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BUILDING A FIBER-CONNECTED WORLD
MAGAZINE

Managing the Bandwidth Surge: Network Evolution for Near and Long-term Capacity Growth

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Managing the Bandwidth Surge: Network evolution for near & long-term capacity growth

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CTO - Network Solutions team

10 November 2020

Broadband is keeping society & the economy running (as best we can) in these hard times…

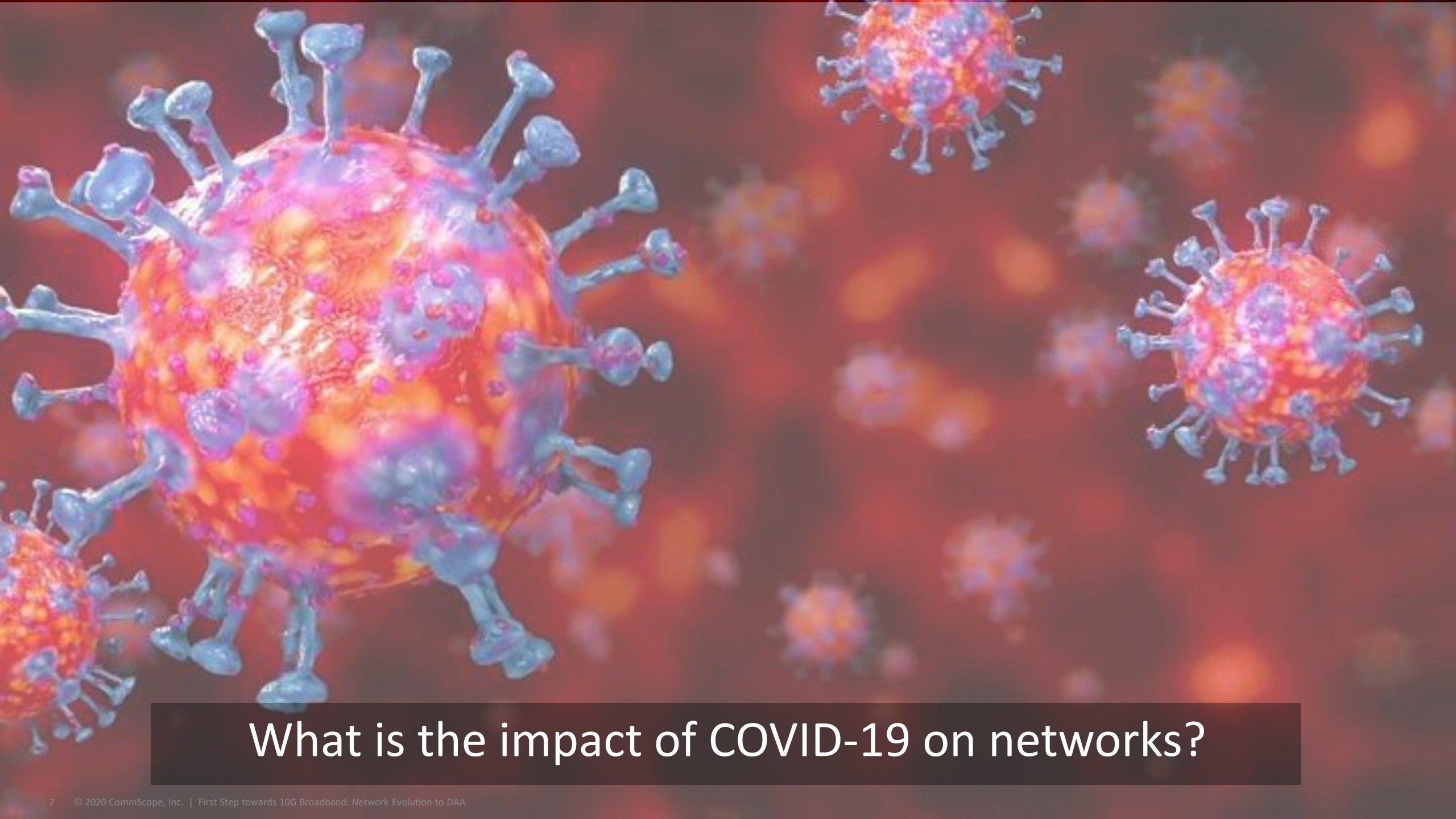
- This is arguably its most significant contribution to society in its short life-span
- Hats off to everyone who has made the Internet available to society. So…. hats off to you!!!

Be proud of the infrastructure we have created; BUT… we have work to do…

- The COVID-19 BW Surge has exposed cracks in the system…
- This should serve as a wake-up call…
- We have improvements to make to the infrastructure…
- It's time to start upgrading the network for the demands of the 2020s

First Things First…

"With all due respect, sir, I believe this will be our finest hour."
From the movie: Apollo 13



What is the impact of COVID-19 on networks?

The Cause
(The Usual Suspects)

The Effect on
Bandwidth (DS & US)

The Effect on Quality
of Experience

Short Term
Quick-Fix Ideas

Mid-to-Long Term
Fix Ideas

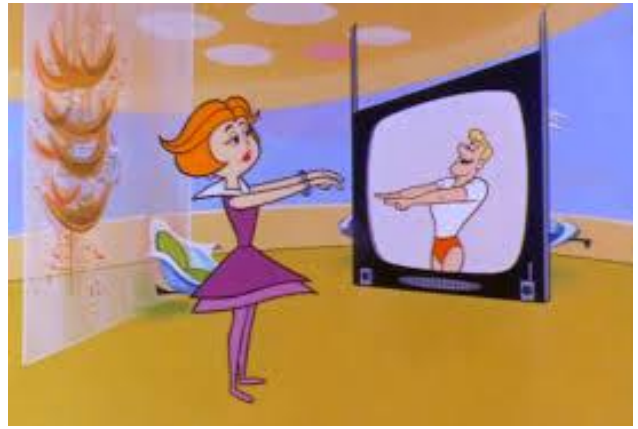
Conclusions

Managing the Coronavirus BW Surge

Work @ Home

Telemedicine

Video Conferencing, Social Networking



Remote Learning

Gaming

Video Streaming

We will focus more on Upstream, because the MSO Upstream is more capacity-constrained… It becomes the Achilles Heel of Cable…

- 20-42 MHz US
  - ~87 Mbps w ATDMA
- 20-65 MHz US
  - ~175 Mbps w ATDMA

The Cause (The Usual Suspects)

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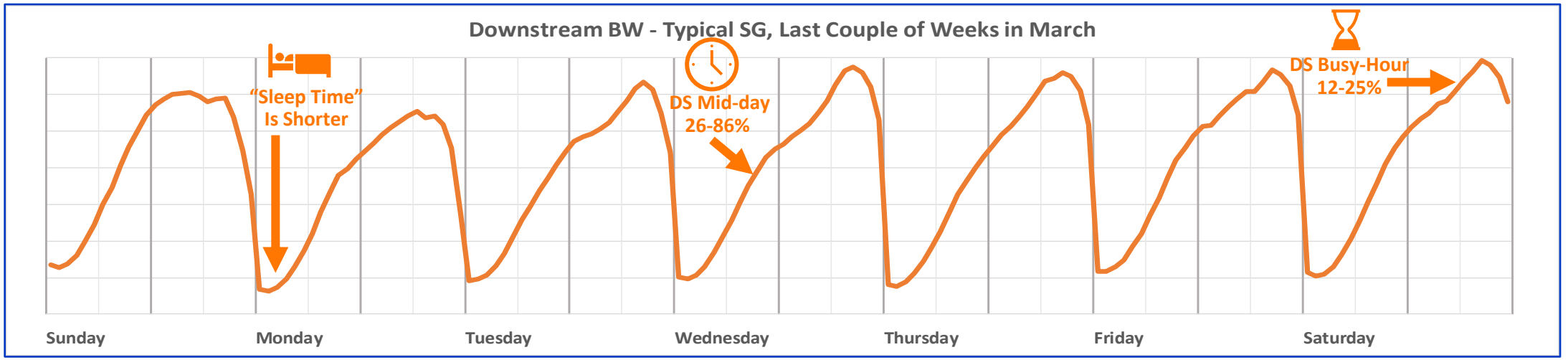

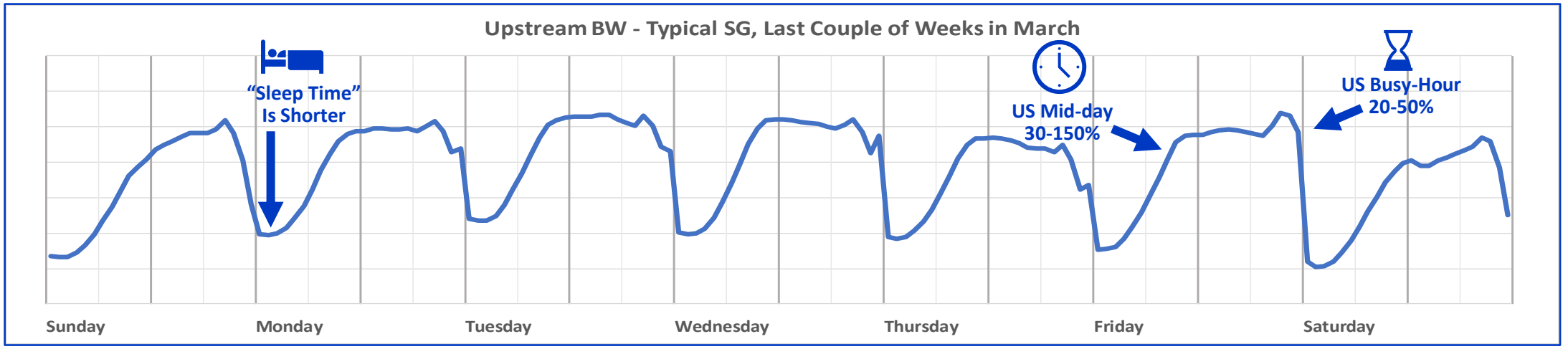

The BW Surge Effect on Bandwidth (US & DS)
Some 7-Day Examples

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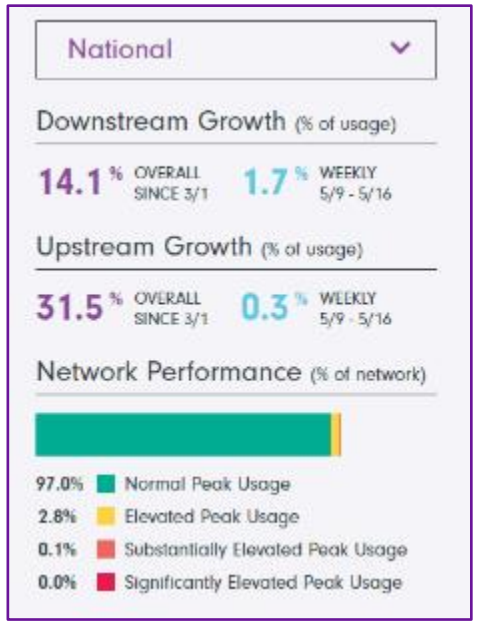
The Effect on Bandwidth – as seen by NCTA, July 18th

NCTA Key Takeaways (May 16):

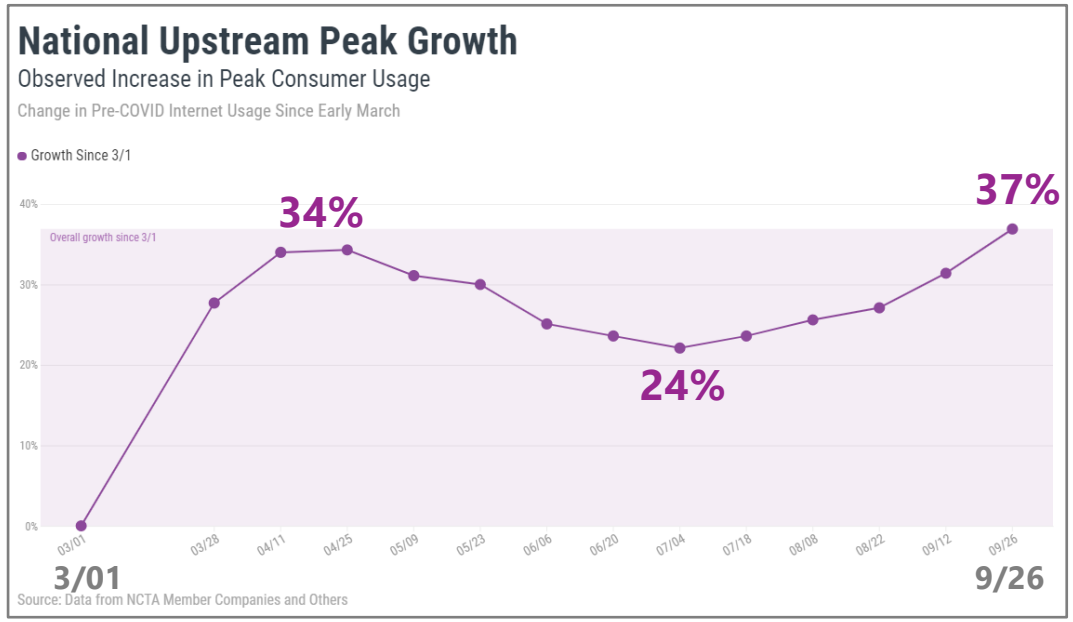
- National US peak ***growth remains mostly flat*** with slight dip from 35% Peak
- National DS peak ***growth receding*** over last 2 months from 20% Peak
- Provider backbone networks ***have significant capacity***
  - Show no signs of congestion
- US peak hours in many regions have shifted from late evening to afternoon
- Wi-Fi data traffic & Wi-Fi calling are increasing as compared to mobile
  - Networks are supporting more Wi-Fi-connected devices

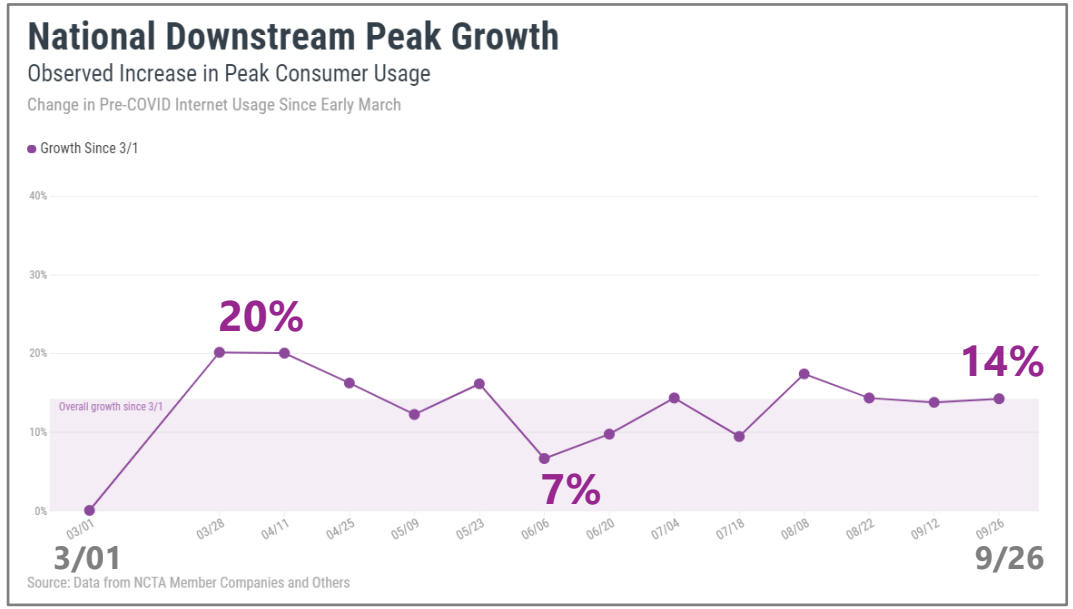
NCTA – National monitoring by member companies: AlticeUSA, CableOne, Charter, Comcast, Cox, GCI, Mediacom, Midco, …



