BROADBAND NETWORK ENGINEERING & ECONOMICS

BROADBAND PRIMER ORIENTATION

MARCH 9, 2022

AGENDA

Welcoming Remarks

Alan Davidson, Assistant Secretary of Commerce for Communications and Information and NTIA Administrator, Department of Commerce

Network Engineering

Sarah Bleau, Broadband Program Specialist, Office of Internet Connectivity and Growth, NTIA

Network Economics

Mike Tibodeau, Telecommunications Policy Analyst, Office of Internet Connectivity and Growth, NTIA

Moderated Discussion

Moderator: **Scott D. Woods**, Director, Office of Minority Broadband Initiatives, NTIA

NETWORK ENGINEERING

Sarah Bleau, Broadband Program Specialist, Office of Internet Connectivity and Growth, NTIA

NETWORK ENGINEERING

○ Why It Matters

○ Architecture

○ Infrastructure Elements

○ Business Models

○ Technology

WHY IT MATTERS | FOUNDATIONAL KNOWLEDGE IS CRITICAL FOR SUCCESSFUL BROADBAND DEPLOYMENT

Addressing persistent barriers to universal broadband deployment in unserved and underserved areas requires a strong understanding of the different components of a broadband Internet network:

> The global **network architecture**, which forms the foundation of a comprehensive network

> The **infrastructure elements** that enable the provision of Internet service

> The **business models** available to network owners, operators, and Internet service providers

> The **technologies** that provide end users (e.g., homes, businesses, anchor institutions) with affordable, reliable, high-speed broadband and the contexts in which they tend to operate

ARCHITECTURE | DATA FLOWS SEAMLESSLY OVER THREE TYPES TO ENABLE INTERNET SERVICE PROVISION

CORE INTERNET BACKBONE

Interconnected networks that transmit data between and across countries and continents

- Built-in redundancy through path diversity
- Contain critical databases and utilizes standards that ensure effective and secure Internet operation
- Principally use terrestrial and submarine fiber-optic cable

MIDDLE MILE

Connect an area/local node with the core Internet backbone

- Where feasible, should employ path diversity
- Need sufficient capacity to carry the traffic from local networks without contention
- Deploy fiber-optic cable or, in some cases, wireless technologies

$1B Middle Mile program

$42.45B BEAD program

LAST MILE

Connect end users via an area/local node to a middle mile network, which enables connection into the core Internet backbone

- A range of organizations own, operate, and provide Internet services
- Use many technologies

$42.45B BEAD program

ARCHITECTURE | THESE COMPONENTS FUNCTION SIMILARLY TO A SYSTEM OF HIGHWAYS AND ROADS
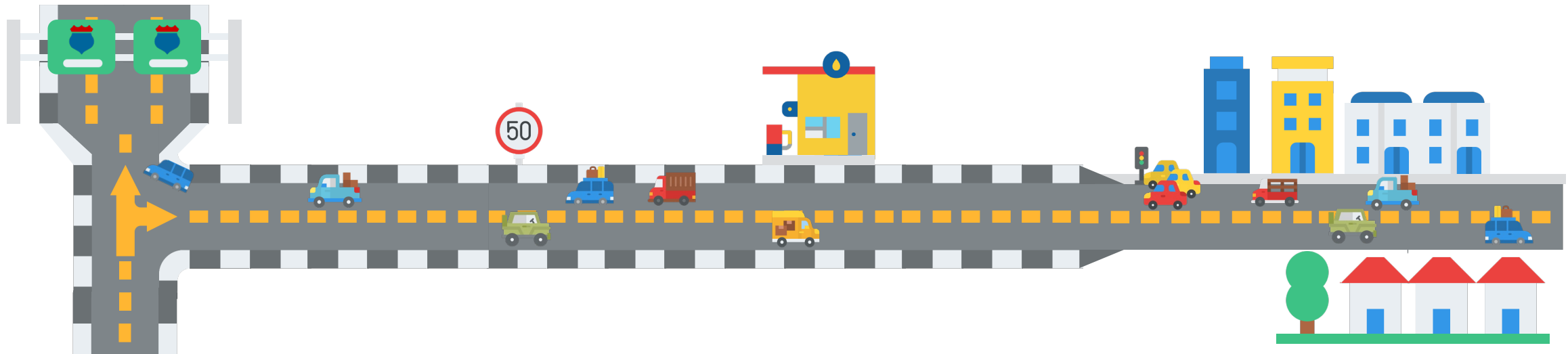
CORE INTERNET BACKBONE

- ✓ "Interstate highways" of broadband
- ✓ Transmit data across the country (and around the world)

MIDDLE MILE

- ✓ "State highways" of broadband
- ✓ Transmit data within a state or region and link end users to the core Internet

LAST MILE

- ✓ "City streets" of broadband
- ✓ Transmit data from the middle mile to and from end users

INFRASTRUCTURE | WHEN INTEGRATED, ENABLES THE PROVISION OF INTERNET SERVICE

Passive infrastructure

The physical layer of material needed to enable connectivity

- **Fixed broadband:** Fiber-optic and copper cables, ducts, conduit, utility poles, adaptors, and splitters
- **Wireless broadband:** Towers, antennas, buildings, fiber conduit, ground station structures, and power equipment

