WHITE PAPER

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Bridging the Digital Divide: Advancing Broadband Infrastructure for a Connected Future

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Introduction

Despite the appearance of widespread Internet availability, most Americans in rural areas, and a large percentage in urban areas, do not have broadband Internet access. This digital divide is a significant barrier to economic and social equality. Studies show that areas with broadband access experience reduced poverty and unemployment rates.

Broadband internet is a game-changer. Individuals can access employment opportunities and basic amenities like education, healthcare, and government services. Commercial and industrial businesses can thrive in today's competitive global marketplace. Municipalities can optimize operational efficiency and public safety. Over the past decade, federal and state governments have launched several initiatives to bridge the digital divide and bring these benefits to all Americans:

- **Broadband Equity, Access, and Deployment (BEAD) Program**—Part of the Infrastructure Investment and Jobs Act (IIJA), BEAD provides $42.45 billion to 56 states and territories to deploy affordable broadband to every household.
- **Broadband Infrastructure Program**—This National Telecommunications and Information Administration (NTIA) program, launched in 2022, provides $288 million to expand broadband access in unserved areas.
- **Rural Digital Opportunity Fund (RDOF)**—Established in 2020 by the FCC, RDOF allocates $20.4 billion to bring broadband service to underserved rural homes and businesses.
- **ReConnect Program**—Launched in 2018, this USDA program provides loans and grants to help local municipalities, tribes, and cooperatives construct the facilities and infrastructure needed to provide broadband service.

The BEAD program has the most significant impact of these initiatives, leading to the largest deployment of last-mile broadband infrastructure nationwide. To qualify for BEAD funds, a broadband service must be considered reliable, which NTIA defines as fixed and available with a high degree of certainty, both at present and for the foreseeable future. The service must also deliver broadband speeds, which the Federal Communications Commission (FCC) defines as a download speed of at least 100 megabits per second (Mbps) and an upload speed of at least 20 Mbps, with latency less than or equal to 100 milliseconds (ms). For community anchor institutions, such as schools, libraries, healthcare facilities, universities, and government agencies that drive economic growth and social benefit in their communities, BEAD-funded service must deliver a download and upload speed of at least 1000 Mbps, with latency less than or equal to 100 ms.

When it comes to delivering reliable broadband service, the BEAD program prioritizes fiber-optic technology, followed by cable using hybrid fiber-coaxial (HFC) technology, digital subscriber line (DSL), and licensed fixed wireless technology. Alternative technologies, including unlicensed fixed wireless and low-earth orbiting (LEO) satellites, can also qualify for BEAD funds if they meet specific criteria.

