451 Research | BLACK & WHITE PAPER

Telco Industry Hopes and Fears

FROM ENERGY COSTS TO EDGE COMPUTING TRANSFORMATION

COMMISSIONED BY

VERTIV™

APRIL 2019

About this paper

A Black & White paper is a study based on primary research survey data that assesses the market dynamics of a key enterprise technology segment through the lens of the "on the ground" experience and opinions of real practitioners – what they are doing, and why they are doing it.

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Introduction

The breathless anticipation for 5G reached a fever pitch at MWC Barcelona 2019 – the annual GSM Association tradeshow – where the halls were dominated by operators touting the latent promise of 5G-enabled experiences for consumers and enterprises. Those same halls hosted a myriad of 5G infrastructure and software vendors highlighting early wins and domain innovations designed to enable operators to make good on their 5G promises. A diverse ecosystem of hardware OEMs from makers of personal and industrial robots to gaming platforms and, of course, smartphones, made their case about how 5G power will be harnessed and consumer and enterprise value and utility unleashed.

After several years of rising expectations, we are now squarely in year one of a decade-long 5G transition for the telecom industry. While it is easy to get wrapped up in the excitement, important questions remain regarding 5G and edge computing, including:

- Business case
- Service and segment focus and timing
- Overall network, IT, and datacenter readiness
- Energy impact of 5G

451 Research and Vertiv set out to answer those questions through the custom research that forms the basis of this paper.

451 Research believes 5G will be the most impactful and difficult network upgrade ever faced by the telecom industry; it is part of the complex 'digital transformation' movement encompassing IT/network convergence and radical changes in how software is created and deployed. Those that can thrive in this period of change will create a new class of telecom operator with value-creation capabilities that far exceed anything we've seen in the past 100 years. Clearly, the brass ring is extra shiny because the long-term target environment will be dynamic, scalable, agile, efficient and programmable.

Executive Summary

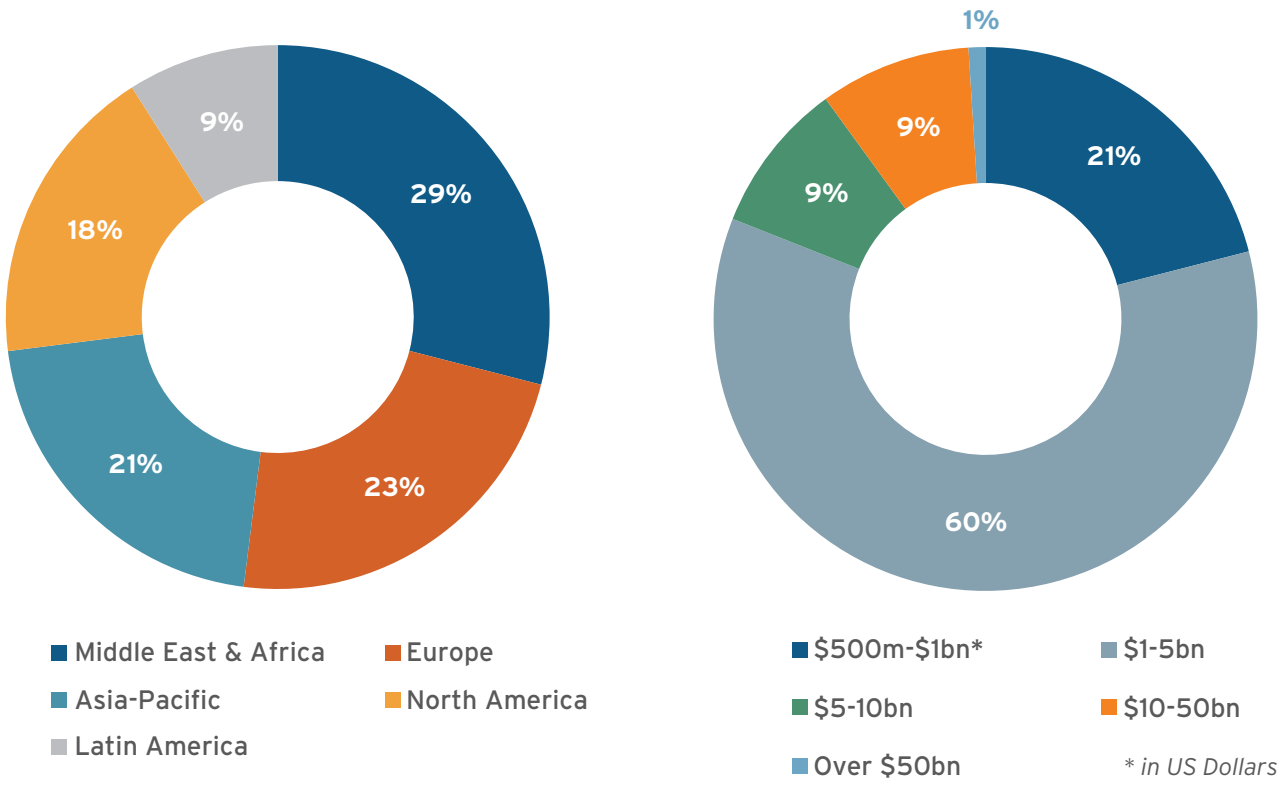
In this Black & White paper, 451 Research seeks to bring fresh insights into how global operators are preparing for the transition to 5G and edge computing. We wanted to hear directly from those charged with implementing 5G about which enabling technologies and services will most affect 5G success over the next decade and beyond while capturing the unique challenges that 5G and edge computing present.

More granularly, this paper assesses site-level concerns surrounding 5G and multi-access edge computing (MEC) deployments. We paid special consideration to the effect on energy use and planned countermeasures given the oversized impact on opex that energy costs represent. From a network operations perspective, we were specifically interested in how 5G/MEC will affect datacenter design, topologies, facilities management, remote operations, connectivity, power, location and operating modalities.

To gain these insights and more, we surveyed 105 global telecom operator tech decision-makers with knowledge and visibility into 5G and edge strategies and deployment plans. The survey was conducted in December 2018 and January 2019. See Figure 1 for geographic and revenue breakdown of respondents.

