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Broadband Battle Royale: Cable HFC vs FTTH

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COVID-19 Impact on U.S. Broadband

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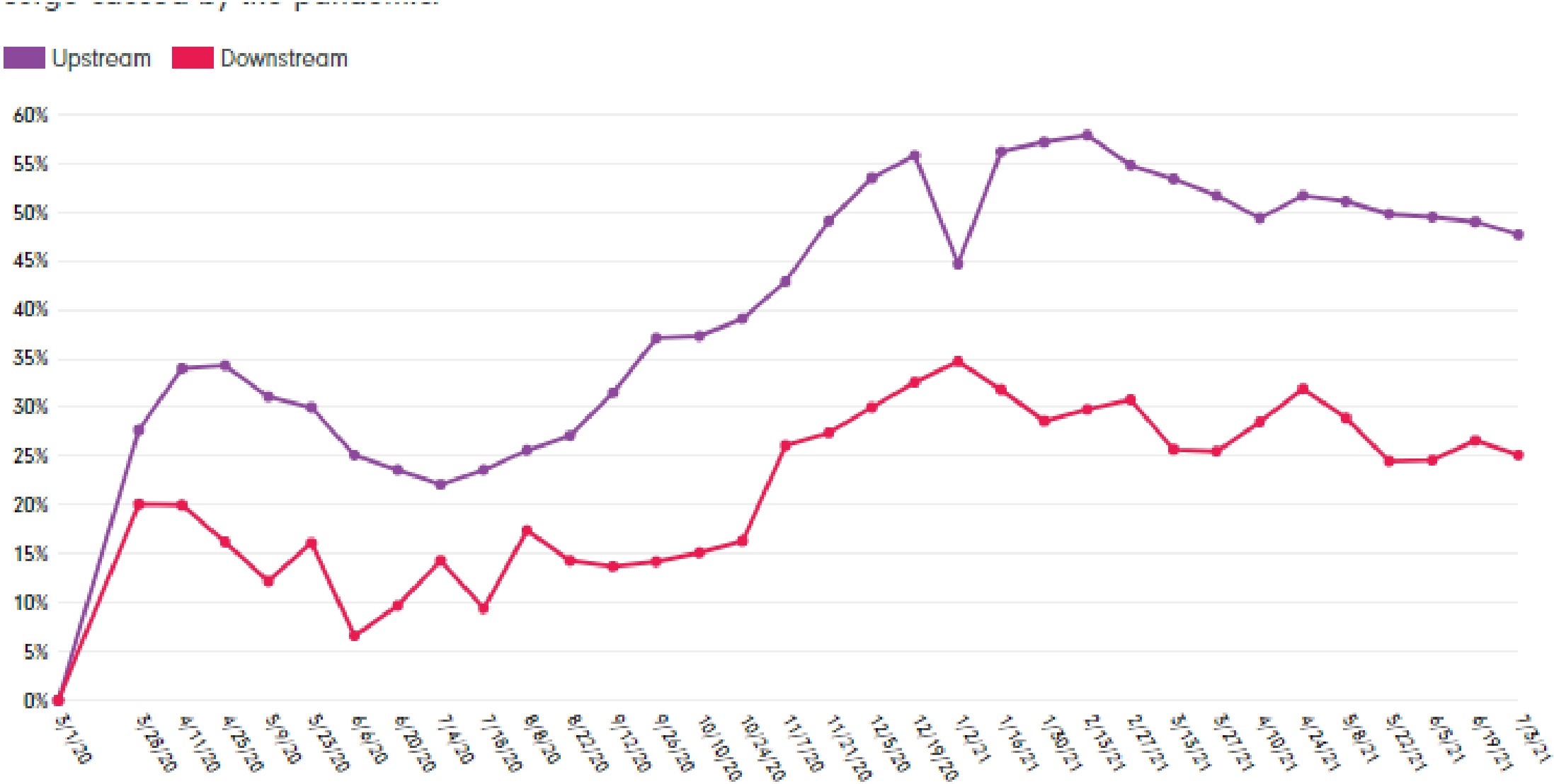
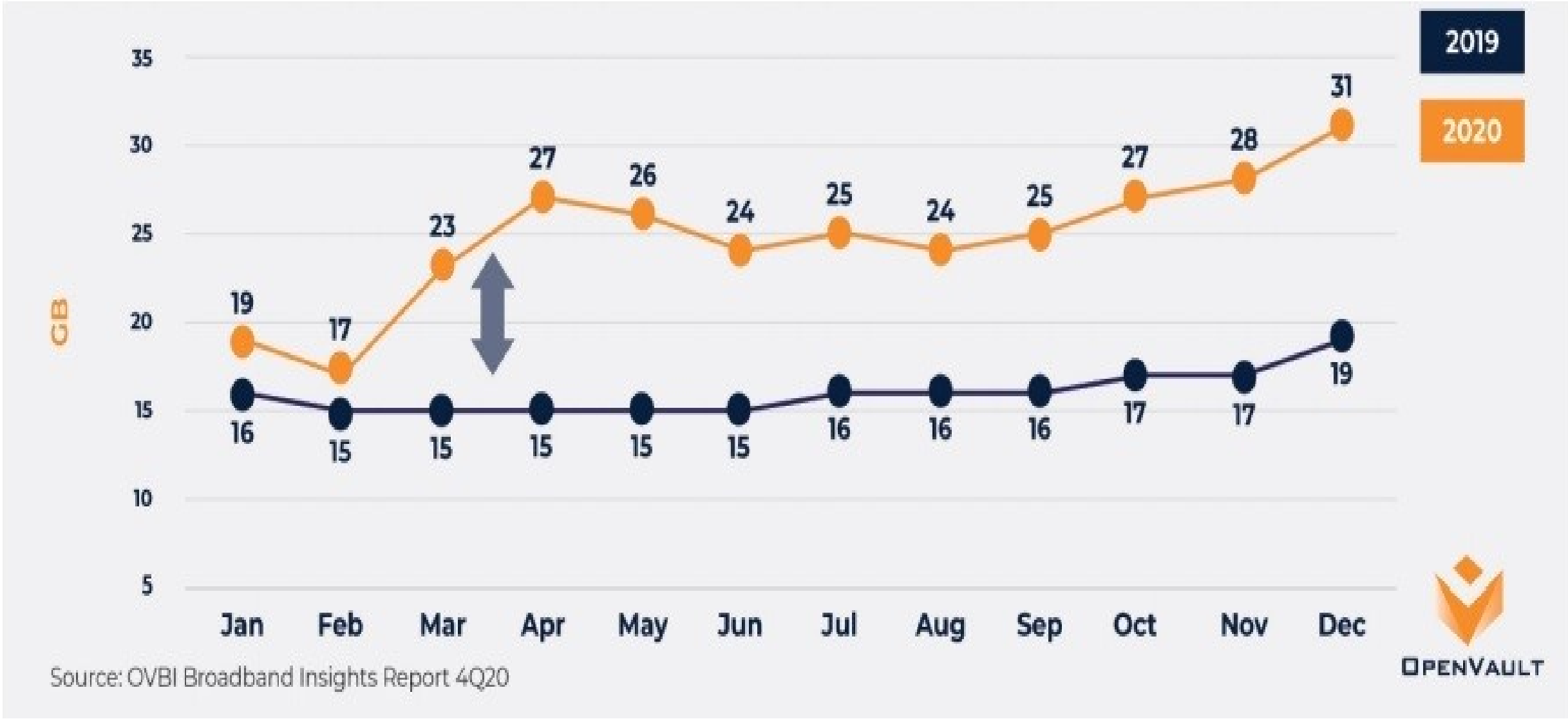
Both Upstream & Downstream Traffic Have Surged