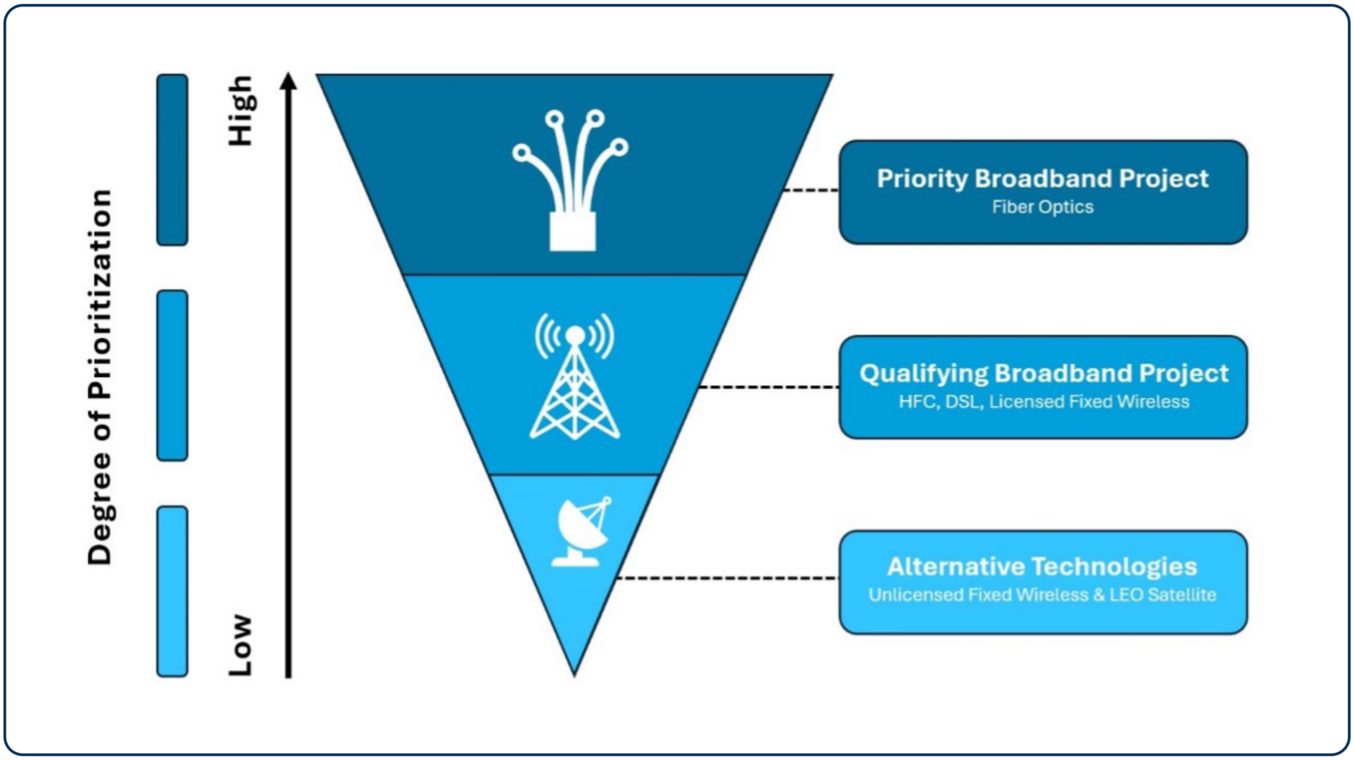


Figure 1: The BEAD program's prioritization for funding reliable broadband service. Source: NTIA

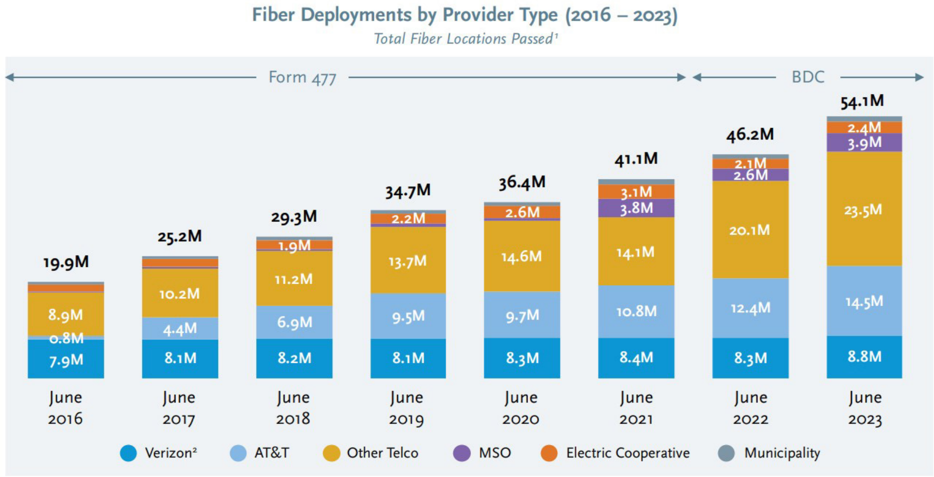
Whether delivered via fiber optic, HFC, DSL, fixed wireless, or satellite technology, broadband networks encompass a range of active equipment and connectivity deployed in various locations and environments. These components must maintain optimal performance and efficiency while remaining physically secure and easy to install, manage, and scale. This white paper provides an overview of the types of broadband deployments and critical considerations for supporting broadband equipment and connectivity to ensure reliable and efficient broadband service.

Types of Broadband Deployments

Broadband internet can be delivered through various technologies. The specific type used to bring broadband to all Americans depends on factors such as location, geography, deployment cost, regulations, population density, and consumer demand.

