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Wireline Access Network

Developing the DOCSIS 4.0 Playbook for the Season of 10G

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2021 Fall Technical Forum
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Agenda

Finally Tackling Upstream
FDX Overview
FDD Overview
HFC Migration to DOCSIS 4.0
Synergistic Elements
Attributes and Key Qs: Side-by-Side
Summary

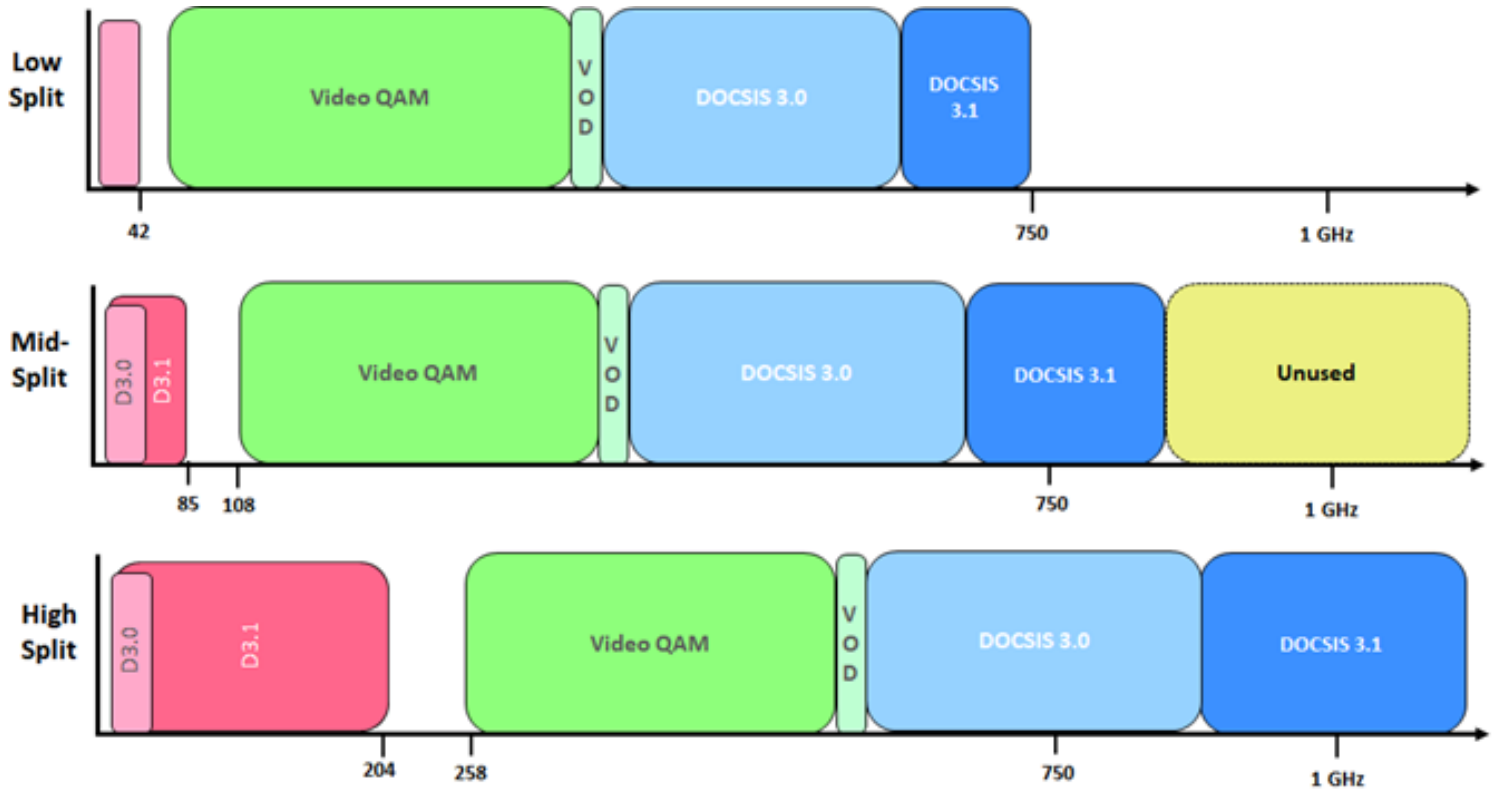
Upstream Spectrum is Finally Getting its Shot

A little spectrum has gone a looooooooooong way

It has not changed since the launch of HSD !

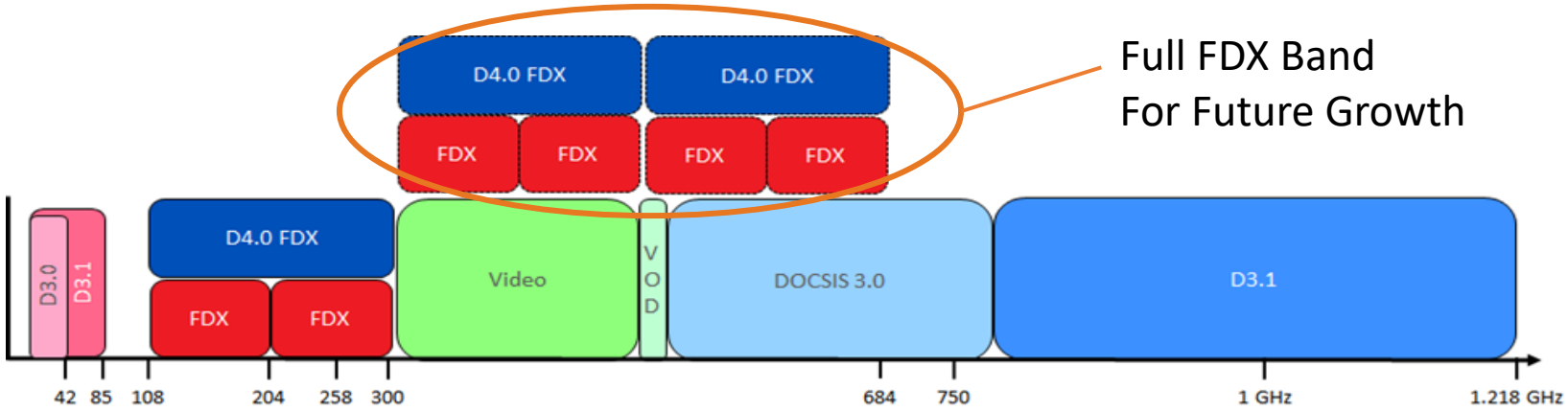
Another looooooooooong capacity runway is ahead – powered by **DOCSIS 3.1 OFDMA** and **Mid-Split** BW and speeds

