SCTE Penn-Ohio Chapter D3.1 Overview – DS & US

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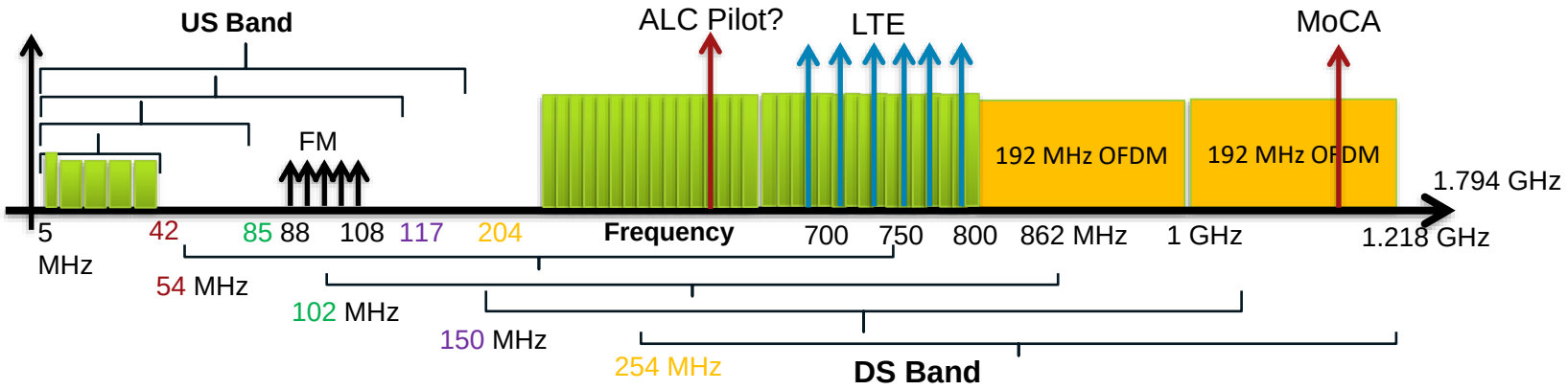
D3.1 DS - OFDM

DOCSIS 3.1 Downstream (DS) General Basics

- 192 MHz max spectrum even though actual is 204.8 MHz
  - May notice time offsets 20X because 10.24 vs 204.8 MHz clocking
- Modulations of 16-QAM – 4096-QAM
- Five data profiles & 5 mixed modulation per profile
- Automatic profile selection and exclusion bands
- Cross-bonding with SC-QAM with OFDM preference
  - Primary can be SC-QAM or OFDM
- CMs support 32 SC-QAM + 2 OFDM blocks
  - Up to 4K QAM support even though 8K & 16K QAM are options in the spec
  - CM spectrum 1 GHz, 1.218, 1.794 GHz?
  - CM US diplex ?

DOCSIS 3.1 DS Spectrum Allocation & Thoughts

- DS out to 1.218 GHz for actives/passives with higher options (1.794 GHz)
- D3.1, 192 MHz block(s) starts at 111 MHz optional & 261 MHz mandatory
  - D3.1 CM's filter may negate any D3.0 operation < 261 MHz
- Potential ingress sources
- US decision affects low-end of DS
- What about DS ALC pilot?



DOCSIS 3.1 DS Interference Testing Observations

- Steady-state interference did not affect throughput as anticipated even at very low MER readings
  - Possibly added affect of LDPC, time/freq interleaving & FFT functionality
- Overall subcarrier MERs dropped when impaired subcarrier MER < ~25 dB
  - Actual impaired spectrum may be a deciding factor
  - Not an issue when exclusion bands used
  - Possibly an added affect of FFT functionality and/or overdrive
- Mixed-mod profiles probably not necessary for ingress, but roll-off maybe

Bit Loading Information from D3.1 CM

CM> **/cm_hal/ofdm_analyzer 32 0**

```
--------|---------|-------------------------------------------------------------
  RxMER |    Max  |          RxMER Histogram for 2749 Subcarriers
    dB  | Bitload |
--------|---------|--------10--------20--------30--------40--------50--------60-
  29 dB |         |
  30 dB |  1K-QAM |
  31 dB |         |*
  32 dB |  2K-QAM |*
  33 dB |         |*
  34 dB |         |*
  35 dB |  4K-QAM |*
  36 dB |         |*
  37 dB |         |***
  38 dB |  8K-QAM |******
  39 dB |         |************
  40 dB |         |****************************
  41 dB | 16K-QAM |**********************************
  42 dB |         |********
  43 dB |         |*
  44 dB |         |
```

- Shows % of subcarriers that would be able to run given modulation
- CM> */cm_hal/ofdm_mer 32 10* (collects RxMER directly from CM)