Fiber Broadband

Fiber optic technology is a cornerstone of broadband networks and is considered the “gold standard” by the NTIA for BEAD-funded projects. Fiber is the highest-performing and most future-proof broadband option due to its superior bandwidth and distance capabilities compared to other broadband technologies. Singlemode fiber supports a bandwidth capacity of 100 Gigabits per second (Gbps) or greater to distances of 100 kilometers (km). Fiber is also considered more reliable and sustainable, offering better energy efficiency, less maintenance, and an overall lower carbon footprint.



1. Includes double passings
2. Fluctuations in figures between years are likely due to quality issues in historical reported coverage.
Source: FCC Form 477 and Broadband Data Collection (BDC) filings, accessed 11/2023

Fiber broadband networks are typically referred to as FTTx, which encompasses fiber-the-home (FTTH), fiber-to-the-premise (FTTP), fiber-to-the-curb (FTTC), and fiber-to-the-neighborhood (FTTN). FTTx deployments are rapidly accelerating across the U.S., with the total number of fiber locations passed increasing from 19.9 million in 2016 to more than 54 million in 2023.[iii] Analysts predict FTTH passings in the U.S. to reach 72.8 million by the end of 2024.[iv] FTTx deployments are rapidly accelerating, with the global FTTx market expected to more than double over the next five years.

Most FTTx broadband deployments use point-to-multipoint Gigabit-capable passive optical network (GPON) technology. In this scenario, fiber optic cables are deployed underground or aerially from a local central office or edge data center to optical splitters that distribute fiber to multiple optical network terminals (ONT) at the customer location. ONTs can be located at a building (FTTH or FTTP) or in a remote area connecting multiple customers (FTTC or FTTN). Fiber broadband deployments can also be dedicated, point-to-point networks where fiber runs directly to a customer location, providing the highest bandwidth and secure connection to commercial customers with many users, such as multi-family residences, hospitals, or universities.

Whether point-to-multipoint or point-to-point, the last mile of a fiber broadband network is the most complex and expensive part, especially in rural areas where buildings are far apart or where rough terrain impedes installation.

Cable and DSL Broadband

Cable and Hybrid Fiber Cable (HFC) broadband uses a combination of fiber and coaxial cabling to deliver internet access to local communities. Fiber is used to bring service to local communities, where the optical signal is translated to radio frequency (RF) and delivered to subscriber residences over the same coaxial cable lines used for cable TV. At the subscriber location, modems connect to the coax infrastructure and are typically paired with a wireless router to provide Wi-Fi access throughout the home or business.

The fiber backbone of cable/HFC provides enough bandwidth to qualify as a reliable broadband technology under the BEAD program, offering download speeds up to 1 Gbps and upload speeds up to 50 Mbps. That makes it a viable option for broadband service in areas where fiber is unavailable. As multiplexing technology advances, cable/HFC broadband may reach speeds as high as 10 Gbps to better compete with fiber providers. However, those same advancements will allow FTTx internet providers to provide even higher speeds.

DSL service is delivered over the same wires that provide landline telephone service, which makes it one of the most widely available types of internet access. DSL modems convert the analog telephone line to an Ethernet connection at the subscriber location. A DSL modem can pair with a router for in-building Wi-Fi access like a cable modem. DSL offers typical download speeds between 5 and 120 Mbps and upload speeds between 1 and 20 Mbps, with newer very high-speed DSL (VDSL) systems able to support 100 Mbps for both upload and download speeds. The farther away the location is from a central office, the slower the speed. Higher-speed DSL meets the definition of broadband and can qualify for BEAD funds. However, it is not considered a long-term solution, as many providers are switching to fiber. DSL is expected to be fully phased out over the next few years in urban areas but will remain an option for broadband access in rural areas until other options become available.

Fixed Wireless Broadband

In rural areas where fiber and other wired broadband technologies are not economically feasible due to geographic limitations, BEAD funds can be used for fixed wireless broadband. While fixed wireless broadband can be delivered via licensed and unlicensed spectrum, BEAD primarily limits funding to projects using licensed spectrum or a hybrid of licensed and unlicensed spectrum, which includes private Citizen's Broadband Radio Service (CBRS). Operating in the 3.5 to 3.7 GHz frequency spectrum, CBRS is considered "lightly licensed" since it is prioritized for incumbents like the U.S. Navy, followed by licensed bidders and general access.

