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Building Edge Infrastructure: Re-thinking how networks can support the hyperconnected building

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The world's cities are rapidly densifying, as more people relocate in search of better jobs, housing, public services and transportation. According to Our World in Data (OWID), an estimated 2 billion more people will move to urban centers between 2018 and 2050. This massive influx will impact all aspects of urban environments, including the buildings where people work.

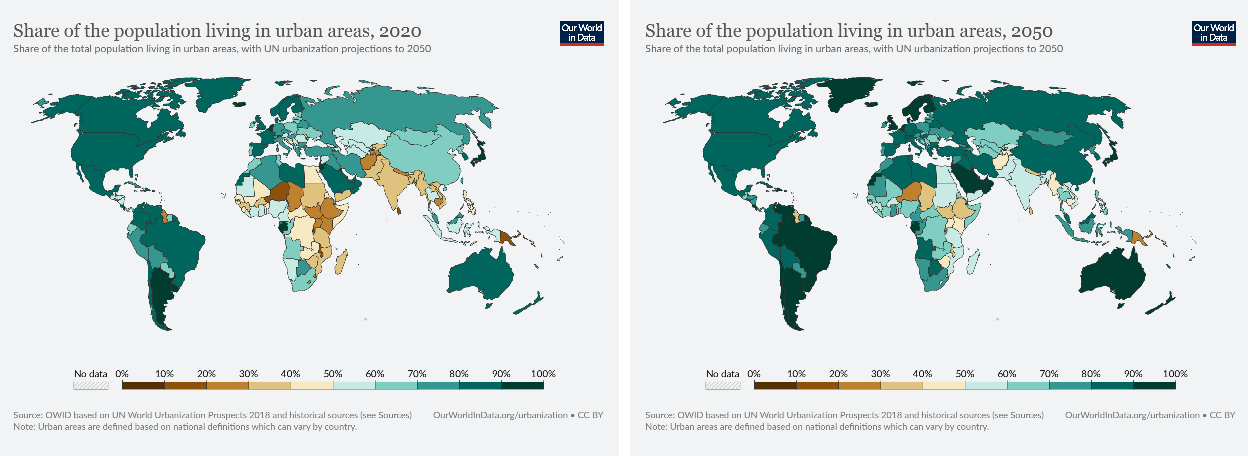

Figure 1: Percentage of people in urban areas
Source: OWID based on UN World Urbanization Prospects 2018 and historical sources

In addition to supporting more people, the world's buildings face increased demands for greater productivity and profitability while addressing the urgency of man-made climate change. This puts their IT/OT networks, which play a critical role in each of these areas, under pressure to support more data, connected devices and automation while lowering their environmental impacts. Exacerbating the situation is an intensifying lack of skilled technicians who can install and manage the growing and converging building networks.

CTOs and building network managers are now looking beyond traditional LAN/IP architectures and toward new edge-based infrastructure designs that support the IoT/IIoT connectivity and manageability that typify today's hyperconnected building. In this paper, we provide an overview of the CommScope Building Edge Infrastructure (BEI) and how it enables enterprise IT/OT networks to continually adapt and evolve.

Primary challenges facing building networks

According to reporting from IoT Analytics, an estimated 27 billion IoT connections will be live by 2025. A large number of these connections will reside in buildings where they will support everything from building automation systems to AI-enabled manufacturing and more. Their presence will have systemic impacts on a wide range of operational variables: energy demands, worker productivity, operational and process efficiency, and the climate crisis.