Figure 1: Survey demographics

Source: 451 Research, custom research commissioned by Vertiv, 2019 (n=105)



Key Findings

The 5G evolution will begin for most in the next couple of years, and telecom providers need to begin to prepare now to maximize their opportunity for success. Across all geographies, telecom providers are ramping up their 5G deployments. Of course, all aren't moving at the same pace, nor are they expressing the same concerns and views on their respective opportunities and overall readiness.

The momentum of telco-driven edge computing crystalizes the notion that telcos see 5G as a way to reestablish a position in the 'cloud to ground' computing and storage value chain beyond what they will require for their internal service operations.

Other key findings:

- **The overwhelming business outlook for respondents is very positive (70%).**
  - *We believe the overall sunny mood is at least partially driven by the promise that 5G and edge computing capabilities will drive service diversity and velocity with a lower-cost platform in response to the insatiable demand for broadband internet services.*
- **5G is widely expected to raise overall energy costs.**
  - *Nearly all (94%) respondents indicated that 5G will raise overall energy costs. Given the prominence of energy as an overall percentage of opex, it's clear that mitigation strategies will be critical to maintain 5G business case viability.*
- **Energy challenges will be addressed with technologies/new risk-sharing models.**
  - *Energy-saving tactics will be varied and address every layer, from intelligent networking equipment that enters sleep mode during idle time to use of artificial intelligence (AI) and new cooling techniques.*
- **5G era starts for most in 2020/21.**
  - *Well over three-quarters (86%) of survey respondents will deliver their first 5G commercial services in 2020 (53%) or 2021 (33%).*
- **Initial 5G services will mostly be 'more of the same.'**
  - *Partially due to the technical limitations of the Release 15 standard and partially due to a lack of innovation, 96% of respondents indicated that 5G services offered in 2021 will be evolved versions of what is offered today on 4G.*
- **Site acquisition and connectivity are critical enablers of distributed 5G/edge topologies.**
  - *The new denser topologies of 5G/edge networks drove issues such as site acquisition and availability of high-quality connectivity to the top of the heap of success factors in 5G; 45% of respondents ranked this as most important to success.*

5G and Edge Opportunities

5G Services – Not Just another G

5G is the next major step in wireless connectivity. Today, many of the world's mobile devices are running on some form of 4G (LTE) network, evolved from 3G, which evolved from 2G, and so on. A minority of devices still connect via 3G and even 2G networks in many places.

Although previous generational shifts brought significant new customer-facing capabilities (e.g., mobile data services, SMS, mobile broadband) and underlying architecture changes (from analog to IP), 5G represents a shift of a different magnitude. 5G will forever alter the role of wireless connectivity in society (in many places eliminating the need for fixed broadband connections) and will also enable previously impossible use cases that help create a more connected world.

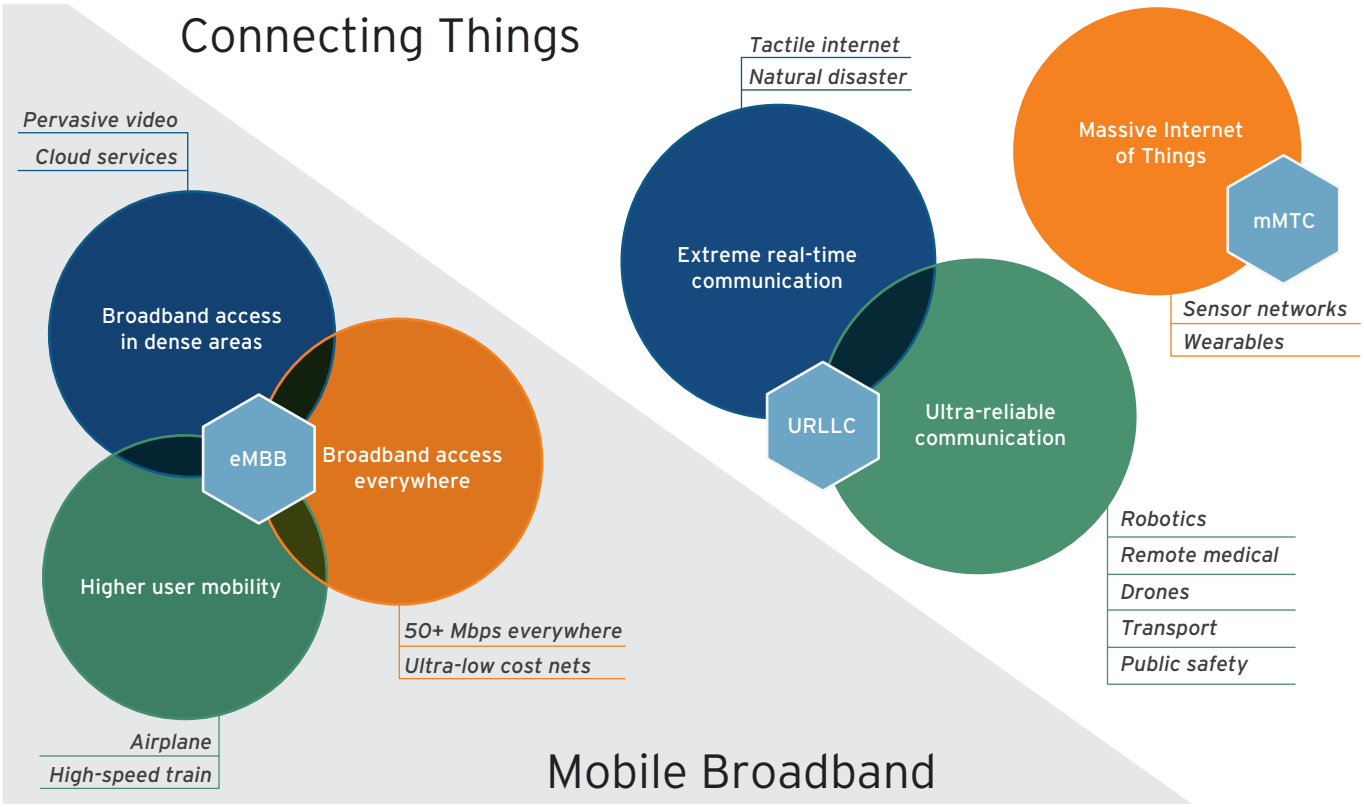
While the transitions from 2G to 3G and 3G to 4G were largely driven by consumer demand for more capable mobile data services, 5G topologies are a response to demand for enterprise functionality beyond broadband access to the internet. That said, as consumer smartphone adoption nears saturation levels in mature economies, 5G systems will be required to reduce the costs associated with delivering high-quality services for mobile and fixed broadband.

