**NETWORK BUSINESS QUARTERLY℠**

# Telecom Edge Compute Market Landscape

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TBR

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# Telecom edge compute taxonomy

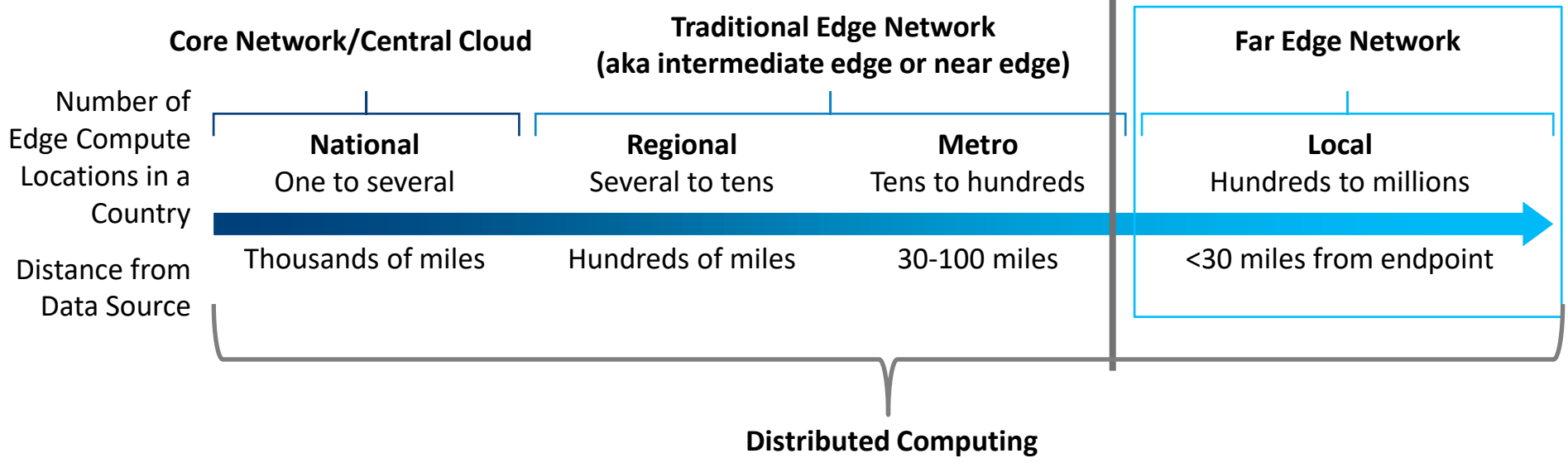
Edge compute environments are essentially data centers that reside in relatively close proximity to a data generation source. Data generation sources could be smartphones, IoT sensors or other devices that connect to a network.

Domains of the network can be understood by their proximity to the data source.

"Local" edge compute environments are typically less than 30 miles from data generation sources and reside next to (on premises) or close to the access layer (or last mile) of the network. Typical locations for local edge compute environments include central offices, headends, cable hubs, baseband hotels, and tower and rooftop sites. Edge locations could also be sited within the premises of a data generation source, such as in stadiums or airports.

**Focus of Research**

Note: The "far edge" is also known as the local edge, new edge, network edge, mobile edge, multi-access edge (MEC) or distributed new edge. All these characterizations refer to the same thing, which is locating mini data centers in closer proximity to data generation sources. On-premises edge is also included.



# Telecom edge compute taxonomy

- TBR's telecom edge compute reports focus on edge compute opportunities specific to the communication service provider (CSP) industry, which includes telecom and cable operators as well as third-party infrastructure owners and cloud service providers (i.e., webscales). Edge compute infrastructure spend by nontelecom verticals is not covered in this report.
- The edge compute market size provided in this report only includes the technology inputs to build an edge environment, which TBR defines as sites being within 30 miles of data generation sources. Infrastructure utilized exclusively for the metro, regional and national domains of the network is not included. On-endpoint device compute is also excluded.
- The edge compute taxonomy includes data center equipment (servers, storage, networking, optical interconnect) as well as services attached to or related to this infrastructure. Close-to-the-box software such as data center infrastructure management software (including operating systems and virtual infrastructure management) as well as related platforms and analytics applications are also included.
- The distance between edge data centers and data sources is contingent on the speed of light and the number of hops the traffic must go through. To get below 10ms of latency in the network, which is the maximum threshold for low-latency services, edge compute resources must be within 30 miles of the data generation source.

CSPs are primarily putting edge resources in the following site types:

- Central offices
- Aggregation hubs
- Cable hubs
- Headends
- Base of cell tower
- Rooftop sites
- Baseband unit (BBU) hotels
- Carrier-neutral facilities
- Enterprise customers' premises
- Commercial real estate locations, such as office buildings, retail locations, stadiums and airports

# Executive Summary

# Webscales will capture the majority of economic value of edge compute

**Nascent trends in the edge computing market should worry telcos**

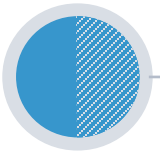
- Webscales have various initiatives underway that will disrupt aspects of telcos' business model, posing a direct threat to their connectivity businesses and ability to capitalize on new value created from 5G and edge computing. Webscales' rapidly expanding presence in the edge compute space and keen focus on private cellular networks — particularly in the U.S. — is a prime example of this trend.
- Though webscales are posturing like they want to partner with telcos on new opportunities, edge compute partnerships involving a webscale and telco to date are more exploitative than cooperative in nature. Arguably, the highest profile agreement to date is between Amazon Web Services (AWS) and Verizon, and while Verizon has touted the monetization opportunities, it is providing little more than site access and network connectivity, while AWS' intelligent edge capabilities provide the bulk of the customer value. In this relationship, AWS doles out a cut of the revenue to Verizon while holding on to the customer relationship and most of the value that emanates from the use of its platform.
- The end-state of this competitive dynamic will see telcos capturing even less value as they increasingly offload towers and other sites to towercos and data center real estate investment trusts (REITs), and as webscales own greater portions of the network.

