Keynote
Broadband Trends

Dan Grossman

Principal, NetAccess Futures

dan@netaccessfutures.net

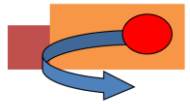
NetAccess Futures

Some Content Courtesy
Of Jeff Heynen
Dell'Oro Group

Personal Introduction

- Broadband Industry Analyst And Thought Leader
- Technology, Business, Policy
- 47-Year Veteran Of Telecom And Datacom Equipment Industry
- Worked in Residential Broadband Space Since The Beginning

International Telecommunication Union



Key Trends

- The US is Now the Largest Market for Broadband Equipment
- Fiber-To-The-Premises (FTTP) Booming
- Hybrid Fiber-Coax (HFC) Giving Way To FTTP
- Fixed Wireless Access Starting to Plateau?
- What About LEO?
- Supply Chain Pain Proliferates
- AI Blah, Blah
- An Era of Abundance
- Things That Go Bump In the Night

US Broadband Markets

US Takes The Lead In New Fiber Deployments

- China And Parts Of East Asia Are Fully Built Out, Replacement Cycle Beginning
- Other Wealthy Countries Nearing Full Build-Out
- US Has Lagged In Fiber But Led In Broadband
- Boom In Fiber Deployments Until ~2030
  - Copper Retirement
  - Private Investment In Overbuilders and Tier-2 Telcos
  - Closing The Digital Divide

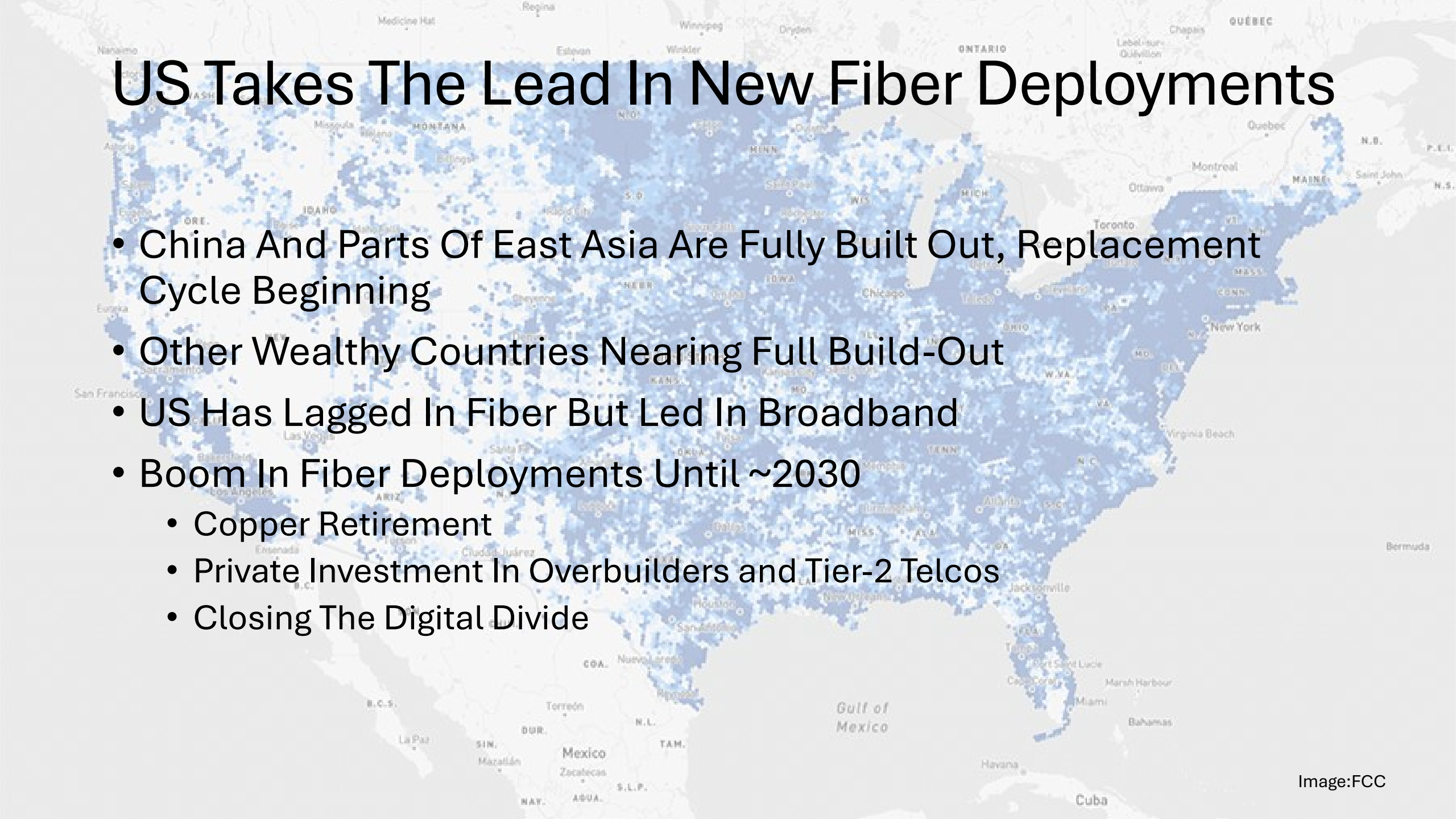


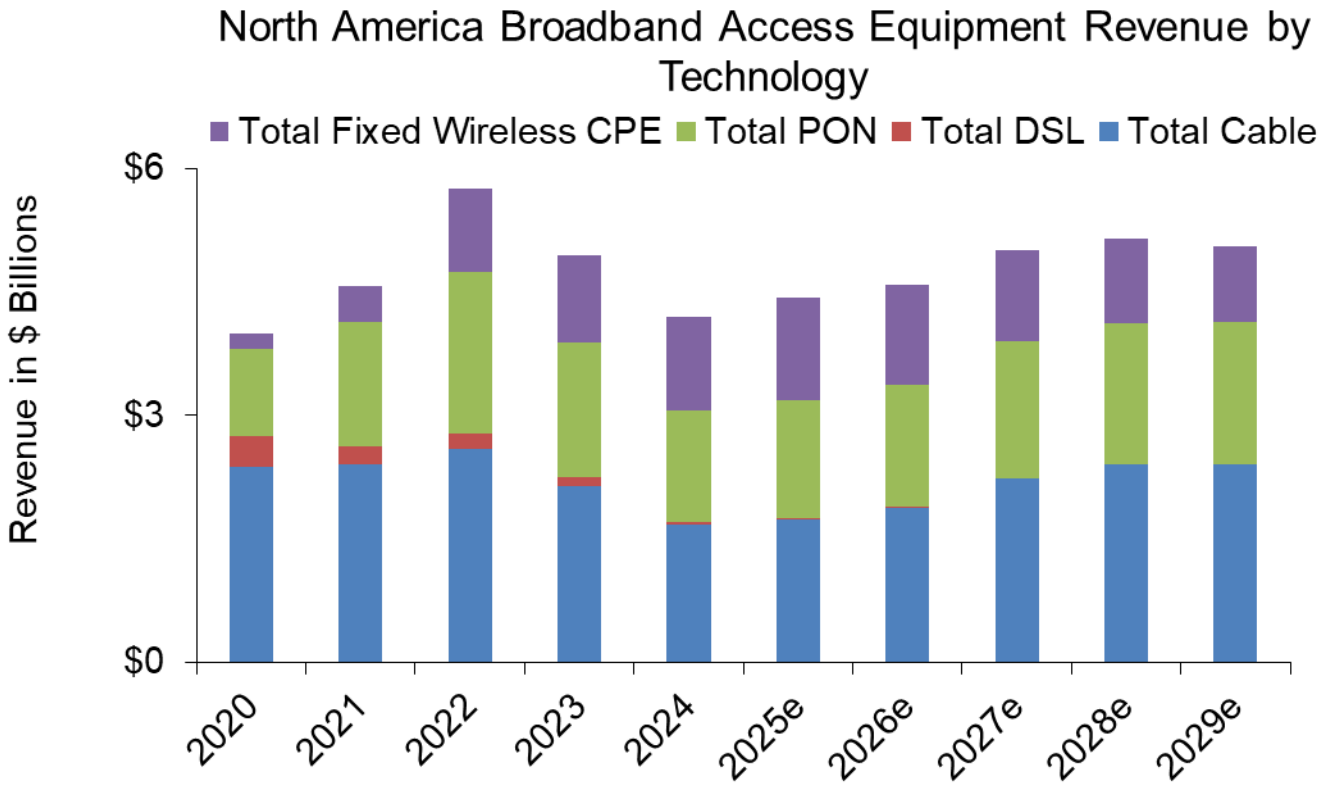
Image:FCC

US Broadband By the Numbers (1H 2025)

- Terrestrial Broadband Coverage: 133 M (94% US Homes Passed)
- Fiber Coverage:84.6 M (60%) US Homes Passed
- Cable Coverage: 112 M (80%) US Homes Passed
- Licensed Fixed Wireless (FWA) Coverage: (≥100/20 Mbps): 52.2 M (37%)
- Gigabit-Capable Coverage: 90% US Homes Passed
- All Competition: 71% US Homes Have Competing Broadband Providers
- Fiber Competition: 17.3 M (16%) US Homes Have Competing Fiber Providers
- Fiber Opportunity: 129.2M Commercially Viable Homes (Incl. Second Passings
- New Fiber Construction: 11.8 M New Passings (3Q24-3Q25)
- Fiber Take Rate: 46.5% (Unique Homes Passed) 40% (All Passings)

