/distance. CMs have time offsets to keep tight timing alignment, so phase could be aligned as well.

**TIP:** A trait of laser clipping is “seeing” artifacts like second and third order harmonics above the diplex filter region. One way to prove a signal is an artifact is to turn off the original, “real” signal or watch a spectrogram view, which is time in the Z axis. If artifacts disappear the same time signal below 42 MHz disappears or fluctuates, then it’s a high probability that it’s a harmonic or by-product of inter-mixing of signals (heterodyning). Keep in mind that sometime DS signals leak on the US, so it’s actually ingress and not a harmonic. Also look below 5 MHz



and make sure AM or HAM radio is not getting into your node. It's been seen in the past where a node using a special port for power insertion wasn't as efficient as believed for RF choking. Installing a power inserter on an RF leg solved the issue.

Other power spikes could be CMs coming online and ranging. A CM on a low value tap will normally only need to transmit maybe 35 dBmV and if it ranges it could go as high as 57 dBmV. Utilizing flexible solution taps (FST) with built-in EQs helps alleviate this since CMs all transmit between 40-50 dBmV and will not have a large range to ramp up.

**Warning:** There could also be a concern with CMs in the "hotlist" as they will still range. Whether this exacerbates the issue is unknown since they never show init(r1), but they're ramping up on every UCD and trying all day long!

- ✓ `cable upstream ranging-init-technique 2`
  - This cable interface command helps US ranging for D3.0 mtc-mode (US bonding) by eliminating contention ranging on the other USs in the US BG once the first US has ranged. The default is technique 1, which means contention IM. Tech 2 is unicast, so basically SM ranging. There have been issues with some CMs with tech 2 in 3.18 code, but tech 3 or 4 could be tried as well. It also helps with RFoG systems and also for D3.0 DS load balance (LB).
- **Throttle CM Ranging**
  - ✓ `[no] cable throttle-modem init-rate <1-1000> holdoff-time <5-100> flush-rate <100-1000>`
    - Suggested values; 32 CM/s; 45 sec; 300 CM/s
  - ✓ `show cable throttle-modem`
  - ✓ `cable up rate-limit-bwreq exempted-priority <priority>`
- **Prioritize Pre-registration Traffic**
  - ✓ `(config)#cable qos pre-registration us-priority [0-7]`
    - Default of 0, with a suggestion of 6 or 7. During CM registration, a CM first goes through init(r1), which is contention-based ranging. Once the CMTS "hears" it, it goes to init(r2), which is unicast ranging to fine tune the levels and add Pre-EQ. Once these physical layers are complete, the CM state will report int(rc) and it can now be "docsis pinged". The next state is dhcp (init(d)) and the CM must now use actual data transmissions that compete with other CM transmissions. If the dhcp discover is small, the CM could use a short grant and its associated modulation, otherwise it will use a long grant with its modulation. If other CM transmissions are higher than priority 0 and lots of US utilization, then this init(d) state may never have any opportunities to be fulfilled, so set it much higher than 0!
  - ✓ DS – "cable service flow priority" (EDCS-1524683). Contact Cisco TAC and/or CX for more information.

✓ **Note:** Setting all BE flows > priority 0 can lead to issues.