Under the BEAD program, fully unlicensed fixed wireless is considered an "alternative" technology because it can experience higher congestion and interference in urban areas, creating concerns about its future availability. As an alternative technology, unlicensed fixed wireless is only available for BEAD funding in areas where other technologies exceed the extremely high cost-per-location threshold or when a waiver for an alternative project is approved.

In a fixed wireless network, a 5G or 4G LTE base station antenna connected to a wired network distributes radio frequency (RF) signals to subscriber 5G gateway units within line of site. Fixed wireless is considered a point-to-point connection that offers better bandwidth, latency, and reliability than shared mobile wireless, which is not considered fixed and is not eligible for BEAD funding. Fixed wireless can support download speeds up to 200 Mbps and upload speeds up to 100 Mbps.

Fixed wireless can be extended throughout an area or facility using small cells and distributed antenna system (DAS) antennas that amplify and distribute the RF signal. Consumer-based fixed wireless modems can also convert cellular service to Wi-Fi for broadband access.

Wi-Fi

While many rely on Wi-Fi technology for a wireless internet connection, Wi-Fi alone is generally not considered a broadband technology. It is a local connection delivered via a wireless access point or router that connects to an existing broadband network. Private Wi-Fi is exclusively for specific users or organizations, while public Wi-Fi is available for anyone to use in hotels, airports, retail establishments, and other public spaces. Some municipalities and service providers deploy public Wi-Fi via multiple outdoor access points throughout downtown centers that form a W-Fi mesh network. These access points require a high-bandwidth broadband connection that provides enough capacity to support multiple users.

Under the BEAD program, funds can be used to deploy Wi-Fi infrastructure within multi-family residential buildings, particularly those housing underserved households or low-income individuals. BEAD program requirements do not address funds for other types of Wi-Fi infrastructure. However, BEAD funding can be used for community anchor institutions once states have enough funds for their unserved and underserved populations. BEAD requirements also do not specify where access points must be located. Therefore, BEAD-funded public Wi-Fi projects will likely be a reality in some jurisdictions, especially those projects that provide internet access to multi-family residences. Other state and federal grants are also available to help municipalities fund public Wi-Fi deployments.

Satellite

Satellite internet access is provided via LEO satellites orbiting the earth that communicate wirelessly with dish-type antennas mounted to the rooftops of buildings or on poles next to buildings. These orbiting satellites receive RF internet signals from large earth station antennas at service provider's network operations centers. At customer locations, satellite modems connect to the dish via twisted-pair or coaxial cable to provide internet access.

Type	Typical Download Speeds	Typical Upload Speeds	Latency	Reliability
FTTX	200 Mbps-20 Gbps	200 Mbps-20 Gbps	Low	High
Fixed Wireless	40-200 Mbps	10-100 Mbps	Low	Medium
Mobile Broadband	20-100 Mbps	4-20 Mbps	Medium	Low
Satellite	25–500 Mbps	5-50 Mbps	High	Low
Cable	10 Mbps-1 Gbps	5-50 Mbps	Low	High
DSL	5-120 Mbps	1-20 Mbps	Low	Medium

Table 1 above provides an overview comparison of the various types of broadband technologies. Service varies based on service provider, region, subscriber location, and technology (e.g., point-to-multipoint vs. point-to-point, DSL vs. VDSL, 5G vs. LTE, etc.). Proximity, weather, foliage, and other environmental factors can impact the reliability of wireless and satellite offerings. Typical download and upload speeds will also evolve with advancements in technology.

While traditional satellite Internet has been around for over a decade, it delivers slower speeds with more latency at a higher cost than other broadband technologies. However, speed, latency, and cost have improved with new players entering the market that operate more satellites in Low Earth Orbit (LEO) and offer affordable plans. For example, as of September 2024, Starlink provides broadband service to about one million U.S. customers via more than 7,000 LEO satellites, with plans to deploy thousands more. LEO satellite technology can now deliver download speeds up to 500 Mbps and upload speeds up to 50 Mbps.