Sources: RVA for Fiber Broadband Association, Cartesian, FCC

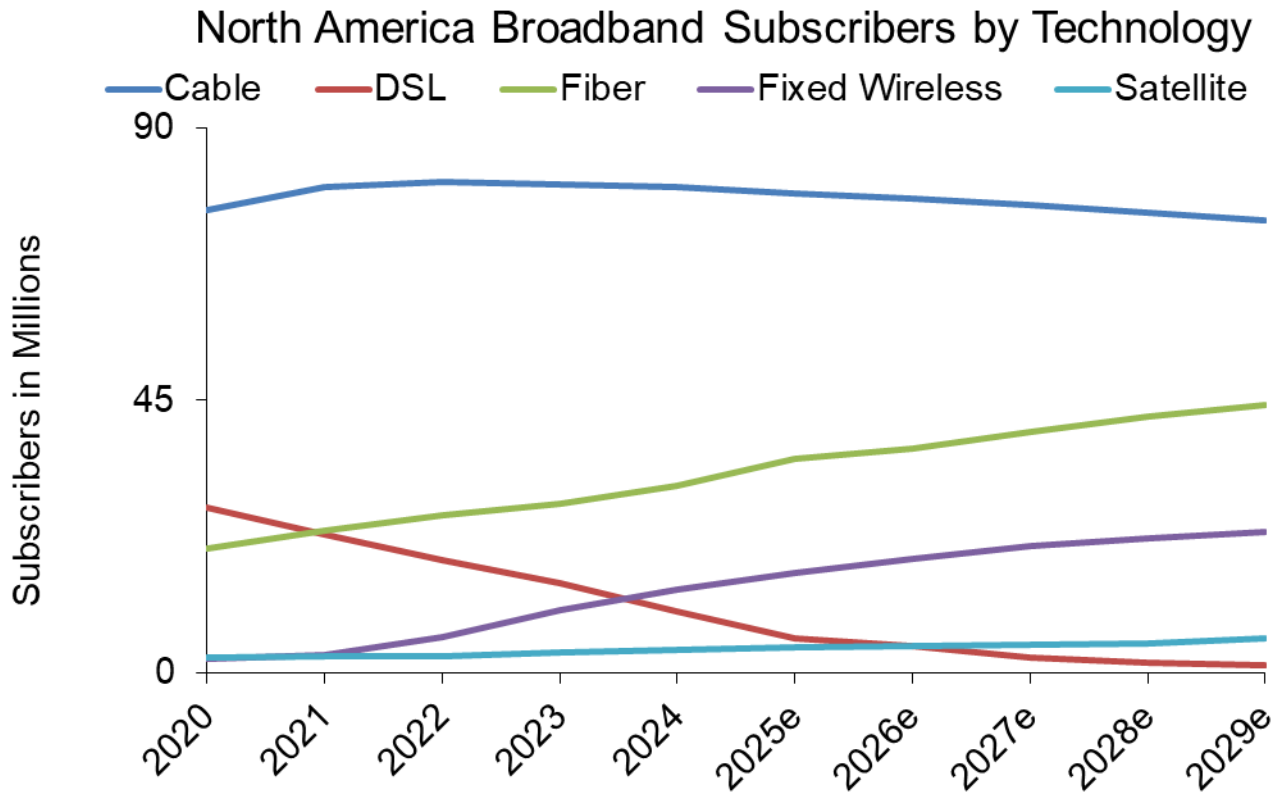
Spending Environment Improving, Thanks to PON and FWA



Passive Optical Network

- Some purchases pulled forward to avoid tariffs
- Fiber expansion plans re-affirmed and accelerated
- FWA CPE spending growing consistently
- DOCSIS 4.0 upgrades focused on outside plant for now

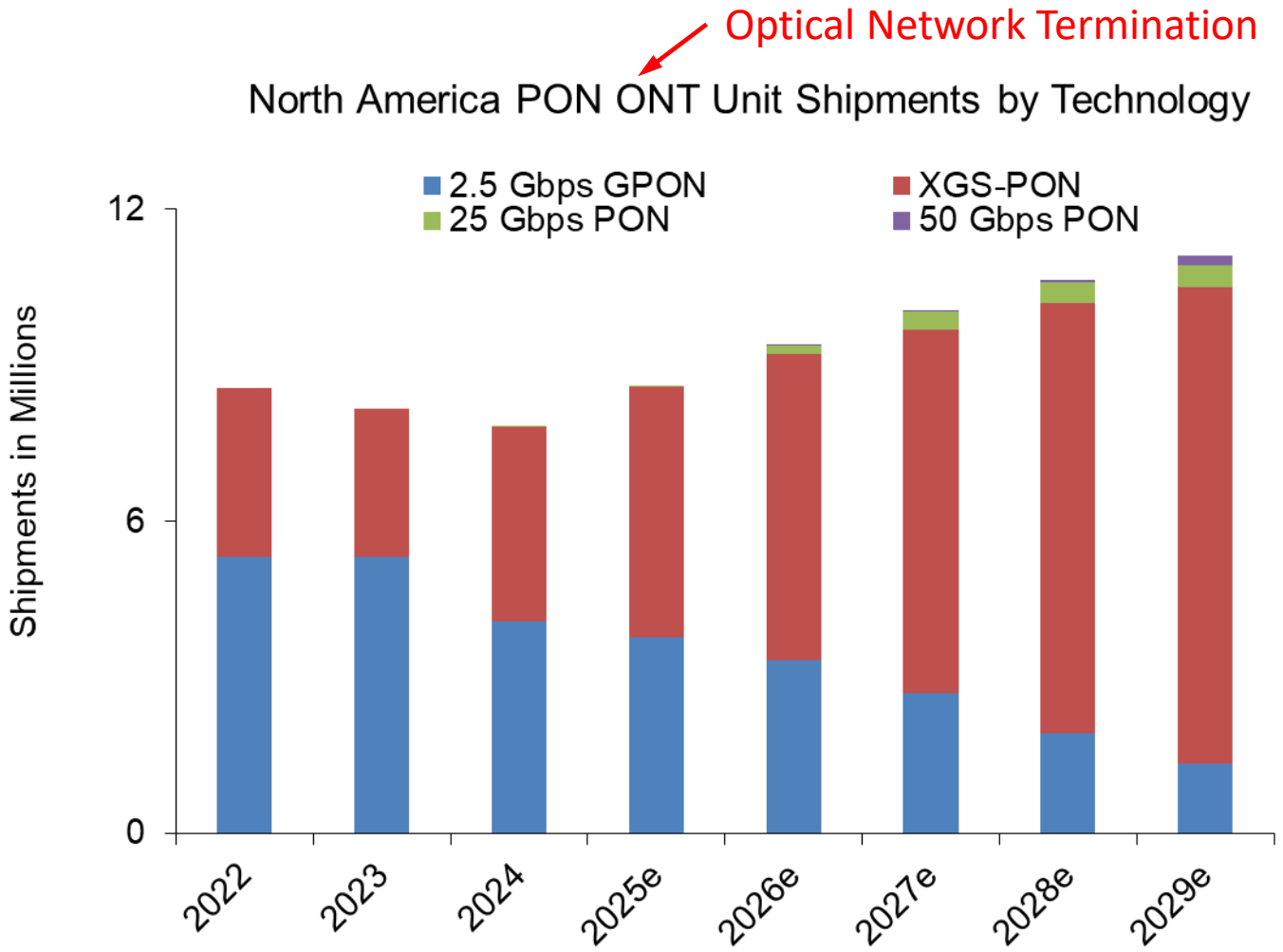
Fiber and FWA Growing at Expense of Cable



- From 2024 to 2029, fiber grows from 22% to 29% of residential subscribers
- FWA grows from 10% to 16%
- Satellite grows from 2.7% to 4%
- Cable declines from 57.8% to 51%
  - Average subscriber losses of 1-1.2M annually,
  - Stabilizing by 2030

Markets By Technology

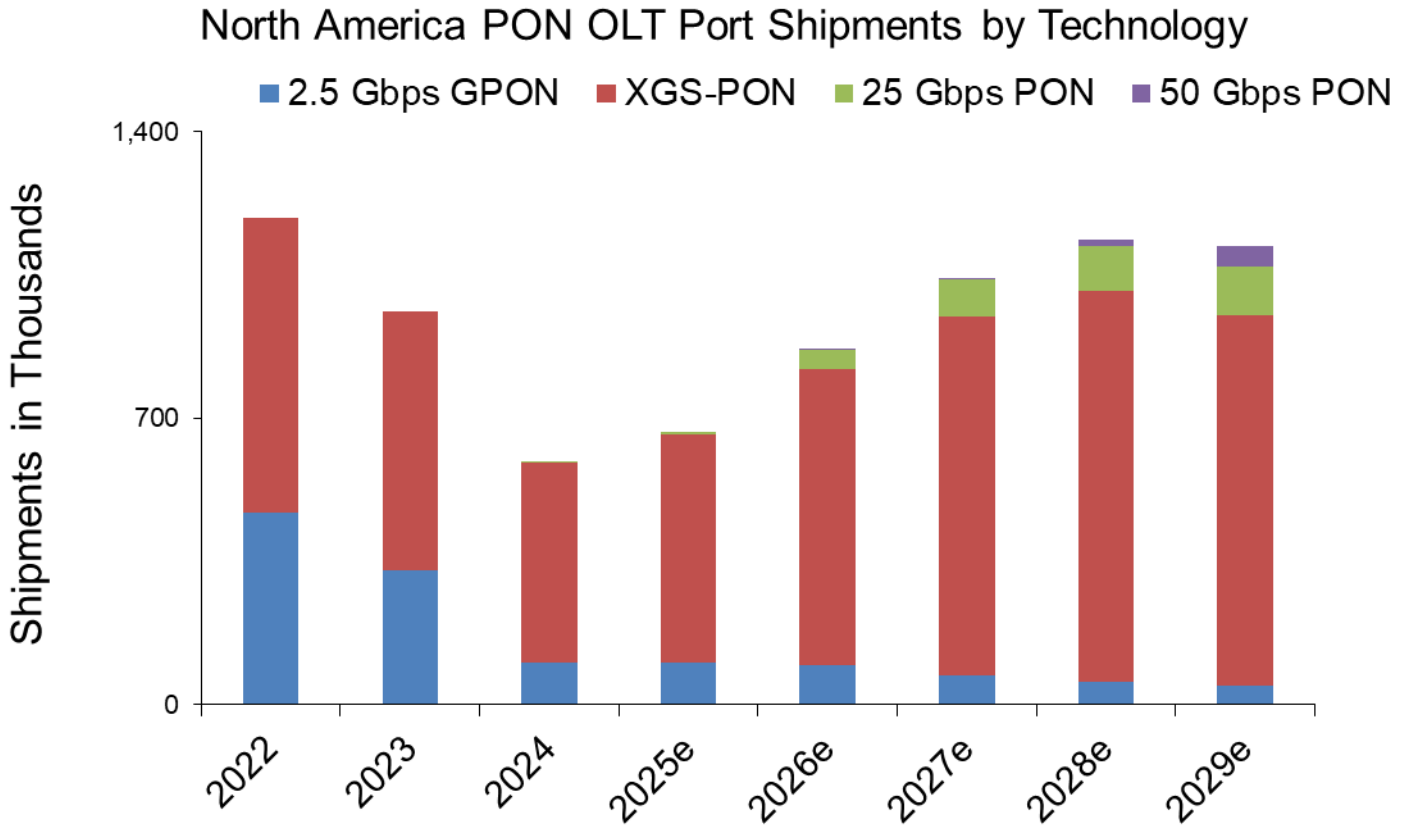
Steady Fiber Subscriber Growth Expected



- NA is roughly 40% of the worldwide XGS-PON ONT market
- All operator tiers now deploying XGS-PON
- Most operators with XGS offering 1x1 and 2x2 services
- With XGS upgrades, operators are also upgrading aggregation for load balancing