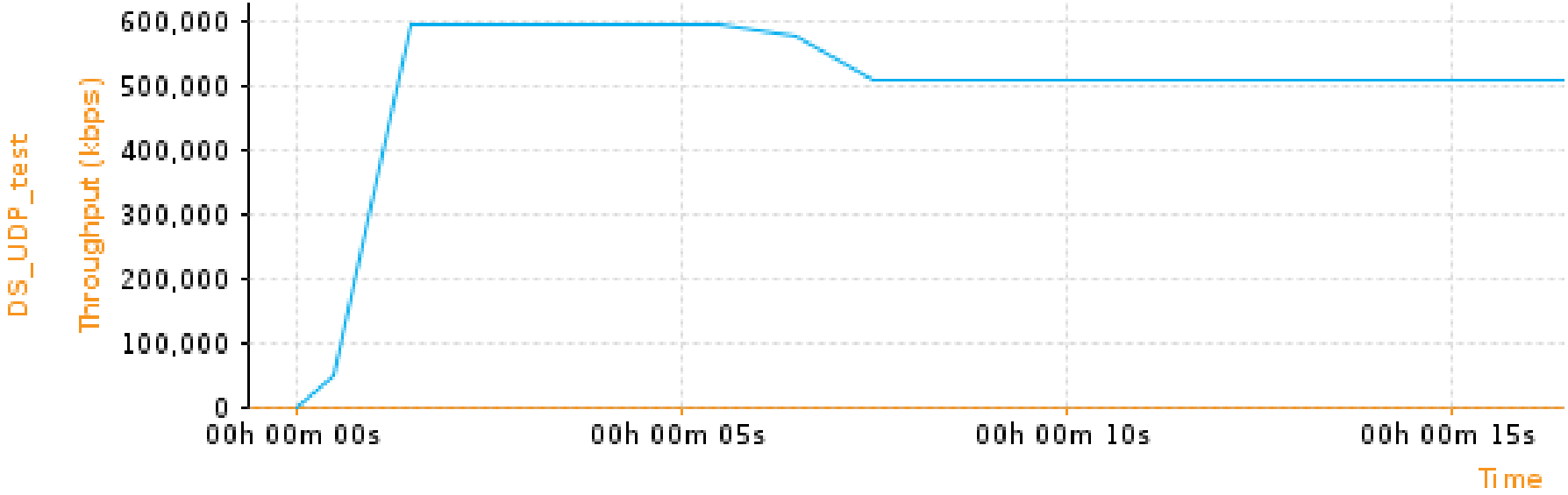
DOCSIS 3.1 DS DS Resiliency / Partial Mode

- PLC is 16-QAM and very resilient
  - Still best practice to find “clean” spectrum
- Cross-bonding may be in best interest
- When D3.1 CM reports non-primary RF ch impairment for SC-QAM or OFDM
  - CM marked `p-online`
  - If RF ch impairment < configured DS resiliency thresholds, D3.1 CM’s service flows moved to resiliency bonding group or Narrowband interface
  - If RF ch impairment > configured DS resiliency thresholds, impaired RF ch temporarily de-activated from all BGs

DOCSIS 3.1 DS Capacity

- Can exploit Powerboost[tm] and peak-rate TLV to satisfy speed test without over-provisioning the typical 10%

- CM file with 510 Mbps max rate, 600 Mbps peak rate, and 70 MB DS max burst
  - Approximately 6 sec Powerboost achieved



DOCSIS 3.1 DS Thoughts

- Can utilize CM FBC for DS “sweep” and ingress testing and verification
  - Can activate CMTS RF without incurring licensing
- 100% corr FEC is expected
- PNM functionality
- No special cm file needed for D3.1 but CM must be in MTC mode (US bonding)
- Performance & features supported can vary dramatically with firmware on CM
- Fiber deep architectures and Remote-PHY will allow much higher speeds
- Utilize CMTS features for robustness & “self-healing”
  - Load balance (2.0 & 3.0), US and DS resiliency, dynamic modulation, …
- Future SDN of OFDM profile management may not be as critical as first thought

Change Profile to 512 Cyclic Prefix & 25 kHz Subcarrier

```
cable downstream ofdm-chan-profile 10
  cyclic-prefix 1024
  interleaver-depth 16
  pilot-scaling 48
  roll-off 256
  guardband-override 1000000
  subcarrier-spacing 50KHZ
  profile-control modulation-default 256-QAM (1024 Mbps)
  profile-ncp modulation-default 16-QAM

  profile-data 1 modulation-default 1024-QAM (1280 Mbps)
  profile-data 2 modulation-default 2048-QAM (1408 Mbps)
  profile-data 3 modulation-default 4096-QAM (1536 Mbps)
```

```
cable downstream ofdm-chan-profile 21
  cyclic-prefix 512
  interleaver-depth 16
  pilot-scaling 48
  roll-off 256
  guardband-override 1000000
  subcarrier-spacing 25KHZ
  profile-control modulation-default 256-QAM (1224 Mbps)
  profile-ncp modulation-default 16-QAM

  profile-data 1 modulation-default 1024-QAM (1530 Mbps)
  profile-data 2 modulation-default 2048-QAM (1683 Mbps)
  profile-data 3 modulation-default 4096-QAM (1836 Mbps)
```

- Change subcarrier spacing from 50 kHz to 25 kHz
- Reduce cyclic prefix from 1024 to 512
- Increase channel capacity by ~20%

Speeds are without PHY overhead and assume 192 MHz channel with 4 NCP messages per symbol