The most significant advantage of satellite broadband is that it is available everywhere. Like unlicensed fixed wireless, LEO satellite broadband service is only eligible for BEAD funding as an alternative technology. However, with the BEAD program requiring broadband access for all individuals, satellite will play a key role in bringing broadband to very rural communities unreachable by fiber and other broadband technologies.

Last-Mile Networks vs. Middle-Mile Networks

In a broadband network, the last mile refers to the final connection physically linking a home or building to the network. This can involve fiber-optic cables distributed via optical distribution points to ONTs in FTTx networks or equipment for distributing wireless connectivity from antennas or satellites.

While complex last-mile networks are the focus of funding initiatives like BEAD, they are essentially useless without middle-mile networks. The middle mile acts as the aggregation layer, connecting multiple last-mile networks to the broader internet and cloud service providers through the core transport network, often called the backbone or first-mile network. As more BEAD-funded last-mile networks are built, the demand for higher-capacity middle-mile infrastructure will increase. Various initiatives, such as the NTIA's $1 billion middle-mile grant program and California's $3.25 billion initiative, aim to fund these networks' construction, improvement, or acquisition.

A single operator or multiple entities can own the middle-mile network. In many cases, the same entity that provides last-mile services also owns the middle-mile infrastructure. This network involves sophisticated equipment to manage data flow, apply customer profiles, and aggregate and direct traffic from multiple customers in a specific area, including optical line terminals, access switches, aggregation switches, servers, and power supplies. Equipment can be housed in remote enclosures or prefabricated containers, known as micro edge data centers, or within existing facilities like regional municipality buildings, central offices, or colocation data centers.

The requirements for a middle-mile network are similar to those of a telecommunications space: high availability, sufficient space, cable management, physical security, thermal management, power, and monitoring. The TIA-942-C Data Center Infrastructure Standard includes an addendum that specifically addresses requirements for edge and micro edge data centers, including:

- Thermal management, efficiency, and performance
- Reliability and redundancy
- Physical security and access control
- Electrical, network, environmental, and access monitoring
- Cable pathways and administration
- Bonding and grounding, lighting, and noise requirements

Although a broadband network infrastructure may not include the compute or storage functions of an actual data center, the TIA standards still apply to powering, securing, and protecting broadband infrastructure gear.

Supporting Last-Mile and Middle-Mile Broadband Technologies

Chatsworth Products (CPI) offers essential infrastructure solutions to house, protect, and mount passive and active broadband equipment. Whether you need to support last-mile or middle-mile network components, CPI has you covered.

Outdoor Broadband Infrastructure Solutions and Micro Edge Data Centers

CPI's RMR® Industrial Modular, Free-Standing, and Wall-Mounted NEMA enclosures are ideal for protecting and securing valuable broadband components and equipment in outdoor and harsh environments. Suitable as a micro-edge data center in middle-mile networks or for housing last-mile connectivity at the customer premises, these sealed enclosures feature precision laser welded steel construction with robotically applied pour-in-place gaskets that offer NEMA Type 4 or 4X protection against dust, dirt, oil, water, and extreme temperatures. RMR enclosures come in a wide range of sizes with 19" EIA rails for sturdy mounting of broadband equipment. They can also be customized with features like thermal management, cable management, power distribution, electronic access control, and robust power and environmental monitoring.

CPI's RMR® NEMA enclosures are used by broadband integrators to replace brick-and-mortar telecommunications facilities, resulting in significant cost savings. These enclosures can secure and protect fiber optic equipment, broadband network gear, and UPS with thermal management and monitoring per the TIA 942 standard within a much smaller footprint than a telecommunications shelter or hut.

Broadband integrators also use CPI's RMR NEMA enclosures to distribute service to Multiple Dwelling Units (MDUs), to protect and secure fixed and mobile broadband wireless equipment at antenna sites, and to protect outdoor and industrial edge routing and switching equipment.

When it comes to wireless broadband, CPI Oberon Skybar series enclosures are ideal for protecting, securing, and mounting antennas and outdoor rated access points in harsh and outdoor locations while allowing RF signals to propagate easily. These rugged NEMA 4/4X polycarbonate enclosures are also ideal for housing Wi-Fi access points in outdoor environments, such as public Wi-Fi networks. Oberon NetPoint™ free-standing weather-resistant bollards protect and secure wireless antenna, equipment, and connectivity in outdoor spaces where wall or pole mounting isn't feasible. Skybar and NetPoint solutions are ideal for outdoor municipal, school, campus, and MDU broadband applications.