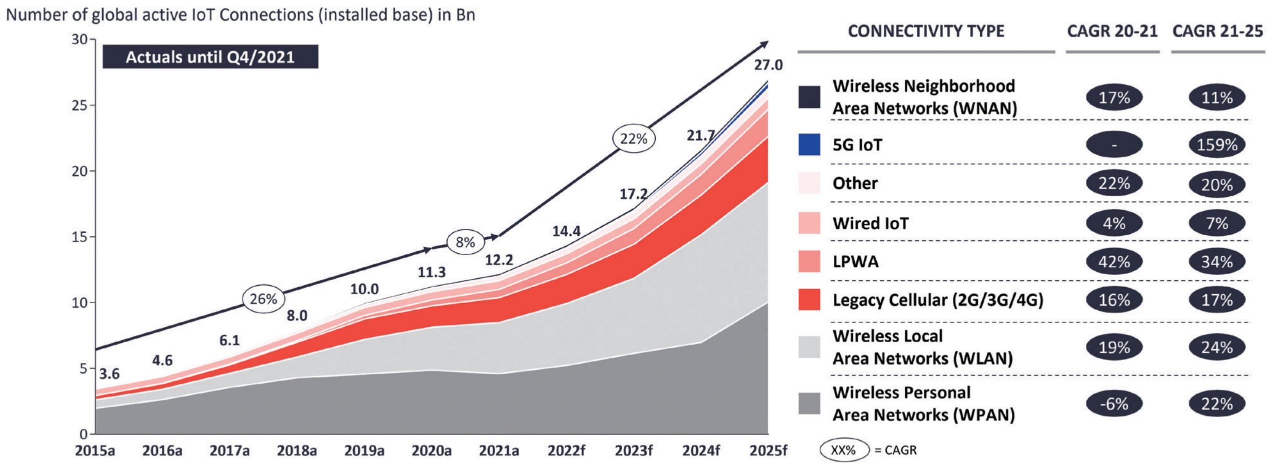

Figure 2: Global IoT connections in billions
Source: IoT Analytics, May 2022

Underpinning and supporting it all is the building's network physical layer infrastructure, which will soon be required to solve three fundamental problems:

Network densification

Building networks must provide lower latency data performance and more power at the edge. The number of connected devices will double from 2018 to 2025. Some will be dedicated to IT networks, others to OT, and still others to IoT or IIoT. In some cases, economics and operational efficiencies will dictate that some segmented networks converge. In addition to providing gigabit data speeds (and above), many of these devices also need to be powered. Therefore, the building's network infrastructure must also serve as a critical power delivery system—able to connect and transport power and data, reliably and efficiently, particularly to the network edge. As these pressures increase, new and innovative approaches to network design and deployments must be considered.

Deployment speed

As the building network's value and the cost of downtime increase, deployment speed is emerging as the new currency. Being able to quickly and flexibly deploy network assets will be imperative as building population needs grow and evolve over time. When we speak of deployment, we're primarily referring to design and installation.

Network design has long been a bottleneck in the deployment process. As network diversity and complexity grow, the time needed to develop and model new designs increases. Accelerating the design of networks and their subsystems by using a modular, repeatable approach would enable faster and easier deployment. But what does this look like on a practical level?

At the same time, accelerating installation times is becoming more critical as well as more difficult. The industry is currently experiencing a historic shortage of skilled labor, which doesn't appear to be short term. Demand for electrical and datacom installers is outstripping supply by a two-to-one margin. Building network managers are looking to their infrastructure partners for solutions that enable installers to complete more projects in less time with potentially smaller sized crews. That suggests more preconnectorized, prefabricated solutions, but is that enough? And what exactly does that look like?

Sustainability

> “ESG is no longer an optional business imperative as stakeholders now expect organizations to address, measure and report on issues related to corporate, environmental and social responsibility.”
>
> **Karen Alonardo**
> **VP ESG Solutions, NAVEX**
>
> **Source: NAVEX ESG Global Survey, May 2022**

Finally, as the intensifying effects of man-made climate change grow into existential threats, building networks are coming under closer scrutiny regarding their sustainability and efforts to be part of the solution. Over the past few years, greenfield networks have made significant strides in terms of enabling building decarbonization and a more circular ecosystem. Efforts include supporting networked HVAC and energy monitoring, controlling lighting, and monitoring occupancy. But building networks are now being asked to be as sustainable as the building operations they support. As the network footprint expands in response to increasing user demands, network managers are being challenged to re-evaluate network components and architectures in order to lower the embodied and operational carbon impact of the building network or building technology.

These are three critical and foundational challenges facing today’s CTOs and network managers. Before outlining a potential solution, we will take a closer look at the traditional building network and the lessons it offers going forward.