**Webscales and data center players invest in India to capitalize on the nascent digitalization opportunity**

- India has become the epicenter of webscales' focus and investment among emerging markets due to the country's large population and growth prospects. Alphabet, Amazon, Microsoft and Facebook are all investing billions of dollars in equity stakes, infrastructure build-out, applications and platforms customized to meet the needs of the Indian market, and setting up business model structures. Reliance Jio, Bharti Airtel and Vodafone Idea are partnering with these webscales on various projects to realize this digitalization opportunity in India.
- TBR expects infrastructure build-outs will include a substantial edge compute presence as webscales leverage telco-owned sites and the telcos' relationships with towercos, such as the soon-to-be combined Indus Towers and Bharti Infratel, to site mini data centers in strategic locations. The vast geographic area of India would be cost-prohibitive for webscales to build out edge compute environments without the aid of incumbents. India's government is more focused on promoting India-based companies for its digital infrastructure evolution and is likely to require U.S.-based webscales to involve incumbents telcos in the edge compute value chain.
- Equinix is also expanding its presence in India by acquiring GPX India, which operates two data centers in Mumbai, for $161 million. The facilities offer access to Amazon Direct Connect, Google Cloud Dedicated Interconnect and Oracle Cloud Infrastructure FastConnect. The acquisition is expected to close in 1Q21.

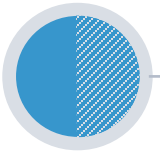
 

# Most initial edge compute deployments will support network transformation initiatives as telcos await commercialization of new use cases



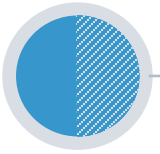
**Edge compute is playing a central role in supporting telcos in their transition to becoming DSPs**

- Edge compute is playing a central role in supporting CSPs as they transition into digital service providers (DSPs) that require dynamic network architecture, which can operate autonomously on a large scale while supporting a broad range of use cases. CSPs ultimately seek to transition to fully virtualized, cloudified and autonomous networks, an aspect of which requires edge computing.
- Telcos are justifying edge compute investment due to the cost savings and greater network agility resulting from the investments as well as the new consumer and commercial revenue opportunities provided by edge compute that will develop over the long-term. Many 5G use cases, including autonomous transportation, remote surgery, VR gaming and manufacturing automation will require computing resources at the edge of the network to reduce latencies and provide optimal experience.



**The pandemic is spurring digital transformation initiatives, many of which require edge compute capabilities**

- After weathering the first phase of the pandemic in 2020 relatively well, telcos will enter 2021 facing a new landscape and many tough decisions. The pandemic is forcing economies and societies to fully embrace digital transformation as they adjust to the new normal, and it is forcing telcos to examine their operational, business and growth models, and to adjust and accelerate their digital transformation road maps accordingly.
- Telcos have significant opportunity to leverage their edge computing capabilities to enhance use cases arising from the pandemic such as the shift to remote work and learning environments as well as increased adoption of Over-the-top (OTT) video streaming, cloud-based gaming and telehealth platforms. The pandemic will also spur development of use cases requiring edge compute in areas such as surveillance, drones, cloud robotics, blockchain and AR/VR to address social distancing and sanitation concerns and prepare for future pandemics.

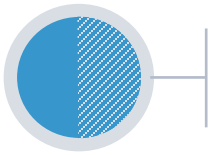


**Private cellular network adoption will advance edge compute implementation**

- 5G can and should be viewed by enterprises as a futureproof platform that can be leveraged to support any use case that requires connectivity. Pairing 5G with edge computing provides clients with a workload-agnostic platform they can adapt to meet business needs. This platform flexibility can greatly improve the business case and provide justification to pay a premium up-front to adopt a 5G-centric system for enterprise digitalization.
- CSPs will have significant opportunity to cross-sell edge compute solutions as private cellular network adoption will accelerate through this decade, especially within verticals including manufacturing, transportation and logistics, and utilities as clients seek to enhance security, optimize costs and support ultra-low latency use cases.

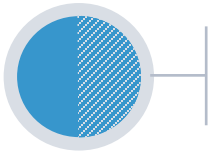
 

# SIOs move more aggressively to leverage their assets for edge computing



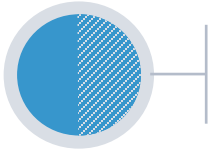
**Tower companies will increasingly site edge compute environments at the base of their towers**

- TBR expects tower companies, such as American Tower, Crown Castle and SBA Communications to involve themselves to a greater extent in edge compute build-outs. American Tower recently launched its American Tower Edge Data Center Initiative and deployed edge data centers in six cities, leveraging the connectivity and power resources present at its cell sites to offer enterprises edge compute resources. The company has not leveraged the assets of its tower tenants for these builds, though it plans to do so in the future.
- While American Tower's initiative is arguably the most aggressive to date of the large towercos, SBA Communications provides its SBA Edge platform and Crown Castle invested in Vapor IO, which is building out its Kinetic Edge platform including in some Crown Castle locations.
- TBR expects towercos globally to site mini data centers across their locations where it is economically feasible, which makes expanding their footprints a high priority. To that end, in November American Tower agreed to acquire InSite Wireless, and additional market consolidation is inevitable.



**The SIO competitive landscape is broadening to include retailers and the USPS**

- Walmart and Walgreens Boots Alliance reached agreements with Verizon in 2020 to enable 5G services at their locations. TBR expects both retailers' stores to become edge compute sites, though neither agreement explicitly states this will occur.
- The United States Postal Service (USPS) is also exploring leasing out space at its 31,000 facilities sprawled across the U.S. to site edge compute and other connectivity equipment, providing the entity with a vital new revenue stream. These sites are often in highly strategic and densely populated locations, as well as in underserved rural markets.