5G will enable (in the long run) three major groupings of use cases: enhanced mobile broadband (eMBB), ultra-reliable low-latency communications (URLLC) and massive machine-type communications (mMTC). The latter targets the efficient and secure connection of millions of devices without overloading the network. Through optimized design and heavy use of technologies born in the cloud, these networks will excel at bandwidth, cost efficiency, scale and latency performance and provide the 'knobs and dials' to rapidly provision exactly what is needed.

The access networks being rolled out today – NB-LTE and LTE-M – will serve as the main 5G access technologies via in-band operation. The challenge for any operator considering 5G will be choosing the use cases, verticals and ecosystems that best meet the demands of their markets. See Figure 2.

Figure 2: The landscape of 5G services

Source: 451 Research, 2019



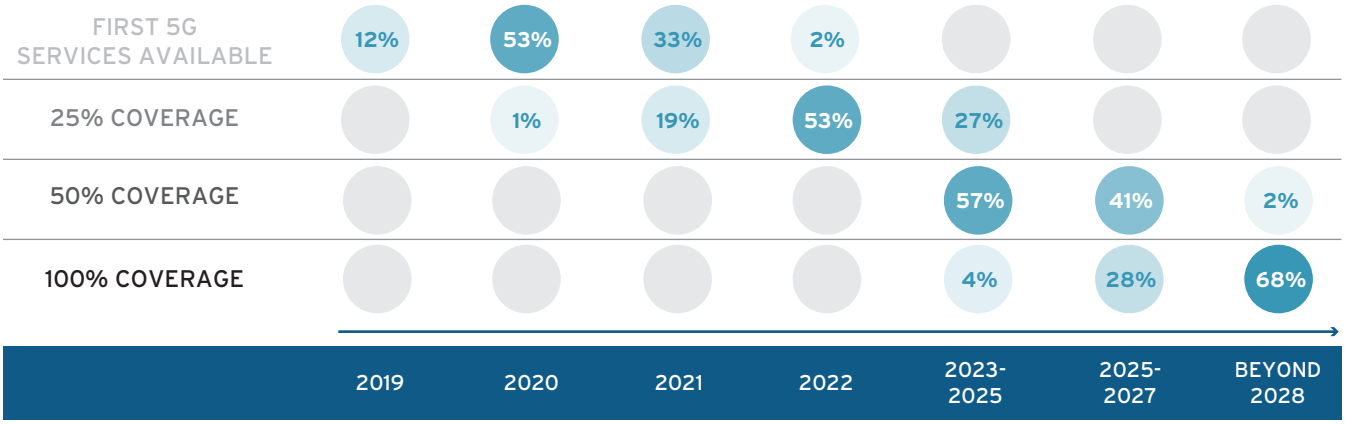
URLLC	Ultra-reliable low-latency communication is one of several types of use cases supported by the 5G NR standard.
EMBB	Enhanced mobile broadband will supply high-bandwidth internet access for wireless connectivity, large-scale video streaming and virtual reality.
MMTC	Massive machine-type communication supports internet access for sensing, metering and monitoring devices.

5G Deployment Roadmap

Across the board, respondents said initial 5G deployment will occur by 2021, or 2022 at the latest (See Figure 3). Just 4% of respondents from Europe and 10% of respondents from Latin America said they won't have initial deployments until 2022. Operators from the rest of the world indicated they would have initial deployments by 2021.

Figure 3: 5G deployment timeline

Source: 451 Research, custom research commissioned by Vertiv, 2019 (n=105)



The majority of respondents said they will not achieve total 5G coverage until 2028 or later. With that said, North America is expected to have the highest percentage of early deployments, driven by the Big Four (soon to be Three?) – AT&T, Verizon, Sprint and T-Mobile – with 47% of North American respondents saying they will have total 5G coverage by 2025-2027. More than three-quarters (78%) of respondents from the rest of the regions, excluding the Middle East and Africa, said they don't expect to complete 5G deployment until beyond 2028. This is on par with earlier G transitions. Growth and deployment will occur gradually with North America setting the pace and the rest of the world playing catch-up.

5G Initial Services – More of the Same at First

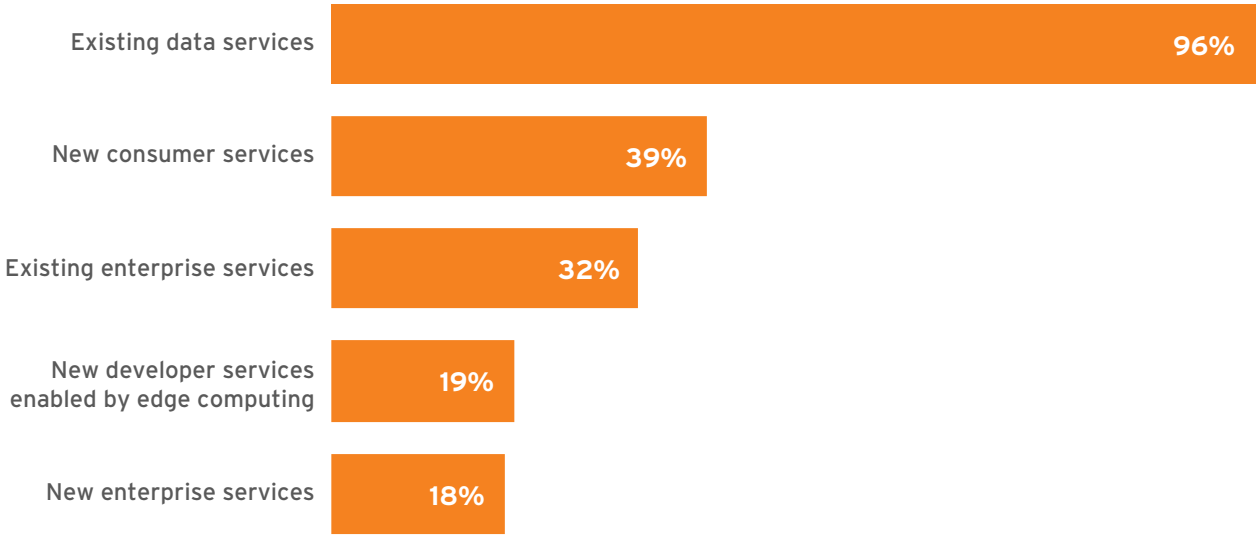
5G networks will only be as capable as the standards upon which they are built. The 5G standards evolution saga has been convoluted, with individual operators, countries and vendors playing tug of war with 3GPP on standard timelines, uniformity and feature priorities. After some debate, the primary focus of the now-ratified Release 15 5G standard was 'new radio' techniques to deliver eMBB services, as well as establishing the foundations for continuing 5G evolution. Release 16 (i.e., the 5G Phase 2 standard), which is currently targeted for completion in December 2019, will bring the advanced goodies that most people associate with 5G, such as URLLC and mMTC, as well as sub-topics such as vehicle-to-everything (V2X) communication and network slicing.