Upstream Traffic Has Especially Surged



Source: OVBI Broadband Insights Report 4Q20

Biggest Broadband Drivers

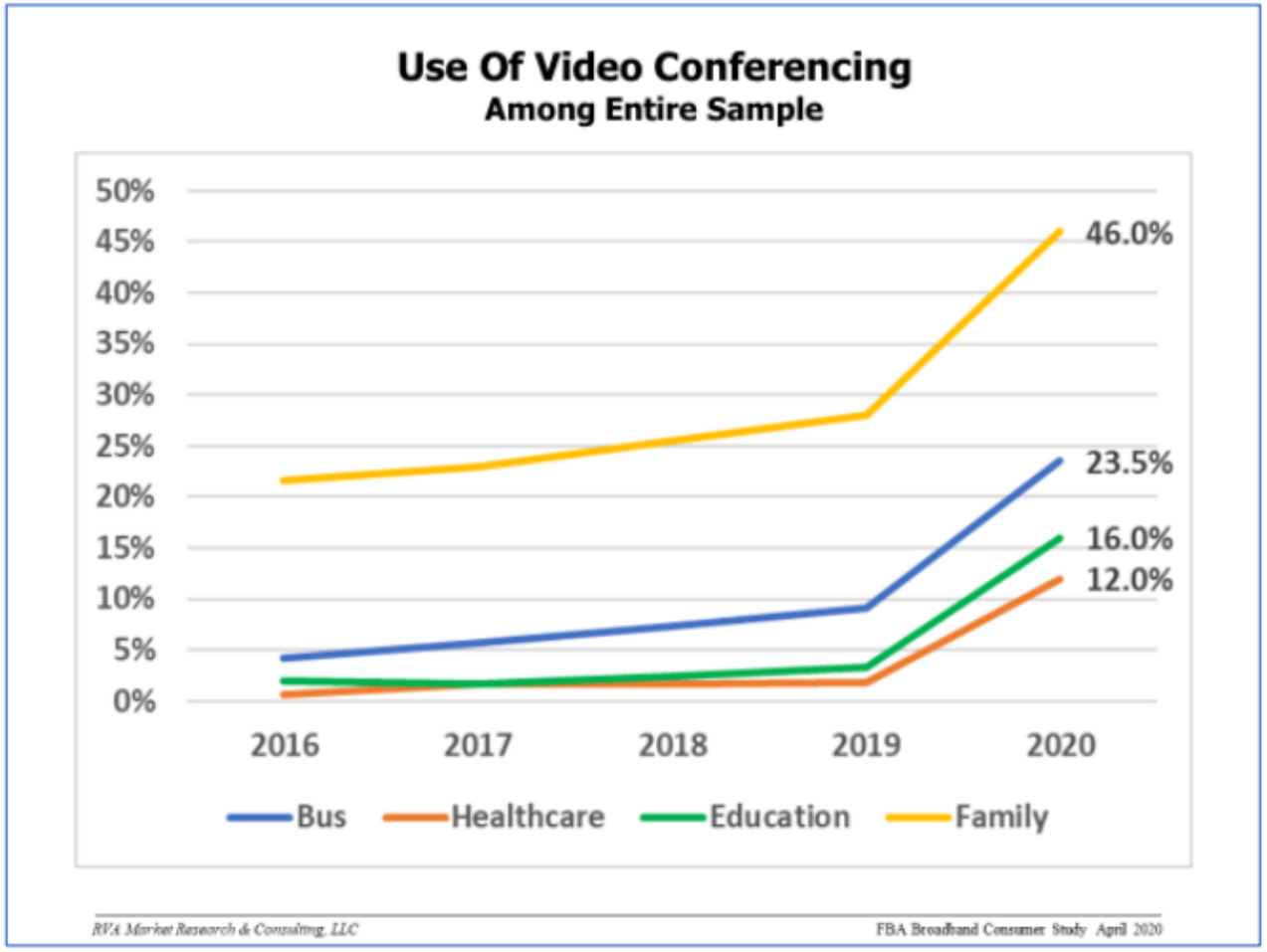
Online Gaming

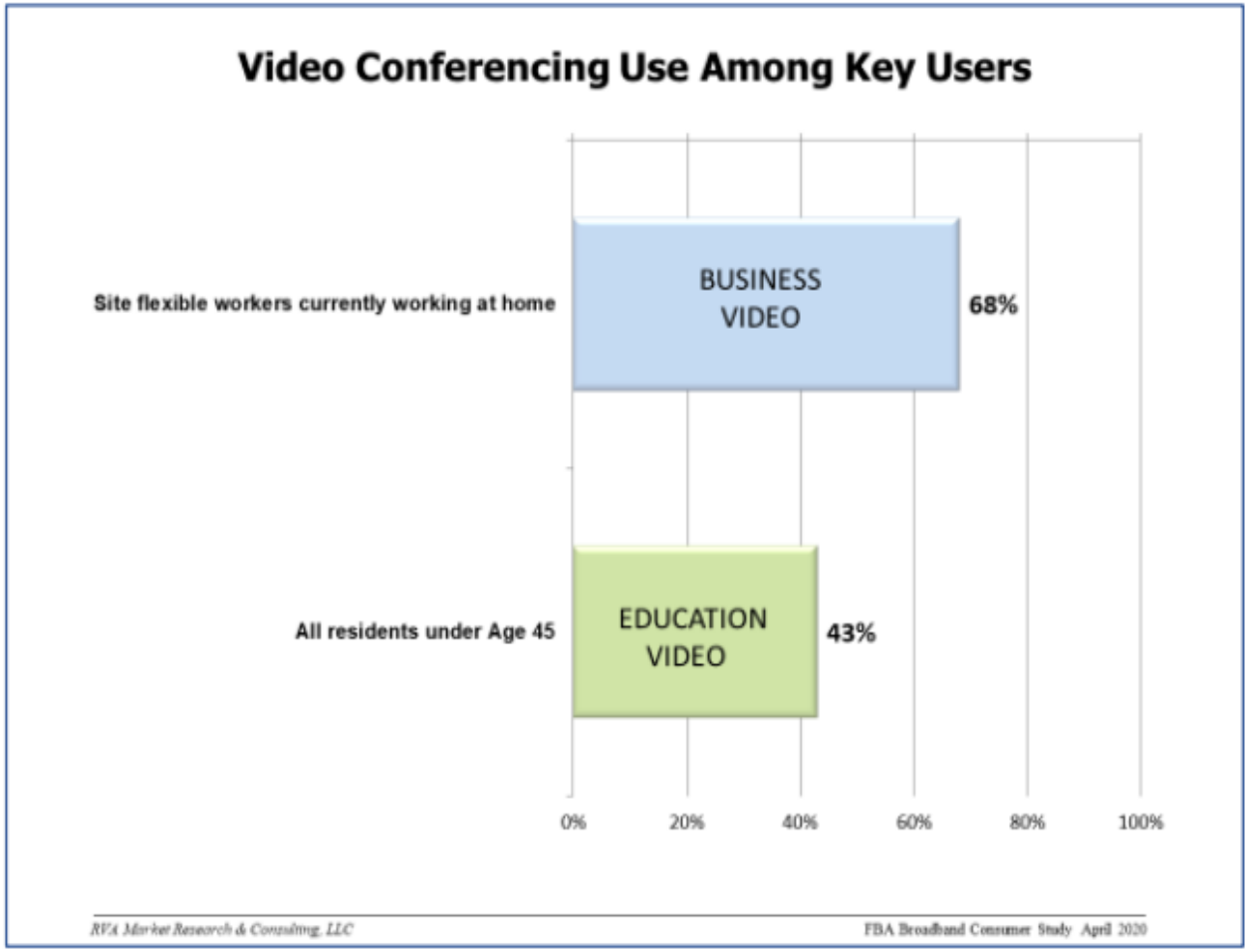
OTT

Teleconferencing

AR/VR

COVID-19 Impact on Broadband Services





U.S. Broadband Market Status Report

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Cable Scored Record Broadband Sub Gains in 2020

Cable Provider	2020 Net Subscriber Adds	Total Subscribers End of 2020
Comcast	1,971,000	30,600,000
Charter	2,215,000	28,879,000
Cox**	210,000	5.380,000
Altice USA	142,200	4,359,200
Mediacom	110,000	1,438,000
Cable One	101,000	857,000
WOW	32,300	813,800
Atlantic Broadband	37,871	504,621
TOTAL	**4,819,371**	**72,831,221**

Source: Leichtman Research Group

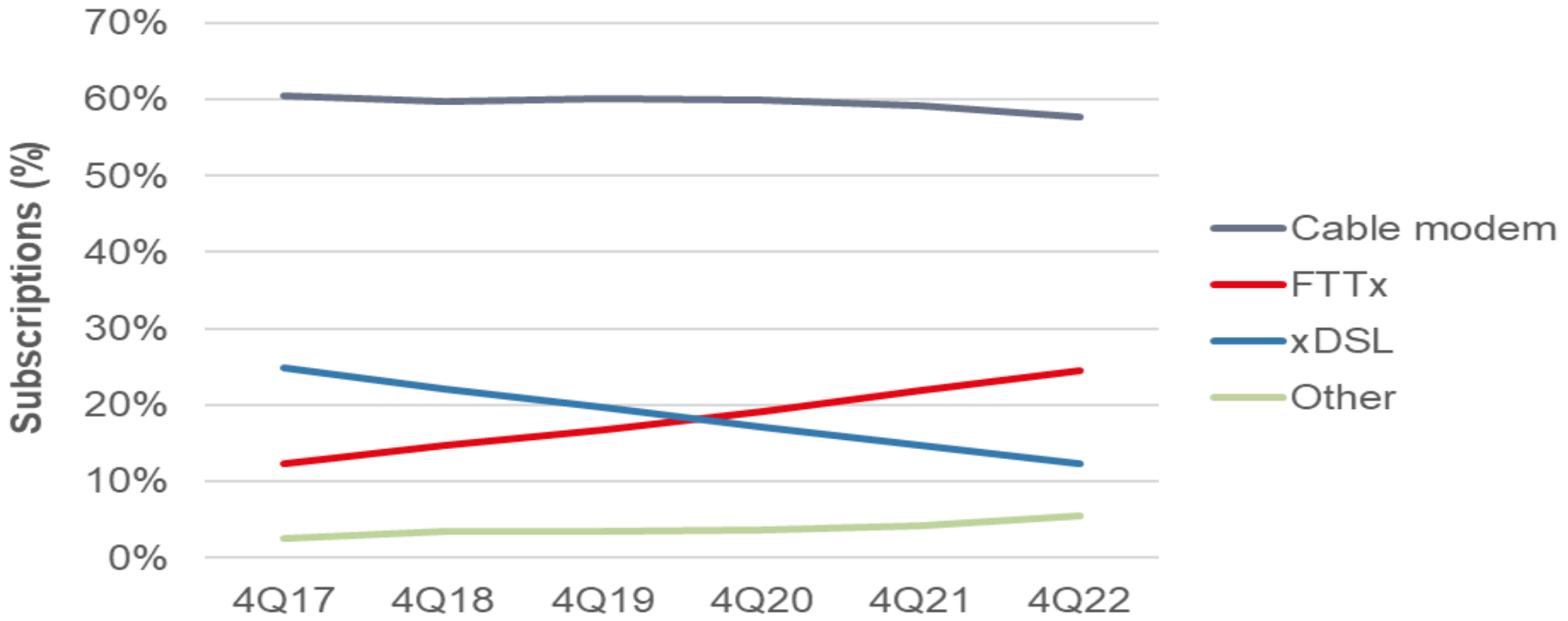
But Cable Broadband Sub Growth Slowed in 2021