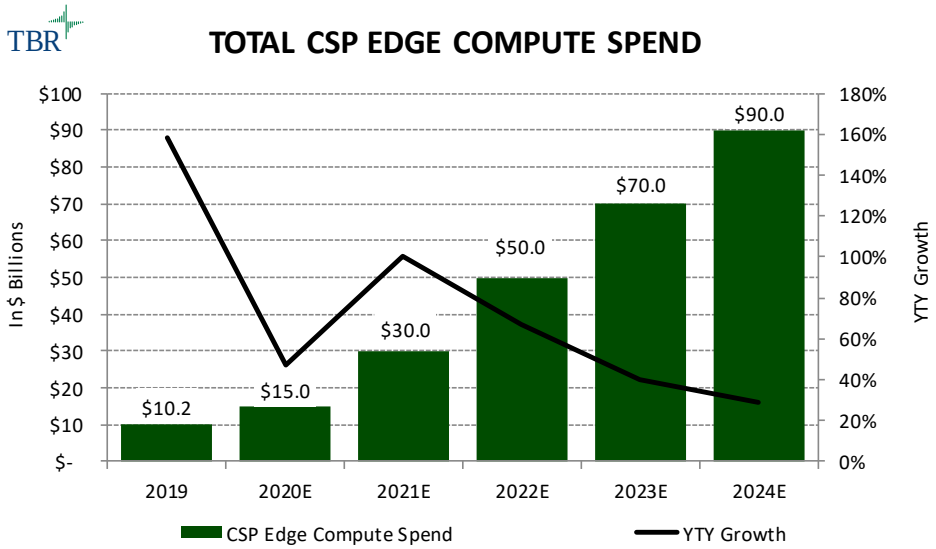
**Sub-tier-1 colocation vendors acquire larger footprints**

- Smaller colocation vendors are establishing themselves with assets in second-tier markets where CSPs, webscales and other colocation vendors such as Equinix may not have a presence. Most recently, 365 Data Centers acquired Atlantic Metro Communications in November and DartPoints acquired Metro Data Centers in December. These colocation firms intend to offer partners edge compute resources.
- Government funding will play an important role in expanding connectivity to underserved communities throughout the country and firms investing in these markets early will be able to capitalize on these investments. TBR believes smaller shared infrastructure owners (SIOs) will focus on niche opportunities, such as those in rural areas where they can access government funds and face limited competition from larger players.

# Market Dynamics

# Webscale investment and operator transformation will drive CSP spend on edge compute infrastructure; market will reach $90B by 2024




SOURCE: TBR ESTIMATES

**Spend Assumptions:**

Spend includes capex and external opex from telecom and cable operators as well as webscales on edge compute infrastructure.

CSPs must procure the edge infrastructure for it to be included in the market size.

Edge compute infrastructure that is procured by non-CSPs is excluded from the market size.

Note: For more information pertaining to the market size and for further breakouts of the data, see TBR's *Telecom Edge Compute Market Forecast.*

**Key Edge Compute Market Growth Drivers**

- vRAN deployments
- Enterprise digital transformation (Industry 4.0)
- Private cellular network adoption
- China's aggressive 5G initiative
- Webscale investment
- Government stimulus for ICT development
- Ability to repurpose existing site grid
- Maturation of white-box, open-based hardware

**Key Edge Compute Market Growth Detractors**

- Complexity of new technology
- 3GPP standards delays (especially Release 17)
- Geopolitical encumbrances
- Government regulatory roadblocks
- Supply chain constraints
- Skilled resource shortages
- COVID-19 impact (economic)
- CSP restructurings and consolidation

# CSPs are growing their partner ecosystems to support edge compute use cases across global markets

**Americas**

- Verizon is growing its partner ecosystem to more effectively support private and public MEC use cases. For instance, AWS Wavelength at Verizon's 5G Edge deployments, which will reach 10 markets by the end of 2020, can support public edge compute use cases across a wide area. Conversely, Verizon is leveraging Microsoft Azure's cloud and edge capabilities to support on-site private 5G environments.
- Edge compute is a central focus of Lumen's Industry 4.0 strategy and the company is benefiting from its vast existing real estate assets, including thousands of central offices. Lumen has already deployed 100 edge compute nodes across the U.S as of December, enabling the company to provide latency of 5 milliseconds or less to 95% of enterprises in the country.
- Canada- and CALA-based CSPs will be laggards in edge compute; CSPs in these countries are likely going to wait for new business models to mature before investing at scale.

**EMEA**

- Vodafone will launch commercial 5G MEC services based on AWS Wavelength beginning in spring 2021 in London, which will be followed by additional markets in the U.K. and Germany. Companies have begun piloting the service, including counter-drone technology company Dedrone, video analytics company Digital Barriers and streaming application company Groopview.
- BT is exploring next-generation edge compute use cases, including recently demonstrating technologies such as a 5G connected ambulance as well as the Edge-XR project, which combines edge compute with enhanced GPU capabilities to support new services such as volumetric video. BT is also exploring other edge compute use cases in areas including holographic communication, smart agriculture and entertainment, and telehealth solutions such as remote diagnostics and surgery.

**APAC**

- Telstra is collaborating with Ericsson to develop an enterprise edge cloud solution that will support use cases for Australian businesses in areas including agriculture, industrial IoT and smart cities. The development follows Telstra and Ericsson collaborating with the Commonwealth Bank of Australia beginning in 2019 to test 5G edge compute use cases designed for the financial sector.
- China has begun large-scale edge compute deployments to support government initiatives, particularly as it pertains to visual-intelligence-related use cases and the social credit system.