Peak Usage Increase (since March 1):

- **Upstream = 37%**
- **Downstream = 14%**





 | First Step towards 10G Broadband: Network Evolution to DAA

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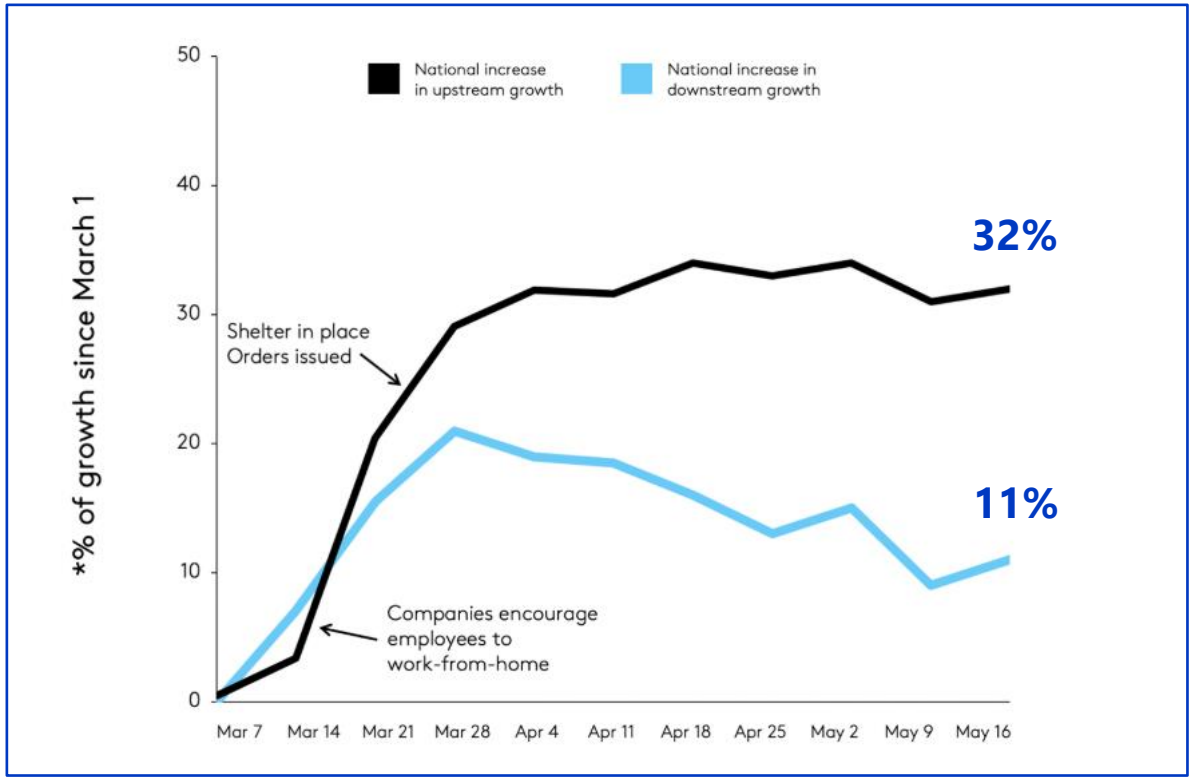
The Effect on Bandwidth – as seen by Comcast

- Weekday usage is up:
  - VoIP & Video Conferencing is up 210-285%
  - VPN traffic is holding steady, up 30-40%
- Evening & weekend usage is up:
  - Gaming downloads are up 20-35% generally, up to 80% during new releases
  - 20-40% increase in streaming and web video consumption
  - Linear video consumption increased +2 hours per day per household
  - Video OnDemand (VoD) hitting record highs, up 50% YOY
- Xfinity Mobile sees a 36% increase in mobile data usage over Wi-Fi
  - But a 17% decline in LTE Data usage

COMCAST

Per cent Growth since March 1st



Peak Usage since March 1:

- **Peak Upstream = 32%**
- **Peak Downstream = 11%**

Comcast info last updated on May 20

COMMSCOPE®

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"Since March 1, our peak traffic is up 32% overall and up 60% in some areas, but still within the overall capacity of our network."

"Downstream peak appears to be moving from 9PM to between 7 PM – 8 PM, while upstream peak is moving from 9 PM to between 8 AM and 6 PM in most cities."

COMCAST

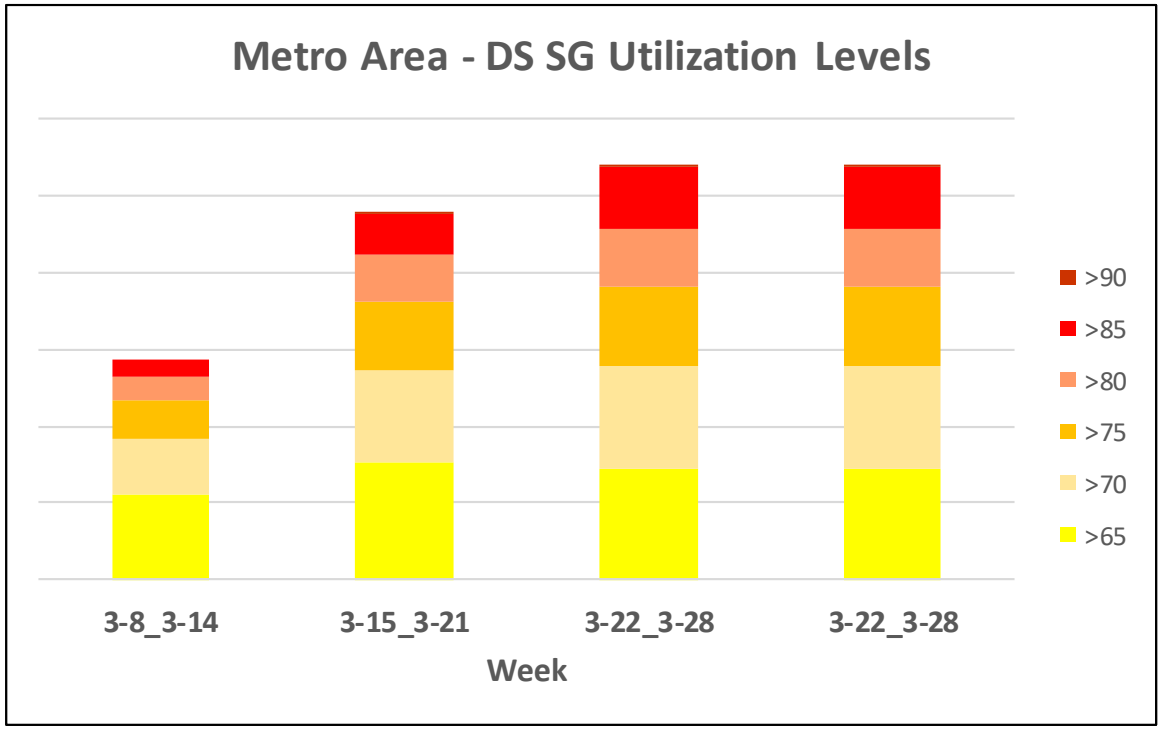
"Network traffic beginning to plateau in most markets."

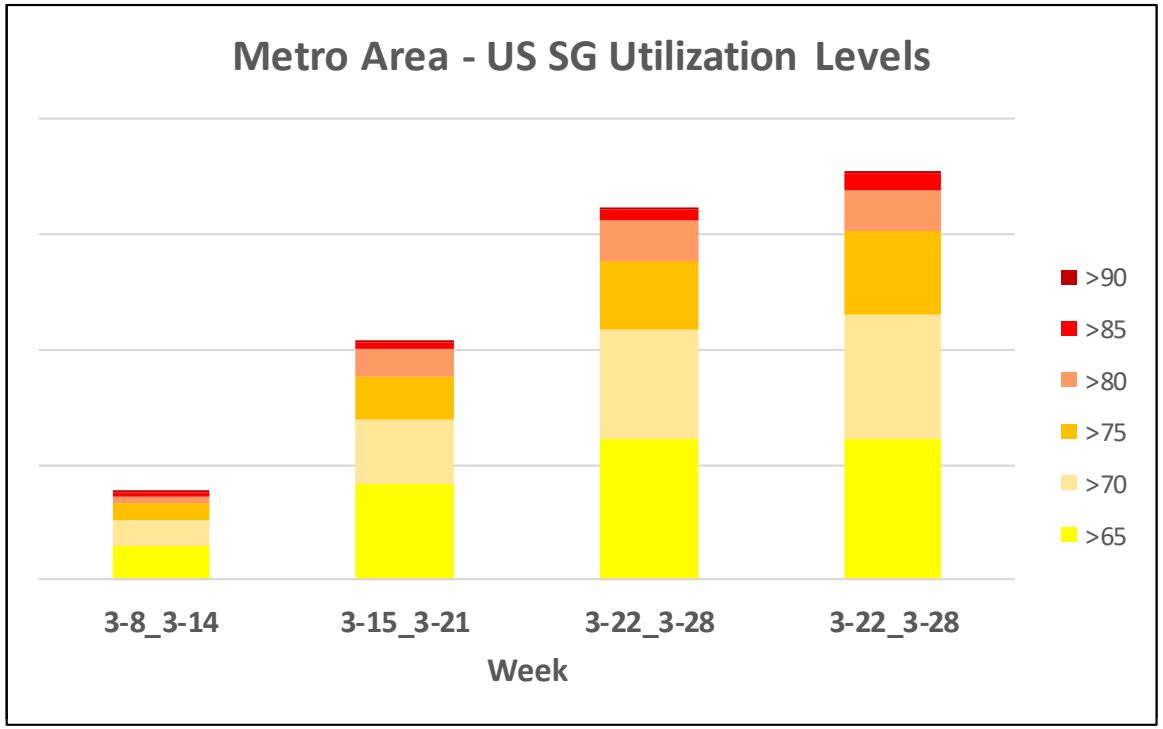
"Nights and Weekends still dominate."

"We engineer the network to handle spikes and shifts in usage, and what we have seen so far with COVID-19 is within our capacity."

TONY WERNER, President – Technology, Product, Xperience

Comcast quotes last updated on April 29





- DS SG in the **Green** – dropped from ~90% to ~80%
- DS SG in the **Red** – tripled from 1% to 3%
  - Immediate attention required
- SG in the **Yellow** – almost doubled from 11% to 18%
  - Need attention in 6-12 months or less

- US SG in the **Green** – dropped from ~98% to ~91%
- US SG in the **Red** – quadrupled from ~0.25% to 1%
  - Immediate attention required
- US SG in the **Yellow** – quadrupled from 1.5% to 6%
  - Need attention in 6-12 months or less

The Effect on Bandwidth
As Seen In A Metro Area

The Ugly

a Year's worth of traffic growth in 1-2 weeks!

Day

DS **26-86%**

US **30-150%**

Rush Hour

30-150%

14-50%

High Usage: 8am to 2am

Sleep time: Only 4-6h

The Bad

QoE ↓

Negative QoE effects:

- **Packet delays for gamers** from higher latencies & buffer-bloat
- **Video tiling in streaming & video conferencing** from packet delays & drops
- **File Download & Upload times increased** (a little bit)

Subscribers are **hitting their data caps** much more rapidly

- for MSOs with data caps

The Good

Bad QoE effects have been relatively minimal to date

- (unless Service Groups are over-subscribed)

In general, the **DOCSIS networks** are holding up to this sudden, stressful packet load… Why? Several reasons:

- Network Capacity planning added **plenty of Head-room**
  - e.g. 1.2*Tmax Headroom to absorb SLA bursts
- Despite **heavily congested US** causing delays & drops:
  - **CMTS Scheduling algorithms are AI Engines, excellent at adapting** to congestion, with fair BW distribution
  - **Most internet applications are elastic and forgiving…** TCP & ABR recover from thruput reductions & pkt loss
  - **Subs are more tolerant about small lapses** when they are more worried about the virus et. al.

