Research study 5G-Advanced

Business and technology priorities of Service Providers and Enterprises

NOKIA | Tech Insights

Snapshot

5G-Advanced begins with 3GPP Release 18, with specification to be completed in 2024. In this white paper we provide an overview of the broad trends that are driving Network Evolution through 2030, operator priorities for the deployment of 5G-Advanced based on the results of interviews and an online survey to identify service provider priorities for both business and technology capabilities of 5G-Advanced.

We also provide inputs from interviews with leading edge enterprise executives on their top requirements for 5G-Advanced in the 2024 – 25 timeframe.

This white paper describes the Service Providers' top 4 Business and top 3 Technology/Feature Priorities with the associated key triggers that will drive 5G-Advanced investment and deployment within the next few years.

Executive overview

In April 2021, the 3rd Generation Partnership Project (3GPP) announced that 5G-Advanced would begin with 3GPP Release 18 and continue with subsequent releases 19 and 20. 5G-Advanced represents the second major phase of 5G and will complete the 5G vision and set the stage for 6G around 2030. Release 18 functional freeze is imminent in the first half of 2023, with a protocol freeze in late 2024.

In this white paper we provide an overview of the potential for 5G-Advanced based on global market trends that are described in section 1. 3GPP standards that are responding to those trends and driving network evolution through 2030 are outlined in sections 2 and 3.

In order to identify Communications Service Provider (CSP) priorities for 5G-Advanced capabilities in section 4 we summarize the results of both in depth service provider interviews and an online telecoms executive survey of operator priorities with respect to both business and the technology/feature capabilities of 5G-Advanced and summarize the implications for the deployment of 5G-Advanced. The survey findings indicate that Service Providers' top 4 Business and top 3 Feature/ Technology Priorities are as follows:

Top four CSP business priorities for 5G-Advanced

- Energy Efficiency
- AI/ML and Network Automation
- New and Enhanced Services
- Multi-Access Convergence to a Common 5G SA Core.

Top three feature/technology priorities

- Enhanced RAN and MIMO Performance, Capacity and Reliability
- Beyond Smartphone - 5G IoT devices for Low Latency, Localized Positioning and Low Cost User Equipment (UE)
- Beyond Connectivity - New Applications and Device Driven Use Cases

Specific CSP priorities are described in detail in sections 4.2 and 4.3 and the degree to which they address long term trends is shown in section 4.4. Some gaps in coverage and operator awareness are identified in the remainder of section 4. Since 5G Standalone (SA) is a pre-requisite for 5G-Advanced deployment we review its status in section 5. Note: 5G SA is expected to be deployed commercially by 40% of operators around the world in 2025.

Separately we also interviewed '5G aware' enterprise executives on their top requirements for 5G in the 2024 – 25 timeframe and the implications for service providers are summarized in section 6. And Section 7 summarizes the report's key findings and the major requirements to complete the original NGMN 5G vision by 2025.

Finally in Section 8 we recommend that CSPs pay close attention to the key triggers that will drive 5G-Advanced deployment over the next few years. These are separated into those related to cost savings and those related to revenue generation. We recommend that operators seize new 5G-Advanced opportunities as they are triggered by broader trends. These 5G-Advanced capabilities ae shown in the final figure 51.

Finally, Appendix A reviews the additional role of three key 5G solutions enablers in the 2024 – 25 timeframe. They are: Software Defined Networking, Edge Services and Network Slicing all of which are likely to facilitate complete solutions based on 5G-Advanced features and capabilities.

Introduction

3GPP 5G standard began with Release 15 in December 2017 with specification for 5G new radio (NR) and continued in 2018 with the 4G transitional non-standalone (NSA) architecture. Although Release 16 Stage 2 standalone (SA) cloud native architecture did not arrive until mid 2020 some countries in China and elsewhere in Asia went directly to SA while North America and Europe experimented with 5G SA for small or Private Networks until this year. Building on Release 17 that was completed in mid 2022, 5G-Advanced Release 18 will soon deliver a fully fledged version of key 5G Use Cases for V2X, Symmetrical Uplink, Non-Terrestrial Networks etc. as well as dramatically enhanced massive MIMO, and Intelligent 5G RAN options.

5G-Advanced (5G-A) is the next evolutionary step in 5G technology. It will be specified in 3GPP Release 18 and beyond, including features of improved coverage and capacity, enhanced end-user experience, expanded capabilities beyond connectivity, etc. 5G-Advanced will create a foundation for more demanding applications and a wider range of use cases, such as a truly immersive user experience based on extended reality (XR) features. It will also expand AI/ML capabilities across multiple domains of RAN, Core for improved performance, network optimization, autonomous network operations and energy efficiency.

5G-Advanced begins with Release 18 and will expand 5G capabilities beyond connectivity to complete the full promise of 5G as a lower Cost per Gigabyte (GB), value added service enabler –in the RAN, the Core and for 3rd. Party Apps. 5G-Advanced will continue to be enhanced in Release 19 and beyond and is expected to evolve in parallel with 6G as a bridge into the future 6G era.
See 'Network evolution towards the 6G era'

5G-Advanced - summary of capabilities

As the figure below indicates there are four major areas where 5G-A provides new capabilities. We discuss each of these in turn.

Figure 1. 5G-A provides new coverage and usage areas for expanded and enhanced services

Source: Nokia Webinar '5G-Advanced in 3GPP Rel. 18 Explained' January 2022

5G-Advanced promises multiple new ways to extend coverage and 5G usage and to enhance services.

Coverage and ysage: 5G-A features include: symmetrical Uplink (UL) capacity, Reduced Capability (RedCap) low end or IoT devices, support for Satellite Non-Terrestrial Networking (NTN), Optimized support for Uncrewed Aerial Vehicles (UAVs) and Intelligent User Equipment (UE) as well as Sidelink relay via UEs for instant coverage extension and new use cases.

Expansion beyond connectivity: 5G-A promises new types of very low latency and high reliability communications 'on demand' through dynamic Network Slicing and SDN control (see Appendix A) as well as very high precision location, positioning and timing capabilities that could allow 5G to replace GPS in many applications including indoors

Enhanced experience: 5G-A will offer improved XR and enhanced massive MIMO performance with multiple antennas at both the transmitter and receiver to leverage array technology for very high data transfer speeds often guaranteed by Network Slicing SLAs, as well as new more flexible Mobility Management, Full Duplex capabilities and support for Edge computing.

Operational excellence: 5G-A will leverage Machine Learning (ML) and AI for intelligent network management of both core and multi-antenna systems to support NG-RAN and the new Air Interface. A major aim of 5G-Advanced is to significantly improve 5G network energy efficiency both through RAN enhancements and intelligent management. 5G-A also improves the performance and manageability of repeaters, Integrated Access Backhaul (IAB), Dynamic Spectrum Sharing (DSS) and Network Slicing.

These will all bring enhanced data rates, security, location precision, timing and coverage that are especially important to Private 5G and enterprise users.

Role and importance of 5G-Advanced in 2024-2025 timeframe

5G Standalone (SA) is an essential pre-requisite for 5G-Advanced that is designed not only to accelerate new 5G service revenues but also to reduce both RAN cost per GB and operations expense. 5G SA is expected to be widely available as a fully commercial service in many areas by late 2024 and 2025. As a result the advent of 5G-Advanced features should further accelerate 5G SA deployment by CSPs who need to leverage all the new 5G-A features. By 2024/25 Operators are expected to be very focused on 5G as a major generator of new revenue growth and should be fully ready to exploit 5G SA core capabilities.

One of the earliest new revenues sources has been Edge Services - that began with LTE but need 5G SA's fully distributed secure, compute architecture to scale cost effectively in the two to three year timeframe. In addition to attract 3rd. party Apps. for vertical market services, Communications Service Providers (CSPs) must offer fully compliant Northbound Open APIs for those services and even 'Network as Code' to leverage the panoply of new 5G-Advanced features.

Similarly while Software Defined Networking (SDN) and Bandwidth on Demand have been available for several years they can become major revenue generators as 5G SA and Dynamic Network Slicing arrives with 5G-A (See Appendix A).

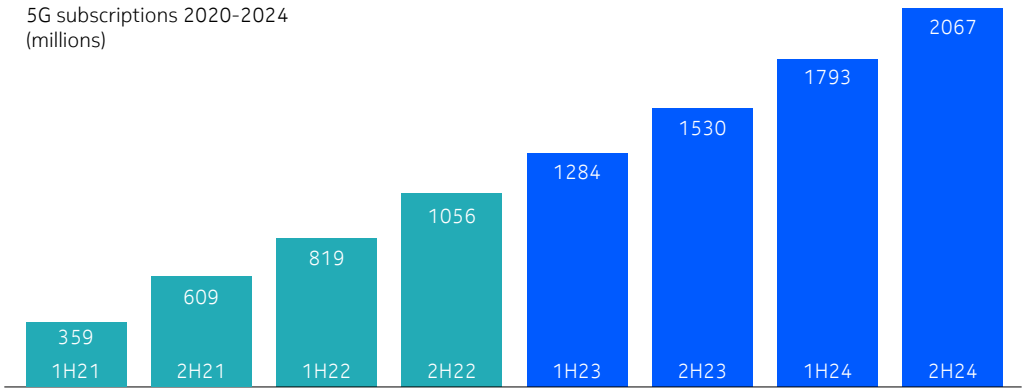
We also expect 5G-Advanced to enhance the CSP's B2B 'Sweet Spot' of Multi-Access transport connectivity over Carrier Ethernet, WiFi or Broadband Wireless to a common 5G SA Core or to deliver managed Network as a Service (NaaS).