Limitations of traditional LAN/IP solutions

The traditional architecture for a building’s LAN and IP connectivity is based on a structured cabling design—and for good reason. Structured cabling provides a solid and scalable foundation, one that can easily be managed. The relationship between building networks and structured cabling is both tried and established. They have enabled not only systems but the people who rely on and work with those systems reliably over the years. These networks and design considerations are (and will continue to be) a reliable way to connect and enable people and systems. Increasingly, however, we have seen needs, applications, and environments where these methods sometimes fall short.

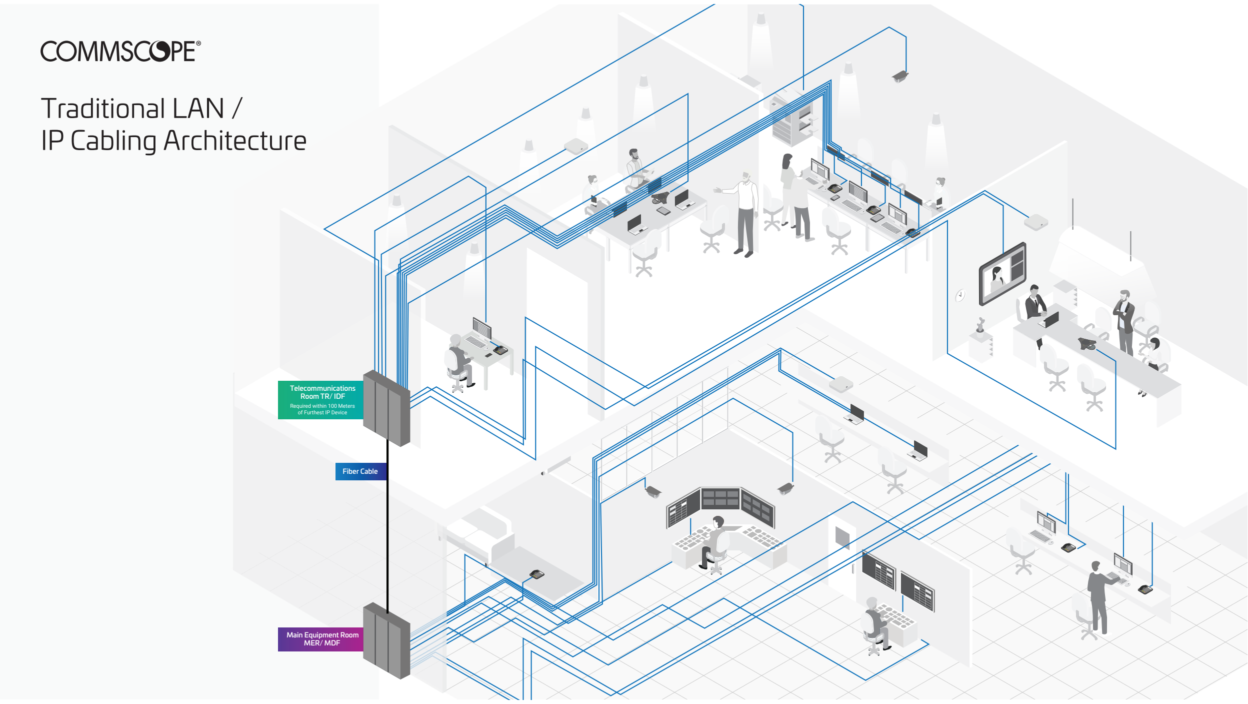

Figure 3: Architecture for traditional LAN/IP network
Source: CommScope

So long as the total number of people and connected devices they use remains manageable, the structured cable architecture provides a perfectly serviceable solution. Where it begins to break down, however, is when the number of devices to be powered and connected becomes too great to justify.

As seen in Figure 3, the traditional network design relies on telecom rooms (TRs) on each floor, with all connected devices on the floor fed via individual cable runs from the TR. In a large enterprise, the number of devices to be connected can easily exceed several thousand, and many of those devices can be located several hundred meters from the TR. This extended distance becomes a serious barrier when we consider the medium upon which traditional building networks are built: copper.