• **US Max Power Issues**

✓ `cable upstream n power-adjust continue 6`

- Helps CMs exceeding Max Tx power to stay online.
- **Note:** A max transmit CM will be commanded to change level every 15-20 seconds during its SM, optimally only once. Some CMs have been observed to go into the fast polling mode (every second) for 5-10 times before moving on. This is a good reason to make sure < 5% of your CMs with a Rx marking of ! are in this state.
- By increasing the “continue” command to 6 dB, the CM will be permitted to stay online if the CMTS receive level is between -6 dBmV and 0 dBmV. If the level is above -1, you won't see a "!". If the level is below -6 dBmV, the CM will go offline. For systems that still have high-value taps (29 & 26 dB), this helps keep the CM online, but will produce CMs with different CNRs & MERs.
- **Warning:** Allowing a large `power-adjust continue` to be configured can lead to CMs having a large range to overcome isolation and potentially appear on US ports where they should not! It could also allow CMs located off low value taps to range very high and create intermittent laser clipping.
- **Note:** If the level of noise on the US is enough to distort the US level being received by the CMTS, then the CM and CMTS will go into "power-adjust noise" averaging mode. A "\*" will be displayed next to the receive level in the `show cable modem` command. When this occurs, CMs are polled using a one second interval. By default, the percentage of "noisy" ranging responses that cause a CM to enter "cable upstream n power-adjust noise" mode is 30%. This percentage may be increased to alleviate excessive power level adjustments in the presence of noise.
- The following command can be used to identify CMs in max Tx power, max time offset and noise averaging mode.

```
cbr8#scm | in *|||MAC|State
MAC Address IP I/F MAC Prim RxPwr Timing
 Add State Sid (dBmV) Offset
38c8.5cb6.63ca -- C2/0/2/U1 online(pt) 15 !0.00 1209
38c8.5c09.42c0 -- C2/0/1/UB w-online(pt) 1 -1.00 !6104
6477.7d90.4368 -- C2/0/7/UB w-online(pt) 12 *0.50 1532
```

✓ `cable upstream max-channel-power-offset 6`

- The above command helps D3.0 & D3.1 CMs select the best US BG. When a D3.0 CM registers, it does so on a single channel, a reference channel, and relays its Tx level back to the CMTS. The CMTS can determine if that level will be adequate for multi-ch bonding. The “power-adjust continue” range is **NOT** used for this decision.

- **Note:** Cisco has a feature that will drop from 4-ch to 2-ch (if configured) and finally single-ch mtc-mode. This depends on the Tx level supported plus it adds in the `max-channel-power-offset` calculations. This command has a default of 3 dB, but a value of 6 is recommended. If that level is not adequate for all options, then the CM resets itself. Example; CM ranges on US0 and reports 55 dBmV, CMTS wants to do 4-ch bonding and determines that 64-QAM for 4-ch US bonding has a max output of 51 dBmV + 3 max-ch-offset = 54, so CM drops to 2-ch BG, if configured.
- ✓ Stick with the double minislot from default like we suggest and never quadruple it. If so, more “time on the wire” will be wasted. Dropping it to the default minislot of 1 when using 6.4 MHz ch width will not save anything and could affect US concatenation and per-CM US speed.
- ✓ `cable upstream balance-scheduling`
  - The US scheduler tends to allocate more minislots in the first US in the US BG if not using this command. This is not “bad” but can affect D2.0 CM US load balancing. This command is not on by default, but highly suggested to implement. Another option would be to assign US0 to your highest, “best” US frequency and the last US in the BG to the lowest, “worst” US frequency.
  - **Warning:** Do not use this command for RFoG (DPON) environments.
- ✓ `cable upstream qos fairness`
  - Implement the `qos fairness cable interface` command to help fairly share between D3.0 and D3.1 CMs so one doesn’t “starve out” the other. It’s not on by default and we have seen D3.1 allocated more speed at the expense of D3.0 CMs. The command doesn’t change the cross-bonding functionality. D3.1 CMs still prefer 3.1 spectrum before utilizing 2.0/3.0 spectrum (chs).

## 4. VoIP & Service Tiers

### 4.1. Call Signaling Insurance

- ✓ Utilize non real-time polling service (nRTPS) for call signaling. This allocates non-contention request opportunities to guarantee call signaling during high US congestion. The beauty of nRTPS is it allows contention requests, if available, along with non-contention requests, while RTPS is non-contention only. It also allows a priority to be configured for the flow associated with the nRTPS request. Keep in mind that this flow will use another SID.
- ✓ This would be a good time to re-evaluate the modulation profile used for the A-UGS burst since much more traffic could be created by eMTAs. Using a more robust modulation vs the A-Long burst may not be in our best interest anymore and cause undesirable wastage of time on the wire.