# CSPs in developed markets will realize the promise of edge computing in Industry 4.0 use cases sooner than previously expected

## Phases of Telecom Edge Compute Market Development

| CDN Era (2000-2015) | Network Virtualization Era (2015-2023) | Industry 4.0 Realization (2023-2030) |
|---|---|---|
| • Edge compute build-out commenced to help CSPs improve video quality of service (QoS) and optimize data traffic.<br>• Content delivery networks (CDNs) were primarily built in regional and metro sites.<br>• Akamai and Limelight were among the pioneering companies in the CDN market, and they have strategic relationships with leading CSPs worldwide to optimize the video traffic flowing through their networks.<br>• The CDN market became highly fragmented in the 2010s as the mobile internet took off and as webscales such as Amazon and Netflix entered the fray. | • Cost optimization of the network (via bandwidth offload and virtualization) as well as CDN and security compliance are the primary initial use cases for edge compute infrastructure.<br>• Leading CSPs target overhauling existing infrastructure sites, particularly central offices, into data centers (aka CORD) as part of their NFV/SDN initiatives.<br>• AT&T pioneers initial CORD overhaul as part of its Domain 2.0 initiative, starting in 2015.<br>• vRAN begins to drive the proliferation of edge compute sites, starting with Rakuten in Japan in 2019. Other CSPs are expected to follow as vRAN technology matures. Open vRAN will expand CSP choice and lead to broader adoption.<br>• 5G drives CSPs to accelerate and broaden the scope of their network transformations, which requires the build-out of edge sites.<br>• Pandemic-induced remote work and school drives heightened demand for edge computing.<br>• CSPs begin to derive new revenue from edge compute use cases that require low latency in the early 2020s. | • 5G standalone, which supports network slicing, will be widely deployed in developed markets, enabling large-scale use of edge compute for Industry 4.0 use cases.<br>• New business models that will require the low latency provided by edge compute will become mainstream.<br>• Many industries, especially manufacturing, transportation and logistics, will be revolutionized by edge compute, and TBR believes CSPs will play a key role by partnering with stakeholders in those industries to realize new value creation from the 5G era. |

# CSPs must weigh drivers and inhibitors for their edge compute strategies, but delaying investment will place late adopters at a disadvantage

## Drivers

- Data traffic optimization
- New use cases of the network, particularly low latency/real-time requirements for mission-critical workloads
- Enable real-time, artificially intelligent communications
- IoT proliferation
- OTT video streaming/content caching
- Enables CSPs to adapt to market needs, creating greater network resiliency, agility and availability to ensure optimal QoS
- Data privacy and data sovereignty requirements
- Lower TCO (e.g., open-source movement and Open Compute Project, which dramatically reduce the cost of ICT infrastructure)
- Cost savings from the virtualization and cloudification of networks
- Improved network reliability/uptime
- Real estate footprint monetization

## Inhibitors

- Build/own versus rent dilemma
- Real estate costs for greenfield sites
- Real estate redevelopment costs for brownfield sites
- Lack of suitable and available sites
- Telcos need for legacy infrastructure decommissioning to free up space in their existing facilities
- Maintaining edge infrastructure with field resources
- Lack of new, monetizable use cases with attractive ROI characteristics
- Security concerns
- Outdated telecom industry regulations
- Power limitations
- Skill set limitations
- Time and cost to scale

# Advanced edge compute capabilities will enable CSPs to support ultra-low latency use cases in areas such as AR/VR and autonomous vehicles

## Telecom Edge Compute Use Cases

**Bandwidth optimization (traffic offload)**
Edge compute enables CSPs to optimize their data transport costs, particularly when data flows need to be looped through central data centers.

**Network virtualization (esp. vRAN)**
NFV requires NFVI (i.e., data center equipment) to house virtual network functions (VNFs). vRAN is a key domain to virtualize because it promises significant benefits, such as agility and cost savings, to CSPs as RAN has historically been the costliest component of building a network.

**CDN**
Caching content closer to end users via edge sites is a major, proven application for edge computing. Most CDNs today are in regional or metro centers, but over time content will have to move closer to endpoints to meet customer experience KPIs, especially for uses such as cloud gaming.


**Immersive experiences (AR/VR)**
AR and VR will be leveraged to create immersive experiences in areas such as gaming, employee training, education and telehealth and for military purposes. Edge computing is vital to support advanced AR/VR use cases to achieve a latency level that supports a sellable QoS.

**Autonomous and Connected Vehicles**
MEC, in combination with 5G, will be essential in supporting autonomous and connected vehicle technologies such as Cellular-Vehicle-to-Everything (C-V2X).

**Visual intelligence (aka computer vision)**
Leveraging high-resolution video cameras and analytics for public safety-related uses such as real-time facial recognition and criminal activity detection, as well as for uses such as thermal imaging, product inspection and quality assurance, could increase safety and improve product outcomes. The high-resolution, low-latency requirements of visual intelligence necessitate the use of edge computing.

# LF Edge's projects attract significant attention in the edge ecosystem; telco collaboration demonstrates their wariness of webscale competition

**Key Edge Compute-related Consortiums**

5G Future Forum

LF Edge (part of the Linux Foundation, sponsors Akraino Edge Stack, EdgeX Foundry, Open Glossary of Edge Computing, and other edge compute-related projects)

KubeEdge

Open Compute Project (OCP)

Open19 Foundation

ONF (sponsors CORD)

OpenShift

Telco Edge Cloud Platform

Telecom Infra Project (TIP)

Note: Consortium list is not comprehensive.

- Industry consortiums are spearheading open infrastructure initiatives, a key feature of which includes creating standardized, modularized and low-cost (commoditized) hardware that is optimized to be used in data center and network environments.
- LF Edge and OCP are the primary open infrastructure consortiums focused on edge computing, each of which are umbrella organizations that support multiple projects. LF Edge's EdgeX Foundry, which aims to create an interoperable framework for IoT-related edge computing, announced its Hanoi release in December. In addition to new capabilities such as data tagging and better scalability testing, the Hanoi release includes capabilities for exporting data from EdgeX to Fledge, an industrial IoT-related project under LF Edge. This follows EdgeX's collaborations with other LF Edge projects such as Akraino, EVE and Open Horizon, which together will increase the value proposition of their open source and containerized offerings and help bring new partners to the projects. TBR expects that EdgeX's creators and contributors will collaborate with members of the LF Edge project KubeEdge, which established integrations with Akraino in 2Q20. This would better enable EdgeX users to run their containerized IoT workloads at the edge in Kubernetes and Docker environments.
- The 5G Future Forum — a consortium formed by América Móvil, KT, Rogers, Telstra, Verizon and Vodafone to create 5G- and MEC-related interoperability standards — released its first technical specifications to members of the consortium in August. This includes the MEC Experience Management and MEC Deployment specifications, which provide intent-based APIs that developers can use to integrate cloud-based workloads with CSPs' edge networks, as well as deployment models, respectively. TBR expects telcos to continue banding together to accelerate deployment and adoption of their edge compute solutions to counterbalance the webscale threat.