The Effect on Bandwidth (US & DS)… The Good, The Bad, & The Ugly

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(The Usual Suspects)

The Effect on
Bandwidth (DS & US)

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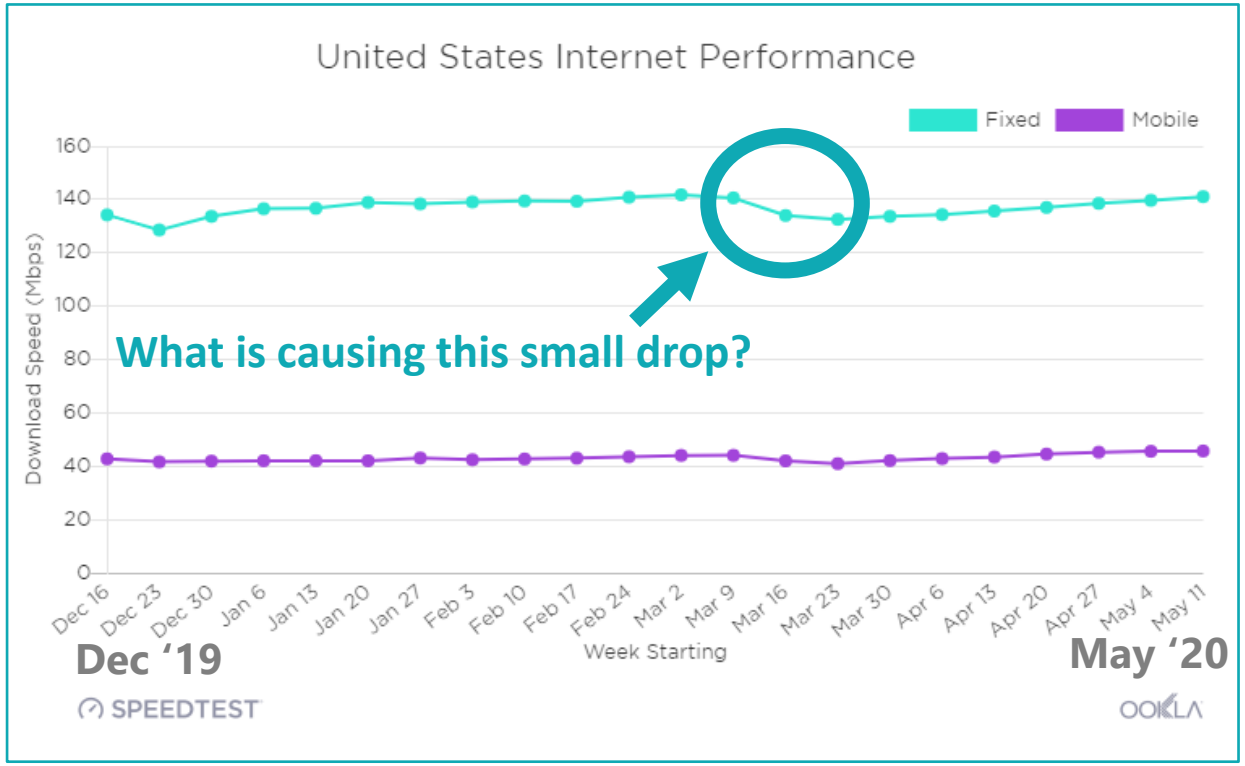


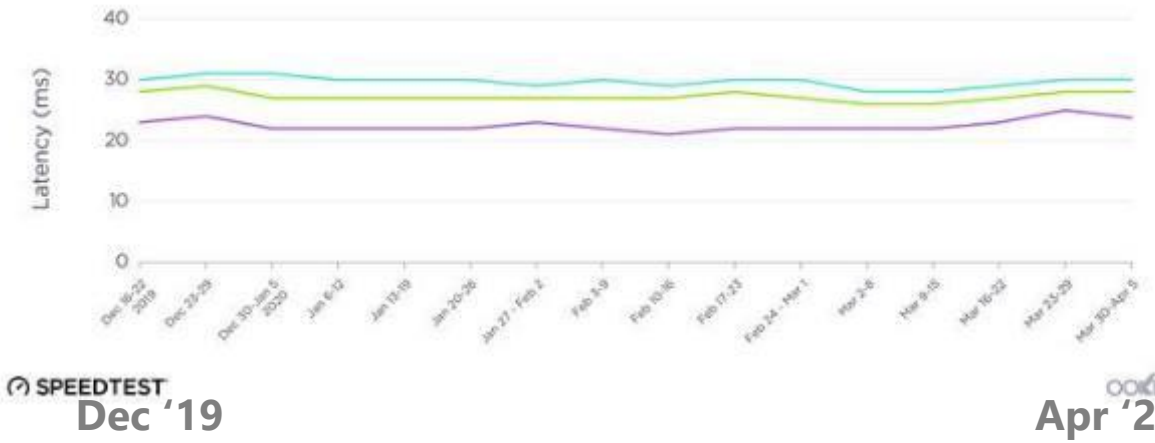
In the USA, initially saw ~9% drop in Mean Download Speed, but since recovered to ~1% down since March 2nd

- Less than the drop seen during the Holiday week of Dec 23-29
- Latencies are relatively unchanged from previous 12 week range

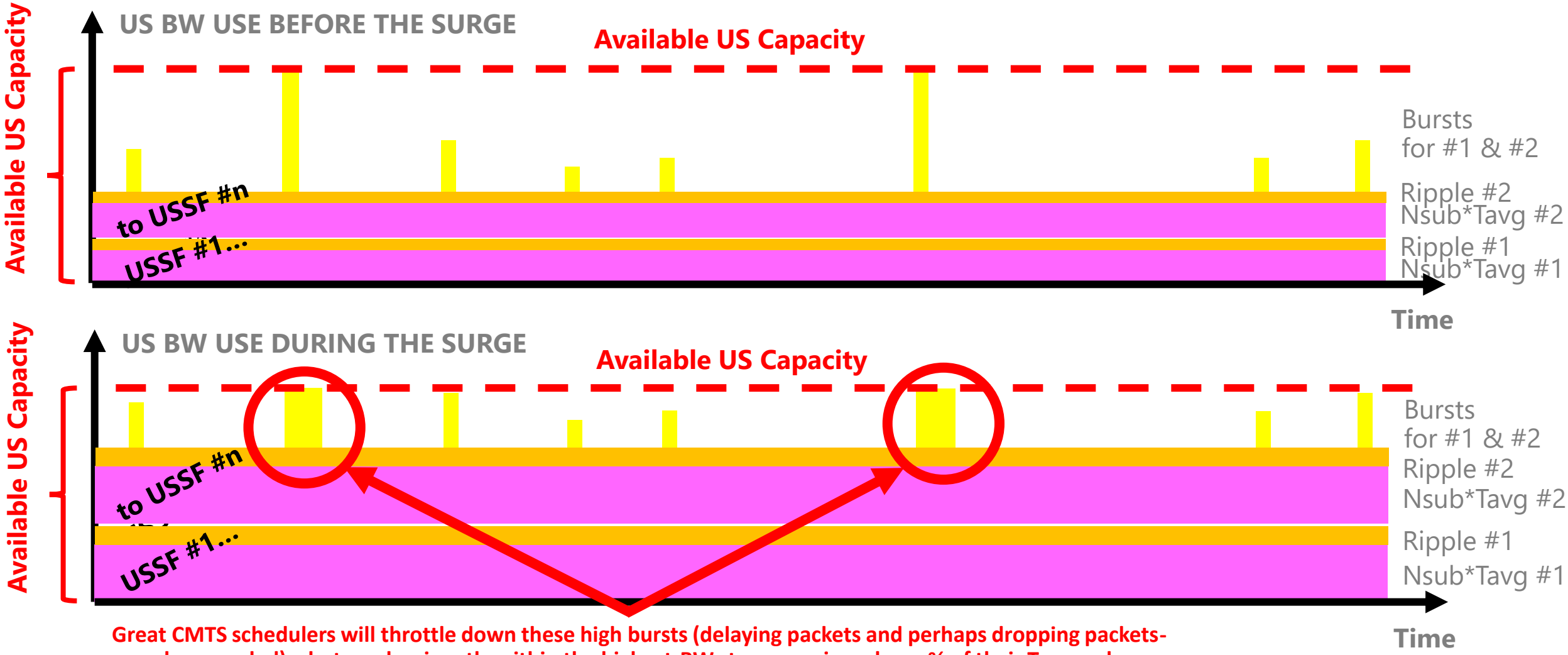
Broadband Networks are holding their own!

How?

https://www.speedtest.net/insights/blog/tracking-covid-19-impact-global-internet-performance/



OOKLA – Weekly Downstream Performance - USA



Great CMTS schedulers will throttle down these high bursts (delaying packets and perhaps dropping packets-when needed)… but predominantly within the highest-BW streams using a large % of their Tmax value

The Beauty of Stat-Muxing Traffic & Intelligent US Scheduling During the Coronavirus US Surge

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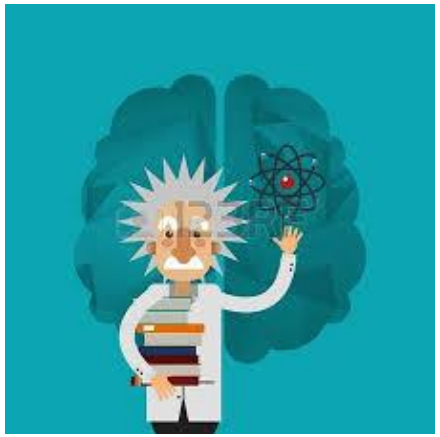
The “Basic” Traffic Engineering Formula: COMMSCOPE QoE-based Formula (2014)

- where 0 <= K <= infinity, but **typically 1.0 <= K <=1.2 for several hundred subs**
- Can use K=0.8-1.0 for very large Tmax (e.g. 1+ Gbps) and/or very small SG (e.g. <100 subs)



THE BASIC TRAFFIC ENGINEERING FORMULA (BASED ON Tmax_max):

$$C >= (Nsub*Tavg) + (K*Tmax\_max)$$

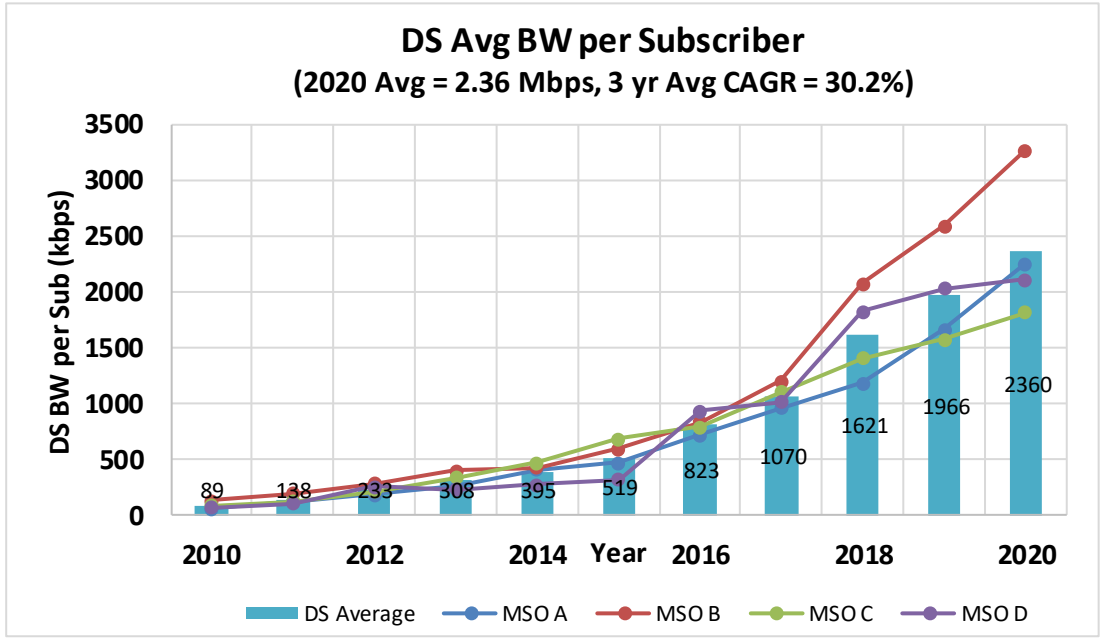
Peak Hour Avg Static Traffic Load For Well-Behaved, Normal Traffic

Headroom for Good QoE for Anomalous, High-BW Traffic

Where:

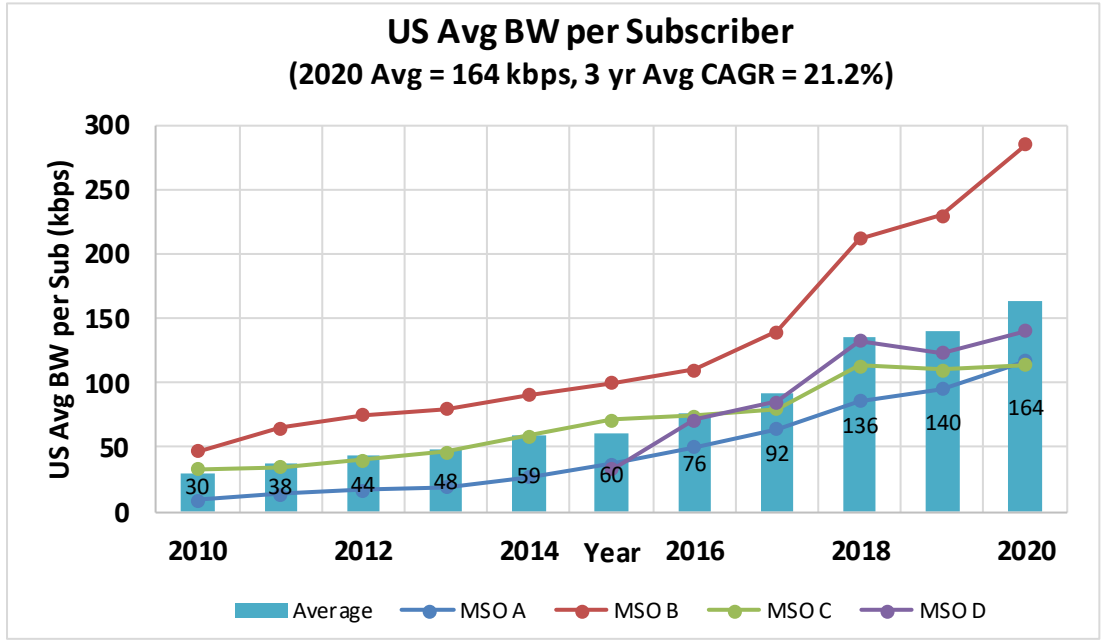
- **C** is the required bandwidth capacity for the service group
- **Nsub** is the total number of subscribers within the service group
- **Tavg** is the average BW consumed per subscriber during busy-hour
- **Tmax_max** is the highest Service Tier Tmax offered by the MSO
- **K** is the QoE constant (larger values of K yield higher QoE levels)…

Downstream Tavg @ Peak Busy Period



- DS Tavg grows 20% to 2.3 Mbps in 2020
  - Fastest growing MSO (B) at 3.27 Mbps
- DS Tavg 3-yr CAGR eases to ~30% from ~34%
  - MSOs' 3-yr CAGRs range from ~18% to ~40%

Upstream Tavg @ Peak Busy Period



- US Tavg bumps 16% to 164 Kbps in 2020
  - Small increase after Flat 2019 and big jump in 2018
  - Fastest growing MSO (B) hits ~285 Kbps,
    - Double the US Tavg of the other 3 MSOs
  - 2020 DS growth close to 2020 US growth
- US Tavg 3-yr CAGR steady at ~21%

Broadband Subscriber Traffic Consumption – Tavg

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CMTS Related Changes

- Add **additional DOCSIS channels**
  - Using new spectrum, new SGs
- Increase **OFDM/OFDMA channels**
  - Reduce SC-QAM over time as 2.0/3.0 modems shrink
- Add **additional CCAP ports** to segment Service Groups

RF Plant Upgrades

- Push **Fiber Deeper** (e.g. N+0, N+1)
- Upgrade remaining plants to (at least) **1218/85 MHz**
- Migrate more nodes to **R-PHY/R-MACPHY** as part of long-term **Distributed Access Architecture (DAA) strategy**

IP Video Migration

- Start migrating all Legacy Broadcast QAM subs to IPTV
  - With a goal to be mostly IPTV subs in a several years
- For IP Video migration, also consider:
  - Multicast ABR, Smart ABR

CM and In-Home Changes

- Migrate all Top Tier subs to **D3.1 CMs**
- Add even **more D3.1 CMs** to better utilize the available OFDMA spectrum
  - Better use of higher spectral efficiencies
- **Upgrade to new Wi-Fi 6E router!!**

Mid-Term Solutions – for 1-3+ Year Capacity Needs
DOCSIS 3.1 is Your Biggest Weapon!