The recipe for capacity and **Gigabit** speed starts with **High Split** bandwidth

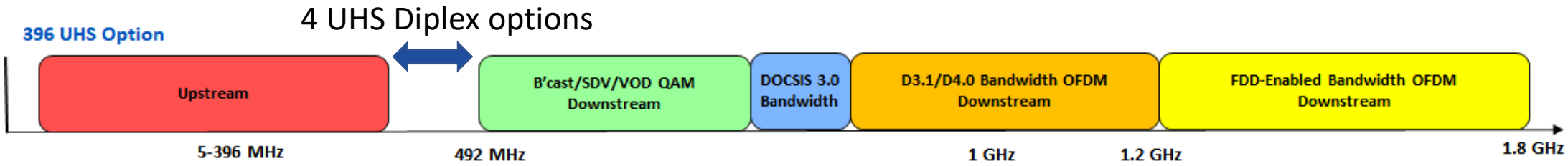


The Two Flavors of DOCSIS 4.0 Deliver it

DOCSIS 4.0 Full Duplex (FDX)

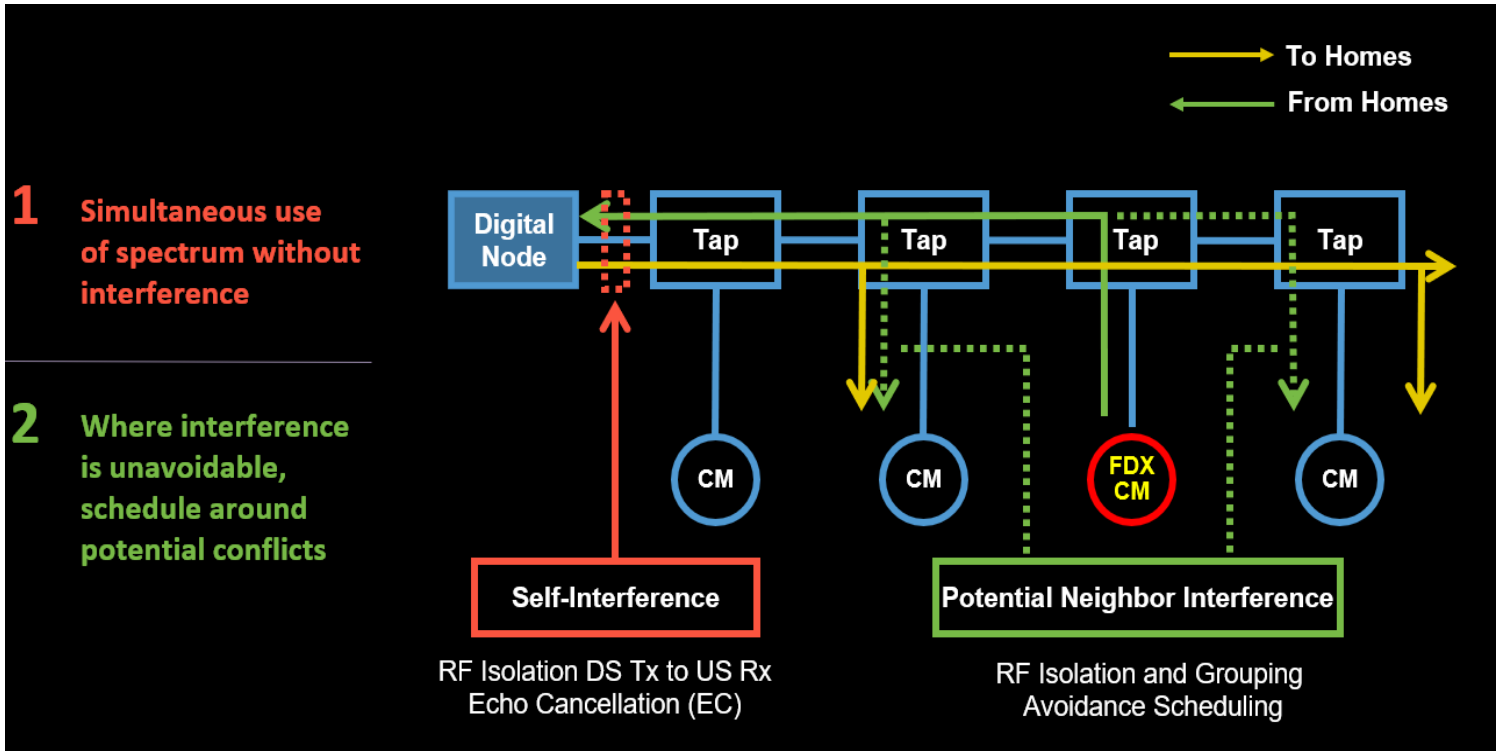


DOCSIS 4.0 Extended Spectrum



Both are powered by the proven DOCSIS 3.1 PHY foundation of DS OFDM and US OFDMA

The Two Big Ideas



Massive new upstream without vacating downstream

- More efficient use of existing spectrum
- Configurable US BW/Speed by FDX band allocation