OFDM Settings to Maximize Speeds

- `cyclic-prefix 192`
  - Make value as low as HFC plant will support - 192 is lowest and 1024 is default
- `pilot-scaling 48`
  - Keep at lowest setting – default is 48
- `roll-off 128`
  - Make as large as possible but must but be less than cyclic prefix value
- `subcarrier-spacing 25KHZ`
  - Less overhead for 25 kHz but most most testing to date done with 50 kHz
- `profile-control modulation-default 256-QAM`
  - Configure 4K, 2K, & 1K-QAM data profiles
- `profile-ncp modulation-default 64-QAM`
  - Make NCP as high as plant will support

D3.1 DS Profile Management

CMTS Selects OFDM Profiles for CMs

- CM comes online and locks on profiles (3 data + control profile)
- CMTS polls CM with OFDM profile test (OPT) to get RxMER for all subcarriers
- CMTS runs RxMER data through profile selection thresholds to determine best profile to use for each CM
- CMTS periodically polls CM for RxMER information and adjust profiles as needed
- If CM sees uncorrectable codeword (cw) errors above threshold for a profile, it sends CM-STATUS event type 16 message (DS OFDM profile failure) so CMTS can adjust profile
- This process is now referred to as “internal PMA”

OFDM Profile Selection Process on cBR-8

- Look at RxMER value for each subcarrier (in ¼ dB increments)
- Can exclude a percentage of subcarriers from calculations as outliers (2% by default) but all data subcarriers will be used to carry traffic
- Compare RxMER value for all remaining subcarriers against thresholds
- If RxMER from one subcarrier is below threshold required to run a particular profile, that profile will not be selected
- cBR-8 considers both default and mixed modulation profiles so is aware of subcarrier location relative to configured profile
- cBR-8 begins transmitting to modem using selected profile
- cBR-8 adjust mod profile based on periodic RxMER data or CM-STATUS messages from CM

Default RxMER Selection Thresholds are Conservative

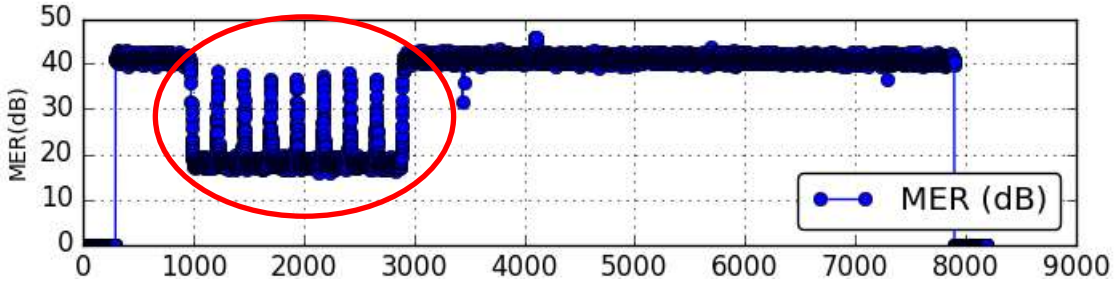
- cBR-8 uses conservative thresholds with ~ 6 dB of margin
- Low density parity check (LDPC) combined with frequency interleaving in D3.1 is very robust to impairments
- D3.1 OFDM can downgrade to lower modulation orders if plant conditions change while D3.0 DSs can not
- Recommend reducing thresholds by 2 -3 dB

Based on Table 7-41 in D3.1 PHY Specification

RxMER (in ¼ dB)	RxMER (dB)	QAM	Bit Loading
>60	>15	16	4
>84	>21	64	6
>96	>24	128	7
>108	>27	256	8
>122	>30.5	512	9
>136	>34	1024	10
>148	>37	2048	11
>164	>41	4096	12

Excluded Subcarrier Percentage Conservative

- cBR-8 only excludes 2% of subcarriers from profile selection calculations
- LDPC and frequency interleaving are very effective at correcting errors
- Testing has shown that over 25% of channel can see severe impairments without impacting channel performance
- Recommend increasing excluded subcarrier to 10% (excluded subcarriers will still carry data just not impact profile selection)



Modem runs 4096-QAM error free with 48 MHz of 192 MHz channel with RxMER below 20 dB

DOCSIS 3.1 DS Graceful Profile Management

- Suggested deviation from defaults
  - `cBR8(config)#cable downstream ofdm-prof-mgmt exempt-sc-pct 10`
    - ✓ 2% default
  - `cBR8(config)#cable downstream ofdm-prof-mgmt mer-margin-qdb 12`
    - ✓ 12/4 = 3 dB correction factor with 0 default
- CMTS transmits to CM on control profile (profile 0) until RxMER information received from CM to determine optimal configured profile
- CMTS periodically polls CM to gather RxMER and recommend best profile
- “Catch-all” of cm-status message of unfit profile
- Can statically map CM to particular data profile
  - `cBR8(config)#cable down ofdm-flow-to-profile profile-data <1-5> mac-addr <>`
- CMs can lock to 4 profiles + control in NVRAM
  - Will need DBC to support 5th & could cause dropped packets

Adjusted Thresholds Allow High Modulations

- Customers implementing suggested values of 10% excluded subcarriers and 2 – 3 dB reduced RxMER thresholds typically see modems using one to two higher modulation orders
- Normal for over 75% of modems to do 2048-QAM or higher
- Customers staying on default settings usually have most modems at 1024-QAM and less than 10% at 4096-QAM