# Telecom edge compute services opportunities will benefit a wide range of vendors

| Telecom Edge Compute Infrastructure Domains | |
|---|---|
| **Networking and Data Center Products** | **Infrastructure Services** |
| • vRAN will become a major driver of edge compute scale-outs in this decade. CSPs that are driving forward with vRAN, most notably Rakuten and Dish Network, will build many thousands of edge sites over the next few years to support their vRAN topologies. It is important to note that Rakuten and Dish Network are leveraging open vRAN solutions from disruptive software vendors Altiostar and Mavenir, as well leveraging hardware from resurgent Japan-based OEMs NEC and Fujitsu. These edge sites, which will house the virtualized baseband unit (vBBU), will need to be located within 10 miles of the remote radio unit (RRU) to meet the strict time synchronization requirements of vRAN, and can be multipurposed, supporting more workloads than just RAN traffic to unlock new monetization options for CSPs. Relatedly, optical vendors are preparing for a surge in demand for fronthaul to support vRAN as well as increased backhaul requirements in the metro.<br>• Data center vendors (OEMs and ODMs) are preparing to meet demand for mini data centers that are optimized to operate at the edge of the network. For example, Hewlett Packard Enterprise (HPE) is bringing edge-optimized data center solutions (e.g., Edgeline portfolio) to the market. However, the share of OEMs like HPE and Dell Technologies will be eroded by ODMs' white-box infrastructure, in combination with self-developed software, such as operating systems (and even in some cases hardware) leveraged internally by webscale players. | • Edge computing's increasingly central role in network deployments will drive demand for engineering and site location and construction services, not just for edge compute infrastructure, but also for fiber to support backhaul and fronthaul needs. Additionally, the conversion of existing telecom sites into edge compute environments will be a key driver of network planning, design and integration work.<br>• Webscales lack field resources to implement and support their edge infrastructure environments, which will compel them to rely on partners that have field resources to deploy their edge infrastructure, creating significant opportunities for companies that have expertise with data center installations. This field work could be provided by or overseen by an OEM (e.g., Ericsson, Nokia, Huawei), IT firm (e.g., IBM, Tech Mahindra), or OSP/ISP (e.g., China Communication Services, Dycom, Mastec), or by an SIO, telco or cableco, that would then likely subcontract to an OEM, IT firm or OSP/ISP.<br>• TBR expects CSPs will increasingly rely on vendors for edge managed services so CSPs can optimize their businesses and focus on their core competencies. |

# White-box hardware is being legitimized by webscales and leading telcos before more widespread deployment in other CSPs' networks

| ICT Hardware Continuum | | | | |
|---|---|---|---|---|
| **Black Box** | **Gray Box** | **Brite Box** | **White Box** | **Bare Metal** |
| Proprietary platform (fully integrated hardware/software) | May still include some integration between proprietary hardware/software | OEM-branded white box | Standard hardware paired with third-party OS | Industry-standard hardware platform |

- Higher cost
- Less open
- Proprietary-centric

- Lower cost
- More open
- Standards-based

Current Market → Future Market

SOURCE: TBR

- Network functions that have traditionally run on purpose-built network appliances will increasingly shift to x86- or ARM-based data center hardware, which will house and provision VNFs. CSPs will increasingly procure white-box ICT gear directly from ODMs, as TBR's research suggests ODM gear is up to 50% less costly than OEM gear and is also lower in TCO. With webscales first showing the way, AT&T, Verizon, Telefonica and Vodafone are key telcos leading the charge toward white boxes. Other telcos and cablecos are expected to follow suit as the market for white boxes matures. At the edge, CSPs — primarily webscales — will push their custom-engineered white boxes (e.g., AWS Outposts or Google Anthos) on their customers, rather than providing higher-cost OEM hardware.
- Though white-box adoption is gaining momentum, early implementations have faced technological hurdles, including interoperability and performance issues that are preventing optimal functionality. Industry initiatives such as OCP and TIP, as well as the DANOS operating system framework, aim to address the challenges of using white boxes and drive mainstream adoption of the approach across the ecosystem.

# Landscape by Stakeholder Type

# Connected vehicles are emerging as a key edge compute use case for telcos as ultra-low latency is vital in ensuring passenger safety

**Key Telecom Operators**

AT&T
BT
China Mobile
China Telecom
China Unicom
Deutsche Telekom (DT)
Dish Network
KT
KDDI
LG U+
Lumen
NTT
Orange
Reliance Jio
SK Telecom
Singtel
SoftBank
T-Mobile
Telefonica
Telstra
Telus
Telecom Italia
TIM Brazil
Verizon
Vodafone

Note: Company list is not comprehensive.

- Tier 1 telcos in developed countries will be early adopters of edge compute over the next few years, followed by emerging market operators.
- Telcos will invest heavily in edge compute environments, initially to support NFV/SDN-related initiatives such as vRAN, but then increasingly to support 5G use cases such as cloud gaming and connected vehicle technologies such as C-V2X and V2X. TBR anticipates supporting autonomous and connected vehicle technologies will become a prominent edge compute use case over the next decade as ultra-low latency is vital to ensure road hazards and other conditions are updated in real time. Verizon has begun making headway in this segment, announcing in November that LG, Renovo and Savari have begun testing connected car services on Verizon's MEC platform.
- Telcos have begun pursuing roaming agreements to enable MEC services to be accessed by customers traveling abroad. For instance, in December Telefonica, KT and China Unicom announced a global MEC roaming agreement supported by technology provided by Altran (Capgemini) and China Unicom's R&D unit.
- Innovation labs will play a vital role in developing edge computing use cases as operators collaborate with academic institutions and leverage research centers such as AT&T's Foundry centers, Verizon's 5G Labs and T-Mobile's 5G Open Innovation Lab. New members joined the 5G Open Innovation Lab in September including Microsoft, Amdocs, Dell Technologies and VMware.

