#networkconvergence

Accelerating Wireless-Wireline Network Convergence

Enabling the Metaverse, Omniverse and Future Digital Infrastructure

CORESITE
An American Tower Company

Foreword

In 2020, businesses around the globe accelerated digital transformation to support remote work and self-serve digital interaction with their ecosystems. **A recent Twilio survey found that 97% of enterprise decision makers believe the pandemic sped up their company's digital transformation by an average of six years.**[1] Decades of communications technology innovation made the acceleration possible. The IT infrastructure, including data centers, clouds and distributed networking, proved its mettle.

The convergence of wireless and wireline networks also was set in motion by that transformation. With the deployment of low-latency, high-capacity data communications – starting with 5G, a wireless network that is 10 times faster, more spectrally efficient and can handle 100 times the density of connected devices than 4G networks while enabling millisecond access latency with local break out and zero perceived downtime[2] – operators can unite the two access networks and deliver next-generation services through an edge-to-cloud interconnection fabric.

The edge is emerging as the critical area of application convergence. By lowering data transport costs with selective IoT edge data processing and achieving bounded latency targeted requirements ranging as low as 10 milliseconds of round-trip latency, solution providers will enable customer success. Without reaching that degree of performance, metaverse "experiences" and low-latency sensitive services, driven by artificial intelligence, machine learning, IoT, etc. will fail to perform as needed.

Steve Vondran

Executive Vice President and President, U.S. Tower Division, American Tower

Steve joined American Tower in 2000. In 2010, he was appointed Senior Vice President, General Counsel for the U.S. Tower Division and served in that role until August 2018, when he was appointed to his current position.

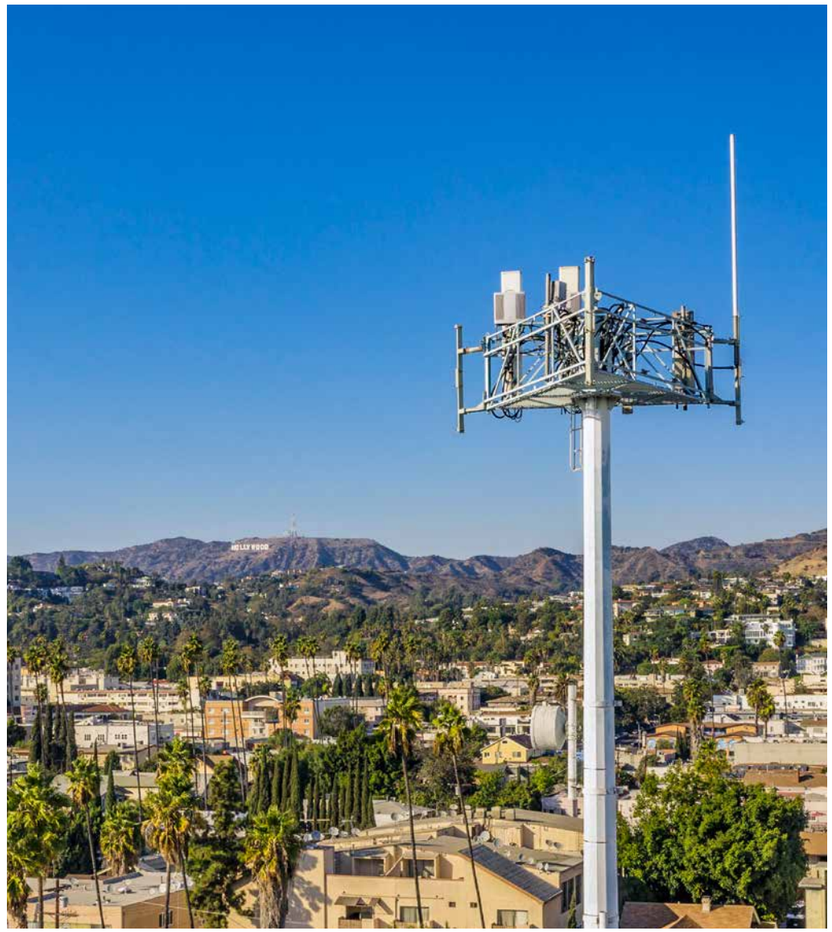
Building the interconnected fabric of tomorrow

In this white paper, we will focus on what data center and wireless network providers will need to do today to build the digital infrastructure of tomorrow. Discussion will include:

- **Tomorrow's infrastructure** – What does the converged infrastructure look like?
- **Use cases** – We look at three examples to ground the discussion in attainable, proof-of-concept applications.
- **The wireless infrastructure provider's role** – Towers are the starting point. From edge data centers to evolving industry regulations, how can wireless network providers facilitate digital infrastructure evolution?
- **The data center provider's role** – How will colocation providers such as CoreSite and American Tower help create the network enabling the metaverse and other latency-sensitive services?

Building the interconnected fabric of tomorrow depends on a digital infrastructure sea change. Wireless and wireline network convergence is an essential element of that change, with 5G/6G and future specialized radio communications equipment on or near towers where wireless and wireline networks meet. Those familiar with that point of intersection will also think about the last mile (or "breakout point"), which is the most distributed portion of the internet and the hardest to build and operate.[3] Convergence also has the potential to finally solve last mile/breakout point challenges.

