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OPERATOR SURVEY 2023

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Jennifer Pigg Clark is Principal Analyst with Heavy Reading where she investigates the challenges and opportunities facing communications service providers as they roll out 5G over increasingly virtualized and cloud native infrastructure. Clark examines the solutions and technology reshaping the telco data center, such as Multi-Access Edge Computing, cloud native infrastructure, open APIs, microservices, container networking, Network Orchestration, Network Functions Virtualization (NFV), and SD-WAN. Clark started her industry research career with the Yankee Group, where she held the role of Sr. Vice President. Prior to joining Yankee Group, Clark was Manager of Network Planning and Strategy for Wang Laboratories' corporate data network. Before joining Wang, she was a member of IT R&D for Commercial Union Insurance Companies.

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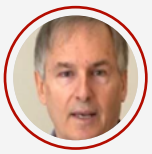

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Introduction

Heavy Reading's 2023 5G Network Strategies Operator Survey is designed to provide insight into how 5G networks are evolving as operators and the wider mobile ecosystem continue to invest in 5G technology and services.

This is the fifth annual version of the survey, and although the results reflect residual impacts from the COVID-19 pandemic, it is clear the disruption has begun to dissipate. The common theme in this year's survey is the shift from 5G network deployment to 5G monetization. In 2023, operators are beginning to turn their focus to building service capabilities that allow them to better monetize RAN coverage and capacity. This includes an acceleration in the move to 5G standalone (SA) as operators look to leverage network slicing and other SA capabilities to enhance their service offerings. 2023 will not be the year for the wide-scale deployment of open RAN solutions. However, Heavy Reading's survey results show it is the year when the industry will see some operators start to scale their deployments while others begin their move to commercial open RAN deployments in select geographies.

A second thematic thread throughout the survey is the challenge of implementing service offerings in an increasingly multicloud environment. This includes edge computing services, which are likely to be deployed across networks and clouds. Likewise, a top-of-mind concern among Heavy Reading's survey respondents is the complexity of realizing consistent security and policy management in a hybrid multicloud environment.

Developed in association with the report sponsors, the online questionnaire was fielded to respondents in the Light Reading service provider database in January 2023. It was open only to employees of telecom operators.

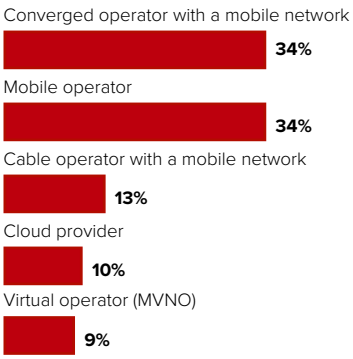
This report analyzes the results of the survey in the following thematic sections:

- 5G RAN evolution
- 5G standalone core
- 5G and edge computing
- 5G transport networks
- 5G security

The questionnaire received 100 responses from individuals who self-identified as working for operators. Rogue, suspicious, and non-operator responses were removed. Technical, engineering, and network operations personnel from large operators in advanced markets account for the majority of responses. The US is the dominant region with 48% of the responses, but all major global regions are represented.

Note: Numbers in figures throughout this report may not total 100 due to rounding.

Figure 1: What type of telecom service provider do you work for?



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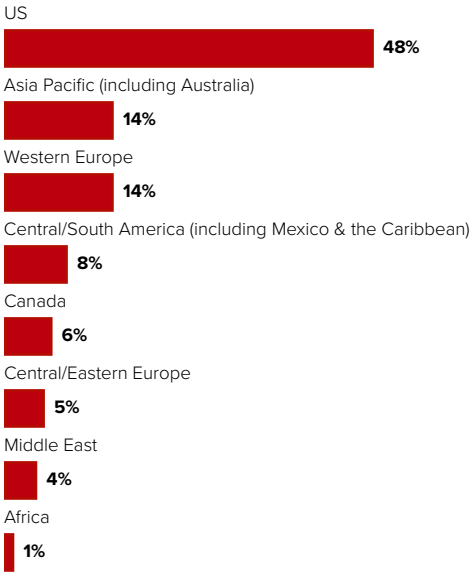
Source: Heavy Reading | © 2023 Heavy Reading

Figure 2: In what region is your organization headquartered?



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"The common theme in this year's survey is the shift from 5G network deployment to 5G monetization."

Introduction

Figure 3: What is your primary job function?

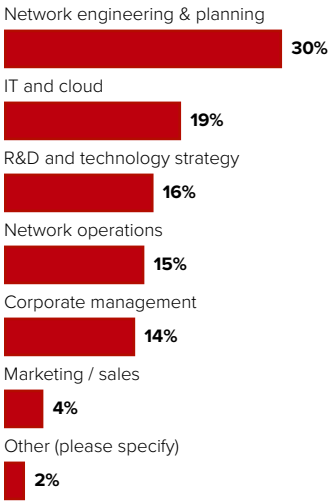

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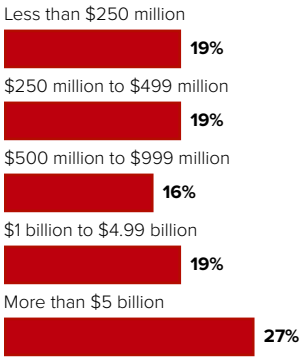
Figure 4: What are your organization's approximate annual revenues?



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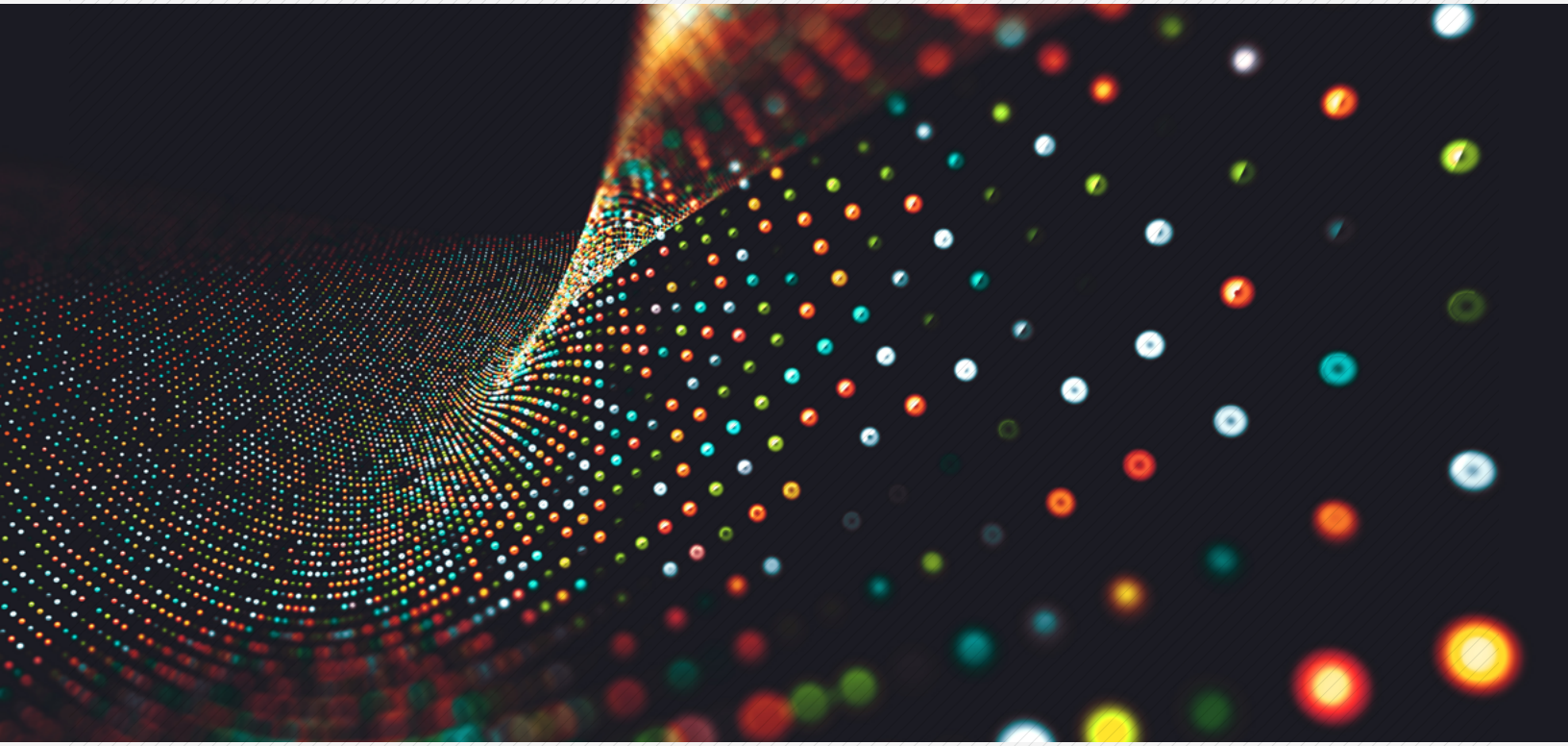


Operational Efficiency Opportunities with 5G Wireless Networks in 2023

As the COVID-19 pandemic fades into the background, a possible worldwide economic slowdown is causing adjustments to the business outlook for technology and the wireless industry. With the first billion 5G connections now online, operators can tap into the various technical capabilities of 5G to improve efficiencies.

Author: Chris Pearson

President, **5G Americas**

Looking back on 2022, the existence of 5G networks and consumer devices helped to propel 5G as one of the most widely used communications technologies around the world. The availability of 5G helped millions of people around the world through a particularly challenging time, giving them the ability to adjust to living through a pandemic and providing options for working from home—or elsewhere remotely from the office. But with a possible challenging global economic outlook in 2023, many network operators could be looking into the operational efficiencies that 5G can deliver to better operate in their networks.

Last year, 5G demonstrated to be an extremely consequential technology. Globally, there were 252 5G commercial networks deployed worldwide by the end of 2022, which set the stage for 5G to enter a powerful growth phase. Global 5G connections achieved "lift-off" by nearly doubling year-on-year, reaching 922 million by the end of 3Q22 and surpassing a billion by the end of the year, according to data from Omdia, Heavy Reading's sister company. This was powered by the availability of over 1,700 announced 5G-capable devices, according to the Global mobile Suppliers Association (GSA).

At the same time, demand for mobile data also reached new highs, as mobile data per smartphone reached 15GB per month in North America and 10.5GB per month in Latin America, according to the November 2022 Ericsson Mobility Report. That growth in mobile data is expected to reach 55GB per month for North America and 41GB in Latin America by 2028, which represents a staggering CAGR of 21% and 25%, respectively.

Other areas of growth included interest from the commercial sector as enterprises began to examine how to innovate new applications and services using 5G connectivity. Yet, many of the early successes for 5G stem from only one capability of 5G networks: enhanced mobile broadband. This is because many other capabilities, such as ultra-reliable low latency (URLLC) applications and services, require 5G SA networks that utilize 5G in both the RAN and the core networks. At the end of 2022, there were only 39 mobile network operators (MNOs) globally that had deployed 5G standalone networks, according to industry analysts, which means technologies like 5G network slicing are still not available across all networks.

5G Capabilities Continue to Grow

Indeed, the industry is still in the early stages of 5G, as many additional innovative capabilities of this generation of wireless cellular are on the horizon. 3GPP continues to complete standards, vendors are creating equipment, and software is being followed by commercial operator deployments.