Global trends

The 5G market is currently on a rapid adoption curve, fuelled in part by the meteoric rise of the 5G smartphone - two-thirds of smartphones sold in 2023 will support 5G. The basic smartphone dominates 5G service adoption and lifts 5G from 12% of global subscriptions in 2022 to 23% in 2024.

While operators are enjoying modest revenue uplift from this technology transition, new and innovative enterprise and consumer use cases are still proving their value in more focused small-scale deployments. Momentum is currently building for 5G SA network deployments and service innovations. As of January 2023 GSA counted 112 operators that are investing in 5G SA deployment plans. At the same time, operators need to evaluate the role of network features beyond Release 16 to support value creation and respond to the global socio-economic and technological changes that will shape the 2nd. half of this decade.

Figure 2: 5G Subscriber Forecasts through mid-2024



Source: TechInsights, Service Provider Strategies

Eight global trends that are driving 5G-Advanced

We have identified eight global trends that will influence strategies adopted by network operators in the 5G-Advanced era. These can be mapped to the drivers for 5G-Advanced as shown in the figure below.

Figure 3: Global trends that will shape the 5G-Advanced era

8 Key trend domains	15 Key trends in the 4G-Advanced era
1. Population change	I. Working from anywhere and rural migration
2. Flexible living and working	II. Gig economy and flexible working
	III. Sharing economy
3. Efficient economies and societies	IV. Smarter healthcare
	V. Metaverse
	VI. Spatial internet
4. Net zero	VII. Environmental handprint
	VIII. Environmental footprint
5. Geo-political friction	IX. Technology sovereignty
6. Device diversity	X. Beyond smartphones
	XI. Dedicated devices for verticals
7. Network evolution and efficiency	XII. Network modernisation
	XIII. Cloud intelligence
8. 3GPP's future role	XIV. Edge cloud
	XV. Road to 5G

Sources: TechInsights, Service Provider Strategies

This paper is not the place for a detailed assessment of the dynamics in all of the trend domains shown above. Below, however we provide a summary of the key factors and change agents for the eight broad global trends that will all influence network choices through 2030.

Eight Global Trends that are driving 5G-Advanced

1. Population Change: Population distribution will be impacted by urbanization and pandemic-fuelled rural migration in developed economies, with international migration (economic, political, and climate-driven) the main source of population growth in high-income countries. Ageing populations will have a major influence on societal priorities, including the delivery of and access to healthcare, 'digitized' public services and private consumption.

2. Flexible Living and Working: Covid-19 has accelerated working from home and flexible working patterns, leading to permanent shifts in workforce participation. The 'Gig economy', temporary and remote freelance work are increasingly important for post-Gen X generations, requiring reliable and high quality connectivity everywhere. Digital platforms will improve access to public and private services for vulnerable populations, while economic and social efficiencies will emerge from the sharing and subscription economy through better resource allocation and more cost control.

3. Efficient Economies & Societies: Digital engagement is changing business practices today and brand engagement strategies will continue to evolve as a part of the social media evolution to the metaverse. Spatial Internet/Web 3.0 and digital twins will be a growing part of business processes and socio-economic interactions. The increased use of telemedicine during Covid-19 will be sustained and healthcare will take growing share of GDP in many countries that will drive a higher priority for lower-cost smarter remote care and support of ageing populations.

4. Net Zero: Environmental factors will continue to have an increasing influence on business processes and consumer purchase decisions. However, the de-carbonization of industrial processes will take decades; AI, spatial Internet, Industry 4.0 digitisation are all key enablers here. CSPs want 'carbon handprint' wins to accompany their Environmental, Social, and Governance. (ESG) goals of moving towards carbon neutral network operations , while recognizing the need to meet business customers' Scope 3 carbon reduction plans. Many consumers will stop trading with businesses that do not have a plan to tackle climate change. For CSPs this will be an important driver for Network Modernization (See 7 below).

5. Geo-Political Friction: Technology sovereignty is a growing political movement with wide-ranging implications for technology roadmaps, its influence felt through data residency to chipset/component supply and secure network vendors. Current geo-political hotspots may resolve in the medium term, but will likely be replaced by others and geo-political tensions involving Russia, China, USA, and EU will remain after 2025. Each region/country is vying for leadership or influence across 5G, AI, blockchain, cybersecurity, cloud, etc.

6. Device Diversity: Smartphones dominate 4G/5G mobile networks today but value growth from 'traditional' mobile services remains very limited and CSPs are putting significant focus on enterprise markets for medium term growth. The 5G IoT market will accelerate from 2025 as dedicated chipset and module markets mature and address discrete verticals. New IoT and Reduced Capacity (RedCap) devices as well as special factory and hospital User Equipment (UE) will leverage those new components and become catalysts for CSP revenue growth. Going forward new kinds of intelligent UE and Video immersion devices will supplement the smartphone e.g. XR headsets to stimulate new service revenues. In the mass market, a device revolution beyond the smartphone will unlock greater opportunities for multi-device value generation for 5G operators.

7. Network Evolution and Efficiency: Multiple challenges remain for networks built to meet market needs as they emerge in 2025-30. These include the seven challenges described in the report 'Next Gen. Networks must meet seven key challenges to deliver IoT Services, Security, FMC, Cloud, Network Slices, 5G and Bursty Video' that cannot be resolved simply with additional bandwidth/ compute capacity and require network modernisation involving improved algorithms and new architectures. Incremental improvements in energy efficiency may also be inadequate.

While many network operators are worried about energy consumption in 2023 and beyond and are targeting carbon-neutral networks (Scope 1 & 2) between 2025 and 2035, the enormous growth in cloud computing data centers could in some industrialized countries consume as much as "27% of national electricity output by 2029". Radical rethinking is required for next generation compute platforms e.g. inter and intra-chip Terahertz communication with Graphene as well as new data center cooling techniques etc. could be critical to prevent the broadband Cloud from itself triggering a climate crisis.

8. 3GPP's Future Role: 5G-Advanced will co-exist with, rather than supersede, wireline and other standardized wireless technologies, with Wi-Fi's evolution in particular representing a strong campus/local network alternative. CSP Edge services need to become a major 3GPP network focus. Edge-native use cases will expand in compute-intensive domains such as AR/VR/MR and closed-loop autonomous systems. 5G-A is an important step on the road to 6G and can support many early '6G use cases', but there is still significant work to be done to define 6G and complete what is still missing in 5G.

Implications for operators through 2030

Operators need to adapt their networks to support these major social, business, and technological changes through 2030. Social and business transformations are driving the value of automated, intelligent, interactive, real-time service experiences. Specifically:

- Consumer market is evolving to XR and the emerging Metaverse, which is pushing businesses and governments to engage digitally with them at extremely high speeds, in many locations on very diverse platforms of the end user's choice that range from smartphones to video headsets, smart glasses, health sensors and many devices that have yet to be invented.
- Business is evolving its digital transformation to leverage Industry 4.0 for manufacturing, with very low latency, ubiquitous remote access and intelligent mobile communications with cars, trains and drones as well as interactive applications for smart city and transport infrastructure etc.. These all demand highly variable on demand bandwidth for fixed and mobile devices and end users which must also meet strict de-carbonization and energy efficiency targets.

Below in Section 4 – see figure 12 and following – our survey of the top business and technology drivers indicates that operators are not only focused on adding new services like XR/Gaming and B2B digital services but also simultaneously concerned about handling massive 5G and Next Generation Network scalability, coverage and complexity as they seek to reduce energy and operations costs through the adoption of AI/ML and RAN optimization.

5G-Advanced will help operators to address these challenges as it brings improvements in downlink and uplink capacity, with lower latency and broader coverage -all important to meet diverse market requirements. In the longer term 'Green 5G' and intelligent RAN and Cloud networks will be critical to support exciting new B2C consumer and B2B services that will both enhance CSP profitability and meet customer expectations.

Descriptions of 15 trends for the 5G-Advanced era

5G-Advanced needs to address the fifteen specific trends shown in figure 3 above. Below are summary descriptions for each of these trends.