We will introduce new concepts of data centers as we move forward in this white paper. Specifically, we will call today's data centers "regional" and data centers closer to the edge "aggregator" facilities, which can serve as either a "hub" or "spoke" in the interconnection fabric topology.



Data centers will need to provide a new level of performance for enterprises, mobile network operators (MNOs), network services providers (NSPs) and cloud services providers (CSPs), who will be moving more data than ever before over public and private networks.

Significantly expanding the number of peering points in regional data centers will help to extend and manage low-latency connectivity into underserved areas, often referred to as Tier 2 and Tier 3 markets.

Edge data centers are another piece of the solution, and obviously are in early-stage development regarding architecture and economics. Edge data centers are smaller facilities with capacity ranging from a handful of racks to a few megawatts. The optimal workload footprint is yet to be determined. However, what is known is that data processing close to the source is critical for many use cases – now and in the future – and edge data centers will need to have both the network connectivity required for low-latency services and, if possible, virtualized network interconnection to native cloud onramps.

While we can envision infrastructure, technology, regulatory and behavioral changes ahead, much remains unknown such as timing of use cases, desired costs for mobility, storage, computing and connectivity. Furthermore, the discovery of broadband capabilities could redirect the course of digital infrastructure development. It's exciting, and potentially life- and world-changing.

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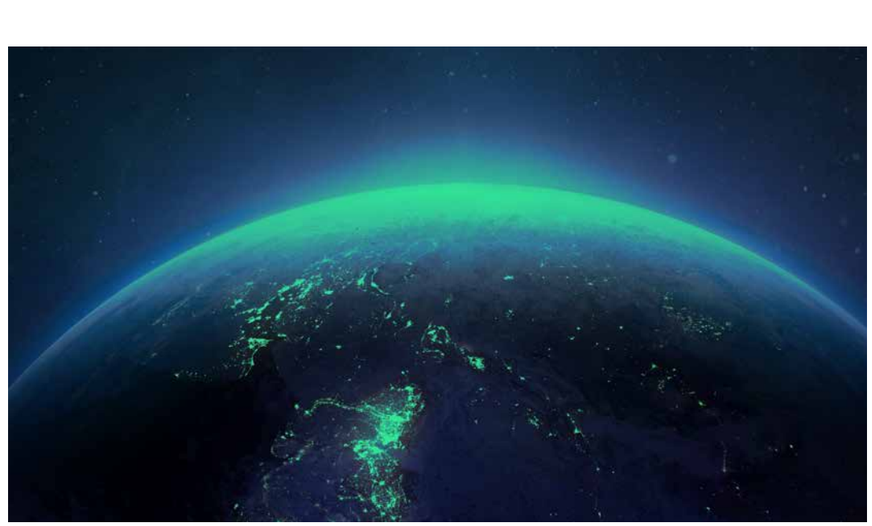


How do we take advantage of the momentum of accelerated digital transformation to build the infrastructure for tomorrow?

Tomorrow's Infrastructure: An Interconnected Fabric

Let's unpack "build the digital infrastructure for tomorrow" by looking at our vision of what comprises an edge-to-core, digital interconnected fabric.

At the center are hyperscale cloud data centers that are accessed by direct, native connections and virtual direct cloud connectivity services. Major clouds are likely to see demand to host virtualized radio access network (RAN) services as convergence enables moving such services onto their platforms. An increase in artificial intelligence (AI) and machine learning (ML) in hyperscale clouds (as well as in regional, aggregator and edge data centers) is sure to occur, with the results from AI processing cascading to the edge through a chain of data centers.