Cable Provider	2021 Q3 Net Subscriber Adds	Total Subscribers Q3 2021
Comcast	300,000	31,688,000
Charter	265,000	29,899,000
Cox**	25.000	5,510,000
Altice USA	-13,200	4,388,100
Mediacom	-2,000	1,466,000
Cable One	13,000	1,030,000
Atlantic Broadband	3,000	717,000
WOW	1,600	509,500
TOTAL	**592,400**	**76,207,600**

Source: Leichtman Research Group

Meanwhile, FTTH Has Passed DSL & Is Now Gaining on HFC

Figure 1: North America broadband subscriptions by type, 4Q17–4Q22



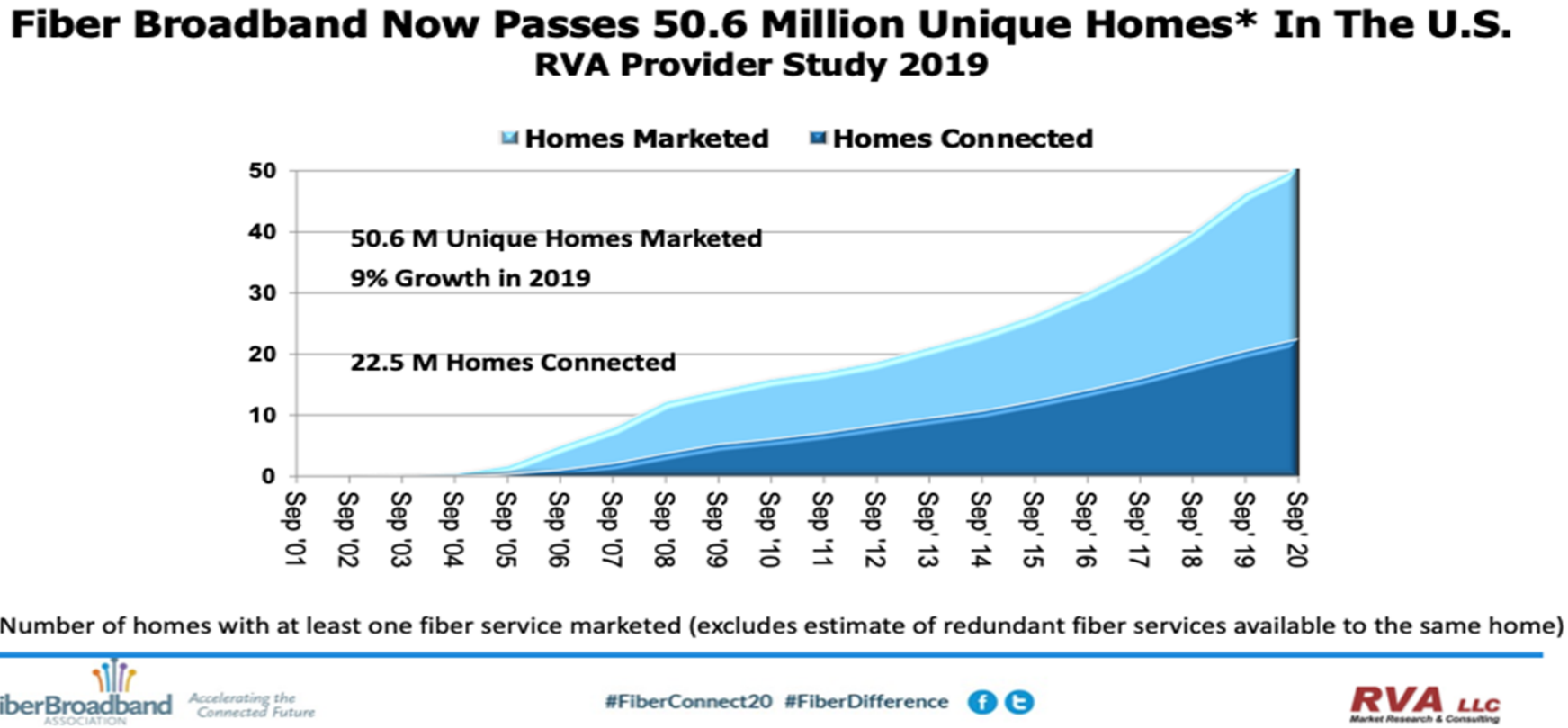
Source: Ovum

Source: Omdia

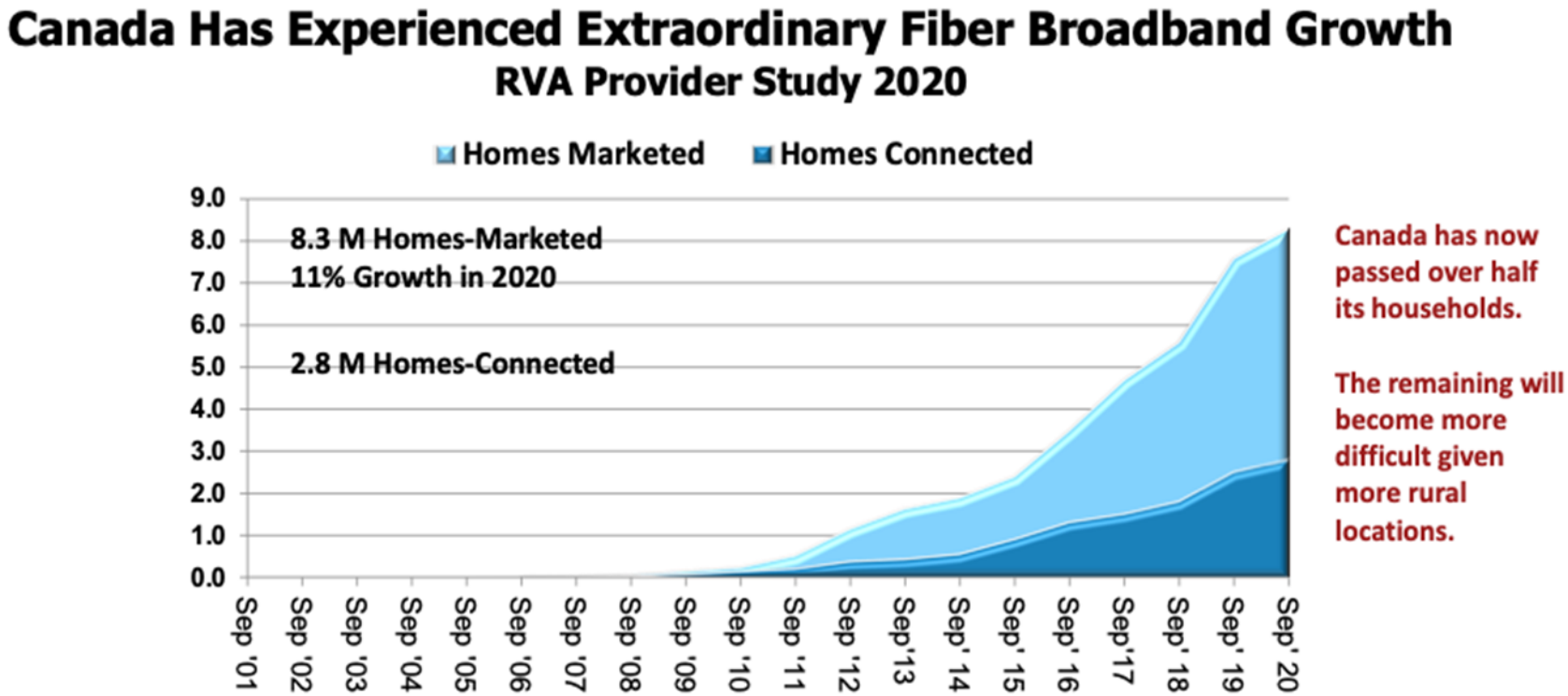
North American SPs Racing to Deploy Fiber

Service Provider	Fiber Plans & Deployments
AT&T	Added more than 1 million new fiber subscribers over past 4 quarters, boosting its total to over 15 million. Plans to extend fiber to 3 million more residential and business locations in 2021, including 2 m7llion homes. Has set goal of reaching 30 million locations with fiber by 2025. Reported 5.2 million AT&T Fiber customers at end of Q3 2021.
Verizon	Now passes more than 15 million homes with fiber. Plans to add another 2.8 million homes by 2030. Says its One Fiber project, which calls for expanding to 60 new markets, is almost complete. Reported 6.5 million Fios Internet customers at end of Q3 2021.
Altice USA	Now passes over 1 million homes with fiber. Plans to extend fiber to 500,000 more homes in 2021 and another 1.5 million homes over 2022 and 2023, including 400,000 "low-penetration and low-speed" homes by the end of 2022.
Bell Canada	Aims to spend up to C$1.2 billion over next 2 years to fast-track fiber, wireless and rural network rollouts. Plans to add up to 250,000 fiber and 150,000 wireless homes in 2021 and more in 2022. Predicted to have 6.9 million locations passed by fiber by end of 2021.
Lumen Technologies (CenturyLink)	Now passes about 2 million homes with fiber. Plans to extend fiber to 6.8 million locations by 2030.