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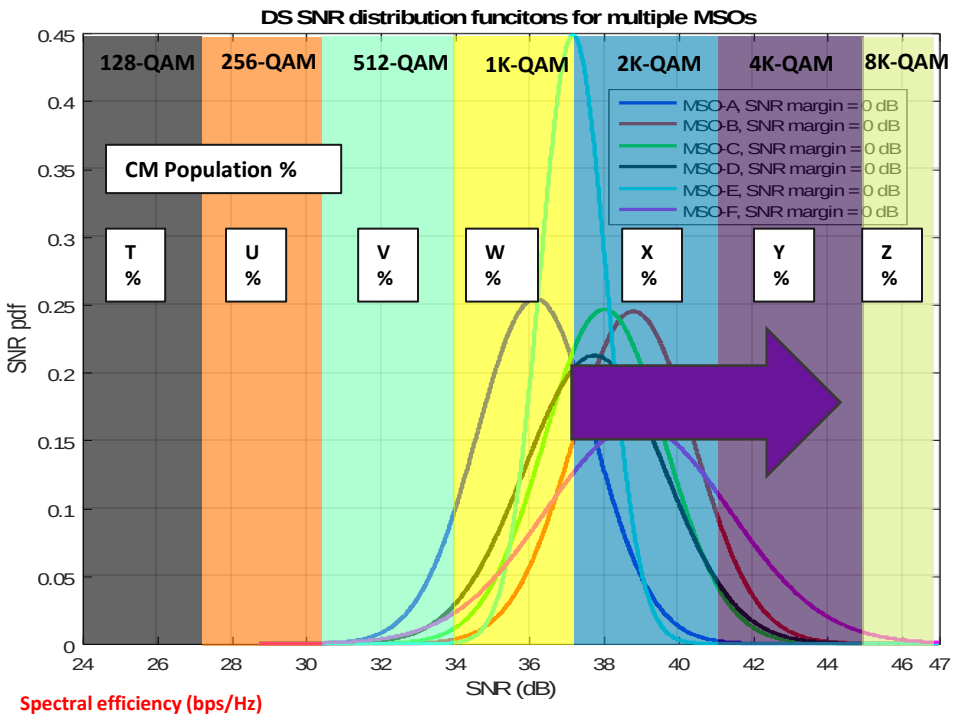
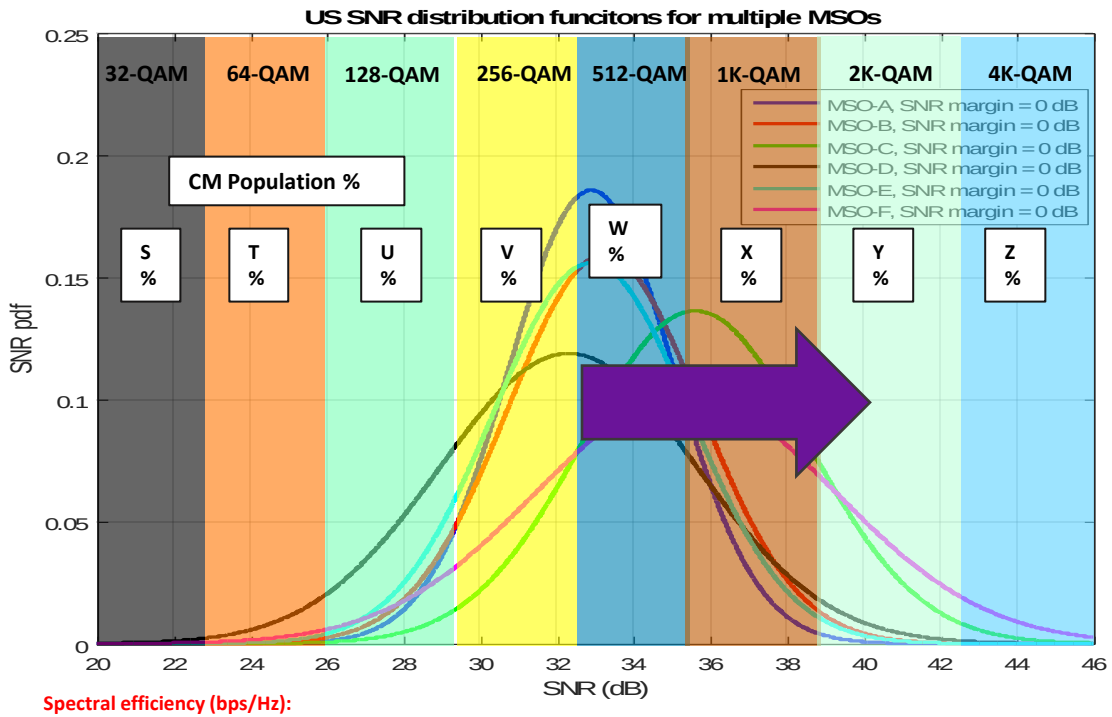
DOCSIS® 3.1 Overview – Extending the Life of HFC for Decades

Recommendations to Maximize Capacity



Spectral efficiency (bps/Hz)

8K:	5.628	6.432	7.236	8.040	8.844	9.648	10.452
4K:	5.216	5.961	6.706	7.451	8.196	8.941	9.686



Spectral efficiency (bps/Hz):

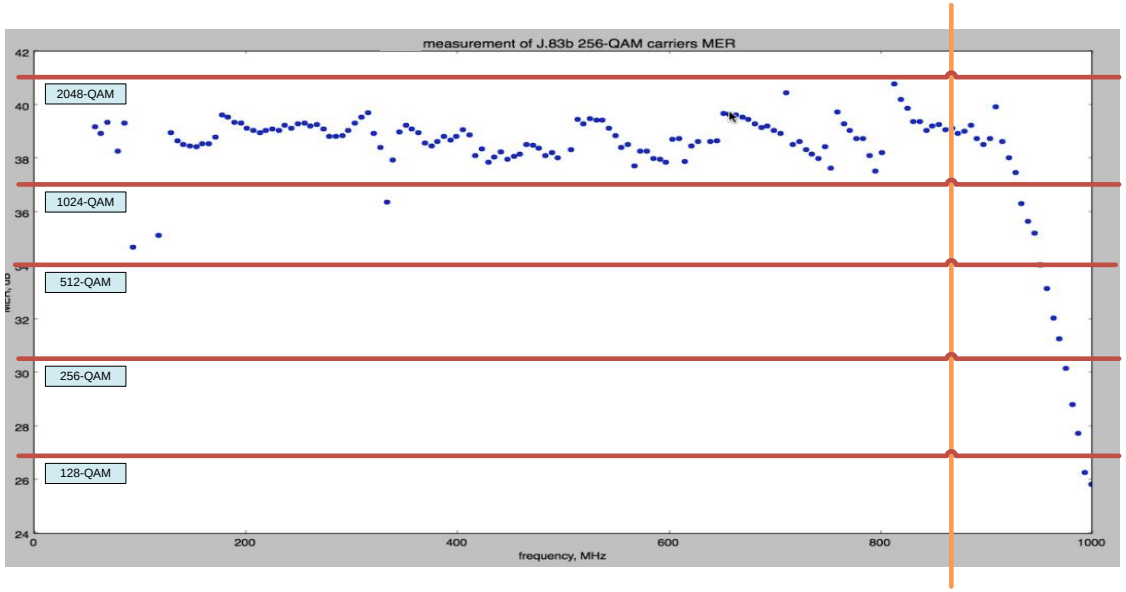
4K:	4.073	4.888	5.702	6.517	7.331	8.146	8.961	9.775
2K:	3.847	4.616	5.386	6.155	6.925	7.694	8.463	9.233

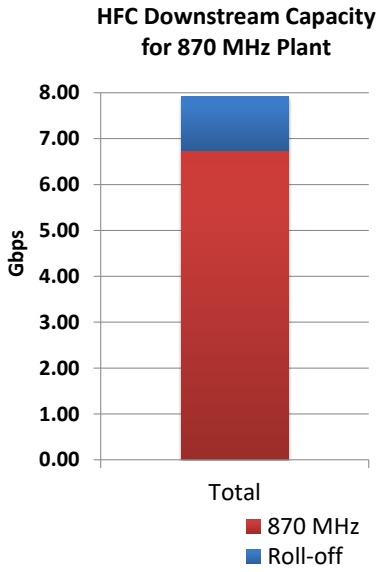
DOCSIS 3.0 DS = 6.33 bps/Hz
Avg D3.1 DS on existing HFC = ~8 bps/Hz; 26% > 3.0
Avg D3.1 DS on Fiber Deep = ~9.65 bps/Hz; 52% > 3.0

DOCSIS 3.0 US (64-QAM) = 4.15 bps/Hz
Avg D3.1 US on existing HFC = ~6.85 bps/Hz; 65% > 3.0
Avg D3.1 US on Fiber Deep = ~9 bps/Hz; 116% > 3.0

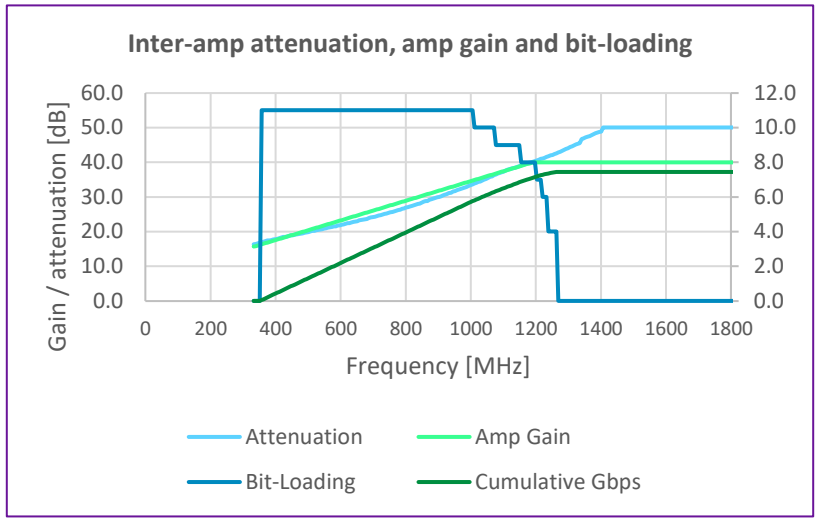
What can I expect from Existing HFC & Fiber Deep?
DS + US Spectral Efficiency Analysis on Existing HFC + FD

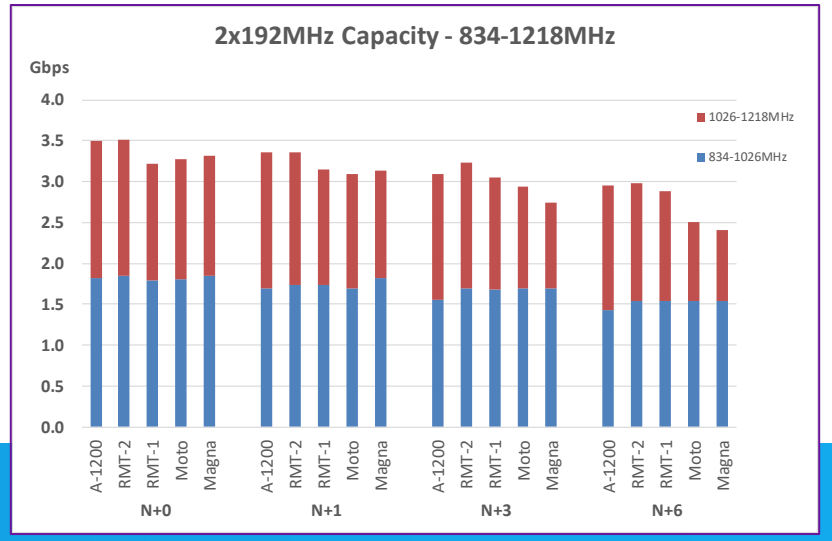
Sample MER Measurements on 870 MHz HFC Plant





1GHz Tap Performance
From COMMSCOPE Ext Spectrum Research





- Robust D3.1 OFDM/LDPC can operate where others can't
- Roll-off region on 550/750/870MHz plant might provide ~1 Gbps of additional 'Bonus' capacity
- 1GHz Taps may be able to support 256-QAM @ 1200MHz

DOCSIS 3.1 – Extending the Life of Your HFC
Examples based on Real Plant + Tap Measurements

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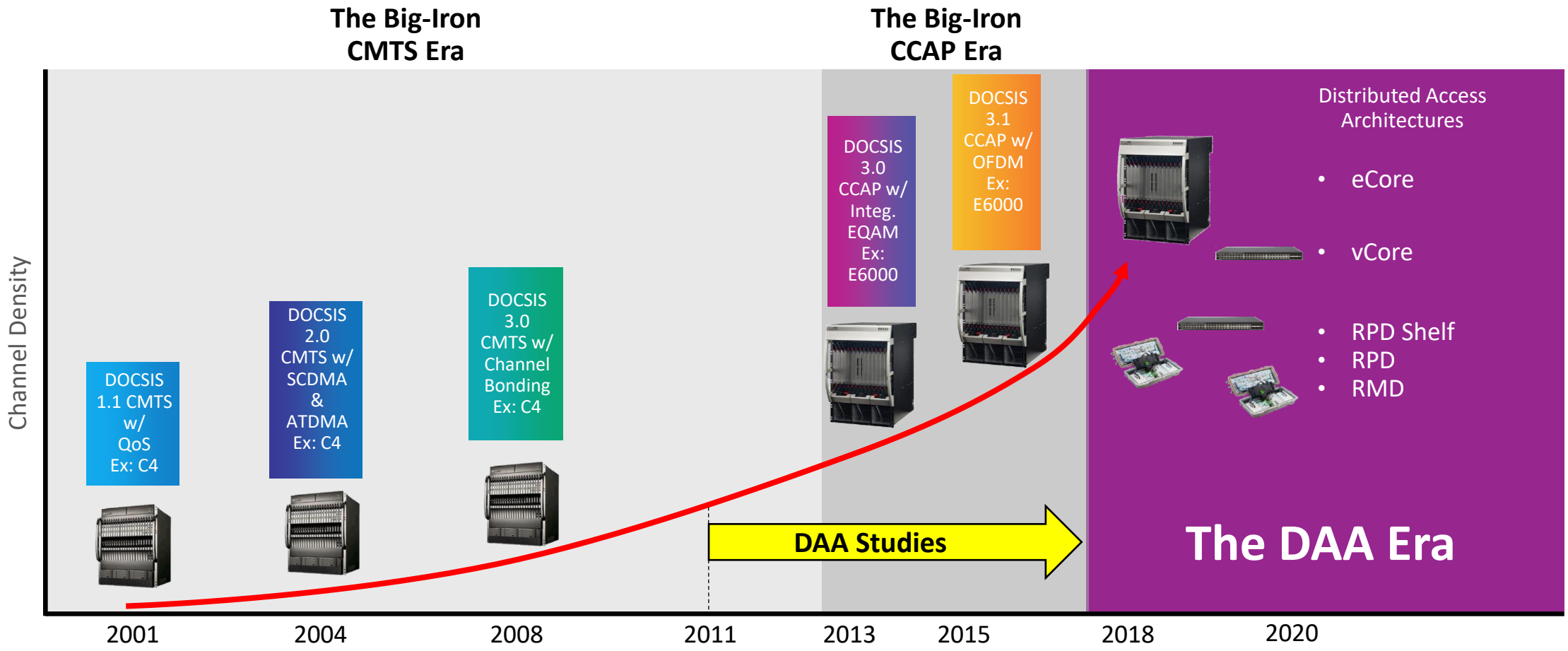
CommScope Distributed Access Architecture (DAA) Overview