Profile Management Applications (PMA)

- Profile management applications (PMA) can now be external to the CMTS and use RxMER data and modem cw errors to construct profiles with modulation orders customized to each channel
- PMA may rely on artificial intelligence / machine learning (AI / ML)
- Custom OFDM profiles are pushed back from PMA system to the CMTS (use CLI currently)
- CMTS can select best profile for each modem or let external PMA determine profiles
- PMA has been able to increase channel capacity when default profile selection thresholds are in use (use 256-QAM as baseline in papers)
- PMA gains are minimal if using suggested profile selection thresholds

Add 1024-QAM and Change Profile to 512 Cyclic Prefix and 25 kHz Subcarrier

```
cable downstream ofdm-chan-profile 10
  cyclic-prefix 1024
  interleaver-depth 16
  pilot-scaling 48
  roll-off 256
  guardband-override 1000000
  subcarrier-spacing 50KHZ
  profile-control modulation-default 256-QAM (1024 Mbps)
  profile-ncp modulation-default 16-QAM
```

```
cable downstream ofdm-chan-profile 21
  cyclic-prefix 512
  interleaver-depth 16
  pilot-scaling 48
  roll-off 256
  guardband-override 1000000
  subcarrier-spacing 25KHZ
  profile-control modulation-default 256-QAM (1224 Mbps)
  profile-ncp modulation-default 16-QAM

  profile-data 1 modulation-default 1024-QAM (1530 Mbps)
```

- Change subcarrier spacing from 50 kHz to 25 kHz
- Reduce cyclic prefix from 1024 to 512
- Add 1024-QAM modulation order (assume modems will use this one)
- **Increase channel capacity by ~49%**

Speeds are without PHY overhead and assume 192 MHz channel with 4 NCP messages per symbol

External PMA Support Added in 16.12.1x

- Option now to disable internal profile selection on cBR-8 (internal PMA) and rely on external PMA for this function
- OFDM data profiles can now be added / deleted on active OFDM channel (previously channel had to be shut down)
- Option for ordered list of downgrade profiles to be configured for each modem on OFDM channel by external PMA
- Modems can be moved to data profile via CLI without resetting
- Interaction with external PMA to cBR-8 done via CLI
- Profile scaling added in 16.12.1z – Now do up to 1024 OFDM ch profiles (was 256) and up to 7 data profiles per OFDM ch (was 5)

Summary Comments on OFDM Deployments

- Modems in early deployments had issues with 25 kHz so many operators deployed with 50 kHz
- Some CMTS vendors do not support options like 25 kHz subcarrier spacing, full range of cyclic prefix values or modifying RxMER selection thresholds so options may be limited
- Operators with multiple CMTS vendors may limit configurations on cBR-8 to achieve uniform configurations across all systems
- External PMA can likely help if your CMTS vendor choses not to support modifying RxMER selection thresholds (also with FDX)
- External PMA will be nice to have, but not required yet

D3.1 US - OFDMA

OFDMA – D3.1 Upstream

- OFDMA offers larger chs (up to 96 MHz) and higher order modulations compared to SC-QAM USs
- OFDMA is like the OFDM DS with many configuration options plus additional features to support multiple users
- Minislot still defined in time as for SC-QAM but also now in freq (400 kHz)
- Still rely on interval usage codes (IUCs) like in SC-QAM US to determine modulation order but now have options for up to 7 per OFDMA ch
- Can optionally override modulation per IUC for range of frequencies per OFDMA ch
- Adjust IUC per CM based on RxMER or CM codeword errors

OFDMA Configuration Recommendations

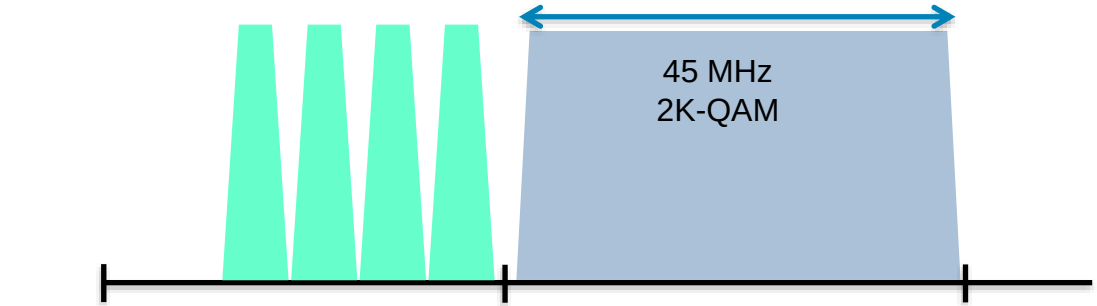
- 25 kHz subcarrier spacing recommended over 50 kHz (less overhead - although minimal with low cyclic prefix values)
- Cyclic prefix seems to have minimal impact on RxMER for OFDMA ch so run as low as possible to minimize overhead
- Pilot patterns with more overhead have been effective in reducing periodic codeword errors in frequencies below 42 MHz
- IUC 13 should be robust enough for all CMs to use error free (64-QAM or 16-QAM) – may need IUC override if in poor spectrum (< 10 MHz)
- Add multiple IUCs with higher modulation orders so CMs can transmit at higher speeds
- Avoid noisy spectrum below 10 MHz (minimal capacity gains)
- 50 kHz subcarrier spacing with large symbols per frame provides more time interleaving which may help with burst noise