New technology (for Cable) to manage overlapping spectrum

- Echo Cancellation
- DS/US-Aware Scheduling in CMTS

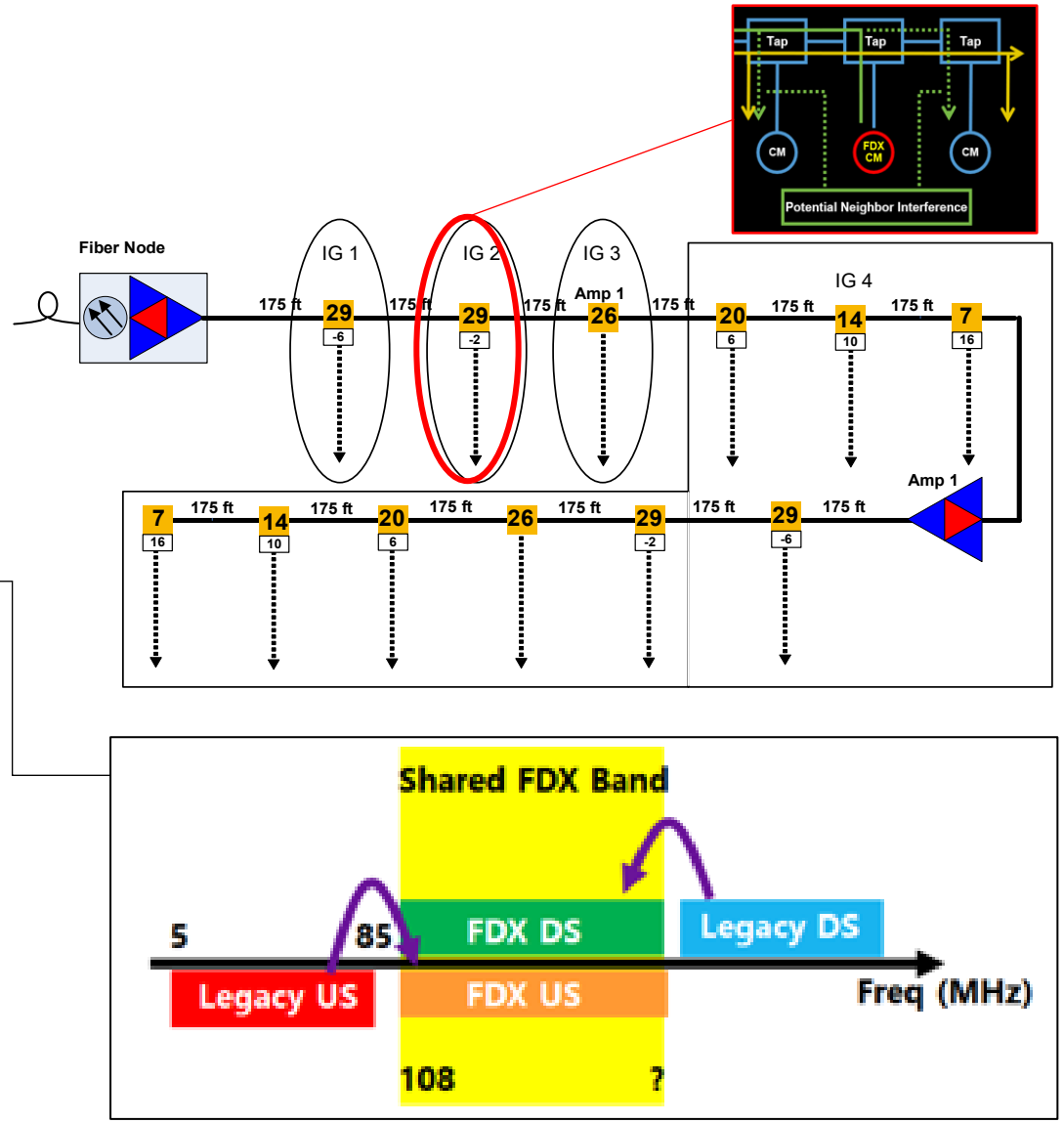
Extending FDX to N+x

Amplifier contains DSP function

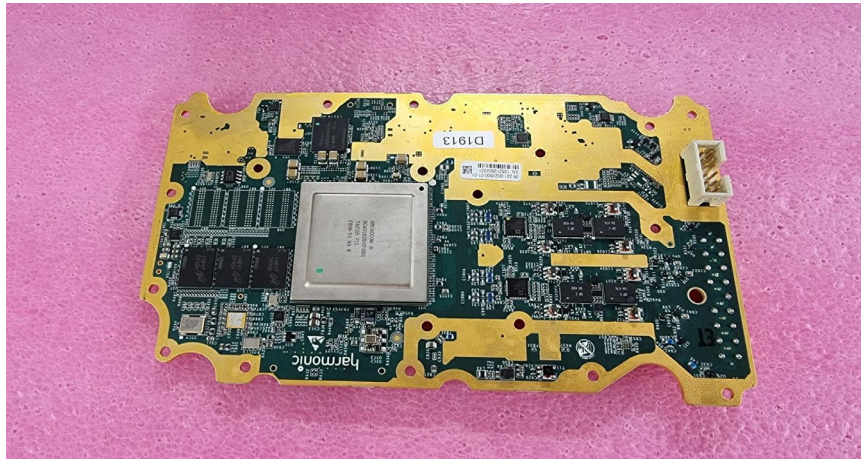
DSP is the same EC used in the RPD

New traffic engineering aspects

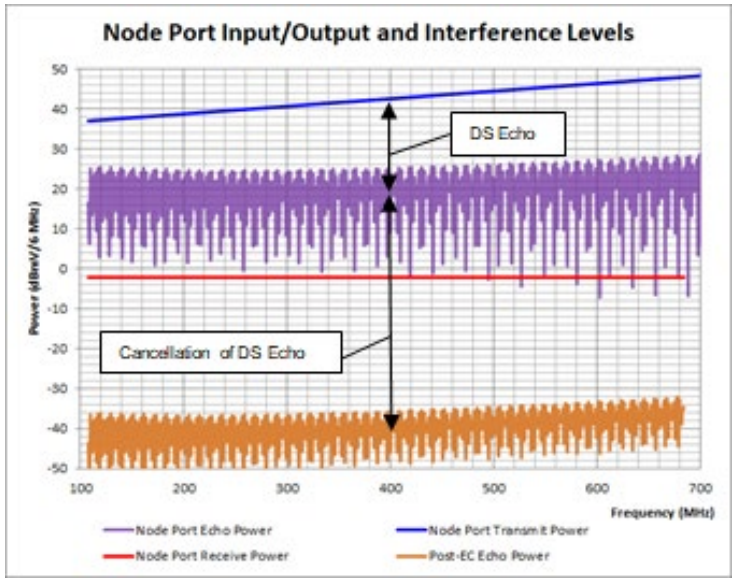
1) % of Total Capacity is Shared
   - FDX US is mostly idle – peak rate US bursts are statistically rare
2) Node Seg for Capacity threshold → "Network" Seg for Speed threshold