The Evolution of the Access Edge in this Century

- DAA is the next step in a 20+ year evolution
- DAA delivers increased performance and flexibility
- A complete portfolio of solutions (Physical & Virtual) will be required for this next phase of network evolution

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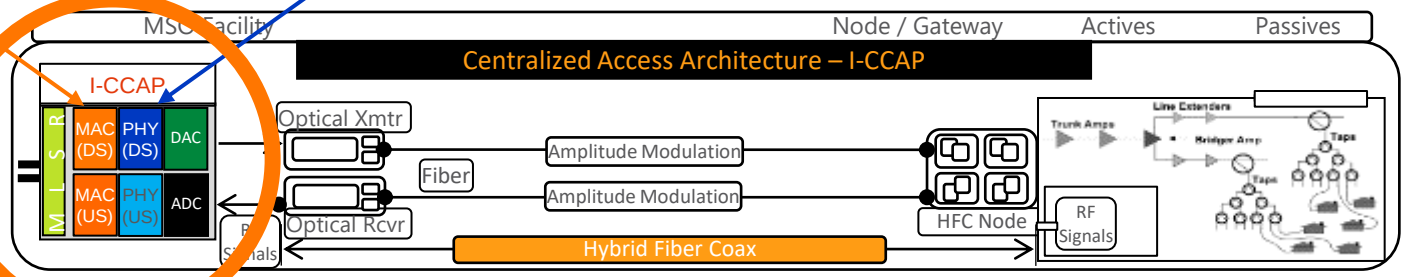
The Primary MSO Benefits from Distributed Access Architectures (DAAs)

Head-End Rack-Space/Power	CCAPs cannot support potential SG growth with current head-end space & power issues… ***DAAs permit it***
Modulation Error Rate (MER)	CCAPs do not always support Higher-order modulations with Nonlinearities of Digital Optics… ***DAAs can***
Fiber Lambda	CCAPs have limited Numbers of Wavelengths on a WDM Fiber, causing more Fiber Pulls… ***not so for DAAs***
Set-It-and-Forget-It	CCAPs & Analog Optics can require level tuning and maintenance… ***not so for DAAs***
Open API	CMTSs do not use standard interfaces between sub-systems and do not permit best-in-class solutions from different vendors to be mixed together… ***DAAs can***

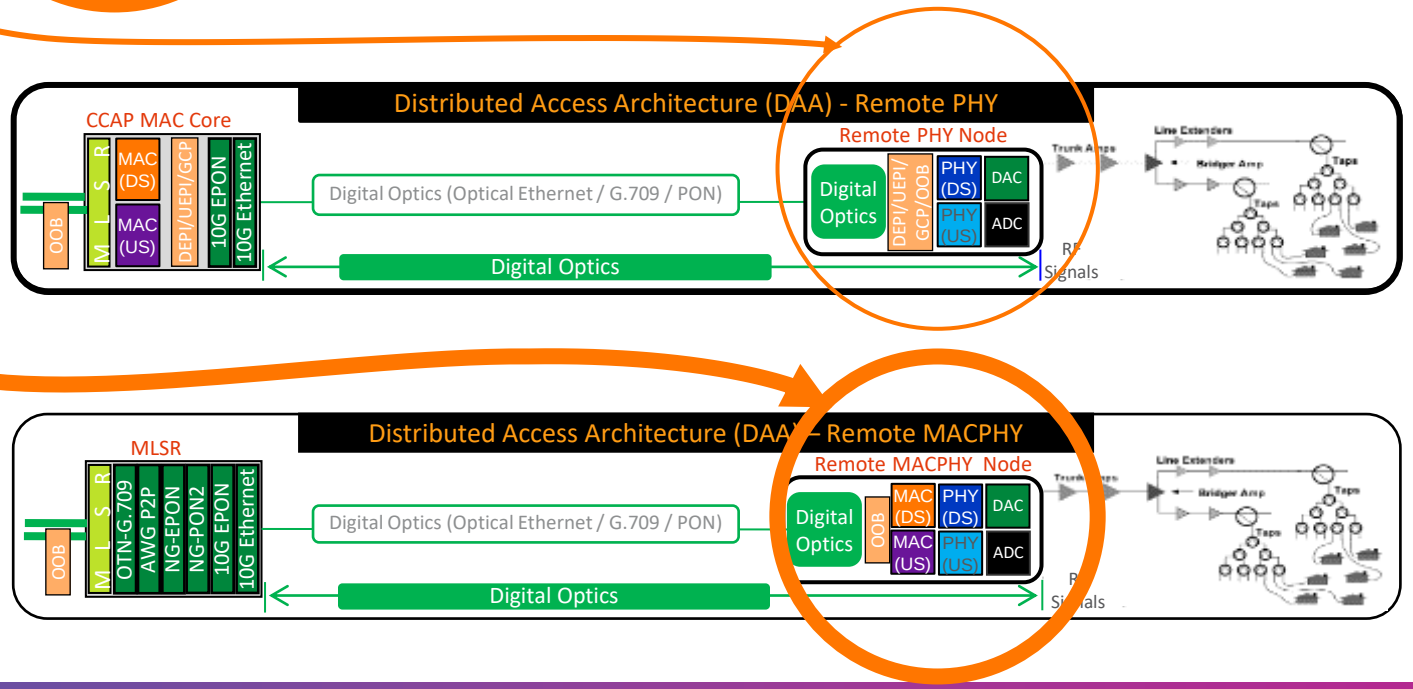
MAC = Packet-Level Scheduling

PHY = Bit-to-RF Signal Conversion

I-CCAP



HFC DAA Variants



Remote PHY (R-PHY)

Remote MACPHY (R-MACPHY)

HFC DAA — Remote MACPHY (RMD) Architecture

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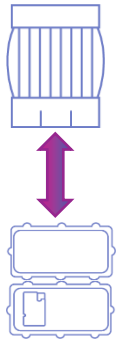
CAA

DAA Options

I-CCAP (DOCSIS)

High Density I-CCAP (MAC & PHY) Management, Control & Data Planes

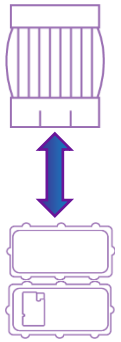


Node Analog No Software

Benefits
BAU - No Software / Simple **Lowest OSP Power** Lowest MTBF / MTTD / MTTR **Familiar OAM&P**

CCAP eCore & RPHY

CCAP Core (MAC) (Management, Control & Data Planes)

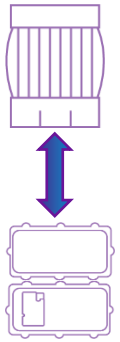


Node + RPHY Module (PHY) Data Plane

Benefits
Low Rackspace in HE Low Power in HE **Lowest DAA Power in the OSP** More Lambdas on Fiber **Leverage existing CCAP MAC processing**

Virtualized Core (vCore) & RPHY

vCore (MAC) (Management, Control & Data Planes)

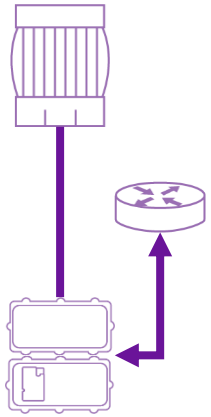


Node + RPHY Module (PHY) Data Plane

Benefits
Med. Rackspace in HE Low Power in HE **Lowest DAA Power in the OSP** More Lambdas on Fiber **Elasticity & Feature Velocity w/ SDN & NFV**

Remote MACPHY Device (RMD) and MAC Mgr

MAC Manager (Management Plane Only)

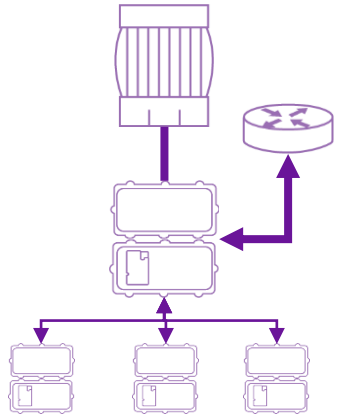


Node + RMACPHY Module (MAC & PHY) (Control & Data Planes)

Benefits
Lowest Power/Rackspace in HE **Lowest Latencies (e.g. 5G)** Med Power in the OSP More Lambdas on Fiber Elasticity & Feature Velocity w/ SDN & NFV

Remote MAC Core (RMC), MAC Mgr & RPD

MAC Manager (Management Plane Only)

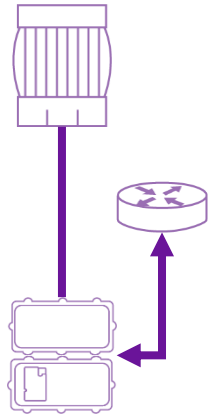


Node + RMC Module (MAC) (Control & Data Planes)

Benefits
Similar to RMD

Remote OLT

MAC Manager (Management Plane Only)



Node + RMC Module (MAC & PHY) (Control & Data Planes)

Benefits
Lowest Power/Rackspace in HE **Lowest Latencies (e.g. 5G)** Med Power in the OSP More Lambdas on Fiber Elasticity & Feature Velocity w/ SDN & NFV

Lots of DAA Options from which to Choose… A Benefits Comparison

MAC = Packet-level processing **PHY =** Bit-to-RF level processing

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Remote MACPHY Device – Pros and Cons

Pros

- **Simplicity** – All in one box
- Largest **Headend space + power savings** of any DAA
- **Lowest Latency** for Edge Computing of any DAA/CAA
- **Lowest total system power** for any DAA or CAA
- Most flexible Headend consolidations –
  - **No DOCSIS distance limitations**
- Compatible with existing Video & OOB Aux Cores
- Can be deployed without Grand Master Clock
- Virtualization – Makes use of Cloud Computing for Management Plane & Video
- Fog Computing – blending benefits of Cloud + Edge

Cons

- Cost: fiber node higher but lower cost in headend
- Adds a small amount of power in the Node (~2-10W AC) due to the inclusion of the MAC
- Limited MAC redundancy options available (redundant links available)
- Does not share or re-use already-deployed CMTS Core in the headend

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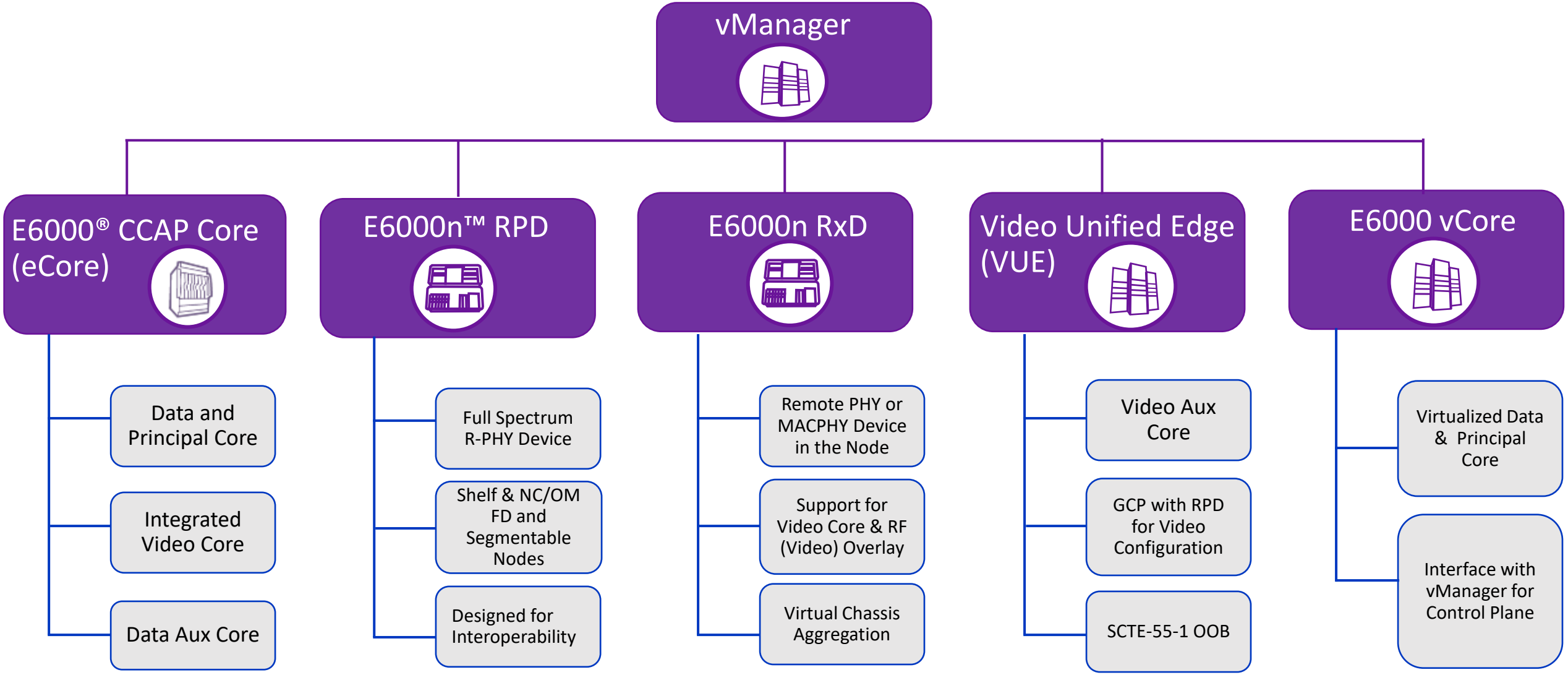
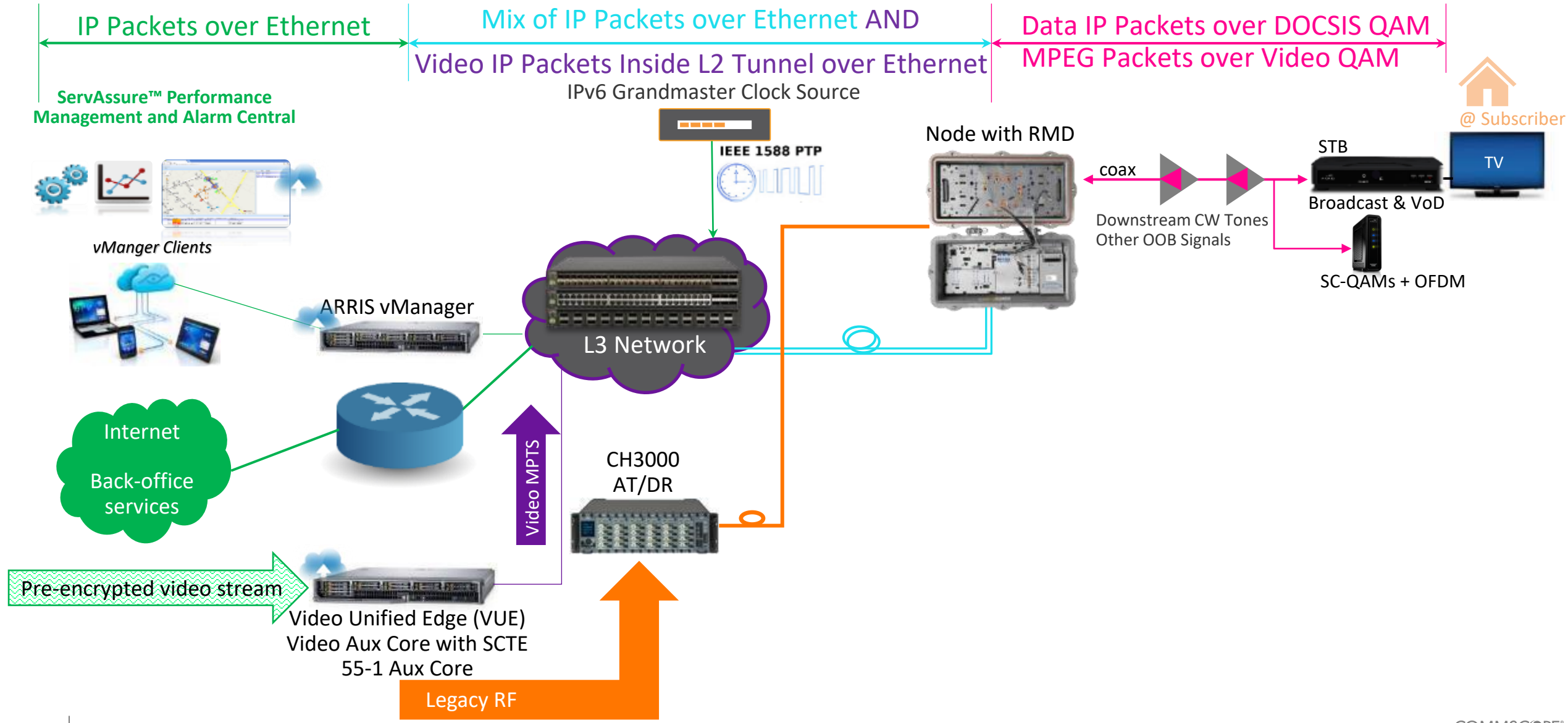
CommScope DAA Solutions



