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Wireline Access Network

100 Mbps DAA Nodes

John Chapman

CTO Broadband Access & Cisco Fellow
Cisco Systems

2021 Fall Technical Forum
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Goals for Today

Network Design Considerations

- Review channel and port differences between an I-CMTS and a node
- Introduce DUCR, the DS:US bandwidth ratio. Discuss peak rate versus total capacity.

Bandwidth studies of DAA Nodes and their CIN requirements

- What is possible today (42 MHz rtn, video)
- What is possible with DOCSIS 3.1
- What is possible with DOCSIS 4.0
- What is possible after DOCSIS 4.0

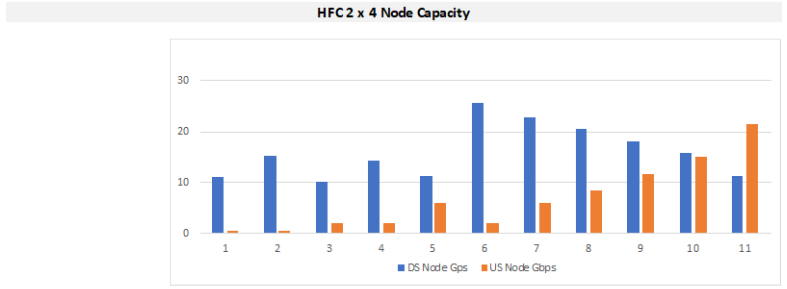
DAA Bandwidth Spreadsheet

The basis of this work is from a spreadsheet developed by the author that is available by contacting me on LinkedIn.

Please send feature requests and bugs to the me.

My address is:

https://www.linkedin.com/in/john-t-chapman/



Summary

2 x 4 Node Capacity	User	DOCSIS 3.1 with MPEG video					DOCSIS 4.0 with MPEG video					
Scenario	Calc	1	2	3	4	5	6	7	8	9	10	11
DS End MHz	1002	1002	1218	1002	1218	1218	1794	1794	1794	1794	1794	1794
DS Start MHz	714	54	54	108	108	258	108	258	372	492	606	834
US End MHz	42	42	42	85	85	204	85	204	300	396	492	684
VOD/SDV MPEG-TS	0	32	32	32	32	32	32	32	32	32	32	32
Linear Video MPEG-TS	0	64	64	64	64	64	64	64	64	64	64	64
DOCSIS DS port Gbps	2.3	3.2	5.3	2.6	4.8	3.3	10.5	9.0	7.9	6.7	5.6	3.3
DOCSIS US port Gbps	0.10	0.10	0.10	0.47	0.47	1.48	0.47	1.48	2.11	2.93	3.75	5.39
Ethernet DS Gbps	4.7	11.1	15.4	10.1	14.4	11.4	25.8	22.8	20.6	18.2	15.9	11.4
Ethernet US Gbps	0.4	0.4	0.4	1.9	1.9	5.9	1.9	5.9	8.4	11.7	15	22
DUCR, Avg	11.6	16	26	2.8	5.1	1.1	11.2	3.0	1.9	1.1	0.7	0.3
DUCR, Peak	23.1	31	53	5.6	10.2	2.2	22.5	6.1	3.7	2.3	1.5	0.6
ODFM ch per Node	2	4	6	2	6	4	12	10	8	8	6	4
OFDMA ch per Node	0	0	0	4	4	8	4	8	12	16	20	28
DOCSIS DS BW MHz	288	372	588	318	534	384	1110	960	846	726	612	384
Cross-over MHz	-	12	12	23	23	54	23	54	72	96	114	150
DOCSIS US BW MHz	26	26	26	69	69	188	69	188	261	357	453	645

32	VOD/SDV MPEG-TS	1794	DS Stop MHz for D4.0	ESD	ESD or FDX for D4.0	4096	OFDM Mod
64	Linear Video MPEG-TS	16.4	US Start MHz	YES	Video in FDX Trans Band	2048	OFDMA Mod
2	DS ports per Node	24	ch SC-QAM @ 6 MHz	120	MHz FDX Trans Band	256	SC-QAM Mod
4	US ports per Node	4	ch ATDMA @ 6.4 MHz	24	MHz DS unused < 108	64	ATDMA Mod