## 4.2. Service Tiers

- ✓ When adding faster service tiers, be sure to delete the old, slower ones. Many people forget to delete obsolete tiers when they migrate to higher tiers.
- ✓ **Warning:** The slow-to-fast ratio should not be more than 1:1000. If it is, the slower rate could constrain the faster rate!
- ✓ Make sure DS call signaling flows utilize an LLQ flow by making sure they use a non-zero max latency value. Then these slow flows will not affect the ratio limit.
- ✓ Look at all the flows forwarded on a Wideband or Integrated interface and verify the highest rate and the lowest rate do not exceed a 1000:1 ratio.
  - Example: if offering a 1 Gbps speed, then the lowest offering should be 1 Mbps and higher.
  - It's also not a good idea to use a minimum guarantee rate for any flows (US or DS). Dynamic QoS flows like UGS are fine.

## 5. Going Forward and Planning for the Next Inevitable Event

- Implement a subscriber-based subscription model for quick activation of more channels/capacity.
- Have segmentable nodes for future segmentation and quick activation.
- Implement DAA for better performance, complementary to D3.1, and a pathway to Cloud.
- When available, implement D4.0 Low Latency DOCSIS (LLD) features.
  - ✓ One of those features is Proactive Grant Service (PGS).
  - ✓ Cisco has its own feature called DOCSIS Predictive Scheduler (DPS).
    - `(config-if)#cab upstream dps`
    - Helps US latency in long CIN delay DAA, lowers latency for DS TCP.
    - **Note:** Intel/TI Puma 5 CMs don't seem to benefit.

## Abbreviations

|      |                                 |
|------|---------------------------------|
| ABR  | adaptive bit rate               |
| APC  | angled physical contact         |
| bps  | bits per second                 |
| CCAP | converged cable access platform |
| CM   | cable modem                     |
| CIN  | converged interconnect network  |
| CMTS | cable modem termination system  |
| cnBR | cloud-native broadband router   |
| CPE  | customer premise equipment      |
| DAA  | distributed access architecture |
| DEPI | DOCSIS external phy interface   |
| DLM  | DEPI latency measurement        |

|        |                                                 |
|--------|-------------------------------------------------|
| DOCSIS | data over cable service interface specification |
| DPS    | DOCSIS predictive scheduling                    |
| DRFI   | DOCSIS radio frequency interface                |
| DS     | downstream                                      |
| DWDM   | dense wavelength division multiplexing          |
| FDX    | Full duplex DOCSIS                              |
| FEC    | forward error correction                        |
| FM     | frequency modulation                            |
| FMA    | Flexible MAC-PHY                                |
| GHz    | gigahertz = 1 billion hertz                     |
| HE     | headend                                         |
| HFC    | hybrid fiber-coax                               |
| Hz     | hertz                                           |
| I-CCAP | integrated converged cable access platform      |
| ISBE   | International Society of Broadband Experts      |
| LLD    | low latency DOCSIS                              |
| LLR    | low latency remote phy                          |
| MAC    | media access control                            |
| MDU    | multiple dwelling unit                          |
| MHz    | megahertz = 1 million hertz                     |
| MPEG   | motion pictures expert group                    |
| NDF    | narrowband digital forward                      |
| NDR    | narrowband digital return                       |
| OOB    | out of band                                     |
| OTT    | over-the-top                                    |
| PGS    | proactive grant service                         |
| PHY    | physical layer                                  |
| PTP    | precision timing protocol                       |
| QAM    | quadrature amplitude modulation                 |
| RF     | radio frequency                                 |
| RPD    | remote phy device                               |
| R-PHY  | remote phy                                      |
| RU     | rack unit = 1.75 inches                         |
| Rx     | receive                                         |
| SCTE   | Society of Cable Telecommunications Engineers   |
| SC-QAM | single carrier quadrature amplitude modulation  |
| SFP    | shared form factor pluggable                    |
| SG     | service group                                   |
| Tx     | transmit                                        |
| UGS    | unsolicited grant service                       |
| US     | upstream                                        |
| VoD    | video on demand                                 |