CommScope Cable DAA Solution Overview

CommScope DAA R-MACPHY with VUE Video Core & E6000n Remote MACPHY Device (RMD)



1.2 GHz Solutions with E6000n DAA Modules

OM6000

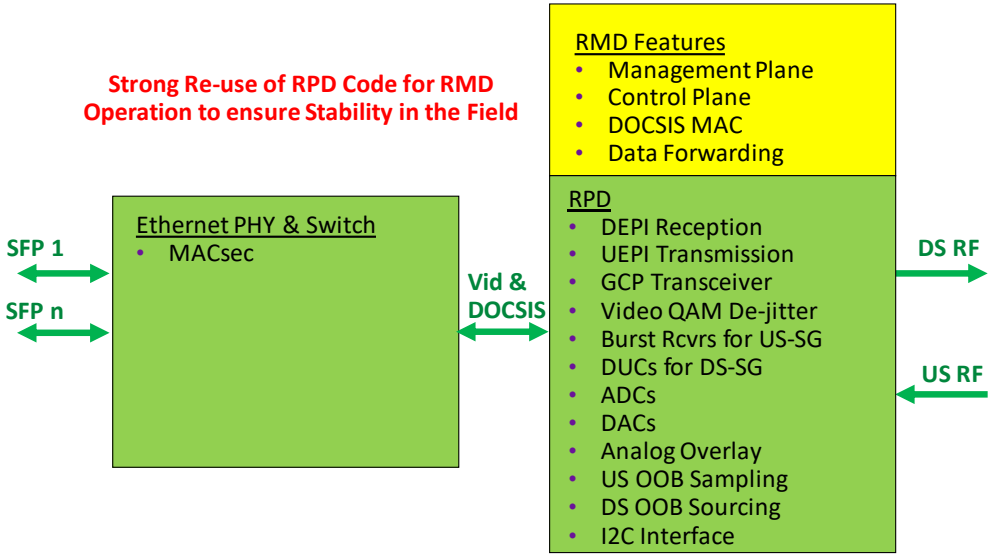
NC4000/OM41x0

NC2000

R-PHY Shelves

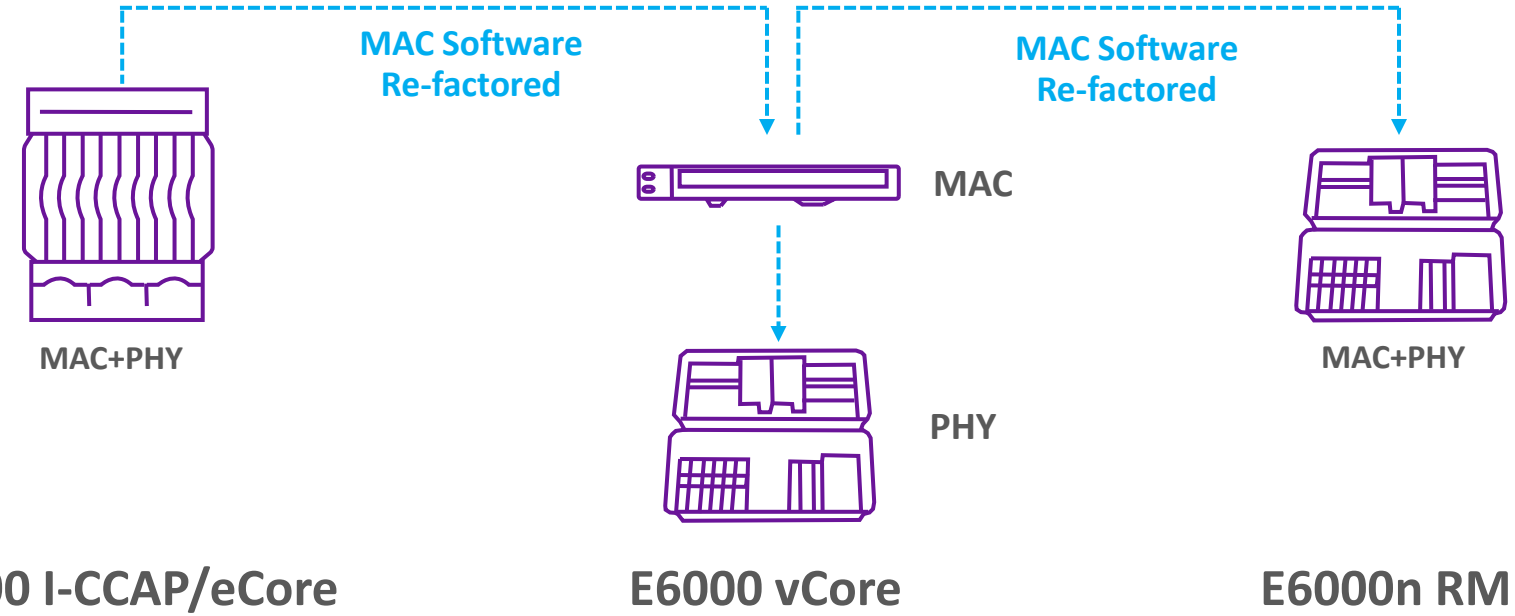
COMMSCOPE®

- **An End-to-End Product Suite (Nodes, Amps, CMs) Guaranteed to Work**
- **An Experienced DOCSIS® Design/Support Team in a Stable Company that will be there with you as part of the Cable Industry… We are in it for the Long Run**
- **Long-term Product Roadmap with Clear Path to the Future of RMDs (DOCSIS 4.0 & Beyond)**
- **A Novel RMD Hardware Design**
  - Low-power
  - Ability/ Flexibility to add novel Future Features
  - Use of proven CommScope software for RPD, DOCSIS MAC, and Data Forwarding
- **A Powerful Combination of E6000® MAC Software & E6000n™ RPD**
  - E6000 MAC Software Application offers:
    - Based on Industry Leading MAC – field proven for 20+ years and 100's of millions of subs
      - Stability due to Field Hardening
    - Stability – Industry-Leading SW Testing Capability (automation, multiple scaling labs)
    - Feature Richness (DOCSIS 3.1 plus many more features added over many years)
  - E6000n RPD offers:
    - Stability due to Field Hardening with a similar Gen 1 Design
- **Novel & Useful Features that Differentiate CommScope**



Benefits of the CommScope RMD Program

An Example – CMTS MAC software can be re-used multiple times in multiple designs



- Leverages the field-proven and widely-deployed software elements – 20 years of field hardening!
- eCore, vCore, and RMD utilize feature-rich CommScope software to provide excellent scalability, operational efficiencies and performance
- Software re-use enables feature velocity across different DAA architectures and solutions

CommScope – DAA with Software Re-Use with CommScope

Longer Term Bandwidth Directions

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What Does The Distant Future Hold?

Nobody knows for sure!!!

But two things are likely to happen:

1. **Bandwidth usage may not snap back to its original pre-Coronavirus levels when Coronavirus ends…** Why? Because this novel social experiment we are all involved in may foster a new social paradigm… workers & companies may decide to explore more work-at-home activities and students & schools may decide to explore more on-line education activities

2. **Bandwidth will obviously continue to grow into the 2020's…** (e.g. eSports is getting a boost right now)

The problem experienced during Coronavirus is **only a sampling of what will happen in the future** when that Bandwidth growth crosses certain thresholds

MSOs & Vendors need to begin working now to upgrade the HFC Plant to support the future Bandwidth Growth

Why Do We Need More Future BW Capacity?

- Perhaps to support Future Applications…. TBD

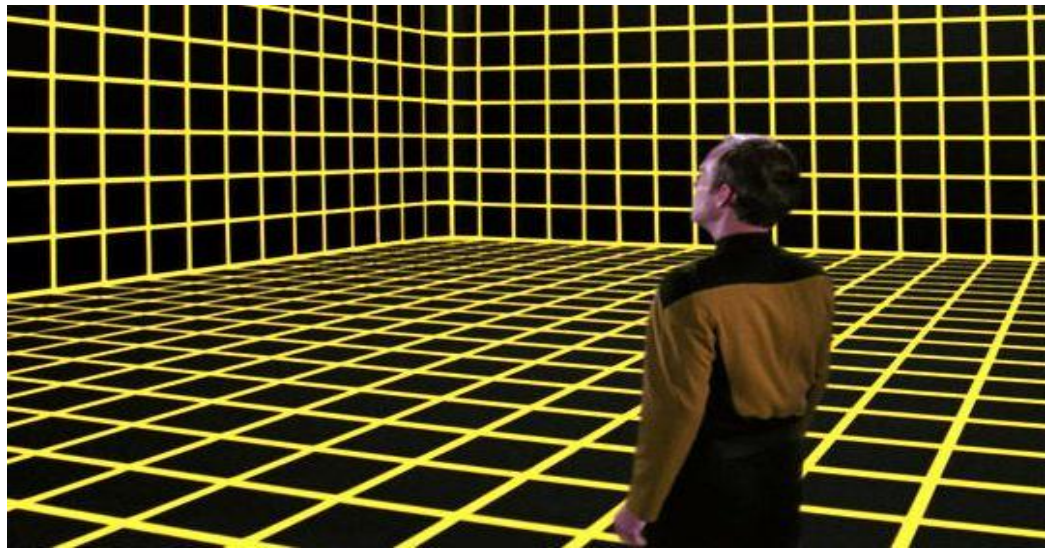
Service "Snappiness"
Ex: Entire 1.7 GB iOS 11 File Downloads in ~1.3 seconds

10 Gbps permits this

Virtual Reality or Augmented Reality w/ "retinal," immersive Experience Levels

~600 Mbps per stream (10 Gbps supports 16 streams)

Light Field Displays (Holodeck-like Applications)



~800 Mbps per stream (uncompressed) (10 Gbps supports 12 streams)

Mid-Term Proposals for Mid-Term Needs (Upstream & Downstream)

- **Maximize D3.1 OFDM/OFDMA capacity**
  - **D3.1 is your biggest weapon** in the arsenal, definitely your biggest bang
  - **Upgrade to Gen-2 CMTS** (D3.1 US – OFDMA, more video, more SC-QAMs)
- **Perform Physical Node-Splits** (helps with Tavg growth)

Long-Term Proposals for Long-Term Needs (Upstream & Downstream)

- **Perform 85MHz Mid-Splits** (helps with US Tavg & Tmax growth)
- **Perform 204MHz High-Splits** (helps with US Tavg & Tmax growth, enable 1G US Tier)
- **Turn on 1218MHz DS** (helps with DS Tavg & Tmax growth, uses existing taps)
- **Push Fiber Deeper** (helps with US + DS Tavg growth)

Longer-Term Proposals for Longer-Term Needs (DOCSIS 4.0, 10G Initiative)

- Add **Ultra-High-Splits or FDX** (helps with Tavg & Tmax growth in the US)
- Add **Extended Spectrum** DOCSIS (helps with Tavg & Tmax growth in the DS)

Longer-Term Solutions for 3 to 10 Year Horizon

Cable's 10G™ – A Journey, not a Destination

What is 10G™?

10G™ is a Goal

- A lighthouse in the distance towards which all MSOs can steer their boats
- Staying ahead of consumer demand to enable myriad of new applications
- Revolutionize the way we live

Combination of Technologies

- 10X faster than today's networks
- 100X faster than what most consumers currently experience

Download Examples (10G vs. 100Mbps)

- 4K movie in 15 sec vs. 25 min
- 100GB game in 90 sec vs. 2½ hours

Multi-Gigabit Upstream BW Too

10G™ – Key Attributes

Speed

- D3.1, FDX, Extended Spectrum
- PON, Coherent Optics, adv Wi-Fi

Latency

- DOCSIS Low Latency

Security

- DOCSIS 4.0, MicroNet AI-based Platforms in Home Networks

Reliability

- Proactive Network Maint.