Fiber ISPs Adding OLT Port Capacity Once Again

Optical Line Termination



- Excess inventory from 2022-2023 has been deployed
- Spending cycle through 2028 driven by:
  - Expansion projects
  - Legacy OLT replacements
  - Strategic upgrades in DOCSIS 4.0 markets
- 25 Gbps PON will remain limited
  - We estimate Gfiber accounts for ~30% of NA active ports

New And Emerging Technologies

- **Higher-Speed PONs**
  - **25 Gbps**
  - **50 Gbps**
  - **100-200 Gbps**
- **Fiber Sensing**
- **Network Slicing**

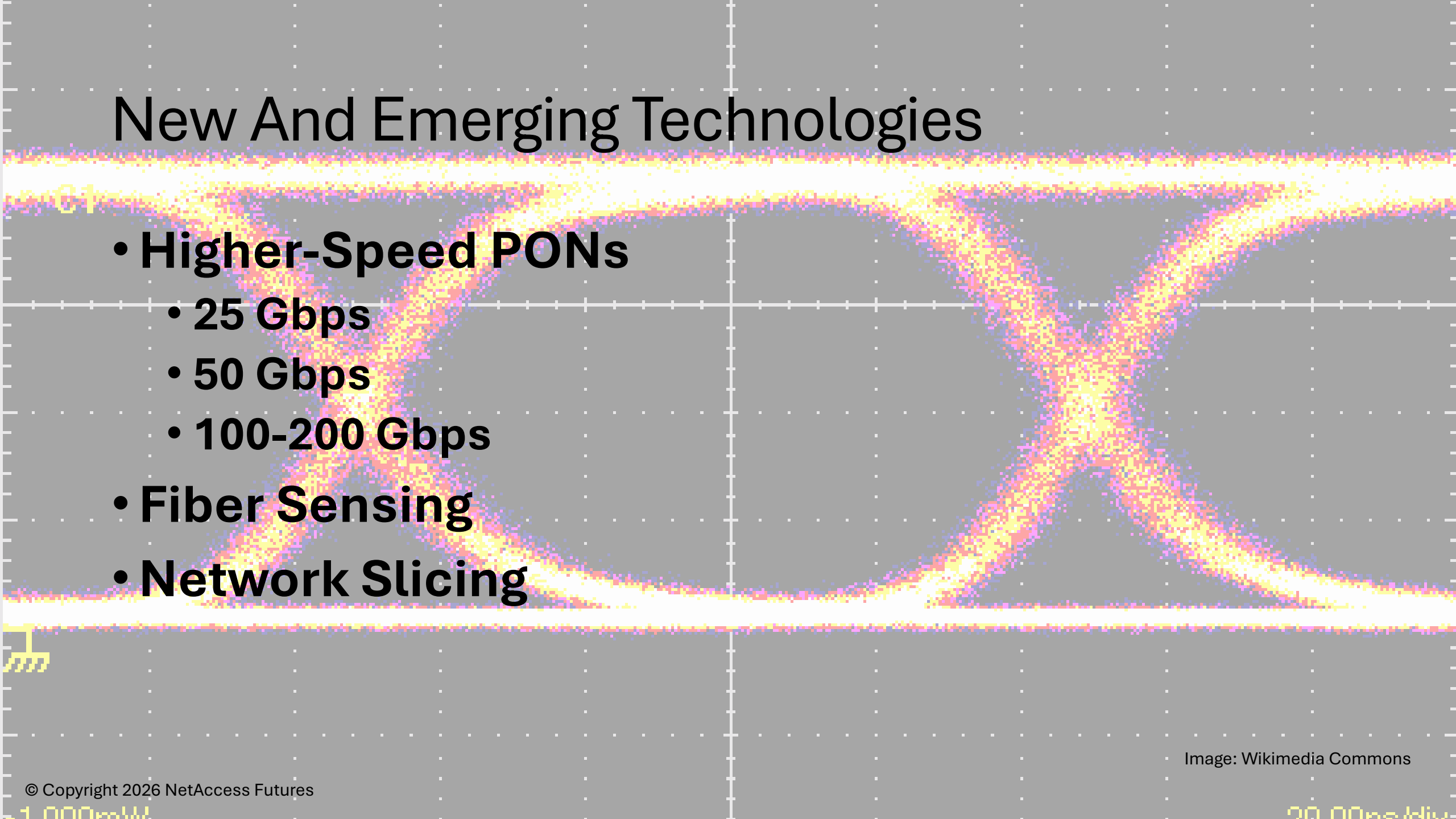


Image: Wikimedia Commons

Hybrid Fiber-Coax (HFC) Has A Long Runway But…

- **Node Splits**
- **N+0 and N+1 Architectures**
- **1.2 GHz Upgrades → 1.8 GHz Extended Spectrum DOCSIS 4.0**
- **DOCSIS Upgrades**
  - **DOCSIS 3.1, DOCSIS 3.1+, DOCSIS 3.1E**
  - **DOCSIS 4.0 (Extended Spectrum or Full-Duplex)**
- **Distributed Access Architecture (DAA)**
  - **vCMTS (Virtualized Cable Modem Termination System)**
  - **R-PHY/R-MAC (Remote Physical Layer/Medium Access Control + PHY)**
  - **CIN (Converged Interconnect Network)**

Image: NetAccess Futures

Fiber or More HFC: MSOs At A Crossroads

The Case For Staying On Coax

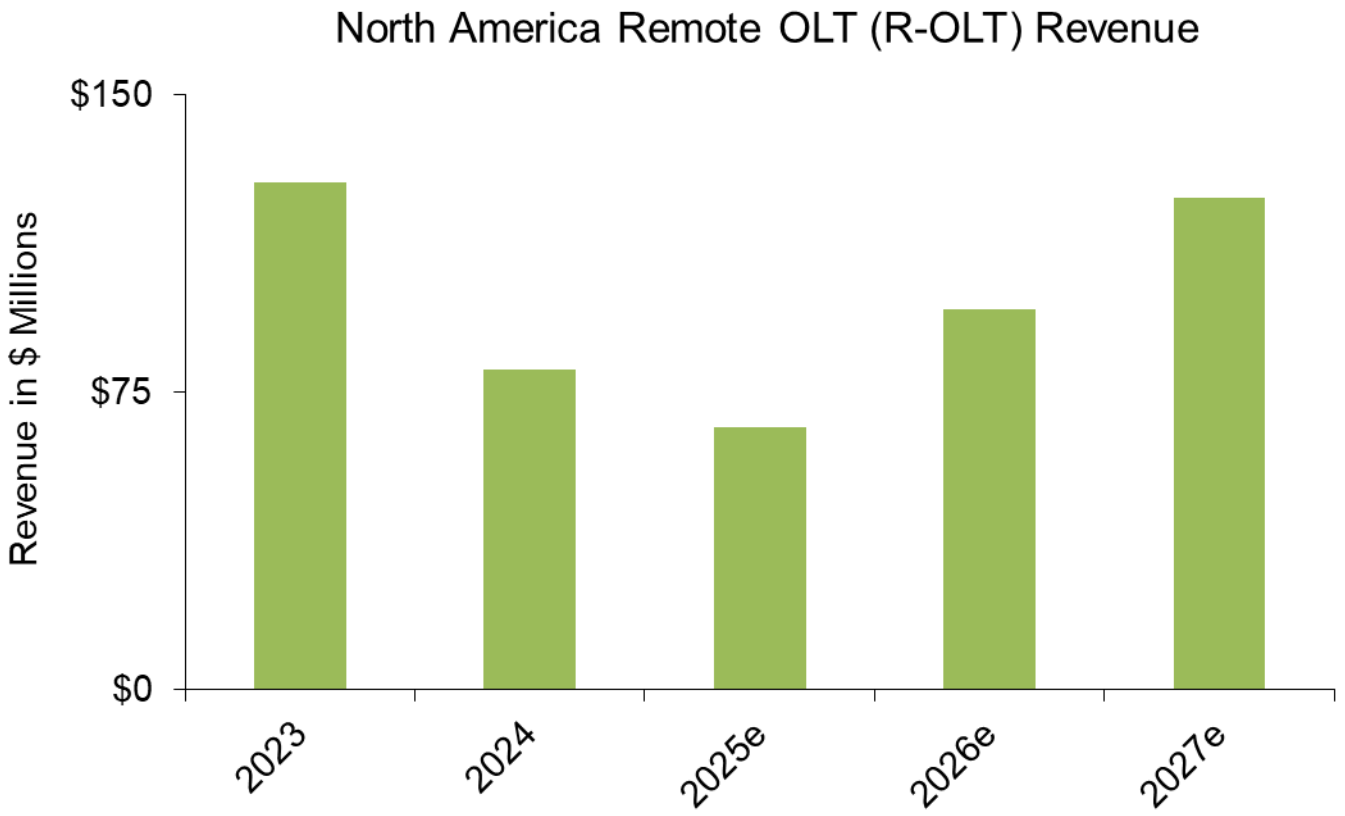
- ~$340 Billion Sunk Cost
- Avoids CAPEX for New Distribution Cables and Drops
- Avoids Rip-and-Replace CPE
- Less Disruptive Transition
- $100-$200 vs. $600++
- Can Counter Competitive Offerings With Upgrades + Pricing

The Case For Fiber

- Competitive Threats
- Symmetric Speeds
- No Active Equipment in OSP
- OPEX
  - Energy Consumption
  - Scheduled Maintenance
  - Remote Power Supplies
- Reliability
- Carbon Footprint
- Lower CAPEX For Greenfields

