Broadband 101

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My Background
(Webpage)

- Public Service
  - Office of Plans & Policy, Federal Communications Commission
  - Frontier Compliance Monitor, California PUC (current)
- Industry — CableLabs
  - EVP and Chief Strategy Officer managing R&D Projects
- Academia — CU Boulder
  - Director, Interdisciplinary Telecom Program
  - Senior Fellow, Silicon Flatirons (current)
  - Sr. Research Assoc., Computer Science Department (current)
- Reed Strategy, LLC
  - C-Band Relocation Payment Clearinghouse (current)

Broadband 101 — Today's Objectives

Key broadband technology, economics, and public policy concepts that industry and government decision makers need to know!

☑ Learn broadband basics: non-technical point of view

   ☑ Wireline/wireless technology options, trends, & economic trade-offs

☑ Understand spectrum management approach by Federal Communications Commission (FCC) to reduce cost of Internet connectivity

☑ Discuss key policy developments shaping future of broadband

   ☑ Broadband Plans

   ☑ Broadband as a Universal Service

   ☑ Net Neutrality

   ☑ Definition of Broadband

Broadband 101 – Outline for Today
Part I (2 hours - 20 min. break for lunch when ready)

Wireline and Wireless Broadband Networks

- ☑ Understanding Broadband Networks
    - Basic network components and software systems
    - The layered Internet architecture
- ☑ Future Trends in Wireline Broadband Networks
    - Copper, Coax, and Fiber Networks
- ☑ Future Trends in Wireless Broadband Networks
   - Wi-Fi, 5G, Fixed Wireless, Satellite, and Small Cells

Broadband 101 – Outline for Today
Part II (2 hours with coffee break)

Broadband Policy Topics

- ☑ Spectrum Management Basics
  - FCC Approach to 5G
- ☑ Regulations to Open Network Access: Net Neutrality Rules
- ☑ Broadband as a Universal Service
  - Broadband Plans and Government Subsidies (Colorado Broadband Plan, BEAD Act)
- ☑ Putting It All Together Via the Definition of Broadband
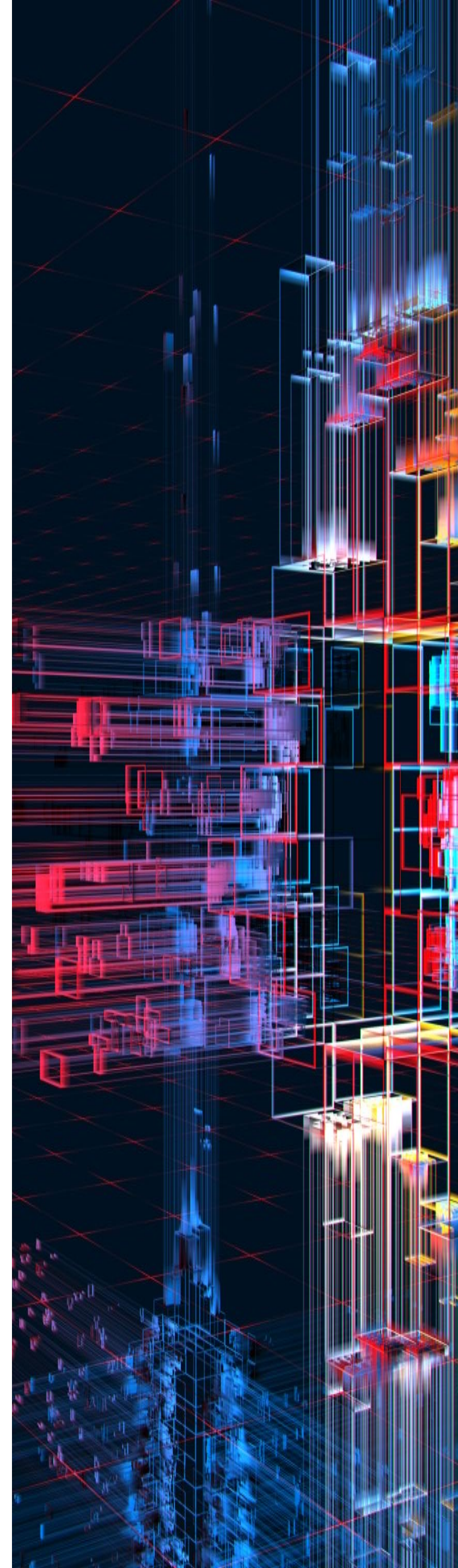
PART I: WIRELINE AND WIRELESS BROADBAND NETWORKS

❖ Understanding Broadband Networks

❖ Basic network components and software systems

❖ The layered Internet architecture

What is Broadband?

- Just a technology?

    - [Pac Bell Web Hog Ad](#) from 20+ years ago
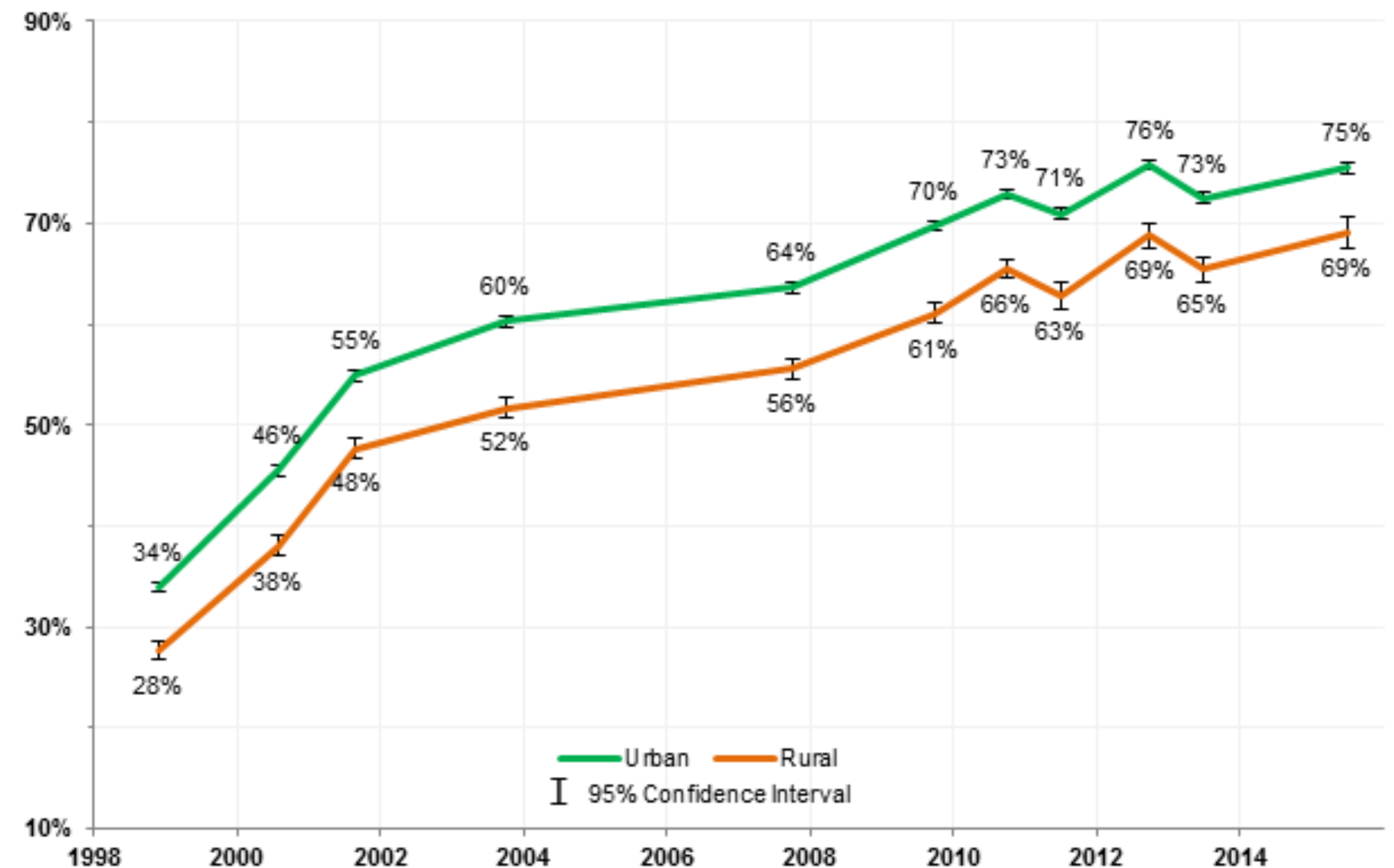
- Lifeline? Life Changer?

- Cyber Commons?

The "broadband vision" for Underserved Areas

Need to address gaps in availability and price (*i.e.,* market failure)

- Economic development

- Telehealth

- Education

- Civic engagement

- Public safety

- Quality of life

- Community Policy?

  - [Community Broadband or Why a Gig?](#)

Internet Use from Any Location

Source: Ali, C. (2020, August 5). Broadband Policy, Deployment, and Access: Lessons for New York State. Retrieved from https://www.benton.org/blog/broadband-policy-deployment-and-access-lessons-new-york-state?utm_source=sendgrid&utm_medium=email&utm_campaign=Newsletters

Source: NTIA. Retrieved from https://www.ntia.doc.gov/blog/2016/state-urbanrural-digital-divide

Digital Equity

Achieved by ensuring everyone has access to high-quality broadband connectivity and the tools and skills needed to use technology to improve their lives

- Access

  - High-quality broadband service available to every household in every community

  - Affordable high-quality broadband plans available to everyone regardless of income

  - Secure device and privacy preserving access available to everyone regardless of income

- Adoption

  - Everyone has the digital skills, tools, and resources needed to safely and privately use information and communication technology to improve their lives

  - Digital content designed for everyone to access with ease regardless of ability, age, income, or language

How Do We Use Broadband?

152.1 MM
subscribers added by
Disney+ in 3Q22

Source: Indiewire.com 8/1/2022

2.5 Quintillion
bytes of data created
everyday

Source: EarthWeb.com 9/22/22

1 GB
of data can create
350,000 emails

Source: EarthWeb.com 9/22/22

333.2 Billion
emails are sent
per day

Source: EarthWeb.com 9/22/22

20%
people online are
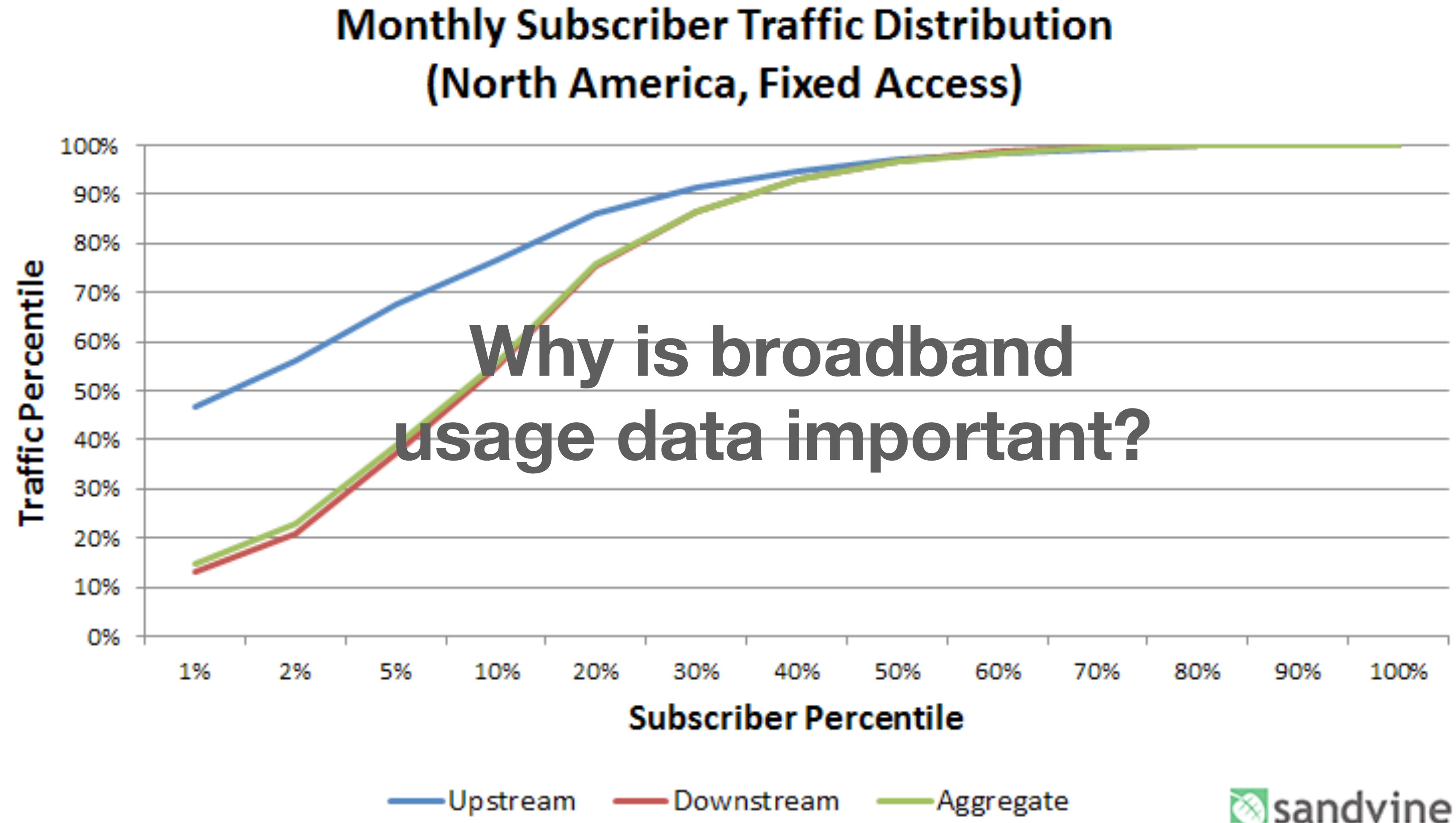watching online games

Source: EarthWeb.com 9/22/22

62 MM
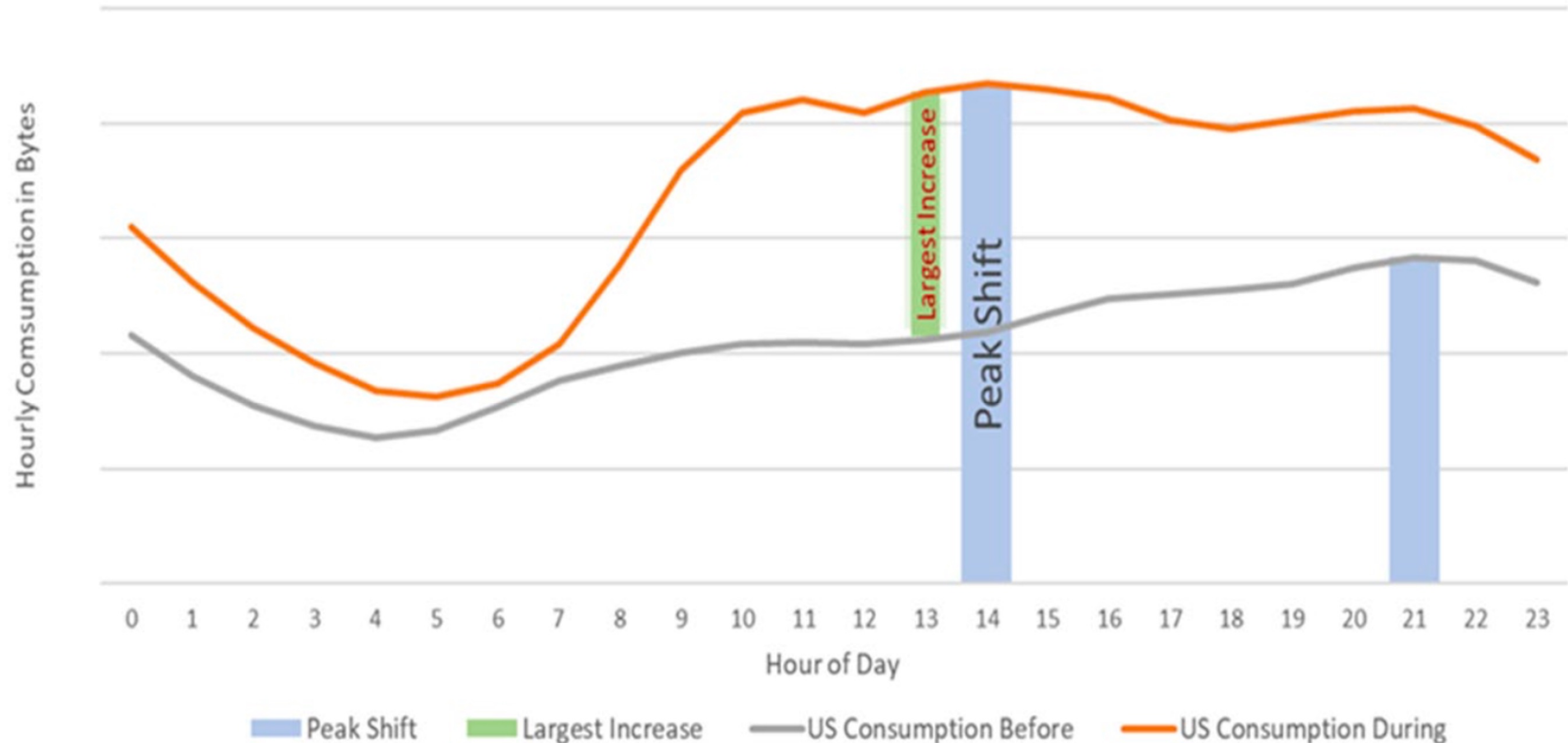hours of streams are watched
daily on Twitch

Source: DataProt.net 8/24/22

Source: OpenVault, Broadband Insights Report (OVBI), 3Q22

Not All Users Are the Same

Monthly Subscriber Traffic Distribution
(North America, Fixed Access)

Why is broadband
usage data important?

Traffic Percentile

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%

1% 2% 5% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Subscriber Percentile

—— Upstream   —— Downstream   —— Aggregate

sandvine

Usage Change for Comcast During Pandemic

US Hourly Consumption
Pre/During COVID-19

Huge Increase in Video Streaming!