Fiber Network Builds Surging in U.S.



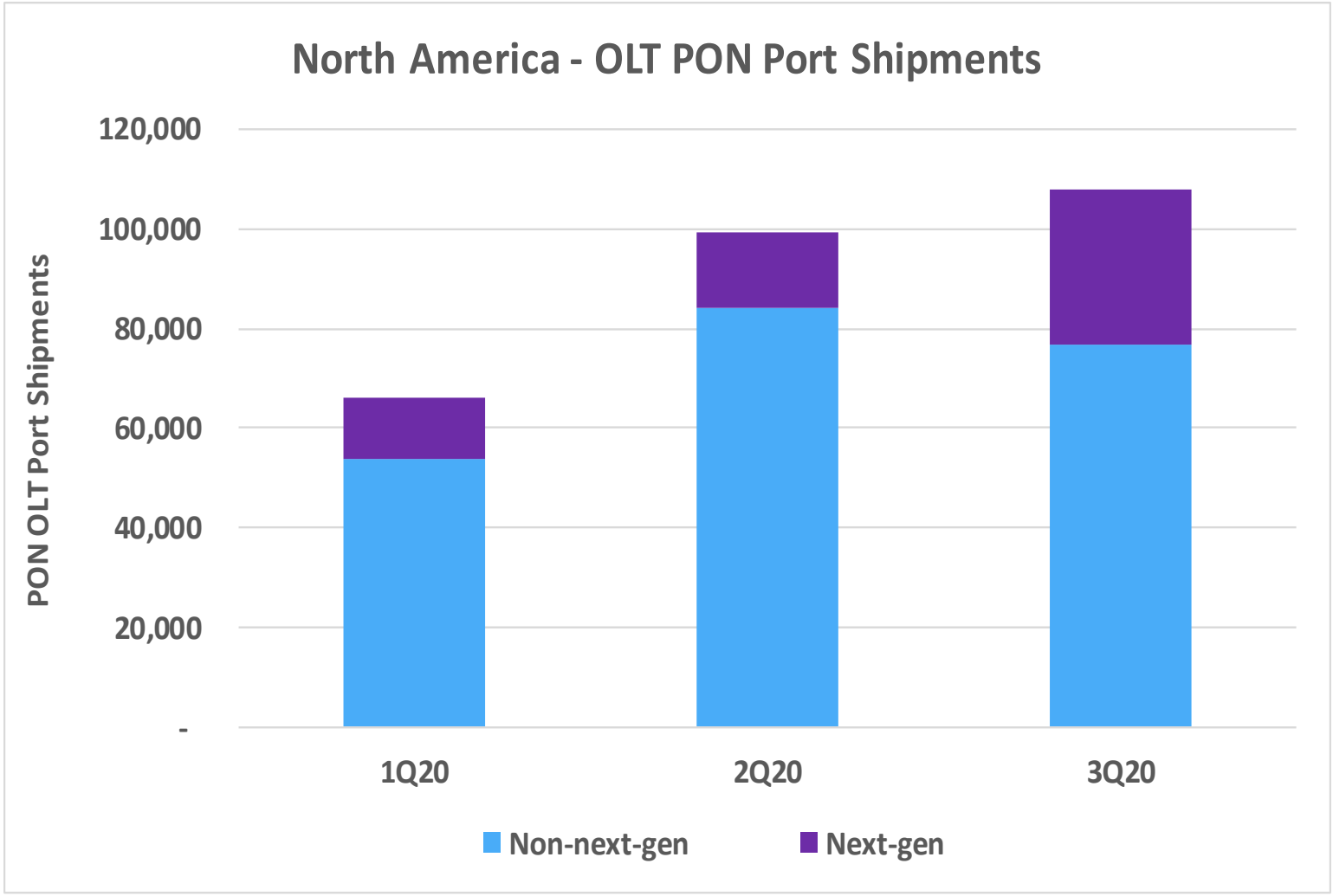
Fiber Builds Surging Even More in Canada



Growth of Next-Gen PON

North America – OLT Port Shipments - 2020

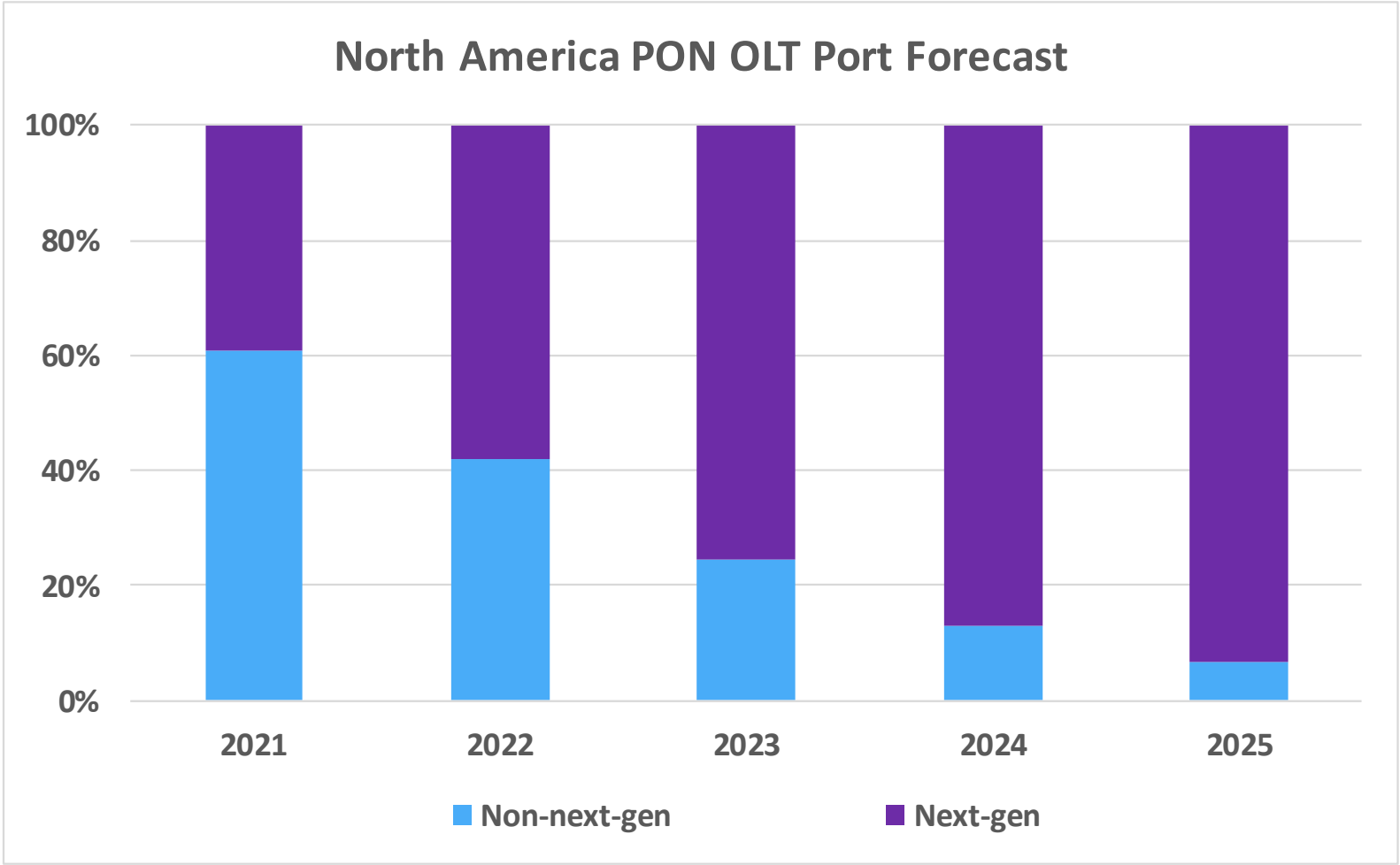
- Strong growth throughout 2020 in OLT port shipments; mirroring network builds and upgrades.
- Strong adoption of next-gen (includes 10G EPON, 10G GPON, and NG-PON2).
- In 3Q20, next-gen accounted for almost 30% of all shipments, compared to 19% in 1Q20.