Figure 4 shows that the great majority (96%) of all respondents expect to deliver 'existing data services' by 2021, which makes sense given the eMBB focus of Release 15 and the massive revenue pools associated with consumer data services. The fact that only 39% said that they expect to deliver

'new consumer services' by 2021 is slightly disconcerting because we'd expect a higher percentage of respondents to be ready with new offerings enabled by 5G, such as connected home, security and gaming. Also slightly worrying is that only 18% of respondents said they expect to offer new enterprise services by then. Our suspicion is that operators are not yet spending enough time ideating new service offerings they can own and deliver and may believe others will capture that value on top of their connectivity, or they want to get the basics right before extending into new services and value chains.

Figure 4: 5G services expected by 2021

Source: 451 Research, custom research commissioned by Vertiv, 2019 (n=105)



5G: Significant Densification, Use of Technologies Born in the Cloud, and MEC

For maximum effect, 5G radio access technologies will use millimeter wave (mm WAVE, >6GHz) spectrum to enable the bandwidth capacities (~1Gbps) to transfer data. Millimeter waves are significantly smaller than submillimeter spectrum (such as 700MHz) used in 4G and earlier cellular generations, which will improve the speed and control of data exponentially.

Because of their size and propagation characteristics, millimeter waves can't travel as far as traditional radio waves and can be more easily blocked or disrupted by rain, trees and concrete walls, etc. To design around these issues, traditional cell towers, which are typically spread out over a large area and connect to thousands of end users, will have to be shifted into smaller, more densely populated nodes that will host far fewer people and things. This massive densification will potentially require operators to double the number of radio access locations around the globe in the next 10-15 years.

Operators will also leverage technologies such as massive multiple input multiple output (M-MIMO) antennas for optimized signal transmission. Of course, 5G is more than just a radio upgrade using MMW and M-MIMO techniques to ramp up bandwidth capacity. 5G systems also will take advantage

of innovations 'born in the cloud' such as network function virtualization (NFV), software-defined networking (SDN) and MEC to enable operators to rapidly provision new services quickly using cloud-like deployment techniques including resource pooling, automation and agile development practices.

SDN and NFV have slowly but surely matured and are now widely deployed in telco core networks – to support functions such as mobile management entity (MME)/evolved packet core (EPC) – and are beginning to be deployed in the radio access network (RAN – to support C-RAN/V-RAN). The combination of innovations at the 5G RAN, edge and core will add up to an ultra-flexible service platform allowing for virtual service 'slices' serving different use cases over the same physical infrastructure concurrently.

Multi-Access Edge Computing

Multi-access edge computing is the emerging telco network architecture that brings capabilities of the cloud directly into the radio access network. This is made possible by physically deploying MEC infrastructure (think small, self-contained datacenter infrastructure) within the operator network footprint. Depending on the use case needs, these MEC locations can be as far 'out' as the radio towers, or at intermediary positions such as metro POPs, aggregation locations, customer premises, roadside enclosures, or some other point between the RAN and core network location.

Once MEC infrastructure is deployed, there is a wide variety of potential usage scenarios that can generally be grouped as 'internal' – i.e., a local serving gateway for the evolved packet core, or traffic monitoring or routing, local content caching, video optimization supporting a 'console-less' gaming service. The internal MEC use cases are about providing the distributed compute and storage infrastructure to deliver the optimal mix of performance, automation and efficiency.

The 'external' use cases for MEC hold the tantalizing promise of new telco revenue streams. New revenue streams have been hard to come by in the telecom industry, which saw the centralized cloud market largely pass it by, so this opportunity will receive the industry's full attention.

With the potential to open IaaS/PaaS cloud capacity as part of their next-generation networks, telecom operators will have something to offer that is quite different from what a hyperscale IaaS provider can deliver today. Because of the distributed topologies in telecom networking, they will have 'tentacles' of compute/storage/network positioned far closer to users than what is possible with AWS or Azure.

This will allow for application performance on the order of >1ms, local data storage to support regulatory requirements, real-time analytics on video feeds, etc. Another possibility will be arrangements between telcos and cloud service providers where telcos open their distributed cloud infrastructure in partnership or in wholesale arrangements with, for example, AT&T and Azure offering jointly integrated solutions spanning cloud, edge and network.