For instance, the deployment timeframe for 3GPP Release 18-compliant networks is 2025. This release will include more than 22 new or enhanced technologies, features, and capabilities for RAN. Enhancements are targeted at several areas, including MIMO evolution, artificial intelligence/machine learning (AI/ML) for the air interface, the evolution of New Radio (NR) duplex, sidelink, improved positioning, RedCap support, energy savings, support for smart repeaters, new spectrum, dynamic spectrum sharing, non-terrestrial networks, unmanned aerial vehicle (UAV) support, and extended reality.

3GPP Release 18 will also include additional system architecture, service, and core network developments, such as improvements for edge computing, personal Internet of Things (IoT) and residential networks, and RAN slicing. More enhancements will be provided for non-public networks, seamless user experience context recovery, access traffic steering split & switch, location services, next-gen real-time communication, timing resiliency and URLLC, deterministic networking, and more.

The upshot is that many business entities, including enterprises, are continuing to learn and experiment with 5G, finding ways in which it will integrate with legacy IT systems that will allow firms to innovate new products and services. In fact, the market for global private 5G networks is expected to reach $36.08bn by 2030, according to Research and Markets. But as we peer into 2023, a new challenge has emerged—a possible worldwide economic slowdown that could put a dampener on capex spending.

What Will 2023 Bring?

In March 2022, the US Federal Reserve began a series of interest rate increases aimed at taming inflation and cooling the pandemic-fueled economic boom. US and global markets seem to have responded, as some large firms have worked to reduce their workforces and rightsize their expenses. The business environment has shifted toward efficiency and operation optimization.

Luckily, 5G has many capabilities for network operators to consider that may address and improve network functionality, efficiency, and optimization. Specifically, it is

possible the conversation will shift toward the following key areas:

- **Energy efficiency and sustainability** represent significant areas of focus. While 5G NR drastically reduces energy consumption over 4G LTE per gigabit, the sheer amount of data transmitted globally will cause the 5G ecosystem to effectively see a 160% increase in power requirements within the decade if network energy efficiencies are not achieved. As network operators are sensitive to energy costs and emissions, 2023 could be a benchmark year for additional emphasis.

- **Spectral efficiency** gains are another area where network operators will likely be focusing a lot of attention. Enhanced dynamic spectrum sharing, improved beamforming, downlink MIMO efficiency, 5G NR-Unlicensed, and enhanced carrier aggregation are all items in 3GPP Releases 16–17, which may help alleviate the need for additional spectrum. Additionally, operators (including three major operators in the US) have already begun the process of sunsetting 3G networks, freeing up that spectrum to be used by 5G devices.

- **Operational/business support system (OSS/BSS)** optimizations in 5G, fueled by the use of AI and ML, will yield positive benefits for MNOs. Operators that have adopted cloud-based operations in core, RAN, and edge networks could stand to see substantial gains across different functions like network balancing, charging, and storage, as well as the creation of value-added services.

- **Convergence** between 4G LTE and 5G networks will also help MNOs manage the operational challenges of dealing with multiple networks. Several operators have already introduced 4G/5G converged cores into their networks. Additionally, "convergence" will likely become a much more used term as MNOs look to integrate or partner with other access technologies like wireline, Wi-Fi, or other systems.

- **RedCap or 5G "reduced capability" devices** introduced in 3GPP Release 17 will offer another area where savings can be realized in both spectrum and energy use. 5G RedCap devices can support narrower bandwidths, optional support for half-duplex frequency division duplex (FDD), lower order modulation, and support for lower transmit power.

- **5G network slicing** will offer another capability for network operators to address enterprise requirements in a year where the capex of standing up a private 5G network might be challenging. The availability of 5G SA networks and a varied mix of spectrum, from low-band to millimeter wave, are providing operators an opportunity to address stringent service-level agreement (SLA) requirements by delivering exactly the right kind of connectivity with the appropriate level of network and spectrum resources.

Looking into the crystal ball of the future is always a tricky challenge. Every operator, along with their vendor partners, is going to address its particular strategies differently. Each operator has different tools in its tool kits and different priorities to address. Although it may be easy to state the obvious—it appears we are possibly heading into an economically challenging time—the way each individual MNO handles the challenge will differ. Certainly, there will be some operators that may decide to invest aggressively in top-line subscriber growth, while others will focus on operational efficiencies. The great thing about 5G is that it is an innovative technology capable of doing both by providing benefits for growth and efficiency.

"With a possible challenging global economic outlook in 2023, many network operators could be looking into the operational efficiencies that 5G can deliver to better operate in their networks."

About **Chris Pearson**

Chris Pearson is the president of 5G Americas. In his executive role, he is responsible for the overall planning of the organization and providing management for the integration of strategy and operations in the areas of technology, marketing, public relations, and regulatory affairs.

North America Maps the 6G Future: ATIS' Next G Alliance

Author: Mike Nawrocki

Vice President of Technology and Solutions, **ATIS**

In 2022, the Next G Alliance (NGA) published the *Roadmap to 6G* to frame the strategic priorities for North America as it advances toward 6G. The issues and ideas across these study areas crystallized a fresh way of thinking about the evolution of communications systems.

The momentum behind envisioning the 6G world continues to increase, with profound implications for policymakers, researchers, vendors, and users spanning the consumer, defense, and industrial sectors. Globally, there is evidence of more organizations participating in 6G development, and the pace of research and investment commitments shows no sign of slowing. Exploratory approaches are converging on formal structures in the communications industry.

Through solicitations for input and a series of symposia, the International Telecommunication Union (ITU) intends to publish a global vision for 6G later in 2023. Many nations and regional blocs have already announced their 6G intentions for the coming decade. There are also discussions within 3GPP on prerequisites for the 6G vision. Examples include study items for integrated communications and sensing and AI/ML integration in the RAN and service architectures. Edge computing (EDGEAPP) is another study item that seeks to prepare for the impact of distributed cloud and compute on communications systems.

How is North America progressing toward a 6G world? Much of this work is taking place in ATIS' Next G Alliance (NGA), which is building the foundation for North American leadership in 6G and beyond.

A North American Roadmap to 6G

Established in November 2020, the NGA is a private sector-led initiative. With over 100 members, it represents North America's collective interests and market development priorities for next-generation communications systems, beginning with 6G. Membership in the NGA spans the economic spectrum and brings together expertise across academic, public, and private sector interests. The NGA is also active on the international scene, fostering cooperation through liaisons with global initiatives in Europe, Japan, and South Korea, for example.

In 2022, the NGA developed the *Roadmap to 6G* to frame the strategic priorities for North America as it advances toward 6G. The Roadmap identifies six audacious goals and explores industry opportunities related to 6G applications, technologies, spectrum, and societal needs.

The issues and ideas across these study areas crystallized a fresh way of thinking about the evolution of communications systems. Past generations of communications systems were focused on densification to raise performance standards around network coverage and capacity. However, 6G will shape a different dynamic around applications and use case diversity. Diversification will be a key trend that drives 6G technology over past generations that have focused more on densification. New architectures will need to support more diverse use cases rather than the usual push for more capacity and coverage. Diversification will drive a proliferation of more device types, such as wearables, climate-sustainable sensors, and devices with multi-sensory capabilities.

The NGA *Roadmap to 6G* is North America's compass for advancing toward the 6G future.

Setting Audacious Goals

Defining what it takes to deliver next-generation wireless leadership is an audacious undertaking. In its *Roadmap to 6G*, the NGA sets forth the North American 6G vision and maps and articulates six goals to help get there. These address the top priorities for North America's contribution to future 6G-related global standards, deployments, products, operations, and services for the diversified networks of the future. They state that

- Trust, security, and resilience must be advanced such that future networks are fully trusted by people, businesses, and governments.
- An enhanced digital world must be achieved that consists of multi-sensory experiences to enable transformative forms of human collaboration, as well as human-machine and machine-machine interactions.
- Cost efficiency spanning all aspects of the network architecture is a critical part of 6G.
- Distributed cloud and communications systems built on cloud and virtualization technologies will lead to increased flexibility, performance, and resiliency for key use cases such as mixed reality, URLLC applications, interactive gaming, and multi-sensory applications.
- An AI-native future network is needed to increase the robustness, performance, and efficiencies of the radio network against more diverse traffic types, ultra-dense deployment topologies, and more challenging spectrum situations.
- Energy efficiency and the environment must be at the forefront of decisions throughout the lifecycle toward the goal of achieving IMT carbon neutrality by

2040. Advances will fundamentally change how electricity is used to support advanced communications and computer networks while strengthening the relationship of IT to the protection of the environment.

Building on the foundation set in the *Roadmap to 6G*, the NGA will publish a second Roadmap report in 2023 focusing on the diversity of application opportunities arising in different industry verticals. The aim is to trace the implications of vertical-specific use cases into applications that 6G can enable and highlight the promising technologies that need to be researched. Access the 6G Library for all NGA publications, including *6G Market Development: A North American Perspective*.

In addition to the NGA's comprehensive technical work, research and policy components are advancing the North American 6G vision.

The Next G Alliance Research Council

The NGA Research Council brings together leading industry and academic experts from the NGA to develop a comprehensive North American 6G research strategy. It will leverage key NGA findings and lay the groundwork for government, industry, and academia cooperative efforts.

In conjunction with the launch of the Research Council, the NGA published its 6G Research Priorities, a significant step in aligning the future vision for North American 6G with the research to drive wireless leadership over the next decade. These focus areas are derived from collaboration among NGA working groups involving more than 800 experts from the 6G wireless ecosystem. Research priorities encompass applications, technology, societal and economic needs, and sustainability.

Research Council member institutions include Ericsson, Google, Intel, Nokia, MIT, University of California Davis, University of Manitoba, Northeastern University, University of Notre Dame, University of Texas at Austin, Qualcomm, and Verizon.

National Policy in Support of the 6G Future

Around the world, standards are increasingly becoming swept up in the political debate over national competitiveness and leadership in advanced technologies. In terms of policy, other governments globally support their technology sectors in ways that the US is just starting to do. Again, the NGA is pivotal in the work to advance North American 6G leadership at the policy level.

While 6G may not be deployed until near the end of this decade, the critical research and skills to support such leadership will require years of investment that must begin now. Indeed, other regions of the world have already made significant commitments to research in support of the next generation of communications technology. The NGA Research Council's research priorities provide a blueprint for government, industry, and academic collaboration necessary to achieve North American 6G leadership.

In addition to the Research Council's work, ATIS also supports full funding of the CHIPS and Science Act research programs—particularly the National Institute of Standards and Technology (NIST) and National Science Foundation (NSF) research, including the work of NSF's new Directorate for Technology, Innovation and Partnerships. All of these components working in a coordinated way are essential to ensuring that North America is the epicenter of 6G innovation. Through its technical, research, and policy work, ATIS' NGA is sending a strong message to the world that the US is committed to being second to none in developing the communications technologies of the future.

"The Next G Alliance is building the foundation for North American leadership in 6G and beyond."