Active infrastructure

The electronic elements that enable passive infrastructure to transmit data

- **Actions that require power** to operate
  - Routing
  - Changing the medium (e.g., optical to electrical)
  - Amplifying
- **Examples:** Fiber-optic terminals, routers, servers, and switches

BUSINESS MODELS | VARIOUS OWNERSHIP AND OPERATIONS ARRANGEMENTS

	Vertical Integration	Infrastructure Sharing	Open Access
Definition	One entity owns the passive infrastructure, owns and operates the active infrastructure, and provides Internet services over the network to end users	Range of models - a network owner and/or service provider makes portions of their passive and/or active infrastructure capacity available for use to other entities	An infrastructure owner provides wholesale access to the network for lease on a non-discriminatory basis but does not themselves provide residential services to end users
Owners	1	1 or more	1 or more
Owners providing services	1	Variable	None
Providers operating	1	1 or more	Many
Competitive use of facilities	None	Limited	Encouraged

TECHNOLOGY | SEVERAL OPTIONS PROVIDE END USERS WITH RELIABLE, HIGH-SPEED BROADBAND

	Fiber	HFC	DSL	FWA	TVWS	LEO Satellite	GEO Satellite
	Fiber-optic cable	*Hybrid Fiber Coaxial*	*Digital Subscriber Line*	*Fixed Wireless Access*	*TV White Space*	*Low Earth Orbit*	*Geosynchronous Equatorial Orbit*
	Terrestrial Broadband			Wireless Broadband			
Speed	Fastest download and upload speeds on average	Varies (# of users on coax segment, distance to fiber)	Slower on average (copper length & quality)	Relatively fast, varies (spectrum, congestion, environment)	Relatively slow (newer tech in early stages of deployment)	Relatively fast (>100 Mbps) theoretically possible	Varies (# of users at same time, satellite line-of-sight)
Latency	Very low	Relatively low	Relatively low	Very/relatively low	Relatively low in theory	Relatively low (distance to satellite)	Relatively high (distance to satellite)
Reliability	High except for risk of damage to aerial and buried lines			May be lower in adverse weather, with line-of-sight obstructions	Avoids some line-of-sight issues	Difficult to ascertain as new tech	May be lower in adverse weather, with line-of-sight obstructions

NETWORK ECONOMICS

Mike Tibodeau, Telecommunications Policy Analyst, Office of Internet Connectivity and Growth, NTIA

NETWORK ECONOMICS

○ Unserved and Underserved Areas

○ Costs

○ Revenues

○ Provider Implications

○ Starting Considerations

CHALLENGE | UNSERVED AND UNDERSERVED AREAS MAY HAVE ONE OR MORE OF THE FOLLOWING CHARACTERISTICS

Low population density

Fewer people per geographic area is an economic challenge for broadband deployment, as per capita costs rise. In these areas, service providers must cover or "pass" a longer distance per end user, measured in passings per mile (PPM). This, in turn, increases their cost per homes passed (CPHP), a common industry metric that informs return on investment (ROI).

Rural and remote locations

Can be more difficult for providers to deploy service to, increasing capital expenditure costs (e.g., construction equipment, labor) and the likelihood of needing to build a longer middle mile to reach the Internet core. For similar reasons, it is also more expensive to operate and maintain networks in these locations, particularly as these locations are likely to also have lower population densities.

Difficult geography

Rocky soil and mountainous terrain, for example, increase costs by making buried or aerial deployments harder and slower. Mountainous areas can also negatively impact the reliability of wireless technologies due to reduced line-of-sight. These geographical factors also likely reduce providers' ability to meet consumer demand and expectations, reducing revenues.

COSTS | TYPICALLY SEGMENTED INTO TWO KEY CATEGORIES

Capital Expenditure (CapEx)

Dollar cost to build the network asset

- Typically, a large, upfront cost which is depreciated over the useful life of the asset for accounting purposes
- Can include material, land, labor for construction and connection, engineering, permitting, upgrades and replacements, and construction equipment

Operational Expenditure (OpEx)

The day-to-day (ongoing) cost to run and maintain a network to provide services

- Can include power, network maintenance, middle mile and/or core Internet transit fees (if any), sales and marketing, customer support, rent, and other business operation expenses

In the context of IIJA, the Broadband Equity, Access and Deployment (BEAD) program in effect provides a significant CapEx subsidy. Therefore, the key cost considerations for providers are their **remaining CapEx costs (match amount) and ongoing OpEx once the network is operational.**

REVENUES | ARE DIVIDED INTO TWO BUSINESS MODELS AND INFLUENCED BY SEVERAL KEY FACTORS

Retail

Typically, individuals and organizations who pay 'recurring' subscription fees to receive Internet services

- Recurring fees usually on a monthly or yearly contract basis. May also pay an initial upfront (non-recurring) connection fee
- Typically for last mile networks

Wholesale

Typically, other broadband providers who pay monthly wholesale or transit fees for the lease of an amount of network capacity

- May also pay a non-recurring fee
- Typically for backbone and middle mile networks

AVERAGE REVENUE PER USER (ARPU)
Average revenue per household activated

CHURN RATE
Percentage of subscribers who unsubscribe over time

TAKE RATE
Percentage of customers with access to the network who choose to subscribe

PROVIDER IMPLICATIONS | SUSTAINABILITY LONG-TERM IS KEY

An economically sustainable network is the goal

A sustainable network is defined by its post-deployment success, whereby it remains financially viable once the network is operational and the provider is offering services.