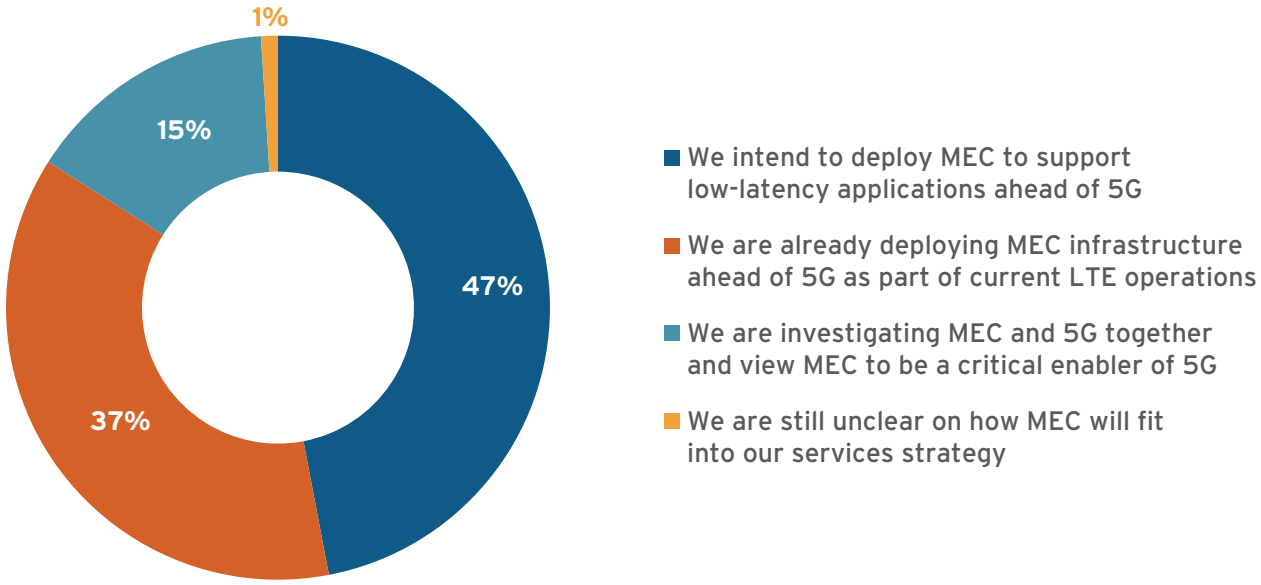
In our survey we inquired about MEC deployment plans both prior to and as part of a 5G transformation. Not surprisingly, 80% of respondents globally are either already deploying MEC infrastructure or intend to deploy it ahead of their impending 5G rollouts. Although more respondents

are in the planning stages (47% intend to deploy; 37% have already started to deploy), telcos clearly view the internal and external possibilities of edge computing as a major area of investment and opportunity.

At a regional level, North America is far and away the leader in terms of in-progress MEC deployment; 68% of respondents are already deploying MEC infrastructure to prepare for 5G deployments. The next closest regions in terms of current MEC deployments are Latin America and the Middle East/Africa, both reporting 40%.

Figure 5: Multi-access edge computing plans

Source: 451 Research, custom research commissioned by Vertiv, 2019 (n=105)



Survey Reveals 5G Challenges

5G/Edge Impact on Datacenter Design/Topology/Requirements

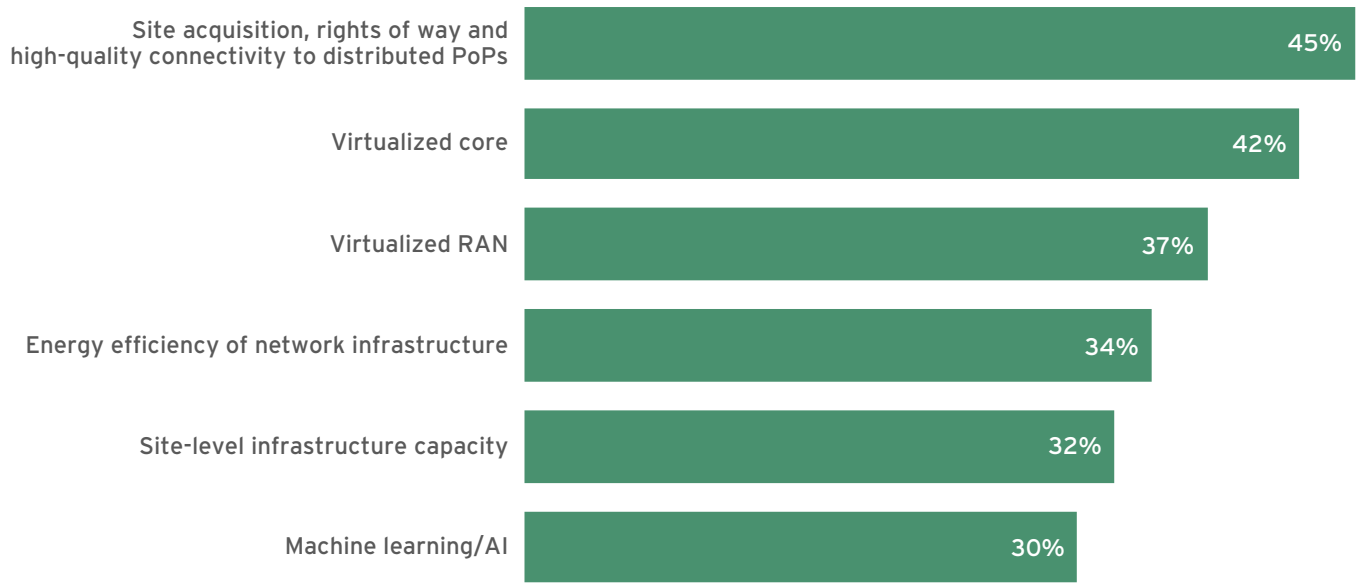
If all goes to plan, (in 15 or so years) telecom operators will operate in much the same way that cloud service providers operate today. They will have leaner opex models, faster service velocity, and a high degree of automation that will drive greater profitability – essentially, all the agility, scalability and flexibility offered by the cloud with the superior performance attributes of a highly distributed edge computing fabric integrated with IP networks and advanced RANs. Given previous statements on the transformation of telco datacenters, it will be mission-critical to anticipate and address new MEC locations, and densification, site-level (i.e., where radio and computing equipment is deployed) considerations.

Site-Level Challenges Rise to the Top

To support 5G and MEC, foundational site-level infrastructure will require enhancements, upgrades and expansion. Connecting 5G sites will also require an overhaul (e.g., time and money) while offering new business opportunities for transport and interconnection service providers. When we asked about the most critical technical enablers for 5G success (see Figure 6), we found that site acquisition, rights of way and high-quality connectivity ranked even higher (45%) than core network technologies such as virtualized core (42%) and RAN (37%).