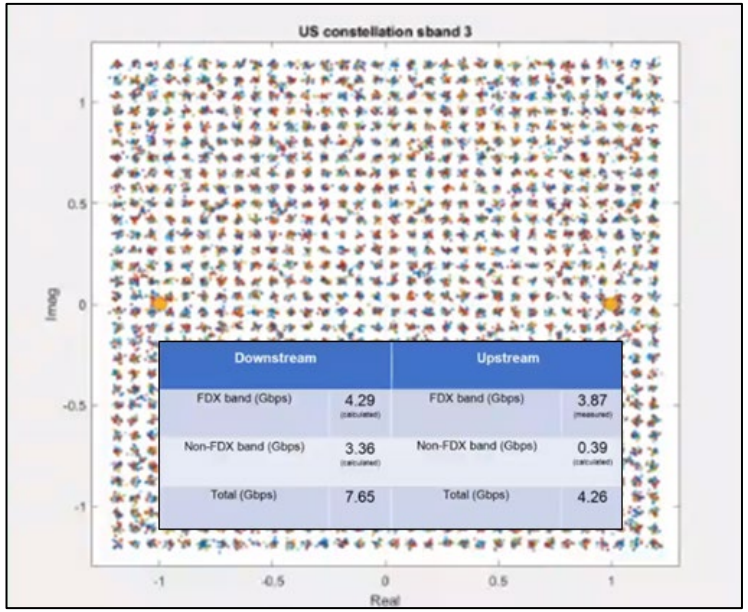
An FDX RPD is Born !



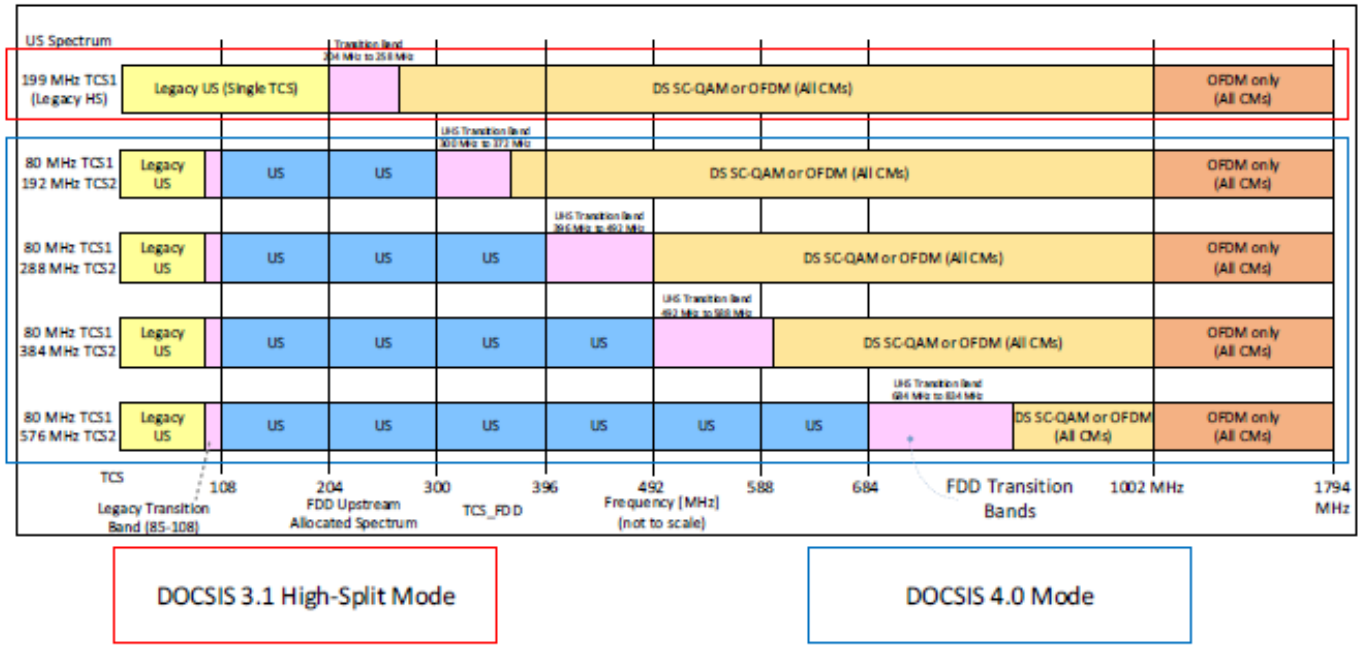
EC effect modeled



Measured US on "Model 1" (SFU) plant segment



Extended Spectrum as a Natural HFC Next Step



Massive new upstream available by moving the diplex split further out

- New US bands identical to FDX:

  108MHz + *K* x 96MHz up to 684MHz

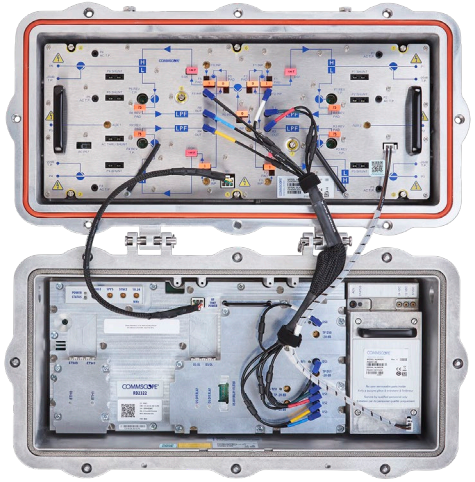
Start of downstream shifts with increasing UHS upstream BW allocation