# The cost savings arising from network transformations are a primary driver of cablecos investing in edge infrastructure

**Key Cable Operators**
Altice
Charter Communications
China Broadcasting Network
Comcast
Cox Communications
Liberty Global

- Cablecos will initially focus on converting their headends and cable hubs into mini data centers to house their virtualized converged cable access platform (vCCAP) and virtualized distributed access architecture (vDAA) functions to derive cost savings and other benefits. Building out the edge closer to customers will also give cablecos the opportunity to provide residential and enterprise services with reduced latency.
- Compared to telcos and webscales, cablecos will be relative laggards in edge compute investment through the early 2020s but will gradually catch up as the technology and business models mature over time. Comcast has invested the most aggressively in network transformation among cablecos thus far, a trend that is expected to continue. A significant portion of Comcast's spend is related to uCPE, vCCAP and vDAA, which implicates the operator's aggregation hub sites and requires the use of data center infrastructure in those sites.
- Edge compute is a key growth pillar for Cox Communications due to the enhanced network performance and security enabled by edge compute as well as the opportunity it provides to offer new residential and enterprise services. Cox's initiatives will be aided by its investment in edge startup StackPath, which offers solutions in areas including virtual machines, containers, CDN and web application firewalls.
- China Broadcasting Network will become a major investor in edge compute over the next several years as it aligns with government initiatives and follows the incumbent China-based telcos into new revenue-generating areas.

Note: Company list is not comprehensive.

# Webscales will focus more of their capex on edge data center builds to capture economic value associated with new network use cases

**Key Webscales**
Alibaba
Alphabet (Google)
Amazon
Apple
Baidu
Facebook
Microsoft
Rakuten
Tencent

- All the world's largest webscales (the "Big 9," listed to the left) are investing in the edge in some way, ranging from edge-optimized infrastructure (e.g., AWS Outposts) to edge-related devices (AR/VR head gear) to low-latency applications (i.e., cloud gaming, autonomous vehicles), all with the intention to build out their digital ecosystems.
- Webscales will pivot from centralized data center to edge build-outs to achieve the latency and quality of service that new use cases of the network will require. TBR believes the world's largest webscales will extend their cloud footprints closer to endpoints in the early 2020s, shifting webscale capex from central cloud to edge cloud over the next decade. These companies will drive significant innovation in the edge space, contributing design references, technology standards and best practices to facilitate ecosystem development.
- Webscales have been experimenting with ways to make it economically feasible to deploy distributed edge network resources at scale. The commercial model will likely see webscales partner with ecosystem stakeholders, such as tower companies and data center REITs, to offset the financial burden of deploying, owning and operating edge compute environments. For example, a webscale could partner with tower companies to site edge data centers at cell sites and plug directly into the access and backhaul network. Models such as this help defray the cost and complexity of building and managing many sites. Telco sites, such as central offices and aggregation hubs, are logical locations to put edge compute resources because these facilities are often strategically located, owned and controlled by the operator, have access to power and cooling, have fiber readily available, offer secure access and are ruggedized.
- Amazon has been aggressive in buying distressed commercial real estate during the pandemic, but other companies are expected to ramp up their investments as new opportunities surface when businesses, particularly brick-and-mortar retailers, downsize, go bankrupt, or shift their stances from in-office work to a more permanent or hybrid remote work policy.

# Partnering with edge compute service providers provides SIOs with a new revenue stream for the existing sites; Walmart and USPS see the potential

**Key Shared Infrastructure Owners**

21Vianet
365 Data Centers
American Tower
Ardian
Arqiva
Brookfield Infrastructure Partners
Cellnex
China Tower
Cologix
CoreSite Realty
Crown Castle
CyrusOne
Cyxtera
DataBank
Digital Realty
EdgeCore
Equinix
Evoque Data Center Solutions
ExteNet Systems
Flexential
Freshwave Group
Indus Towers
Markley
Newbridge Wireless
Phoenix Tower International
PT Dayamitra Telekomunikasi
QTS Realty Trust
SBA Communications
Telxius
Teraco Data Environments
TierPoint
Tillman Infrastructure
Vantage Data Centers
Vantage Towers
Vertical Bridge
vXchnge

Note: Company list is not comprehensive.

- Tower operators, data center colocation providers and other network infrastructure owners are transitioning into the edge compute space to enhance their core businesses and drive their next stage of growth. In many cases, these companies can leverage their existing assets (e.g., land and facilities) to place edge compute infrastructure.
- New entrants with little background in networking recognize the potential to monetize their assets by contracting with edge compute companies to site mini data centers at their locations. Entities exploring this model include retailers, notably Walmart, and the USPS.
- Tower operators are well positioned to benefit from vRAN implementations, whereby the BBU is virtualized and housed in a server — an edge site — near the radio site, which could be a traditional tower site or a rooftop site. vRAN will compel CSPs to build edge sites at the base of cell towers or at aggregation hubs in the access layer of the network. vRAN requires edge compute resources to be within 10 miles of the RRU to get the latency to 200 microseconds, which is the maximum threshold allowed to support vRAN traffic.
- Meanwhile, data center REITs are well positioned to benefit from opportunities that arise when CSPs want to rent space in colocation facilities to extend their cloud footprint.
- Strategically located office and retail real estate is being purchased or leased by SIOs (as well as webscales) inexpensively compared to pre-pandemic valuations. These companies intend to convert most of these locations into edge computing sites. This practice will be widely adopted as COVID-19 fundamentally reshapes the economic landscape and accelerates digitalization. In many cases, these freed-up real estate sites are in ideal locations, close to power and population centers and, in some cases, fiber.

# Dedicated edge portfolios, CSP collaboration and services can help OEMs fend off ODMs in the short term

**Key OEMs**
Arista
Ciena
Cisco
Dell Technologies
Fujitsu
H3C
Hitachi Vantara
HPE
Huawei
IBM
Juniper
Kaminario
Lenovo
NEC
NetApp
Nokia
Oracle
Pure Storage
ZTE

Note: Company list is not comprehensive.