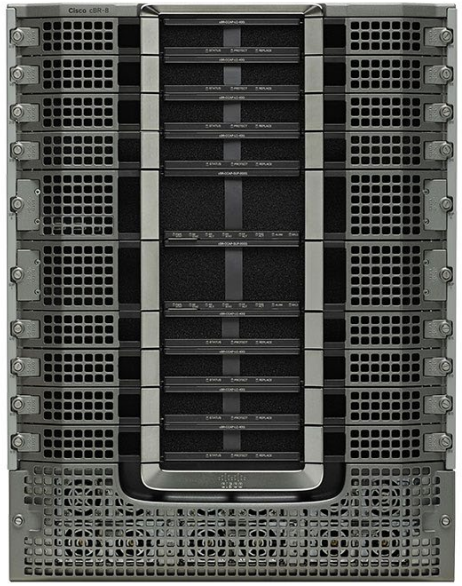
Acceptance Criteria

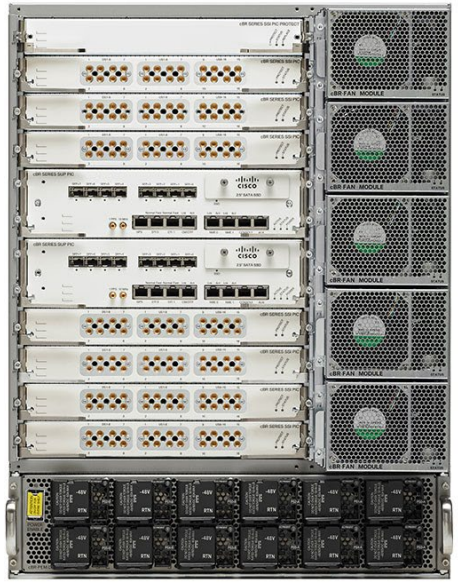
Scenario	Calc	1	2	3	4	5	6	7	8	9	10	11
DS End MHz	1002	1002	1218	1002	1218	1218	1794	1794	1794	1794	1794	1794
US End MHz	42	42	42	85	85	204	85	204	300	396	492	684
1) DS Path ≥ 5 Gbps	47%	63%	106%	53%	96%	66%	210%	180%	158%	134%	111%	66%
2) 2 < avg DUCR < 20	173%	127%	76%	141%	255%	55%	178%	152%	94%	57%	37%	15%
3) US SF 1 Gbps, 0.4 K	7%	7%	7%	33%	33%	106%	33%	106%	151%	209%	268%	385%
4) 100% > 85 MHz US	-78%	-78%	-78%	0%	0%	217%	0%	217%	350%	526%	701%	1051%
Combined Results:	-78%	-78%	-78%	0%	0%	55%	0%	106%	94%	57%	37%	15%

Acceptance Criteria	1)	5	Gbps DS path min					Success Criteria	
	2)	2	DUCR min	20	DUCR max	avg	based	success if >	100%
	3)	1	Gbps US SF with	40%	of additional headroom (K)			borderline	
	4)	100%	more BW than a	85	MHz return path			reject if <	90%

Diplexer ratio %	1600%	29%	29%	27%	27%	26%	27%	26%	24%	24%	23%	22%

Review of an I-CMTS port configuration (Example)





CMTS Capacity depends on:

CMTS ports (DS and US separate)

- 7 LC @ 8 DS x 16 US = 56 DS x 128 US

Channels per port

- DS: 96 SC-QAM, 4 OFDM
- US: 8 A-TDMA, 2 OFDMA

Ethernet capacity

- Dual 100 Gbps
- This represents aggregate capacity and allows for CMTS oversubscription
- Ethernet connectivity drives network costs