Working from anywhere and rural migration
As working from home (WFH) becomes an option – especially for white collar employees - migration away from population centers is a growing trend. Over 10% of US workers have either moved or are considering moving as a result of WFH flexibility. Evidence includes:

- 'Doughnut effect' visible already in some US cities in through migration to suburbs
- Rural migration delivering lifestyle gains and pressure on high-speed connectivity expansion

Gig eEconomy and flexible working
Flexible working patterns will not only fuel the Working from Home/Anywhere trend but also broader workforce trends embracing lifelong learning & skill 're-tooling' and an increase in gig economy and freelance employment

- Businesses need cost reduction/flexibility to support growth in outsourcing and talent recruitment that will encompass gig work and offshoring (or nearshoring where supply chain or cultural factors)

Sharing economy
Sharing economy maximizes the utilization of idle resources (vehicles, premises, savings, food, etc.) for both cost and environmental benefits

- Car sharing revenue to increase 1.6x by end of decade

Smarter healthcare
Smart technologies will boost access healthcare from remote consultations to proactive healthcare with wearables, AI-driven diagnostics, and smart hospital management. The bump in telemedicine experience during the Covid-19 pandemic is likely to stay in place and accelerate steadily during this entire decade

Metaverse
Plans are underway for a multi-dimensional immersive Metaverse that could enable large scale consumer or enterprise virtual, augmented & mixed reality by 2024 – 2025. Metaverse will generate significant enterprise spend in 2025-30 and will emerge as important brand platform for customer engagement, though modest (ad-driven) service revenue. (Metaverse Quote from Meta) "will require a step-change enhancement to today's overall network architecture. It will need .....a ubiquitous end-to-end QoS management strategy at every segment of its networks, as well as at every application/network protocol layer vertically (i.e., from the application layer at the top of the stack to the OS layer at the bottom of the stack)."

Spatial internet
Spatial Internet is the 'mirror image' of a Metaverse that creates a digital representation fully anchored in the real world i.e. a 3D computing environment that pairs virtual and real spaces using inputs from connected devices, smart objects, and sensors. Key use cases in 2025-30 will center on Digital Twins, combining data analytics, AI and real world inputs to produce 3D models that can be used to monitor and optimize processes across IoT, Smart Manufacturing/Industry 4.0, Smart Cities, Healthcare, etc.

Environmental handprint
Carbon handprint recognizes actions that have a positive impact on the climate i.e. Processes that absorb carbon – re planting forests, carbon removal from air

Environmental footprint
Carbon footprint is the total amount of greenhouse gases (including carbon dioxide and methane) that are generated by our actions. 'Net Zero' is a Footprint Target

Technology sovereignty
Anti-Globalization movements and countries desire for national control of key technologies is driving a move for Technology Sovereignty that could move traditional IPR control from corporations and patent holders to political entities. This process could fragment or slow global network technology evolution in 2025 – 2030.

Beyond smartphones
Alongside smartphones a broad range of consumer equipment (CE) & connected and computing device categories with embedded cellular connectivity will emerge.

Dedicated devices for verticals
By 2030 growth in IoT/ mMTC connections as well as new intelligent User Equipment (UE) and End User Headsets/Terminals will lead to a plethora of new devices that are optimized for vertical markets and unique applications.

Network modernization
Despite the dramatic growth in bandwidth and network capacity many networking problems still need to be addressed with more modern approaches. TechInsights has identified seven key networking challenges including generic capabilities - Security and Bursty Traffic Optimization as well as the specific requirements for IoT Services, Fixed Mobile Convergence, Cloud, Network Slicing, 5G and 4K Mobile Video create significant challenges that cannot be addressed at scale today.

Cloud intelligence
Cloud Intelligence leverages multiple types of Cloud Hosted/Server Based Applications – On-Premise, IaaS, CaaS. PaaS, SaaS. CSPs can complement Hyperscaler Cloud Providers (HCPs) B2B Services with Platform as a Service (PaaS) and add connectivity for intelligent Applications including AI in the 'Edge Cloud' or with 'Network as a Service' (NaaS) for MVNOs, other CSPs and HCPs

Edge cloud
Edge services and Edge Cloud include distributed processing and load management for storage and processing. This is a key enabler for Industry 4.0 and has implications for public Metro area network design and resource management based on 5G SA architecture. 3GPP Re. 18 Enables Edge Ecosystem for RAN P2P, Media Distribution, Dynamic Uplink Control and Backhaul optimisation.

Road to 6G
Although 5G-Advanced Release 18 partially sets the stage for 6G, the exact roadmap is not yet determined and is beyond the scope of this report.

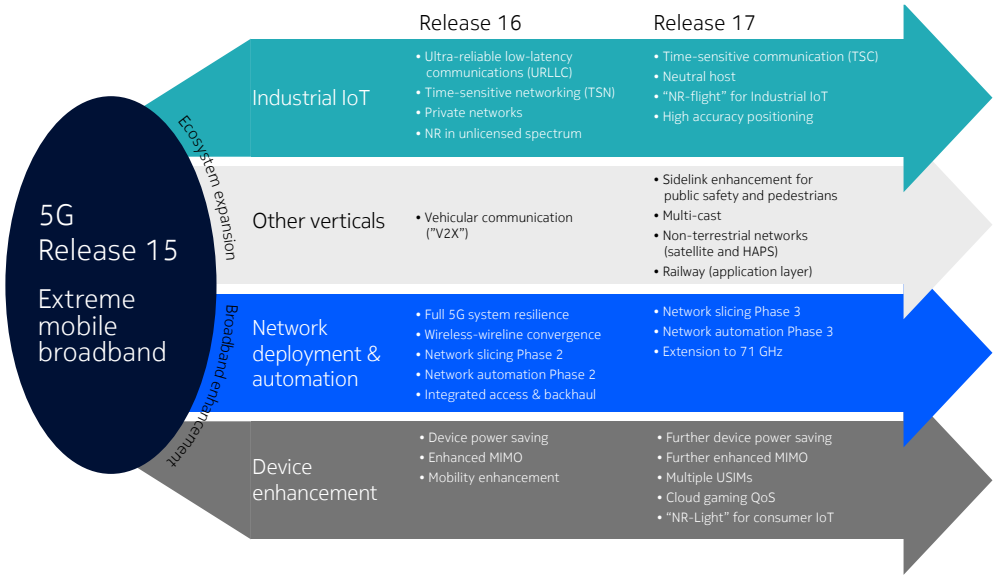
5G-Advanced standards evolution

The initial 5G standardization began with 5G NR in 2017. Since then, 3GPP has completed three major releases for 5G NR system, i.e., Release 15, 16, and 17. Release 15, as the first 5G standard release, was delivered in three distinct steps:

- 'Early' Drop contained Non Standalone (NSA) 5G specifications;
- 'Main' Drop contained Standalone (SA) 5G;
- 'Late' Drop contained additional migration architectures.

Releases 16 and 17 continued to improve 5G system capabilities while expanding 5G into new devices, applications, and deployments. As pointed out by Nokia Whitepaper, Release 16 and 17 "are not just about incremental improvements to the performance of Release 15" rather, they "are primarily about expanding the ecosystem that can take advantage of 5G, by adding features to provide the full range of functionality required by new industry segments, as well as making 5G networks easier to deploy and optimize." The figure below summarizes the key themes of Release 16 and 17.

Figure 4 Key themes of current 5G NR Release 16 and Release 17

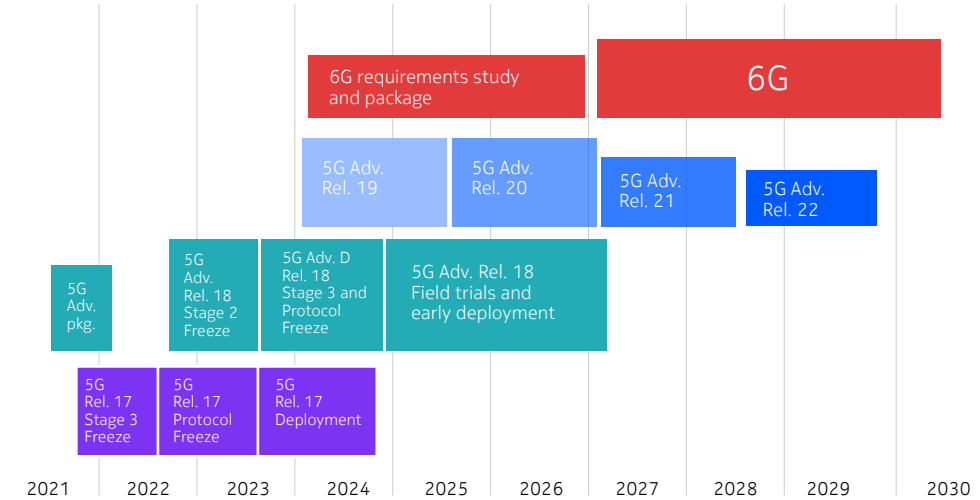


Source: Nokia '5G Releases 16 and 17' April 2020

In April 2021, 3GPP officially adopted the 5G-Advanced (5G-A) Content Package' as the new marker for 5G Evolution. This new marker will be used starting with 3GPP Release 18. From late June to early July 2021, 3GPP RAN held an internal workshop on the radio-specific content of Release 18 to identify topics for immediate and longer-term commercial needs. By December 2021, the content of Release 18 was largely decided.