DOCSIS 3.1 US General Thoughts

- US max Tx level is 65 dBmV
  - 4, 6.4 MHz ATDMA chs at 51 dBmV/ch = 51+6 = 57 dBmV total power
  - D3.0 Ext pwr = 51 dBmV/ch for 8 chs = 51+9 = 60 dBmV total power
- US Tx level reports based on 1.6 MHz bandwidth
  - 6 dB correction factor compared to 6.4 ATDMA ch
  - `Scm ver norm` or `scm phy norm` for actual ch power
- At least 1 SC-QAM with OFDMA
  - T4 multiplier of 2
  - Resiliency (SM on both)
  - Max Tx doesn't change much
  - May be simpler for voip and other scheduled flows
- Only 2 IUCs may negate usage of lower spectrum with lower modulation

What Will an 85 MHz System Provide?

- Traditional 42 MHz systems limited to 100 Mbps ATDMA or 150 Mbps with OFDMA & ATDMA
- Mid-split (85 MHz) could achieve 500 Mbps (D3.0 using 8 SC-QAMs = ~ 200 Mbps)



4 SC-QAM & 45 MHz OFDMA
100+400 = 500 Mbps

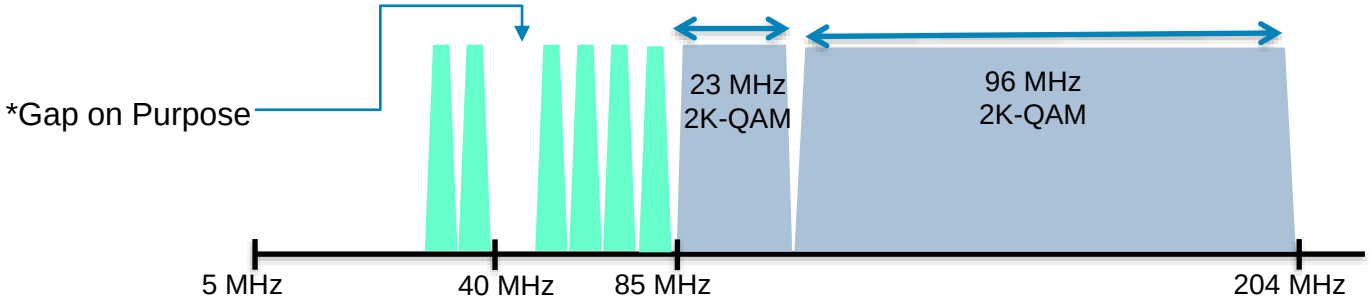
*Could also drop some ATDMA

- Ultimately, we want to offer 1 Gbps

D3.1 - 204 MHz US

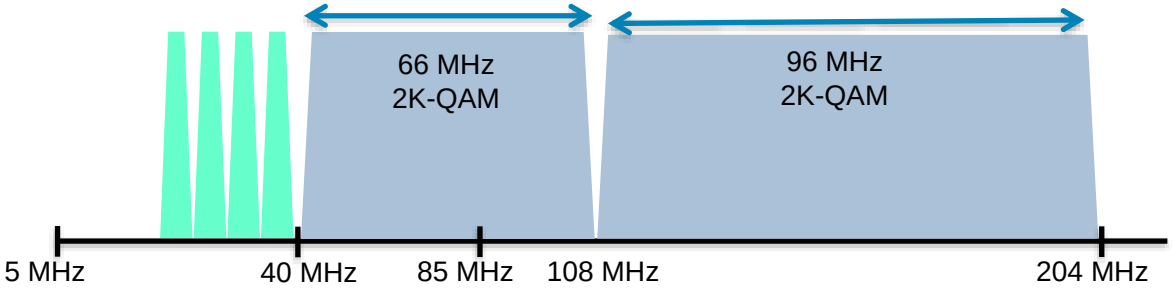
- Available Now
  - D3.1 CMs available today can support 204/258 MHz split
- Can achieve potentially 1.5 Gbps aggregate speed
- No special nodes with echo cancellation like FDX
- No need for N+0 or 1 like FDX
- DAA advantages along with no US laser clipping
  - EDR with analog link may be an option as well