While copper access in the LAN is a tried-and-tested method, the distance and powering limitations of Ethernet technology are well known. Maximum channel lengths and performance limitations (defined in ANSI/TIA-568, ISO 11801 and other cabling standards for commercial buildings) limit Ethernet links to less than 100 meters. While there are ways to extend that distance—adding intermediate TRs or using power over Ethernet (PoE) extenders, for example—the tradeoffs in terms of things like installation costs, power requirements, and network manageability negate their use as a reliable and repeatable alternative.

Fiber access in the LAN can provide near-limitless bandwidth delivery, but it is not without its own set of limitations. First, the options for delivering power via fiber optics are limited. Second, the end devices that support fiber connections tend to be limited to specialty devices, such as remote digital distributed antenna systems, that require high-bandwidth support. Lastly, the skilled labor needed to support, grow and scale fiber networks is, as noted at the outset, in scarce supply.

With increasing demands of devices at the edge, traditional networks and designs are full of compromises:

- Distance limitations for both Ethernet and PoE end points
- Lack of day-2 flexibility for workspace
- Cost of floor space for additional TRs (Table 1)

One promising alternative for supporting the device density, deployment speed and environmental requirements of hyperconnected building networks is taking shape in the form of the CommScope Building Edge Infrastructure.

City	Rent per SqFt	10ftx10ft TR Cost	# TRs per floor	Annual TR Rent
New York	$ 82.51	$ 8,251.00	2	$198,024.00
San Francisco	$ 79.93	$ 7,993.00	2	$191,832.00
Silicon Valley	$ 65.29	$ 6,529.00	2	$156,696.00
Los Angeles	$ 44.85	$ 4,485.00	2	$107,640.00
Miami	$ 46.01	$ 4,601.00	2	$110,424.00
Boston	$ 44.19	$ 4,419.00	2	$106,056.00
Philadelphia	$ 28.40	$ 2,840.00	2	$ 68,160.00
Atlanta	$ 30.78	$ 3,078.00	2	$ 73,872.00
Chicago	$ 34.70	$ 3,470.00	2	$ 83,280.00
Austin	$ 49.10	$ 4,910.00	2	$117,840.00
Dallas	$ 30.82	$ 3,082.00	2	$ 73,968.00
Minneapolis	$ 28.99	$ 2,899.00	2	$ 69,576.00

Table 1. Annual commercial building rents per square foot
Source: U.S. Office Outlook Q2 2021, Jones Lang LaSalle Inc.

Building Edge Infrastructure (BEI)

Whereas traditional multi-layer networks are based on legacy technology and design constraints, the BEI is technology/application agnostic and is far less limited. For reasons we'll explain shortly, its design allows for longer link spans and flexible built-in power delivery that support a high density of networked devices. Deployed as a single-layer solution, it does not require the multiple TR systems—campus distributor, building distributor, floor distributor—that tend to bloat and bog down the traditional networks. Or, put another way, the BEI is designed to thrive at the network's edge.