DS extensible to 1.8GHz to offset BW allocated to UHS

Four UHS options to balance DS/US allocation by market needs

DOCSIS 4.0 FDD SoCs now in lab testing

Distributed Access Architecture is Required



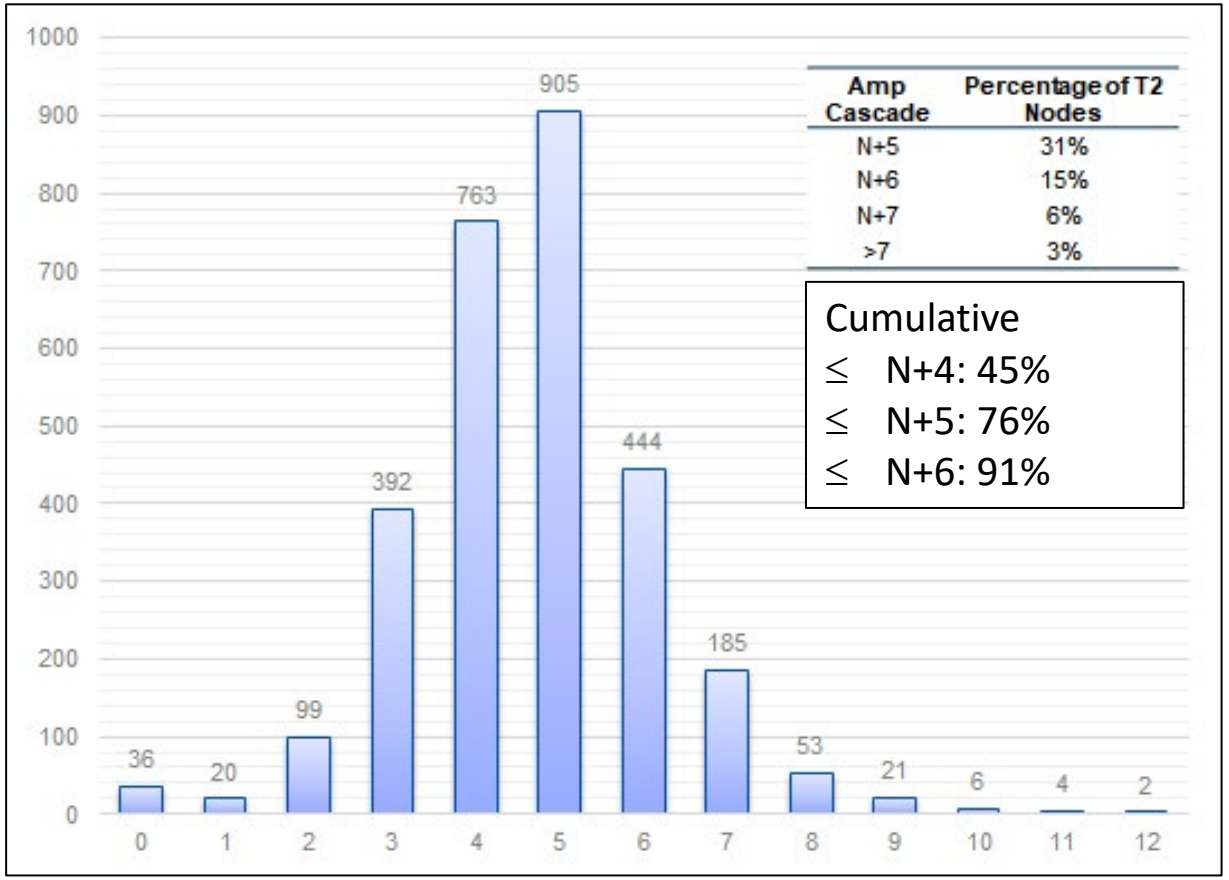
Distributed Access Architecture (DAA) is the foundation for DOCSIS 4.0 solutions

- Greatly improves signal fidelity
- More efficient use of fiber
- Longer reach of digital optics
- Major space and power efficiencies at Hubs, supporting continued traffic increases
- Ethernet-based ecosystem for connectivity to Digital nodes
- Opportunities for deeper real-time telemetry

DOCSIS 4.0 will be implemented into a majority of the node platforms that exists today

Cost-Benefit of Active Cascade Reduction

Cascade Stats of Sample Area (varies by region, MSO)



Amp Cascade	Percentage of T2 Nodes
N+5	31%
N+6	15%
N+7	6%
>7	3%

Cumulative
≤ N+4: 45%
≤ N+5: 76%
≤ N+6: 91%

YAY

1. Common design rules
2. Network performance consistency
3. Reduce lowest-common denominator impacts of aged and stretched cases

BUT

As-built variables impact migration Cost of (for example) “N+5 Max”

- Original network bandwidth / spacing
- MDU, SDU mix – density in hhp/mile
- Properly engineered Node splits
- Aerial or Underground; conduit / no conduit
- Regional and Muni regulatory differences
- Implications to network powering