The Stage 2 functional freeze for Release 18 is expected in Q2 2023, the Stage 3 and initial protocol freeze in early 2024 – see figure below. As the figure indicates there are parallel enhancements and deployment of Release 17 in the same timeframe – including early versions of Sidelink and more precise location options. 5G-Advanced will be significantly enhanced in Releases 19 and 20. 6G requirements that hope to build on 5G-Advanced are evolving in parallel in 2024 through 2026.

Figure 5 3GPP's 5G Standards Evolution Timeline



Source: 3GPP, TechInsights, Networks and Service Platforms

5G-Advanced kicks off the second wave of 5G innovations and is expected to strengthen the 5G system foundation with improved speed, coverage, mobility, and power efficiency. 5G-Advanced also aims to bring 5G to virtually all devices, deployments, and use cases. 5G NR Release 18 will be a foundation for longer-term R&D for the 5G vision and lead to the evolution toward 5G NR Release 19, 20, and eventually the 6G. 5G-Advanced is expected to offer improved experience for people and machines, extensions for new use cases, and expansions to offer new services beyond pure communication, according to Nokia 5G-Advanced Whitepaper.

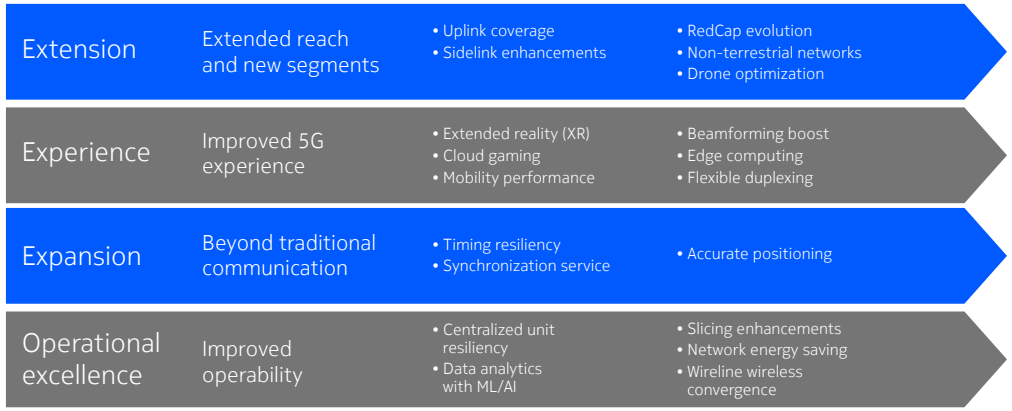
The Domain of Enhanced Experience aims to lift 5G end-user experience to the next level, including better support for eXtended Reality (XR); enhancement techniques include further development of massive MIMO, and improvements in mobility and flexible duplexing are envisioned.

The Extensions Domain aims to extend the reach of 5G connectivity and to make it available to new market segments; including innovations for improved coverage, enhanced low-cost massive IoT, and further support for Non-Terrestrial Networks (NTN) and drones.

The Expansions Domain targets the expansion of 5G services beyond traditional communication by introducing enhanced positioning with sub-10cm accuracy consistently both indoors and outdoors, as well as time synchronization as a service, offering valuable benefits for use cases as diverse as smart power grid control, industrial automation, and real-time financial transactions.

5G-Advanced will be powered by Operational Excellence that aims to enhance and optimize the 5G platform and its operation by the gradual introduction of Artificial Intelligence (AI) and Machine Learning (ML) enablers, network slicing enhancements, wireline, and wireless convergence, network coordination and energy efficiency enhancements. Energy efficiency improvements for both the network infrastructure and the devices will be in focus. These operational enhancements should ensure highly efficient network operation at affordable operational expense (OPEX) so that 5G-Advanced can efficiently serve a larger number of services with diverse QoS requirements. The figure below summarizes 5G-Advanced domains and related candidate features.

Figure 6 Summary of 5G-Advanced domains and related candidate features



Source: Nokia '5G-Advanced: Expanding 5G for the connected world 2022'

5G-Advanced will continue to evolve in Release 19 and beyond. 3GPP SA1 Working Group (Service Requirements) has started discussing requirements for new services of Release 19. The latest list of 3GPP SA1 study items is shown in the figure below. Schedule dates for Release 19 will be discussed in March 2023 and finalized at workshops in June 2023.

Figure 8 3GPP SA1 Service related Study Items for Release 19

SA1 Rel. 19 studies

New features

- Study on integrated sensing and communication (FS_Sensing)
- Study on ambient power-enabled Internet of Things (FS_Ambient IoT)
- Study on localized mobile metaverse servces (FS_Metaverse)
- Study on roaming value added services (FS_RVAS)

Enhancements

- Study on energy effieciency as service criteria (FS_EnergyServ)
- Study on upper layer traffic steering, switching and split over dual 3GPP access (FS_DualSteer)
- Study on AI/ML model transfer_phase2 (FS_AIML_MT_Ph2)
- Study on network sharing aspects (FS_NetShare)

Verticals + NTN focused

- Study on network of service robots with ambient intelligence (FS_SOBOT)
- Study on satellite access - phase 3 (FS_5GSAT_Ph3)
- Study on FRMCS - phase 5 (FS_FRMCS_Ph5)

Cont. Rel. 18: Study on supporting of railway smart station services (FS_RAILSS)

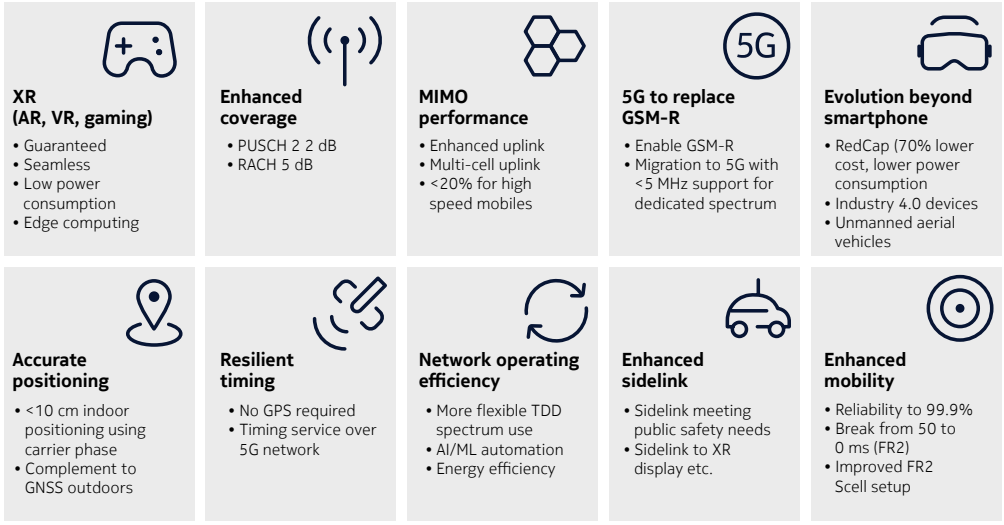
Source: ATIS Webinar 3GPP Release 18 Overview: A World of 5G-Advanced

The key performance indicators (KPIs) of 5G/5G-Advanced, such as data rate/ throughput/capacity, latency, reliability, scale and flexibility, will continue to be important measures for 6G performance. Key technologies in the 5G-Advanced system, such as AI/ML based networks and services, will play a growing role in the 6G system. Technical expertise, IPRs, operation experience, etc. obtained from 5G-Advanced will be critical for 6G success in 2029 and 2030.

Roadmap for 5G-Advanced release 18

The chart below indicates how Release 18 will proliferate new features and Technology to multiple UEs/devices across multiple applications and use cases as it enhances coverage, improves mobility and over the air performance.

Figure 9 Ten areas of feature/technology enhancements on the roadmap for 5G-Advanced



Source: Nokia Webinar '5G-Advanced in 3GPP Rel. 18 Explained' January 2022

As noted in Section 2 Release 18 is the first of several 5G-Advanced Releases and 3GPP has issued some early indications for Release 19 Services as shown in figure 5 above. Figures 10 and 11 below provide a summary of the wide range of agreed new features and capabilities in Release 18 for RAN and Services respectively.