- Leading OEMs are investing in dedicated resources to capitalize on the edge opportunity, which is increasingly viewed as adjacent to but different from selling infrastructure for central cloud. Investments span edge-optimized hardware to edge applications and edge security software. Though TBR believes there will be a robust market for these products and solutions in enterprise environments (not owned by the CSP), most CSPs, especially webscales, will deploy lower-cost white-box hardware from ODMs and integrate their own software platforms in edge environments.
- OEMs are responding to the ODM threat by participating in open-source initiatives and coming to market with gray boxes, which are a hybrid between proprietary black boxes and commodity white boxes. Among incumbent RAN players, Samsung and Nokia have shown the most willingness to self-disrupt, giving them an advantage over Ericsson and Huawei. Still, the market will shift to ODMs during this decade as they provide the most customization at the lowest price. Open specs provided by consortiums, such as OCP, will enable ODMs to threaten the market share of incumbent OEMs.
- Leading OEMs have purpose-built edge infrastructure that is optimized for edge environments and able to be produced at profitable price points. This can be seen with Nokia's AirFrame and HPE's Edgeline product lines. Leading OEMs are also partnering with CSPs and other vendors to complement their portfolios and resources and drive edge opportunities forward. Key initiatives include innovating with CSPs in labs to test new edge infrastructure and business models.
- An advantage OEMs have over ODMs is that some CSPs will want services attached to the equipment they procure, which ODMs do not provide, especially as increasing complexity forces CSPs to rely more on vendors to support edge initiatives. However, many CSPs will look to vendor-agnostic IT services firms for this. Accenture aims to capitalize on this market via a three-year, $3 billion investment in the Accenture Cloud First group, which will in part focus on edge compute opportunities.
- Optical vendors have avoided significant disruption by ODMs largely because of the need for programmable, adaptable transport technologies in distributed networks that can, to date, only be satisfied by proprietary technology. OEMs such as Ciena and Nokia will capitalize on the needs placed on the transport grid to support edge computing. These vendors have come to market with anyhaul or xHaul portfolios to help CSP networks dynamically align with traffic demand in real time, which is key to cost-effectively supporting the low-latency requirements of edge use cases.

# ODMs will overcome their lack of product-attached services offerings and the complexity of open networking as the ecosystem matures

**Key ODMs**

Accton (owns Edgecore)
Adlink
Advantech
AppliedMicro
Celestica
Compal Electronics
Cumulus
Delta Electronics
Flex
Foxconn
Geniatech
Hyve Solutions
Inspur
Inventec
Kontron
Lanner
MiTAC
Pegatron
Penguin Computing
Quanta Cloud Technology (QCT)
Supermicro
Wistron
Wiwynn
ZT Systems

Note: Company list is not comprehensive.

- The largest telcos and cablecos will follow webscales' lead and increasingly procure white-box ICT gear directly from ODMs. White boxes are becoming a key feature of leading CSPs' road maps as ODM gear is significantly less expensive than OEM gear (30% to 50% lower on average). The edge infrastructure market is especially price-sensitive due to the differing economics between edge sites and central data centers.
- Leading ODMs are transforming into more sophisticated entities, and some are starting to resemble OEMs in go-to-market and sales and support structures. This evolution of ODMs into more "Westernized" businesses will enable them to continue penetrating new accounts and expand internationally. Despite these advancements, ODMs remain disadvantaged in offering CSPs the services wrapper around their open infrastructure. While CSPs aim to obtain the same or similar performance characteristics at lower cost to black boxes using white boxes, they are struggling to support white boxes because they do not come with product-attached services, such as maintenance, from ODMs.
- Another hindrance to CSP adoption of open infrastructure is the complexity and lack of robustness and maturity of the source code. CSPs aim to leverage open infrastructure because it promises to reduce vendor lock-in and be lower cost compared to traditional proprietary solutions, but the complexity can be cost-prohibitive. However, TBR expects this problem to abate as the ecosystem matures and SIs and software firms bring more automated solutions to market.
- ODMs are predominantly based in Taiwan and China, though there are exceptions. Supply chain and trust concerns toward China among the U.S. and its allies will put more emphasis on Taiwan-based ODMs to provide edge compute infrastructure to developed countries, but the ultimate market impact remains unclear.
- Supermicro stands to benefit as one of the few U.S.-based ODMs. It is armed with a portfolio that includes centralized and distributed unit hardware for open RAN implementations, as well as edge compute server hardware, all of which will be in demand as telco 5G networks proliferate.

# Software-centric startups will drive lower-cost edge compute deployments

**Key Startups**

Acromove
AlefEdge
Arrcus
Axellio
BASELAYER
Cartesian
Cato Networks
ClearBlade
Compass Datacenters
DartPoints
DediPath
Digital Bridge
EdgeConneX
EdgeInfra
Edge Intelligence
EdgeMicro
EdgePresence
Edgeworx
Eurotech
Fastly
FogHorn
German Edge Cloud
Hangar
Immersion Edge
MetroEdge
Mimik
MobiledgeX
Mutable
Nearby Computing
Ori
Pensando
Pluribus Networks
RackN
Rafay Systems
Rigado
Saguna Networks
ScaleMatrix
Section
SiMa.ai
SixSQ
StackPath
Swim.AI
Vapor IO
Zededa
ZephyrTel
Zellabox