Figure 6. Most important technical enablers

Source: 451 Research, custom research commissioned by Vertiv, 2019 (n=105)



This result serves as a stark reminder that operators will increasingly require 5G site-access regulations that are designed to reduce the time and administrative overhead involved with gaining permission to deploy new sites and infrastructure. Once sites are deployed, it will be important to reduce the need for human intervention and maximize the use of advances in intelligence technologies. In the US, the FCC

has taken steps to reduce the ability for local governments to restrict and regulate 5G infrastructure by implementing tight deadlines, limits on rights-of-way access charging, and so on. Similar efforts are afoot from regulators across the globe.

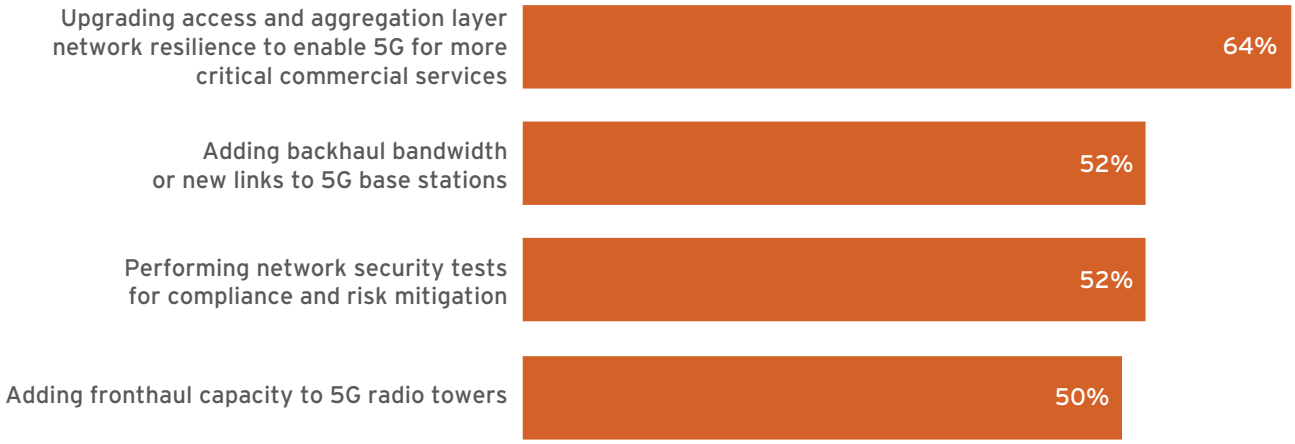
Following site access, respondents cited virtualized core (42%) and virtualized RAN (37%) as key technical enablers. Both results were highly skewed by North American telecom providers, which far and away find these two enablers the most important. A staggering 74% of North American telecom providers said virtualized RAN will be the most important enabler for 5G success, and 53% said virtualized core. North America is home to some of the largest datacenter markets in the world, so the physical infrastructure – in terms of PoPs and places to host MEC – is generally in place. The fact that 74% of North American telecom providers find virtualized RAN to be the most significant enabler of 5G is a massive outlier. Only 25% of European respondents shared the same sentiment, and just 20% from the Middle East and Africa.

Connectivity Challenges a Mixed Bag

Once infrastructure is deployed, whether in a small datacenter (micro-datacenter), central office recast as a datacenter, at a cell tower, central office or point of presence, those locations must have access to high-quality network connectivity. For 5G to run successfully, certain updates will need to be made to enable improved connectivity – whether this means adding physical infrastructure or virtualizing existing physical infrastructure. The existing configuration of our cell networks won't suffice. We briefly touched on the importance of updating physical infrastructure – that is, replacing massive cell towers with smaller, more densely scattered nodes. Across all respondents, site acquisition, rights of way and high-quality connectivity to distributed PoPs is the most important enabler of 5G, coming in at 45%. This number is consistent across geographies, excluding a major spike (60%) in Latin America and a less significant dip (32%) in North America.

Figure 7. Connectivity challenges for 5G

Source: 451 Research, custom research commissioned by Vertiv, 2019 (n=105)



Regarding connectivity challenges to support 5G (see Figure 7), upgrading access and aggregation layer network resilience for critical commercial services received the most responses across all geographies (64%). While this was a significant concern across all regions, there was a major spike from respondents in Europe (83%). Europe yielded some other outlier results as well. European respondents showed the least amount of concern (17%) about adding backhaul bandwidth or new links to 5G base stations, which reflects the maturity of connectivity routes and deployed infrastructure, compared to 52% of respondents overall. Respondents from North America, Asia-Pacific and Latin America all see adding backhaul bandwidth as one of their top concerns moving forward (68%, 68% and 60%, respectively).

Adding fronthaul capacity to 5G radio towers (e.g., C-RAN architecture) was also a significant concern across geographies. North American telcos showed the same level of concern for implementing fronthaul capacity as backhaul capacity – 68% of telcos said they believe this will be a challenge. Across all geographic regions, the task of identifying metro area datacenter providers with the right connectivity options evoked the least amount of concern. The world's datacenter markets are well established, so it makes sense that identifying the physical data hubs would be a lower overall concern.

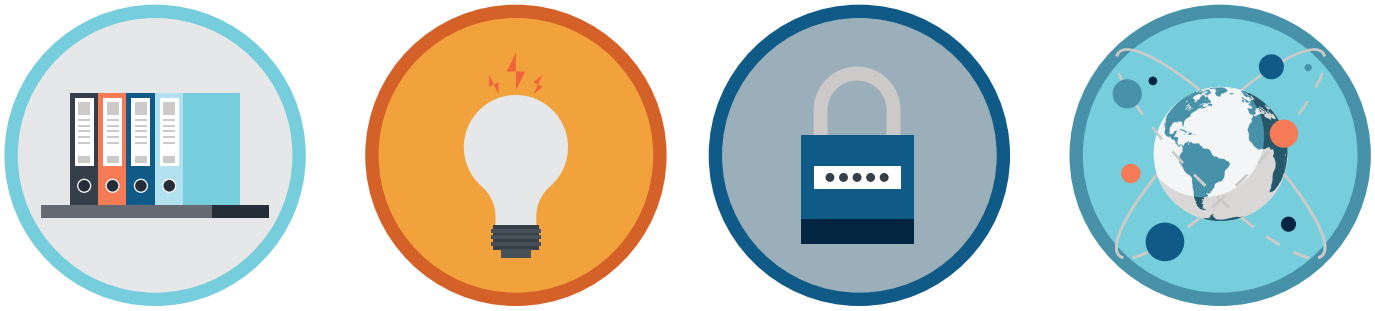
The only other noteworthy regional outlier is North America's lack of concern with performing network security tests for compliance and risk mitigation. Across all respondents, 52% said this was a major concern, but only 26% of North American telco providers agreed with this sentiment. Regarding connectivity challenges, telcos throughout the world – aside from North America and Europe – are on similar terms and share the same general concerns.