Source: Omdia

North America – OLT Port Shipment Forecast 2021-2025

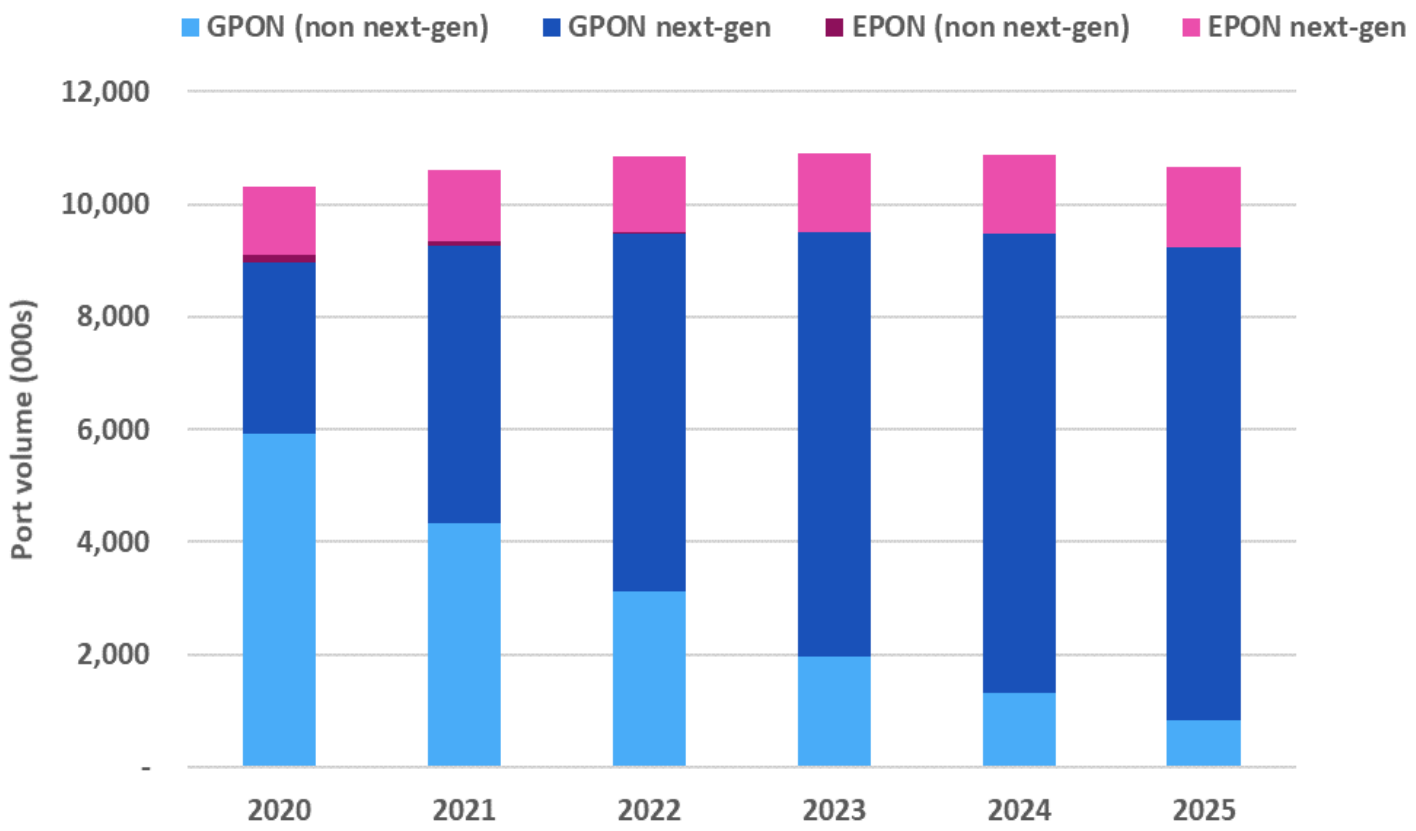
- Rapid adoption of next-gen PON OLTs.
- With volume deployments, ASPs continue to decline rapidly.
- 10G PON OLTs support:
  - 1G homes
  - SMEs
  - Smart city applications
  - xHaul transport – wireless backhaul



Source: Omdia

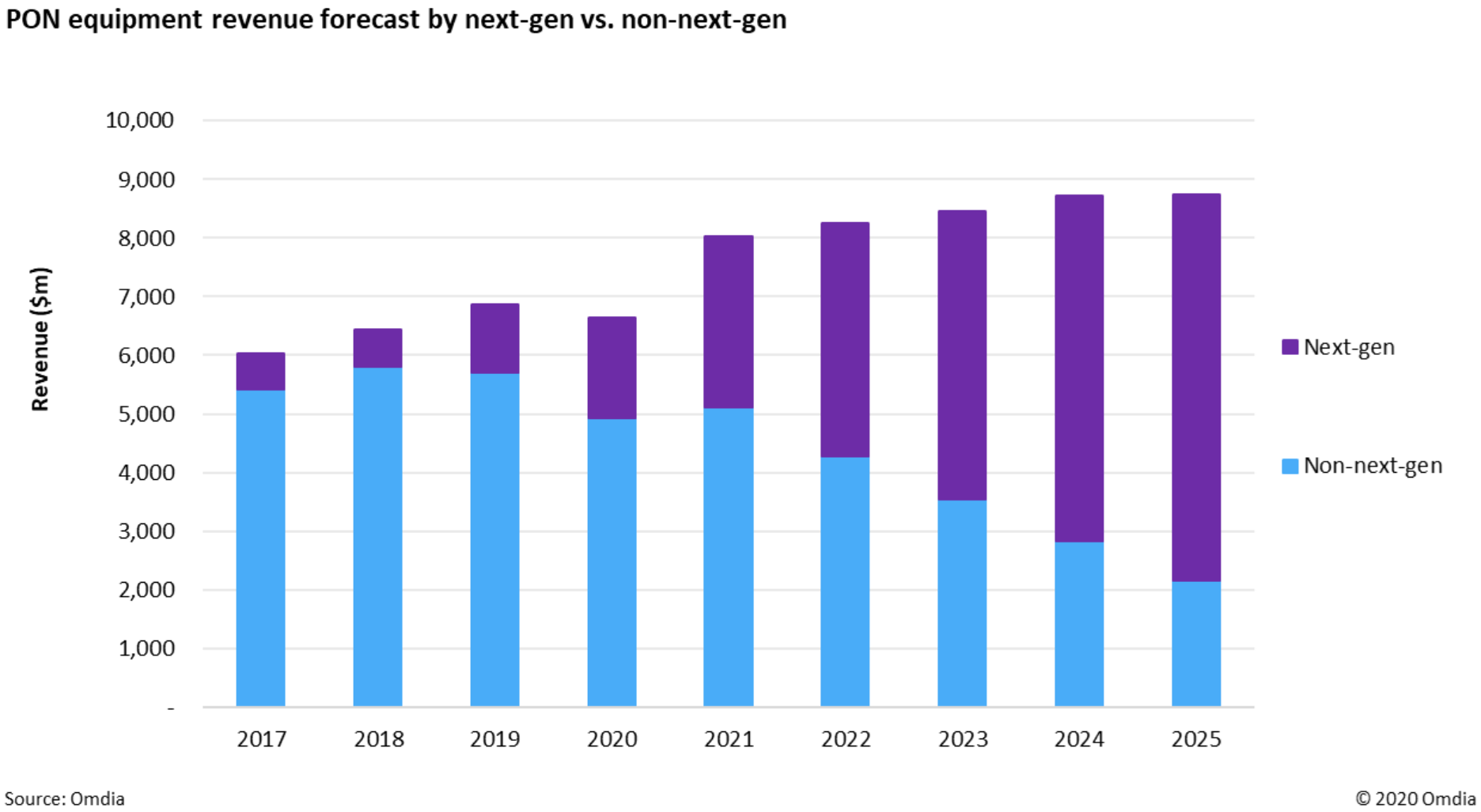
Global OLT Fort Shipment Forecast 2020-2025

- Aggressive next-gen forecast.
- AND strong total OLT forecast as PON is used for both residential and non-residential customers and applications.
- 2.5G GPON will take longer to fade away.
- 10G XGS-PON is rising rapidly.