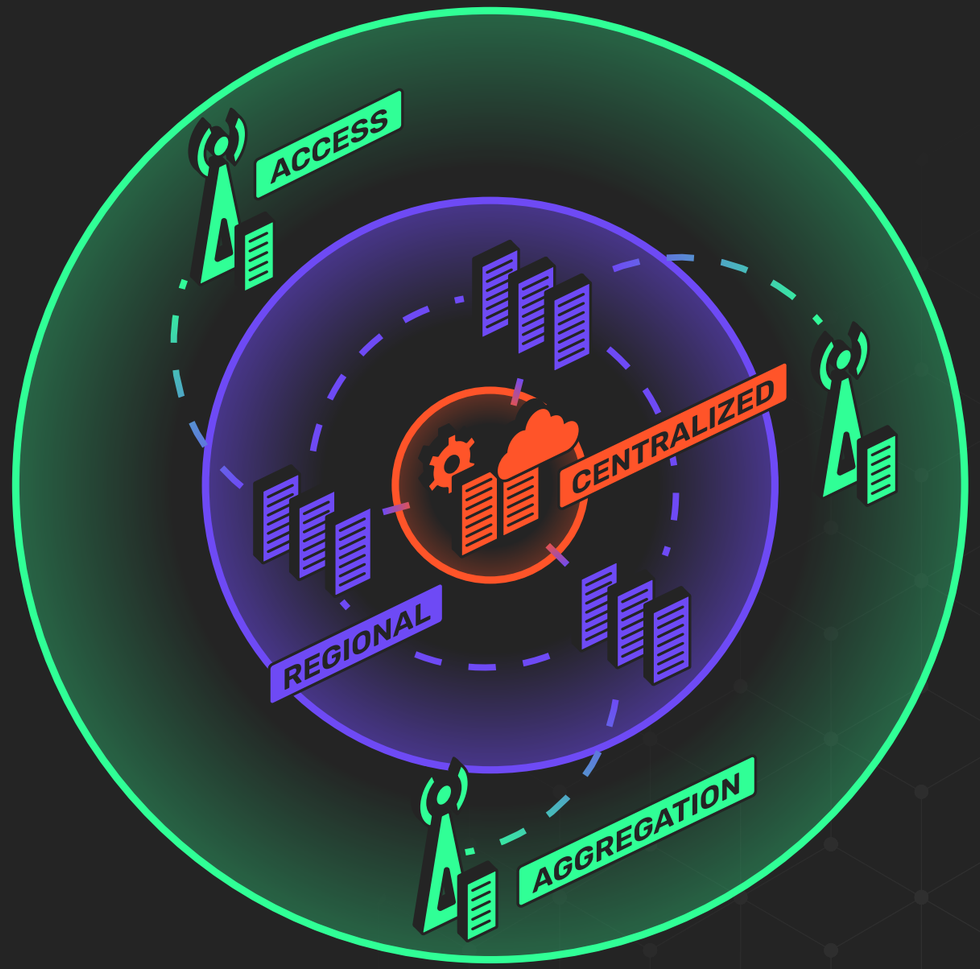


FIGURE 1: What does a converged infrastructure look like? While the vision is in flux, what's coming into focus is that it includes distributed multi-access edge computing for wireless/latency sensitive applications, data centers near the edges where data is aggregated, regional data centers in high-density population locations, and centralized data centers with direct access to hyperscale cloud providers.

Working toward the edge(s), regional data centers – essentially today's colocation data center facilities – will not only increase in density but also continue to play a pivotal role in low-latency connectivity. The number of peering points will need to ramp up in response to the rise in connected devices and traffic. By peering at the decentralized edge, network providers reduce congestion at core facilities and improve performance overall.

Colocation data centers in the regional ring will help to control the total cost of operation by enabling multiple data sources to be managed at a central location, which reduces the number of switches, routers and other devices needed in a highly distributed network.

Towers, edge and aggregation data centers will populate the access layer, where the initial exchange and routing of data between the wireless and wireline networks occurs.

Then, the data can be:

- **Processed in an edge data center**
- **Sent to an aggregation data center, where data from multiple sources in the access layer is amassed and processed in colocation-deployed workloads**
- **Routed to a regional data center, where traditional colocation services are executed**
- **Relayed to the core, which includes high-density data centers and data center campuses**
- **Routed via native cloud onramps to hyperscale CSP facilities for processing in hosted services**

It's important to keep in mind that all the components of the evolving digital infrastructure – data centers, clouds, physical networks, radio/microwave/fixed wireless technologies and towers – already exist. It's the ability to innovate with new intelligent platforms upon existing infrastructure that gives credence to the possibility for seamless, end-to-end connectivity between mobile data networks at the tower and digital platforms in data centers, and even edge-to-cloud interconnection at low-millisecond speed.

> **The ability to innovate upon existing infrastructure creates the possibility for seamless, end-to-end connectivity between mobile data networks at the tower and digital platforms at the data center campus and gives credence to wireless/wireline network convergence.**

Enabling Use Cases: The Converged Network Potential Realized

One of the most exciting things about wireless/wireline convergence is the almost limitless number of use cases that will be invented.

Shared immersive experiences in the metaverse are often shown as examples. By strapping on a virtual reality headset, you will be able to interact virtually with people anywhere in the world – if the network speeds achieve the low latency required to do so. Digital twins can create new business opportunities and productivity gains in enterprise workflows and business processes.

While the most exotic of those use cases are not yet implemented, there are many examples of what's to come already in use. Here are just three.

Augmented Reality and Virtual Reality

The global augmented reality (AR) and virtual reality (VR) market size is expected to reach over $105 million by 2028, exhibiting a CAGR of 35.7%.[4] AR and VR depend on real-time data processing. Convergence can make that happen, and the expansive reach of a converged digital infrastructure creates the possibility of improving business processes without geographic constraints.

For example, in the oil and gas industry, employee safety is a top priority. As with every business, controlling costs is a daily exercise. Imagine you are a technician in an oil field with 5G coverage, tasked with inspecting or maintaining equipment on a rig. An AR headset attached to your hard hat would be able to project instructions telling you exactly what to look for. Your colleague back at headquarters, who sees what you see over video, could talk you through the process. Meanwhile, IoT sensors in the system being worked on could provide feedback on process changes or warn you if conditions are unsafe.

5G-enabled AR coupled with IoT helps decrease human error, mistakes that even can be deadly, and reduces the number of field technicians needed on expeditions into the field.

Remote Robotics

We just mentioned breaking geographic constraints. One of the most challenging problems is providing healthcare in underserved regions by enabling the skills of highly specialized physicians to be “transported” where they are needed.

AR-based telemedicine and more advanced applications such as telesurgery could solve that problem. Right now, you can visit a nurse or doctor in a 2-D teleconference call; soon, thanks to AR/VR, you’ll be able to add the third dimension, making it easier to understand the often-complex subject being discussed. That’s a new definition of the house call, and it could happen anywhere through a smartphone.