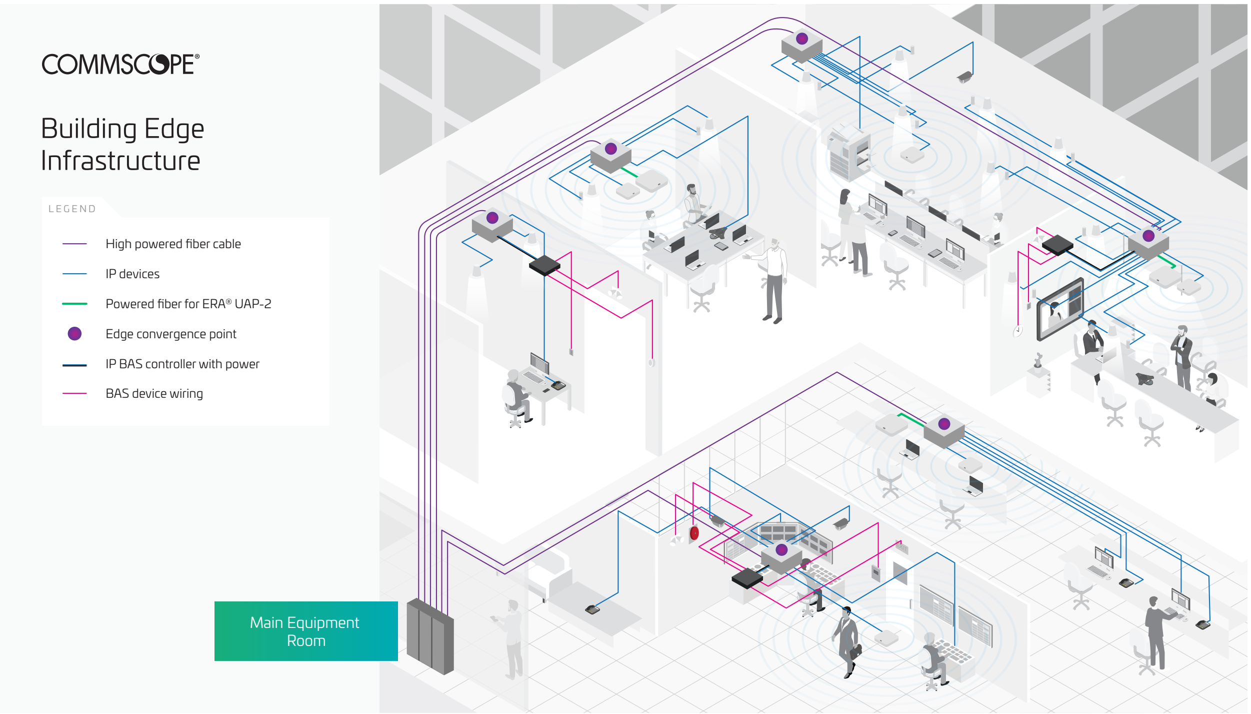

Figure 4: Building Edge Infrastructure
Source: CommScope

The BEI is composed of the following components to enable end-to-end connectivity:

Location	Equipment: Description
Main equipment room	**Power sourcing equipment:** Provides bulk power to service areas
	Fiber shelves and modules: Provide fiber uplink connectivity to the network
	Power termination, cross-connect: Break-out panel to connect power to transport media
	Aggregation and core layers
Transport media	**Hybrid fiber trunk assemblies:** Copper and powered fiber cables under one jacket transport power and data from the main equipment room to service areas throughout the building.
Service areas	**Powered consolidation point:** Ceiling-based "micro TR" containing active switching equipment
Device connectivity	Copper and fiber connectivity, cabling, patch cords, apparatus.

In comparing the traditional LAN/IP network design (Figure 3) to the BEI network design (Figure 4), several differences become obvious. Whereas the traditional design requires discrete data and power feeds from each TR to the devices within reach, the BEI design uses a single hybrid trunk that delivers power and data to each consolidation point. This simplified architecture reduces the length of cable runs to each device and ensures reliable and manageable delivery of data and power to all areas of the building with fewer floor distribution points or TRs. By taking advantage of new powering and network technologies, further space savings can be realized by recovering usable floor space and conveyances currently used for network cabling (see Figure 2).

From the consolidation points within each service area, hybrid (power/fiber) cables support devices at the edge. Locating the switching gear within the service area enables improved bandwidth, latency performance and PoE efficiency while providing an easy path to Day 2 service provisioning, upgrades and expansions.

Leveraging fault-managed, limited power (FMLP) technology

Moving the active electronics closer to the end device is not a new concept. It has long been a feature of outside plant networks and continues to be used to increase bandwidth and performance for home broadband users. Within the enterprise, however, the design has not translated well, mainly due to the difficulty and cost of providing local power to the switching devices. In some cases, remote direct current (dc) power using hybrid cables can alleviate this issue; but, even then, this solution can only support lower power delivery to about four to eight devices per connection point. Thus, the number of consolidation points (along with the cabling requirements and complexity) needed to support hundreds of connected devices quickly becomes a barrier for entry.