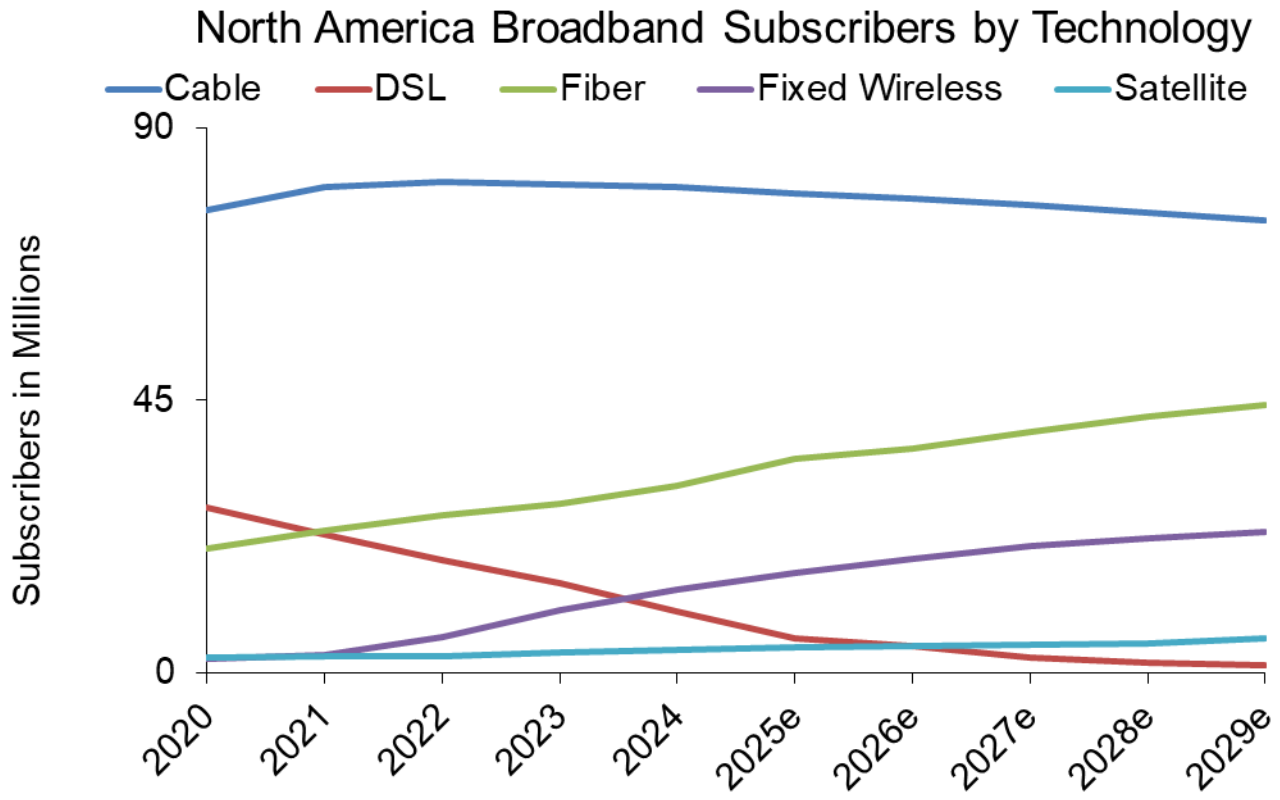
Image: ✨NetAccess Futures

Cable MSOs Gradually Moving to Fiber



- Comcast BEAD wins now expected to drive significantly more R-OLT volumes
  - Comcast building out to 1.2 million locations by the end of 2025
- Charter continuing to build out RDOF and now BEAD locations
  - Committed to 1.75 million fiber locations by end of 2026
- Midco, Astound, and others also expanding fiber footprint via R-OLTs

Fiber and FWA Growing at Expense of Cable



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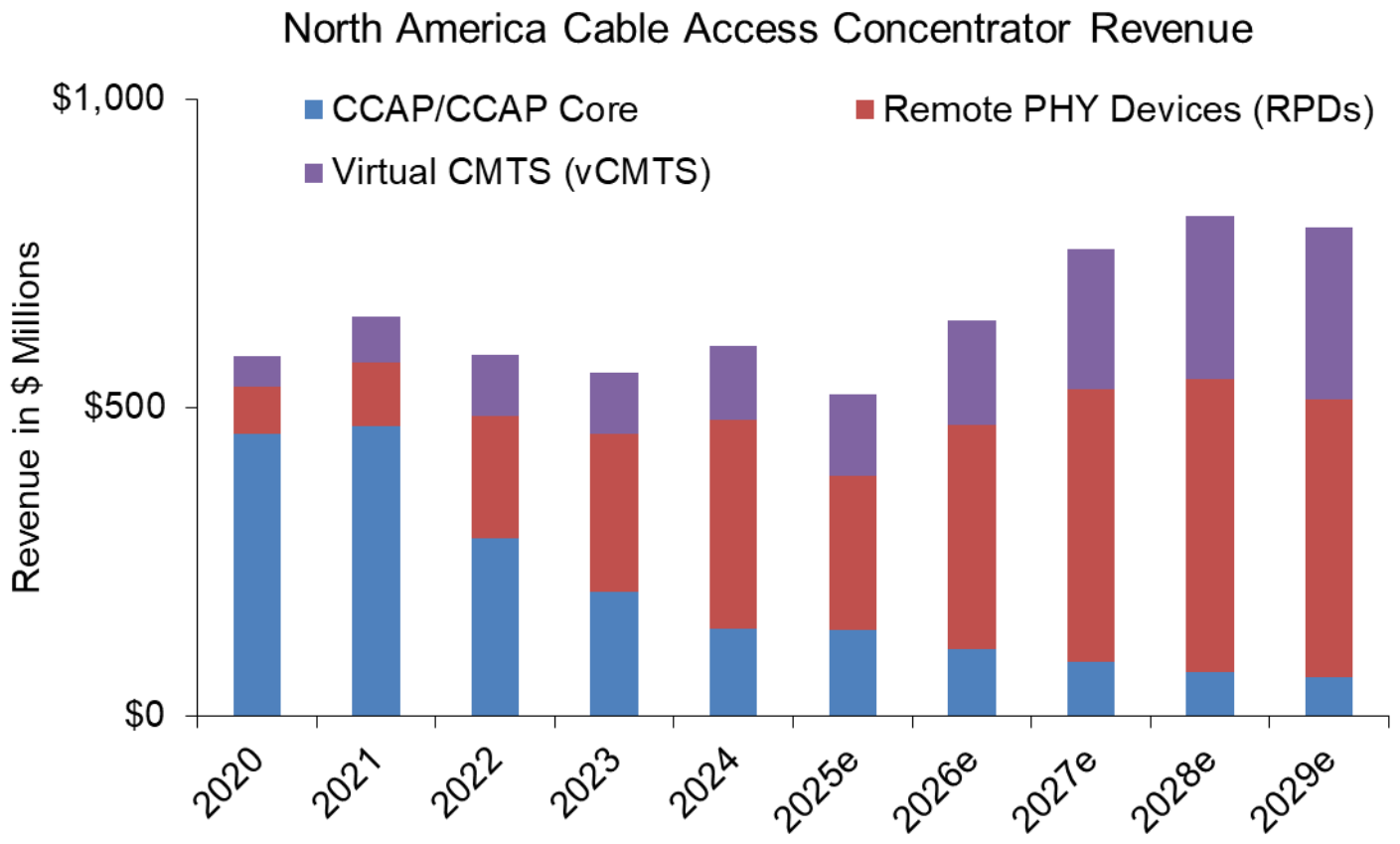
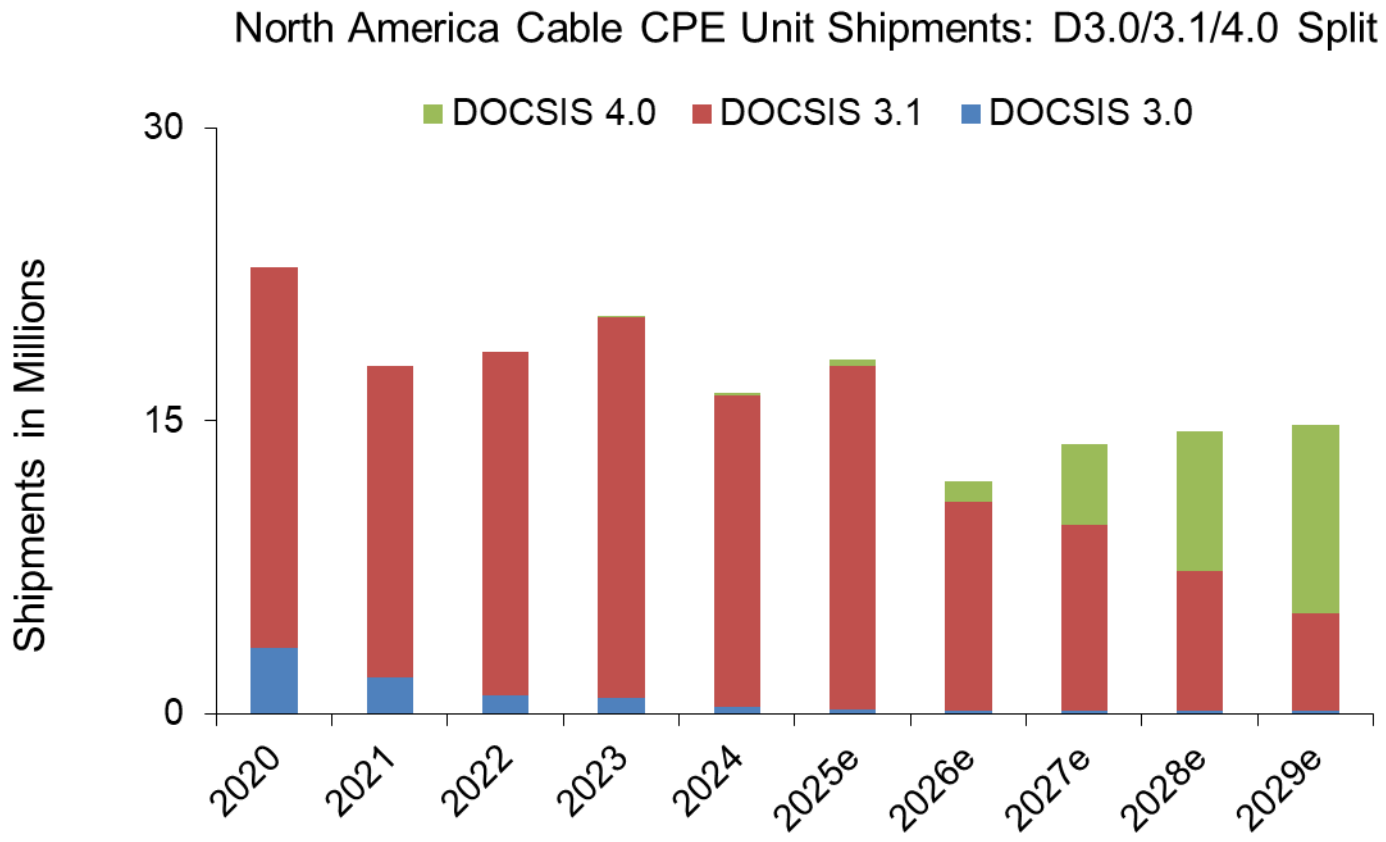
  - Stabilizing by 2030

2025 DOCSIS Spend at Historic Lows



- DOCSIS 4.0 Unified chipset integration is a gating factor
- Operators shifting capex to outside plant
  - Have to manage total capex and maintain FCF
- Total DOCSIS market outside of tier 1 operators is smaller
  - More operators beginning to overbuild with fiber
- Vendor consolidation expected