Internal constraints

- bus BW, memory, PPS, redundancy, CPU

For DAA, the CMTS physical config is now node based

Config rules

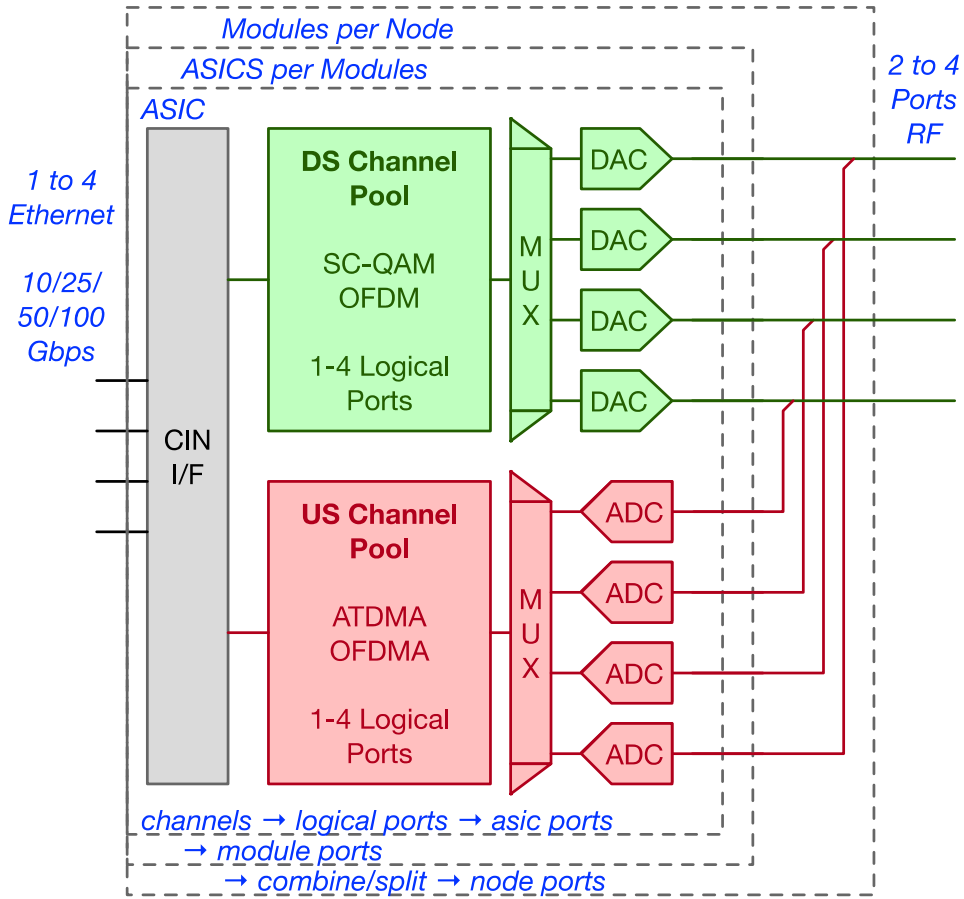
- are the same for RPHY and RMACPHY (FMA)
- are different than I-CMTS as they have built-in diplexers, combiners, and splitters.

Nodes have 2 to 4 bi-directional ports with internal combining and splitting

I-CMTS has separate DS and US RF ports

DS x US			
1x1	Single-return	2x2 2x4	Two single 1x1 modules, or one module with newer silicon
1x2	Dual-return	4x4	Two 2x2 modules or future silicon

Inside a DAA Node



There are:

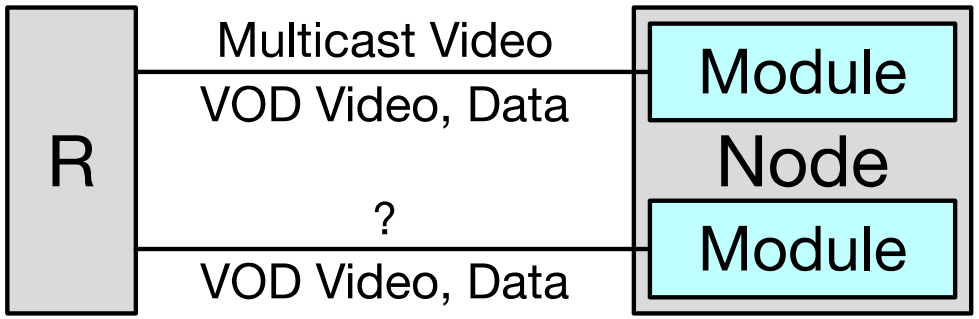
- Channels per channel group
- One of more channel groups per ASIC
- One or more ASICs per module
- One or more modules to a node
- Splitting and combining in the node

Regardless, a 4x4 DAC/ADC is good for

- DPD (Digital Predistortion)
- Reduction of US noise funneling

So, a 2x4 DAA Node means 2 unique DOCSIS DS ports and 4 unique upstream ports.

Ethernet Connectivity for DAA Nodes



Backhaul requires one or more Ethernets per DAA node. They may range from 10 Gbps today to 100 Gbps later

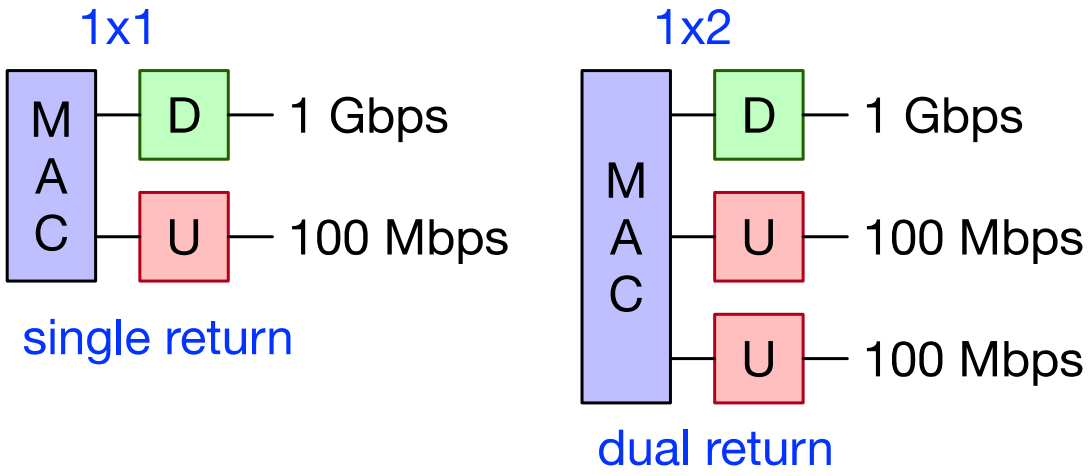
Multicast:

- Multicast video may be shared across network ports of the same module if designed to do so
- Multicast video cannot be shared across network ports that go to separate modules

Ethernet capacity may become the bottleneck

Leave room for signaling

Designing for Peak or Capacity



Dual return has the same peak capacity (100 Mbps) as a single return but has twice the capacity (200 Mbps)