Let’s ratchet up the amazement. Microsoft’s HoloLens 2 is a headset that surgeons can use to train faster, immersed in a virtual operating room. In the real operating room, physicians implementing HoloLens 2 can get information while using both of their hands during the procedure. They can connect with remote experts and call up patient data and go beyond X-rays to consult MRI images in 3D at the point of care. They can even collaborate globally with other physicians as 3D avatars.

Mobile Gaming

Gamers will reap the advantages of network slicing, because 5G solves for jitter and especially latency. By utilizing end-to-end network slicing, operators can create a low latency slice for enhanced gaming experiences and another high bandwidth slice for video streaming within the same mobile network. Separate slices allow services to be delivered with the quality of service (QoS) appropriate for each application and at a price point that the market will bear.

Mobile gaming is big business and growing. Predictions are that 75% of pandemic-driven gaming activity will continue. In fact, it should persist indefinitely. Therefore, we can expect to feel the positive consequences of the pandemic on mobile gaming in 2022 and the years to follow.[4]

Building Access: The Wireless Infrastructure Provider's Role

Wireless infrastructure providers will "own" the access and aggregation layer for mobile devices. Towers with edge data centers onsite will serve as the location for most areas. In urban settings, rooftop sites will be where wireless data first meets the interconnection fabric, enabling city-wide coverage. Small cells will help fill in the capacity hot spots.

The fundamental role of wireless infrastructure providers is to establish interconnection-rich access and mobile internet of things (IoT) gateways at the edge. It's also here, at the access network aggregation points, where gigabit passive optical networks (GPON) will carry broadband data and content to be rendered and processed in edge data centers. The traffic from both these networks will meet at aggregation data centers and transit as needed to-and-from the network core and public cloud.

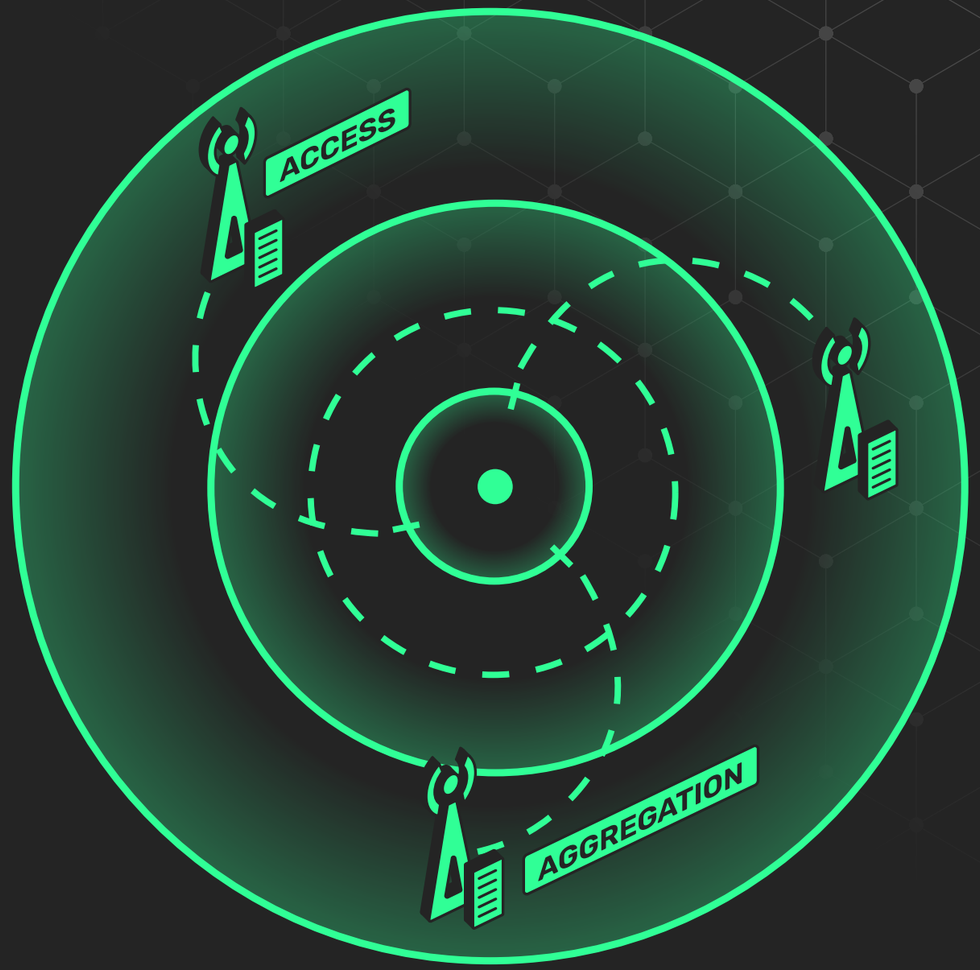


FIGURE 2: The access/aggregation layer, where wireless network providers create the connection between the edge and the inner rings of the interconnection fabric.