Figure 10 RAN enhancements in Rel-18 package as approved by TSG RAN#94e1

RAN1 led items	RAN2 led items	RAN3 led items
• Uplink coverage enhancements • MIMO enhancements • Evolution of duplex operation (study) • RedCap evolution • Sidelink enhancements • Enhanced positioning • AI/ML for air interface (study) • Network energy saving • Network-controlled repeater • Wake-up signal (study) • Carrier aggregation enhancements • Dynamic spectrum sharing (DSS) enh.	• Enhancements for XR • Mobility enhancements • Enhanced NTN • NTN IoT • NR support for UAV (drones) • Multiple SIM enhancements • Evolution for broadcast and multicast • Sidelink relay • In-device co-existence (IDC) enh. • Small data transmission (SDT)	• AI/ML for NG-RAN • SON/MDT enhancements • QoE enhancements • Mobile IAB • gNB-CU resiliency (study on scenarios only) **RAN4 led items** • Support for dedicated spectrum less than 5 MHz • More to be decided in March 2022

Source: Nokia Webinar '5G-Advanced in 3GPP Rel. 18 Explained' January 2022

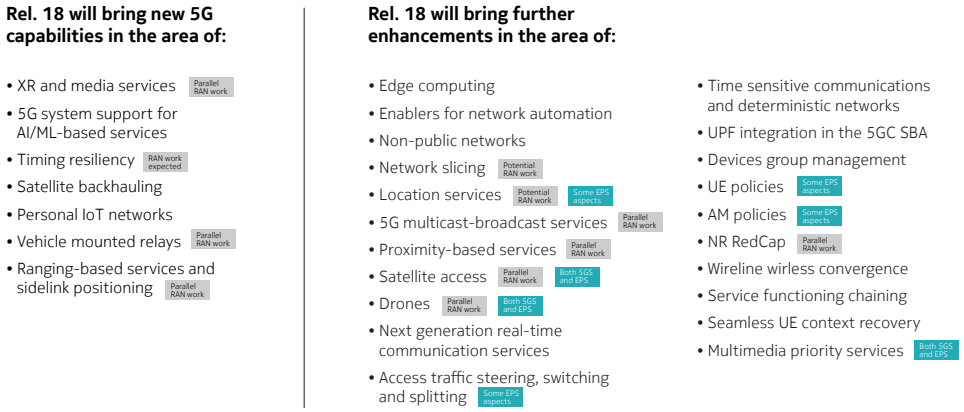
The list covers a wide range and while some items will be high priority for almost all CSPs i.e. MIMO Enhancements, Network Energy Savings, Enhancements for XR and Mobility and AI/ML for NG-RAN, others will be primarily of interest for specialized applications - at least initially.

Similarly for the services under discussion in SA 2 – shown in figure 8 below - many broad horizontal market opportunities such as XR and media services, Edge Computing, Non Public Networks (NPN), Network Slicing and 5G multicast/ broadcast as well as Wireline Wireless convergence and real time communications will attract immediate attention from CSPs around the world, while others like Sidelink and Personal IoT may appeal at first only to 'niche' markets or specific vertical industries.

As a result the timing of deployment and the revenue impact of the diverse range of Release 18 services will vary widely between 2024 and 2027.

Nonetheless, going forward we expect to see increasing CSP focus on the new services that 5G-Advanced enables, as the operators expand their 2023 - 2025 commercial rollout of truly Cloud Native 5G Standalone (SA) and refocus on the original NGMN Value Added vison for 5G services and the revenue growth those services can generate. See Section 6 for an update on the status of 5G SA commercial deployment.

Figure 11 SA2 Rel-18 Service Capabilities package approved in December 2021



Source: Nokia Webinar '5G-Advanced in 3GPP Rel. 18 Explained' January 2022

Evolution of services in Release 18 will leverage key enablers

While services providers always announce that their primary goal progress on creating new high value 5G services has been slow this will be an important focus as ARPU continues to fall in the 2024 -25 timeframe. While they are not uniquely part of 5G-Advanced, three key 5G Solution Enablers are needed to complete the 5G services vision and generate revenue growth with improved margins by 2025. The three are:

- Software Defined Networking (SDN)
- Edge Compute
- Network Slicing.

For 5G-Advanced SDN will bring increasing control of Enterprise bandwidth and service provider feature options in conjunction with Open APIs for trusted 3rd. parties; Edge Cloud which is already growing is expected to take off as 5G-Advanced capabilities demand increased processing and storage at the Edge; and Network Slicing that has long been touted as the 'killer App.' service for 5G revenue growth and after years of disappointment should finally come into its own as a manageable on demand service with dynamic slice assignment in Release 18.

Some specific examples of 5G-Advanced features that can leverage these three Solution Enablers to create new services include:

SDN to enable:
- Uplink bandwidth expansion
- Two-way Interactive Video on demand
- On Demand Non-Terrestrial Network (NTN) Uplink to satellite

Edge Compute for:
- Fast, secure, low latency IoT device responses
- Very precise Timing and Positioning Services
- XR for Gaming
- End User Line of sight Uncrewed Aerial Vehicle (UAV) control
- NR Duplex management with Edge Server backup

Network Slicing to support:
- Seamless, Secure, Private Enterprise VPNs across Fixed and Mobile Access
- Optimized Slice Selection e.g., for Telemedicine,
- With End to End (E2E) Mobility Management across multiple private and public domains
- Intelligent User Equipment (UE) that requests class of service for diverse Apps.

See Appendix A for more details on all three of these Solution Enablers.

Survey research reveals 7 key service provider drivers for 5G-Advanced adoption

TechInsights has recently completed:

- In-depth interviews with 16 service providers that were specially recruited
- Online multi-choice survey of a standing panel of 40 senior telecoms executives

Both types of primary research included regional and global CSPs and Cable operators from different parts of the world. The online survey included:

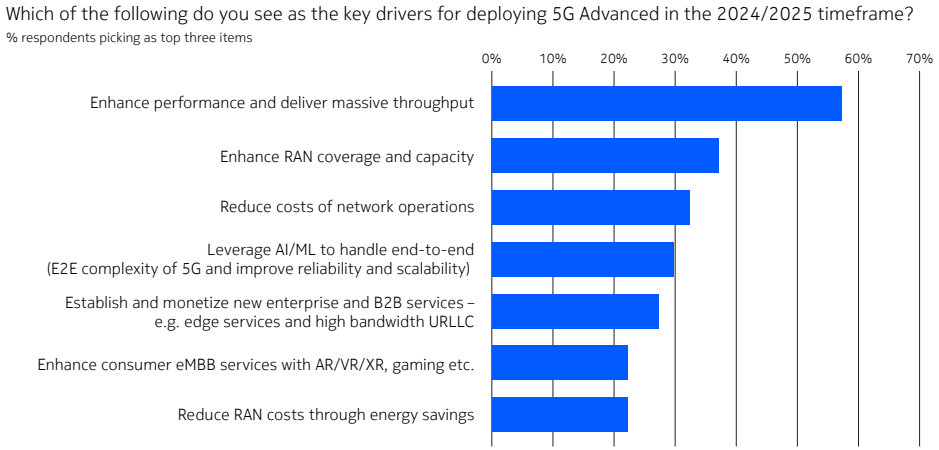
- 42.5% Service Providers from Europe, 27.5% from the Americas, 25% from Asia Pacific and 5% from Africa.
- 30% of respondents were Mobile Operators and 60% Converged Mobile and Fixed Operators.

In the section below statistical results from the online survey are shown as charts and quotations from the In Depth Interviews (IDIs) are shown multi-column figures with all quotes anonymized.

Key drivers for 5G-Advanced deployment

To establish the context for the online survey we asked a preliminary question about the overall and business drivers for deploying 5G-Advanced. The figure below shows the service providers desire to enhance Performance, Coverage and Capacity closely followed by their focus on Reducing the Cost of Network operations. In the next section we examine each of the specific Business and Feature/Technology drivers in turn.

Figure 12. Overall drivers for deployment of 5G-Advanced in the 2024 – 2025 timeframe



Source: TechInsights Online Survey

Interestingly the figure above shows that for deployment decisions operators are more realistic about their core connectivity value and the need to handle 5G complexity and scalability. They want to add B2B and XR/Gaming services but those are less important for deployment decisions than AI/ML to handle complexity and improve reliability and scalability and Edge B2B service monetization. Although RAN energy savings were only selected by 23% of respondents, they will play a key role in deployment timing as they are highly correlated the number two ranked objective of enhancing RAN Coverage and Capacity.

Below we provide select quotes from our in depth interviews on what is driving operator decisions from a similar question that was posed to a completely different set of respondents. While these quotes do not have the statistical significance of the online survey rankings above, they indicate operators' key objectives and concerns in different regions.

Figure 13 Operator comments on their top 3 business drivers

Topic	Key highlights by region	Key quotes for North America and Europe	Key quotes for China and SE Asia
Top 3 drivers for 5G-Advanced	North American and European operators offered broad generic responses on the need for performance and cost savings as well as top application requirements.	"It's a lot about optimisation and efficiency." "Three drivers are: 1. Enhancement of network performance to support increasing eMBB traffic; 2. Meeting future new service demands, e.g. XR applications; 3. Exploring new market opportunities e.g. as full-duplex to lower latency, passive IoT for ultra-low cost to IoT, joint communication and sensing (JCAS) for industrial apps." "Improving network performance is the dominant driver for us. First our main use case is Enhanced Mobile Broadband where 5GA could help us deploy services that demand low latency and also those applications and services that are very demanding of Uplink. Second is industrial IoT with ultra-low latency communication, high durability."	"First thing is gtting into the business case. We are betting heavily on healthcare and petrochemical industry." "First enhance 5G Rel. 16 and 17 performance and then enhance RAN coverage, capacity and management and next establish and monetize new enterprise and B2B services - expecially Edge services and dynamic network slicing. And at the same time reduce network operations costs." "Enhance 5G Rel 16 and 17 performance and enhance RAN coverage, capacity and management then establish and monetize new enterprise and B2B services - especially Edge services and dynamic network slicing and finally enhance generic consumer eMBB services with XR, gaming etc."