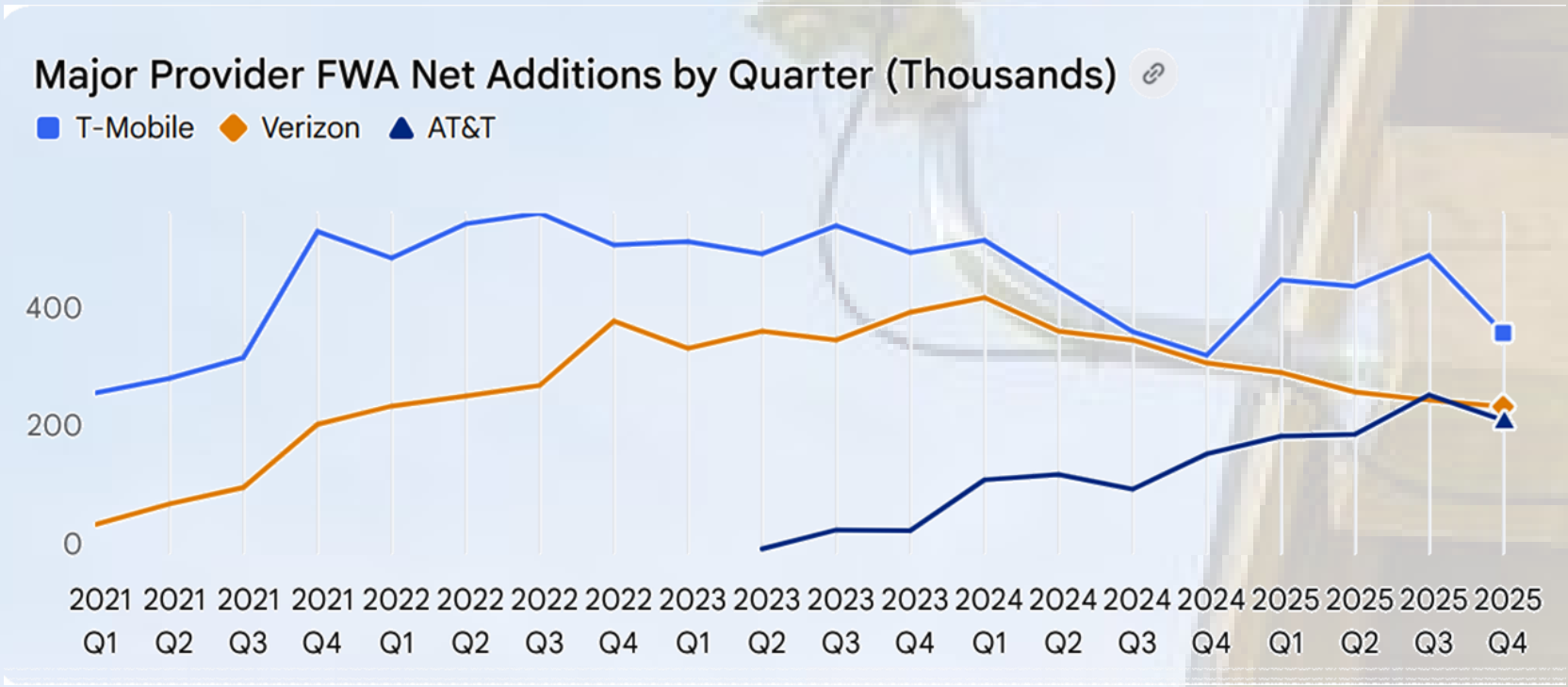
DOCSIS CPE Will Never See Previous Shipment Levels



- DOCSIS 4.0 limited to NA and Europe
- DOCSIS 4.0 units also used in DOCSIS 3.1 Extended deployments
- Many tier 2 and tier 3 MSOs in NA moving to fiber

Licensed Fixed Wireless Growth Peaking

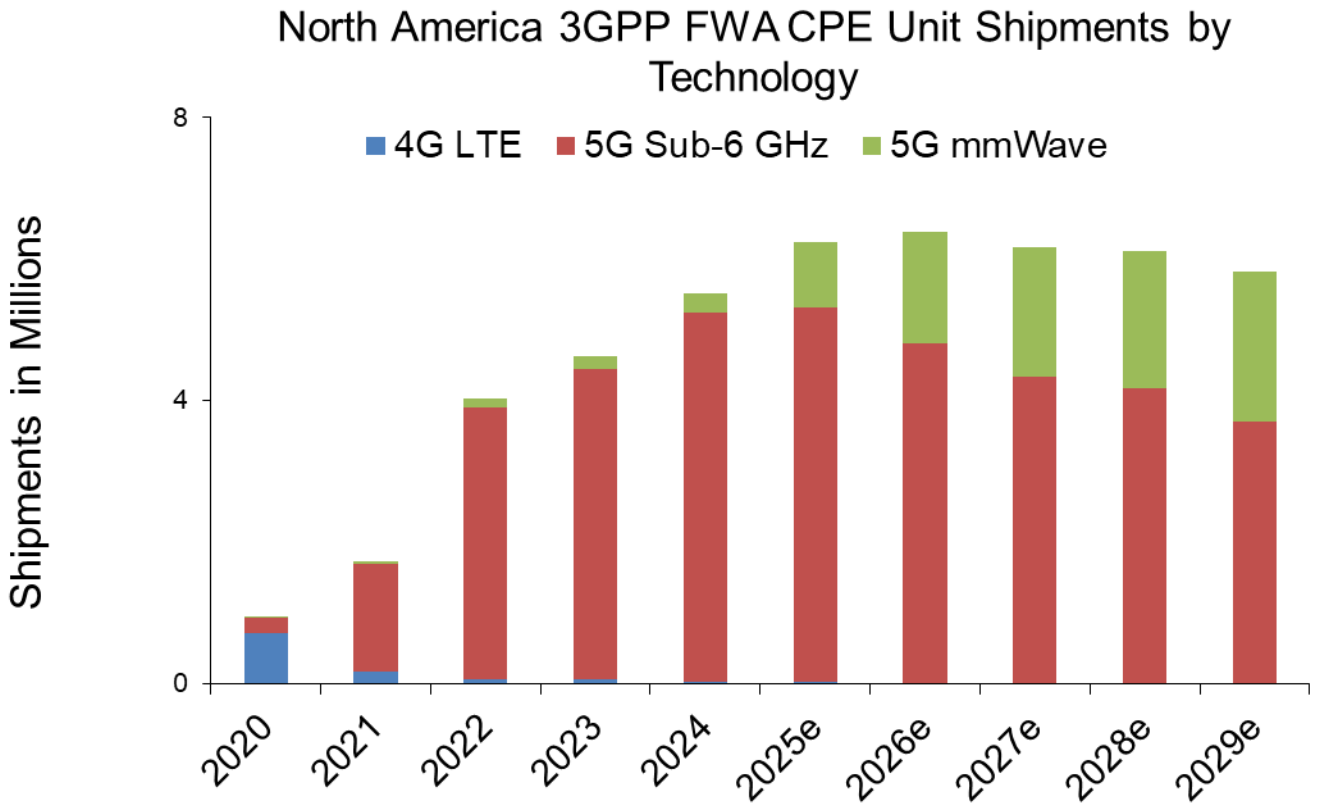
- **Growth Was Fueled By:**
  - **Unserved Households**
  - **Dissatisfied Cable and DSL Customers**
  - **Value Seekers**
- **Are Those Segments Reaching Saturation? Is It New Fiber Competition?**



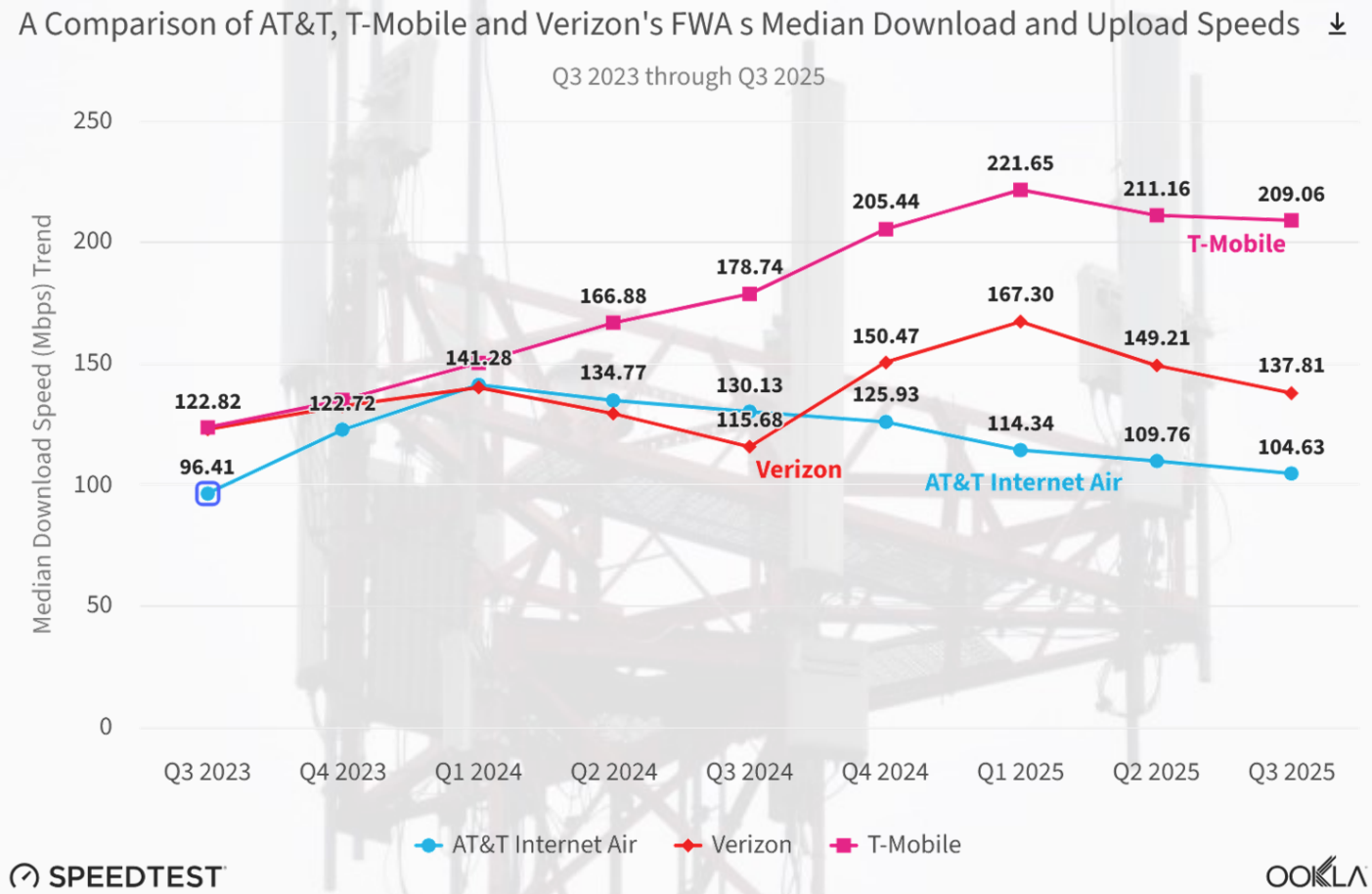
Source: NetAccess Futures

FWA CPE Shipments to Peak in 2026

Customer Premises Equipment



Is Licensed FWA Running Out Of Capacity?