Suggested rule-of-thumb

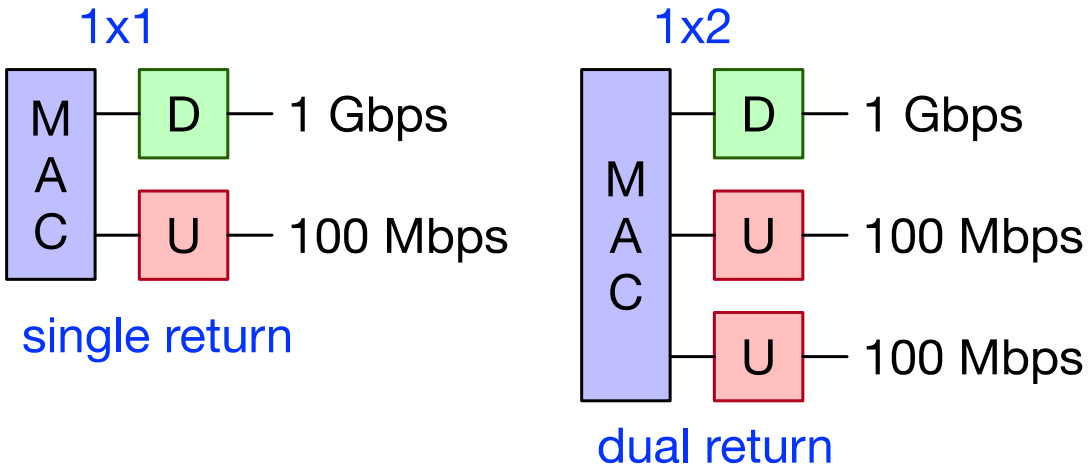
Use 1x1

- If a significant number of your subs are >> half the peak rate
- Then you are designing for peak rate

Use 1x2

- If most of your subs are << half the peak rate
- Then you are designing for capacity

DUCR – Downstream to Upstream Capacity Ratio



		1x1	1x2	
Peak DUCR	peak DS bw / peak US bw	10/1 = 10	10/1 = 10	=> what the CM sees
Avg DUCR	total DS bw / total US bw	10/1 = 10	10/2 = 5	=> what the CMTS sees

DUCR is a measure of asymmetry that takes ports into account.

Two upstream ports have more total capacity than one upstream port

DUCR allows capacities to be compared between system configurations.

5G TDD DDDSU is a DUCR of 4 to 5

There is also a CM DUCR

DUCR			
Avg	Peak		comment
20	40	high	TCP limit
10	20	good	classic
5	10	best	avg matches 5G
2.5	5	good	peak matches 5G

Table Defaults

32	VOD/SDV MPEG-TS	1794	DS Stop MHz for D4.0	ESD	ESD or FDX for D4.0	4096	OFDM Mod
64	Linear Video MPEG-TS	16.4	US Start MHz	YES	Video in FDX Trans Band	2048	OFDMA Mod
2	DS ports per Node	32	ch SC-QAM @ 6 MHz	120	MHz FDX Trans Band	256	SC-QAM Mod
4	US ports per Node	4	ch ATDMA @ 6.4 MHz	24	MHz DS unused < 108	64	ATDMA Mod

Optimistic modulation of 2K OFDMA and 4K OFDM

Scenarios are run with either:

- 32 VOD/SVD (unique per port) so duplicated on the Ethernet, and
- 64 linear (shared across ports), so one instance per Ethernet
- remaining bandwidth is DOCSIS (at 6 MHz/channel, this is 576 MHz of video)

and

- no video and all DOCSIS

2x4 Node, DOCSIS 3.1, with/without MPEG video

2 x 4 Node Capacity	DOCSIS 3.1 with MPEG video					DOCSIS 3.1 with no MPEG video				
Scenario	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
DS End MHz	**1002**	**1218**	**1002**	**1218**	**1218**	**1002**	**1218**	**1002**	**1218**	**1218**
DS Start MHz	54	54	108	108	258	**54**	**54**	**108**	**108**	**258**
US End MHz	**42**	**42**	**85**	**85**	**204**	**42**	**42**	**85**	**85**	**204**
DOCSIS DS port Gbps	3.0	5.1	2.5	4.6	3.1	8.7	10.9	8.2	10.3	8.8
DOCSIS US port Gbps	0.10	0.10	0.47	0.47	1.48	0.10	0.10	0.47	0.47	1.48
Ethernet DS Gbps	10.8	15.1	9.7	14.0	11.0	17.4	21.7	16.4	20.7	17.7
Ethernet US Gbps	0.4	0.4	1.9	1.9	5.9	0.4	0.4	1.9	1.9	5.9
DUCR, Avg	15	26	2.6	4.9	1.0	43	54	8.7	11.0	3.0
DUCR, Peak	30	51	5.2	9.8	2.1	87	108	17.5	22.1	6.0

2x4 Node, DOCSIS 3.1, with/without MPEG video

Scenario 1 & 2: 42 MHz return with 1002/1218 MHz forward

- US bw is 100 Mbps. DUCR ratios are too high (with no video) which is not good.
- US can be expanded to 150 to 200 Mbps with OFDMA below 42 MHz, which halves DUCR
- DS bw is 3-5 Gbps with MPEG video and 9-11 Gbps without MPEG Video. Awesome!