D3.1 CMTS US Rx Examples for 204 MHz



Example 1: 23 MHz & 96 MHz OFDMA

50+100+200+875 = 1225 Mbps



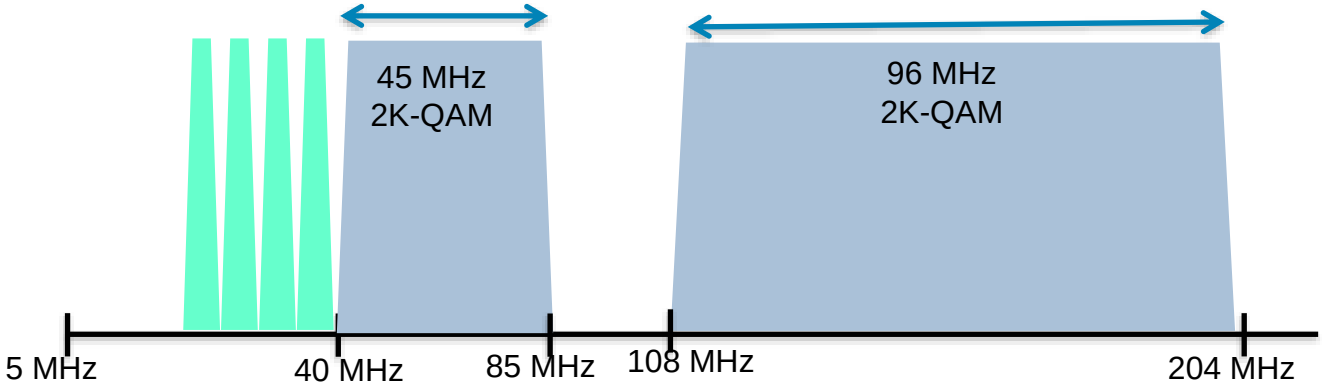
Example 2: 66 MHz & 96 MHz OFDMA

100+600+875 = 1575 Mbps

- **Note**: Need to address CMs that support 42, 85 and 204 MHz in same plant

OFDMA Block Straddling 85 MHz Creates Issues

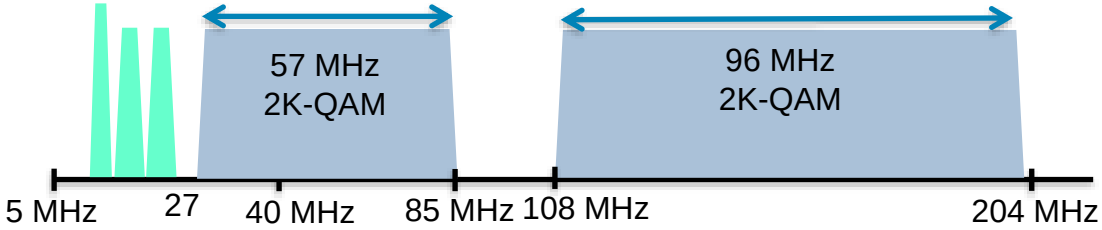
- CMs with 85 MHz filters exhibit issues locking on correct US BG
- **Fix** - Have smaller OFDMA block from 40 to 85 & another above 85 MHz
  - ➢ Avoid FM band altogether
- Working group looking at this and how to create partial mode scenario properly



Example 3: 66 MHz & 96 MHz OFDMA

100+400+875 = 1375 Mbps

Feedback on One Customer's Ideas



Example 4: 57 MHz & 96 MHz OFDMA

50+500+875 = 1425 Mbps

The Good

- 1.4 Gbps aggregate could potentially provide 1 Gbps US service
- Avoids CB and FM band
- Also foresee need for SC-QAM for D2.0 & eMTAs, and 2-ch US bonding for D3.0 CMs
  - Cross-bonding also allows US partial mode, support of US scheduled flows like nRTPS and UGS, and a T4 multiplier of 3 for added resiliency 30*3 = 90 sec before a T4 timeout would occur
- Avoids issues with D3.1 CMs with 85 MHz filters

The Bad

- IRT leakage testing, not sure just avoiding those freqs will be acceptable in throughput lost or if FCC will even allow it
- Cablelabs working with test equipment vendors & D3.1 CMs OUDP test burst solution
- Testing on "house-by-house" basis is necessary for adjacent device interference (ADI) concerns and may require filters

The Ugly

- Still need to decide what to do about STBs
- Conditioned taps are desirable, but not if they have internal 42 MHz filters
  - Flexible solution taps have an EQ/CS from 5 or 10 MHz all the way to 1.2 or maybe even 1.8 GHz

OFDMA Configurations Recommendations

```
cable mod-profile-ofdma 428
  subcarrier-spacing 25KHz
  initial-rng-subcarrier 64
  fine-rng-subcarrier 128
  data-iuc 6 modulation 2048-QAM pilot-pattern 8
  data-iuc 9 modulation 1024-QAM pilot-pattern 8
  data-iuc 10 modulation 512-QAM pilot-pattern 8
  data-iuc 11 modulation 256-QAM pilot-pattern 8
  data-iuc 12 modulation 128-QAM pilot-pattern 8
  data-iuc 13 modulation 64-QAM pilot-pattern 8
```

```
us-channel 12 docsis-mode ofdma
us-channel 12 subcarrier-spacing 25KHz
us-channel 12 modulation-profile 428
us-channel 12 frequency-range 108000000 204000000
us-channel 12 cyclic-prefix 96 roll-off-period 64
us-channel 12 symbols-per-frame 9
no us-channel 12 shutdown
```

- OFDMA channel speed ~ 875 Mbps (2048-QAM)
- Have been able to obtain 2048-QAM in production systems below 42 MHz without increased modem transmit power
- OFDMA channel speed ~ 800 Mbps (1024-QAM)
- OFDMA channel speed ~475 Mbps (64-QAM)