Source:Ookla

What About LEO?

Low Earth Orbit Satellite

- **Satellite Is ~4% Of US Broadband Subscriptions (Source: Dell'Oro)**
- **Mainly A Rural Solution Where Fiber And FWA Can't Reach**
- **22.6% Of BEAD Locations (Source: Connected Nation)**
- **Higher Prices For Slower Service Than FWA Or Fiber**
- **Congestion Constrained**
- **Starlink**
  - **Only LEO Broadband Service In Commercial Operation (1Q26)**
  - **9,400 Satellites On Orbit, 7,500 Gen2, 7,500 More Authorized 1/9/26**
  - **Awarded $733.5 M For 472,600 BEAD Locations**
- **Amazon LEO**
  - **First 180 Satellites On Orbit, 3236 Authorized**
  - **"Enterprise Preview" 11/25, Staged Rollout 2026**
  - **Awarded $311 M For 415,000 BEAD Locations**

Market Drivers For Fiber

Copper Retirement

- Tier-1 and Tier-2 ILECs Are 55% Of New FTTx Deployments
- Plan To Retire All Copper Plant By 2030 For Fiber or FWA
- In 2006 There Were 6.5 M Sheath-km of Copper Cable in US Outside Plant
  - Some Dates Back A Century Or More
  - Much Of It Is Decrepit, Neglected and Long Past Its Design Lifetime
- Obsolete Equipment, No Spares
- Shrinking Workforce
- Declining Revenue To Cover Increasing Maintenance
- Reclaimed Copper Cable Is 4.00/Lb

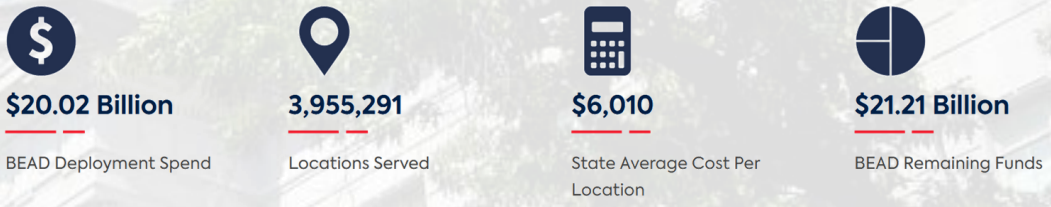
- Big OPEX Savings From Replacement
  - A Single CO/Hub Location Serves A Larger Area
  - No/Little Active Equipment In Outside Plant
  - Better Reliability, Fewer Truck Rolls
  - Negligible Routine Maintenance
  - Less Staff
  - Lower Energy Consumption, Cost
  - Less Air Conditioning
  - Less Space
  - Lower Pole Attachment Costs
  - Better Resiliency

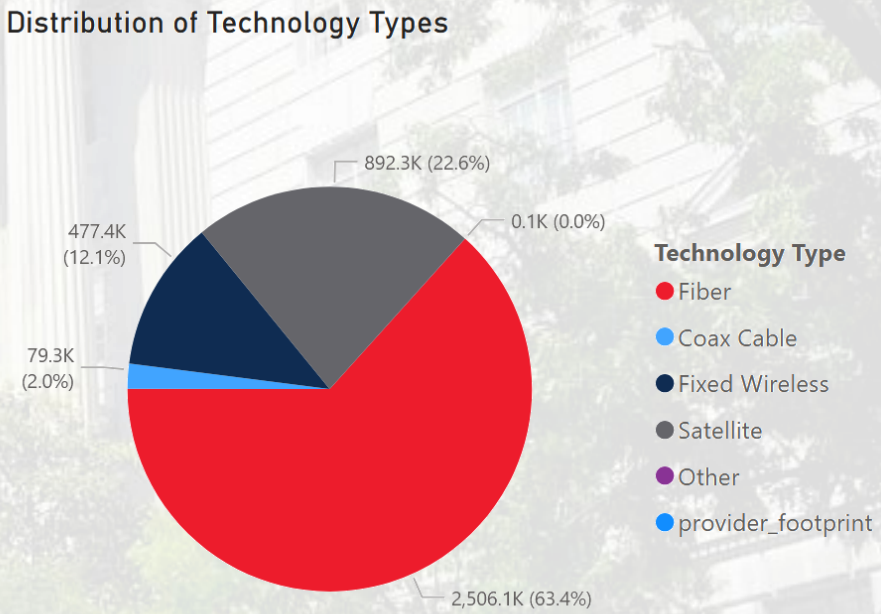
Fiber As An Investable Asset

- Predictable Returns For Patient Investors
- Private Equity Investment in Tier-1 and Tier-2 ILECs
  - Some A Turnaround Play For Distressed Assets
  - Frontier: Ares Management, Jana Partners, Cerberus, Elliott Investment Management, Apollo Global
  - Brightspeed: Apollo
  - Consolidated (Now Fidium): Searchlight Partners
  - Ziply: Searchlight Partners, Wavedivision Capital
  - Gigapower: Blackrock
- Private Investment In Overbuilders
  - SiFi Networks - APG Group, Whitehelm Capital, Patrezia Infrastructure
  - GoNetspeed – Oak Hill Capital
  - Allo Communications – SDC Capital Partners
  - Hotwire Communications – Blackstone → Brookfield Infrastructure
- Municipal Bonds

State And Federal Subsidies

- Digital Divide Persists
- About 4 M US Homes and Businesses Not Served With At Least 100/20
- Service Providers Cannot Close Business Cases For Rural Areas Without Subsidies
- Past US Programs Are Winding Down Including
  - Rural Digital Opportunity Fund (RDOF)
  - CAF-II
  - USDA Reconnect
  - ARA Capital Projects Fund
- Broadband Equity And Deployment (BEAD) Program
  - Long Story... 😡
  - State Proposals *Finally* Approved
  - Boots On The Ground Mid-Late 2026
  - Work Must Be Done ~2030
  - > Half The Appropriated Money Not Granted
  - 6 of 10 Biggest Winners Are Tier-1 Telcos, MSOs and Space-X
- State Programs





Source: Connected Nation

Headwinds and Tailwinds

- Headwinds
  - **Inflation And Materials Cost**
  - **Interest Rates**
  - **Skilled Labor**
  - **Heavy Construction Machinery**
  - **Subcontractors Face Margin Compression**
  - **Permitting, Make-Ready And Pole Attachments**

- **Tailwinds**
  - **100% Bonus Depreciation**
  - **State and Federal Efforts To Speed Up Bureaucratic Hurdles**
  - **State Governments Stepping Up**

Artificial Intelligence

- ⚠ Caution: Hype, Fluff & FOMO
- “Telecom For AI”
  - Data Center Interconnect
  - Little Effect On Mass-Market Broadband
- “AI For Telecom”
  - All Major Equipment Vendors Have An AI Story
  - Ties With Automation & Autonomy
  - Business Objectives
    - Reduce Outages & Duration
    - Track and Optimize Performance
    - Reduce Friction
    - Improve Workforce Productivity

- Real Applications
  - Predictive Maintenance
  - Fault Diagnosis
  - Root-Cause Analysis
  - Performance Optimization
  - Cybersecurity
  - Marketing
  - Customer Self-Service
  - Improved Chatbots
  - Accent Masking
  - Call Center Agent Support
  - Identifying At-Risk Customers
  - Capacity Planning
  - Fiber Sensing
- ⚠ Only As Good As The Data Behind It