Common Extension of "DOCSIS 3.1" Resources

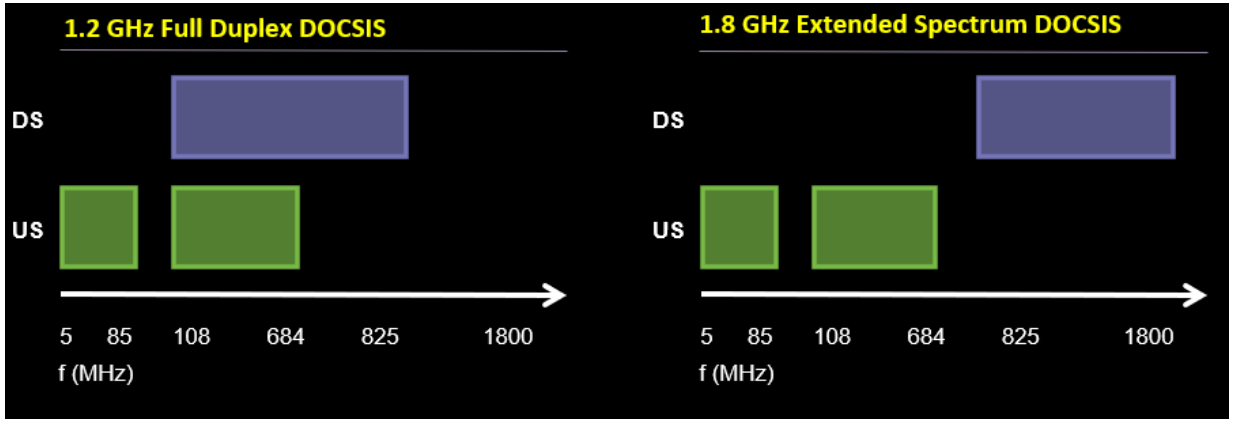
FDX

Item	Device	OFDM/OFDMA	SC-QAM
Downstream Channel Support	CM	5 total OFDM channels; 3 channels capable of FDX operation; All channels capable of non-FDX operation up to 1218 MHz	32
	CMTS	6 total OFDM channels; 3 channels capable of FDX operation; All channels capable of non-FDX operation up to 1218 MHz	32
Upstream Channel Support	CM	At least 7 total OFDMA channels; 6 channels capable of FDX operation; 2 channels capable of non-FDX operation within the legacy diplexer configuration. (Some channels can be configurable to support either FDX or non-FDX operation. When supporting 6 FDX OFDMA channels, only 1 non-FDX OFDMA channel is required.)	4 (or 8) SC-QAM channels, operating within the legacy diplexer configuration
	CMTS	8 total OFDMA channels; 6 channels with FDX operation; 2 channels capable of non-FDX operation based on operator deployment requirements.	4 (or 8) SC-QAM channels, operation dependent on operator deployment requirements

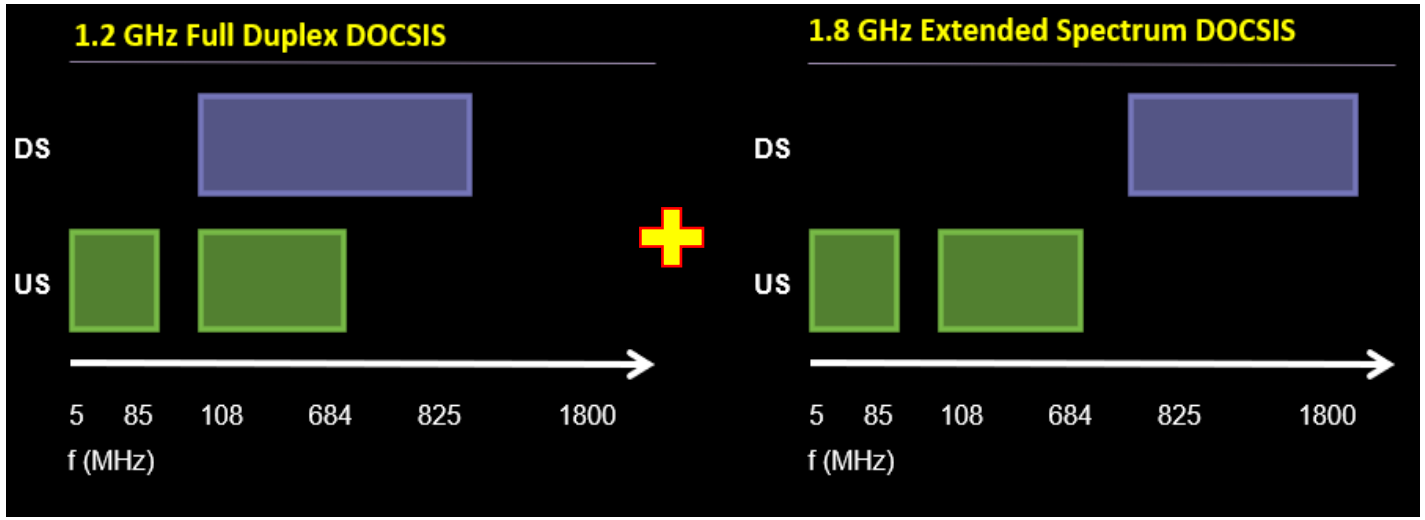
FDD

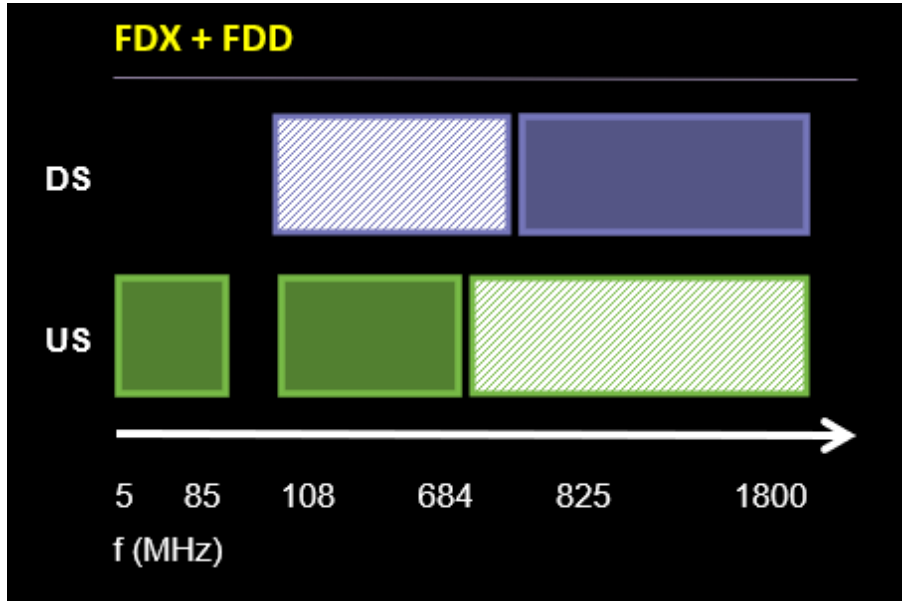
Item	Device	OFDM/OFDMA	SC-QAM
Downstream Channel Support	CM	5 OFDM channels	32
	CMTS	6 OFDM channels	32
Upstream Channel Support	CM	7 OFDMA channels	4 upstream SC-QAM channels, operating within the diplex filter configuration. Optional support for up to 8 SC-QAM channels
	CMTS	8 OFDMA channels	4 upstream SC-QAM channels, operation dependent on operator deployment requirements. Optional support for up to 8 upstream SC-QAM channels.