➔ *Removing MPEG video can triple DOCSIS DS performance but US is limited.*

Scenario 3&4: 85 MHz return with 1002/1218 MHz forward

- 470 Mbps upstream with 2.5-10 Gbps forward. DUCR ratios are great

➔ *This is optimized D3.1 performance (per DUCR), especially with dual return*

Scenario 5: 204 MHz return with 1218 MHz forward

- 1.5 Gbps return with 3-9 Gbps forward. DUCR ratios are low

➔ *use if 1 Gbps service is needed.*

2x4 Node, DOCSIS 4.0 ESD/FDX with MPEG video

2 x 4 Node Capacity	DOCSIS 4.0 ESD with MPEG video						DOCSIS 4.0 FDX with MPEG video					
Scenario	**6**	**7**	**8**	**9**	**10**	**11**	**6**	**7**	**8**	**9**	**10**	**11**
DS End MHz	**1794**	**1794**	**1794**	**1794**	**1794**	**1794**	**1218**	**1218**	**1218**	**1218**	**1218**	**1218**
DS Start MHz	108	258	372	492	606	834	108	108	108	108	108	108
US End MHz	**85**	**204**	**300**	**396**	**492**	**684**	**85**	**204**	**300**	**396**	**492**	**684**
DOCSIS DS port Gbps	10.3	8.8	7.7	6.5	5.4	3.1	4.6	4.6	4.6	4.6	4.6	4.6
DOCSIS US port Gbps	0.47	1.48	2.11	2.93	3.75	5.39	0.47	1.29	2.11	2.93	3.75	5.39
Ethernet DS Gbps	25.5	22.5	20.2	17.8	15.6	11.0	14.0	14.0	14.0	14.0	14.0	14.0
Ethernet US Gbps	1.9	5.9	8.4	11.7	15	22	1.9	5.2	8.4	11.7	15	22
DUCR, Avg	11.0	3.0	1.8	1.1	0.7	0.3	4.9	1.8	1.1	0.8	0.6	0.4
DUCR, Peak	22.1	6.0	3.7	2.2	1.4	0.6	9.8	3.6	2.2	1.6	1.2	0.9

2x4 Node, DOCSIS 4.0 ESD/FDX with no MPEG video

2 x 4 Node Capacity	DOCSIS 4.0 ESD with no MPEG video						DOCSIS 4.0 FDX with no MPEG video					
Scenario	**6**	**7**	**8**	**9**	**10**	**11**	**6**	**7**	**8**	**9**	**10**	**11**
DS End MHz	**1794**	**1794**	**1794**	**1794**	**1794**	**1794**	**1218**	**1218**	**1218**	**1218**	**1218**	**1218**
DS Start MHz	108	258	372	492	606	834	108	108	108	108	108	108
US End MHz	**85**	**204**	**300**	**396**	**492**	**684**	**85**	**204**	**300**	**396**	**492**	**684**
DOCSIS DS port Gbps	16.1	14.6	13.4	12.2	11.1	8.8	10.3	10.3	10.3	10.3	10.3	10.3
DOCSIS US port Gbps	0.47	1.48	2.11	2.93	3.75	5.39	0.47	1.29	2.11	2.93	3.75	5.39
Ethernet DS Gbps	32.1	29.2	26.9	24.5	22.2	17.7	20.7	20.7	20.7	20.7	20.7	20.7
Ethernet US Gbps	1.9	5.9	8.4	11.7	15	22	1.9	5.2	8.4	11.7	15	22
DUCR, Avg	17.2	4.9	3.2	2.1	1.5	0.8	11.0	4.0	2.5	1.8	1.4	1.0
DUCR, Peak	34.3	9.8	6.4	4.2	3.0	1.6	22.1	8.0	4.9	3.5	2.8	1.9