% Increase in video streaming traffic
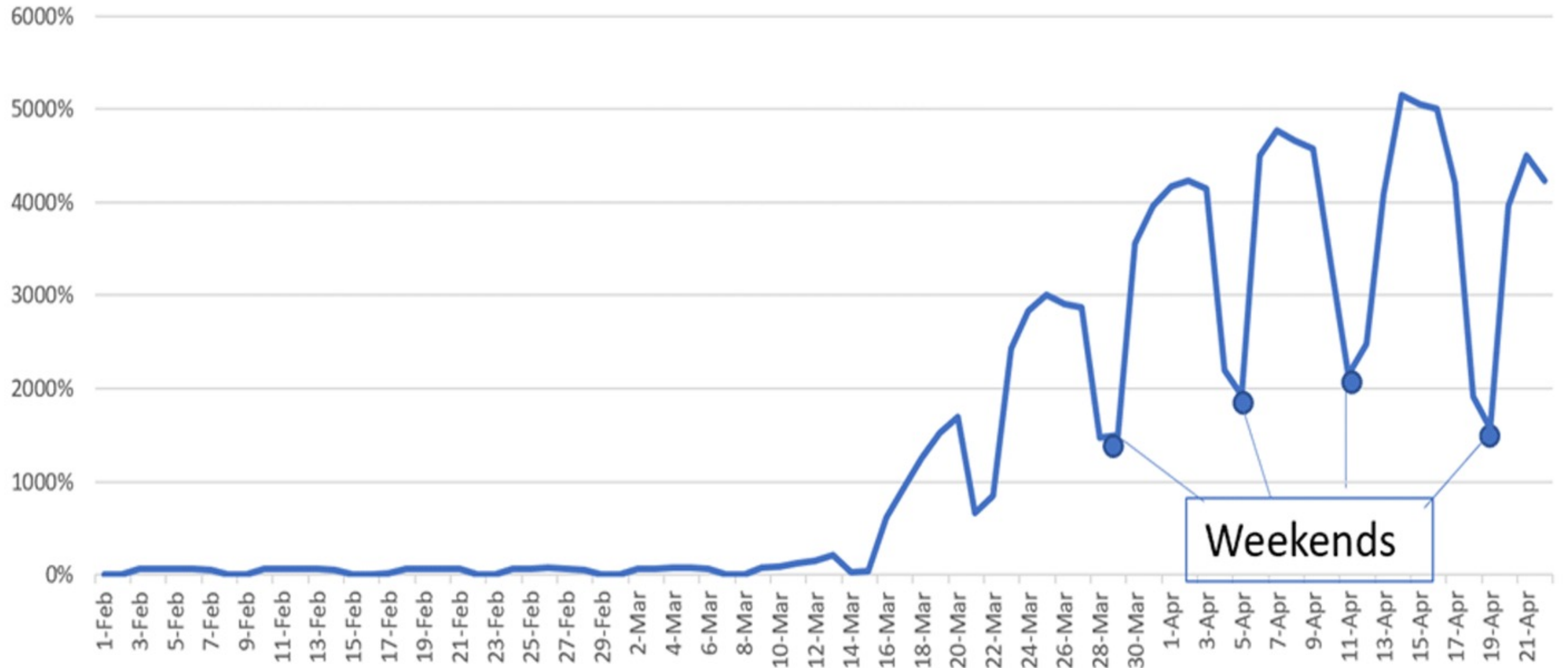
Source: NetScout

FCC's Definition of Fixed Broadband

Section 706 Inquiries Required by 1996 Telecom Act

- Every year, FCC determines whether advanced telecommunications capability is deployed in reasonable and timely fashion

    - Advanced telecom capability = high-speed, switched, broadband that enables users to originate and receive high-quality voice, data, graphics, and video telecommunications using any technology

- FCC relies on single benchmark to analyze whether advanced service is deployed: SPEED

    - Latency, capacity (usage allowances), consistency not used

See FCC web page at https://www.fcc.gov/reports-research/reports/broadband-progress-reports for access to all Broadband Progress Reports

Evolution of FCC's Definition of Broadband

Establishes minimum speed threshold benchmarks that reflect "advanced telecommunications capability"

Year	Generation	Downstream Speed	Upstream Speed	Comment
1999	First Generation	200 Kbps	200 Kbps	Low-speed threshold
2010	Second Generation	4 Mbps	1 Mbps	Moderate improvement
2015	Third Generation	25 Mbps	3 Mbps	• 29% HH already with these speeds • 17% without access (53% in rural)

Fourth Generation Broadband Definition Coming Soon?
Section 706 Notice of Inquiry announced July 2023

- Increase fixed broadband standard to 100/20 Mbps
  - Cites BEAD Act as evidence supporting this standard
  - Proposes separate national goal of 1 Gbps/500 Mbps for the future
- Several characteristics to determine whether broadband deployment is available in reasonable and timely fashion to "all Americans"
  - Affordability, adoption, availability, and equitable access

"Anything short of 100% is just not good enough."

-FCC Chairwoman Jessica Rosenworcel

So Then, What Exactly Is the *Internet*?

- Access to email, websites, search information, etc.

- Internet of (Interesting) Things!

- Information Technology in businesses

- Community broadband

- *Network of networks*…

Service View of the Internet

- Distributed infrastructure that provides data transport services to applications
    - Web, VoIP, email, games, e-commerce, social nets, …
- Provides application programming interface (API) to online applications
    - Software that allows app programs to "connect" to Internet (aka "socket interface")
- Provides service options to apps

Importance of Internet Layers

Basis of Internet architecture managed by IETF (Internet Engineering Task Force)

- Cross-layer interoperability based on data "packets" using IETF protocols

- Openness – nobody owns core protocols

- Ideal: Firms compete independently at each layer without having to enter market for services at other layers

  - Reality: App, ISPs, Datacenter, Cloud providers overlap layers

- "Hourglass" innovation on the Internet

Application Layer	*Services*
Network Layer	*Protocols*
"Physical" Layer	*Cables*
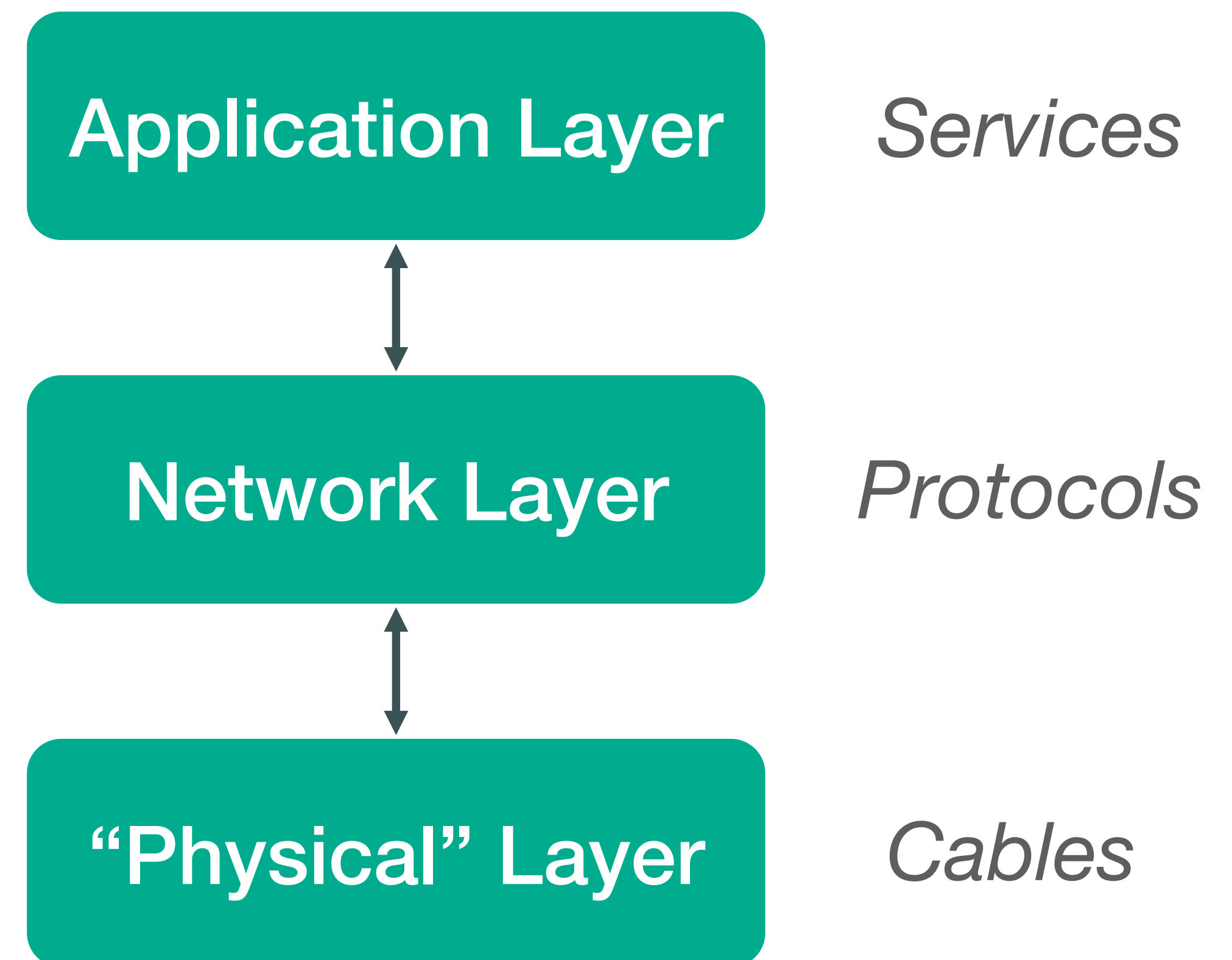
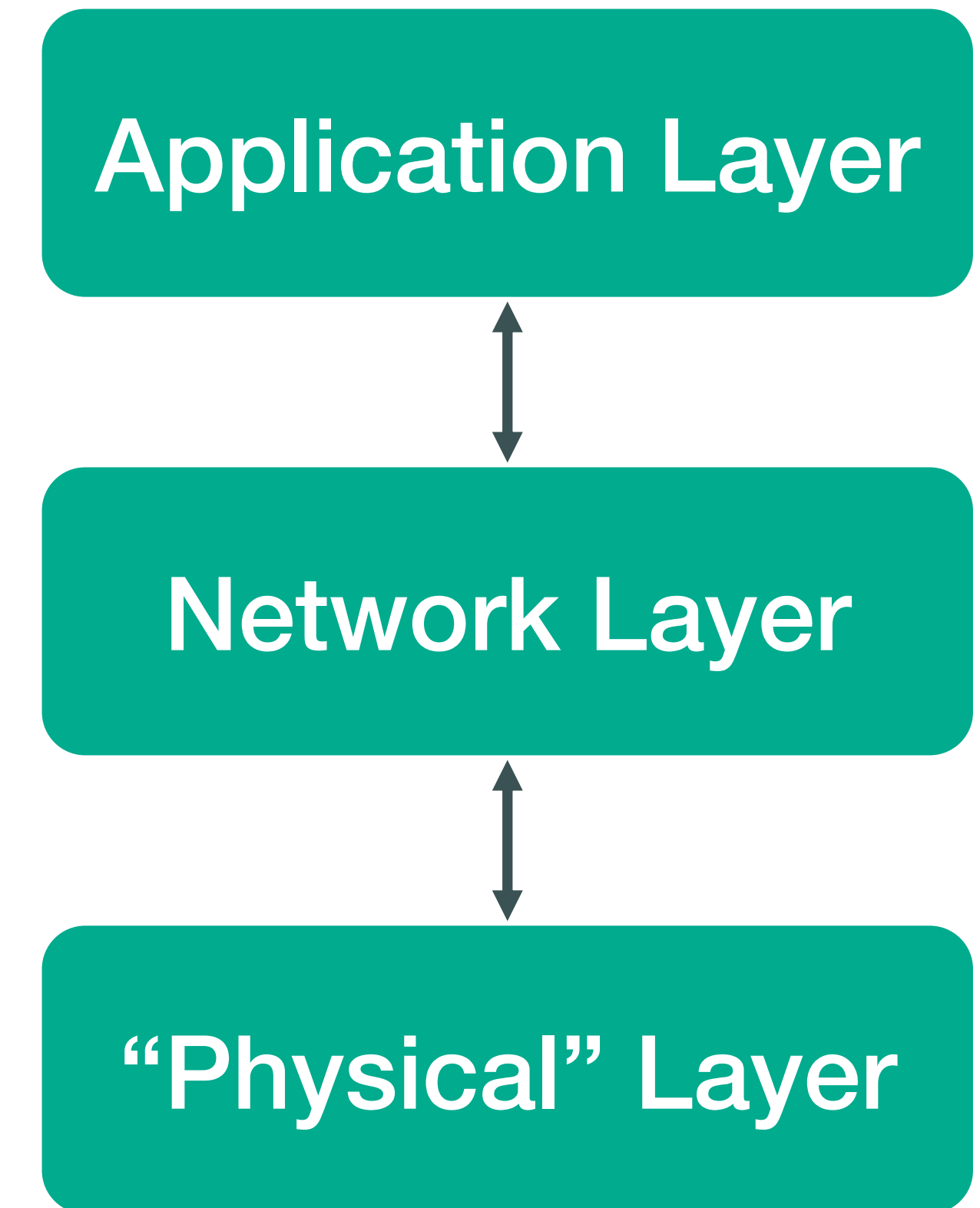# Internet Hosts Send *Packets* of Data

- Host sending function:
  - Break application message into smaller chunks of data called packets
  - Transmit packet into network connection at some transmission rate or link bandwidth
- Network core
  - Routs and forwards packets from one router to the next on path to destination
- Host receiving function:
  - Receive packet from network and send to appropriate application in host for message reassembly
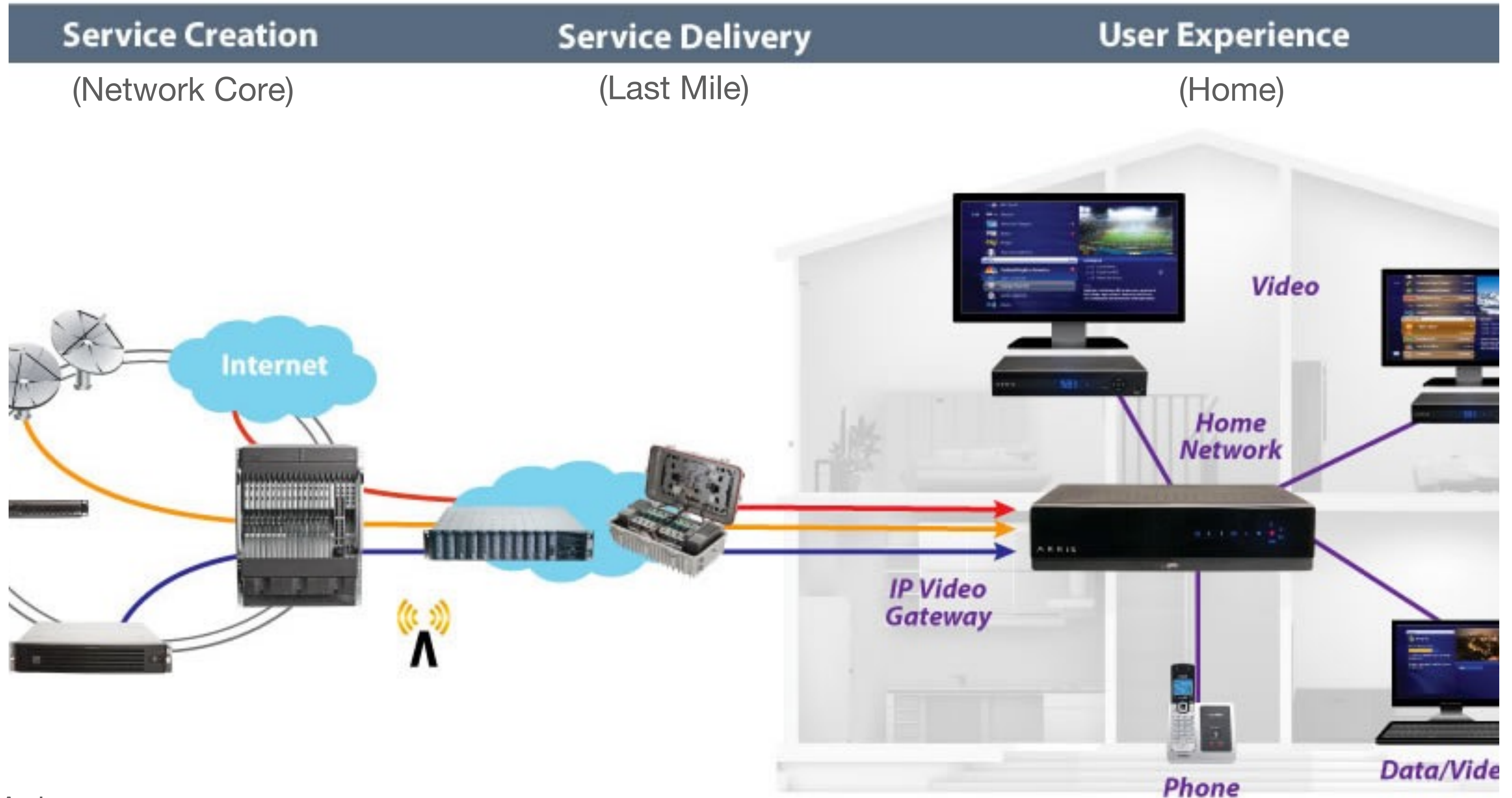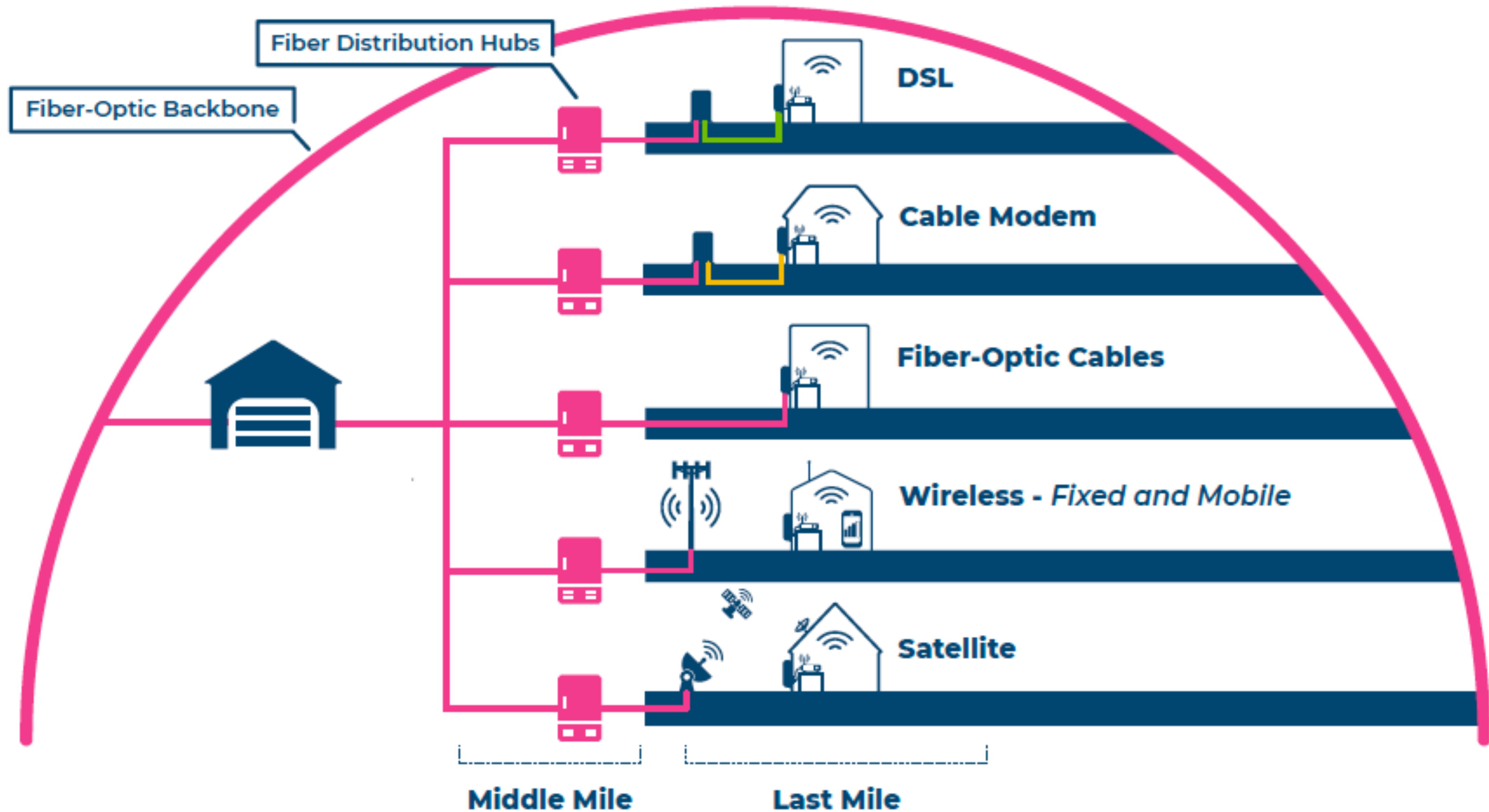
Layered Internet Architecture