Chinese and S.E Asian operators focus is on Performance, RAN coverage and new B2B services for Healthcare and Petrochemical industries but all operators agree on the importance not only of Performance but also of consumer eMBB and XR applications opportunities as well as IoT. Similarly the operators indicated that the broad drivers for their network evolution are Performance, Coverage and Capacity .

The quotations from the next interview question below also indicate that AI, RAN management and Energy Efficiency are very important as ways to scale the network without proportional cost increases.

Figure 14 General Drivers for 2023-25 network evolution and expectations from 5G-Advanced

Topic	Key highlights by region	Key quotes for North America and Europe	Key quotes for China and SE Asia
General drivers for 2023-25 network evolution	Many operators were not sure how to answer this question but those in Europe that did focused on AI to handle capacity increases and three Asian operators focused heavily on RAN management for enhanced services	"We are focusing on AI coverage, energy consumption and so on." "No doubt that in 2024-2025 we will have much more traffic than today." "In the 2025 time frame, mainly those things which are helping us to roll out our standalone network more easily and more cost effectively."	"New and enhanced services with RAN performance (real time) and smart RAN management as well as energy savings and power control."

As the figure above indicates operators will focus in the 2023 – 25 timeframe on more RAN automation and AI capabilities to facilitate cost savings in order to deliver of the promise of new 5G SA based services.

Similarly the figure below indicates that 5G-Advanced is important to Mobile and Converged CSPs both for saving money and for making money. Nearly all the interviewees told us that they were looking for new service revenues, but every one of them also indicated that – especially in the near term – better Performance/Capacity and Cost savings will come first. When asked to choose between saving money and making money operators state that they are very interested in Growing Revenues and Enhancing quality. In all regions – N. America, Europe and Asia. However, service providers are focusing in the near term on Cost Reduction and especially Energy Savings and Power/Energy Control.

Figure 15 Business priority – cost savings or new revenues

Topic	Key highlights by region	Key quotes for North America and Europe	Key quotes for China and SE Asia
Business priority save money (cost and efficiency) or make money (new revenues)	Very strong focus around the world on saving money in 2023-2024 timeframe and making money with new B2B services in 2025 and after.	"All the time we need to generate revenue and need to be cheaper without compromising quality." "We have the longer term target of making additional revenues, especially on the enterprise side."	"Saving money is the focus in the short term, but we will pay more attention to new business opportunities in the long term. So, have an interest in JCAS, passive Iot, etc." "B2C market will target OPEX reduction, while B2B market is seeking for new business models."

Below we discuss how operators see the Investment Outlook and their specific top Business and Technology/Feature Drivers for 5G-Advanced deployment based on both the online survey and interviews.

Outlook for 5G-Advanced investment and deployment

Overall outlook for operators

Around the world there is considerable concern about the economic conditions in 2023. Many of the interviewees have delayed hiring and are not yet committed to spend currently budgeted investment for 5G upgrades except where it will lower OPEX. Increasing price pressure is expected for standard 5G consumer services. And in the B2B market Release 15 Private LTE Advanced Pro is often performing so well under NSA that the case for Private 5G SA upgrade is not yet obvious- even though it will dramatically simplify managed services and Network Slice provisioning for operators. Delays in 3GPP Release 16 capable UE devices for both industrial and consumer applications are also delaying scale adoption of 5G Standalone (SA) and potential new service revenues until 2024.

Planned investment and budget for commercial deployments of 3GPP Rel. 17 and Rel. 18

Although the larger operators are finally rolling out Release 16 5G SA as a commercial service in 2023 – an important pre-requisite for many 5G-Advanced capabilities - they may delay investment in Release 17 in 2024 and wait for enhanced capabilities from Release 18. In the online survey nearly 55% of providers in the Americas and 50% of Asian providers expect to invest in Release 17 in 2023-24 while 50% of Asian providers and just over 40% of European ones are planning investment in Release 18 in 2024-25. The two releases look increasingly likely to arrive in the marketplace very close together. The online survey showed a number of operators are planning investments in Release 17 in 2023 – 24 - in Europe 29%, in the Americas 55%, and in APAC and Africa 50%. Those planning Release 18 Investments in 2024-25 were 41% in Europe and 50% in APAC. In the Americas it was a disappointing 27% possibly because so many are planning Release 17 deployment the year before. A simultaneous upgrade for both releases could be a likely option. Key quotes from the IDIs are below.

Figure 16 Planned investment and budget for commercial deployments of 3GPP Rel. 17 & Rel. 18

Topic	Key highlights by region	Key quotes for North America and Europe	Key quotes for China and SE Asia
Release 17 and 18 plans	Several operators are planning for Release 17 and 18 investment. One operator has begun pre-Release 17 field trial and another has prepaid for Release 17. But several are still struggling with Release 16 and waiting to decide on Release 17. Some have explicitly not yet budgeted for Release 17 and beyond. There is clearly significant caution at this time.	"For Release 17, 2023-24. The answer is yes, it's in the plan. And Release 18 is just to keep up with the latest and greatest on the ramp per se." "Deployment is not strictly related to 3GPP releases. Pan EU project is deployed country-by-country, so depends on market situation. Just starting with 2023 budget. 2023 budget much later."	All operators declined to respond.

Top business and feature/technology drivers for 5G-Advanced deployment decisions

Although it is still early for CSPs to finalize their investment decisions for 5G-Advanced, following the Introductory overview questions we narrowed the focus to identify the priority for specific capabilities.

Below we separately summarize the priorities that operators have mentioned both in our online survey and in the in-depth interviews. We have grouped the service provider responses around two sets of priorities – Business Drivers and Technology/Feature Drivers and for each we have inserted key quotations from the in-depth interviews after each online survey ranking. Based on these responses, we have identified and numbered the following seven major drivers -four for Business and three for Features and Technology as shown in the figure below.

Figure 17. Seven Top Business and Feature Drivers

A	**Top business drivers**
A1	Energy efficiency
A2	AI/ML and automation
A3	New and enhanced services
A4	Multi-access convergence to a common 5G SA core
B	**Top feature and technology priorities**
B1	Enhanced RAN and MIMO performance, capacity and reliability
B2	Beyond smartphone - 5G IoT devices for low latency, localized positioningand low cost user equipment (UE)
B3	Beyond connectivity - new applications and device driven use cases

Source: TechInsights, Networks and Service Platforms

Top 4 business drivers for deploying 5G-Advanced

Based on the survey research we have identified the top four business drivers as:

A1. Energy Efficiency

A2. AI/ML and Network Automation

A3. New and Enhanced Services

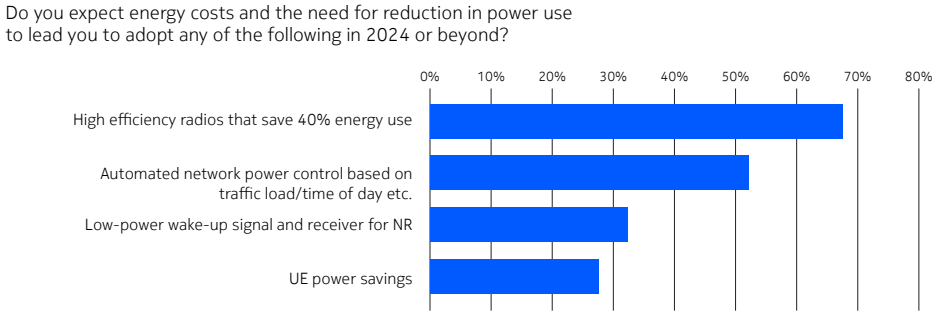
A4. Multi-access convergence to a common 5G SA core.

For each of these we evaluate the specific operator priority rankings and comments in turn.

A1. Performance at lower cost with enhanced ran energy efficiency and throughput for more cost effective delivery of massive 5G Bandwidth.
As ARPU stagnates in the 5G consumer market and traffic escalates by an order of magnitude every few years, operators see major value in investing in energy efficiency. Recent energy cost increases have also made it a business necessity to ensure that Cost/GB declines at least as fast as 5G Revenue/GB.

Energy efficiency has become 'Table Stakes' for CSP's choice of infrastructure vendor, generally in association with intelligent power control based on network traffic and time of day etc. Vendors are also expected to offer low-power wake-up signal and receivers for New Radio (NR). The online survey identified that nearly 70% of providers – one of the highest responses in the whole survey – hope to adopt radios that deliver 40% energy savings in 2024 and soon after. See figure below. We expect energy efficiency to be a major trigger for RAN and device upgrades in 2024 – 25.