5G RAN Evolution

Author: Gabriel Brown

Senior Principal Analyst, Mobile Networks & 5G, **Heavy Reading**

Key takeaways

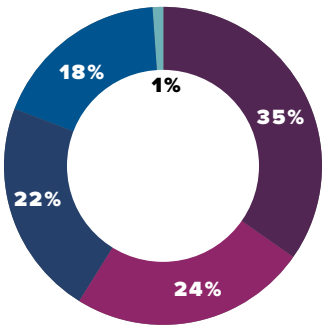
The key findings for this section are as follows:

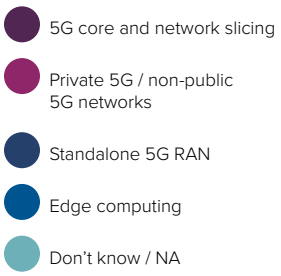
- After three years of 5G deployment and commercial service, operator investment priorities are starting to shift from network build to service capabilities that allow them to better monetize RAN coverage and capacity. In capex allocation, for example, the high scores to prioritize 5G core with network slicing (35%) and private 5G networks (24%) are consistent with the view that 5G networks are moving into a new phase. This is the fifth annual Heavy Reading 5G Network Strategies Operator Survey, but this is the first time this trend—which is still not firmly established—has been detected.

- 2023 is the year more operators will start to scale open RAN in their live commercial networks, but according to the survey, it is not the year open RAN goes mainstream. A lead cohort representing about a fifth of respondents (19%) expects their company will have a live commercial deployment in multiple cities or regions by the end of 2023. This also means 81% will not be in the commercial scaling phase this year. Encouragingly for open RAN, however, a further 27% say their company will have a live commercial deployment "in 1 city or region" and 16% "a small live deployment"; this shows the technology continues to be of interest and has the potential for broader commercial scaling at some point after 2023.

- Now that 5G has been operational for some years, it is useful to think again about the role of mmWave in 5G RANs. The survey identifies a group of positive respondents (20%) that say mmWave will have a "major role – we plan a dense mmWave deployment in our urban networks." This result speaks for itself. Yet, the 49% of respondents that see "a big supporting role" for mmWave in urban mobility networks is harder to analyze. At face value, it is positive and suggests mmWave is starting to gain widespread support. Thinking deeper, given the costs involved in mmWave deployment and the penetration rate of compatible handsets, the response by this larger cohort could better be interpreted as, "we like it, but we are not fully committed … yet."

Figure 5: Which domain do you anticipate your organization will make the greatest investment in over the next two years?





Notes: n=100
Source: Heavy Reading

5G RAN is being deployed at a rapid pace. There are now hundreds of networks and millions of cell sites in live service worldwide. According to Omdia, the overall RAN equipment market set a record high of $47bn in 2021, followed by a very strong $45bn in 2022.

With the rapid nationwide 5G buildouts in the US and China set to slow down in 2023, the RAN equipment market has likely peaked in overall dollar terms. Nevertheless, there will be continued deployments of 5G coverage, features, and capacity that will generate RAN investment above the long-term trend for the next several years. Globally, many operators are still in the early phase of 5G RAN builds.

The rate at which 5G RAN is deployed and how different frequencies and technologies are integrated into the overall RAN architecture have a direct impact on customer experience, mobile data economics, and, therefore, the wider mobile services ecosystem.

Mobile operators are careful to allocate capex efficiently and focus their investment according to the requirements of the deployment and service cycle. The first question in this section **(Figure 5)** seeks to understand the relative importance of four major areas of investment: standalone 5G RAN, private networks, edge computing, and 5G core with network slicing.

The results show a pretty even spread of results, with 5G core and network slicing ahead at 35%, private 5G/non-public 5G networks second with 24%, and standalone 5G RAN in third with 22%. Edge computing comes in fourth in terms of capex priorities with 18%.

The major finding is that investment in standalone 5G RAN, which was far ahead of the other categories in last year's survey with a 54% score in 2022, now scores 22% and is no longer the standout priority for investment. (Note that rather than asking about RAN in general, which is nearly always the largest area of investment, the question asks specifically about RAN investment to support "standalone 5G.")

This result is perhaps a signal that, after three years of 5G deployment and commercial service in lead markets, operator investment priorities are starting to shift to service capabilities that allow them to better monetize RAN coverage and capacity. As such, operators are likely more confident that their RANs have sufficient coverage and uplink-signaling capability to support SA operation.

It should be noted that by isolating the respondents working at operators with more than $5bn in annual revenue, the score for prioritizing standalone 5G RAN jumps to 33% (still behind 5G core and network slicing at 37%). This finding indicates that the move to investing in service capability over network buildout is still tentative and not yet a firmly established trend.

The high score (35%) for 5G core and network slicing is consistent with the view that 5G networks are moving into a new phase. 5G core is a prerequisite for SA operation and for services such as network slicing. Consistent with this, in other research, Heavy Reading has identified strong 5G core deployment activity is underway and that an advanced cohort of operators will start to commercialize network slicing over the next two years.

Private 5G networks—a.k.a. non-public networks—also score reasonably highly at 24%. This is a long identified opportunity for telecom operators, and while this sector is not yet booming, it is a growth market. Heavy Reading observes a steady increase in private network business activity and expects this to continue over the next two years and far beyond. In the short and medium terms, the focus is on how private networks are deployed on-premises at the enterprise site. Over the medium and longer terms, how local-area private networks are integrated with wide-area virtual private networks (that leverage network slicing) is of great interest.

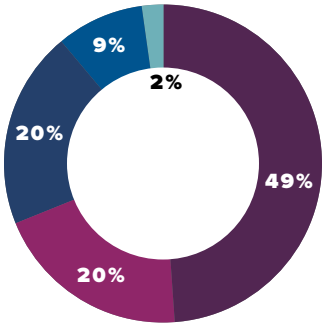
Now that 5G has been operational for some years, it is useful to think again about the role of mmWave in 5G RANs. To get a refreshed view of how operators plan to use this technology, the survey asks operators what role mmWave will play in their urban 5G mobility networks (i.e., excluding fixed wireless access and private networks) over the next two years. The results in **Figure 6** show operators are positive on the role of mmWave, but quite how supportive they really are remains open to question.

The 20% that say mmWave will have a "major role—we plan a dense mmWave deployment in our urban networks" is a group of positive respondents that speaks for itself. It might be argued that 20% is a high number, given the fairly limited deployment of mmWave outside a few lead operators.

The 49% that sees "a big supporting role" for mmWave and plans "a deployment focused on select high-traffic areas" is interesting but harder to analyze. At face value, a "big supporting role" is very positive and suggests mmWave is starting to gain widespread support. Yet, given the costs involved in deployment (in terms of site costs and equipment), this could be interpreted as, "we like mmWave, but we are not fully committed." Those operators that will truly deploy for urban mobility are probably captured in the 20% "major role" group.

The other important barrier to widespread deployment in the urban mobility network is the need for a sufficient penetration of handsets with mmWave-capable RF modules to make the deployment worthwhile. In some markets, there is an appetite to pay for this capability because of the remarkable improvements mmWave can make to customer experience and network capacity. In most markets, though, Heavy Reading does not yet see that operators and customers are enthusiastic about paying this premium.

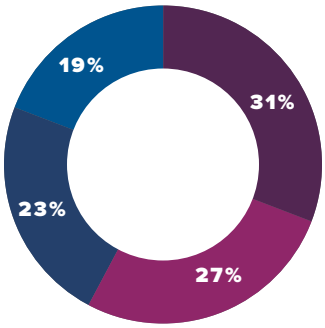
Figure 6: What role does your organization expect mmWave to play in its urban 5G mobility network within the next two years?



Notes: n=100
Source: Heavy Reading

Turning back to mid-band 5G, the next question **(Figure 7)** asks respondents to judge the biggest threat to the user experience from a list of four technical challenges commonly seen in mid-band systems. The result is interesting in that no single technical challenge stands out as a priority. And by the same token, all four challenges are seen as reasonably significant threats that, therefore, must be addressed. The conclusion is that operators will continue to need a broad-based set of monitoring and optimization tools to deliver the best customer experience.

Figure 7: What is the biggest technical threat to 5G mid-band user experience?



Notes: n=100
Source: Heavy Reading

Aside from the deployment of 5G itself, the major story in the RAN market over the past few years has been open RAN. Open RAN is a term normally taken to mean the ability to deploy and operate a disaggregated RAN using subsystems connected over open interfaces. The O-RAN Alliance specifies the

reference open RAN architecture and interfaces in line with the wider 3GPP RAN architecture.

Open RAN is often also associated with multi-vendor RAN because open interfaces enable the operator to deploy a system using components from different suppliers. It is also associated with virtual RAN (vRAN), where distributed unit (DU) and centralized unit (CU) software is deployed on general-purpose hardware or cloud infrastructure. In some cases, open interfaces, multi-vendor, and virtualization/cloud native are combined.

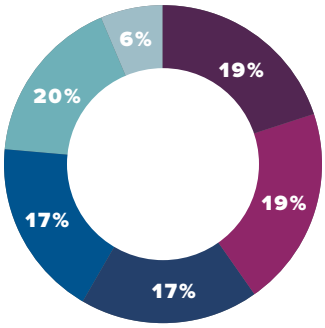
After several years of development, network trials, and a few commercial launches (mainly in greenfield scenarios), the survey sought to understand if operators collectively think 2023 is the year for open RAN to scale in a significant way. Asked specifically what role they expect multi-vendor open RAN to play in their company's wide-area public networks by the end of 2023, **Figure 8** shows interesting responses. In short, 2023 is not the year open RAN goes mainstream, but it is perhaps the year that more operators start to scale deployments in their live commercial networks.

A fifth of respondents (19%) expect their company will have a live commercial deployment in multiple cities or regions, showing clearly that a lead cohort of operators plans to scale open RAN in 2023. But this also means 81% will not be in the commercial scaling phase this year.

Encouragingly for open RAN, a further 27% say their company will have a live commercial deployment in "1 city or region" and 16% "a small live deployment." This shows that the technology continues to be of interest and that there is potential for broader commercial scaling at some point after 2023. RAN lifecycles are long, and the technology is R&D intensive, which makes a longer timeline appropriate.

Most of the rest of the responses are some version of "we have an open RAN trial system." This is, at face value, positive because very few (just 6%) are outright rejecting open RAN. As the last few years have shown, however, it is a long road from a trial to an "at-scale" commercial deployment.

Figure 8: What role does your organization expect multi-vendor Open RAN to play in its wide-area public network architecture by the end of 2023?



Notes: n=100
Source: Heavy Reading

The final question in this section covers 5G RAN field testing, which is required through the RAN lifecycle to ensure consistently excellent network performance and customer experience. From a list of four options, **Figure 9** asks which aspect of 5G field testing is of greatest concern to operators. Similar to the results of previous years, the response is fairly evenly split.

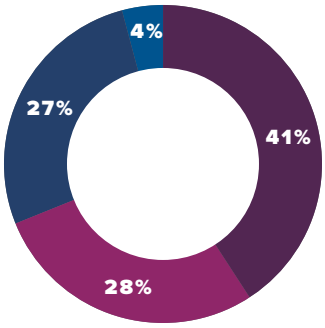
In first place in the list of field test concerns is "massive MIMO and beamforming performance validation," with a score of 41% (vs. 38% last year). Massive MIMO helps deliver capacity and cell edge performance and has been a major success in 5G, but it is a complex technology that is hard to monitor and optimize. It is also evolving rapidly, with various beamforming techniques and different MIMO configurations still being developed, evaluated, and deployed. That this is a top concern for field testing makes sense.

Fiber infrastructure testing (28%) and the level of complexity for testing 4G and 5G over-the-air (27%) both have a high enough score to show that these are still active concerns for operators.

The 4G and 5G air interfaces are obviously complex and hard to debug. With new RAN architectures and capabilities being introduced on an ongoing basis—e.g., 5G carrier aggregation, RAN slicing, or URLLC—it is clear these technologies will present an ongoing challenge for field testing.