o Layered reference model defines roles and relationship of a complex system of network segments

o Different *protocols* at each layer define format, order of messages, and the actions taken on messages to transmit and receive

o Each layer offers service model to layer above

o Modularization eases maintenance, updating of system, transparency of layer's service to rest of system
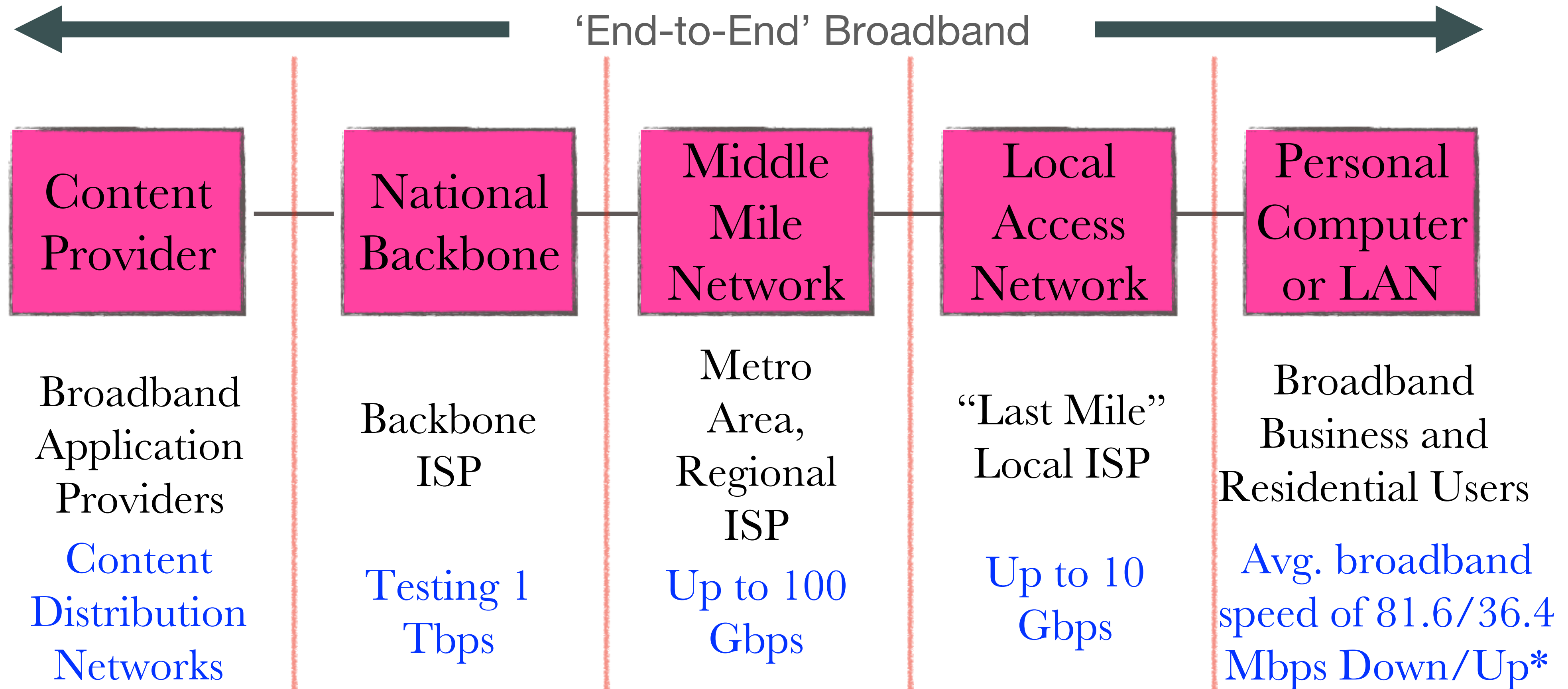
Application Layer

Network Layer

"Physical" Layer

Application Layer (Services) View

Service Creation	Service Delivery	User Experience
(Network Core)	(Last Mile)	(Home)

Source: Arris

Broadband Service Delivery

Fiber Distribution Hubs

Fiber-Optic Backbone

DSL

Cable Modem

Fiber-Optic Cables

Wireless - *Fixed and Mobile*

Satellite

Middle Mile

Last Mile

Broadband Service Delivery

← 'End-to-End' Broadband →

Content Provider	National Backbone	Middle Mile Network	Local Access Network	Personal Computer or LAN
Broadband Application Providers	Backbone ISP	Metro Area, Regional ISP	"Last Mile" Local ISP	Broadband Business and Residential Users
Content Distribution Networks	Testing 1 Tbps	Up to 100 Gbps	Up to 10 Gbps	Avg. broadband speed of 81.6/36.4 Mbps Down/Up*

*Global average speed of fixed broadband from <u>ookla speed tester</u>, July 2023

Varieties of xDSL Over Telco

- DSL – Digital Subscriber Line
- An alphabet soup of alternatives can be used over the telephone network
    - ADSL/ADSL2/ADSL2+/HDSL/VDSL/VDSL2…
- Bottom line that you need to know:
    - Options differ in service rate due to transmission path length, upstream capacity, generation/capability of technology

DSL Network Evolution (To Fiber)

Technology	Distance	Speed
ADSL2+	< 5 km	≈ 10-20 Mb/s
VDSL2	< 1 km	≈ 20-50 Mb/s, ≈ 100-150 Mb/s (vectored)
Vplus	< 400 m	≈ 200-300 Mb/s
G.fast	< 250 m (1:8-16)	≈ 0.5-1 Gb/s
XG-Fast	< 50 m (1:32-128)	≈ 5-10 Gb/s
FTTH	(1:32-128)	≈ 2.5-10 Gb/s

Central office — Cabinet — Cabinet — Distribution point — Building/driveway — Home

Time
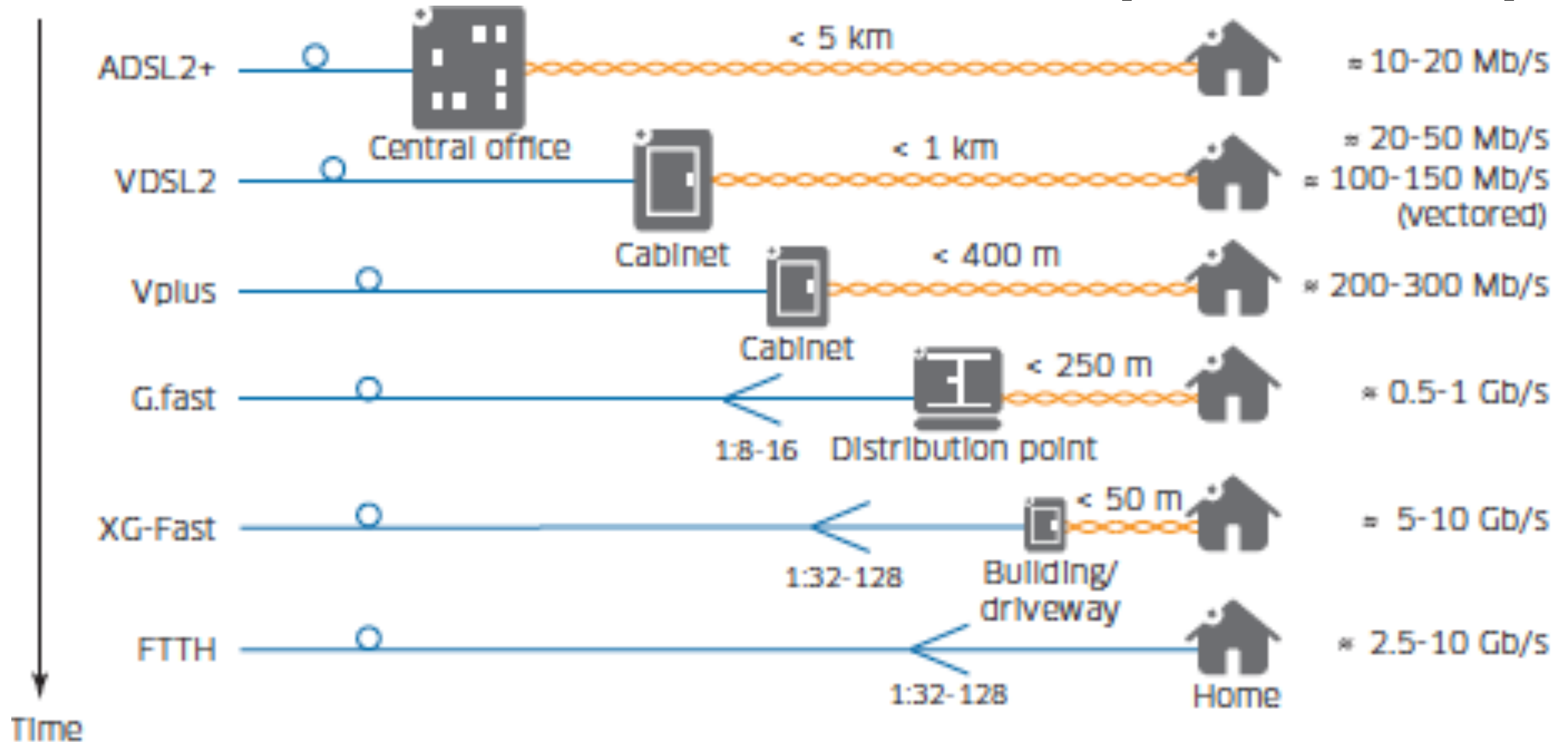
Source: The Future X Network, A Bell Labs Perspective, Chapter 7, 2016

DSL Tradeoffs

Near "End-of-Life" Due to Speed and Distance Constraints

<u>Advantages</u>

- Low cost when telephone network is present

<u>Disadvantages</u>

- Delivers relatively low broadband speeds unless fiber extended very close (200 m.) to customer

- Speeds delivered not consistent for every customer

- Technological obsolescence
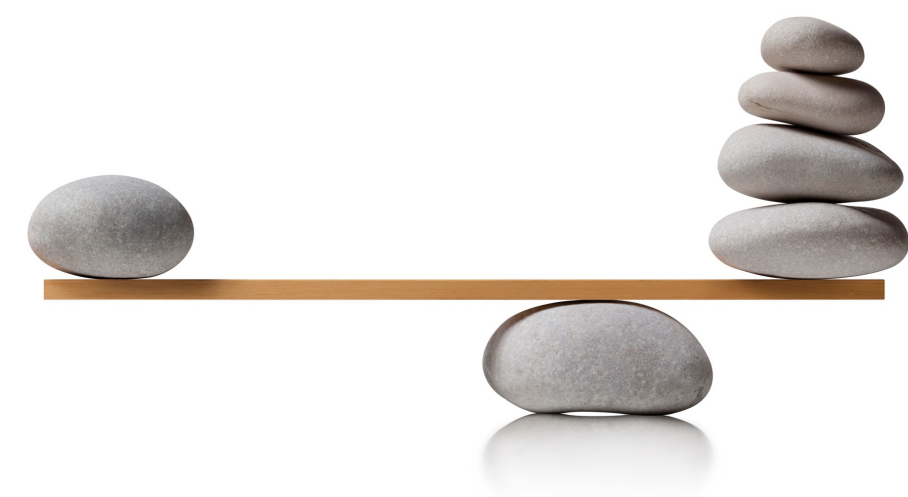
Cable Network (HFC – Hybrid Fiber Coax)

- Usually 750 MHz cable system (860 MHz or 1 GHz becoming more common)
- Old view: 6 MHz of cable spectrum = 1 "channel" of video or DOCSIS
- New view: 192 MHz channels of cable spectrum = max Internet "channel" of 1.89 Gbps
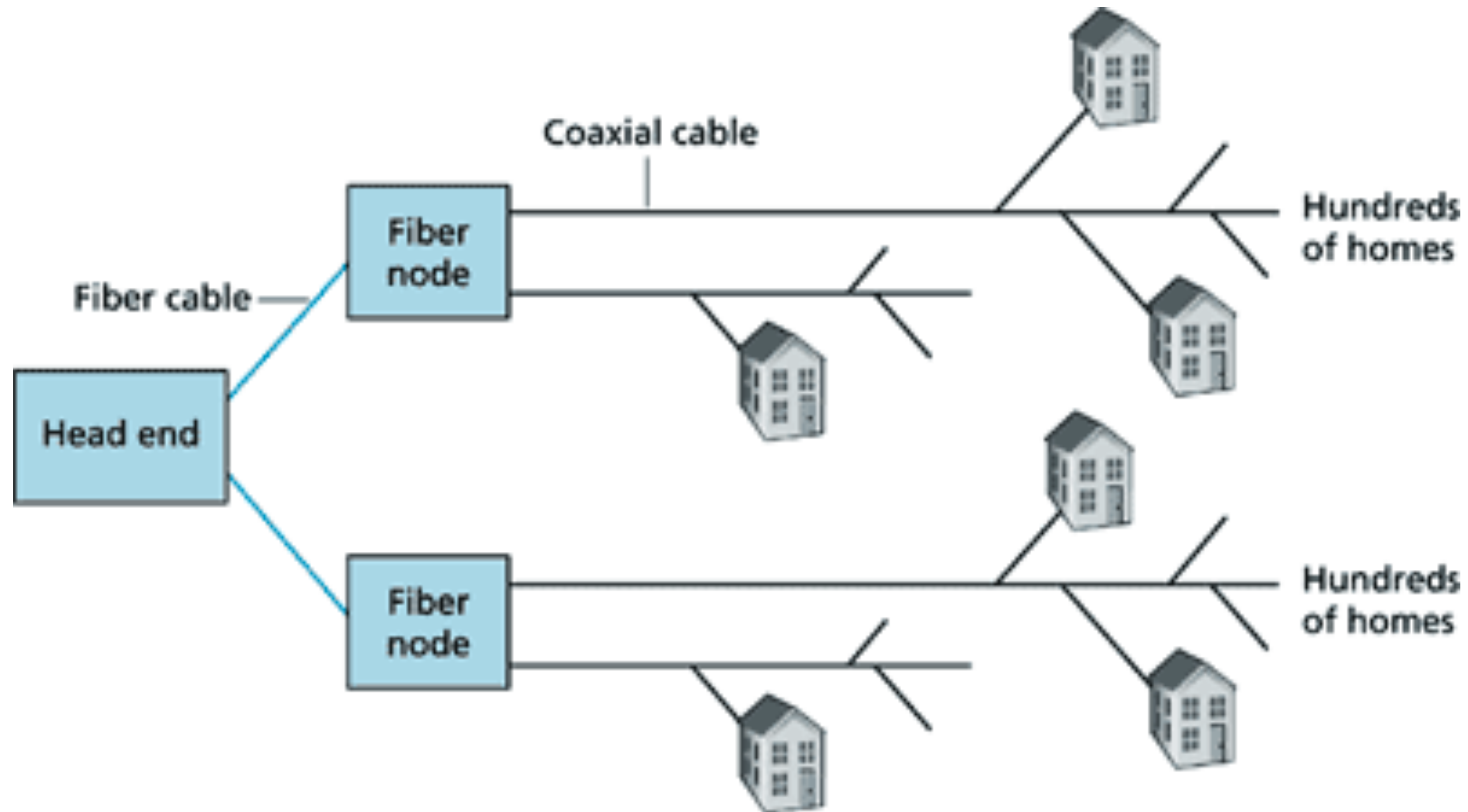
Cable Tradeoffs