- Startups are generally software-centric, focusing on leveraging automation to make edge environments more economically feasible to deploy, maintain and operate remotely at scale, with minimal to no on-site labor required.
- Vapor IO's Vapor Chamber system uses cylindrical enclosures instead of rectangles. This revolutionary approach to how data centers are architected promises significant cost savings compared to the rows of cabinets found in traditional data centers. Vapor IO has gained considerable mindshare among SIOs. The company has a strategic partnership with Crown Castle in which both companies are exploring how to commercialize new edge technologies and drive new business models, and Vapor IO has a partnership with Digital Realty in which the two companies integrated Digital Realty's PlatformDIGITAL and Vapor IO's Kinetic Edge platform. The combined solution has launched in three cities.
- Arrcus will play a role in MANO for edge environments. Arrcus' ArcOS is a Linux-based, hardware-agnostic network operating system that can operate white boxes at scale — a key need in the industry.
- AlefEdge partnered with IaaS provider DediPath to expand its reach in U.S.-based 5G markets in October. AlefEdge integrated its Software Defined Mobile Edge Platform with DediPath's infrastructure and the partners will jointly target customers with LTE, CBRS, Wi-Fi and 5G-enabled private networks.
- Cablecos and telcos recognize the need to expose themselves to disruptive technologies and new business models brought to market by startups to enable them to remain competitive with webscales in the edge compute space, driving these incumbents to invest in new market entrants.
- TBR expects significant M&A activity in the edge startup space over the next decade. In November EQT Infrastructure, an investment organization, completed its acquisition of EdgeConneX. The acquisition expands EQT's data center network and its portfolio of 5G and IoT use cases. EdgeConneX has large regional centers and mini data centers at the far edge of the network in 40 computing facilities in 33 markets in the Americas and Europe.

Note: Company list is not comprehensive.

# Acquisitions and Alliances

# Colocation vendors acquire to expand their footprints, increasing their appeal to CSP customers in the telecom edge compute market

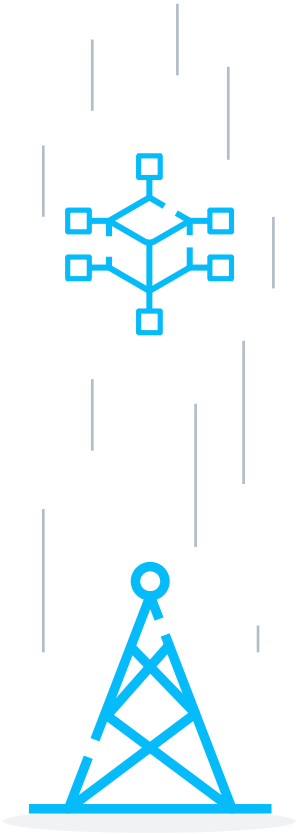
## 365 Data Centers acquires Atlantic Metro Communications

365 Data Centers (365), a colocation and IaaS provider in the northeast U.S., acquired Atlantic Metro Communications in November. The acquired company brings a new data center in Herndon, Va., to 365, as well as 65 network points-of-presence (POP) in the metro areas of Boston, New York, New Jersey, Philadelphia and Virginia, and two partner-owned co-located data centers in northern Virginia and Los Angeles. In addition to doubling its customer base, the data centers and POPs expand 365's geographic reach. TBR expects that 365 will leverage the new sites to expand on its existing relationships with telcos, as well as AWS and Azure.

## Fastly acquires Signal Sciences

Edge cloud platform provider Fastly acquired Signal Sciences in October and will integrate the company's web application and API security offerings with its proprietary security solutions and edge cloud platform. TBR believes Signal Sciences' API Protection solution will help Fastly attract customers that directly integrate their IT environments via APIs, while its broader portfolio will also appeal to customers that run hybrid environments on the cloud, VMs or containers.

**Edge Compute-related Acquisitions**



## Cisco acquires Portshift and Banzai Cloud

Cisco is building out its portfolio around Kubernetes with its October acquisition of Portshift, a cloud vendor with security-oriented solutions for containerized applications, and its planned acquisition of Banzai Cloud, a Hungary-headquartered vendor with technology for Kubernetes-based application development, deployment, runtime and security. The Banzai Cloud acquisition is expected to close in December. Banzai's team will help Cisco with incubation projects related to cloud-based networking, security and distributed applications in edge computing environments. Both the acquired teams will join Cisco's Emerging Technologies and Incubation group.

## DartPoints acquires Metro Data Centers

Edge colocation data center company DartPoints acquired Metro Data Centers and its Dublin, Ohio-based data center in December, building on the vendor's recent activity in the Midwest where it launched an Iowa-based data center in July. DartPoints' strategy focuses on colocation services in underserved markets via metro and edge data centers, positioning the vendor to support CSPs as the U.S. government expands "broadband for all" plans.

# Incumbent telecom operators and historically proprietary-tech-centric vendors collaborate to capture value in key edge compute use cases

## Google Cloud partners with MobiledgeX to simplify app deployment and management

Google Cloud announced over 30 new ISV partners in December as the vendor builds out its ecosystem around Anthos for Telecom. Among these new partners is MobiledgeX, which provides a cloud-based offering that unifies edge resources into a single UI across enterprise- and webscale-owned networks. This interface, alongside its Distributed Matching Engine, will help simplify edge application design, deployment, management and analytics processes for Google Cloud developers.

## Cisco partners with Verizon for large entertainment venue edge use case

In October Cisco expanded on its existing alliance with Verizon, integrating Cisco DNA Spaces, analytics, switching and data center solutions with Verizon's 5G network and 5G Edge offerings to target large entertainment venues. The joint solution leverages Verizon's 5G MEC capabilities with Cisco's Sports and Entertainment portfolio to provide stadiums with real-time venue analytics and crowd management capabilities.

**Edge Compute-related Alliances**

## Lumen and VMware bring compute closer to end users

In September Lumen expanded its partnership with VMware to collaborate in edge computing, networking and security. The companies will focus on enabling data to be processed closer to customer locations to support business applications requiring ultra-low latency. As part of the collaboration, Lumen will integrate VMware SD-WAN by VeloCloud and VMware SASE Platform security architecture to provide a Work from Anywhere solution to support thin-branch applications for businesses of all sizes.

## Samsung and IBM partner to help enterprises with 5G PCN and edge compute analytics

In December, Samsung and IBM expanded their alliance to integrate Samsung's 5G networking solutions and Galaxy devices with IBM's Watson AI, Edge Application Manager and Red Hat OpenShift. This will enable the two companies to provide customers with private 5G network solutions that integrate with IBM and Red Hat's hybrid cloud offerings, which will be particularly attractive for customers that need to upload data from the edge for AI-enabled analytics.

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