Similarly, the sheer scale and diversity of the fiber network needed to run a 5G network explain the response to this question. With very diverse fiber plants (fiber modes, cable counts, etc.), diverse active equipment (different transmission technologies, vendors, etc.), and diverse SLAs offered (e.g., for in-house and outsourced backhaul), the challenges to fiber infrastructure field testing are clear.

Figure 9: What aspect of 5G field testing is your greatest concern?



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Source: Heavy Reading

"With the rapid nationwide 5G buildouts in the US and China set to slow down in 2023, the RAN equipment market has likely peaked in overall dollar terms."

"2023 is not the year open RAN goes mainstream, but it is perhaps the year that more operators start to scale deployments in their live commercial networks."

VIAVI Solutions Summary

With 200-plus networks in service at the beginning of 2022, 5G now supports billions of subscribers. The diversity of applications – including consumer, industrial and IoT – requires a more adaptive and intelligent radio access network (RAN), based on multi-access edge computing (MEC), disaggregation, open networking, and evolution to the cloud.

To support massive volumes of data over swathes of spectrum to multitudes of users at challenging latencies, different logical functions will need to be flexibly placed at different physical locations and coordinated by a new RAN Intelligent Controller (RIC). In addition, previous RAN technologieshave always been cell-centric. That model starts to disappear with 5G as we move to a 3D beam-centric model with both coverage and users' beams. And with core functions such as the user plane moving to the RAN, the RAN is indeed starting to look like the new core. This complexity means that quality of experience will increasingly be dependent on: network validation to confirm interoperability and performance of multivendor architectures; service assurance to meet subscriber-level KPIs; allconnected intelligently via the cloud to speed and even automate network adaptation and service enablement.

5G Standalone Core

Author: Ruth Brown

Principal Analyst, Mobile Networks & 5G, **Heavy Reading**

Key takeaways

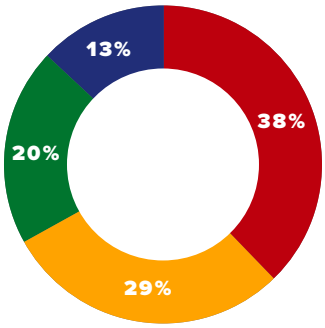
The key findings for this section are as follows:

- Respondents to Heavy Reading's 5G Network Strategies Operator Survey indicate that 5G SA will be available in their networks in some form during 2023. 49% of respondents initially expect a less widely available 5G SA service for a "soft launch to a restricted number of users" (29%) or "within defined geographic areas" (20%). The leading group of operators (38%) believes that 5G SA will have "nationwide or quasi-nationwide coverage" in 2023. This is a strong indication that 5G SA is maturing, though operators have confirmed mixed approaches for initial public wide-area availability.

- Network slicing is the most valuable SA capability to operators in terms of service creation, ahead of network capability exposure via APIs in second. Enhanced analytics, fixed and mobile coverage, and advanced policy control rank close together but score a little lower. Operators indicate that 5G SA value is derived from services demonstrating considerable advancement and capabilities to previous generations.

- Operators recognize that 5G SA services require new commercial models, as results reveal that traditional models, such as "connectivity only," are the least popular. The top three models (in order) were "connectivity to support business services (business-to-business [B2B])" at 55%, "enterprise service-based offering via vertical supplier partner (B2B2B)" at 51%, and "connectivity and some bundled services (business-to-consumer [B2C])" at 48%. The significance of the B2B2B model may highlight the expectation of mobile operators to commercialize popular 5G vertical industry offerings (e.g., automated logistics, smart manufacturing, port operations, etc.). In comparison, other modern commercial models, including revenue share (B2B2X), were less popular, perhaps pointing to the immaturity of the current ecosystem and associated charging systems.

Figure 10: How widely available will your 5G SA wide-area public network be at the end of 2023?



Notes: n=100
Source: Heavy Reading

The 5G core is the central element of a 5G mobile network. It securely establishes and manages sessions, handles mobility, makes policy decisions, and provides external internet or network connectivity. To support the advanced network experiences and services 5G enables will require a 5G core. Yet, to date, most 5G public wide-area networks are non-standalone (NSA), with Omdia figures showing just 28 public 5G SA commercial launches worldwide at the end of 2022.

Public wide-area 5G SA is complex. While it is technically challenging to implement a 5G cloud core network, the frequency of SA launches is starting to increase. More operators expect to deploy a 5G core in 2023, with reports confirming rigorous testing of production core networks and live test sites already underway.

To successfully deploy a public wide-area 5G SA core requires strategic thinking since it affects the entire network—from devices and the RAN to transport and the cloud. This section explores how mobile operators view 5G SA availability and the long-anticipated new service types, such as network slicing, low latency, and edge applications, that this technology supports.

Mobile operators are eager to support wide-area public 5G SA networks and the advanced services they can offer. However, many mobile operators have highlighted that network quality—i.e., coverage, stability, and reliability—should come ahead of the race to launch public 5G SA. Several approaches to wide-area 5G SA deployments are likely, including smaller targeted user groups, defined geographic areas, and nationwide or quasi-nationwide coverage. **Figure 10** looks to identify how widely available wide-area public 5G SA will be at the end of 2023.

The results indicate that almost half of the respondents (49%) expect a wide-area public 5G SA network to be available by the end of 2023 for a "soft launch to a restricted number of users" (29%) or "within defined geographic areas" (20%). Yet, the highest single category among respondents is "nationwide or quasi-nationwide coverage" (38%). While positive, this reveals that operators have a mixed approach to wide-area public network 5G SA support within the coming year.

Encouragingly, only 13% of operators "don't know/still deciding" their 5G SA wide-area public network avail-

ability strategy. The survey's most significant finding is 87% of respondents expect that 5G SA will be available in their networks in some form during 2023.

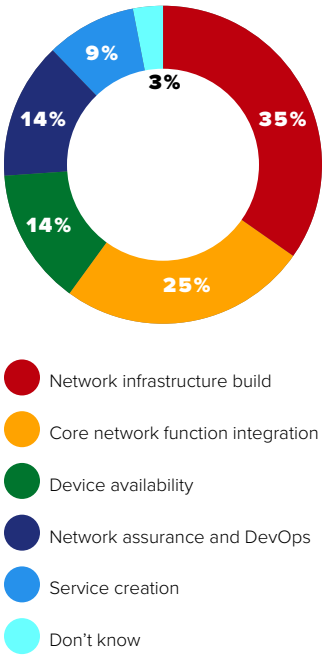
5G SA services are reliant on a 5G core deployment. A cloud native 5G core is a common expectation, but achieving this goal requires dedicated planning and technical knowledge. To support and deliver cutting-edge services will require multiple considerations, including cloud infrastructure build, core network function integration, network assurance and DevOps, device availability, and how to support advanced service creation. **Figure 11** captures the current operator opinion on challenges to delivering end-to-end public 5G SA services.

About a third of operators (35%) believe the "network infrastructure build" has been the most challenging area. This figure is higher still when isolated by region, with almost half (48%) of US operators finding "network infrastructure build" to be the most challenging aspect. Cloud native infrastructure is a huge step change from previous mobile generations, so it is not surprising that this is taking some time to resolve. There are many considerations around infrastructure approaches and choices for operators (e.g., infrastructure as a service [IaaS], platform as a service [PaaS], or even hybrid clouds). Telco cloud stack immaturity has also been another huddle, but ultimately, deciding on the best infrastructure and operations hurdle to support new services is very demanding.

A quarter of operators (25%) determined that "core network function integration" is the second most challenging area, followed third by "network assurance and DevOps" (14%). Again, these responses echo the immaturity of cloud native technology and initial problems within the telco domain (e.g., challenges around telco protocol support, networking, and network visibility). These aspects add complexity to core network function integration, the supporting management, assurance, and DevOps tooling required for a mobile core network.

Respondents place "device availability" a joint third (14%) in the list of challenges. 5G has multiple frequencies, and device availability was initially a large barrier to new services. Yet, in recent reports, device availability seems to be increasing rapidly, with support for over 1,400 commercially available 5G devices, according to the GSA in January 2023.

Figure 11: What aspect has been the most challenging for delivering end-to-end public 5G SA services?



Notes: n=100
Source: Heavy Reading

"Service creation" (9%) is regarded as the least challenging, implying that despite multiple difficulties in delivering a 5G SA core capable of supporting new services, service creation might follow promptly after 5G SA public launches.

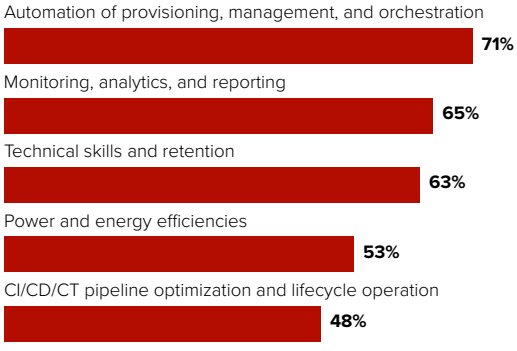
To deliver advanced services will require consideration of multiple aspects, including operations, analytics, lifecycle, energy efficiencies, and skills. **Figure 12** asks operators what areas have the greatest importance to their public 5G SA services.

The main observation is the fairly even distribution of votes among the top three categories: "automation of provisioning, management, and orchestration" (71%), "monitoring, analytics, and reporting" (65%), and "technical skills and retention" (63%). Notably, the importance of all three areas has been greatly publicized and debated by the mobile industry.

When isolating responses to this question to operators with "revenue of more than $5bn," the need for service automation is more visible, with 93% of responses confirming the importance of this area for provisioning, management, and orchestration. This indicates that services such as network slicing will rely heavily on automation, but successfully deploying and managing customer experience across 5G SA services will also require a raft of skills and other technical processes, an issue that operators seem to acknowledge.

Continuous integration, continuous delivery, and continuous testing (CI/CD/CT) pipeline optimization is often also grouped within the automation category, but it is separated here to analyze the importance of lifecycle changes. For example, 5G will require frequent cloud native function and compute infrastructure updates. Operators appear to recognize the importance of "power and energy efficiencies" (53%) along with "CI/CD/CT pipeline optimization and lifecycle operation" (48%) but score both lower. This may be a reflection of the current technology priority to launch public SA services. Regardless, it is likely that these will have a greater focus in the future.

Figure 12: What areas have the greatest importance in your public 5G SA services?
(Instructions to the survey respondents: select the top 3)



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Source: Heavy Reading |

5G SA services have the potential to help operators generate a return on their large investment in 5G networks and spectrum. 5G core will help mobile operators and ecosystem partners to create and enable a new generation of advanced services due to capabilities inherent to the 5G SA network. **Figure 13** shows the weighted scores for respondents ranking which 5G SA capabilities are most valuable for service creation.

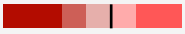
Operators ranked network slicing as the most valuable SA capability ahead of network capability exposure via APIs in second. This is not surprising since these advanced services are achievable only using new features within the 5G SA core. Other capabilities, such as "enhanced analytics," "fixed and mobile convergence," and "advanced policy control" (ranked third, fourth, and fifth, respectively), were less popular and separated from one another by only a tiny margin. Although these areas can provide considerable service value and differentiation, operators seem to place a higher value on services that can demonstrate the full benefits of 5G SA compared to previous mobile generations.

New commercial models are required to support service creation methods introduced by 5G SA. For example, network slicing and API exposure are likely to drive collaboration and marketplaces for the revenue sharing of these services. **Figure 14** illustrates the proportion of responses cast against various commercial models available to monetize 5G SA services.