In 2023, the National Electrical Code (NEC) announced a new power classification for U.S.-based networks: fault-managed power systems or Class 4. Power systems falling under this new classification are characterized as "fault-managed, limited power" (FMLP) systems, meaning they monitor and limit power transmission between a fault-managed power transmitter and receiver in order to minimize the risk of shock and fire. Standards organizations have been actively working to define operations, components and deployment of fault-managed power. In addition to NEC Article 726, Underwriters Laboratories (UL) has produced guidance regarding the powering equipment (UL 1400-1) and cabling (UL 1400-2) used to deploy fault-managed power.

FMLP is seen as a core enabling technology for BEI deployments, as it is able to deliver enough power to easily support up to 50 devices from one consolidation point (Figure 5). This allows for the direct placement of switching gear in the service area without the need for local power. Coupled with fiber cabling, FMLP enables the delivery of large amounts of power and data over distances that far exceed those of traditional network architectures.

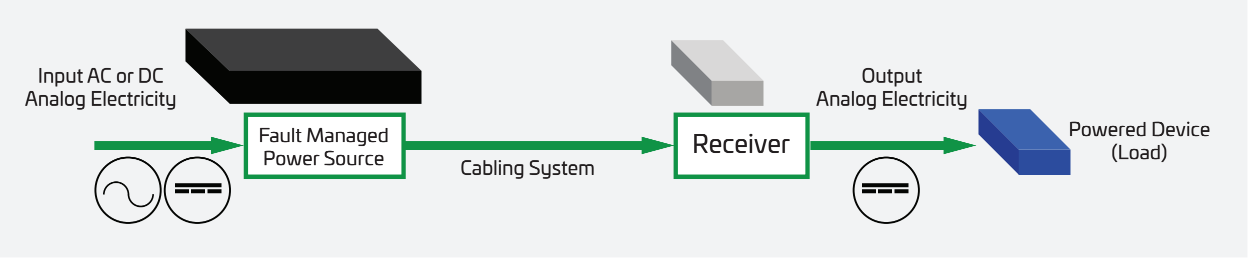

Figure 5: Fault-managed, limited power explained
Source: CommScope, VoltServer

Technology agnostic

BEI, at its core, is a network architecture that uses FMLP power delivery and fiber connectivity to support a large number of connected devices from service areas across the facility. The fiber-optic connectivity and power delivery remain transparent to the BEI architecture. The BEI architecture is vendor and application agnostic and able to support active ethernet or PON, IT and OT networks or a converged IT/OT/IoT network supporting hyperconnected buildings.

Thus, the BEI architecture provides a stable and reliable platform for power delivery and data connectivity that can be easily and flexibly deployed regardless of the application. This resiliency offers some important advantages, as building networks evolve from current Ethernet and optical network technologies to future generations of optical transport. Most notably, the ability to support multiple generations of technology and application upgrades increases the infrastructure's lifespan—lowering the total cost of ownership as well as the building's environmental impact.

Centralized core switching and power backup

By utilizing BEI's core enabling technologies, network designers are free to plan network deployments with more flexibility and resiliency. As stated earlier, the BEI architecture enables designers to consolidate or even remove intermediate TRs—replacing them with a single and compact ceiling-based solution containing all switching and power backup gear. Again, these concepts have been used for several years in service provider and data center environments. Armed with the BEI and its core technologies, designers and architects can address a wide range of operational challenges:

- Simplify network deployments by eliminating intermediate equipment rooms and associated equipment and services
- Power backup and redundancies: Location of aggregation and core layers, UPS and battery backup can be centralized and take advantage of multiple backup sources for connectivity and power
- HVAC requirements: Eliminate HVAC requirements for floor distributors (by eliminating intermediate equipment rooms)
- Power circuits: Reduced need for building mains to more equipment rooms and to support remote devices and building control systems in the ceiling and equipment rooms

Sustainability

As with traditional networks, BEI architectures support the systems and devices that track, control and enable energy efficiency, water use and other critical metrics of the building's sustainability. The BEI then goes a step further by helping reduce embodied and operational carbon emissions while extending the life and utility of the building network.

Carbon reduction: The BEI replaces long runs of multiple four-pair copper cables with shorter patch cords and single two- or four-pair hybrid power and fiber cables. Typical building models indicate that, compared to traditional network deployments, the BEI reduces copper use by over 50 percent, and plastic reduction by over 60 percent.