Scalable

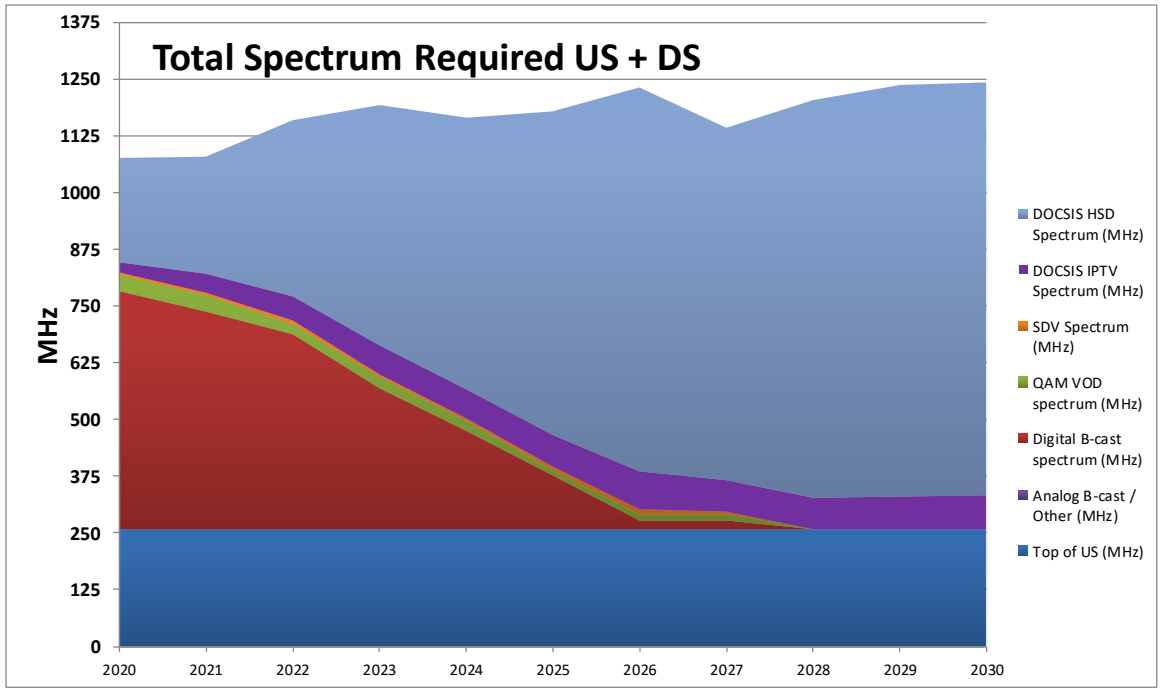
Dates are still TBD

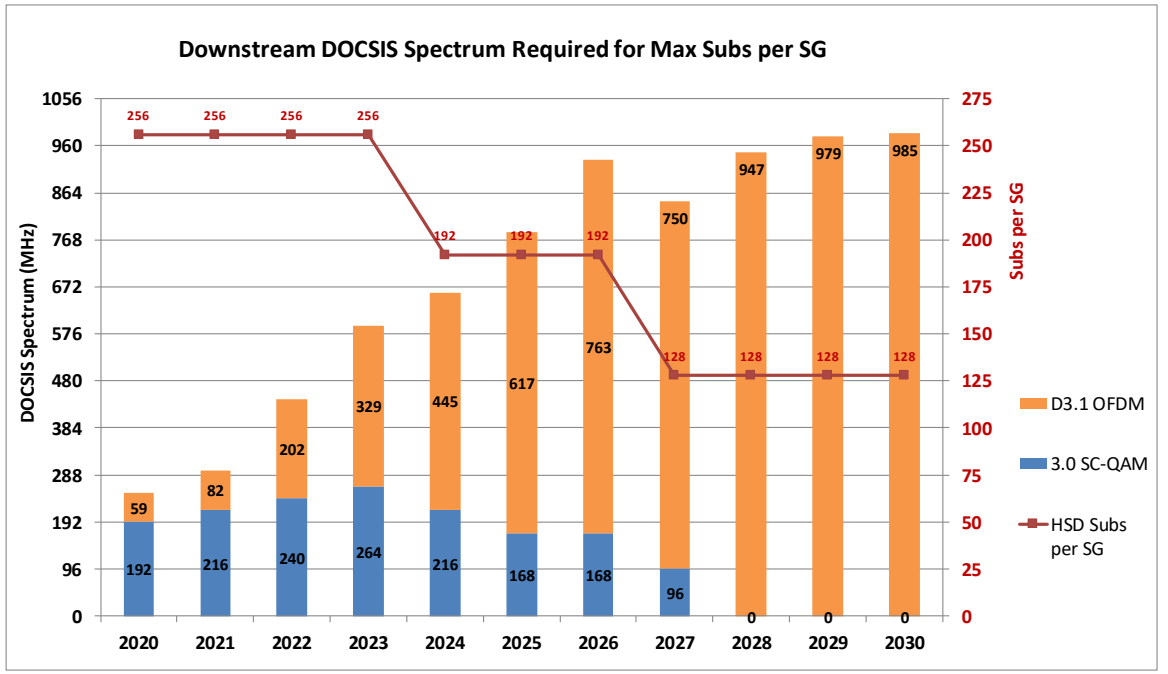
Competitive Market – Service Tier Growth

Service Tier Migration with a 1218/204 MHz plant

Service Tier	2020	2022	2024	2026	2028
Top Billboard	1G/1G	2G/1G	4G/1G	6G/1.5G	7.5G/1.5G
Performance	400/40	1G/100	1G/1G	2G/1G	4G/1.5G
Flagship	200/20	300/30	400/40	1G/1G	2G/1G
Economy	100/10	100/10	200/25	300/30	500/100
% D3.1 Modems	5%	23%	46%	70%	100%

- 100% D3.1 modems by 2028
- 1218/204 MHz plant is capable of handling up to 7.5 Gbps DS X 1.5 Gbps US Tiers
  - Higher US Tiers possible with FDX or soft-FDD
  - Higher DS Tiers possible with 1.8 GHz upgrades
- DS Tavg Growth slows gradually over decade = 20 Mbps by 2030; US Tavg = 2 Mbps
  - Tavg is weighted by Service Tier (e.g. Top Tier is 2X Flagship Tier)

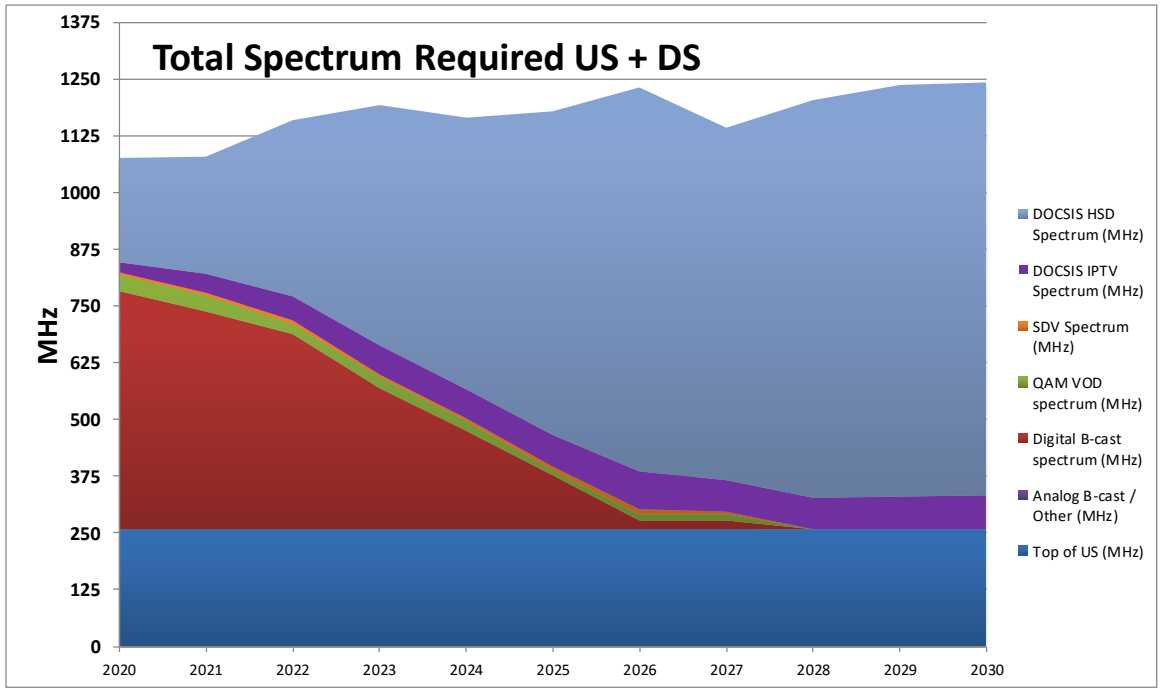


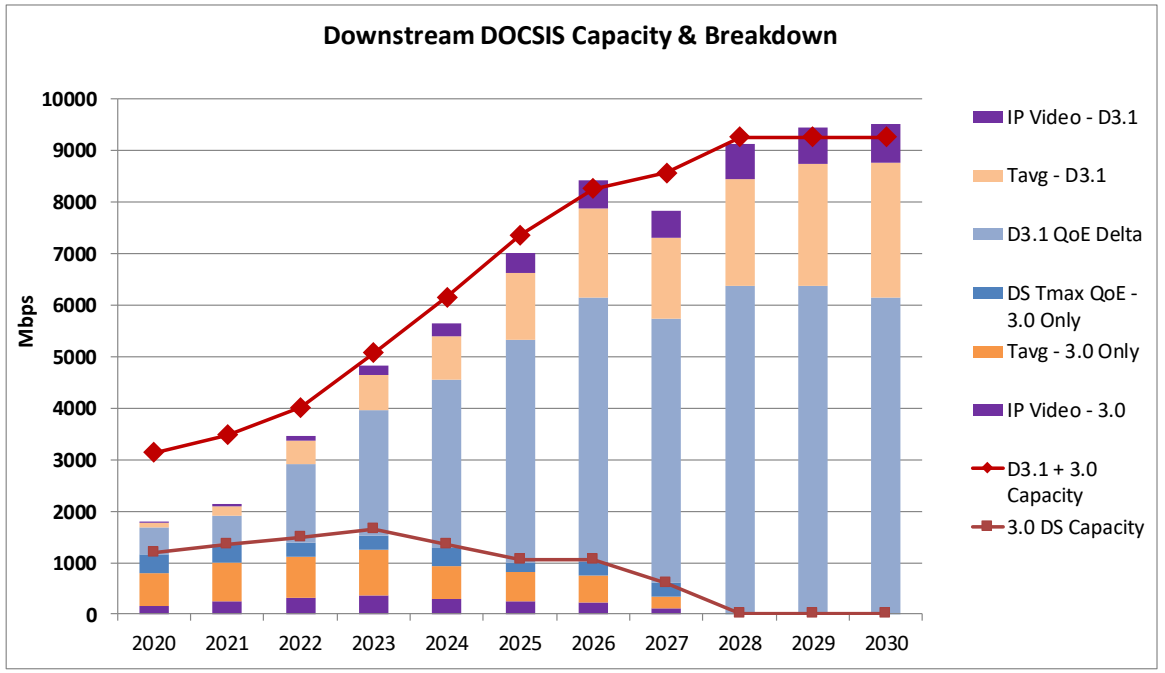


- 1218/204 MHz plant
  - Downstream starts @ 258 MHz
- Reclaim legacy video:
  - Using IP video, SDV &/or MPEG-4

- Transition to 100% D3.1 modems by 2028
- 512 HP, 256 subs/SG to start
- **256 HP, 128 subs per SG in 2030**
  - **E.g. 2x2 segmented 512 HP N+X**

Network Capacity Modeling for 10G Downstream





- 1218/204 MHz plant
  - Downstream starts @ 258 MHz
- Reclaim legacy video:
  - Using IP video, SDV &/or MPEG-4

- Transition to 100% D3.1 modems by 2028
- Tmax dominates over Nsub*Tavg
  - IP video is relatively small %
- **2x2 500HP N+X supports 7.5 Gbps DS SLA**
  - **N+0 nice, but not a 10G requirement!!**

Network Capacity Modeling for 10G Downstream

Getting to Cable's 10G™ – Summary

Recommended Steps

500 HP Node is Reasonable for 10G Over Next Decade Provided 2x2 Segmentation

- N+0 helps but not required

Migrate to All D3.1 Modems

- Important for overall network capacity
  - OFDM >> SC-QAM, especially US

Start to Remove Legacy Video

- IP Video, MPEG-4, Cloud-based SDV

Migrate to 1218 MHz and DAA

- DAA maximizes OFDM capacity, enables scaling with Fiber Deep HFC systems
- 1 GHz Taps fine for next decade
  - Consider 1.8/3.0 GHz when cost effective

Other Upstream Considerations

85/204 MHz for 10G DS Only

- Fine for many markets, pair with 500 Mbps or 1.5 Gbps US SLA

'Traditional' FDX for N+0

- Strategic direction – stepping stone to FTTH
- Best in very competitive markets

Static or Dynamic Soft-FDX for N+X

- Defer fiber deep investments
- Re-use FDX modems

Consider Blended HFC/FTTH Systems

- Selective early adopter subs on FTTH or FTTtap later next decade and beyond
- 90%+ of subs stay on traditional HFC

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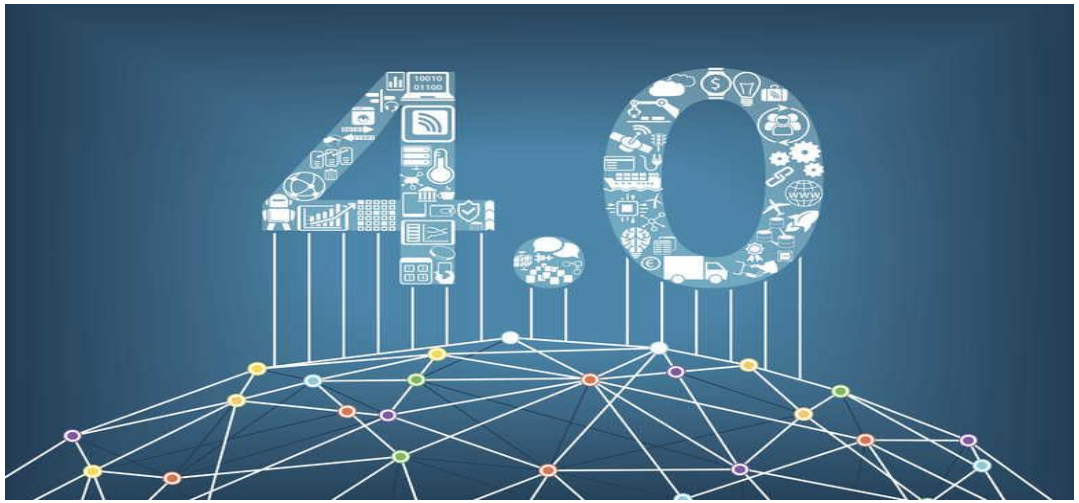
DOCSIS 4.0 Update

What Is DOCSIS 4.0?