Benefits of Incremental Economics

Advantages

- Lower upfront incremental costs to increase speed

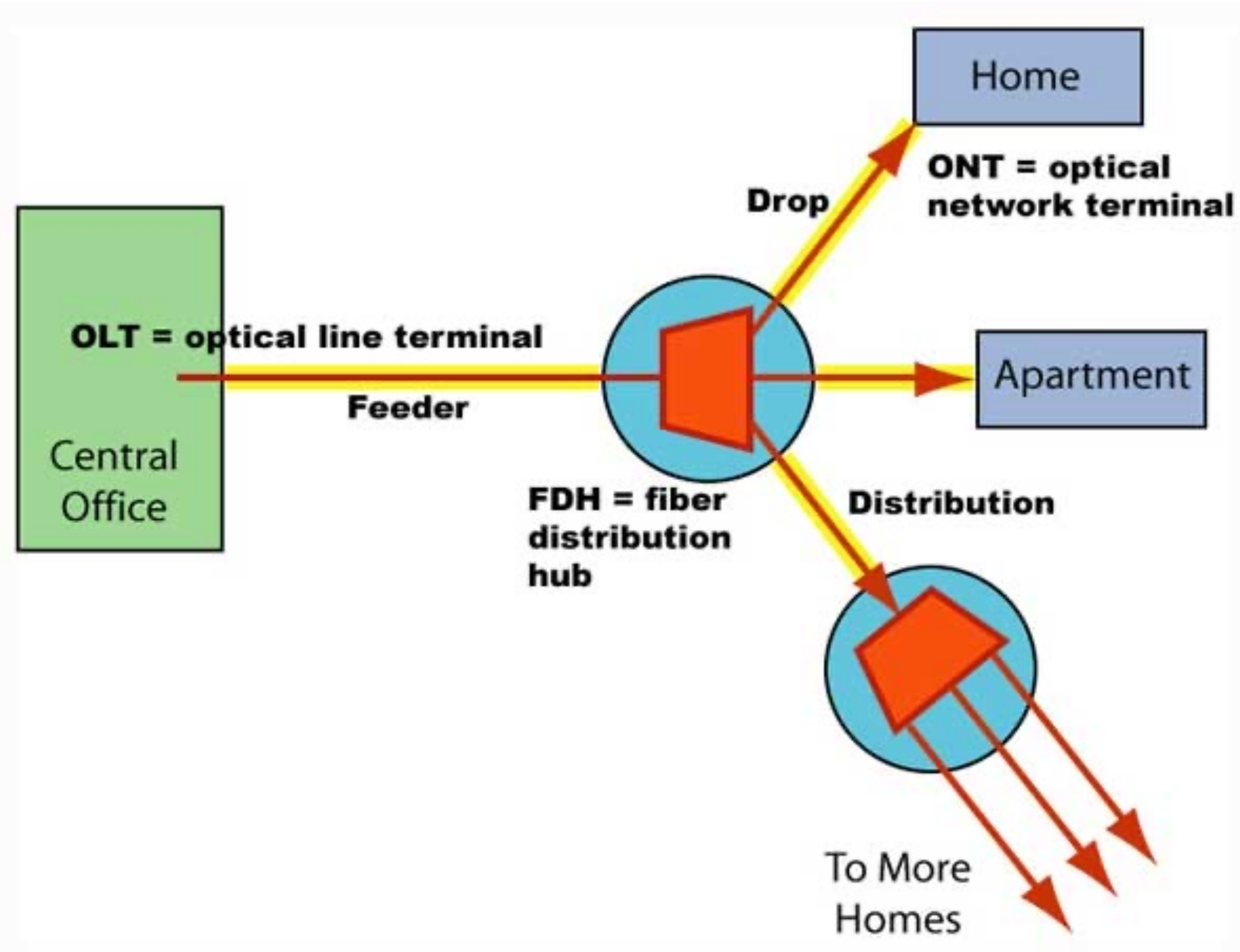- Delivers high-capacity broadband

- Consistent service speeds to customers

Disadvantages

- Upstream capacity limits
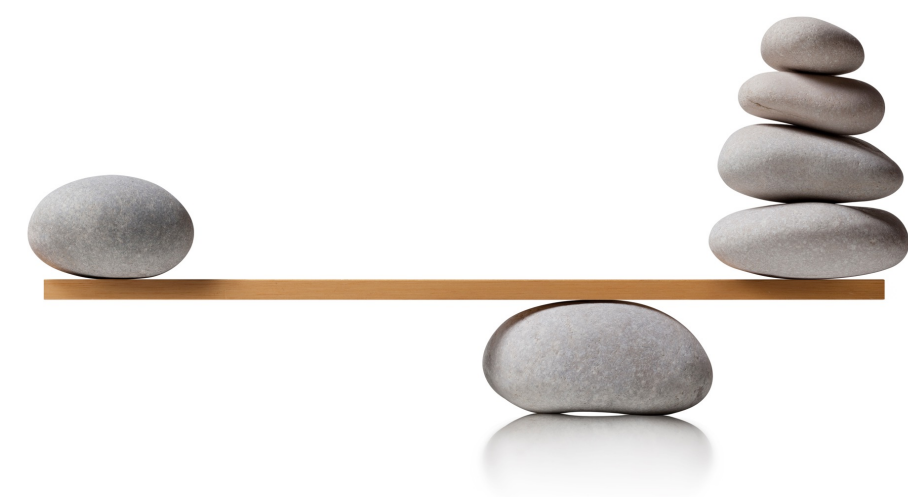
Fiber to the Home – Passive Optical Networks (PONs)

- PON: Lowest cost fiber design due to sharing

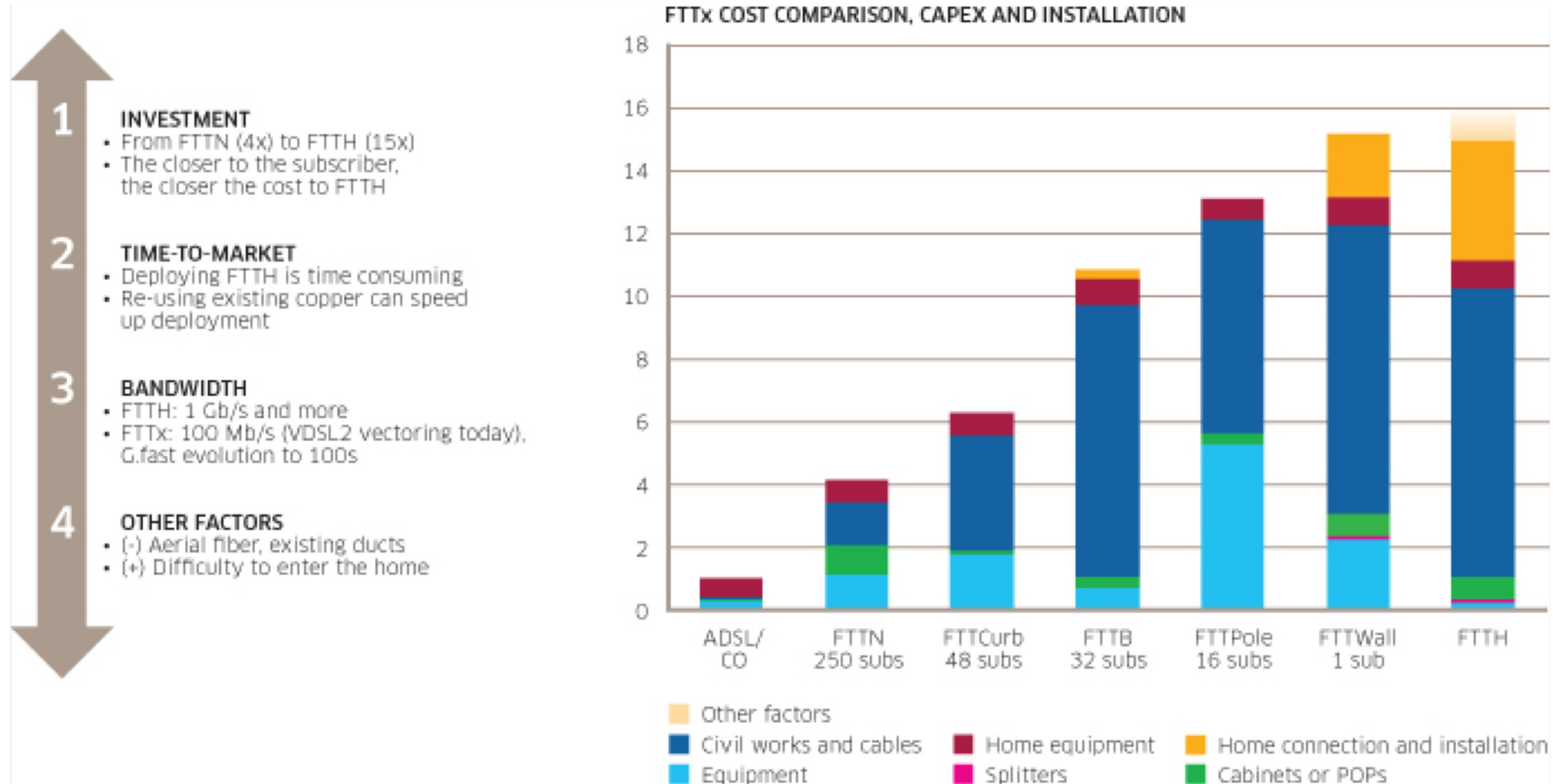- Separate wavelengths for up/down paths

Fiber-Optic Networking Standards

- Gigabit Passive Optic Network (G-PON) is the lowest cost and most broadly deployed FTTP access technology

- Four standardized options

PON Technology	Downstream	Upstream
G-PON (Gigabit)	2.4 Gbps	1.2 Gbps
XG-PON (10 Gigabit)	10 Gbps	2.4 Gbps
XGS-PON (10 Gigabit Symmetric)	10 Gbps	10 Gbps
TWDM-PON (Time Wavelength Division Multiplexing)	4x10 Gbps	4x10 Gbps

Cost of FTTH

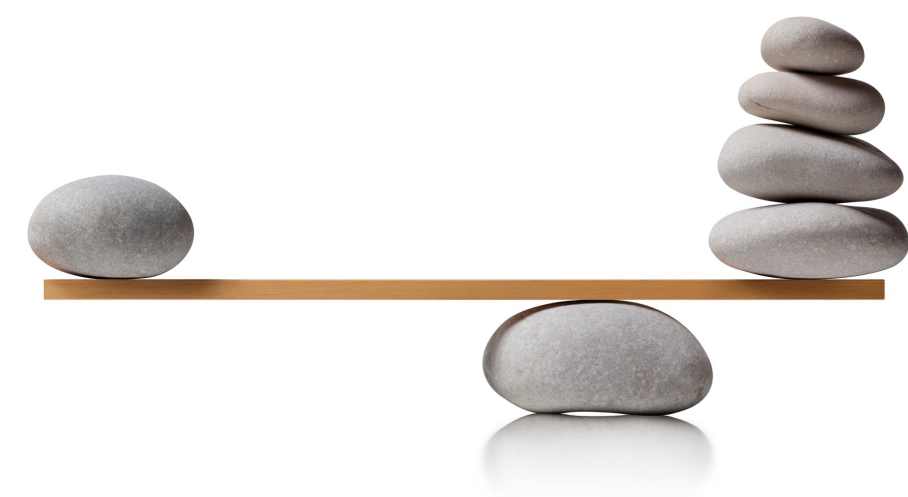## Roughly 10x Cost Premium over Fixed Wireless in Rural

INVESTMENT
1
- From FTTN (4x) to FTTH (15x)
- The closer to the subscriber, the closer the cost to FTTH

TIME-TO-MARKET
2
- Deploying FTTH is time consuming
- Re-using existing copper can speed up deployment

BANDWIDTH
3
- FTTH: 1 Gb/s and more
- FTTx: 100 Mb/s (VDSL2 vectoring today), G.fast evolution to 100s

OTHER FACTORS
4
- (-) Aerial fiber, existing ducts
- (+) Difficulty to enter the home

FTTx COST COMPARISON, CAPEX AND INSTALLATION

Categories: ADSL/CO, FTTN 250 subs, FTTCurb 48 subs, FTTB 32 subs, FTTPole 16 subs, FTTWall 1 sub, FTTH

Legend:
- Other factors
- Civil works and cables
- Equipment
- Home equipment
- Splitters
- Home connection and installation
- Cabinets or POPs

Source: http://www2.alcatel-lucent.com/techzine/the-numbers-are-in-vectoring-2-0-makes-g-fast-faster/

FTTH Tradeoffs

Often cited as "One-Size-Fits-All", "Future Proof" Approach

<u>Advantages</u>

- Very high capacity (virtually unlimited bandwidth)

- Low operations costs (immunity to electrical noise and interference)
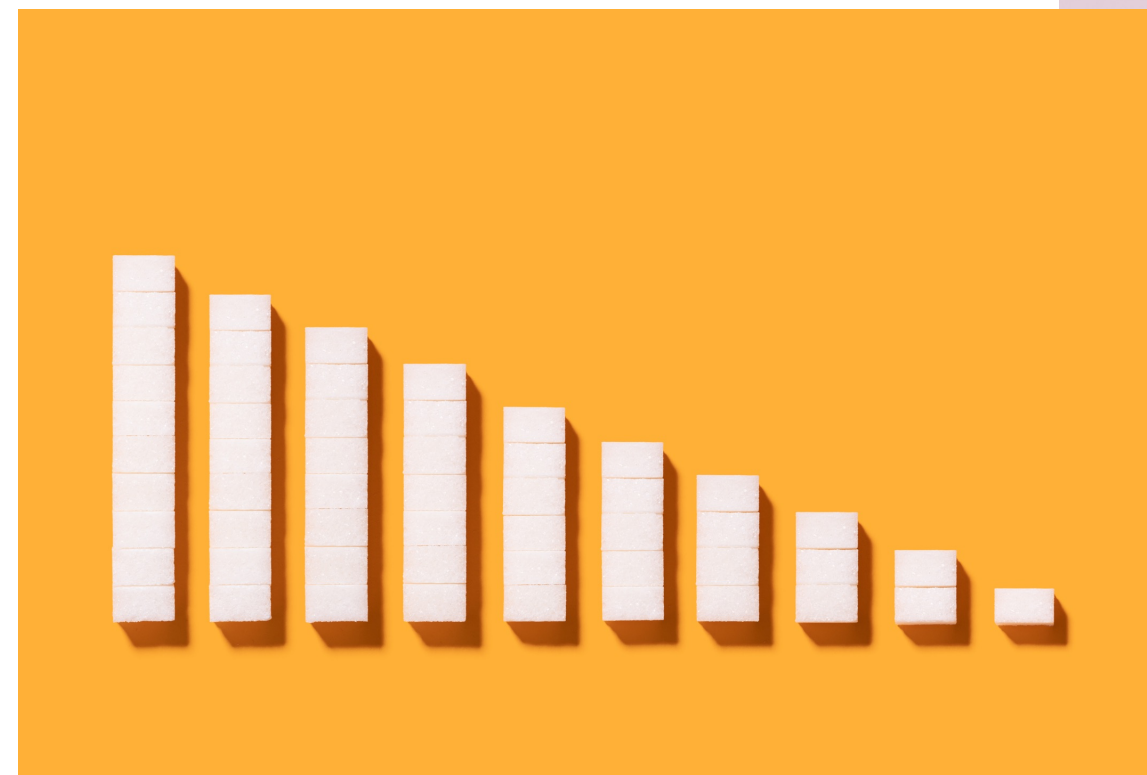
<u>Disadvantages</u>

- Very high fixed cost

Wireless Network Components

- Wireless devices

  - Laptops, smartphone, Internet of Things (IoT) devices
  - Run applications
  - May be stationary (fixed), portable, or mobile
  - May require location that is line-of-sight with cell site