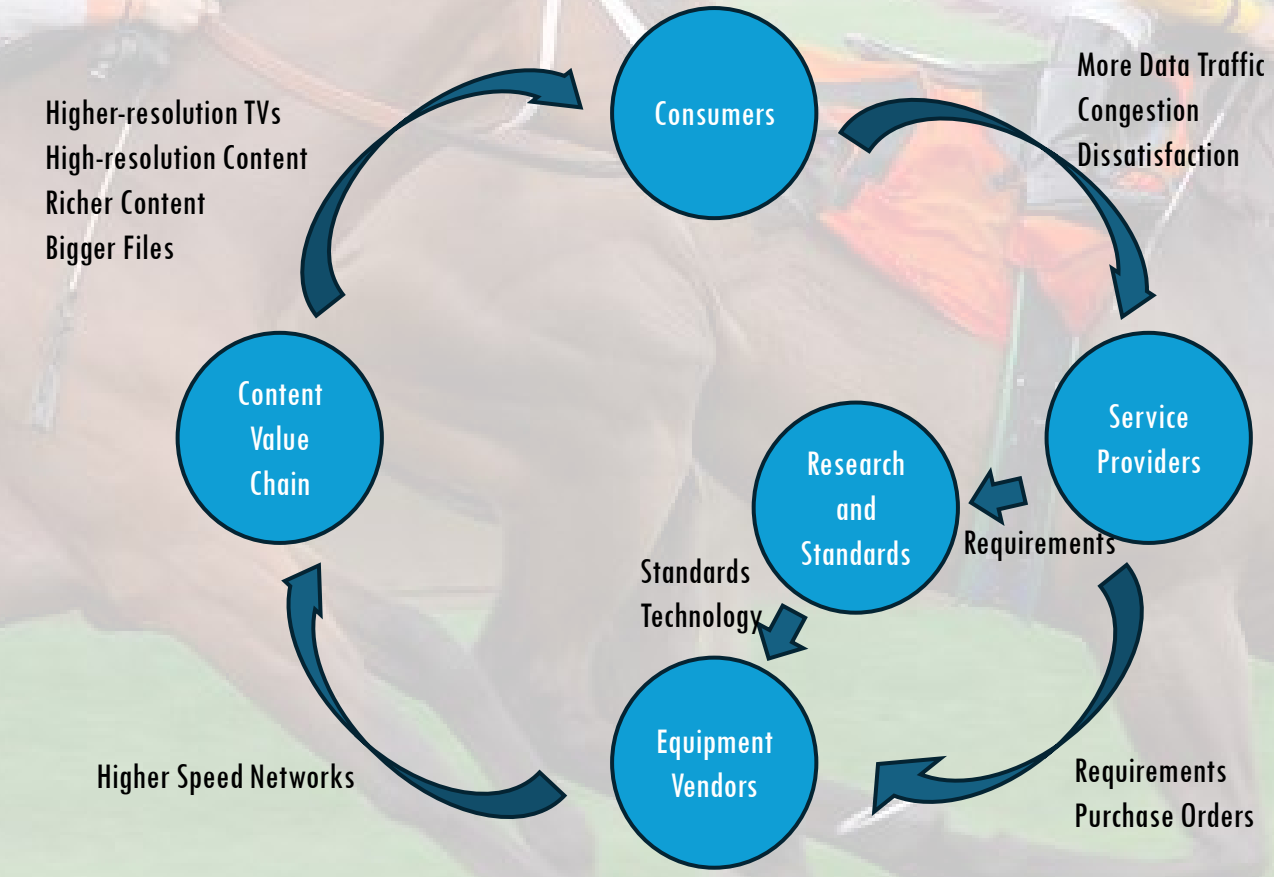
Image: AIA

An Era of Abundance

Image: Jill Wellington

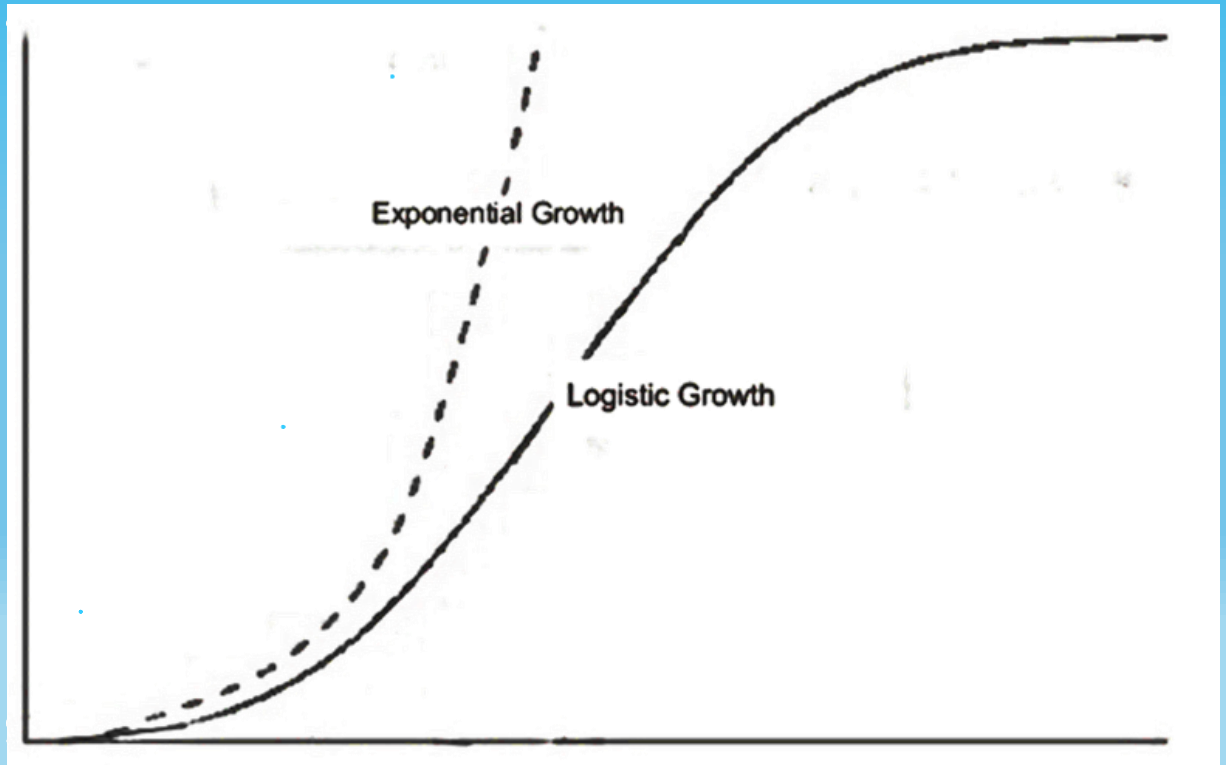
The Virtuous Cycle

- **Horse Race Between Headline Network Capacity and Demand Growth Since 1980s**
- **Apparent ~Exponential Traffic Growth**
- **~2X Headline Speed Growth Every 21 Months (Nielsen's Law)**
- **Major Network Upgrades Every ~7 Years**



But There is No Such Thing As Exponential Growth!

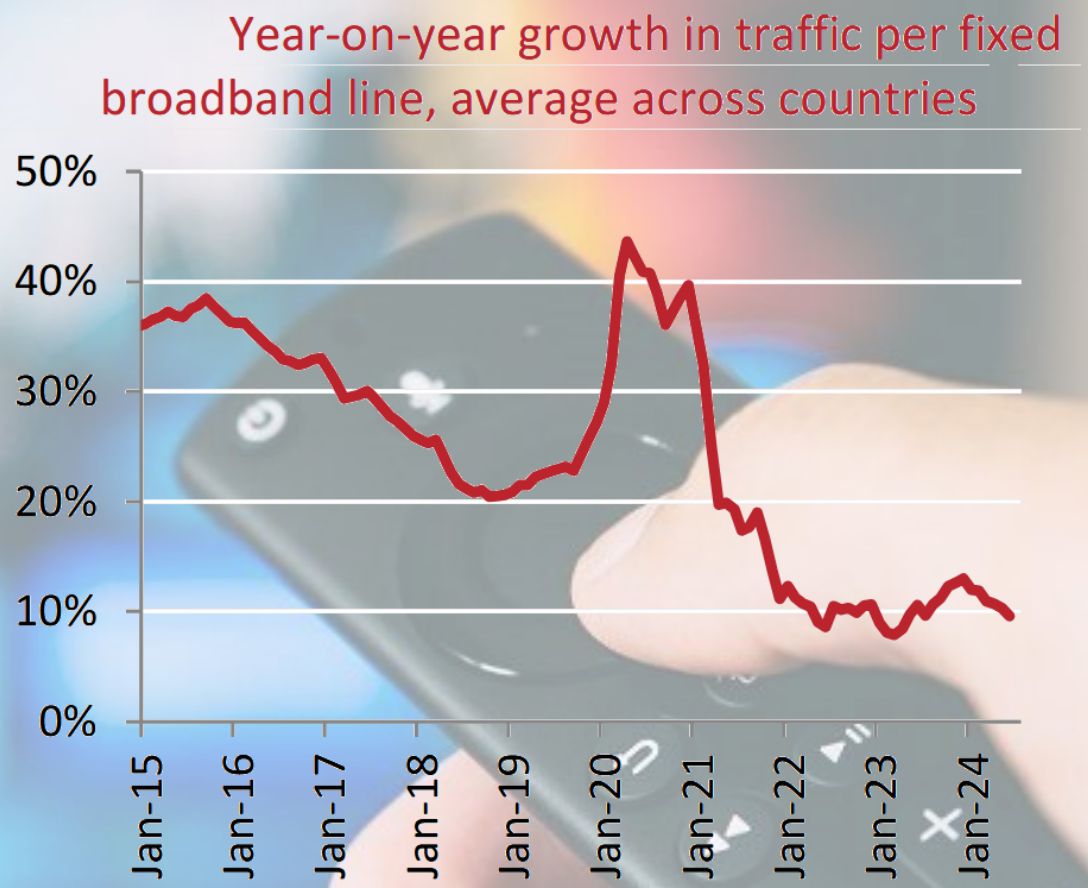
- **All Growth Has A Natural Limit**
- **Sigmoid (Logistical), Not Exponential**
- **“Nature Abhors a Hockey Stick”**
- **Logistical Growth Initially Appears Exponential**



Traffic Growth is Slowing

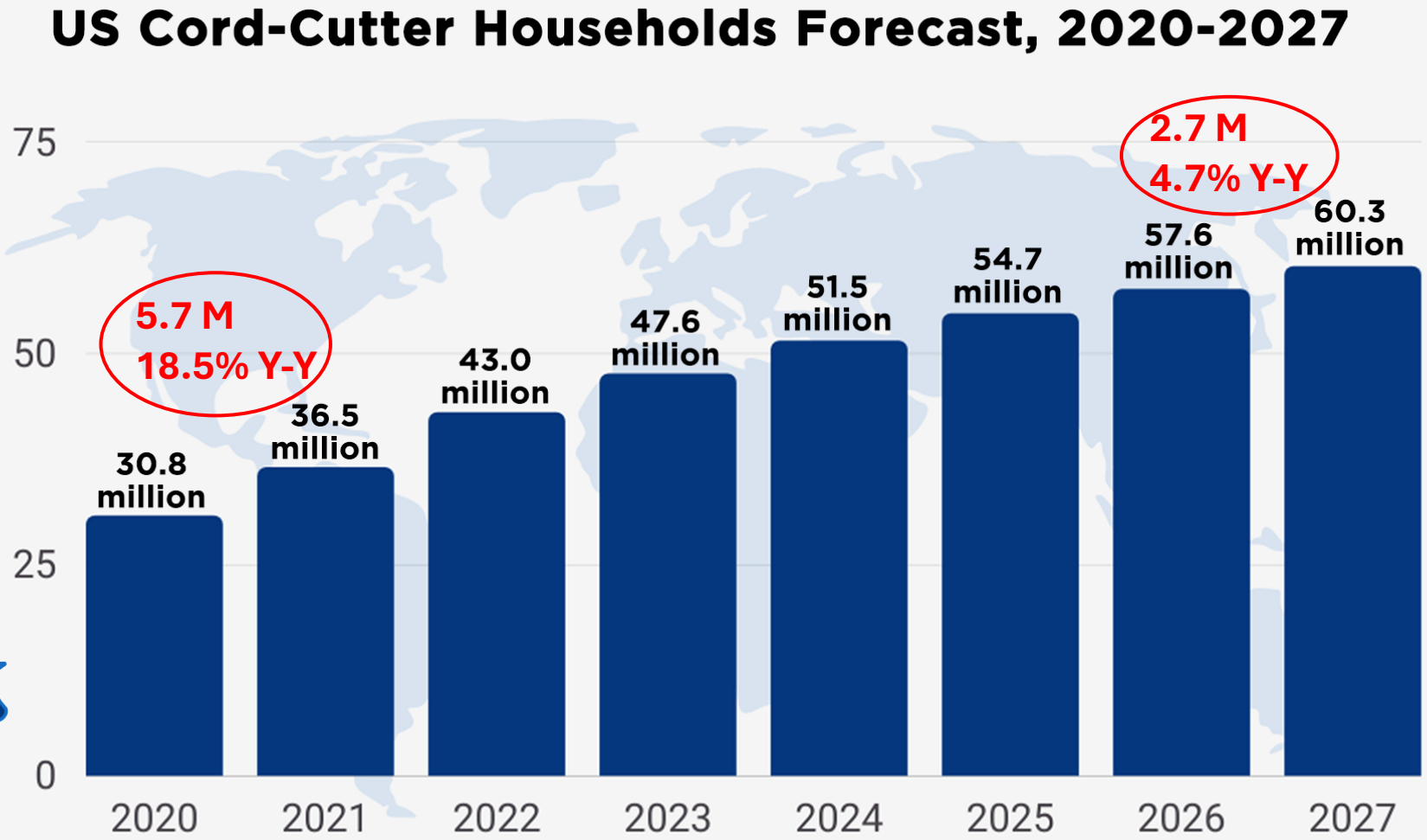
Why?