Source: Omdia

Move to Next-Gen PON Drives Vendor Revenues



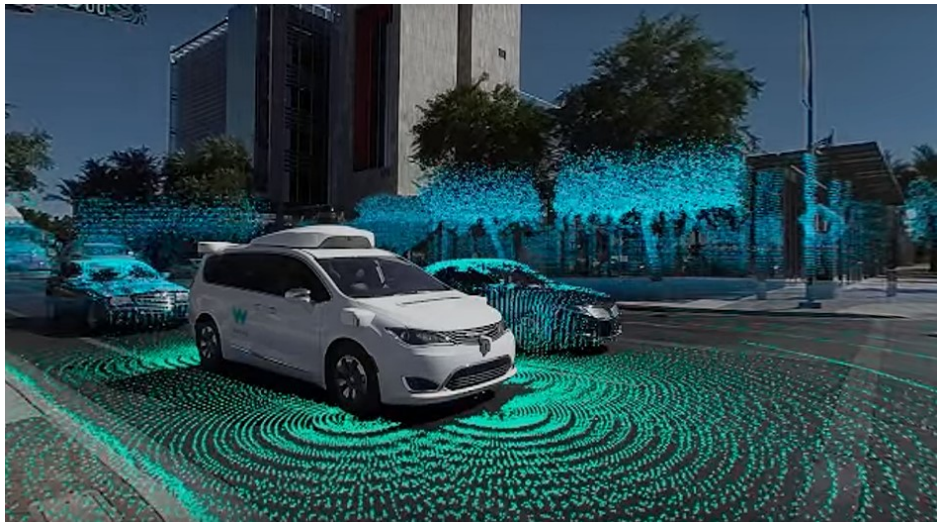
Source: Omdia

Emerging Next-Gen Wireless & Satellite Broadband Players

5G Mobile Spreads Wings

General Capabilities

- Faster speeds
- Super low-latency apps and services
- Spectrum agnostic
  - Low/mid/high spectrum bands
  - Licensed/unlicensed
- “Network slicing”



Applications & Services

- In-home broadband (as a fixed wireless service)
- The new mobility
- Automation: Factories, autonomous vehicles

Fixed Wireless Access Grows

- Small but growing segment
- Attention from big and small companies
- Millimeter wave – high speeds but faced with limitations
- Gathering attention from cable operators, notably Cable One/Sparklight & Charter

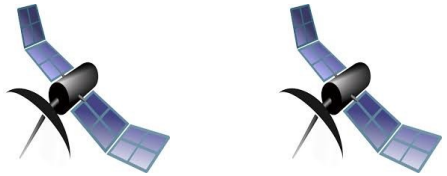
Sparklight™

Satellite Broadband Fires Up

Geostationary (GEO) orbit

- Orbit at ~22K miles
- Few satellites for broad coverage
- High latency (~600ms)
- Viasat: 603,000 subs
- HughesNet: 1.58M subs

Medium-Earth orbit (MEO)



- Orbit at ~5K miles
- Dozens of satellites for coverage
- Lower latency (~120ms)
- SES O3b and O3b mPOWER

Low-Earth orbit (MEO)

- Orbit at ~300-350 miles
- Hundreds to thousands of satellites for coverage
- Low latency (~50ms)
- SpaceX (Starlink)
- Amazon (Kuiper)
- OneWeb

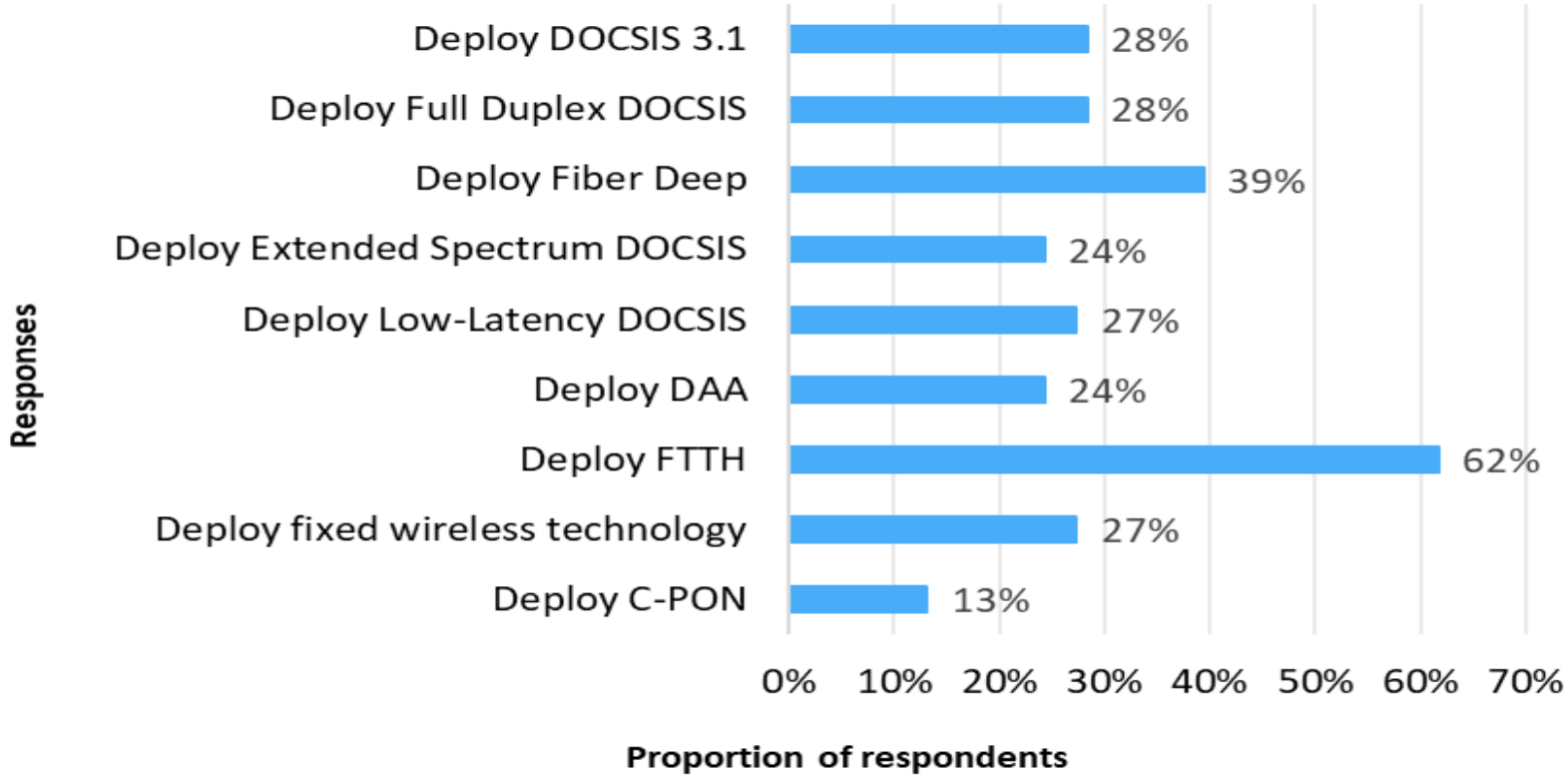
Cable’s Competitive Strategy

Cable's Competitive Options

- Boost existing capacity of HFC networks
- Pull fiber deeper in network and split more optical nodes
- Upgrade upstream capacity by increasing spectrum amount
  - Mid-Splits (5MHz-85MHz)
  - High-Splits (5MHz-204MHz)
- Prep HFC plant for DOCSIS 4.0 upgrades
- Pursue FTTH builds in greenfield and adjacent edge-out areas
- Employ AI, automation and ML to boost network efficiency
- Leverage benefits of DAA, network virtualization, edge computing and other next-gen technologies

Types of HFC Network Upgrades Planned

Which types of network upgrades does your company plan to carry out over the next five years (by fall 2026)? (Select all that apply.)



Source: Omdia

Most North American MSOs Have Rolled Out DOCSIS 3.1

MSOs	Deployments
Comcast	Now offers DOCSIS 3.1 to virtually whole footprint after completing rollout in Oct. 2018.
Charter Communications	Now offers D3.1 to about 95% of its footprint; aimed to wrap up rollout by end of 2018.
Cox Communications	Now offers D3.1 to over 50% of its footprint; plans to reach 99% coverage by end of 2019.
Altice USA	Despite plans to build FTTH networks, now quietly rolling out D3.1 in New York area
Mediacom Communications	One of the first MSOs to deploy D3.1, it now offers service to virtually all its footprint
Shaw Communications	Now offers D3.1 service to virtually all its Canadian homes, using Comcast's Xb6 modems.
Midco	Another early D3.1 adopter, it now offers service to over 90% of its footprint
WOW	Has now rolled out D3.1 to at least 95% of its footprint
Rogers Communications	Now offers D3.1 service to virtually all its Canadian homes, using Comcast's Xb6 modems.
Cable One	Now offers 1-Gig service to 95% of footprint; but relying solely on D3.0, not D3.1.
RCN	Offers D3.1 in all legacy markets; now upgrading former Wave Broadband markets
Atlantic Broadband	Has rolled out DOCSIS 3.1 to 90% of its footprint
BCI	Now offers D3.1 to 99.9% of homes in footprint.
Videotron	Has broadly deployed DOCSIS 3.1 throughout its Quebec markets.
Cogeco Connexion	Now offers D3.1 service Has to 60% of its Ontario & Quebec homes.