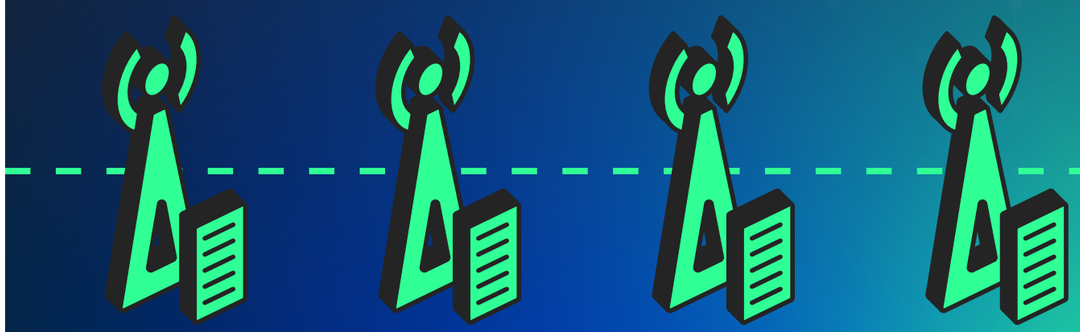
Key Requirements

For wireless infrastructure providers to be able to help build the converged network of tomorrow, they must:

- **Own or lease distributed real estate in suburban and rural markets, enabling rapid deployment and access to new customers**
- **Possess the capital necessary to make investments for network buildouts at scale**
- **Have relationships with MNOs and, in the long run, network providers to deliver requisite connectivity**
- **Offer virtualized native connection to major CSPs, eventually reaching from edge data centers to hyperscale clouds**

Furthermore, they must own or partner with a data center provider which operates colocation facilities, has native onramps (also called direct connections) to CSPs and the ability to interconnect an ecosystem of services providers. Enterprises need secure interoperability among core business processes, cloud-hosted enterprise resource planning (ERP), customer relationship management (CRM) solutions, etc.

To be competitive, they also need dynamic secure interconnection between their business partners through what CoreSite has identified as "a native digital supply chain." Future digital supply chains also will leverage blockchain technology for proof-of-work (e.g. transactions).

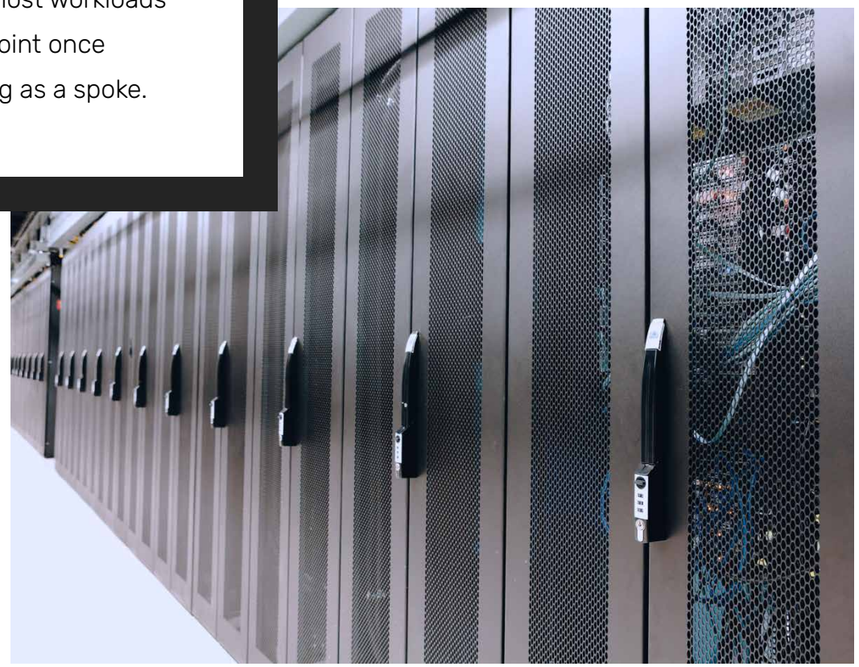


Purpose-Built Aggregation Data Centers

Even as more direct paths between a data source and multiple hyperscale cloud providers are established, aggregator data centers at the "sweet spot" between the edge(s) and the interconnection fabric core will be best for storing and processing data. Another benefit is that well-situated aggregation data centers will reduce backhaul and help control broadband costs inherent with the increased traffic volume.

Scalability is often the center of data center discussions. Aggregator data centers bridge the gap in scale between edge data centers and regional data centers, providing compute and storage for some use cases.

Is an aggregator considered a hub or spoke in the network? We think it can be both. Aggregator data centers can provide switching to route data to other interconnection points across the infrastructure mesh, acting as a hub. They also can host workloads and services, including storage, at a point once removed from the edge, thus operating as a spoke.



Edge Data Centers

Edge data centers will be at or close to the tower base. Today, the number of edge data centers is relatively low. Convergence should result in thousands of edge data centers at tower sites, where multiple MNOs, enterprises, networks and cloud providers can peer seamlessly through neutral host exchanges.