Indoor Broadband Infrastructure Solutions

For indoor environments, CPI CUBE-iT® cabinets serve as an ideal micro edge data center for saving space and safeguarding middle-mile broadband equipment. They can also support last-mile equipment and connectivity inside customer premises.

CPI Oberon In-Plane, H-Plane, Hi-Point, and Wi-Tile wireless access point mounts and enclosures are ideal for extending and securing wireless broadband throughout practically every indoor environment. These products maintain proper antenna height and orientation for optimal coverage while ensuring security and aesthetics. Wi-Tile ceiling enclosures also feature a solid back box and cable entry plugs for superior protection and compliance with infection control risk assessment (ICRA) procedures to avoid contaminant spread in healthcare environments. Wi-Tile ceiling enclosures are available for all leading brands of Wi-Fi and small cell access points.

Power Management Solutions

CPI intelligent eConnect® PDUs provide reliable equipment power and real-time remote monitoring of power parameters and environmental factors like temperature and humidity. When critical thresholds are reached, these intelligent PDUs alert operators to swiftly address issues and prevent costly unplanned downtime, making them ideal for use in remote, unmanned locations. eConnect PDUs also manage and power electronic access control to ensure physical security. With the ability of eConnect PDUs to provide kW readings with +/-1% accuracy, middle-mile network operators can also accurately bill service providers based on actual energy usage.

CPI long-lasting lithium-ion battery UPS solutions can be easily deployed in CPI enclosures to manage power and maintain uptime for remote broadband sites. These high-power UPS feature hot-swappable battery packs that are easy to replace without interrupting the power load. They also include a network connection for remote monitoring of critical power values, controlling outlets, and performing graceful equipment shutdown to ensure operating system stability.

CPI Power IQ for eConnect provides a centralized data center intelligent management (DCIM) solution to optimize middle-mile broadband networks better. Power iQ enables configuring, managing, and reporting data collected from all eConnect PDUs and UPS deployed in multiple micro-edge data centers. This allows for better oversight and optimization of middle-mile broadband networks across large geographic regions.

BUILD AMERICA, BUY AMERICA

Enacted as part of the 2021 Infrastructure Investment and Jobs Act, Build America, Buy America (BABA) requires that broadband networks funded by BEAD must use components that are at least 55% made in America.

CPI offers several solutions that are BABA compliant, helping to strengthen the U.S. manufacturing sector, create jobs, and boost the economy. Selecting CPI's BABA-compliant solutions also helps eligible entities under the BEAD program maintain their funding.

The following CPI solutions are BABA compliant:

- RMR® Industrial NEMA enclosures
- Oberon® In-Plane™, H-Plane™, and Hi-Point™ series wireless mounts
- Oberon® NetPoint™ free-standing weather-resistant bollards
- Oberon® Wi-Tile™ wireless access point enclosures

For more information about CPI's BABA-compliant products, visit: chatsworth.com/BABA

Edge Data Centers

For larger edge data centers that support multiple service providers connecting to last-mile networks, CPI ZetaFrame® integrated cabinet solution meets the needs of next-generation broadband middle-mile equipment. ZetaFrame provides superior cable management and works seamlessly with CPI thermal management and aisle containment while integrating with CPI intelligent eConnect® PDUs that facilitate remote power monitoring and control and access control.

CPI two-post Universal Racks and four-post adjustable QuadraRack® solutions are also ideal for these environments. These cabinet and rack solutions also protect point-to-point FTTx service provider equipment in commercial premises that provide broadband access to multiple users, including schools, universities, hospitals, malls, and municipal buildings.