- **For many rural areas**, the cost of middle mile access and maintenance can be key factors in network viability.

- **Project success also relies on key metrics**, such as the take rate and corresponding ARPU

- A network may become unsustainable if **aggregate demand is low** and/or if the customers and revenue in an area are split across multiple providers

- **The time it takes to deploy infrastructure** is also an important metric, as longer build times increase costs and delay revenue generation

- Investments in increasing network **resiliency may increase CapEx costs**

> Financially, long-term viability depends on annual revenues being greater than OpEx (including the depreciation and servicing cost of CapEx)

PROVIDER IMPLICATIONS | BROWNFIELD BUILDS CAN REDUCE COSTS

Leveraging Existing Infrastructure Can Lower Costs

To manage costs, providers can work with state and local entities, as well as private entities, to leverage existing infrastructure or planned construction work in relevant areas (e.g., transportation) to lower mobilization and permitting costs.

- **"Brownfields"** are networks built by extending or upgrading an existing network, thus leveraging existing infrastructure to reduce deployment costs
- **"Greenfields"** are networks built entirely from scratch and thus deployment costs are typically higher
- **The majority of CapEx tends to be in civil works** (e.g., digging, plowing, construction, permitting), and then in network materials (e.g., fiber) and electronics

STARTING POINT | MANY CONSIDERATIONS WITH PROJECTS IN UNSERVED & UNDERSERVED AREAS

DEMONSTRATED UNDERSTANDING OF THE AREA FOR DEPLOYMENT

- Why the area is unserved/underserved
- The population density in the area
- Complexity of the build
- Existing competition in the area, and associated pricing and take-rates
- Accessibility to an affordable middle mile
- Understanding of area's existing infrastructure

ESTIMATED COSTS

- Capital expenditure
- Operating expenditure
- Middle mile access and associated cost (if last-mile project). If no middle mile is accessible, include cost to build necessary middle mile.
- Supply chain or labor constraints that would increase costs or delay project development

ESTIMATED- REVENUES

- Are planned revenues sufficient to ensure economic viability? (*Pricing schedules can show how applicants anticipate prices to change with various take rates and/or demand*)
- Is the end-price sufficient for estimated costs (including inflation) and reasonable in local market?

KEY ASSUMPTIONS & HOW THEY WERE CALCULATED

- Take rate over time
- Average Revenue per User (ARPU)
- Cost Per Home Passed (based on building density and technology type)

COST MINIMIZATION STRATEGIES & EXPECTED IMPACT

- Coordination with state/local entities or third parties to speed up permitting and utilize existing infrastructure
- OpEx economies of scale from adjacent businesses

REVENUE OPTIMIZATION STRATEGIES & EXPECTED IMPACT

- Development and consideration of alternative revenue streams
- Utilization of the infrastructure for other business purposes

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QUESTIONS & ANSWERS

To ask questions about IIJA broadband programs or provide additional feedback:

BroadbandForAll@ntia.gov

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Please join us for our upcoming broadband program public virtual webinars!
March 23, 2022
April 6, 2022
April 27, 2022
May 11, 2022

For more information about upcoming sessions:
https://broadbandusa.ntia.doc.gov/events/latest-events

THANK YOU FOR JOINING TODAY'S SESSION

APPENDIX

UNSERVED AND UNDERSERVED LOCATIONS

UNSERVED LOCATION

A broadband-serviceable location, as determined in accordance with the *broadband DATA maps* that—
- Has no access to broadband service; or
- Lacks access to reliable broadband service[1] offered with
  - A speed of not less than 25 megabits per second for downloads; and 3 megabits per second for uploads
  - And a latency sufficient to support real-time, interactive applications

UNDERSERVED LOCATION

A location that, as determined in accordance with the *broadband DATA maps*, is—
- Not an unserved location; and
- Lacks access to reliable broadband service offered[1] with
  - A speed of not less than 100 megabits per second for downloads and 20 megabits per second for uploads
  - And a latency sufficient to support real-time, interactive applications

Note: definitions from Infrastructure Investment and Jobs Act (IIJA), Division F, Pub. L. 117-58 (Nov. 15, 2021), under Title I.
1. IIJA, Section 60102(a)(2)(L). The term "reliable broadband service" to mean broadband service that meets performance criteria for service availability, adaptability to changing end-user requirements, length of serviceable life, or other criteria, other than upload and download speeds, as determined by the Assistant Secretary in coordination with the FCC.