At the same time, switching to FMLP power delivery also reduces the amount of copper in the electrical alternating current (ac) mains needed to power consolidation points. This, in turn, lowers the need for steel conduit (and the associated packaging waste)—further reducing the network's carbon impact. Lastly, because BEI architectures are simpler and faster to install, the total number of man-hours required is lower, as is the carbon output.

Longevity and utility: As noted earlier, the BEI architecture is both technology agnostic and application agnostic. Therefore, it is able to support multiple generations of network upgrades, as hardware continues to evolve to provide faster, more efficient data transport. This eliminates the need—and environmental costs—to purchase, design and deploy new infrastructure components and systems to support new and emerging technologies. As BEI can support a wide range and number of devices, systems and applications, it adds further overall value and utility to the building network.

Comparison modeling

When considering a BEI architecture, it is important to understand how it compares to the available network design approaches. We have already discussed what separates BEI from current traditional network designs. It is also instructive to look at some of the key building and network variables used to model the costs for the different network designs.

The models in Figure 6 show a significant advantage to deploying active Ethernet with a BEI architecture versus the Category 6A cabling used in the traditional network design or remote powered passive optical network architectures. Using active Ethernet within a BEI architecture provides the simplified design and extended link distances of the BEI plus the manageability and ease of device configuration found in a traditional network design.

Building Models		
Category 6A	**Remote Powered Fiber (PON or P2P fiber)**	**Building Edge Infrastructure**
• 10 story office building • 2500 device locations • 2500 Cat 6a cable locations • Equipment room (ER & TR) on each floor (total 10) • No network switches • No pathways / conduit / cable tray included • Equipment room buildouts include backboards, power circuits and grounding • 185’ average 6A cable length • Pre-term fiber in riser	• 10 story office building • 2500 device locations • 3 PoE devices supported per powered PON location (PON ONT / max 60 Watts) = 833 locations / 83 per floor • 1 equipment room • No PON OLT & ONT included • No PON Splitters–homerun cables for remote powering (powering per floor and splitting fiber added costs to this model) • No pathways / conduit / cable tray included • No savings included for centralized UPS BBU • Equipment room buildouts include backboards, power circuits & grounding • Field terminated fiber	• 10 story office building • 2500 device locations • 25 devices per consolidation point (40 watts per device avg) = 100 CPs / 10 per floor • 1 equipment room • No network switches • No pathways / conduit / cable tray included • No saving included for reduced electrical circuits for BAS • No savings included for centralized UPS BBU • TR buildouts include backboards, power circuits & grounding • Pre-term fiber and copper assemblies for BEI model
	19% faster deployment speed	**57% faster deployment speed**

Figure 6: Cost model comparisons

A brave new edge-based world

The term “Web 4.0” is typically reserved to describe the accelerating digital expectations for always-on, omnipresent connectivity in the consumer sector. But it has quickly taken root in commercial facilities of all types. More and more devices—both those that serve end users as well as those that inform and control a growing number of automated building systems—are being deployed.

As network managers plan their response to this newest network disruption, their focus is on delivering more power and bandwidth on the edge and keeping deployment times and costs in check while remaining true to the environmental objectives that have become the new normal. The power and bandwidth levels will continue to rise incrementally, even as the pool of skilled installers and network techs shrinks. The traditional structured cabling network architecture that has served the industry so well for so long still has a critical role to play going forward, but—for some of the larger building environments—the network performance, deployment and management requirements seem to suggest an alternative solution.

The Building Edge Infrastructure is one such alternative with a variety of advantages. With its technology-agnostic design, simplified distributed topology and use of FMLP power delivery and high-bandwidth fiber, BEI is able to address the new challenges of today's hyperconnected, edge-based applications. Whether looking to deploy bandwidth and power to the edge quickly and efficiently, or to deploy a more sustainable network, BEI gives network designers and architects a scalable, adaptable path forward—today and well into the future.

To learn more about CommScope's Building Edge Infrastructure, contact your local CommScope representative.

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WP-117374-EN (02/23)