MEC/5G Drives Increasing Need for Remote Management via DCIM

As new computing locations (i.e., datacenters) come online via MEC, the ability to remotely monitor and manage those locations will become critical because the sheer quantity of disparate endpoints will be onerous to manage via regular human visits. Remote management of 5G network and IT infrastructure will be critical to the success of 5G networks. The densification of both the radio network sites and compute locations will place a premium on both fronthaul (from base station controller to tower) and backhaul (from base station to network core) connectivity (See Figure 8).

Figure 8. Importance of remote management

Source: 451 Research, custom research commissioned by Vertiv, 2019 (n=105)



Latin America's top concerns seem to be focused on physical infrastructure. In addition to the 60% respondent rate regarding site-acquisition concerns, 60% of Latin American telcos are concerned about energy efficiency of network infrastructure, and 50% are concerned about site-level infrastructure. The datacenter market in Latin America is one of the fastest growing in the world, most likely because it previously lacked a market. The only regions that even came close to Latin America in terms of infrastructure updates were Europe (50% of respondents cited site-level infrastructure capacity improvements) and the Middle East/Africa (50% chose site acquisition and rights of way).

For 5G to be profitable and worthwhile, certain advancements and adjustments need to be made regarding how networks and datacenters are managed. 5G connectivity requires a significant amount of energy to run, especially after technologies are put in place to manage and dictate the direction of the traffic. The technology inside datacenters will have to adjust to make 5G adoption cost-effective for telecom providers.

According to 55% of respondents, datacenter infrastructure management (DCIM) is the most important technology for achieving operational and profitability goals. That percentage spiked (68%) with respondents from Asia-Pacific. Only the Middle East and Africa region had a noticeably below average response rate (47%), which was still just eight percentage points lower than the worldwide consensus. This was one of the most consistent responses across the globe, highlighting the importance that DCIM will have on 5G's success.

Energy/power efficiency came across as the second most important attribute, flagged by 49% of respondents. Most regions' respondents were near the group percentage, except for respondents from North America and Europe, who seem to feel strongly but in different directions (which has been a recurring theme). More than two-thirds (68%) of North American respondents said energy efficiency will be a key step in achieving profitability and operational success, but just 33% of European telecom decision-makers said the same.

Security management was also cited as important by 45% of respondents. Those from the Middle East and Africa have the most concern regarding security management, while those from North America expressed the least. It's clear that telcos are going to make strategic upgrades to their current datacenter management internally, and this should come along with massive amounts of energy savings and security improvements. We expect an increase in datacenter technology sales to track 5G and MEC evolution.

Energy Costs: Fly in the 5G Ointment?

As we mentioned above, 5G is going to be significantly more energy-intensive than previous generations of wireless connectivity – so much so that extra efficiency measures will need to be taken to ensure a worthwhile investment for infrastructure and telecommunications providers alike. A whopping 94% of our survey respondents indicated that they expected overall energy costs to increase along with 5G/MEC deployments.

To grasp how the energy-saving landscape will change as 5G becomes real, we asked about current energy savings tactics and the outlook in five years. Currently, reducing AC to DC conversion is the top method of energy savings across networks, according to 79% of respondents (See Figure 9). Five years from now, 85% of telecom providers said they will be deploying methods to reduce AC to DC conversion, which will remain the most commonly used energy-saving method.

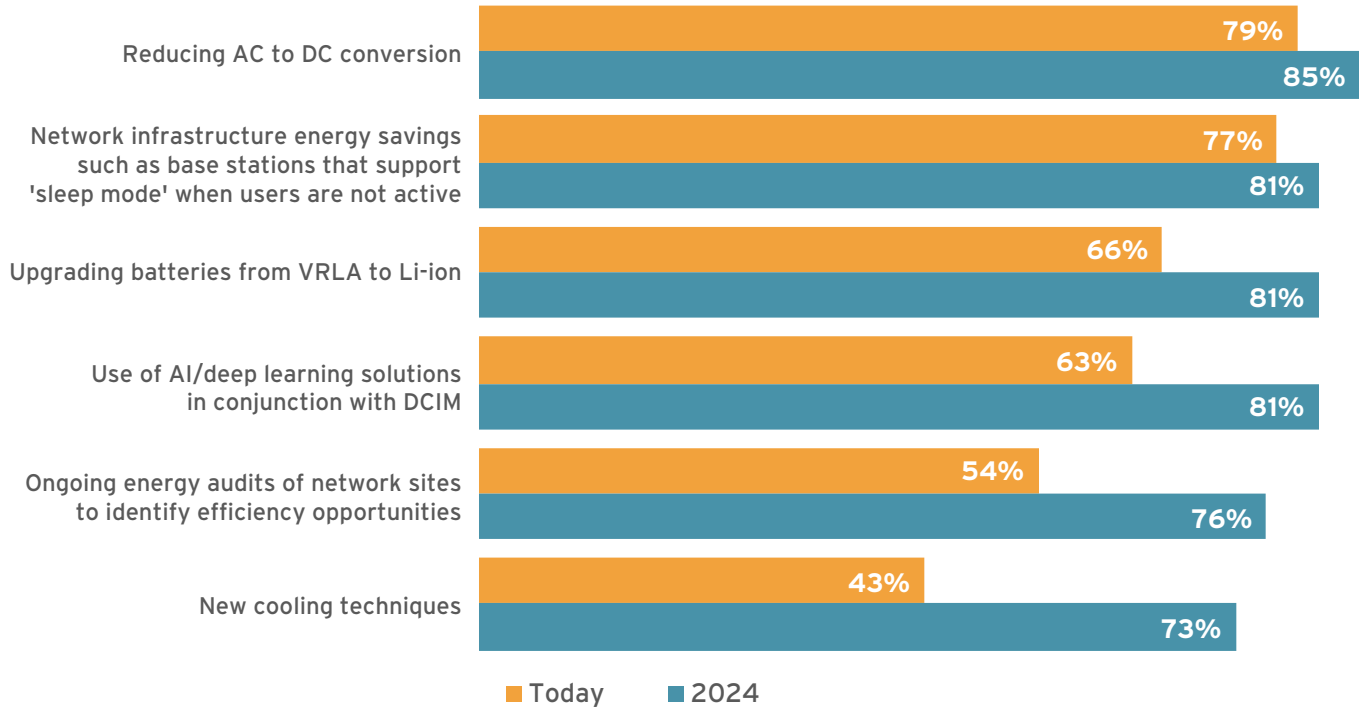
New cooling techniques will see the biggest jump in adoption over the next five years. Currently being used by 43% of telcos worldwide, this number is expected to spike to 73%. This is the largest growth of any energy-saving method across all geographies, which is understandable – 5G will consume too much energy and produce too much heat to let cooling go unchecked.