- Streaming & IPTV Adoption in Late Majority/Laggard Phase
- IPTV and Streaming Stuck on HD, Limited 4K
- Streaming Video Optimizations
- Consumer Electronics Industry Out of Ideas
- Consumer Behavior
  - Limits of Time and Attention
  - Limits of Human Perception?
  - Diminishing Marginal Utility?



Source: Communications Chambers

Correlation Between Cord-Cutting and Traffic Growth?



Source: Broadband Search

Broadband Search

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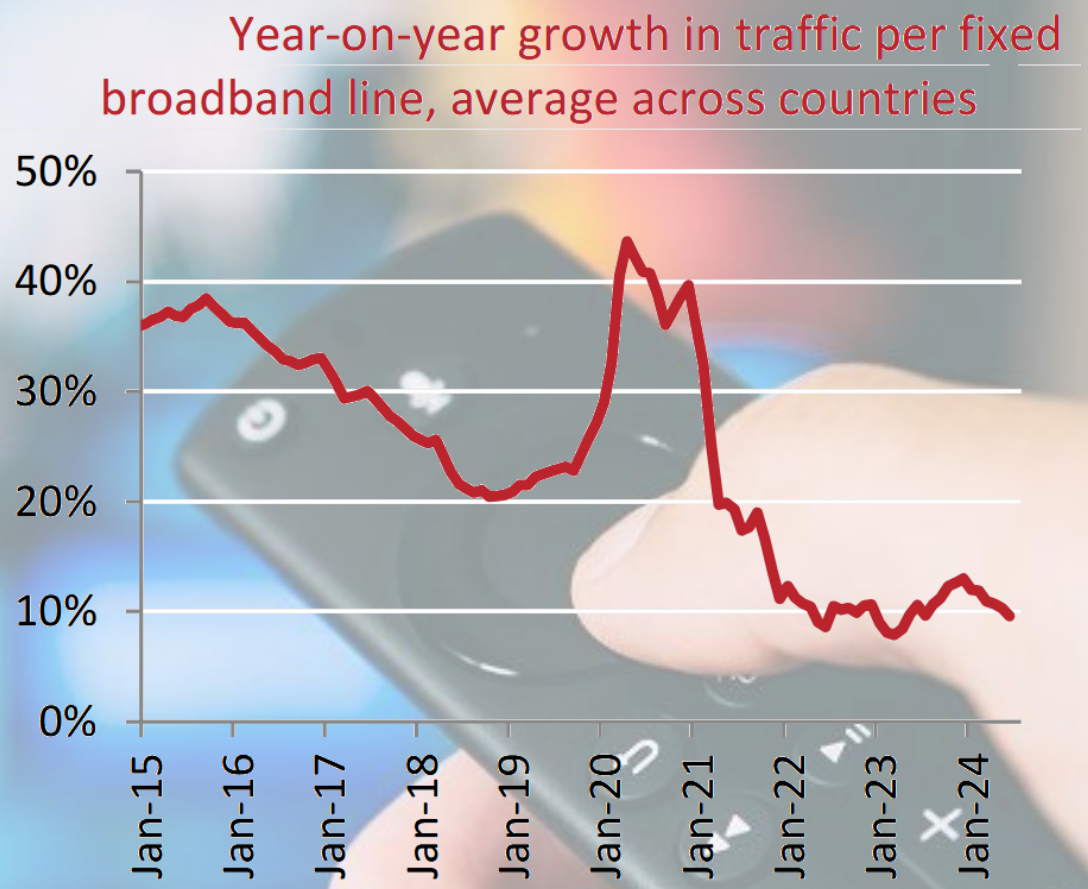


Source: Communications Chambers

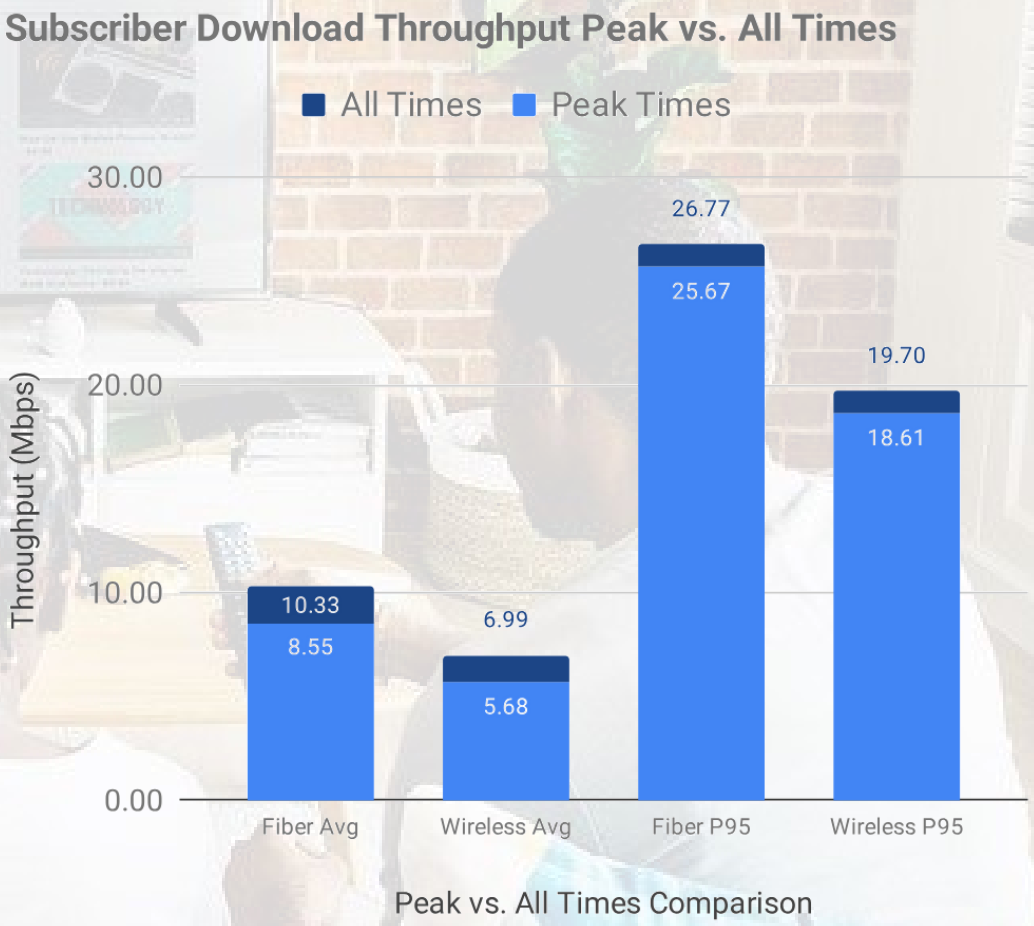
No Consumers Need Gigabit Service (Almost)

Activity	Minimum Download Speed (Mbps)
General Usage	
General Browsing and Email	1
Streaming Online Radio	Less than 0.5
VoIP Calls	Less than 0.5
Student	5 - 25
Telecommuting	5 - 25
File Downloading	10
Social Media	1
Watching Video	
Streaming Standard Definition Video	3 - 4
Streaming High Definition (HD) Video	5 - 8
Streaming Ultra HD 4K Video	25
Video Conferencing	
Standard Personal Video Call (e.g., Skype)	1
HD Personal Video Call (e.g., Skype)	1.5
HD Video Teleconferencing	6
Gaming	
Game Console Connecting to the Internet	3
Online Multiplayer	4

Student 5-25

Telecommuting 5-25

Streaming Ultra HD 4K Video 25



Source: FCC

Source: Preseem

Customers Seem To Be Figuring This Out

PROVISIONED SPEED	SEP 24	SEP 25	YoY
1 Gbps+	34.1%	33.8%	-0.8%
500-900 Mbps	26.4%	22.9%	-13.4%
200-400 Mbps	21.6%	30.5%	41.1%
100-200 Mbps	9.7%	5.3%	-45.6%
50-100 Mbps	3.2%	3.0%	-6.8%
< 50 Mbps	4.9%	4.5%	-8.3%

Source: Ookla

Network Capacities Are Far Ahead of Demand

- **Most New FTTP Deployments are XGS-PON @10 Gbps Symmetric Shared 1:64 Or 1:128**
- **Cable Evolutions Toward 10+ Gbps Downstream Shared**
- **5G and Next-Generation Unlicensed Fixed Wireless Can Exceed 100/20 Mbps Benchmark – "Good Enough" at Lower Price Point**
- **Networks Have More Capacity Than Consumers Can Realistically Use Plus LOTS of headroom**

Implications of Abundance

- **Speed Wars Are Over**
- **CSPs Must Find Other Differentiators**
  - **Latency**
  - **Reliability**
  - **Service Enhancements and Apps**
  - **Customer Service**
  - **Trust and Community**
- **Network Assets No Longer Become Functionally Obsolete**
- **Upgrades Driven By Residual Lifetime, Not Competition**
- **Future Network Enhancements Are Software**
- **Net Neutrality Is Moot**

Image: Jill Wellington

And Finally...

Closet of Anxieties

- Inflation
- Trade Wars
  - Capricious Tariffs
  - Tit-for-tat Sanctions
- High Interest Rates
- Reduced Discretionary Spending
- Supply Chain
  - Competing Demands
  - Geopolitical Tensions
  - Threats Of War Over Taiwan
  - Natural Disasters & Terrorism
- Cybersecurity Incidents
- Major Correction In Financial Markets
- Shortages Of Skilled Labor
- Hard-line Immigration Policies Removing Workers From The Workforce
- Regulatory Chaos And Broken Guardrails
- Continued Turmoil In The BEAD Program

Image:: ©Berkley Breathed

50 Years of Progress

1976:

- **300 Bits per Second (bps) Dial-Up**
- **Dumb Terminal**
- **Text-Only**

Photos: Creative Commons/ ClickRick (L) Secretlondon123 (R)

2026:

- **~10 or 2.5 Gbps (Shared) Fiber or Cable**
- **Home WiFi**
- **Hi-Res Color Touch Screens**
- **4K TVs**
- **Rich Multimedia**
- **Connected Home**

7-8 Orders of Magnitude Faster!

Thank You!

Dan@NetaccessFutures.Net

www.linkedin.com/in/danielbgrossman