Wireless Network Components

- Base station or WIFI access point
  - Often (though not always) connected to wired network at antenna cell site location
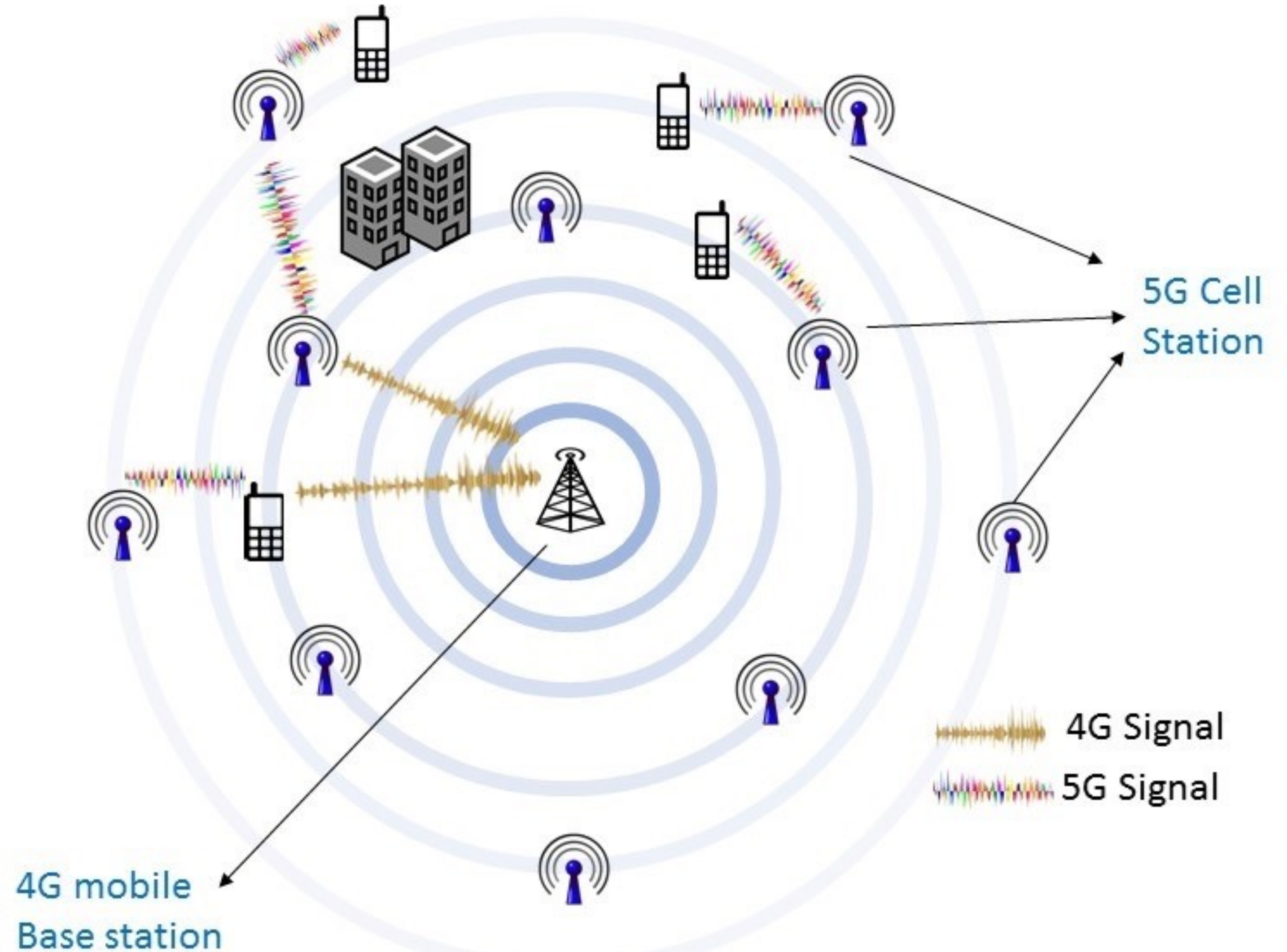 - Sends packets between wired network and wireless host(s) in the coverage area of antenna
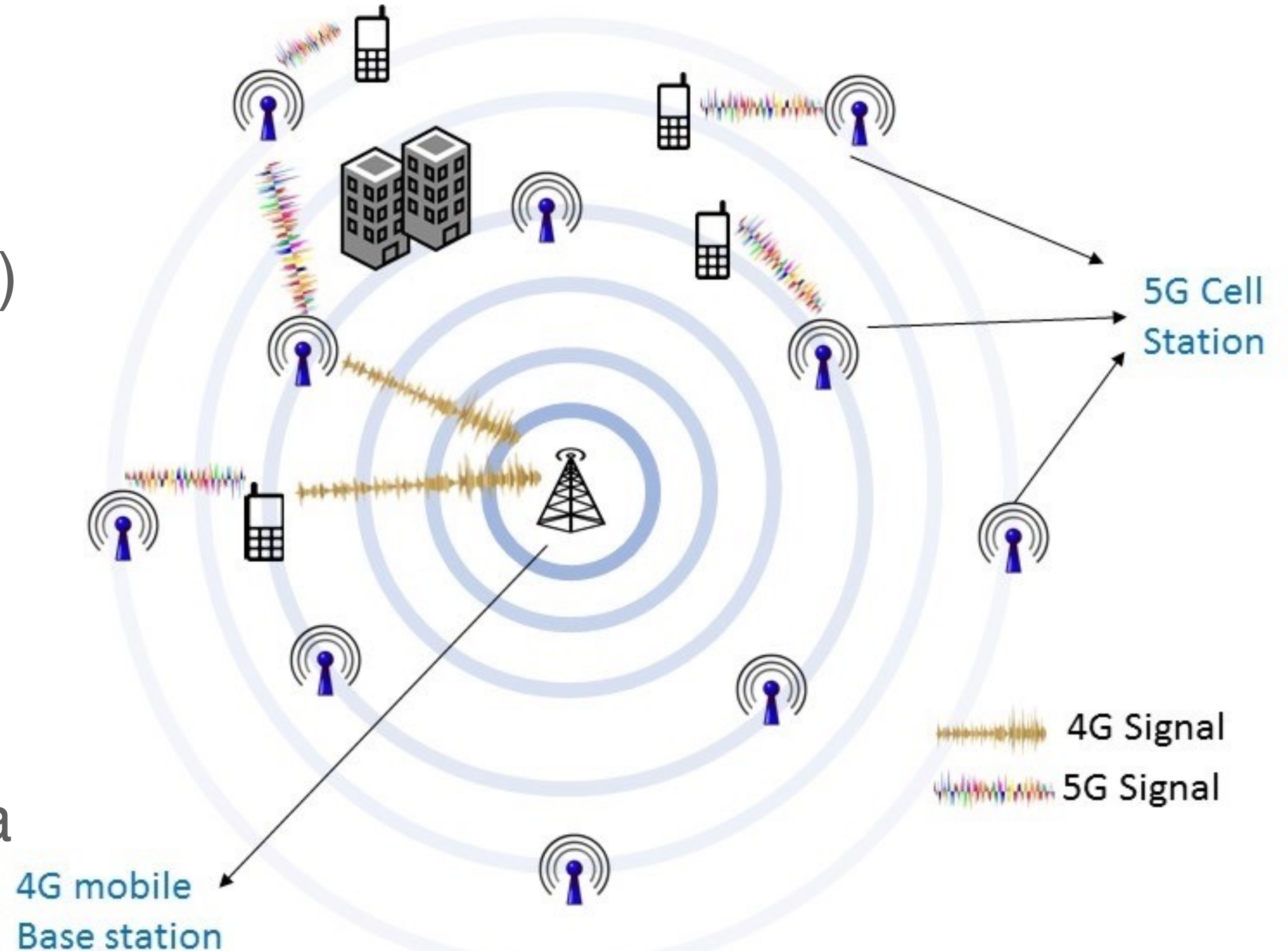
5G Cell Station

4G Signal
5G Signal

4G mobile Base station

4G-5G mobile Network Infrastructure

Wireless Network Components

- Wireless link
  - Connect mobile(s) to base station
  - Increase capacity using small cells
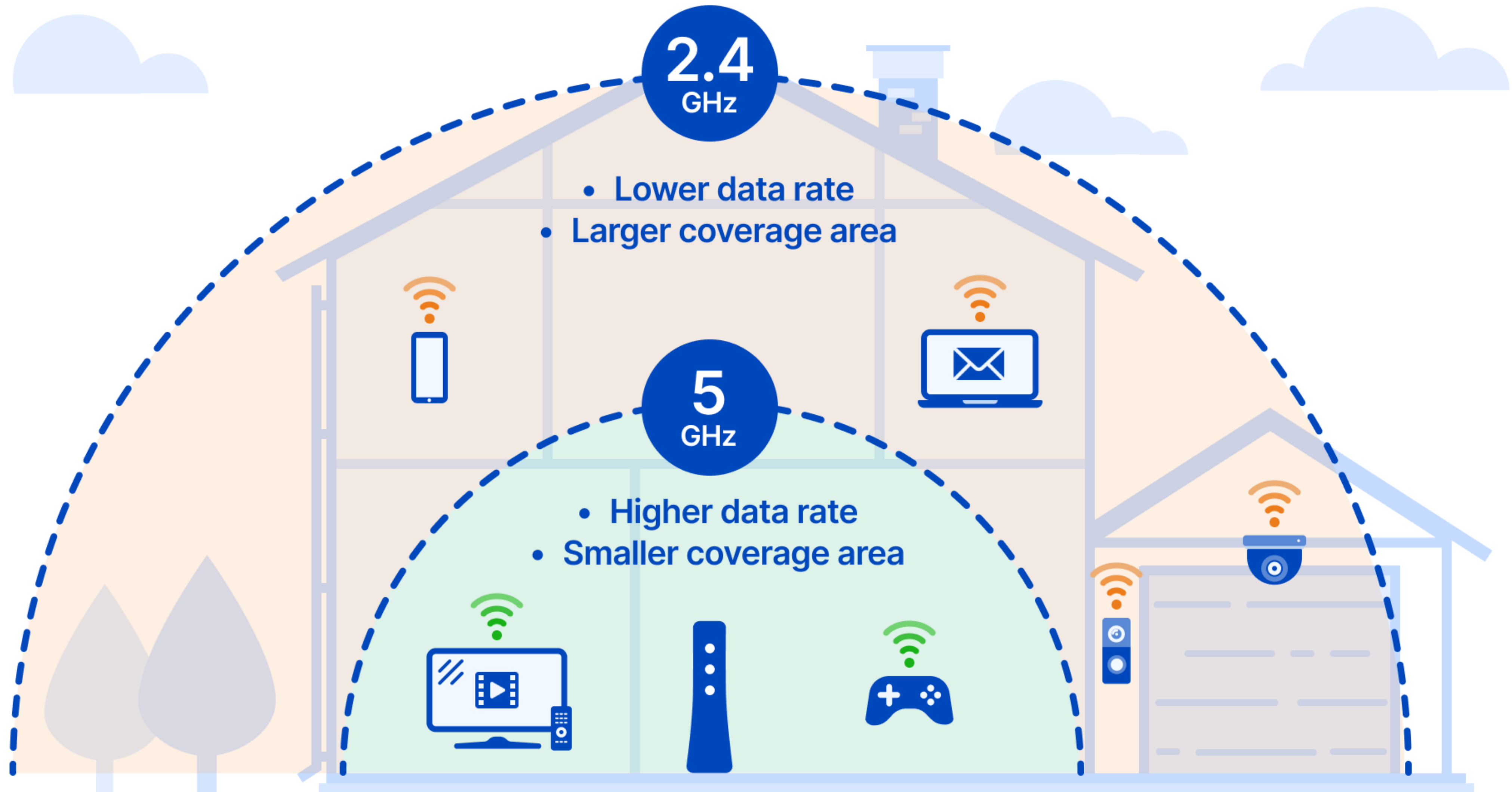 - Various transmission rates and distances, frequency bands

5G Cell Station

4G Signal

5G Signal

4G mobile Base station

4G-5G mobile Network Infrastructure

36

Wireless Network Design Principles

- Cells cover unique geographical region
- Designed for capacity vs. coverage limitations
- Cell splitting increases capacity by reducing cell size, causing higher spectrum reuse


37
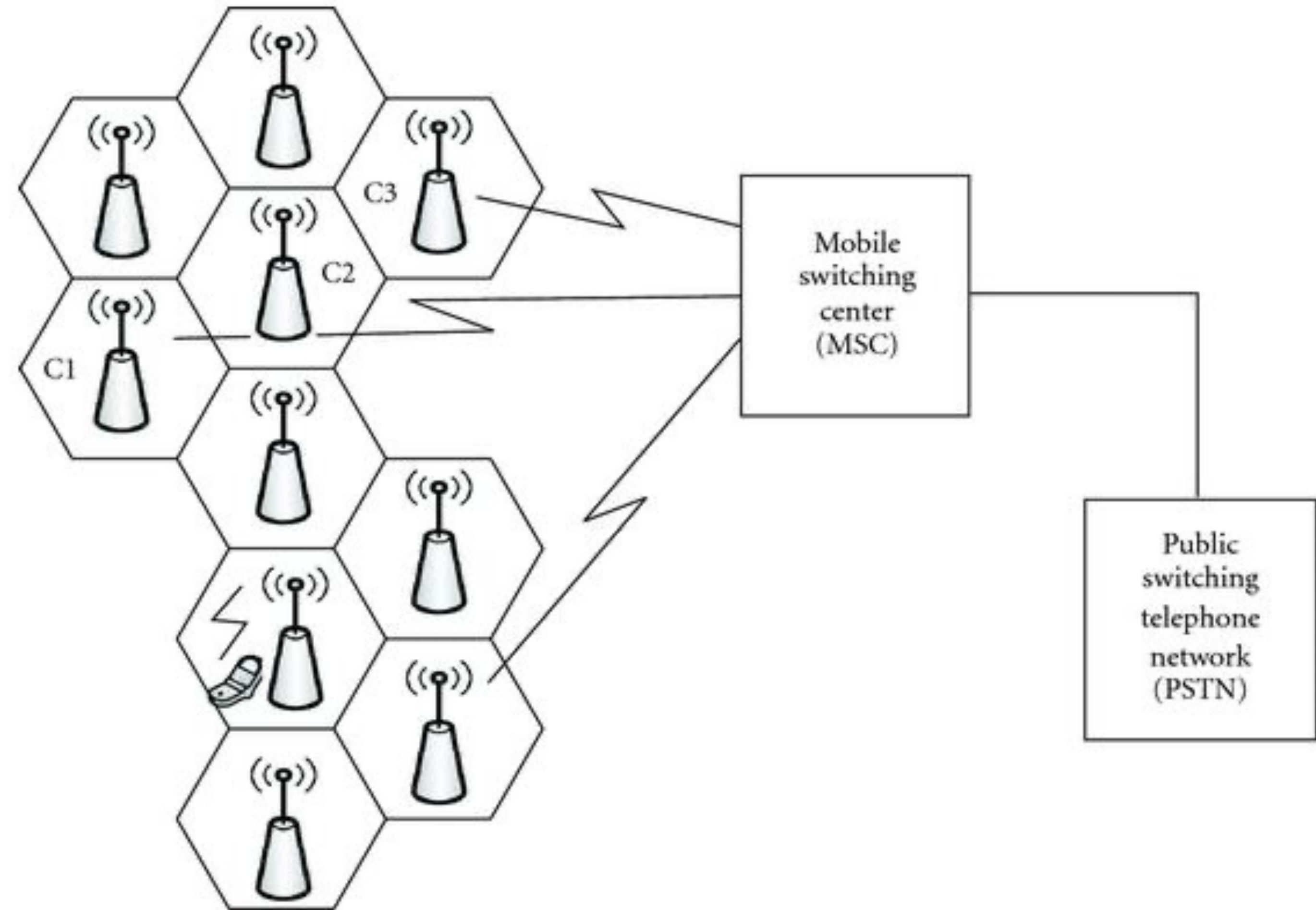
Type of Spectrum is Important

2.4 GHz
- Lower data rate
- Larger coverage area

5 GHz
- Higher data rate
- Smaller coverage area

Source: CenturyLink website at https://www.centurylink.com/home/help/internet/wireless/which-frequency-should-you-use.html

38

"Real-World", Maximum Speed of Wireless Systems (Wi-Fi)

2.4 GHz	Theoretical Speed	Real-World Speed
802.11b	11 Mbps	2-3 Mbps
802.11g	54 Mbps	10-29 Mbps
802.11n	300 Mbps	150 Mbps

5 GHz	Theoretical Speed	Real-World Speed
802.11a	6-54 Mbps	3-32 Mbps
802.11ac	433 Mbps - 1.7 Gbps	210 Mbps - 1 Gbps
802.11n	900 Mbps	450 Mbps

Source: CenturyLink website at https://www.centurylink.com/home/help/internet/wireless/which-frequency-should-you-use.html

Fixed Wireless Access (FWA) Approach

- Using wireless options with more bandwidth and longer range

- Usually requires line-of-sight connectivity for high speed

- 5G, WiFi-based, microwave radios…

- More spectrum becoming available via 5G or unlicensed

- 5G and Wi-Fi lowering equipment costs

Source: AFNet
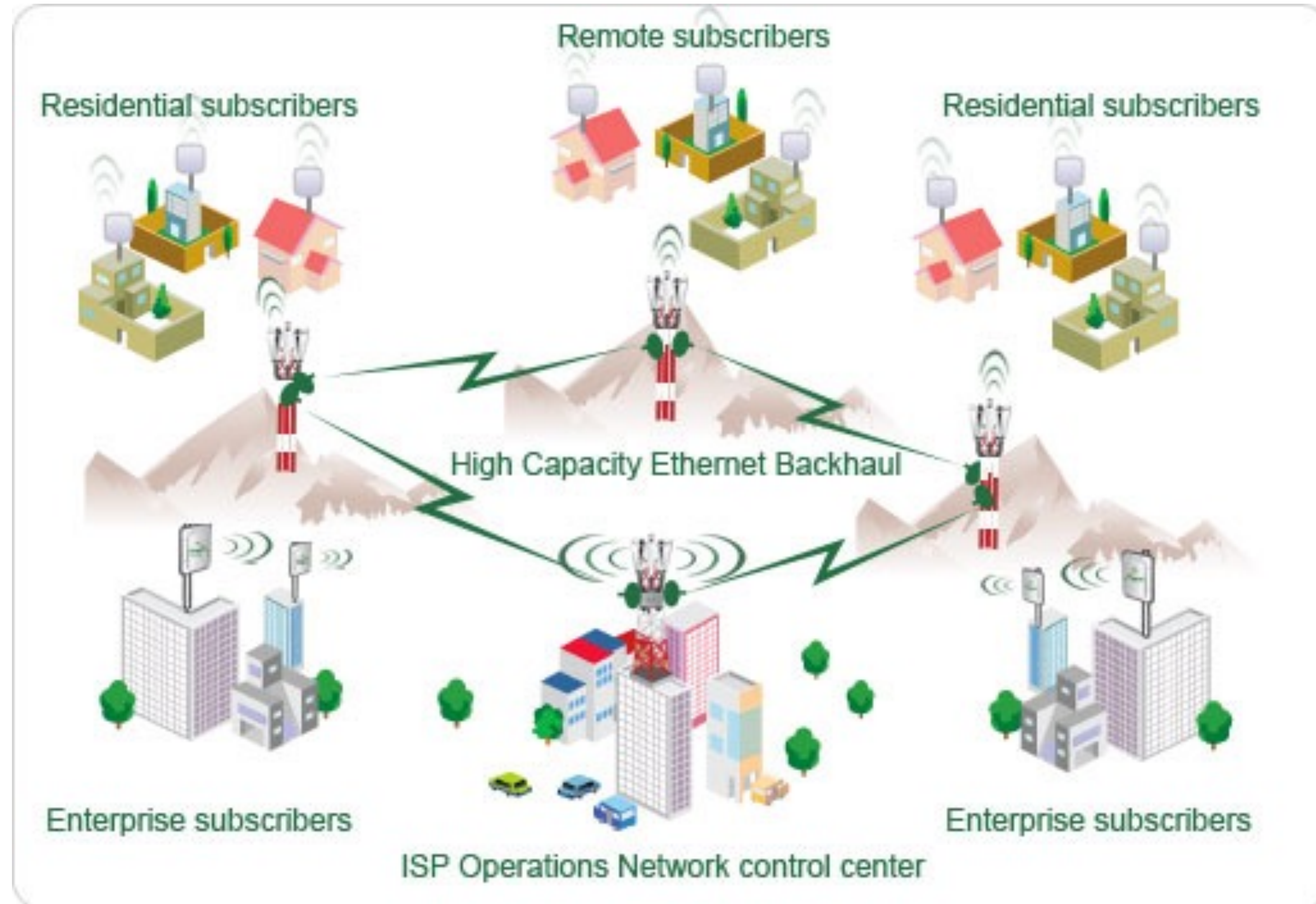
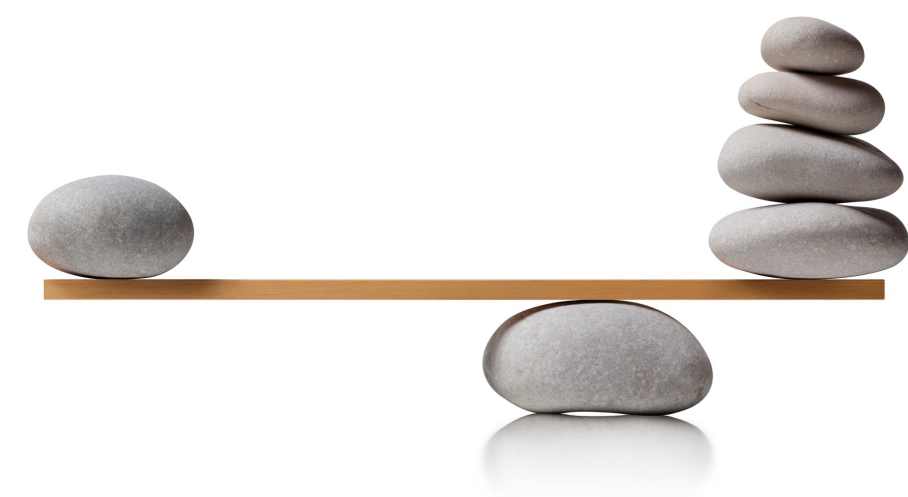# Wireless Tradeoffs