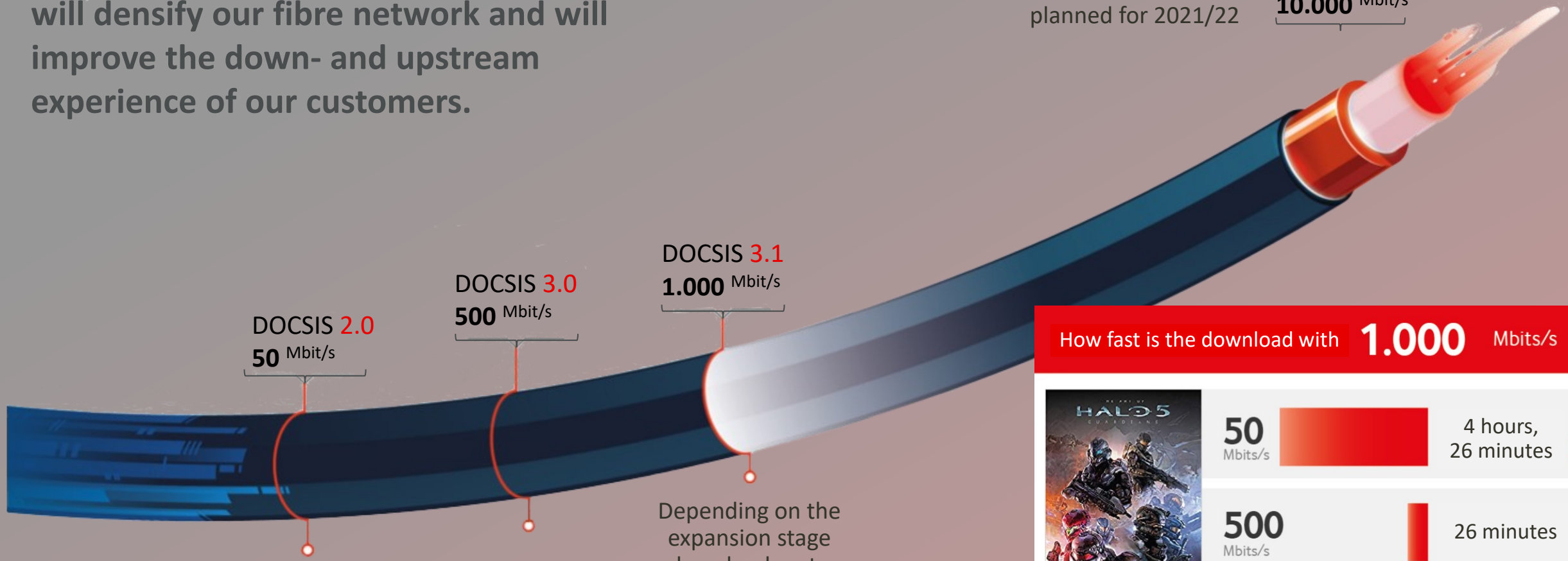
While DOCSIS 3.1 Era Well Underway in Europe too

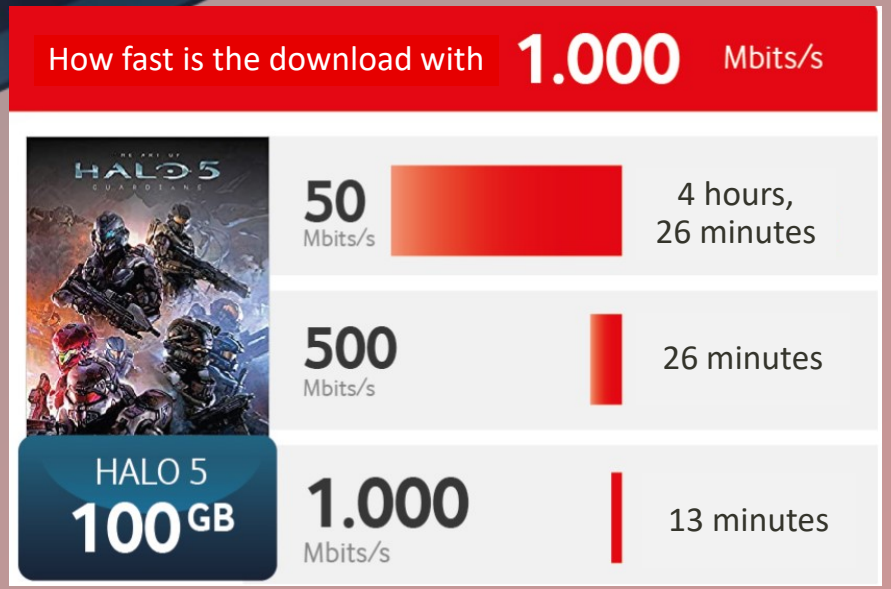
MSO	Deployments
Liberty Global	Plans to offer DOCSIS 3.1 service to its nearly 15 million UK homes by the end of 2021, after starting with Southampton and Manchester launches this fall.
Vodafone	Launched D3.1 in four Bavarian cities in fall 2018, covering 400,000 homes. Aims to offer service to 13 million German homes by the end of 2020.
Com Hem (Tele2)	Has upgraded most of its HFC network in Sweden for D3.1, with many small sites left.
Stofa	Has now deployed D3.1 & DAA to 60% to 65% of its 400,000-home network in Denmark, with plans to reach 90% to 95% coverage by spring 2021.
TDC	Planned to complete rollout of D3.1 in Denmark by the end of 2018.
NOS	Has completed full network upgrade to D3.1 in Portugal and developed D3.1 routers.
Telenet	Started rolling out D3.1 service in Belgium in Sept. 2019.
Eltrona	Launched D3.1 service in Luxembourg in September 2018.
Melita	Completed upgrading its Malta network to D3.1 in April 2019.

The speed increases:

THE EVOLUTIONARY LEAPS OF DOCSIS

Through the 'Fibre Deep' approach we will densify our fibre network and will improve the down- and upstream experience of our customers.





Introducing DOCSIS 4.0

FDX ESD

- Multi-Gigabit speeds, support for symmetrical services:
  - 10 Gbit/s downstream and up to 6 Gbit/s upstream
- Support for lower-latency applications (online gaming, telemedicine, etc.)
- Enhanced security
- Two technological approaches:
  - Full Duplex DOCSIS (FDX)
  - Extended Spectrum DOCSIS (ESD)
- Specifications released by CableLabs in March 2020
- First prototype products could emerge in 2021, with certification testing to follow in 2022
- Work on 3GHz technology already underway (DOCSIS 5.0?)
- Ties into industry's broader, multi-access "10G" initiative

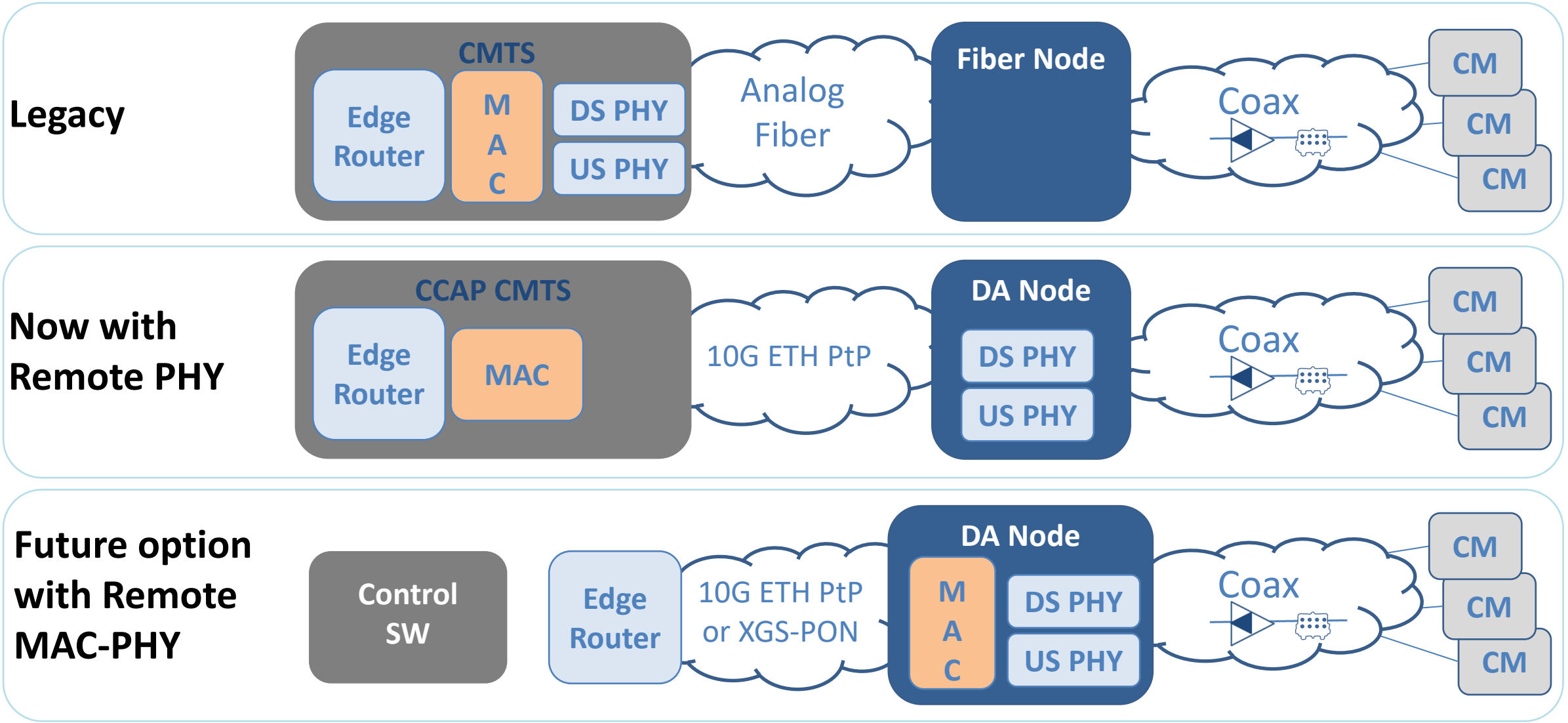
Cable's Great 10G Quest

- Concept introduced at 2019 CES to counter launch of 5G wireless
- Access network agnostic: HFC, FTTP, wireless
- Targeting symmetrical speeds of 10 Gbit/s
- Enhanced security and lower latency benefits