On average, operators chose 2.6 responses each, which supports the view that 5G SA services will require multiple commercial models. Traditional connectivity-only models (33%) are the least popular, but operators have split opinions across the remaining options. The top commercial models are "connectivity to support business services (B2B)" at 55%, followed closely by "enterprise service-based offering via vertical supplier partner (B2B2B)" at 51% and "connectivity and some bundled services (B2C)" at 48%. While B2B and B2C are well-established commercial models already, B2B2B operators expect to commercialize 5G vertical industry offerings (e.g., smart manufacturing, port operations, connected and automated logistics, healthcare, etc.).

"Consumer service-based offering via supplier partner (B2B2C)" with 41% and "revenue share models (B2B2X)" with 38% are the least popular of the newer commercial models but nevertheless get decent support. These results perhaps illustrate the immaturity of the operational and charging systems that are meant to support revenue share models. Or they may simply show that the current service ecosystem needs to develop further.

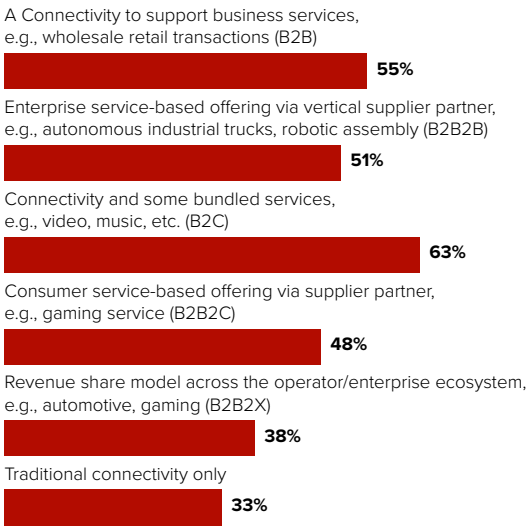
Figure 13: What 5G SA capabilities are most valuable in your service creation?

Item	Overall Rank	Rank Distribution	Score	No. Of Rankings
Network Slicing	1		342	96
Network capacity exposure via APIs	2		289	96
Enhanced analytics	3		274	96
Fixed and mobile convergence	4		273	95
Advanced policy control	5		272	97

Lowest Rank Higest Rank

Notes: n=95-97
Source: Heavy Reading | © 2023 Heavy Reading

Figure 14: What commercial models will you use to monetize 5G SA services?
(Instructions to the survey respondents: select the top 3)



Notes: n=100
Source: Heavy Reading | © 2023 Heavy Reading

"Operators ranked network slicing as the most valuable SA capability ahead of network capability exposure via APIs in second."

5G and Edge Computing

Author: Jennifer Clark

Principal Analyst, Edge Computing & Cloud Infrastructure, **Heavy Reading**

Key takeaways

The key findings for this section are as follows:

- Today's edge services favor multicloud deployment strategies, and service providers are highly motivated to work with partners that can help manage this complex environment.
- Operators are increasingly looking outside of their organization to hyperscaler and systems integration partners to offset the lack of internal resources.
- The move to containers, despite the complexity, is accelerating. Heavy Reading's survey indicates that 31% of respondents have shifted between 50% and 100% of their edge cloud workloads to containers, compared to 9% in 2022.

Edge computing continues to be a focal point of innovation for communications service providers (CSPs) and their partners. The 2023 5G Network Strategies Operator Survey results show that multi-access edge compute (MEC) deployments continue to accelerate and scale regardless of vertical industry. Top of mind with CSPs is the need to effectively and efficiently manage edge services in a highly complex environment made up of multiple infrastructure solutions, networks, and service providers. The current MEC market shows the impacts of the COVID-19 pandemic, with the highest edge service penetration in the media & entertainment and healthcare verticals. However, survey respondents predict an uptick in edge deployments over the next 24 months across all verticals, with the highest growth forecast in manufacturing, retail, and, again, healthcare.

The 2022 survey pointed to rapid growth in edge services within the media & entertainment industry, and responses from this year's survey reflect that carriers lived up to their predictions. "Already offered" for media & entertainment doubled from 19% last year to 38% of respondents in this year's survey. Edge services benefit the media & entertainment industry in the content creation stage with streamlined, higher performance, and more scalable workflows, particularly with the increasingly distributed workforce. Edge services also enhance the network operational efficiency of content distribution by placing frequently accessed content nearer to the end user, and they enhance the customer experience by improving latency and response time. Respondents anticipate that media & entertainment, along with healthcare, transportation & logistics, and manufacturing, will achieve the highest penetration overall of edge services in 2025.

The automotive industry is second in terms of currently offered edge services. Like last year, the adoption rate clearly does not refer to fully autonomous vehicles on public highways. It is a catch-all for auto-centric applications such as insurance IoT cameras and devices, onboard entertainment, and campus autonomous vehicles, with some manufacturing and fully autonomous driving trials and proofs-of-concept thrown in.

In terms of regional differences, edge services are expected to receive heightened focus in healthcare and financial services in the US through 2025, while the transportation & logistics industry will see the greatest growth outside of the US. The transportation & logistics industry can be heavily subsidized outside of the US and frequently bubbles to the top in Heavy Reading's edge surveys, particularly when the spotlight is on Europe.

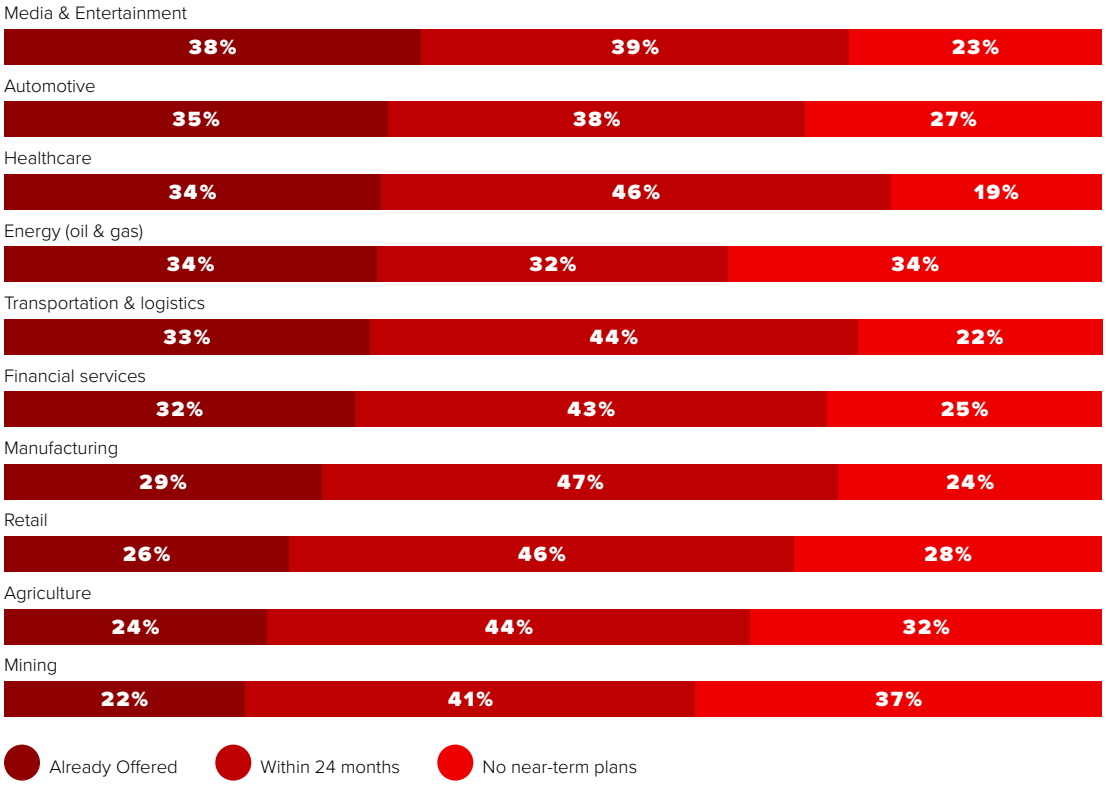
Mining again shows the greatest percentage (37%, down from 49% last year) of respondents with "no near-term plans" to deploy MEC. Note that these responses are weighted toward smaller CSPs and CSPs outside of the US. Similarly, energy (oil & gas) shows the lowest penetration of MEC deployments by 2025 for the Rest of World (RoW) region, most likely because the geographic regions served have few or no oil & gas resources. These regions are increasing their focus on and investment dollars in energy—but it is alternate, green energy.

Edge services are offered via a variety of infrastructure solutions with differing degrees of ownership, control, and geographic reach. A "hybrid public/private telco cloud infrastructure," giving CSPs the most attractive combination of both control and reach, garners a third of survey responses, as it did last year **(Figure 16)**. When looking only at the largest CSPs (greater than $5bn in annual revenue), that percentage grows to 41% (lower than 49% in 2022). There are two significant differences between last year's responses and those from this year:

- The second most popular solution—cloud infrastructure—jumped almost 20 percentage points from last year.
- This year's survey added the option of choosing a secondary infrastructure model. The results show that the three top deployment models are almost identical in terms of the percentage of respondents choosing each as either a primary or secondary solution.

Operators with annual revenue of less than $5bn divided their responses almost equally between the first four responses, with little

Figure 15: When will your organization start to offer 5G edge services in the following industries?



Notes: n=100
Source: Heavy Reading | © 2023 Heavy Reading

variation between the US and RoW. The reluctance to deal with hyperscalers seen from some regions outside the US in earlier surveys has dissipated, as CSPs have been lured by the ease with which they are able to get an edge service up and running in their own region and beyond.

The solutions that pull in public cloud are the most popular deployment models. However, more parochial solutions are very popular for secondary deployment models. "Using on-prem edge at the enterprise location" pulled in only 4% of respondents as a primary choice of infrastructure—but jumped to 19% as a secondary method—the second-highest secondary deployment model. The top response for secondary infrastructure solutions is the carriers' own telco edge cloud platform solutions at 28%.

This year, Heavy Reading added a new category: "at internet exchange points (IXPs)." Despite being the new kid on the block, this category managed to pull in almost 10% of responses (mostly as a secondary solution) compared to "repurposed content delivery network (CDN) locations," which (like last year) still claimed only 2% of responses. The two respondents that chose the expedient strategy of leveraging repurposed CDN locations were a cable operator and a mobile virtual network operator/enabler (MVNO/MVNE).

Given the reliance on multiple cloud-based infrastructure models, both public and private, revealed in **Figure 16**, one would assume that the ability to operate efficiently with high availability, scalability, and manageability across cloud platforms would be important to service providers. **Figure 17** reveals that this is the case. 90% of respondents believe a consistent experience across cloud platforms is either "critical" (35%) or "very important" (55%). Among carriers with annual revenue of more than $5bn, only 4% think a consistent experience is only "somewhat important," and zero think it is "not important."