Spectrum scarcity driving new spectrum sharing solutions

Advantages
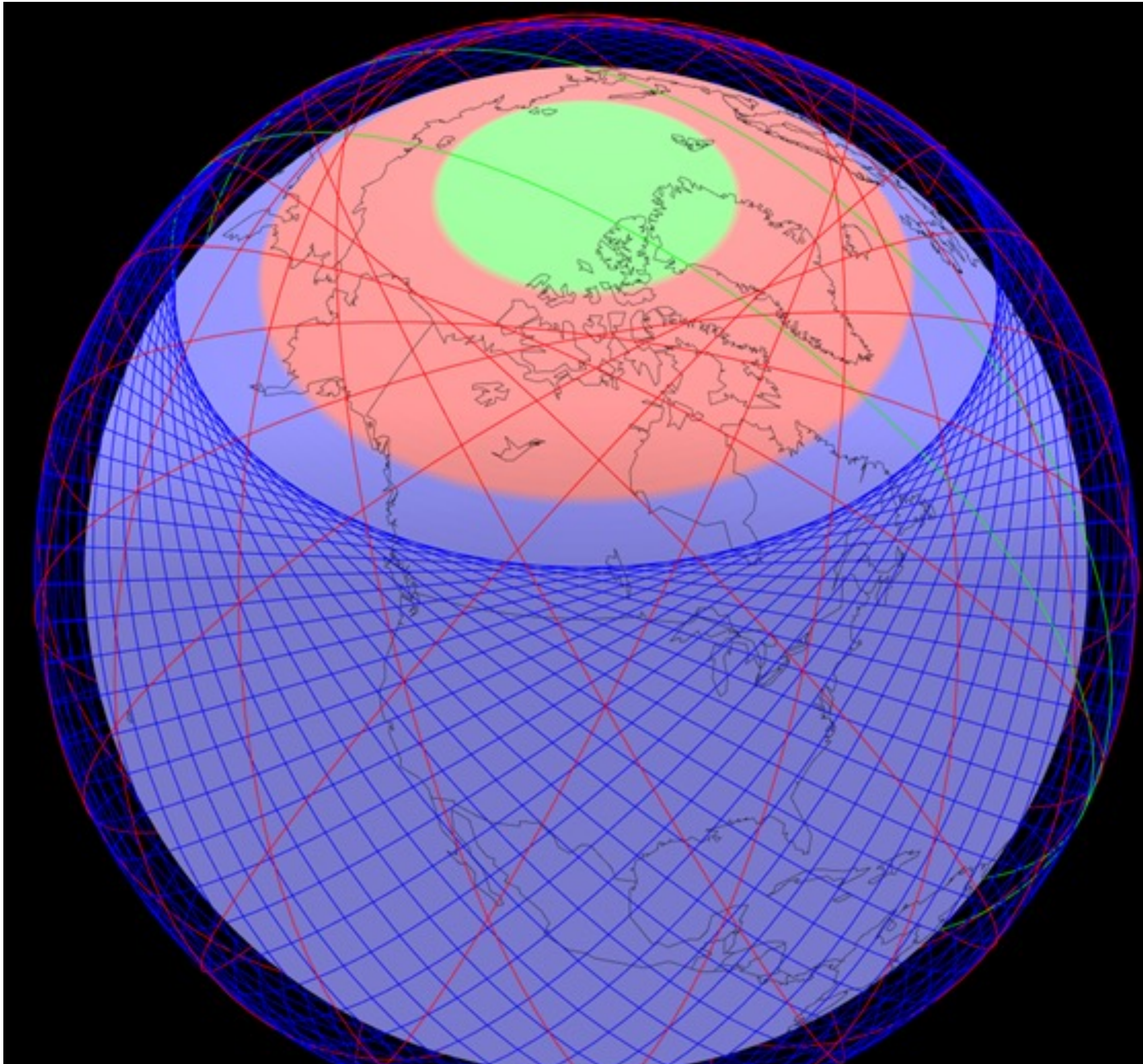
- Low cost in last mile

- Standards lowering equipment costs

Disadvantages

- Cost and characteristics of spectrum license
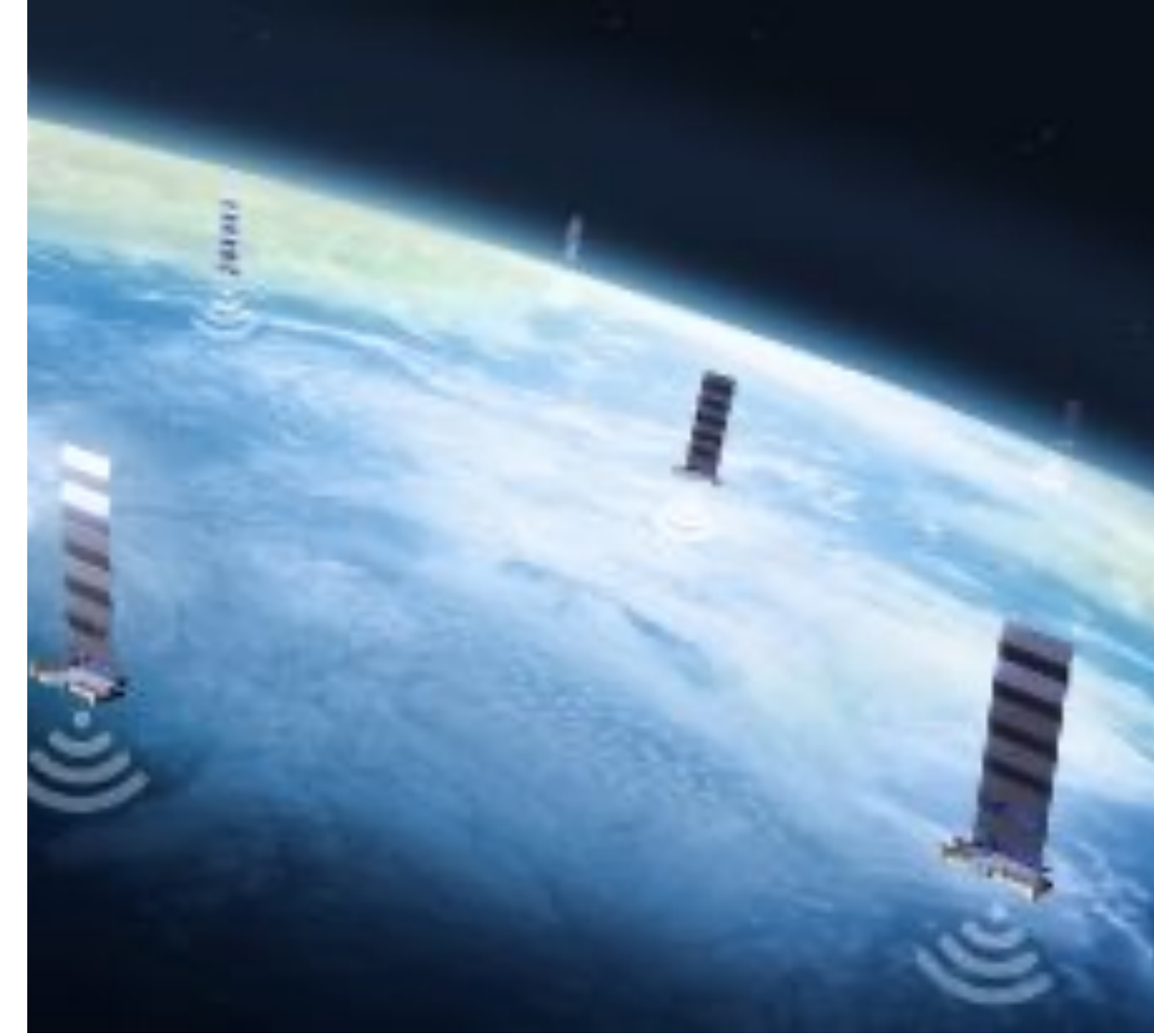
- Speed limitations

Emerging Broadband Option: LEO Satellites

- GEO-based systems were heavily shared, slowing speeds

- LEO-based systems can improve latency/speed

- Offers global coverage to eliminate service gaps

Satellite Broadband Trends

Undergoing significant disruption with LEO satellites

- LEOs lower latency to support mobile/voice transport and increase speed up to 100 Mbps
- Best fit in rural settings connecting to dedicated or shared customer segment sites that fan out with shared Wi-Fi
- Platform limits
  - Effectively line-of-sight
  - Cost of satellite launch, and cost of ground segment equipment
  - Lack of capacity for high bandwidth services (e.g., streaming HD)
- Good at broadcasting – good technology fit for IP video

Key Disruptive Force
SpaceX Launch Vehicles

DRAGON

FALCON 9

FALCON HEAVY

STARSHIP

Satellites Re-Emerging for Broadband

Mega-constellations of LEO Satellites

Broadband Operator	# of Satellites Deployed	Spectrum	Technology	Operational
Space X (Starlink)	12000+ (3580)	Ku-band	Proprietary	Yes
OneWeb	648 (542)	Ku-band	Proprietary	TBD
Kuiper	3236 (0)	Ka band	Proprietary	2024 (estimate)
Galaxy Space	1000 (7)	Q/V spectrum	Proprietary	TBD

- Performance improves with additional satellites and terrestrial gateways on global basis

- Direct-to-Cellular services also emerging for emergency and messaging services (partnerships include T-Mobile/SpaceX, AT&T/AST, Verizon/Kuiper)
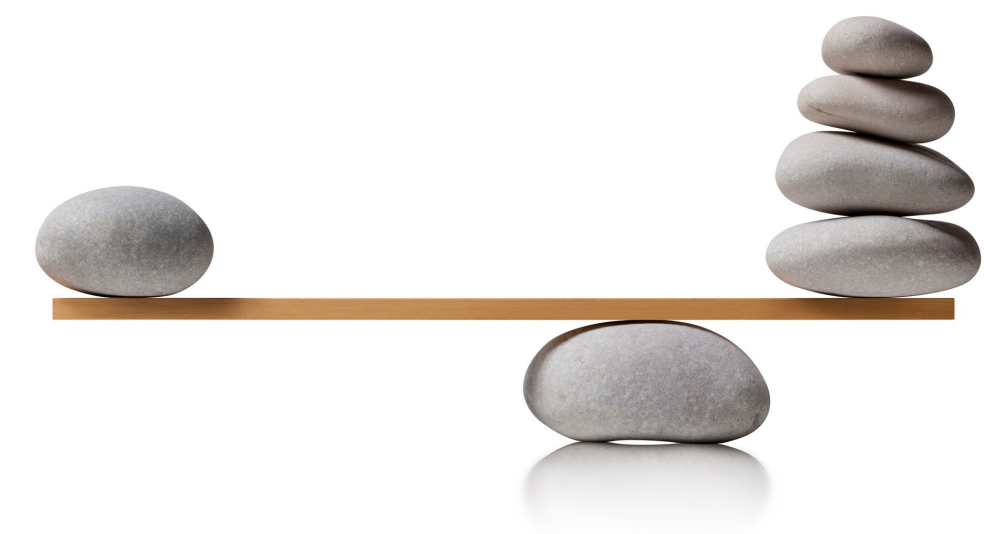
Satellite Tradeoffs (LEOs)

Ubiquitous Coverage with Mega-Constellations

Advantages
- Global coverage without significant gaps
- Latency can be similar to terrestrial
- Low-cost portable and/or broadcast platform
- Low marginal cost

Disadvantages
- High fixed cost
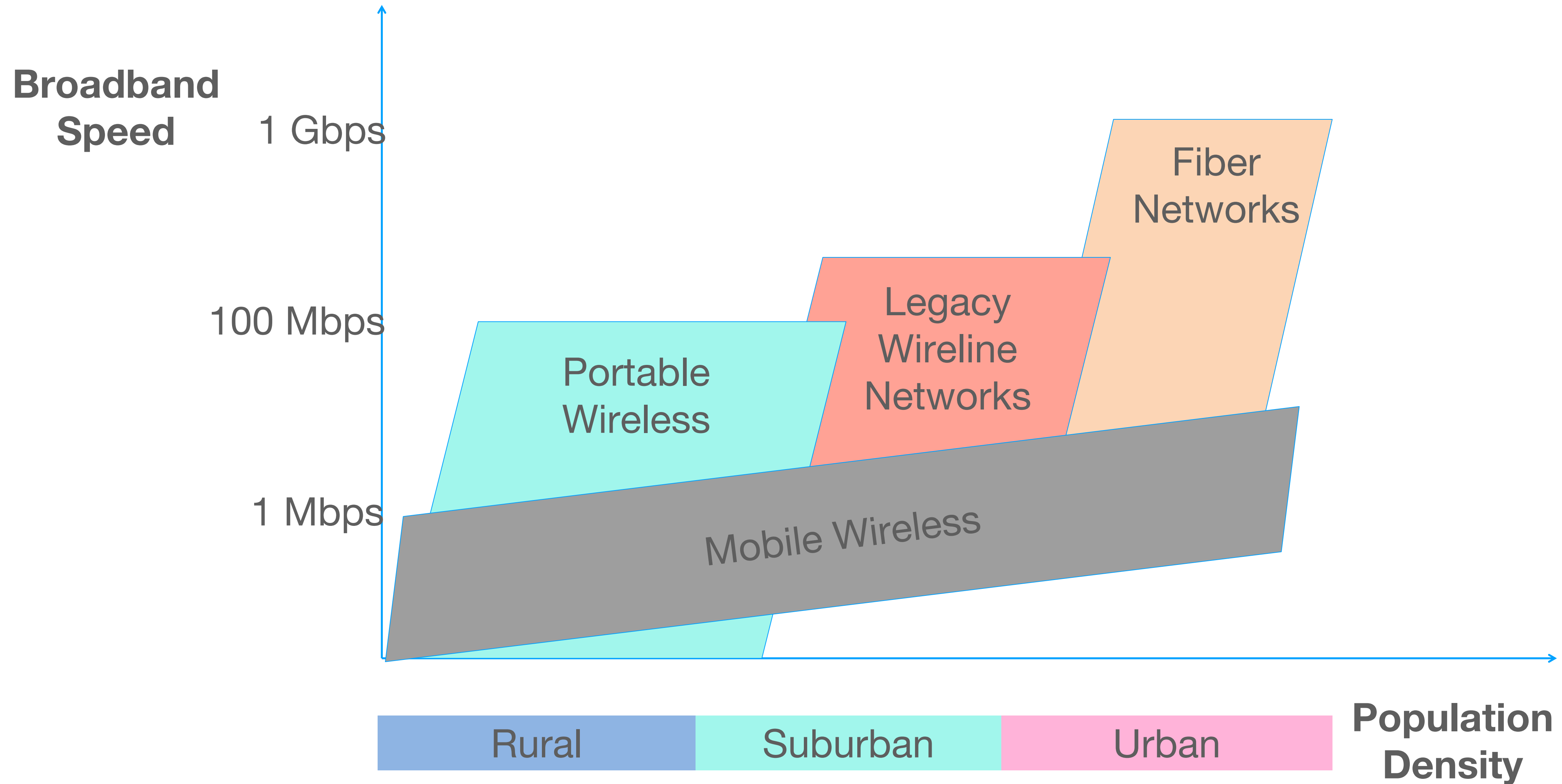- Cost and characteristics of spectrum license
- Speed limitations under load