2x4 Node, DOCSIS 4.0 ESD/FDX

Scenario 6: 85 MHz return (not a real D4.0 scenario for ESD or FDX)

- FDX: Nice avg DUCR (10) with video 10Gx 470 Mbps (940 Mbps aggregate)
- ESD: DUCR is too high for all data, but good for video+data and for < 1794 MHz

Scenario 7: 204 MHz return

- Optimum DUCR values for ESD and FDX

Scenarios 8 thru 11:

- Low DUCR ratios mean the US may not get fully utilized with asymmetrical traffic.
- 396 MHz is 2x the throughput of 204 MHz and may be the best choice of the group
- 684 MHz is less practical as it is near symmetric

Ethernet

- Dual 10 Gbps Ethernet is not enough for 2x4 D4.0. A shared 25 or 40 Gbps is better

4x4 Node, DOCSIS 3-GHz ESD/FDX, no MPEG video

4 x 4 Node Capacity	Post DOCSIS 4.0 ESD with no MPEG video						Post DOCSIS 4.0 FDX with no MPEG video					
Scenario	**6**	**7**	**8**	**9**	**10**	**11**	**6**	**7**	**8**	**9**	**10**	**11**
DS End MHz	**2946**	**2946**	**2946**	**2946**	**2946**	**2946**	**2946**	**2946**	**2946**	**2946**	**2946**	**2946**
DS Start MHz	108	258	372	492	606	834	108	108	108	108	108	108
US End MHz	**85**	**204**	**300**	**396**	**492**	**684**	**85**	**204**	**300**	**396**	**492**	**684**
DOCSIS DS port Gbps	27.5	26.0	24.9	23.7	22.6	20.3	27.5	27.5	27.5	27.5	27.5	27.5
DOCSIS US port Gbps	0.47	1.48	2.11	2.93	3.75	5.39	0.47	1.29	2.11	2.93	3.75	5.39
Ethernet DS Gbps	110.1	104.2	99.6	94.8	90.3	81.2	110.1	110.1	110.1	110.1	110.1	110.1
Ethernet US Gbps	1.9	5.9	8.4	11.7	15	22	1.9	5.2	8.4	11.7	15	22
DUCR, Avg	58.8	17.5	11.8	8.1	6.0	3.8	58.8	21.4	13.1	9.4	7.3	5.1
DUCR, Peak	58.8	17.5	11.8	8.1	6.0	3.8	58.8	21.4	13.1	9.4	7.3	5.1

4x4 Node, DOCSIS 3 GHz ESD/FDX, no MPEG video

~25 Gbps DOCSIS DS

100 Gbps Ethernet required

4x4 forces one upstream port per downstream port.

Peak DUCR = Avg DUCR

396 MHz US provides a DUCR ~10

684 MHz US provides a DUCR of 4-5 (same as mobile)

DAA Node Summary

Design Principles

- Node capacity involves constraints from ASIC/Module/Node
- DPD and lower noise funneling benefits from 4x4 ASIC to node connectivity, even if node is 2x2 or 2x4
- Multicast video impacts Ethernet BH
- DUCR is a great tool for rating solutions
- Design for capacity or peak rate
- CIN can be reused for Business Ethernet, PON, FWA, 4G/5G small cell

DAA Node Ethernet Requirements

1x1 or 1x2 node

- D3.1 needs 10 Gbps BH

2x2 or 2x4 node

- D3.1 can work with dual 10 Gbps BH but
- D4.0 needs 25 Gbps BH
- 2 x 10 Gbps can be hard to configure with multicast video

4x4 node

- D3.1/4.0 needs 40 Gbps
- DOCSIS NG 3 GHz needs 100 Gbps

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Thank You!

John T Chapman

CTO Broadband Technologies & Cisco Fellow
Cisco Systems
jchapman@cisco.com
https://www.linkedin.com/in/john-t-chapman/

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