Figure 18 Importance of Energy Cost Reduction



Source: TechInsights Online Survey

The operator responses from both the survey above and the interviews below indicate the importance of energy cost reduction for both the RAN and for UE/devices including receiver wake up.

Figure 19 Energy cost reduction and need for reduction in power use

Topic	Key highlights by region	Key quotes for North America and Europe	Key quotes for China and SE Asia
Energy efficiency	Major global issue for all operators. Key trigger for upgrading 5G to 5G-Advanced as Over the Air (OTA) radio efficiency in the next 1-2 years. Energy efficiency has become a key competitive capability for all vendors.	"Energy cost is key focus." "A key driver." "We are really focused on power consumption reduction. So any initiative in RAN is welcome." "Yes, it is a big focus but it's almost table stakes for vendors. Also we are more worried about getting stuff out to customers. It is key driver for 5G-A."	"We have set up a joint committee to reduce carbon emissions, from multiple levels, including equipment, cell site solutions, network features, and also renewable energy resources. On the UE side, we are paying attention to the low-power wake-up signal and receiver."

Although all regions are concerned about energy cost reduction, in N. America and Europe RAN Energy costs were mentioned more often, while in China and S.E Asia RAN and UE/device power consumption were both emphasized.

A2. RAN automation powered by AI/ML to simplify operations and reduce OPEX on path to autonomous networking

CSPs see a critical need for new approaches that allow them to massively scale 5G network operations by leveraging End to End (E2E) service management and support without a comparable escalation in OPEX. Operators are developing the datasets for 5G RAN optimization in multiple dimensions -time, frequency and space (beamforming). As Machine Learning produces increasingly better solutions operators want to move to Autonomous Networking and AI for routine operations, anomaly detection and rapid fault isolation and repair. See Strategy Analytics reports on 'SON Powered Managed Services Leverage AI and Automation for Network Operations' and 'AL/ML Use Cases December 7 2022 Presentation'.

Powered by AI/ML

Key CSP priorities for AI/ML are to simplify network operations, reduce outages with automated diagnosis and recovery and guarantee service Quality of Experience (QoE) and Service Level Agreements (SLAs) automatically.

AI/ML requirements show up in multiple online survey rankings – 'Leverage AI/ML to handle complexity and improve reliability and scalability' is third in figure 12 and 'AI/ML for Load management across Edge Platforms' is seventh in figure 22 (see below). Note that 'Automated Network Power Control' is also second for Energy Savings in figure 18. AI is viewed as a key aspect of network Evolution -see Figure 14 above and as part of the requirement to optimize New Radio in figure 27 below.

In the in-depth interviews we also asked specifically "Where should AI and ML be first applied for automation?" And "Will ML be first applied for RAN automation?"

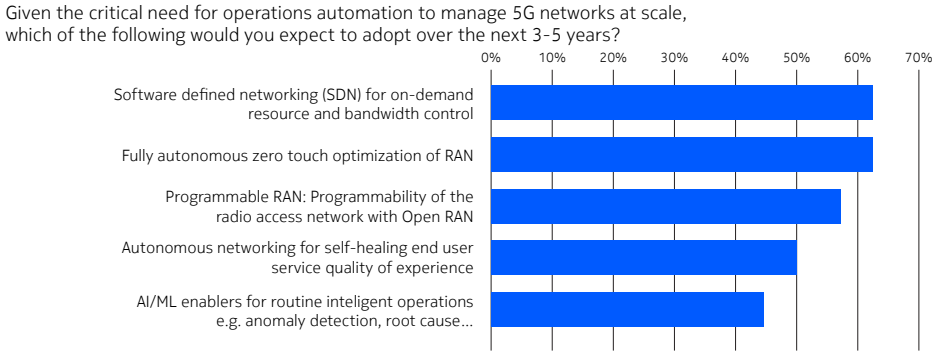
The quotes shown in the figure below indicate the significant value that operators attach to AI/ML opportunities for Network Management and Operations – especially for RAN Automation and Optimization. The three key priorities mentioned for the application of AI/ML are Intelligent management of RAN - including Air Interface, Zero Touch Network Operations and Energy Management.

Figure 20 AI/ML first applications for RAN, zero touch and energy management

Topic	Key highlights by region	Key quotes for North America and Europe	Key quotes for China and SE Asia
AI/ML first applications and RAN focus	Around the world operators are looking at AI/ML across every aspect of their operation from the RAN to fixed connectivity and 5G Core. RAN automation is however consistently an early requirement despite the enormous challenges of 5G optimization that includes beamforming/space division multiplexing and antenna tilt options etc.	"Definitely not in the physical layer. That's the most complicated area. We see this clearly in network automation and optimization." "Top 3 for automation are: 1. Network management and zero touch NetOps automation, 2. Intelligent energy management, 3. Real time hadling of NR air.	"Most important area for AI/ML is network management and zero touch NetOps automation."

The next figure below shows the results from the online survey when we asked about Operations Automation capabilities that would be adopted in the 3-5 year timeframe.

Figure 21 Adoption of Operations Automation over the next 3 – 5 years.



Source: TechInsights Online Survey

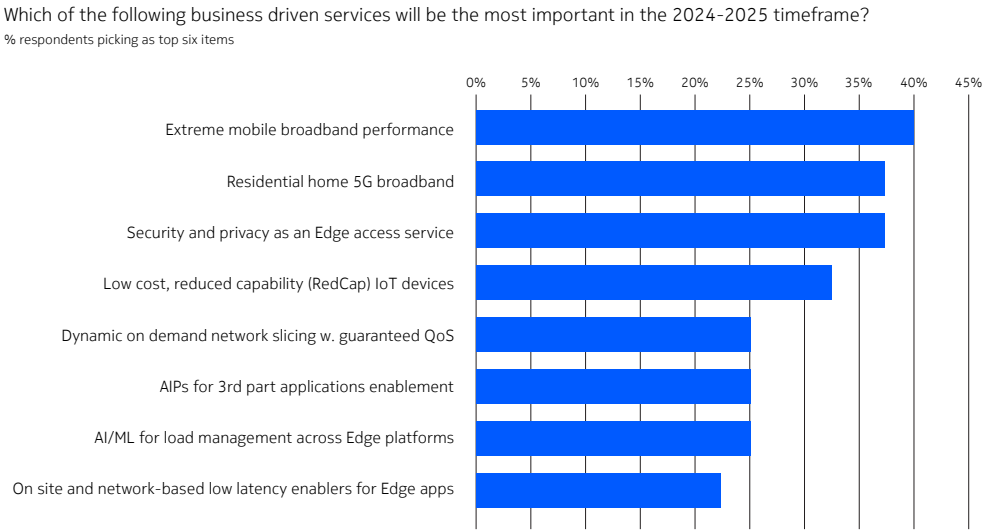
Note that Autonomous Networking and AI/ML for Intelligent Operations showed up three times in second, fourth and fifth positions. Also importantly in the ranking above, Software Defined Networking (SDN) is tied for first place with Autonomous RAN Optimization – both chosen by over 60% of respondents. Programmable RAN is only slightly behind at 58%. One very important but often untold story is that any reduction in network operations costs as a result of automation immediately improves operator margins.

In some cases more flexible provisioning e.g. SDN for on-demand bandwidth automated software control can simultaneously lower costs and add billable revenue to produce a doubly positive impact on margins. Similarly if operations automation enables rapid scaling of 'elastic' 5G resources through Open APIs it may also accelerate new revenues by attracting 3rd. party developers. See our insight 'Management, Orchestration & Automation not just Overhead anymore' for additional discussion.

A3. New and enhanced services for new revenues and potential cost savings in 2024/25

Operators are increasingly concerned as to where their new revenue growth will come from; and several expect that to become a critical issue by late 2024/2025 - just at the time when 5G-Advanced comes to market. So what revenue growth will 5G SA and 5G-Advanced stimulate in that time frame? The top business driven services identified in the online survey are shown in the figure below.

Figure 22 Top Business Driven Services that will be most important in the 2024-25 Timeframe



Source: TechInsights Online Survey

The top two business driven services relate to pure Broadband connectivity for more performance and to reach the Residential customers followed first by Security and Privacy for Edge access services and then by low cost RedCap/IoT devices – both key B2B capabilities. Applications for future 5G RedCap devices are still very limited but RedCap will get significant interest over time as a low cost 5G UE termination that could create an entirely new device market. As shown above Dynamic Network Slicing, APIs for 3rd. Party App. enablement and AI/ML for load management at the Edge ere all ranked in the top six by 25% of the respondents, with low latency enablers at the Edge at 23%.

Note: Three of these top business drivers relate to Edge Service differentiators that Hyperscaler Cloud Providers (HCPs) cannot match i.e. Security and Privacy where firewall cannot be available, dynamic load management to optimize Edge assets and low latency enablers for URLLC Apps. These are three key areas where CSPs can 'Outscale' the Hyperscalers. See TechInsights Video.