Summary of Broadband Infrastructure Types
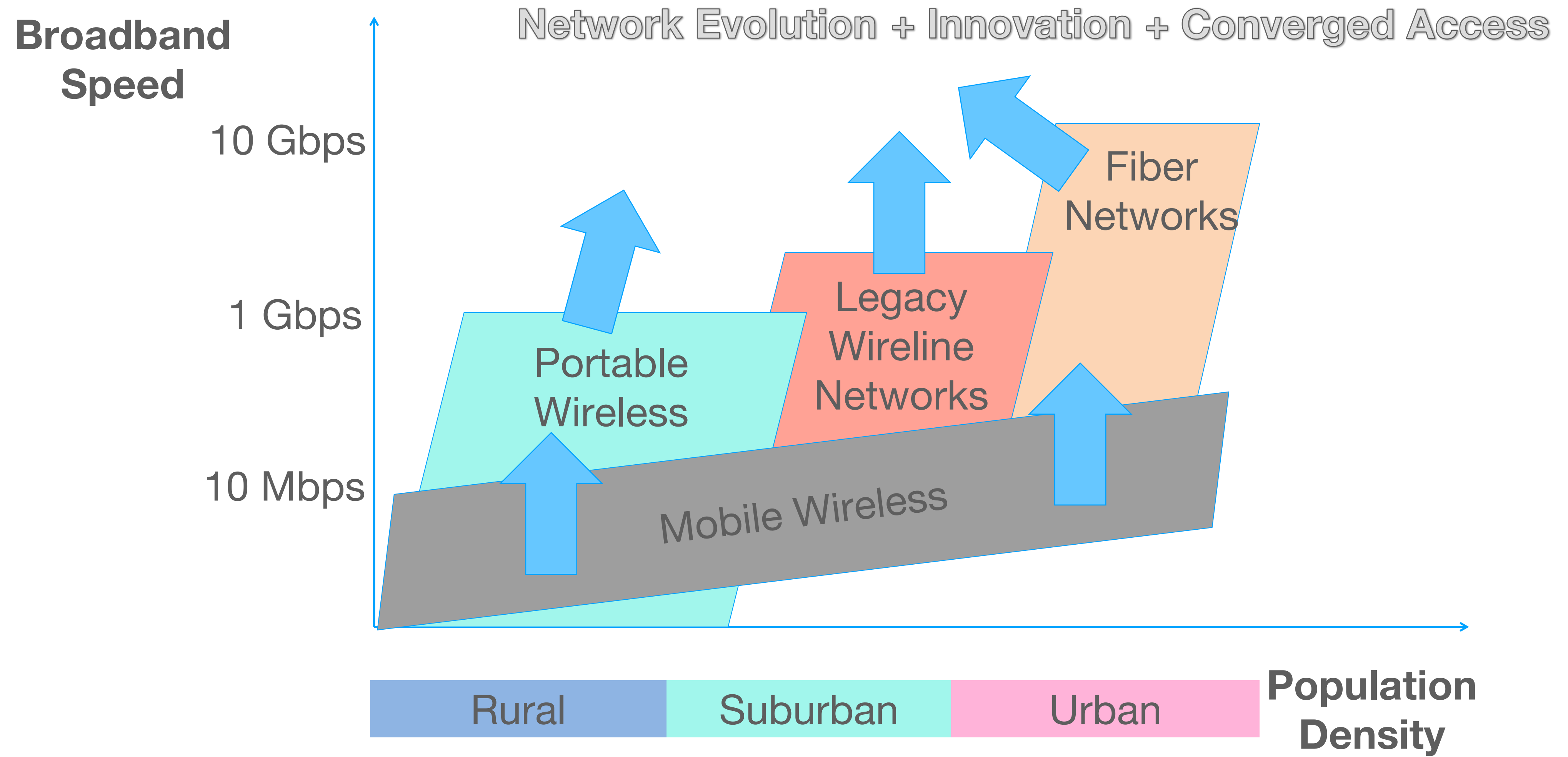
Local Access Network Technologies

- DSL — Tech options differ in speed, transmission length, generation

- FWA — Spectrum barriers falling

- HFC — Incremental economics can fit rural towns, not remote homes (farms)

- FTTH — Very high speed, high fixed cost, "one size fits all" urban solution

- Satellite — Rural solution, if scale achieved with LEOs, provides _substitute_ to terrestrial rural options

Option	Speed	Last-Mile Technology	Rural Cost
DSL (Telco)	<25 Mbps	Copper	Low
FWA (WISP)	100+ Mbps	Wireless	Low (4x)
HFC (Cable)	250+ Mbps	Coaxial Cable	Medium (8x)
FTTH (Telco)	<1 Gbps	Fiber Optics	High (10x)
Satellite (LEO)	150 Mbps	-	Very Low (if scale)

Traditional "Best Fit" Deployment Zones

Broadband Speed

1 Gbps

100 Mbps

1 Mbps

Fiber Networks

Legacy Wireline Networks

Portable Wireless

Mobile Wireless

Rural | Suburban | Urban

Population Density

48

Long-Term Trends

Broadband Speed

Network Evolution + Innovation + Converged Access

10 Gbps

1 Gbps

10 Mbps

Fiber Networks

Legacy Wireline Networks

Portable Wireless

Mobile Wireless

Rural | Suburban | Urban

Population Density

49

PART II: BROADBAND POLICY TOPICS

- ❖ Spectrum Management Primer
- ❖ Broadband Plans
- ❖ Universal Service
- ❖ Net Neutrality
- ❖ Policy Principles for the Definition of Broadband

Spectrum Management

All activities associated with regulating the use of the radio spectrum. Basic elements:

- Allocation

- Service Rules

- Assignment

- Enforcement

Spectrum Allocation

- FCC only allocates for private, state, and local government uses
- National Telecommunications and Information Agency (NTIA) allocates for federal government and military
  - State Department coordinates with International Telecommunications Union (ITU)
- FCC decides amount of spectrum or bandwidth in license

Sharing Spectrum – Allocation Terminology

- Primary allocations grant specific services priority in using allocated spectrum
- Co-Primary allocations occur when there are multiple primary services within a frequency band
  - All have equal rights, protected from others by starting date
- Secondary allocations
  - Cannot cause harmful interference to stations of primary services
  - Cannot claim protection from harmful interference from stations of primary service
  - Can claim protection from harmful interference from stations of same or other secondary service(s) to which frequencies assigned at a later date

Service Rules

- Duration of the license

- Limits on transferability

- Maximum power levels

- Technical standard requirements

- Build-out obligations

Spectrum Assignment

- Comparative hearings (up to 1980s)
  - Meet public interest by selecting "most qualified" users
  - Slow, difficult process with high costs, delays, and arbitrary outcomes
- Lotteries to Qualified Users (late 1980s)
  - Delays in processing large number of applications and fairness concerns as most licenses were quickly "flipped"
- Auctions (early 1990s – present)

Principles of Modern Spectrum Management

- Maximizing <u>flexibility</u> to find highest valued use, subject to interference limitations
  - Choice of use, technology, and right to transfer, lease, or subdivide spectrum rights
- Clear and exhaustive <u>definition of spectrum rights and responsibilities</u>
  - Designated frequency range and bandwidth
  - Geographic scope of right to operate
  - Maximum power output, both in-band and out-of-band
  - Interference protection (max. interference from other sources)

Spectrum Management Models

Command and Control
Exclusive Use
Commons

Traditional "Command and Control" Regulation

- After the Communications Act of 1934, FCC decided who and what was worthy of using spectrum

- Granted renewable licenses for specific government-defined uses

- Service rules define eligibility and service restrictions, power limits, and build-out requirements

- Users had no ownership right in spectrum

- Rules designed to prevent "harmful interference"

Criticisms of Command and Control Approach

- Rigid allocation and assignment of spectrum
  - "Static" spectrum management results in unused spectrum in frequency, time and/or space dimensions
  - Under-utilization exacerbated by the use of "worst-case" interference models
  - Can "lock-in" existing uses at the expense of new, more socially-valuable uses

Exclusive Use of Licensed Spectrum Regulation

- Licensee has exclusive and transferable rights to use of specified spectrum in defined geographic area
- Flexible use rights with technical rules to protect other users against interference
  - Exclusive rights resemble property rights
  - Coase's Theorem: with well-defined property rights, free market will allocate resources to their most efficient use
- Owners, acting as "band managers," can sell or lease spectrum
- Steps to date: auctions, license flexibility for mobile spectrum

Commons (aka Unlicensed) Model

- Allows unlimited numbers of unlicensed users to share frequencies
- Usage rights governed by technical standards that set power limits
- No right to protection from interference
- Popular examples: amateur radio, CB radio, Bluetooth, Wi-Fi

Best Conditions for Applying Models (According to FCC Spectrum Task Force in 2002)

- Exclusive Use: when spectrum scarcity is high and transaction costs to moving to more efficient uses are low (e.g., bands below 5 GHz)

- Commons: when spectrum scarcity is low and transaction costs to moving to more efficient uses are high (e.g., bands above 5 GHz)

- Command and Control: Prescribing specific usage is necessary for the public interest (e.g., public safety)

FCC's Spectrum Allocations for 5G

	Spectrum Allocation	Status
High Band	•24 GHz (Seven 100 MHz blocks) •28 GHz (Two 425 MHz blocks) •37, 39, and 47 GHz (34 100 MHz blocks)	•$2B auction on 5/2019 •$700M auction on 1/2019 •$4.5B auction on 3/2020
Mid-Band	•2.5 GHz (194 MHz EBS band) •3.5 GHz (150 MHz shared access CBRS) •3.7 - 4.2 GHz (Add mobile/flexibility)	•NPRM 5/2018; R&O 7/19 •R&O 10/2018 •$81B auction on 2/2021
Low-Band	•600 MHz (Seven 10 MHz blocks) •800 MHz (18 MHz for public safety) •900 MHz (6 MHz block)	•$19B auction on 4/20 •R&O 12/2019 •NPRM 3/2019
Unlicensed	•6 GHz (1.2 GHz block with AFC system) •Above 95 GHz (Exp. licenses up to 3 THz)	•NPRM 10/18; R&O 4/20 •R&O 3/2019

Universal Service for Broadband

"Broadband is the great infrastructure challenge of the early 21st century."

-National Broadband Plan, 2010

National Broadband Plan Summary

Competition

Design policies to ensure competition that maximizes consumer welfare, innovation and investment

Government Efficiency

Ensure efficient allocation of government assets (e.g., spectrum, poles, and rights of way)

Availability and Affordability

Reform universal service for broadband deployment in high-cost areas and ensure its affordability for all

Capture Benefits

Reform policies to maximize benefits to public education, health care and government operations

Establishing Competition Policies

Some highlights of current broadband pricing and competition

- FCC Measuring Broadband America Reports 2011 - 2021 (not to be confused with Section 706 Broadband Progress Reports 1999 - 2021)
  - FCC announced pause in program in July 2023
- FCC establishes National Broadband Map in 2011 based upon broadband availability data submitted by service providers
- FCC adopted Broadband Consumer Labels rules in November 2022 and July 2023
  - Required broadband providers to display at the point of sale, easy-to-understand labels to allow consumers to comparison shop for broadband services
  - Labels show service prices, speeds, data allowances, and other critical service information

Aside: FCC Broadband Mapping Effort

- FCC's initial Broadband Map suffered from over-estimates of number of service providers offering service to locations

  - Due to map granularity only down to census block (serve one location in a census block, then you served them all!)

- FCC relaunched the Broadband Map in January 2023 consisting of 2 datasets

  (1) Fabric Locations – all locations in U.S. where fixed broadband is or could be installed

  (2) Broadband Availability – broadband services, if any, available at locations in Fabric

- FCC provides map of locations, but employs [crowd-source challange process](#) to validate, ISPs report availability data every 6 months

Aside: FCC Broadband Labels

Developing disclosure requirements for "Empowering Broadband Consumers Through Transparency"

- Transparency drives service providers to compete for customers based on actual performance

- Pricing and performance information ensures consumers can find best broadband provider

- Net Neutrality Rules also relevant (aka Transparency Rule)

Broadband Facts

Provider Name
Service Plan Name and/or Speed Tier
Fixed or Mobile Broadband Consumer Disclosure

Monthly Price	**[$]**

This Monthly Price [is/is not] an introductory rate. [if introductory rate is applicable, identify length of introductory period and the rate that will apply after introductory period concludes]

This Monthly Price [does not] require[s] a [x year/x month] contract. [only required if applicable; if so, provide link to terms of contract]

Additional Charges & Terms

Provider Monthly Fees
　　[Itemize each fee]　　　　　　　　　　**[$]**

One-time Fees at the Time of Purchase
　　[Itemize each fee]　　　　　　　　　　**[$]**

Early Termination Fee　　　　　　　　　　**[$]**

Government Taxes　　　　　Varies by Location

Discounts & Bundles

Click Here for available billing discounts and pricing options for broadband service bundled with other services like video, phone, and wireless service, and use of your own equipment like modems and routers. [Any links to such discounts and pricing options on the provider's website must be provided in this section.]

Affordable Connectivity Program (ACP)

The ACP is a government program to help lower the monthly cost of internet service. To learn more about the ACP, including to find out whether you qualify, visit GetInternet.gov.

Participates in the ACP　　　　**[Yes/No]**

Speeds Provided with Plan

Typical Download Speed　　　　　　　**[] Mbps**
Typical Upload Speed　　　　　　　　　**[] Mbps**
Typical Latency　　　　　　　　　　　　**[] ms**

Data Included with Monthly Price　　**[] GB**
Charges for Additional Data Usage　　**[$/GB]**

Network Management　　　　**Read our Policy**
Privacy　　　　　　　　　　　**Read our Policy**

Customer Support
　Contact Us: example.com/support / (555) 555-5555

Learn more about the terms used on this label by visiting the Federal Communications Commission's Consumer Resource Center.

fcc.gov/consumer

[Unique Plan Identifier Ex. F0005937974123ABC456EMC789]

Universal Service

Government-sponsored subsidy to add or keep users of a desirable service by low rates

- Principal market failure justification: network effects
- Benefits society by enhancing economic development, democratic participation, and public safety
- Started with Vail's "one system, one policy, universal service" slogan in 1910 for the telephone network

Funding Principles for Rural Broadband

National Broadband Plan recommended universal service access to broadband

- Provide funding in areas without private sector business case to provide voice and broadband

- At most one subsidized provider of broadband per area

- Eligibility for funding should be company and technology agnostic so long as service provided meets FCC specifications

- Identify ways to drive funding to efficient levels

- Recipients subject to enforceable timelines for achieving universal access

Broadband Universal Service Efforts

Progression of funds for fixed & mobile broadband

- Cost per location using terrestrial networks likely to rise over time

- 4-year implementation plan for BEAD starting 2024

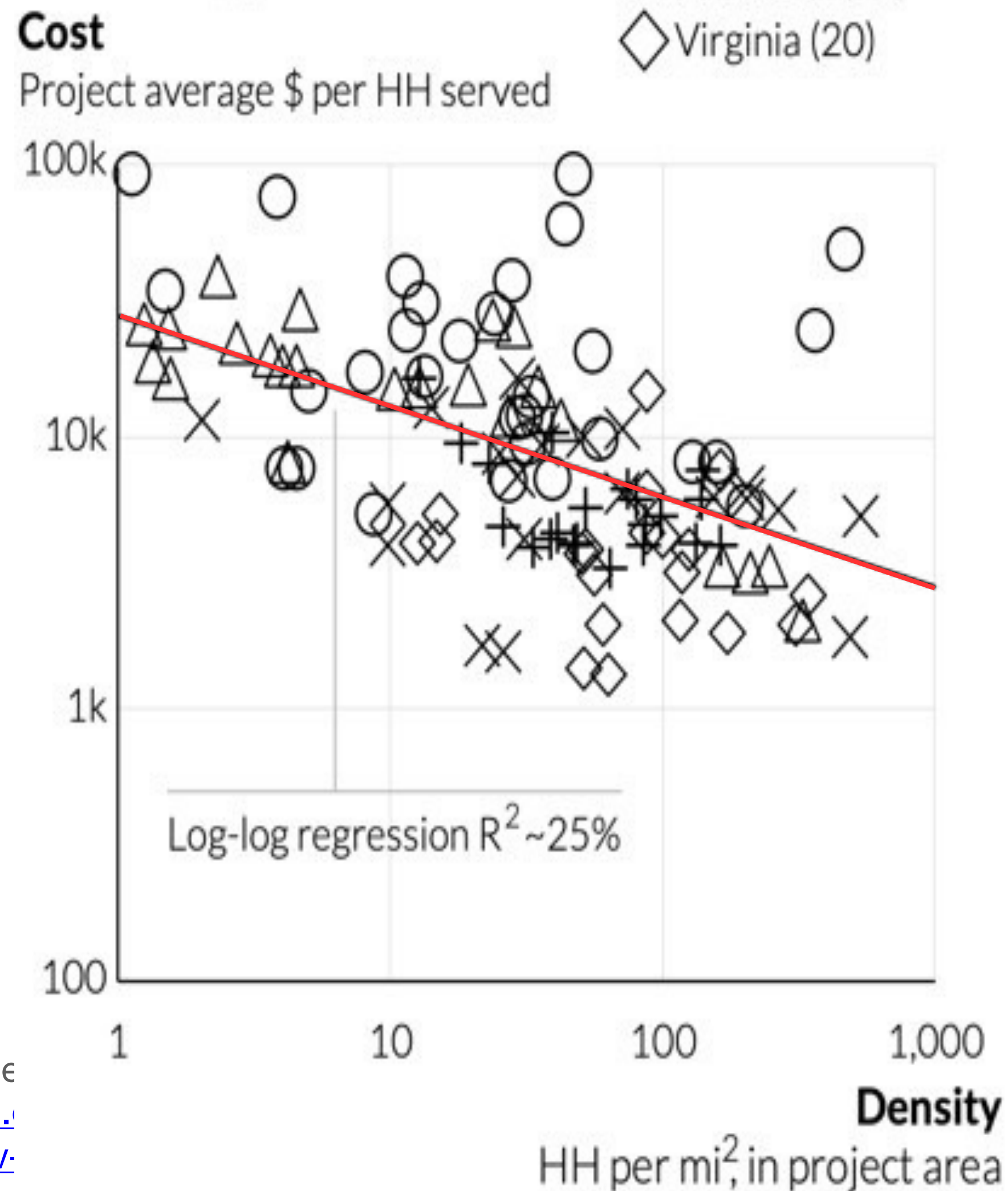|	Award Years 2015–2024	Earmarked Amount (Millions)	Eligible locations (Millions)	Implied cost per location
Connect America Fund (CAF) Phase II - Price Cap Carriers		$9,006	3.63	2,481
Connect America Fund (CAF) Phase II - Auction		$1,488	0.71	2,086
Rural Development Broadband ReConnect Program		$3,140	0.38	8,311
Rural Digital Opportunity Fund (RDOF) - Phase I		$9,230	5.22	1,768
Tribal Broadband Connectivity Program		$3,000	-	
Broadband Infrastructure Program		$283	0.16	1,026
Capital Projects Fund		$10,000		
Broadband Equity, Access, and Deployment (BEAD)		$42,450	7.26*	9,786
Rural Digital Opportunity Fund (RDOF) - Phase II		$11,170	?	