Cable's Great 10G Quest

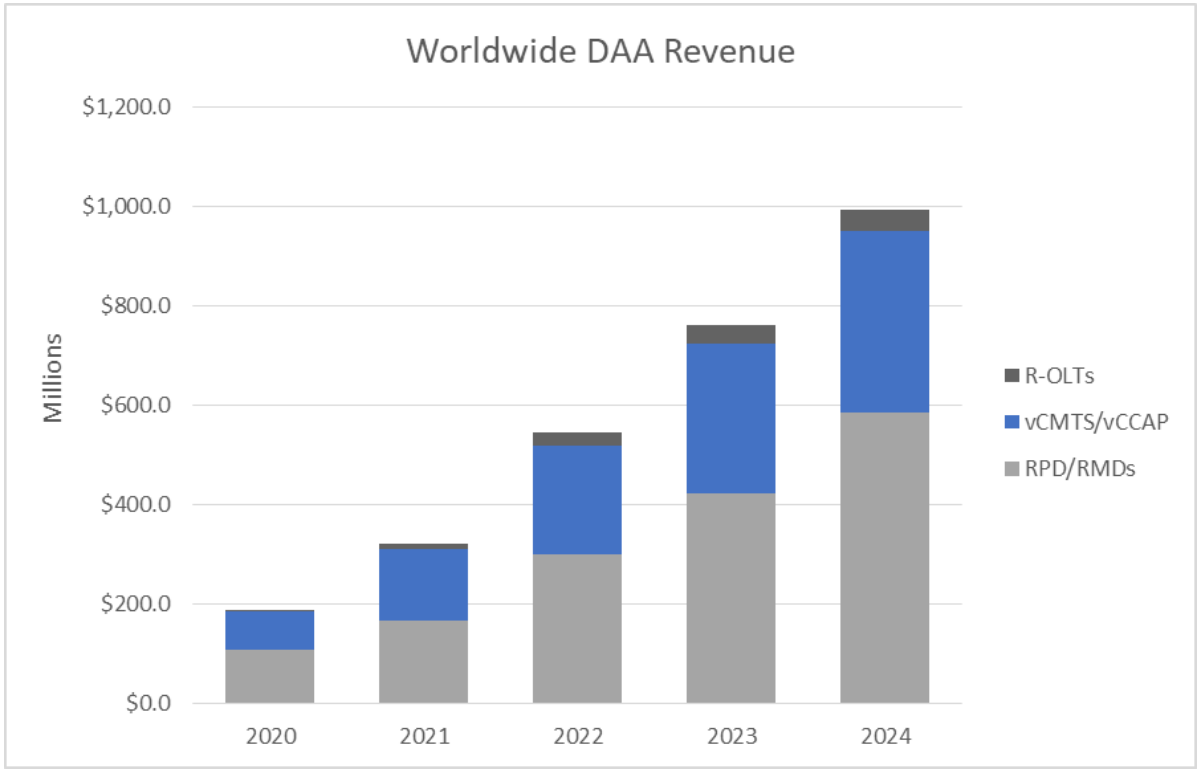
- Mediacom conducts 10G Smart Home demo in Ames, Iowa
- Comcast tests symmetrical 1.25 Gbit/s on HFC in Jacksonville, Fla.
- Virgin Media trials symmetrical 2.2 Gbit/s on HFC in Southampton & Manchester
- Comcast tests symmetrical 4+ Gbit/s over HFC (FDX) in Denver lab trial
- Comcast tests symmetrical 4 Gbit/s over D4.0 modems in another Denver lab trial
- Charter tests 8.5 Gbit/s downstream and 6 Gbit/s upstream in D4.0 lab trial
- Vodafone Germany plans to conduct D4.0 field trials by early 2022
- Comcast eyes FDX Amplifier trials in 2022

DOCSIS Distributed Access Evolution



CCAP Converged Cable Access Platform; PON – Passive Optical Network; MAC – Media Access Control; CM – Cable Modem

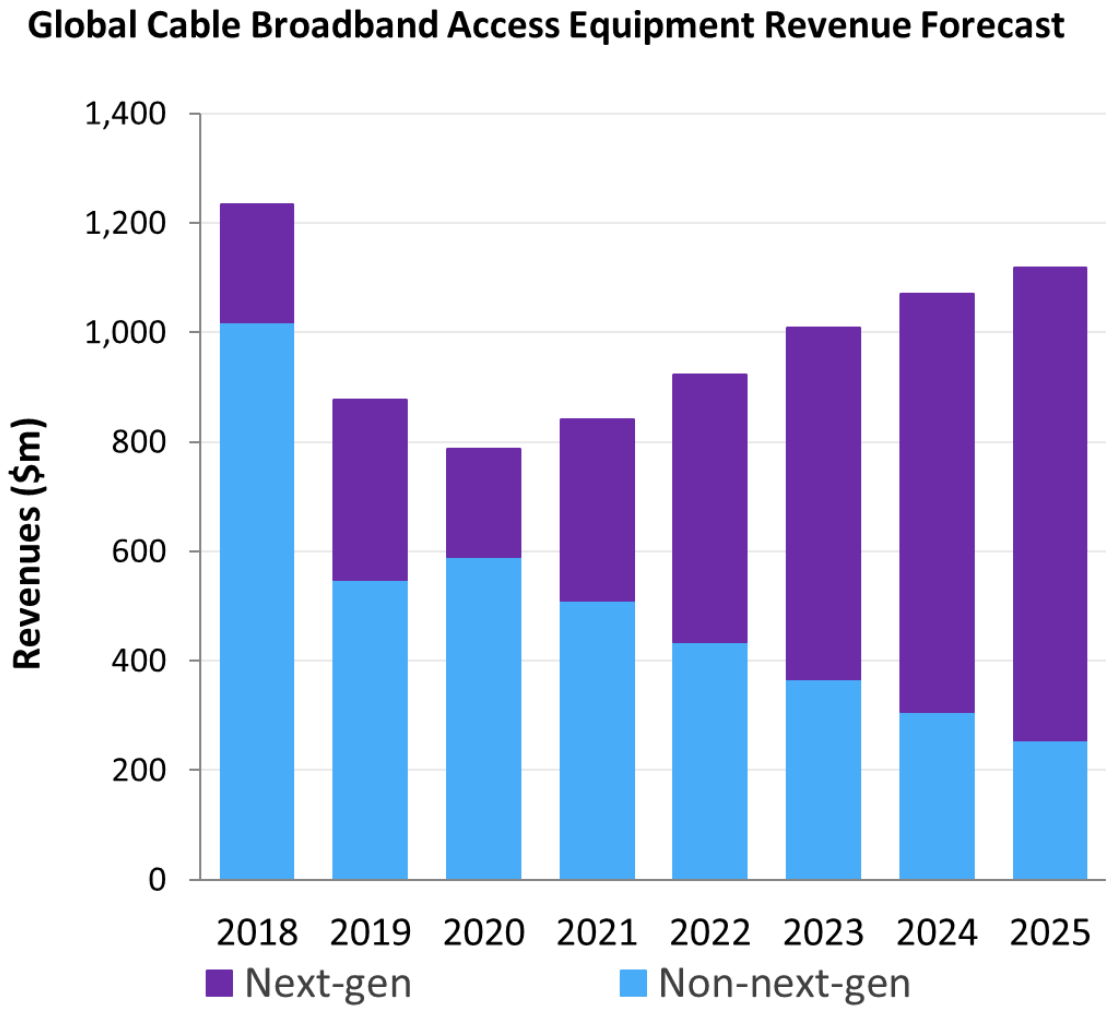
DAA Growth Will Pick Up Speed in 2022



- Modest growth expected in 2021 as focus remains on shoring up upstream bandwidth via mid- and high-split architectures
- 2022 will see larger R-PHY and R-MACPHY deployments to improve MER and as part of DOCSIS 4.0 transition to 1.2GHz

DAA Momentum Will Transform Cable Market

- Omdia's cable broadband access equipment forecast – updated August 2020.
- Next-gen technologies include vCMTS/CCAP, Remote PHY/Remote MACPHY Devices and Shelves, and DAA Fiber Nodes.
- Post-pandemic, market will regain momentum, approaching $1.2B in 2025.
- By 2025, next-gen technologies will make up 75%+ of global cable access equipment revenues.



Source: Omdia

Thank You! Questions?