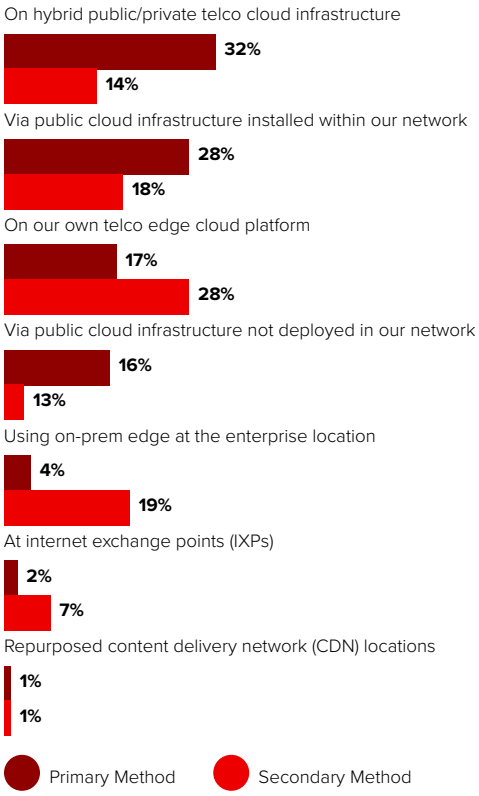
To deliver edge services, carriers must be able to monitor the network performance and infrastructure end-to-end across network boundaries. Today, their hyperscaler partners rely on the newest in automation technology to monitor services running in the cloud. Yet, they do not have visibility into carrier networks. When all their KPIs go red, they cannot discern the underlying or root cause. Similarly, the telcos cannot troubleshoot service delivery problems that are outside of their geographical region. As the logical barriers between networks fall, the physical realities of the network become more and more of an obstacle to reliable end-to-end performance. Both operators and hyperscalers are striving to be more proactive in problem identification and resolution. But this is tough to achieve in today's multicloud environment. Operators are searching for a common cloud software framework and reference implementation that promise to reduce the fragmentation of the cloud infrastructure layer for telecommunications and edge services.

Containers Today

The use of containers enables enterprises to build and run highly scalable and flexible applications for deployment at the edge and/or in a public, private, or hybrid cloud. Key benefits of containers/microservices include the following:

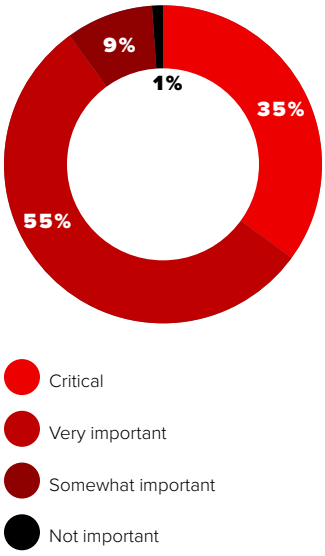
- Users can deploy only what is needed, rather than entire monolithic network functions, resulting in a lower total cost of ownership.

Figure 16: On what type of infrastructure is your organization offering (or planning to offer) edge services?



Notes: n=100
Source: Heavy Reading | © 2023 Heavy Reading

Figure 17: How important is it to have a consistent experience (operating environment, management) across cloud platforms?



Notes: n=100
Source: Heavy Reading
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- Faster time-to-market for new services and applications.
- Ability to decouple the application from the infrastructure, simplify application development, and enable applications to run in a highly distributed fashion.
- Increased cadence of small and regular updates to applications enabled by the microservices/containerized architecture and the use of CI/CD.

As compelling as these benefits may seem, the transition to containers and cloud native network functions (CNFs) from virtual machine (VM) virtual network functions (VNFs) is much more complex than the transition from appliance-based network functions to network functions virtualization (NFV) and VMs. Containers and cloud native represent a fundamental change to the way CSPs design, deploy, and manage applications and services. Despite these challenges, Heavy Reading's survey respondents have progressed in their transition to containers compared to last year **(see Figure 18)**. In the 2022 survey, 84% of respondents said that they had containerized less than 50% of their workloads. Today, that number has dropped to 62%. In fact, 31% of respondents have containerized between 50% and 100% of their edge cloud workloads, compared to last year's 9%.

The numbers do not differ dramatically when looking at the US versus RoW. Nevertheless, the percentages do show a more rapid transition to containerized workloads in the US. It is, therefore, a little surprising that the numbers shift fairly sharply between operators with revenue of more than $5bn, which show less of a transition to containers, and operators with less than $5bn. Four out of five of the largest operator respondents, or 81%, have containerized 50% or less of their workloads. These operators are dealing with a much larger body of workloads than their smaller colleagues. They are juggling multiple generations of mobile networking and are spreading their already scarce CI/CD development resources over a wider workload landscape. In addition, they are dealing with complex deployment strategies, potentially involving thousands of edge locations and dozens of ecosystem partners and crossing multiple networks and cloud environments. These are the service providers that are most in need of the consistent operating environment and management discussed above.

The operators are on track with their predictions for the transition to containers **(see Figure 19)**. By the end of 2025, 52% of respondents expect to have moved 50% or more of work-

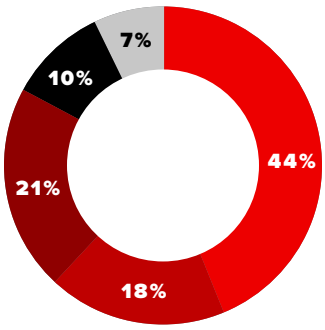
"The 2022 survey pointed to rapid growth in edge services within the media & entertainment industry, and responses from this year's survey reflect that carriers lived up to their predictions."

loads to containers. This includes 21% of respondents who forecast they will have transitioned over 75% of workloads to containers.

When Heavy Reading repeats surveys or individual survey questions for multiple years, responses usually become more positive (indicating that obstacles to deployment have become less of a concern). Not so with this year's 5G Network Strategies Operator Survey. All of the obstacles received responses that were 3 to 5 percentage points higher than in last year's survey, with a few exceptions. First, "internal skills and readiness" was the only obstacle that became less of a concern—it dropped 6 percentage points to 43%. Maybe those new resources have heightened organizations' awareness of all the other obstacles in the way of edge cloud deployments. The more likely scenario, however, is that operators are increasingly looking outside of their organization to hyperscaler and systems integration partners to offset the scarcity of internal resources.

The second, more dramatic change is with "limited tools to automate provisioning, management or orchestration," which leaped 27 percentage points, from 22% of respondents in 2022 to 49% this year. While other challenges pulled in more responses, the lack of tools and automation is clearly a significant obstacle and hot button with the operators today, and it deserves heightened focus from their vendor partners.

Figure 18: What percentage of your edge cloud workloads are containerized now?



Notes: n=100
Source: Heavy Reading
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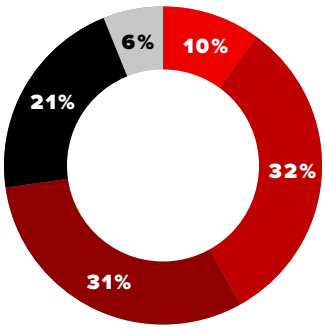
Figure 19: What percentage of your edge cloud workloads will be containerized by the end of 2025?



Notes: n=100
Source: Heavy Reading
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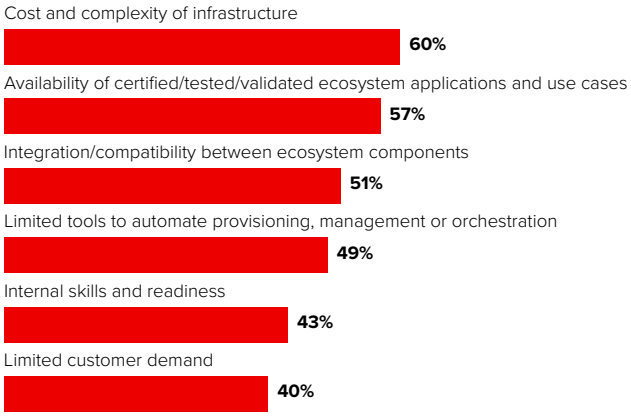
Figure 20: What is limiting your 5G and edge cloud deployment the most?
(Instructions to the survey respondents: select the top 3)



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Red Hat Summary

Digital service providers (DSPs) who use the powerful combination of 5G with edge computing offer better user experiences and support bandwidth-hungry apps through a more flexible, agile, and resilient network. Using cloudnative solutions for their radio access networks (RANs) allows them to quickly scale to dynamically meet changing demand. With multi-access edge computing (MEC), service providers can deliver innovative, latency-sensitive services and applications for enterprise customers, and capture new revenues.

DSP organizations are looking for a unified, horizontal platform—from the core to the edge—with a consistent deployment and operations experience. Red Hat provides the flexibility to develop and deploy with speed and ease in any cloud you choose. Together with our ecosystem partners, we help customers make the most of 5G opportunities with preintegrated offers to build out services with confidence and without fear of lock-in. For the foreseeable future, digital service providers will have many different kinds of workloads in multicloud environments. Our telcograde hybrid cloud solutions provide a consistent, predictable foundation that lets service providers move between clouds as strategic, business, or technology needs evolve. Partnering with Red Hat, DSPs can provide the experience that customers expect, and address.

5G Transport Networks

Author: Sterling Perrin

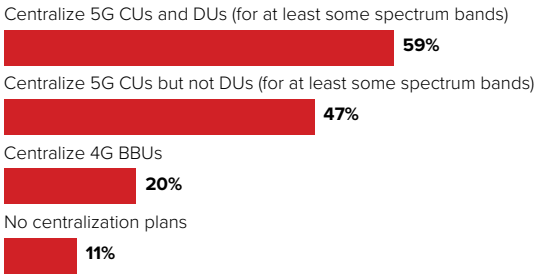
Senior Principal Analyst, Optical Networks & Transport, **Heavy Reading**

Key takeaways

The key findings for this section are as follows:

- Operator interest in full centralization of both CU and DU functions is on the rise. At 59%, the majority of operators surveyed expect full centralization of both the CU and DU functions over the next three years, while nearly half (47%) expect partial centralization of just the CU. The results are a significant change from the 2022 survey, in which the top architecture selected was centralization of the CU only (minus the DU), with full centralization ranking second.
- Globally, operator interest in fronthaul connectivity continues to grow. Over three-quarters of operators surveyed (76%) expect at least 25% of their macro cell sites to contain at least some fronthaul functionality within the next three years. For 29% of the survey group, at least half of their macro cell sites will have fronthaul. Although the US has the most aggressive plans for fronthaul, RoW countries also expect significant adoption.
- Packetized fronthaul is on the radar for many operators, but there is unlikely to be a single winning approach to how to transport Common Public Radio Interface (CPRI) traffic. IEEE Radio over Ethernet (RoE), proprietary CPRI-to-eCPRI conversion, and standardized O-RAN CPRI-to-eCPRI conversion options are each being considered by a quarter of respondents over the next 24 months.

Figure 21: Which centralized RAN architecture(s) do you plan to deploy within the next three years (i.e., by the end of 2025)? *(Instructions to the survey respondents: select the top 3)*



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The demands on the transport network to fully support 5G are more complex than in any previous mobile generation, but in 2023, there are clear signs of progress along several fronts. Centralization of the RAN is moving ahead globally along with associated fronthaul connectivity. Meanwhile, network operators are tackling key issues around packetized fronthaul, transport slicing, and network-based timing and synchronization.

RAN centralization continues to be a hot topic within the industry and within mobile operators themselves, and several centralization options exist. Full centralization of the CU and DU baseband components requires fronthaul connectivity with CPRI and eCPRI, but a partial centralization of only the CU function results in a midhaul transport segment handled by Ethernet. Additionally, some mobile operators are choosing to centralize their 4G RANs along with 5G **(see Figure 21)**.