Specifically targeting a large increase in US OFDMA



DOCSIS 4.0 Technologies are Complementary





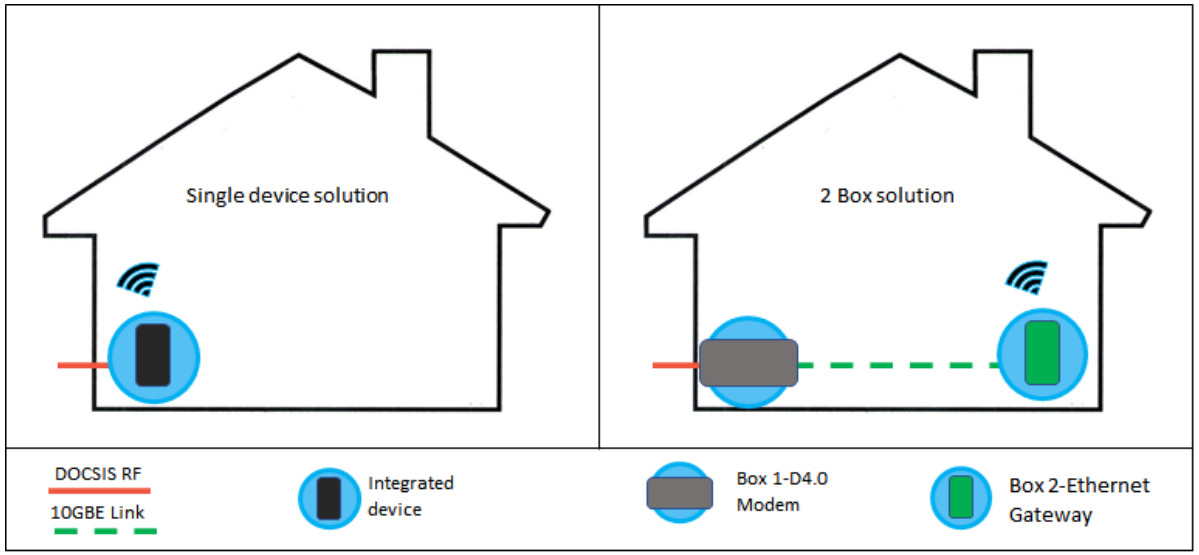
[FDD DS BW + US BW] = [FDX DS BW + US BW]

US Allocation flexible to Speed Demand

- FDX → SW to configure FDX US allocation, existing DS BW intact
- FDD → SW to select a HW option with different DS/US ratios

Path to 10 Gbps of upstream capacity

Point-of-Entry Termination Part to DOCSIS 4.0



Single Box Solution	Two-Box Solution
Lower Cost	DOCSIS 4.0 CM demarc to Common GW
Simple provisioning and mgmt	Optimize WiFi location
Self-install Kit (SIK) model	WAN | LAN trajectories differ
WiFi + Mesh – GW location less critical	Outdoor CM Oppt'y @ PoE
GW turnover with LAN (WiFi) pace	Ethernet WAN and Link Security
	Voice port location

Why PoE?

FDX

- No splitter loss
- Predictable echo environment
- Can operate deep in home with a 15% US capacity penalty

FDD

- No splitter loss
- No replacing in-home passives for 1.8GHz

Attributes Summary & iFAQs

Attribute	FDD/ESD	FDX
Strategy/Philosophy to 10G	• Based on access network BW extension upgrade, up to 1.8GHz, for existing actives and passives • Introduction of DAA to migrate to 10G, similar to previous HFC plant upgrades with a choice of diplex split configurations	• Based on access network technology upgrades to introduce new DSP (EC) into RPHY nodes and Amplifier platforms • Build on DAA production and scaling of vCMTS as the foundation for 10G
Migration Factors	• 1.8 GHz DOCSIS 4.0 DAA Nodes, Amps, Taps and Passives • Allows for cascade of amplifiers • New CPE	• RPD Nodes with DOCSIS 4.0 EC function • FDX-capable amps with DSP • New CPE
Complexity	• New tech challenges – BW and TCP extension • Use of "low power" amp extender for edge cases	• New tech challenges – EC function, CMTS scheduler, DSP-based amps • New capacity mgmt rule for IG/TG size for peak speed
Spectrum/Capacity	• 1536 MHz DS/656 MHz US (see **Figure 13** and **Table 1**) • Up to 15G/5G (all-DOCSIS 3.1) • DS/US: BW and Capacity per diplex selection	• 1110 MHz DS / 656 MHz US (see **Figure 2**) • Up to 11G/5G (simultaneous, all-DOCSIS 3.1) • FDX BW/speed by SW config
Operations	• Utilize existing common operational practices – FDD system with different possible split choices • New field tools	• New operational practices for handling of spectrum overlap and amplifier installations • New field tools
Network	• N+X • Cascade reduction/trade-off based market capabilities	• N+0 (optimal) • N+X – Cascade reduction/trade-off based on market speeds
As-Built Migration	• Continue node split and introduce DAA node splits, leverage for HFC migration activity, introducing components of FDD over time • Migration path and timing considerations for Underground vs Aerial and MDU vs SDU cost implications	• Introduce DAA for node splits with vCMTS, leverage for HFC migration activity and platforms that enable FDX activation • Migration path and timing considerations for Underground vs Aerial and MDU vs SDU cost implications