Higher Pilot Pattern Can Reduce Occasional Codeword Errors

```
cable mod-profile-ofdma 428
  subcarrier-spacing 25KHz
  initial-rng-subcarrier 64
  fine-rng-subcarrier 128
  data-iuc 6 modulation 2048-QAM pilot-pattern 11
  data-iuc 9 modulation 1024-QAM pilot-pattern 11
  data-iuc 10 modulation 512-QAM pilot-pattern 11
  data-iuc 11 modulation 256-QAM pilot-pattern 11
  data-iuc 12 modulation 128-QAM pilot-pattern 11
  data-iuc 13 modulation 64-QAM pilot-pattern 11
 us-channel 12 docsis-mode ofdma
 us-channel 12 subcarrier-spacing 25KHz
 us-channel 12 modulation-profile 428
 us-channel 12 frequency-range 108000000 204000000
 us-channel 12 cyclic-prefix 96 roll-off-period 64
 us-channel 12 symbols-per-frame 9
 no us-channel 12 shutdown
```

- OFDMA channel speed ~ 800 Mbps (2048-QAM)
- OFDMA channel speed ~ 725 Mbps (1024-QAM)
- OFDMA channel speed ~ 425 Mbps (64-QAM)

Can Override IUC Modulation and Pilot Pattern

```
cable mod-profile-ofdma 428
  subcarrier-spacing 25KHz
  initial-rng-subcarrier 64
  fine-rng-subcarrier 128
  data-iuc 6 modulation 2048-QAM pilot-pattern 8
  data-iuc 9 modulation 1024-QAM pilot-pattern 8
  data-iuc 10 modulation 512-QAM pilot-pattern 8
  data-iuc 11 modulation 256-QAM pilot-pattern 8
  data-iuc 12 modulation 128-QAM pilot-pattern 8
  data-iuc 13 modulation 64-QAM pilot-pattern 8

 us-channel 12 docsis-mode ofdma
 us-channel 12 subcarrier-spacing 25KHz
 us-channel 12 modulation-profile 428
 us-channel 12 frequency-range 108000000 204000000
 us-channel 12 cyclic-prefix 96 roll-off-period 64
 us-channel 12 symbols-per-frame 9
 us-channel 12 data-iuc 6 band 175000000 180000000 modulation 16-QAM pilot-pattern 11
 us-channel 12 data-iuc 9 band 175000000 180000000 modulation 16-QAM pilot-pattern 11
 us-channel 12 data-iuc 10 band 175000000 180000000 modulation 16-QAM pilot-pattern 11
 us-channel 12 data-iuc 11 band 175000000 180000000 modulation 16-QAM pilot-pattern 11
 us-channel 12 data-iuc 12 band 175000000 180000000 modulation 16-QAM pilot-pattern 11
 us-channel 12 data-iuc 13 band 175000000 180000000 modulation 16-QAM pilot-pattern 11
 no us-channel 12 shutdown
```

- Example below assumes some impairment at 175 – 180 MHz
- Uses 16-QAM with pilot pattern 11 for this part of spectrum for all IUCs
- Can support 4 override zone per IUC per OFDMA Channel (only showing a single override zone in example)

cBR-8 OFDMA Upstream Scheduling

- Recommend US bonding group with both SC-QAM and OFDMA for D3.1 CMs
- OFDMA currently only supports best effort flows on cBR-8 (no UGS)
- cBR-8 attempts to schedule D3.1 CM traffic on OFDMA first before using SC-QAM
- Real time nature of US scheduling may not fully load OFDMA before some traffic utilizes SC-QAM
- Minislot 0 starts at the lowest OFDMA frequency per the specs
- cBR-8 loads OFDMA starting with minislot 0 first
- CMs appear to prefer to use OFDMA for initial ranging (over SC-QAM)

D3.1 US IUC (Profile) Management

IUC Selection Process from Probing

- Can assign each OFDMA ch up to seven IUCs (5, 6, 9 -13) and each can have different modulation order and pilot pattern
- Each D3.1 CM can only have up to 2 assigned OFDMA US Data Profile (OUDP) IUCs
- Interval Usage Code (IUC) 13 is default and intended to be most robust per the specification (will always be one of two OUDP)
- CM comes up on OFDMA and assigned IUC 13
- cBR-8 schedules probe time for CM but may not be immediate
- After probe, cBR-8 calculate RxMER for all active subcarriers from probing and then determines ***average*** value per minislot (400 kHz)
- cBR-8 determines best IUC based on exempt minislot / threshold settings
- Dynamic Bonding Change (DBC) used to alert CM to change IUC – will use IUC 13 during change if sending traffic
- One recommended IUC will be used across entire OFDMA ch

Use Same Bit Loading Recommendations as OFDM

Based on Table 7-41 in D3.1 PHY Specification

RxMER (in ¼ dB)	RxMER (dB)	QAM	Bit Loading
>60	>15	16	4
>84	>21	64	6
>96	>24	128	7
>108	>27	256	8
>122	>30.5	512	9
>136	>34	1024	10
>148	>37	2048	11
>164	>41	4096	12

- Recommend using the default thresholds since it uses **average** RxMER per minislot
- Normal to see quite a bit of RxMER variance in neighboring subcarriers