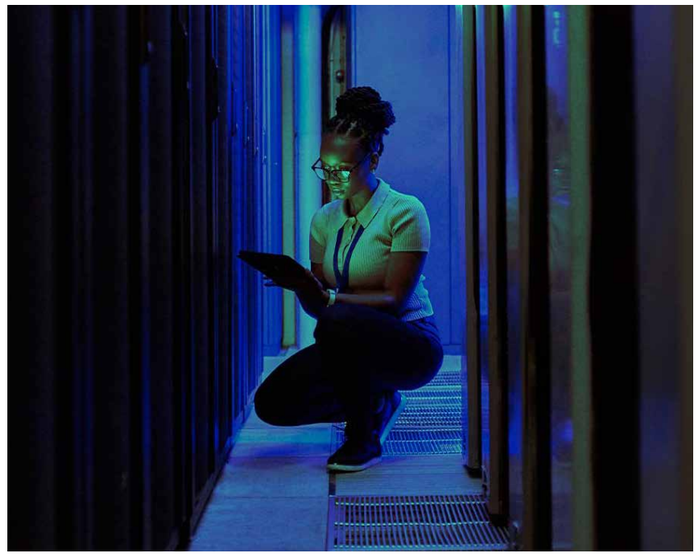
Edge data centers will include specialized hardware, power and environmental controls. In terms of size, it's safe to say that the definition of an edge data center will evolve in alignment with advances in server capabilities and changing customer requirements.

Convergence of the Stakeholder Community

Why do we include "relationships with MNOs and network providers" as a critical requirement? Convergence goes beyond wired and wireline technologies merging, and the role of wireless network providers is not simply to build more towers.

Achieving the full potential of convergence includes heightened degrees of network interoperability and synchronization as well as the evolution of RAN architecture. New standards are in development, governed by global industry and national authorities. LF Edge, a group within the Linux Foundation, is also championing collaboration on common software components. The mission of LF Edge is to establish an open, interoperable framework for edge computing independent of hardware, silicon, cloud or operating system.

Clearly, there's another type of convergence in action. More than ever, shared interests will drive shared commitment to transforming the digital infrastructure and creating value as well as future opportunities for all stakeholders.



Interconnection: The Data Center Provider's Role

Let's start with clouds as we map out the probable changes in data centers that a converged infrastructure will drive. We suggest starting here because clouds "live" in data centers and 89% of organizations currently have a multicloud strategy; 80% of this group utilizes a hybrid approach by connecting multiple public and private clouds.[5]

Digital transformation leaders have already seen the advantages of a multicloud strategy. Before the COVID-19 pandemic, leaders in enterprise technology adoption enabling digital transformation were growing revenue 2X faster than laggards. Latest research shows that leaders are now growing revenue 5X faster than laggards.[6]

5X

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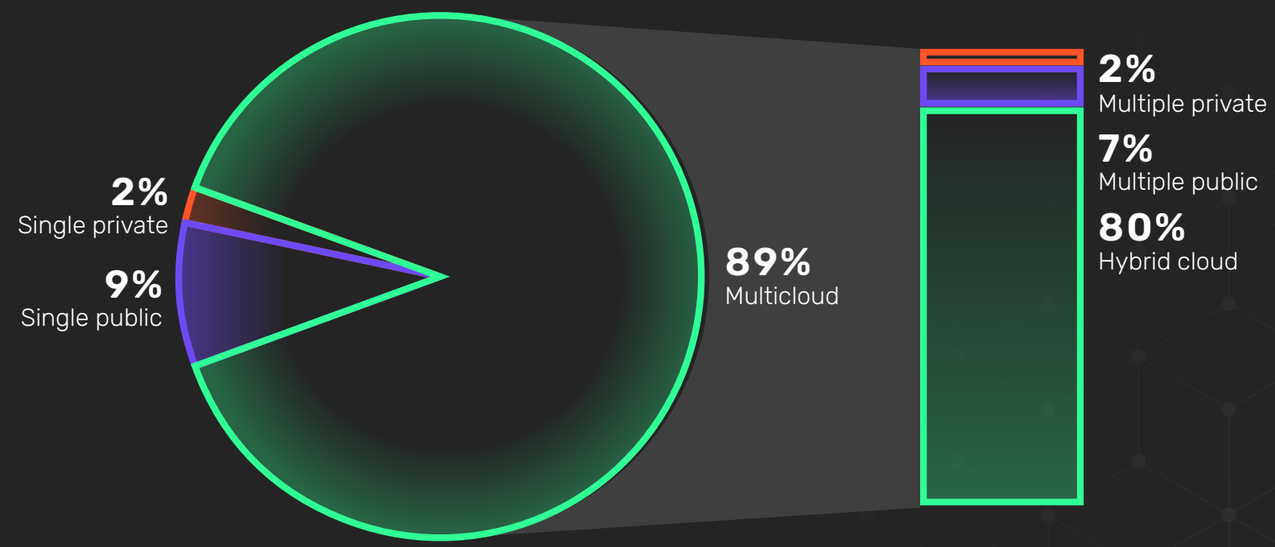


FIGURE 3: 89% of organizations have a multicloud strategy; 80% of that group utilizes a hybrid approach by connecting multiple public and private clouds.[5]

One part of their success is smart workload deployment; they have been able to place, evaluate and redistribute applications in the highest-value environments, whether on-premises, in colocation data centers or hyperscale data centers such as AWS as part of their hybrid IT strategy.

Similarly, establishing clouds where they best meet business objectives – which includes edge data centers – is a logical strategy. Achieving the latency future use cases require can happen only by moving compute resources to the edge.

Cole Crawford, founder and CEO of Vapor IO, frames it up this way:

> "The deployment of infrastructure edge computing – in the form of micro data centers at the edge of the wireless and wired networks – will bring powerful cloud resources to the edge. By turning network functionality into software running at the edge, the historically separate silos of networking and compute will converge to operate seamlessly together on the same underlying infrastructure. Compute and storage will fan out across the network, creating a gradient of cloud resources that occupy new edge data centers extending all the way to the last mile."[7]

Where does this leave today's data centers? Although a network capable of supporting the metaverse as well as emerging IoT use cases necessitates "disruptive" infrastructure change, many fundamental characteristics that differentiate data centers remain the same – and for this discussion we will focus on location, network density and management, data processing capacity and energy consumption.