At 59%, the majority of operators surveyed expect full centralization of both the CU and DU functions, and nearly half (47%) expect partial centralization of just the CU. At 20%, a minority of operators surveyed plan to centralize 4G baseband units (BBUs) within the next three years, and just 11% of those surveyed have no plans for centralization.

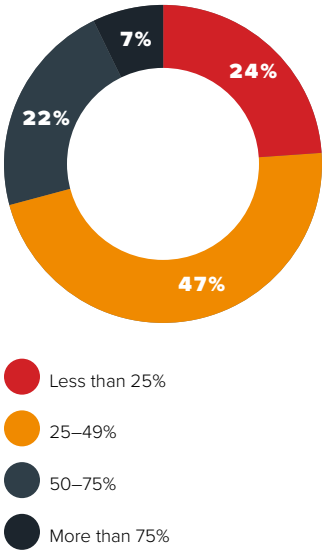
The results are a significant change from 2022, when Heavy Reading asked the same question. In the 2022 survey, the top architecture selected was partial centralization of the CU only, with full centralization ranking second. Complexity of the required fronthaul connectivity has hindered full centralization plans for some operators, so the strong showing in 2023 could indicate a maturation of technology and standards. Full centralization could also indicate increasing expectations for virtualized RANs (including CU and DU functions) down the road.

Lastly, 4G BBU centralization is important for 20% of operators surveyed, but that is down from the 2022 survey. The results indicate that mobile operators are strengthening their focus on 5G moving forward.

As noted, fronthaul connectivity supports centralized RAN architectures in which operators seek the efficiencies that come from pooled CU and DU baseband resources and tight coordination across radios. Fronthaul also introduces stringent latency thresholds and reach restrictions. Globally, operator interest in fronthaul continues to grow. More than three-quarters of operators surveyed (76%) expect at least 25% of their macro cell sites to contain at least some fronthaul functionality within the next three years. For 29% of the survey group, at least half of their macros will have fronthaul **(see Figure 22)**.

RAN centralization plans vary significantly by geographic region, with US operators leading in centralized

Figure 22: What percentage of your 5G macro cell sites are expected to contain at least some fronthaul functionality three years from now (i.e., by the end of 2025)?



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Source: Heavy Reading

RAN interest and deployments to date. Breaking out the data by geography shows that, while interest is growing globally, RoW countries continue to lag behind the US. 35% of RoW operators expect less than 25% of macros to contain some fronthaul by the end of 2025 (vs. just 13% for the US). Still, this means that 65% of RoW operators surveyed anticipate at least 25% of their macros will have fronthaul. The RoW fronthaul expectation represents a modest uptick compared to the survey data from 2022.

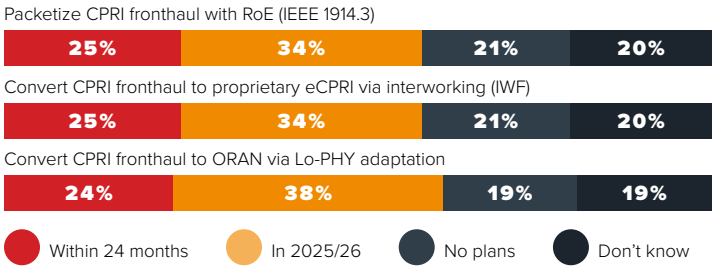
5G transport efficiency is improving significantly through the CPRI Consortium's eCPRI specification. However, CSPs will continue to have massive amounts of legacy CPRI streams since 5G and previous mobile generations (particularly 4G) will coexist in networks for many years. Handling legacy CPRI traffic as 5G emerges is a crucial issue for nearly every mobile operator globally. The current mode of CPRI transport in fronthaul is fiber or wavelength division multiplexing (WDM) overlay, which is the simplest but also the least efficient means of fronthaul transport.

The future mode of CPRI transport is packetized fronthaul, but there are several means to achieve packetization, including IEEE 1914.3 RoE, proprietary CPRI-to-eCPRI conversion, and standardized CPRI-to-eCPRI conversion via O-RAN specifications.

Heavy Reading's 5G Network Strategies Operator Survey data shows that all three options will be used over the next four years and in relatively equal measures. Each packetized option is being considered by a quarter of respondents over the next 24 months. Longer-term (in the 2025 and 2026 timeframe) views diverge slightly. 34% of operator respondents selected both RoE and proprietary CPRI-to-eCPRI conversion for 2025/2026, and slightly more anticipate standardized O-RAN CPRI-to-eCPRI conversion at 38% **(see Figure 23)**.

It is also worth noting that, at roughly 40% of the survey group, a large number of operators either do not know or currently have no plans for packetizing fronthaul. This finding is a reminder that, despite many years of discussing fronthaul and eCPRI, the architecture and the associated protocols are still very new in terms of commercial adoption globally. Although CPRI overlay networks are a suitable early-stage option, the expansion of 5G radios and traffic—combined with virtualization—will require packetizing all fronthaul traffic in the long run. But this migration will take time.

Figure 23: Which approaches to packetized fronthaul are you considering adopting?



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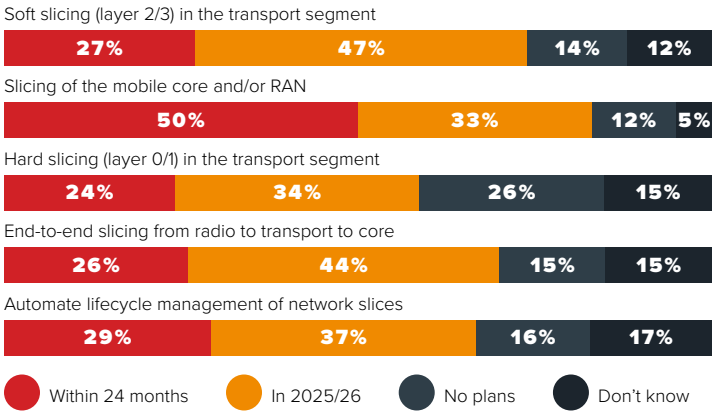
Source: Heavy Reading |

Network slicing is a crucial component of 5G architectures, and transport slicing is required for end-to-end slicing to become a reality. Within transport slicing, there are two broad categories: soft slicing and hard slicing. Each has its own set of advantages and disadvantages, as well as different techniques. To gain a better understanding of network slicing priorities, Heavy Reading asked operators to identify timelines for various slicing approaches **(see Figure 24)**.

Network slicing will occur first in the mobile core and/or RAN, based on the survey results, with 50% of operators expecting adoption within the next 24 months. This is roughly double the percentage of any other option over the same time period. Comparing the results to the same question in the 2022 survey, the trend is unchanged: mobile core/RAN slicing will come well ahead of the transport network.

Figure 24: Which of the following approaches to network slicing is your organization considering?



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Source: Heavy Reading |

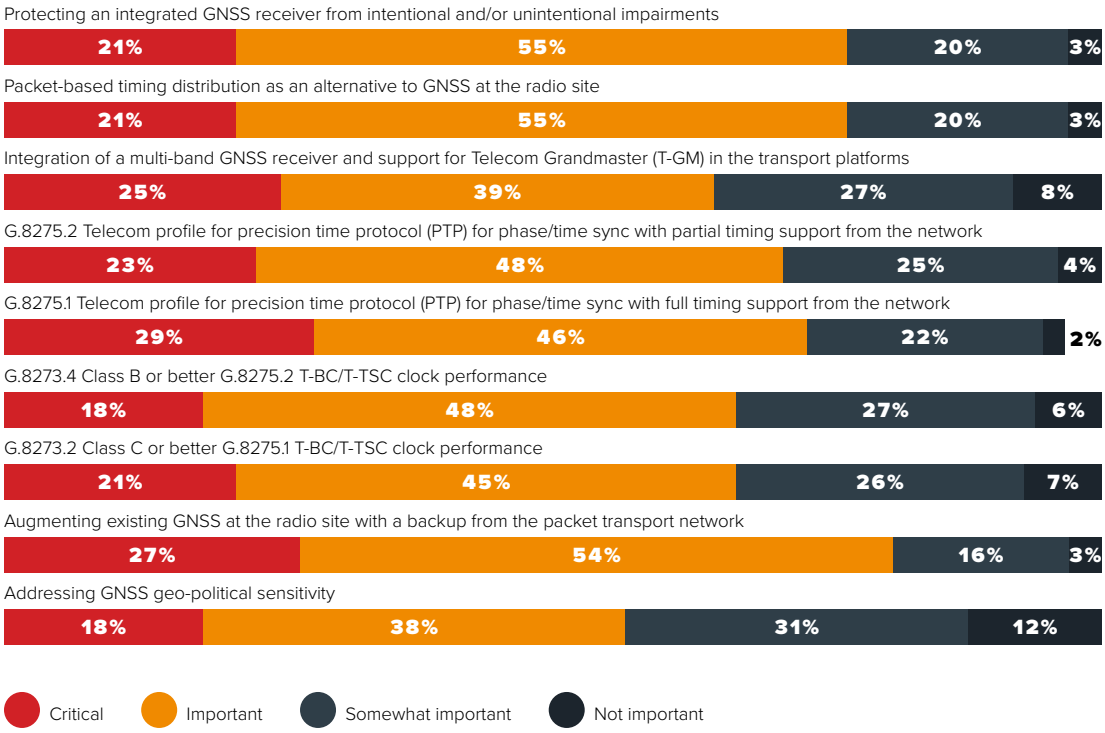
Still, end-to-end slicing remains a longer-term goal for most operators, with 70% of respondents expecting end-to-end slicing by the 2025/2026 timeframe. End-to-end slicing necessitates a sliced transport network, and transport slicing plans are largely aligned with operators' end-to-end slicing timelines, particularly for soft slicing. 74% of operators surveyed expect soft slicing in the transport network by 2025/2026. Past Heavy Reading research shows that hard slicing (using circuit technologies) will be important for specific use cases (such as certain government or financial use cases), but it will not be needed everywhere.

Data from this survey reinforces the earlier research findings. While 58% of operators surveyed expect to have hard slicing in their transport networks by the 2025/2026 timeframe, more than one-quarter (26%) currently have no plans to use hard slicing.

The move from 4G radio technologies to 5G introduces new challenges and requirements in delivering timing and synchronization, including the migration from FDD spectrum to time division duplex (TDD) spectrum, cell site densification, coordinated RAN features, and others. Heavy Reading asked operators to identify the biggest timing and synchronization challenges for their transport network **(see Figure 25)**.

The headline finding is that nearly every aspect of 5G timing and synchronization is a challenge. All nine of the challenges provided were rated either "important" or "critical" by the majority of respondents. At the high end, augmenting existing global navigation satellite systems (GNSS) at the radio site with backup was selected as "important" or "critical" by 81% of respondents, and at the low end, geo-political sensitivity was selected as "important" or "critical" by 56% of the survey group.

Figure 25: How important are the following timing and synchronization requirements/challenges for your 5G transport network?