Battery upgrades – from VRLA to Li-ion – also show massive amounts of growth in deployment within the next five years. Currently, 66% of telcos are upgrading their batteries to save energy throughout their networks, but five years from now, that number is projected to jump to 81%, the same as network infrastructure energy savings and the use of AI/deep learning solutions in conjunction with DCIM.

If energy saving is crucial for profitability now, it will be even more mission-critical in five years when 5G is reaching mass deployment levels. The market for energy-saving products and services will clearly rise with 5G maturity.

Figure 9. Energy Saving Tactics Today vs. 5YFN

Source: 451 Research, custom research commissioned by Vertiv, n=105



Conclusion: The 451 Take

The global telecom industry stands at the precipice of a several-year period of reinvention driven by the combination of 5G, network virtualization and orchestration, edge computing, composable and automated IT infrastructure, cloud-native application development tools and processes, and modern hybrid and multi-cloud execution environments. Operators around the globe are scrambling to ensure they have the right software and cloud partners, personnel, IT and network platforms, and processes to pull these game-changing innovations into premium customer-facing products and ultra-lean operations. Across the industry, it seems as if every region will reach full coverage about the same time; however, their paths will be drastically different.

North America and Latin America are showing steady growth, implementing the proper upgrades in a timely manner and upgrading at a reasonable rate. Other regions, such as Europe and Asia-Pacific, will take giant leaps to get to full deployment – going from little to widespread coverage in short spurts. Throughout this growth, it's clear that updates to networks and infrastructure, whether physical or virtualized, will cause the most drastic changes and separate the early adopters from the laggards. **Expect massive growth for datacenter equipment providers because they will supply the infrastructure necessary for the 5G evolution to take place in a safe, secure and cost-effective manner.**

There is still much work to be done. Basic infrastructure readiness, site access and quality interconnection will trump all others in the race to efficiently deploy 5G and edge topologies. The impact of distributed 5G infrastructure on energy consumption will be vast and will require a collaborative effort that will cut across business units, new datacenter designs, technological innovations in battery and cooling, and AI-enabled remote management. Because 5G is starting up in earnest this year and next, the time to act is now. Preparedness and collaboration among network, IT and datacenter operations will be critical, as will strong support from ecosystem partners. The promise of 5G and edge for new service brokering and revenue generation will only come to fruition if new models of operation can be mastered and scaled.

Recommendations

- **Begin planning for 3GPP Release 16 features now.**
  - Establish initial target use cases for Release 16 5G NR features and begin groundwork of ecosystem development in infrastructure, application and service layers. DevOps/agile processes should be the target environment for 5G apps.
- **DCIM will play a critical role in managing distributed 5G and MEC infrastructure.**
  - Ensure that existing DCIM tools can take advantage of AI/machine learning for continuous improvement along with remote management.
- **Consider a 5G/edge core to create center of gravity within the organization.**
  - Establish 5G/MEC center of excellence with participation from IT, network and line-of-business stakeholders to establish a center of gravity to address technical and business issues, roadmaps and governance.
- **Order an energy audit ahead of 5G rollout to ensure site-level readiness.**
  - Conduct an energy audit across existing IT facilities in anticipation of 5G net-energy increase.

Appendix: 5G Definitions

- **3GPP Release 15**: The primary focus for the completed 3GPP Release 15 5G NR NSA standard is enhanced mobile broadband (eMBB) services, as well as establishing the foundation for the 5G New Radio (NR) design to support the future evolution. The 5G standard completed in December 2017 supports a specific configuration called Non-Standalone (NSA) 5G NR. NSA utilizes the existing LTE radio and core network as an anchor for mobility management and coverage while adding a new 5G radio carrier.
- **3GPP Release 16**: The focus of 3GPP Release 16 will be the expansion to new areas — new types of services/devices, new deployment/business models and new spectrum bands/types. The roadmap of 5G NR technologies coming in Release 16 and beyond spans ultra-reliable low-latency communications (5G NR URLLC), utilization of unlicensed and new spectrum sharing paradigms (5G NR-U and 5G NR-SS), vehicle communications for autonomous driving use cases (5G NR C-V2X), and the continued evolution of the 3GPP low-power wide-area (LPWA) technologies (NBIOT/eMTC).
- **URLLC**: Ultra-reliable low-latency communication is one of several types of use cases supported by the 5G NR standard.
- **eMBB**: Enhanced mobile broadband will supply high-bandwidth internet access for wireless connectivity, large-scale video streaming and virtual reality.
- **mMTC**: Massive machine-type communication supports internet access for sensing, metering and monitoring devices.

About 451 Research

451 Research is a preeminent information technology research and advisory company. With a core focus on technology innovation and market disruption, we provide essential insight for leaders of the digital economy. More than 100 analysts and consultants deliver that insight via syndicated research, advisory services and live events to over 1,000 client organizations in North America, Europe and around the world. Founded in 2000 and headquartered in New York, 451 Research is a division of The 451 Group.

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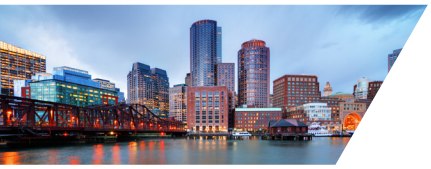

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