Enable IUC Downgrade Enhancements

- 16.12.1x - cBR-8 will downgrade to lower modulation IUC (if available) when uncorrectable codeword errors (cw errors) are higher than thresholds
- 16.12.1y – cBR-8 will place in partial service for OFDMA ch if CM is only using IUC 13 and cw errors are higher than thresholds
- 16.12.1z – cBR-8 will place CM in partial service for OFDMA ch if RxMER values from probe are below a selected IUC (normally most robust – IUC 13)
- IOS release 16.12.1z2 is popular release for OFMDA / 17.6.1w has a few more OFDMA bug fixes (some CMs occasionally getting stuck in IUC 13)

OFDMA Profile Management Recommendations

Optimal settings will tolerate occasional cw error but avoid constant trickle of cw errors – Settings should be adjusted to obtain desired outcomes

- Probe CMs every 10 minutes to measure RxMER
- Check for CM codeword errors on 10 second interval
- Downgrade if over 0.8 % cw errors with minimum of 500 codewords (>4 cw errors)
- Hold-down for 60 minutes after downgrade
- Enable partial service if RxMER below threshold to run on IUC 13

```
cable upstream ofdma-prof-mgmt rxmer-poll-interval 10
cable upstream ofdma-prof-mgmt prof-upgrade-auto
cable upstream ofdma-prof-mgmt downgrade enable
cable upstream ofdma-prof-mgmt downgrade interval 10
cable upstream ofdma-prof-mgmt downgrade threshold 80
cable upstream ofdma-prof-mgmt downgrade hold-down 60
cable upstream ofdma-prof-mgmt downgrade min-cws 500
cable upstream ofdma-prof-mgmt downgrade partial-threshold 80
cable upstream ofdma-prof-mgmt downgrade partial-hold-down 60
cable upstream ofdma-prof-mgmt downgrade rxmer-enable
```

OFDMA Deployments Thoughts

- OFDMA much more deployable today than 12 months ago but still learning
- Per CM IUC downgrade feature is a must for production deployments
- Current CM firmware much more stable on OFDMA
- Assure D3.1 CMs' firmware is upgraded *before* enabling OFDMA – CMs use OFDMA first, may not be able to download firmware if unstable
- Some CMs had issues with pre-equalization that caused subcarrier power to either drop very low (CM goes into partial service on OFDMA) or raise very high (US laser clipping drops all US chs)
- High and stable RxMER values lead to higher order modulations
- OFDMA does not fix bad plant

D3.1 US Spectrum Concerns

- Increasing US spectrum = more coax loss & tilt from CM to CMTS
  - US max Tx level issues
  - DRW violations (12 dB)
- More USs may lead to laser clipping
  - OFDMA even in 42 MHz may cause issues with AM link
  - 85 MHz or higher may necessitate EDR (digital return) (A/D clipping?)
  - 204 MHz may necessitate DAA (Remote-PHY, FMA, …)
- No US ALC/AGC
  - Relying on CM/CMTS long-loop-level control and CM 12 dB DRW
  - Typical +/-2 dB swing @ 42 MHz (annual thermal fluctuations) w/ 4000’ coax
  - CMTS US level settings and adjustable range

204 MHz US Concerns

- 204 MHz could be troublesome for N+3 or higher
- Need to replace line equalizers, subscriber drop pads/EQs (whether standalone or in tap), and house amps
- Legacy STB OOB at 104 MHz, DACs at 75 MHz
- Leakage testing at 138 MHz
- Adjacent device interference (ADI) affects STB AGC & analog TV IF
  - Filters in house where needed - just like MoCA
  - Gateway architecture
- Home passives can generate passive device intermodulation (PDI) distortion when hit with high US Tx
- FM carriage in European markets (seems to be going away)
- Off-Air Broadcast potential interference

Potential Fixes for Higher Upstream Frequencies

- No Coax
- Conditioned taps - EQs & InvEQs for levels & DRW issues
  - Field Equalizers (FEQs) at least
  - EQ 5 MHz - 1.2 GHz, no cutoff & grp delay or concern for diplex changes later
- Thermal issues
  - Underground cable
    - ✓ Passives still above ground
  - US thermal EQs to help stabilize negative fluctuations on cold days
    - ✓ Higher noise floor assuming aerial plant
  - Idea of US AGC driven by DS AGC circuitry or I-AMP especially for D4.0
- D3.0 CM with Extended Pwr ECN = 54 dBmV max for 4-ch bonding
- D3.1 CM has ~ 5 dB more power per equivalent 8-ch D3.0 CM
  - D3.1 = 65 dBmV total avg power

Closing Points

- Be aware of US temperature affects @ 204 MHz
  - Design 48 dBmV +/-3 dB for taps with < 25 dB of coax between RPD & tap, 46 +/-2 dB otherwise
- Conditioned taps alleviate US power & tilt issues
  - Disparate SC-QAM US ch widths exacerbate D3.1 CM DRW issues
    - ✓ Get rid of narrow SC-QAMs in TCS
- Fiber deep architectures with DAA will allow better performance and higher D3.1 modulation along with higher speeds
- Need to research ADI & PDI concerns
- OFDMA below 117 MHz may force 85 MHz filter to engage
  - Same can happen below 65 MHz where 42 filter engages
- Legacy devices will go through attrition leading to more efficiency
  - Drop SC-QAMs, add more OFDM on DS, & allocate more OFDMA on US

THANK YOU!