Location

Regional Data Centers

Data centers primarily have been built in highly populated urban locations, where enterprises choose to locate and where large audiences and consumers live. These data centers will still be well-situated and help anchor the interconnection fabric core.

Regional data centers will be interconnected via an intelligent mesh network connectivity and exchange data with clouds through direct connection (physical cross connects) as well as Layer 2 ethernet virtual connections. Just like today, two characteristics of a regional data center will help determine its performance and value: native onramps to hyperscale cloud providers and extensive interconnection to digital ecosystems.

FIGURE 5: Data center providers will focus on innovations to the legacy operational model, including enabling ever-greater processing horsepower to handle the increased flow of data wireless-wireline convergence will produce.

Centralized Data Centers

Hyperscale data centers will serve as the centralized processing location for web-scale data analysis, efficient sharing of compute resources, storage, and high-intensity compute applications (for example, social media, AI/ML model training and deep learning) and large-scale storage and archiving. Considering the volume of data anticipated, hyperscale data storage will be a significant consideration for users, particularly in regard to data egress fees.

As for location, obviously more hyperscale data centers will be built around the globe as the demand for cloud continues to increase. But that's a discussion for another white paper.

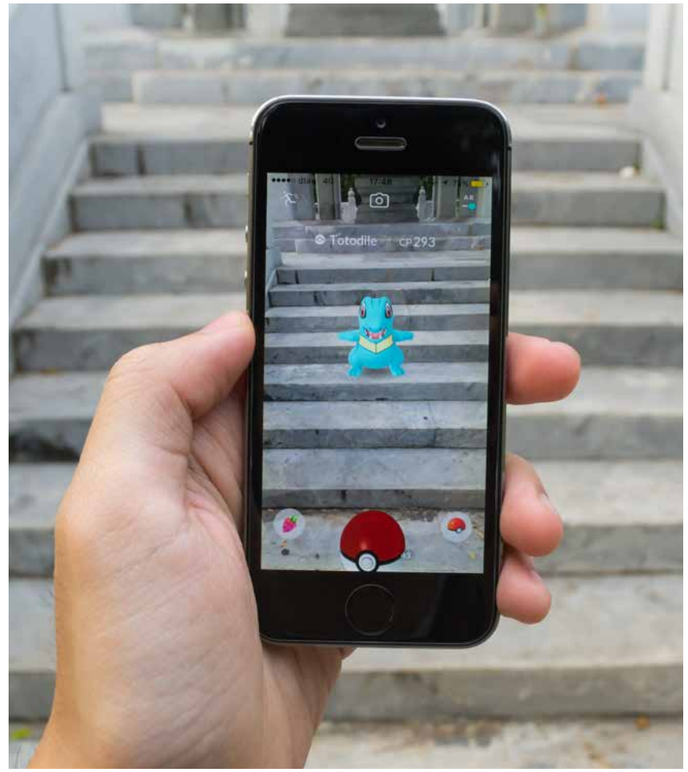
FIGURE 6: Centralized data centers include hyperscale facilities capable of meeting the processing, storage and interconnection as well as cloud services developed for ultra-low latency use cases.

Network Density and Management

Sometimes, in light of the potential for amazing outcomes, we forget that networks and data centers are the wireline core of the digital infrastructure delivering connectivity to the services in the cloud and, ultimately, end users.

Data centers have always been a hub for network interconnection. Convergence escalates the importance of network density and control. The criticality of network diversity is nothing new, but the anticipated strain from 5G-enabled use cases cannot be ignored. A case in point is the augmented reality game Pokémon Go; unanticipated demand caused servers in the U.S. and U.K. to crash on the weekend after the game was released.[8] The lesson is that networks can be overwhelmed, and being caught flat-footed is painful, given enterprises' dependence on connectivity for revenue.

Automation and virtualization of network functionality (NFV) will help data center providers and carriers meet the need for drastically increased network flexibility, sustainability and performance. Integrating AI and ML models into the edge and regional data centers also will help improve and optimize 5G performance management, with intent-based networking solutions added to measure and validate outcomes against business objectives.[9]



Capacity/Data Processing

Data centers already are handling data from multiple clouds. With 5G and future networks, they will need to handle data from a multitude of edge devices as well. On-premises data centers typically aren't built for sustainable, low-latency, high-capacity networks, whereas colocation data centers are – or will be.

The obvious place to start is by upgrading equipment – servers, routers, switches – as well as existing technologies such as NFV and software-defined networking (SDN). Adding in AI, ML and deep learning could help the hardware perform at optimal levels sufficient for 5G (and beyond) processing.

Then, there's the link to cloud resources involved in data processing. Direct cloud access, where available, enables handling data bursts more elegantly and provides complementary, dynamic data processing resources.

175

By 2025, there will be 175 zettabytes of data in the global datasphere.[10]

Energy Consumption

Reducing energy use has become a global and industry priority, in response to sustainability initiatives and rising costs.