Pivots On……

Adopting new technology vs Extending existing paradigms

FDX and FDD HW premiums and projected network upgrade costs

Risk assessment of key tech features and magnitude of plant upgrade

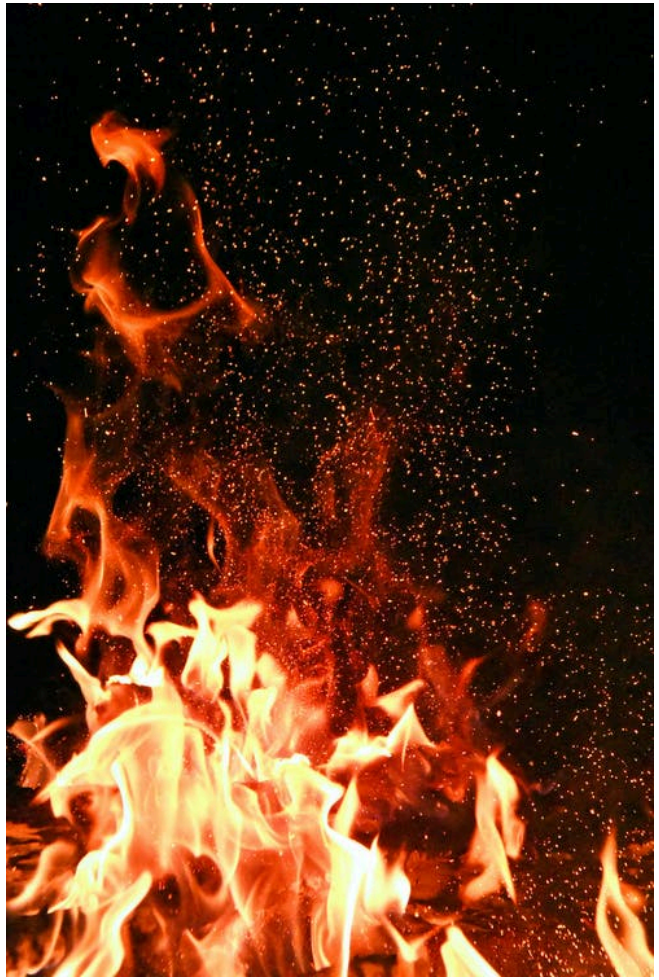
Probably does not pivot here – eyes will be on measured BW efficiency connected to new tech features
Extending current practice to new freqs vs new digital metrics and practices

Limitations to system performance imposed by existing N+x

Relative limitations (or advantages) of as-built

Debate Kindling Top 3 ?

Challenges	FDD/ESD	FDX
1	Total Composite Power limitations for 1.8 GHz	N+0 foundation implications for cost
2	As-built frequency response over N+x	New technology risk
3	Upgrade and replacement of all taps and passives	FDX amp and N+x operation



DOCSIS 4.0 has Moved from Slideware to Hardware !

Addressing upstream for capacity and speed is the primary objective

- FDX brings technology new to HFC to increase efficiency in the existing D3.1 band by adding new US channels without vacating DS BW
- FDD brings new total spectrum to HFC to add new US channels above existing D3.1 US, and creates new bands to support ample DS BW

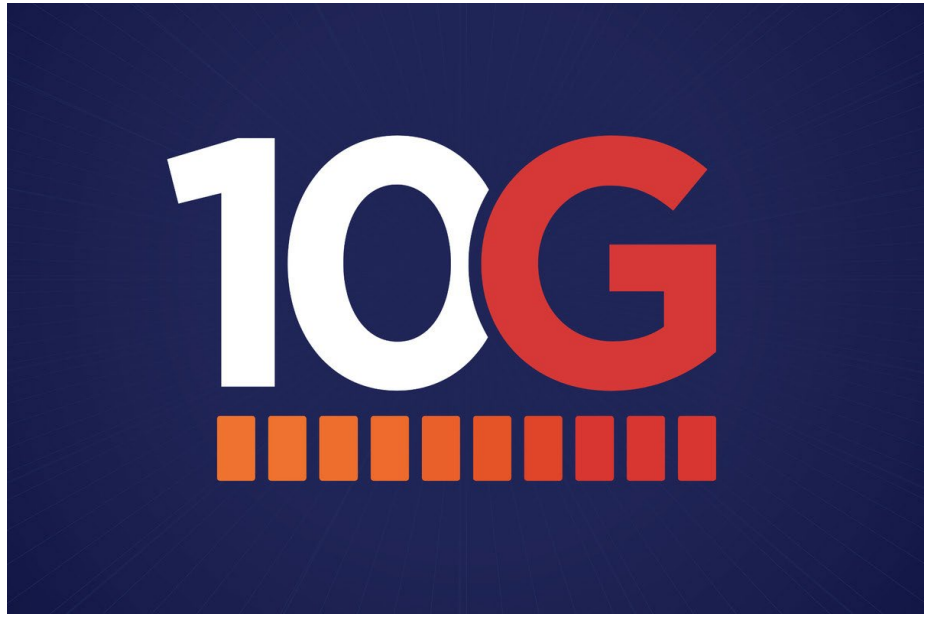
2021 is a year of component level development and early results

In the not too distance future, there will be a year of integration of components and field validation

Network upgrade planned timing is WIP with several key factors

- Market speed targets
- Alignment to planned network upgrade cycle (i.e. next node splits)
- Business factors balancing pro-active network prep vs JIT launches

Charter and Comcast are committed to bringing the 10G vision to life, and will continue to share experiences with one another and with the industry along the way



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Thank You!

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