Solution	Broadband Equipment	Application	Benefit
RMR® Wall-Mount and Free-Standing Enclosures	Rack-mounted switches, fiber connectivity, OLTs, servers, ONTs	• Outdoor locations • Supporting middle- and last-mile components • Micro-edge data center	• NEMA 4/4X protection • Optional 19" EIA mounting rails and cable management • Customizable • BABAA compliant
CUBE-iT® Enclosures	Rack-mounted switches, fiber connectivity, OLTs, servers, fiber distribution hubs, ONTs	• Indoor locations • Supporting middle- and last-mile components • Micro-edge data center	• Rack-mounting rails and cable management • Customizable • BABAA compliant
Oberon® SkyBar™ Series Enclosures	Wireless receivers, antenna, connectivity	• Wall or pole mounting in outdoor locations • Mounting and protecting wireless receivers and antenna in last-mile networks	• NEMA 4/4X protection • Optimal RF signal propagation • Locking • Easily field modified
Oberon® NetPoint™ Wireless Bollards	Wireless receivers, antenna, connectivity	• Outdoor locations where wall and pole mounting aren't feasible • Protecting wireless receivers and antennas in last-mile networks	• NEMA 3R rating • Optimal RF signal propagation • Multiple color options • BABAA compliant
Oberon® Wi-Tile™ Wireless Access Point Mounts	Wireless receivers, antenna, connectivity	• Indoor locations • Protecting wireless receivers and antenna in premises environments	• Optimal signal propagation • Locking • Full back-box • Aesthetically designed • BABAA compliant
ZetaFrame® Cabinets	Rack-mounted switches, fiber connectivity, OLTs, servers	• Indoor locations • Supporting next-generation broadband equipment and connectivity in middle- and first-mile data center environments	• Integrated high-capacity cabinet solution • Superior cable management • Customizable with thermal management, aisle containment, eConnect® PDUs, and UPS • Locking door and optional access control • BABAA compliant
Two- and Four-Post Rack Solutions	Rack-mounted switches, fiber connectivity, OLTs, servers	• Indoor locations • Supporting broadband equipment in middle- and first-mile data center environments	• High-strength, sturdy support • Customizable with cable management and eConnect® PDUs • BABAA compliant
eConnect® PDUs	Delivers power to rack-mounted switches, fiber connectivity, OLTs, servers	• Mounts in CPI enclosures, cabinets, and racks	• Advanced power monitoring and control • Environmental monitoring • Access control
UPS	Provides uninterruptible power to protect equipment and maintain uptime for remote broadband sites	• Mounts in CPI enclosures, cabinets, and racks	• High output power • Long-lasting swappable lithium-ion battery packs • Double conversion to protect against utility power variations • Remote monitoring and control
Power IQ®	DCIM software for centralized energy, power, and environmental monitoring and control	• Configure, manage, and aggregate power, current, temperature and humidity data from eConnect PDUs and UPS across multiple broadband locations	• Real-time data center health map and user-configurable dashboard • Control power on individual outlets • PUE and power usage monitoring and reporting • Chargeback reports

Conclusion

With various government initiatives aiming to provide broadband internet access to all Americans, large-scale network deployments are already in progress. As BEAD funding becomes available to states, we can expect these deployments to accelerate significantly. As service providers and their subcontractors roll out fiber and wireless broadband networks nationwide, protecting active and passive broadband equipment is critical—outside the customer premise, in a remote micro edge data center, or within an existing controlled facility.

CPI is dedicated to supporting the nationwide effort to expand broadband access. We offer a comprehensive range of enclosures, cabinets, racks, cable management, thermal management, aisle containment, power, and management solutions designed for first-, middle-, and last-mile networks. We also understand that navigating the complexities of BEAD, BABA, and state broadband office requirements can be challenging. Therefore, CPI provides expert guidance, working closely with your broadband teams to assess your specific needs and deliver solutions that help you efficiently bridge the digital divide.

References

[i] *American Enterprise Institute, June 2024*
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Reliable Broadband Service & Alternative Technologies Guidance

[iii] *Fiber Broadband Association*
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[iv] *Fierce Network, April 2024*
Analysts predict U.S. fiber subs to double in the next 10 years to 45M

Contributors

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Scott Thompson is the founder and president of Oberon, a Division of Chatsworth Products. Mr. Thompson founded Oberon in 1999 as a wireless networking design firm, and, from lessons learned in wireless network design, created products and solutions for other professionals in the industry. He is focused on enabling and facilitating secure wireless infrastructure in virtually any venue. Prior to Oberon, Mr. Thompson worked in the automotive radar and defense electronics industries.

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