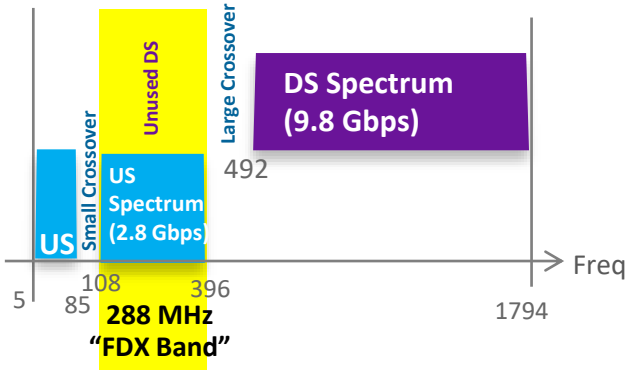
It is a Spec being defined at CableLabs that was driven strongly by the "Band Of Twenty" MSOs…

It is a Steppingstone to 10G…

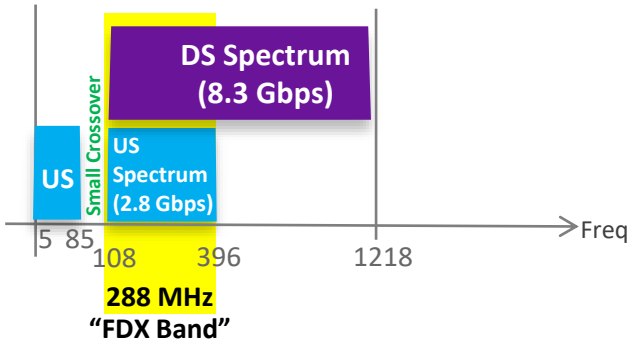
The Spec is coming to completion quickly… likely available in a few weeks



- **Extended Spectrum DOCSIS**
  - ESD is for Node+X MSOs (X>0)
  - It include extensions to DS Bandwidth & US Bandwidth
  - CommScope proposed this concept in 2015



- **Full Duplex DOCSIS (FDX)**
  - Full Duplex DOCSIS is for Node+0 MSOs
  - It includes only extensions to the US Bandwidth



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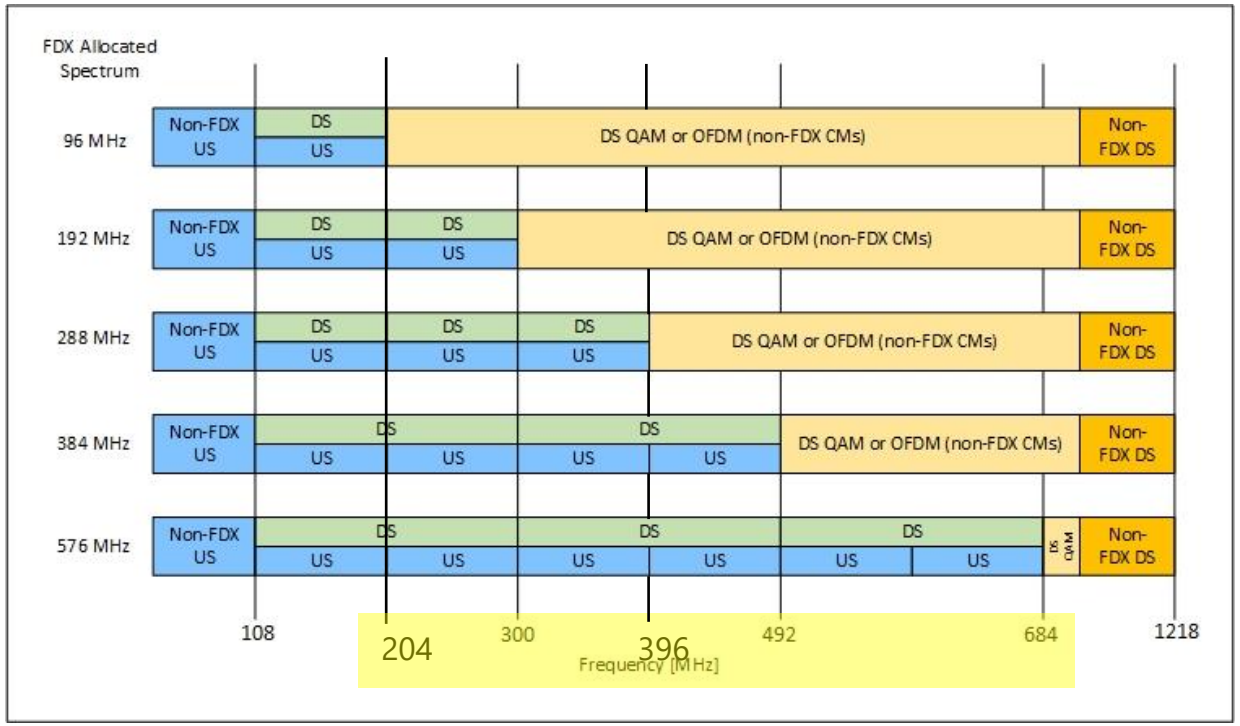
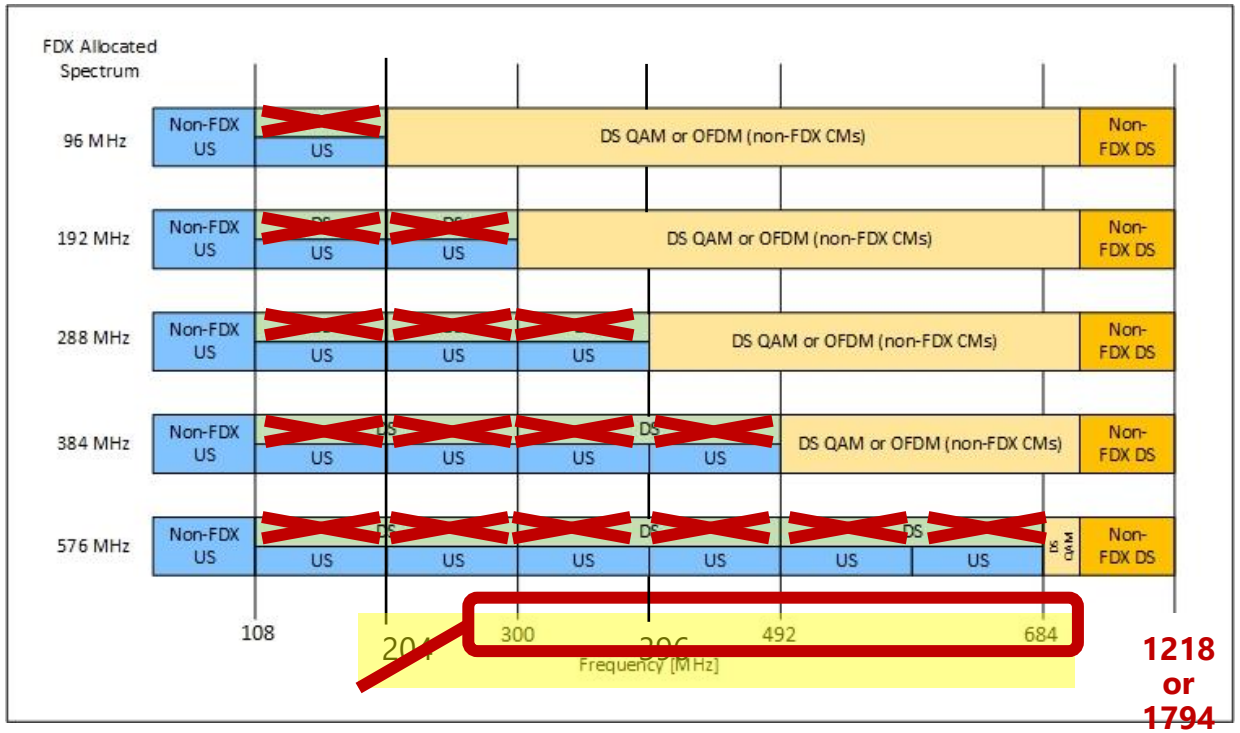
DOCSIS Version (Date)	Upstream	Downstream
DOCSIS 1.0 (1997)	42 MHz (16QAM)	870 MHz (256QAM)
DOCSIS 1.1 (1999)	42 MHz (16QAM)	870 MHz (256QAM)
DOCSIS 2.0 (2001)	42 MHz/65 MHz (64QAM)	870 MHz (256QAM)
DOCSIS 3.0 (2006)	42 MHz/65 MHz/85 MHz (64QAM)	1002 MHz (256QAM)
DOCSIS 3.1 (2013)	204 MHz (4096QAM)	1218 MHz (16384QAM)
DOCSIS 4.0 FDX (2019)	684 MHz (4096QAM)	1218 MHz (16384QAM)
DOCSIS 4.0 ESD (2020)	684 MHz (4096QAM)	1794 MHz (16384QAM)

Let's Take A Quick Tour Of DOCSIS Spectra & Modulation Orders Over Time





Spectrum Plans - DOCSIS 4.0 FDX Splits, ESD Splits

The Cause
(The Usual Suspects)

The Effect on
Bandwidth (DS & US)

The Effect on Quality
of Experience

Short Term
Quick-Fix Ideas

Mid-to-Long Term
Fix Ideas

Conclusions

Managing the Coronavirus BW Surge

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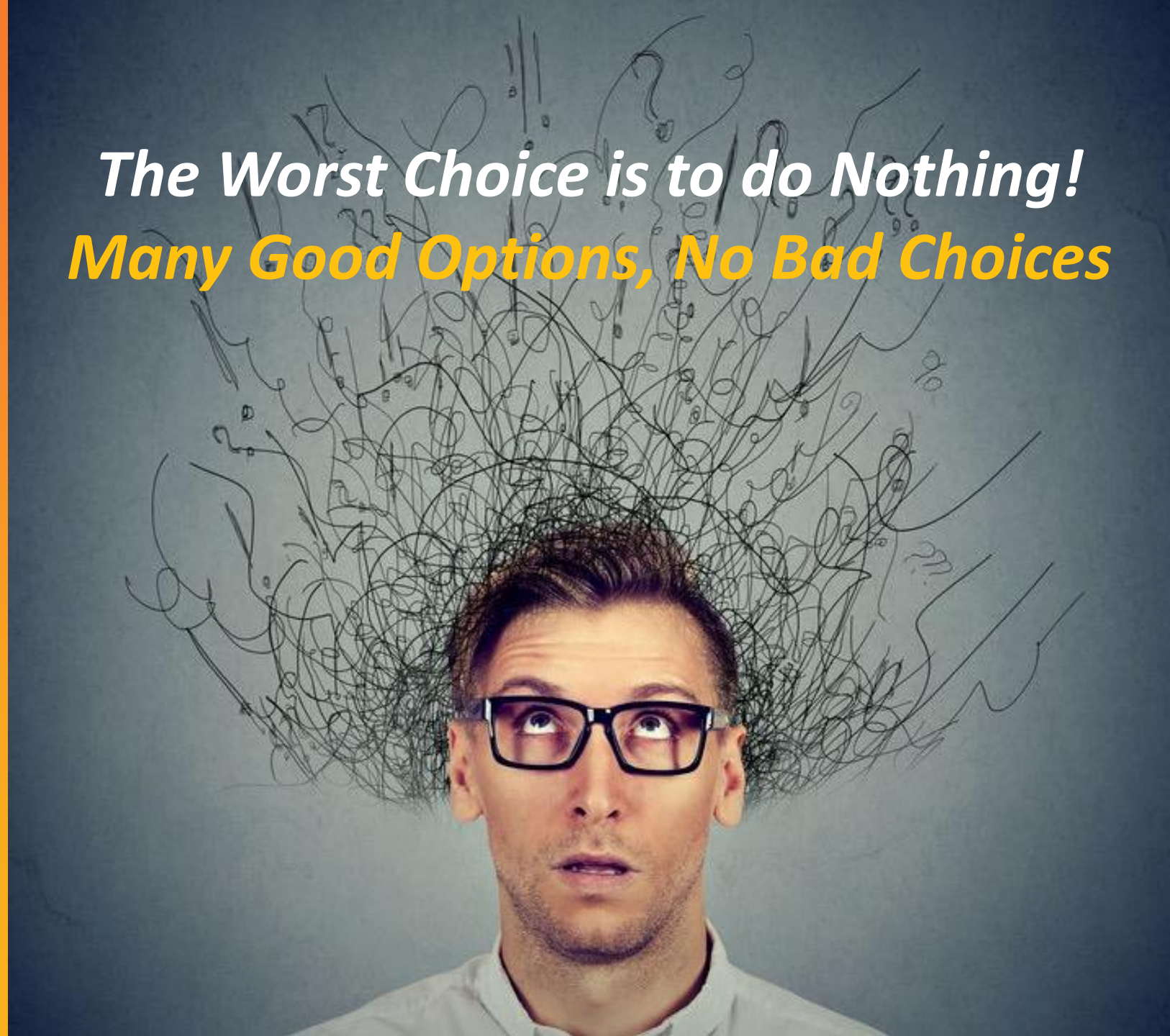
Which Options Do I Pick???

Too Many Choices!!!

How Do I Choose?

The Worst Choice is to do Nothing!

Many Good Options, No Bad Choices



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Professional Services from CommScope

Network Evolution Consulting

- Analyze and plan network bandwidth capacity
- Informed, targeted and optimized decisions
- Specific architectural / equipment recommendations
- Clear Capex and Opex implications

ISP integration

ISP build & upgrade

OSP build & upgrade

Construction management

Playbooks

Monitoring

Quality control

Plant survey

As-builts

ISP design

OSP design

Leaf/Spine design

Node splits

Optical design

Node upgrades

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Summary –

Managing the Bandwidth Surge: Network evolution for near & long-term capacity growth

DOCSIS is still working very well… even during the Coronavirus BW Surge… but this event has shown weaknesses & **cracks in the system** that need filling to make it through the 2020's… this should **serve as a wake-up call to us all**

- **Near-term solutions that can double or quadruple BW Capacity**
  - **Add more DOCSIS channels (especially OFDM/OFDMA) and more CCAP ports**
  - **Perform Virtual Node Segmentation: from 1x1 to 2x2 to 4x4**
  - **Reclaim spectrum from video by leveraging IPTV, switched digital video (SDV)**
  - **In home: Add more DOCSIS 3.1 Modems; Add Wi-Fi 6 mesh routers**
- **BW will not snap back after Coronavirus… and will continue to grow through the decade**
- MSOs need to **begin upgrading their networks** with more aggressive BW Capacity for the future… the current BWs are a mere fraction of that which is coming…
  - **e.g. Fiber Deep, Node-splits, Mid-splits, High-splits, Ultra-High-splits, ESD**
  - **DAA will be the next step in the 10G Network Evolution**
    - **RMD (R-MACPHY) is the latest DAA technology to consider**

DOCSIS 3.1 & 4.0 are well-prepared to support both Short-term & Long-term BW needs of the future

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Q&A

Thank you!

john.ulm@commscope.com

now meets next

Award-winning innovation

BroadbandCommunities
BUILDING A FIBER-CONNECTED WORLD
MAGAZINE

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