There's a paradox in action. On the one hand, the increasing demand for data center services chews up more energy and greater computing capacity generates more heat. On the other hand, traditional data center energy use dropped from 97.6 terawatt hours in 2015 to 50 terawatt hours in 2019; a forecast by Statistica indicated further reduction to 33 terawatt hours by 2021, while hyperscale data centers doubled their energy demand over the same period.[11]

Furthermore, the data center industry has achieved significant reductions in greenhouse gas emissions through its core business model. For example, before the advent of centralized data centers, every enterprise had its own computer room, which required its own power supply, cooling, security and backup power. By moving all that equipment into a purpose-built, highly efficient shared facility, both carbon footprint and costs were reduced.

The same model applies for edge and aggregation data centers. By centralizing the interconnection in network-neutral facilities, the cost of power, equipment and backhaul are markedly reduced.

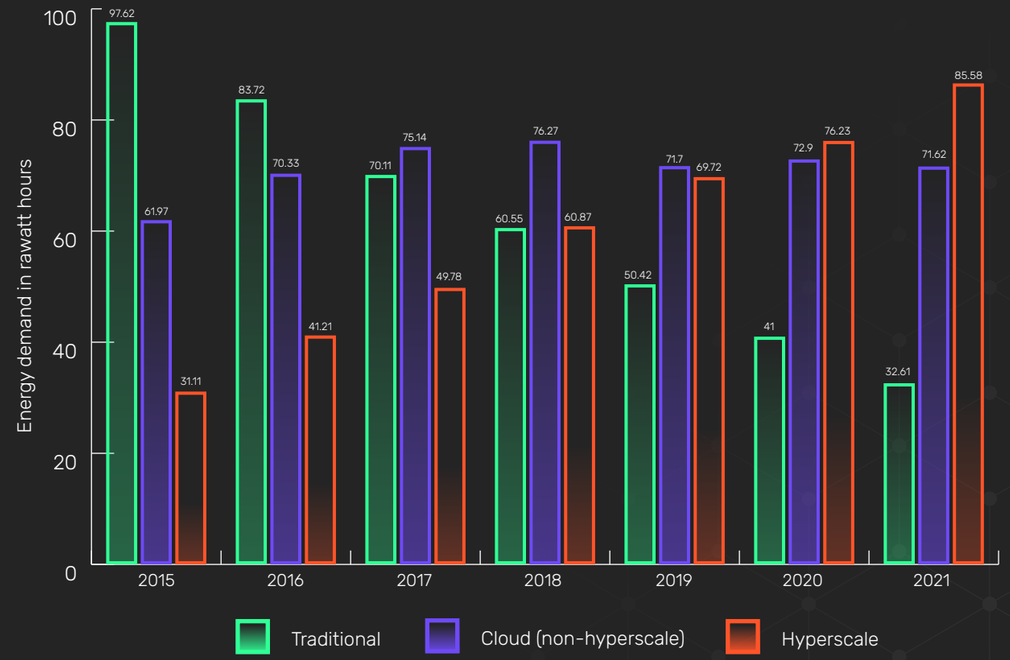


FIGURE 7: Data centers accounted for almost 200 terawatt hours of energy use in 2021. A terawatt is one trillion watts.[11]

> **By centralizing the interconnection for MNOs, carriers and cloud providers in network-neutral facilities, the cost of power, equipment and backhaul are markedly reduced.**

Building Tomorrow's Converged Digital Infrastructure Today

Wireless/wireline convergence is not only about a holistic, intelligent and adaptable multi-access edge computing infrastructure (e.g. MEC): it's also about accelerating enterprise digital transformation and moving from speculation to implementation of technologies that will change commerce, social norms, work and leisure life.

Interconnection between wireline and wireless converged networks will become ever more critical for enabling end-to-end, data distributed networks, with cloud-native data centers at the core and at the edge serving as the backbones and brains for the radio equipment positioned to create coverage, capacity and reliability for the next generation of wireless applications.

Convergence creates billions of interconnections and promises an incredible number of applications. It also creates revenue opportunities for the entire stakeholder ecosystem: MNOs, carriers, service providers and enterprises, in nearly every industry and niche.

How long will the transformation take and what will it cost? It took 10+ years to reach digital transformation's "Big Bang" moment, ironically accelerated by a pandemic. Expect the timeline to be almost as long and the evolution to require hundreds of billions of dollars in investments to realize the full potential of wireless and wireline network convergence.

It will not be easy. Change at this magnitude never is. However, it absolutely is possible, and it is beginning now! CoreSite and American Tower have the knowledge, resources and capabilities to accelerate that change. The combined assets of the companies – CoreSite's data centers, decades of operational experience and unique interconnection platform and American Tower's domestic and international real estate portfolio – establishes a differentiated foundation for accelerating wireline and wireless convergence and building the interconnection fabric of the future.

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CoreSite, an American Tower Corporation subsidiary, provides hybrid IT solutions that empower enterprises, cloud, network, and IT service providers to monetize and future-proof their digital business. Our highly interconnected data center campuses offer a native digital supply chain featuring direct cloud onramps to enable our customers to build customized hybrid IT infrastructure and accelerate digital transformation. For more than 20 years, CoreSite's team of technical experts have partnered with customers to optimize operations, elevate customer experience, dynamically scale, and leverage data to gain competitive edge.