Cost Implications of Using Only Fiber

- Note analysis is from an Ericsson study – a non-terrestrial equipment supplier

## Fiber Costs Profile in Digital-Divide Deployments

Sources: 132 state-funded fiber broadband projects, 2019-2022, in...

+ Alabama (n=21)
○ California (46)
✕ Michigan (20)
△ Nebraska (25)
◇ Virginia (20)

Cost
Project average $ per HH served

Log-log regression R^2 ~25%

Density
HH per mi^2 in project area

Distribution of ~16M Un-/Underserved US HH
Estimate based on HH density pattern in projects sample

6.1M, 3.2, 3.5, 1.9, 1.4, 0.03
0 20 50 100 250 500 750 HH/mi^2
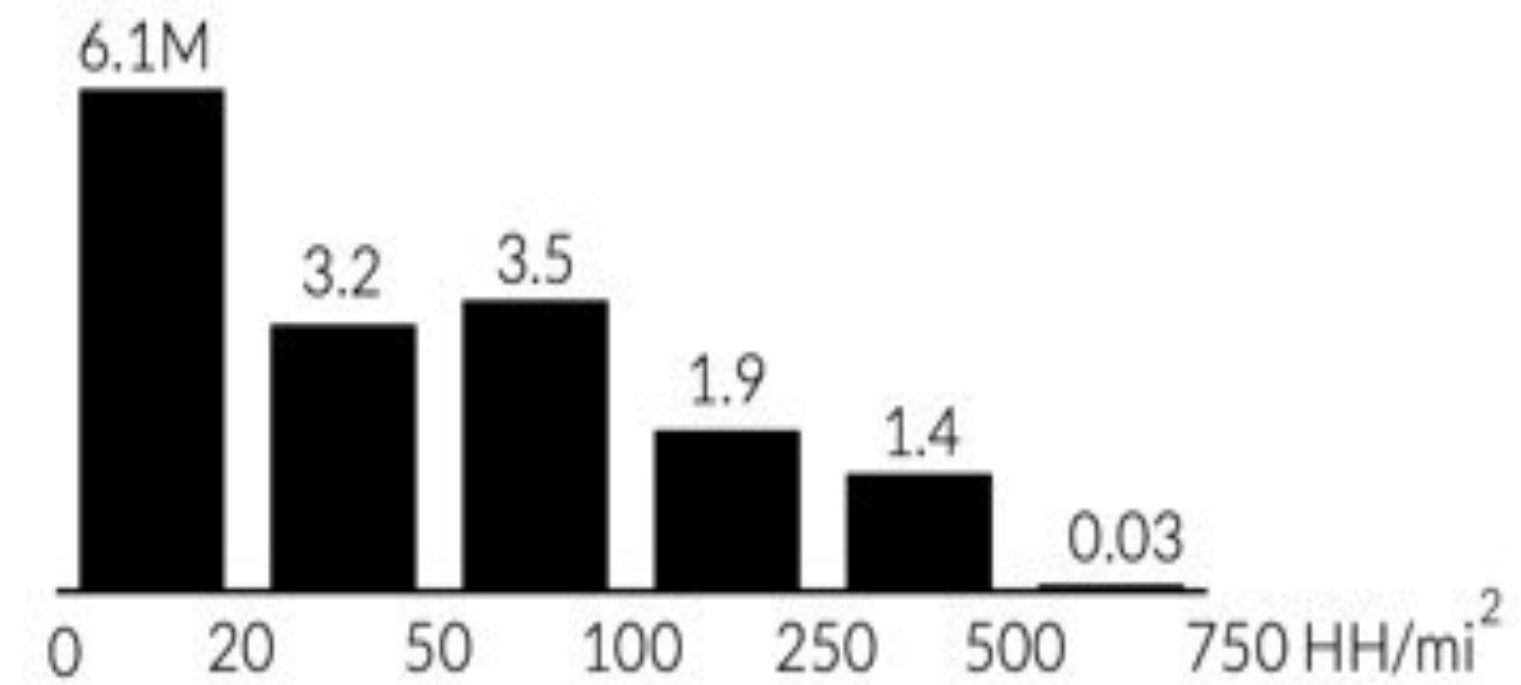
Cost = f(Density) Model from Fiber-Project Actuals
Using log-log regression, applied at density-class average

$18k / HH served
$3.3k
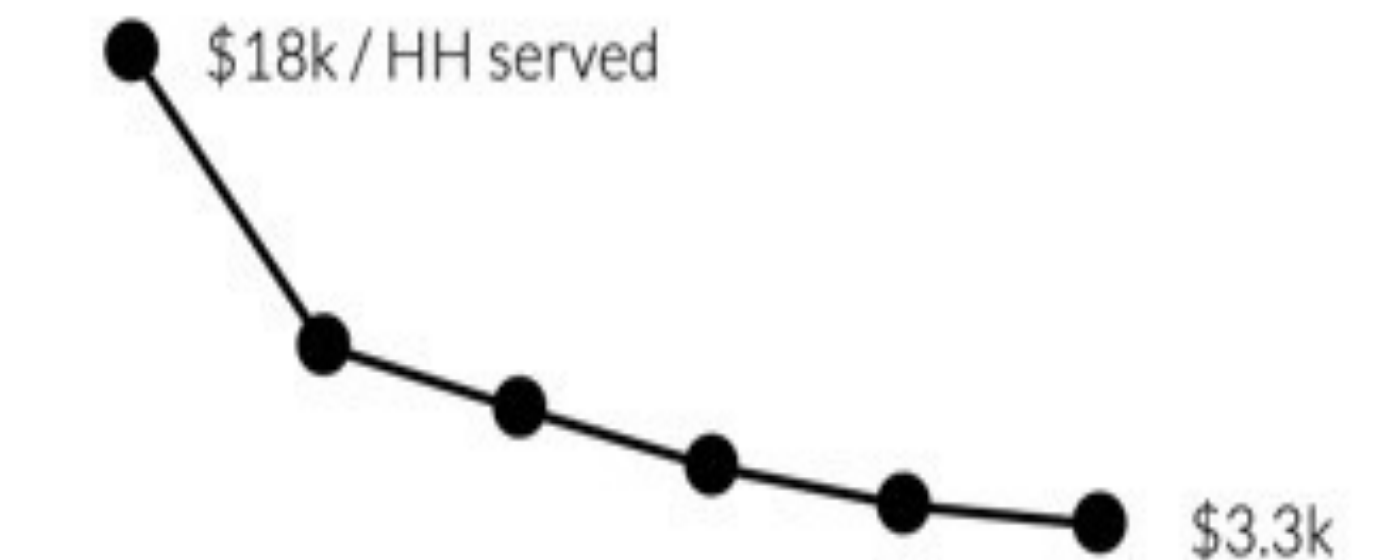
~$230B BEAD Funds Required for 100% Fiber
On top of 25% operator matches ($78B)

$191B (grant + match)
$19.2k/HH average for 16M served

$191B, 50, 42, 18, 10, 0.2
0 20 50 100 250 500 750 HH/mi^2

Infrastructure, Investment and Jobs Act (IIJA, 2021)

- $42B in competitive grants for Broadband Equity, Access and Deployment (BEAD) Program managed by NTIA

  - Broadband deployment in unserved (< 25/3) and underserved (<100/20) areas

  - Connectivity at anchor institutions

  - Broadband data, maps and plans

  - Internet infrastructure or low-cost broadband for multifamily dwelling units

  - Broadband adoption

- Grants prioritized in order of unserved areas, underserved areas and anchor institutions

Technologies Eligible for BEAD funding

Qualifying broadband service provides:
    (1) Speed of at least 100/20 Mbps
    (2) Latency sufficient for real-time, interactive applications (< ~100 ms)
    (3) Network reliability below 48 hours of outage time over 365-day period
NTIA: *reliable broadband service* requires fiber, HFC, or FWA utilizing some element of licensed spectrum – deployment hierarchy for states to use:
    (1) Consider priority (fiber) broadband projects first
    (2) If fiber cost *extremely high* (established by each state), state may fund use of alternative technology that supports reliable broadband service
    (3) If no *less costly* solution is available, may select best available technology, as long it can provide qualifying service

Colorado Broadband Roadmap

Leverage IIJA funding to connect 99% of households by 2027 (14% of locations unserved/underserved, 166K households lack Internet access)

- <u>Goal One</u>: Connect 99% of residents, particularly those in rural communities, to high-speed internet by 2027

  - Prioritize fiber deployment and target funding in areas where a negative business case for investment for the unserved and underserved exist

  - Set high-cost per location threshold, balancing funding the use of fiber and alternative technologies to expand coverage

  - Utilize location-level mapping and analytics to assess areas of critical need and to target areas that require subsidies.

Colorado Broadband Roadmap

Leverage IIJA funding to connect 99% of households by 2027 (14% of locations unserved/underserved, 166K households lack Internet access)

- <u>Goal Two</u>: Expand digital inclusion and adoption to achieve affordability, access, and digital literacy by 25% by 2027

- <u>Goal Three</u>: Enable Colorado to thrive by fostering and supporting a digital economy by 2027

- <u>Goal Four:</u> Strengthen resilience across Colorado communities through broadband by 2027

Policies Addressing Non-Discriminatory Access to the Internet
FCC's Net Neutrality regulations

- Internet designed as a layered stack of protocols

- Competition and diversity have flourished at higher layers because of consistent interfaces to lower layers

- **Policy challenge**: when is government intervention needed to prevent dominant provider at one layer from stifling competition at another?

  - Also, a debate of *ex ante* vs. *ex post* regulation

Protecting and Promoting the Open Internet (2015)

"America needs more broadband, better broadband, and open broadband networks."

Policy Justifications

- Finding: broadband providers—both fixed and mobile—have both the incentives and ability to harm the open Internet

- Finding: relatively small incremental burdens imposed by rules outweighed by benefits of preserving the open nature of the Internet

Preserving the "Virtuous Cycle"

- Internet is level playing field
  - Thrives due to "freedom and openness"
  - No gatekeepers blocking lawful network uses or picking online winners

- Openness promotes competition

Foster cycle of broadband investment and innovation

New Broadband Applications

Increased Adoption of Broadband

Network Improvements
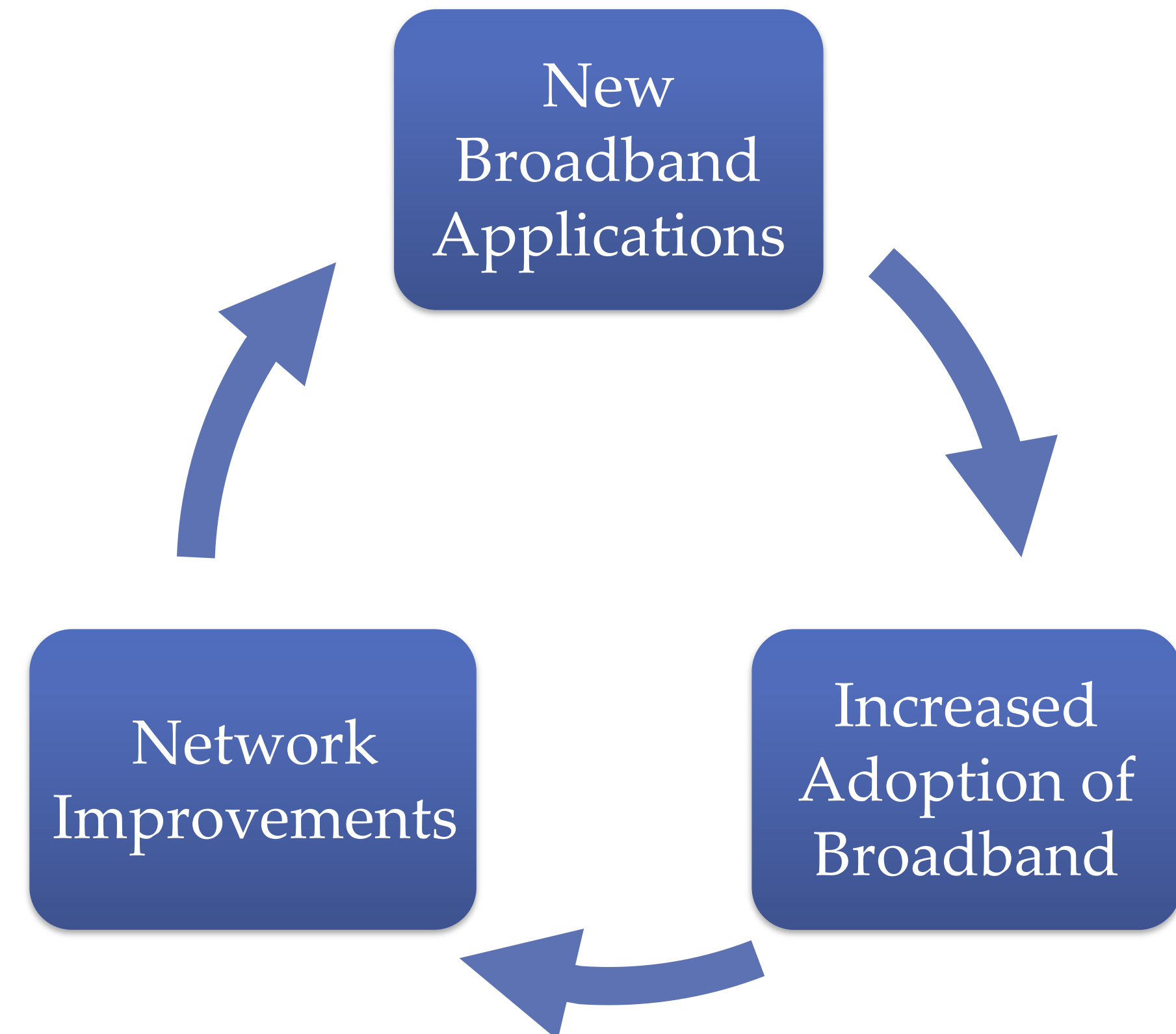
"Strong, Bright Line" Rules

- No blocking

- No throttling

- No paid prioritization

- No unreasonable interference/disadvantage standard

- Transparency requirements

"Modern" Title II

- Forbearance of over 700 common carrier rules
  - No unbundling of last-mile facilities
  - No tariffing
  - No rate regulation
  - No cost accounting rules
- Application of Sections 201 (interconnection), 202 (discrimination), and 208 (complaint process)

Sustainable Open Internet Rules

- Retail broadband Internet ac~~~~~~~~~best viewed as separately id~~~~~~~

  - a broadband~~~~~~~~~~~~~telecommunications service (~~~~~~~~~~~~~~~~~~~management and control of that service)

  - Various "add-on" applications an~~~~~~~~~~~~~information services

- Mobile broadband Internet acces~~~~~~~~with the public switched network~~~~~~~Commercial Mobile Service

"transmission, between or among points specified by the user, of information of the user's choosing, without change in the form or content of the information as sent and received,"

"capability for generating, acquiring, storing, transforming, processing, retrieving, utilizing, or making available information via telecommunications."

Restoring Internet Freedom Rules (2017)

"We eliminate burdensome regulation that stifles innovation and deters investment, and empower Americans to choose the broadband Internet access service that best fits their needs."

Policy Objectives

- End utility-style regulation and restore market-based policy approach to preserve Internet freedom
- Require ISPs to be transparent
- Eliminate Internet conduct rules and other *ex ante* regulations
- Promote infrastructure investment throughout America
- Promote innovation and consumer choice among ISP and edge provider services

Policy Changes

1. Reinstating *information service* classification (unregulated) of broadband Internet access service
   - ISPs offer broadband users "capability for generating, acquiring, storing, transforming, processing, retrieving, utilizing, or making available information via telecommunications."
   - *Not* "the transmission, between or among points specified by the user, of information of the user's choosing, without change in the form or content of the information as sent and received,"

Policy Changes (cont'd)

2. Reinstating private mobile service classification of mobile broadband

- Classify <u>all</u> fixed/mobile broadband as information services

3. Returning broadband privacy authority to the Federal Trade Commission (FTC)

- History of policing online company's privacy practices
- Title II order created role for FCC to regulate ISP privacy
- Consumers "treated consistently across the Internet ecosystem"

Policy Changes (cont'd)

4. Lite-Touch Regulatory Framework

- Believes *ex ante* regulatory intervention in market is unnecessary versus *ex post* enforcement

- Eliminating the Internet conduct standard

- No need for no-blocking rule

- No need for no-throttling rule

- No need for no-prioritization rule

- Need for the transparency rule

New Transparency Rule

- Network management practices to disclose

  - From 2010 rules: congestion management, application-specific behavior, device attachment rules, and security practices

  - New: any blocking, throttling, affiliated prioritization, or paid prioritization in which they engage

Some Closing Thoughts…

Policy Principles for the FCC's Definition of Broadband

As applied in Section 706 Inquiries for "Advanced Telecommunications Capabilities"

I. Policy makers should continue to rely upon a Definition of Broadband, not a technical standard

II. Policy makers should favor positive or pragmatic interpretations of broadband outcomes over normative aspirations

III. Focus the Definition of Broadband on measurable, core service characteristics

Policy Principles for the FCC's Definition of Broadband (cont'd)

IV. Maintain technological neutrality in establishing service thresholds

V. Graceful evolution based upon comprehensive, ongoing national and state broadband roadmaps

VI. Consistency in approach across different funding mechanisms

Things to Watch

- FCC's changes to its Broadband Definition (service metrics matter!)
- How states allocate BEAD funds for deployment projects
- Growth of mega-constellations for residential broadband and direct-to-cellular
- Emergence of Wi-Fi 7 and use of the 6 GHz unlicensed band to provide broadband service

Questions or Comments?

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Recent Publications
- **Is Speed Enough? Examining the Definition of Broadband and Its Implications for Public Policy**, 49th Annual Research Conference on Communications, Information, and Internet Policy, September 22 – 24, 2021; available here
- **Measuring ISP Performance in Broadband America: A Study of Latency Under Load**, (with Levi Perigo), Internet Architecture Board Workshop on Measuring Network Quality for End-Users, available here.
- **Estimating the Cost of Broadband in "Ultra-Rural" Areas**, coauthored with Matt Larsen, available upon request.
- **Examining the prospects for Gigabit Broadband: Lessons learned from Google Fiber**. *Telecommunications Policy*. 44 (5) (June 01, 2020)