Notes: n=100
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Looking at challenges rated as "critical," the most significant are the following:

- G.8275.1 telecom profile ("critical" for 29% of respondents)
- Augmenting existing GNSS at the radio site with backup ("critical" for 27%)
- Integration of multi-band GNSS receiver and support for telecom-grand master in the transport platform ("critical" for 25%)

5G Security

Author: Jim Hodges

Research Director, Cloud, and Security, **Heavy Reading**

Key takeaways

The key findings for this section are as follows:

- Although the majority of the mobile operators surveyed agree that they have in place a comprehensive 5G strategy and resources to secure 5G services, they also believe that they face formidable challenges in the implementation process. A top-of-mind concern is the complexity of implementing consistent security and policy management in a hybrid multicloud environment. As a proof point, 83% of respondents believe applying security policy in this environment is either "extremely challenging" (24%) or "challenging" (59%).
- In response, mobile operators are looking for new approaches to help them manage 5G multicloud security challenges. A crucial component of this strategy is the commitment to implement a real-time/on-demand strategy. 90% of these mobile operators believe these capabilities are either "extremely important" (37%) or "important" (53%), which leaves little doubt that a real-time/on-demand-based security strategy represents the path forward.
- Mobile operators are unclear about the business value of deploying add-on security solutions. 40% adopted a positive stance, but the remaining 60% believed it either provided no value (25%) or was unsure (35%) of the value proposition.

In the early phases of 5G network definition, a flurry of standards work was undertaken to create a new security reference architecture to ensure that 5G would be highly secure. This work was driven by the realization that 5G's inherent cloud native and disaggregated core and RAN design philosophy would present new security challenges and broaden the threat landscape.

Years after the initial 5G NSA deployments that utilized the 5G RAN with the 4G core, the mobile industry is now commercializing SA deployments. This approach, which pairs the 5G RAN with the new cloud native 5G SA core, effectively triggers the need for additional security capabilities since it facilitates the implementation of complex sliced-based services while running services in a disaggregated multicloud environment.

This section of the report investigates mobile operators' overall views of their readiness to secure 5G networks, including their commitment to implementing innovative security policies and principles.

To assess overall security readiness, the first question in this section asks the respondents simply whether they agreed or disagreed with several security-related foundational statements.

The overall sentiment captured in **Figure 26** is that most mobile operators believe they are in a good place security-wise. The area with the highest confidence level agreement relates to having the necessary internal 5G resources and skill sets (83%).

The majority of respondents (80%) also agree that automation will be a key element in addressing security chain weaknesses. Rounding out the top four are the belief that their 5G security strategy will support the implementation of zero-trust principles (79%) and even the ability to secure 5G network slices (78%).

Other key foundational security elements are also positive, including supporting the new requirements associated with disaggregated infrastructure (77%) and securing 5G workloads in public clouds (70%). The areas with the lowest level of positive responses ironically relate to having a mature and production-ready 5G strategy (66%), as well as the incorporation of AI/ML into their security stance (65%).

Even though mobile operators believe they are embracing 5G from a position of strength, pragmatically they also accept that security challenges await. One consideration is the complexity of implementing consistent security and policy management in a hybrid multicloud environment.

This is not surprising given 5G is the first mobile generation to implement multicloud service execution. Consequently, as shown in **Figure 27**, 83% of respondents believe applying security policy in a multicloud environment is either "extremely challenging" (24%) or "challenging" (59%). Heavy Reading interprets this input as reinforcing that just as 5G is moving into a new development phase, security must also evolve to address new challenges.

A key consideration in this new security phase is the importance of having a greater level of visibility of events running in a multicloud environment. The conventional thinking is that an effective strategy requires a clear line of sight, which is critical to assess what is happening in a broadening threat landscape. Only with this level of enhanced visibility is it possible to respond by utilizing real-time/on-demand security policy enforcement tools.

The results in **Figure 28** irrefutably confirm that mobile operators believe a real-time/on-demand security strategy is a vital element in managing and mitigating multicloud-related security challenges. As shown in the figure, 90% of all mobile operators believe these capabilities are either "extremely important" (37%) or "important" (53%).

Although these inputs are specifically documented in the context of a multicloud environment, Heavy Reading believes that a real-time/on-demand security strategy is also beneficial for ensuring security in a

Figure 26: Do you agree or disagree with the following statements?

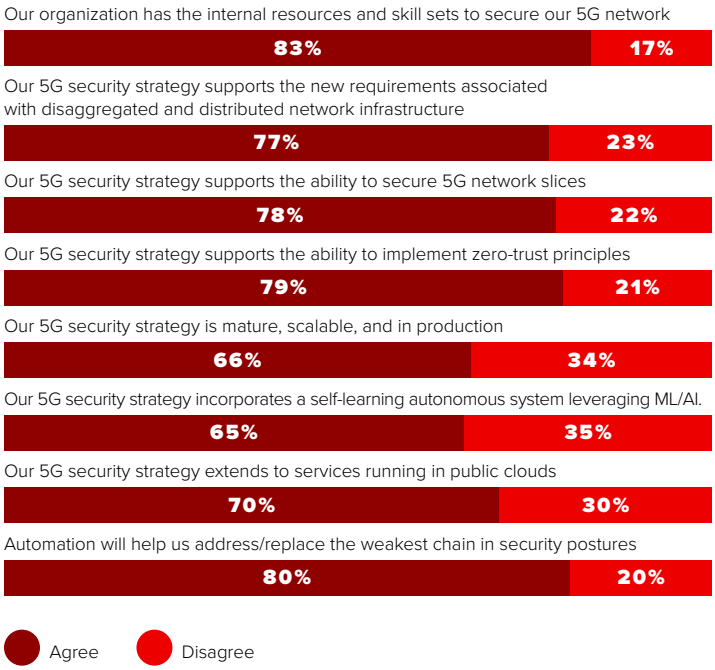

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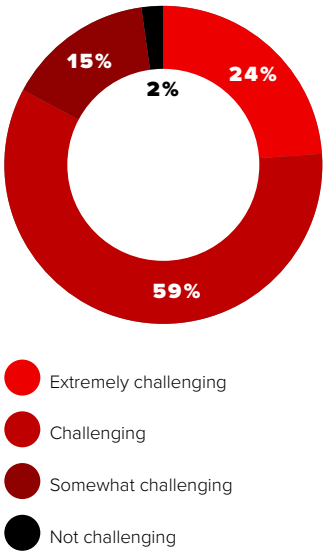
Figure 27: How challenging is it to implement consistent security & policy management in a hybrid multicloud environment?



Notes: n=100
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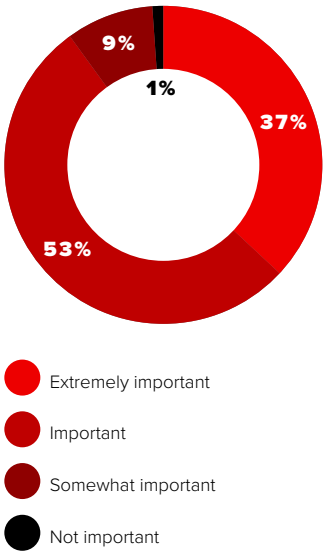
Figure 28: How important is it to have real-time/on-demand security & policy observability in a multicloud environment?



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single private cloud environment. This is because all 5G services utilize a cloud native API exposure design model, which warrants an additional layer of service visibility when the 5G service-based architecture (SBA) core is commercialized.

Service-level visibility is not just a consideration in the live services execution environment; the design cycle must also be addressed. Since 5G adopts a cloud native API model, how services are designed and baselined is different from previous mobile generations. Essentially, 5G cloudifies service design, which mandates the adoption of a cloud-centric service design.

This model relies heavily on the support of CI/CD processes to support the agile initial development or patching of software service code. The execution of these processes relies on a DevOps operational model, which ties together various operational teams so that they interact seamlessly when software changes are pushed out to clients.

While this approach emulates the service agility of the cloud, it also introduces the opportunity for bad actors to integrate threat vectors into the service creation and delivery supply chain. This can have disastrous impacts if malicious code is released. Therefore, mobile operators must always have visibility into their service supply chain to mitigate this risk and ensure that services are fully tested and hardened before commercialization.

To assess mobile operator readiness, the next question in this security section asks survey respondents to assess their ability to utilize DevOps patterns in their CI/CD delivery pipelines to support distributed services hardening.

The results shown in **Figure 29** confirms that many mobile operators believe they are relatively well-positioned to mitigate security risks. The largest group (53%) believes they can support hardening for "most, but not" all distributed services, and the second group (26%) is limited to a "select number" of distributed services.

In contrast, only a very small group (13%) can support hardening for "all" distributed services. Fortunately, the most vulnerable group of mobile operators with "no" service hardening capabilities is also the smallest (8%).

Heavy Reading interprets these results as confirming that many mobile operators have taken important requisite steps to secure their supply chain, but more work is necessary to expand the capabilities to ensure that service hardening is extended to provide 100% coverage.

The final question in this section investigates the business impacts of deploying security products to address the challenges document-

Figure 29: Can your existing CI/CD pipelines with DevOps patterns support distributed services hardening?

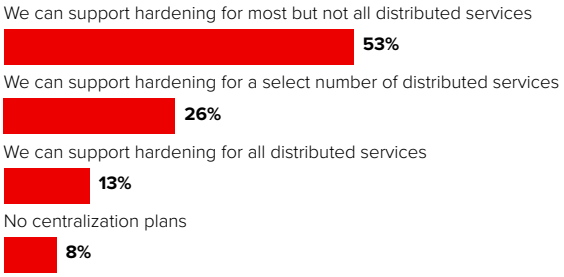

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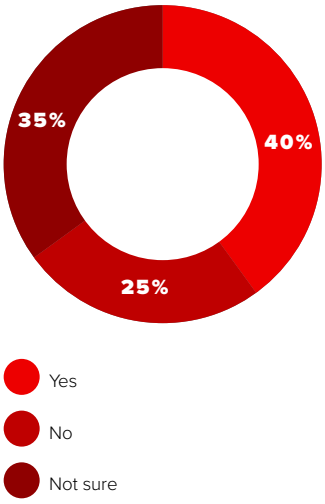
Figure 30: Do expensive security product add ons (not part of the original solution) provide a satisfactory value/impact on the business?



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ed above. Specifically, as captured in **Figure 30**, the survey respondents were asked to comment if grafting another layer of security products beyond the original security platform delivered a satisfactory value/impact from a business perspective.

This question was included in the 5G Network Strategies Operator Survey to assess if the adoption of a "bolt-on" security product strategy often implemented in 3G and 4G mobile networks is still relevant in the 5G cloud native world. The inputs in the figure capture that many mobile operators are unclear about the value of this approach. While 40% answered "yes," the remaining 60% felt there was no value (25%) or they were "not sure" (35%) of the value. These responses confirm that a considerable level of uncertainty exists regarding whether add-on solutions can play a meaningful role in 5G network security.

Heavy Reading believes that although numerous factors are fueling this split, the cost concerns of scaling these adjunct solutions as the cloud transitions into an aggressive scaleup phase is a leading consideration.

Red Hat Summary

You are only as secure as your weakest link. As application environments evolve, security teams are increasingly challenged to keep up with the changing risks, compliance requirements, tools, and architectural changes introduced by these innovations. Traditional perimeter-based networksecurity is no longer effective on its own. Security should be implemented within each layer of the application and infrastructure stack. Automation is a critical part of scaling how the organization addresses security and compliance monitoring.

Red Hat wants to help you have confidence as you adopt a continuous security strategy to maintain security and regulatory compliance, while helping your business remain competitive, flexible, and adaptable. Red Hat provides telco-grade technologies to build, manage, and automate hybrid clouds more securely as part of a layered, defense-in-depth security strategy, and our broad partner ecosystem extends these capabilities even further. You can take advantage of the capabilities at each layer in your environment, including operating systems, container platforms, automation tools, Software-as-a-Service (SaaS) assets, and cloud services. Visit redhat. com/security to learn more about Red Hat's commitment to protecting your environments and the data and privacy of your customers.