Figure 23 Operator Focus on New and Enhanced Services in 2024/25

Topic	Key highlights by region	Key quotes for North America and Europe	Key quotes for China and SE Asia
New and enhanced services	North American operators had very broad service objectives for connectivity and enterprise services which most European and Asian operators had very specific service capabilities in mind.	"We want to have entertainment as #1 product. IoT and connected devices for smart home connected living probably #2." " Slicing will be mature. Private 5G will be very mature. Edge is fially materialising. There is a definite uplink opportunity, and eventually metaverse." "Postitioning, less than 10cm indoor positioning."	Enhancement for short video applications, such as TikTok - short video users often have higher requirements for network experience than long video users. They can't wait for buffering. So the network needs to be enhanced further.

In the selection of new and enhanced services, N. America and Europe still emphasize consumer entertainment and in China and SE. Asia consumer video Apps. like TikTok. Going forward all operators are looking for Enterprise service revenues i.e. Network Slicing, Private 5G and Edge services.

The figure below provides specific new and enhanced services mentioned by operators. These include XR, Network Slicing and Edge Services and even Multicast and Broadcast. On this question . American and European operators agree in endorsing XR and associated RedCap devices although one adds "Autonomous vehicles, Mixed Reality and Gaming".

Figure 24 Focus on features/technologies that are new and enhanced service drivers

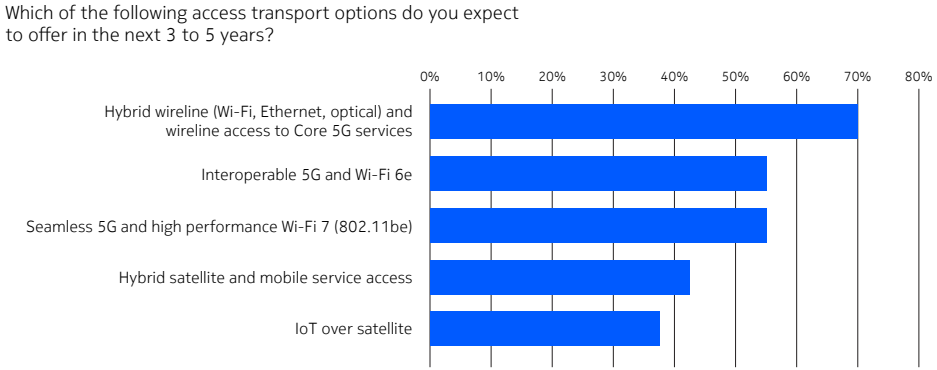
Topic	Key highlights by region	Key quotes for North America and Europe	Key quotes for China and SE Asia
Specific new and enhanced services	In the interviews there were 16 mentions of XR, 10 of Network Slicing, 8 of Edge services and 6 mentions of the Metaverse and Uncrewed Aerial Vehicles (UAVs) i.e drones, 3 of Gaming and 2 of Multicast-Broadcast. RedCap devise related service had 6 references.	"XR and RedCap devices are key drivers which might give us a new type of gadgets, like smart trackers. For really fascinating new services I hope XR will be the breakthrough, e.g. for people wearing glasses." "Autonomous vehicle, mixed reality, gaming." "Low latency communication in order to have more use cases within the industrial environment."	"eXtended Reality (XR), NR support for UAV (Uncrewed Aerial Vehicles). Fully dynamic multi-domain network slicing with guaranteed SLAs on demand and Metaverse enablers for Edge services, plus Network Energy Saving." "Multicast and Broadcast - it is actually a requirement of China Broadnet."

This question about new and enhanced service drivers is one of the few that evoked strong support for XR as well as Network Slicing (including Multi-Domain Slicing) and Metaverse enablers for Edge Services and even Multi-cast Broadcast.

A4. Access agnostic SA core services to lower OPEX and CAPEX

This capability not only offers major financial savings for operators, it also adds significant end user value through seamless ubiquitous services. The figure below shows the online survey responses for several Access Transport Options that can be integrated with 5G. The top choice – a strong 70% desire hybrid access to a common 5G core in the next 3 to 5 years. This bodes well for the adoption of 5G architecture well beyond mobile only operators. However, the organizational and sales channel disruption required to bring even loosely coupled multi-access solutions to market should not be underestimated.

Figure 25 Top access transport options with 5G integration over the next 3 – 5 years



Source: TechInsights Online Survey

The figure above highlights the enormous but often unrecognized value of seamless connectivity to a common set of services. In many ways that is the secret of the Internet. The section below describes the value of multi-access for services over WiFi and Optical Fiber.

Seamless access to 5G Core and cloud services over 5G-Advanced, WiFi and fixed broadband

Fixed multi-transport access to a shared common 5G SA Core could save billions for operators that have both Wireline and Wireless Networks. As 5G SA becomes widely deployed by 2024/25 it will be ready to facilitate new converged 5G-Advanced capabilities over WiFi or Optical connections.

- WiFi Access to 5G-Advanced Core Services will leverage WiFi 6 and WiFi 7 in conjunction with integrated stadium solutions, and mid-Band indoor Office solutions as well as seamless UE device management and Digital ID services in the Cloud. By 2025 users will expect 5G core services to be accessed over any transport.
- Optical Fiber deployment for fixed access to Core Services as well as 5G RAN fronthaul, backhaul and xHaul. Another major source of CSP cost savings could be the seamless integration of Optical Access for fixed broadband access to 5G Core Services. Optical fiber can simultaneously meet the need for fixed access to vIMS and for fixed connectivity between Remote Radio Heads, Baseband Processing or Distributed Units (DUs) and Centralized Units (CUs)/ RAN Intelligent Controller (RIC) or Base Station Controllers.

Fiber is first choice of CSPs for both broadband and RAN fixed connectivity. Today fiber wavelength and multiplexing technologies make it feasible for wireless operators to share commercial fiber in many locations. 5G Fixed Wireless Access (FWA), 5G Integrated Access Backhaul (IAB) and occasionally satellite connectivity can also be considered for access to a common 5G Core wherever access density is too low to justify fiber. The strong preference for fiber is echoed in the operator quotations below, although IAB is endorsed where fiber is not available.

Figure 26 Fiber deployment vs. other transport access solutions for RAN fronthaul/backhaul

Key highlights by region	Key quotes for North America and Europe	Key quotes for China and SE Asia
Globally, every operator would prefer fiber where it is available, but IAB is gaining acceptance where fibre is not economically justified. Some operators will consider NTN as well as IAB in the future.	"Fiber is #1 especially in this country, but considering other solutions based on economics." "We also love IAB." "It is about economics more than anything, but yes, more fiber except where alternatives are cheaper."	Fiber would be preferred primarily.

Top feature and technology priorities

Questions in the in depth Interviews and the online survey covered range of technologies and services as shown in figure 22 above, which indicates the relative importance of eMBB, 5G Residential Broadband, Edge Security and Privacy, Low Cost RedCap and IoT devices, On Demand Network Slicing, Open APIs, AI/ML for Edge Load Management and Low Latency enablers. Separate questions covered some specific features and technologies. Below we summarize the top operator responses for the top features/technologies that service providers believe will drive 5G-Advanced deployments.

It is important to set the stage by looking at the most important innovations 5G-Advanced brings. One operator summarized its view of the three high level 5G-A innovations as "Telco cloud, edge and automation of networks" , while another in Asia thought that all technologies that bring improvement in customer experience are 'most important' – see figure below. Other operators unfortunately see no major dominant innovation in 5G-A, while still others see only very specific features like RedCap, V2X, Uplink or Full Duplex Radio

Figure 27 Most important 5G-A innovations in architecture, technology and services

Topic	Key highlights by region	Key quotes for North America and Europe	Key quotes for China and SE Asia
Most important 5G-Advanced innovations in architecture, technology and services	Operators outside S.E. Asia have not yet fully experienced the benefits of 5G SA architecture - so many do not yet value all the capabilities. So far it is the radio-related features of 5G-Advanced that operators around the world are most aware of.	"There is no one big feature that makes 5G-Advanced as prominent as LTE-Advanced." "Challenging to introduce O-RAN RIC architecture into 3GPP system in the short term. Expect the architecture could be introducedin 6G. In current 3GPP architecture." "Telco cloud, Edge and automation of networks." "RedCap and new radio V2X enhancement for automotive." "Uplink has not been tapped yet and been ignored, e.g.stadium use cases with thousands of other users, 5G has only solved 1 of 4 problems inherent in a hugely complex consumer network."	"Technologies that can improve customer experience are the most important." "Architecture: more use of network-controlled repeaters and mobile IAB, Technology: Full duplex radio maximizing spectral efficiency, Services: Network energy saving providing more battery life for customers and OPEX reduction for CSP."

Top 3 Feature/technology drivers for 5G-Advanced deployment

The figure below summarizes the operator comments on the Top 3 Feature / Technology driving their 5G-Advanced deployment decisions.

Figure 28 Operators' Top 3 Feature/Technology Drivers

Topic	Key highlights by region	Key quotes for North America and Europe	Key quotes for China and SE Asia
Top 3 drivers for 5G-Advanced	Asian operators all had very specific features and applications in mind.	"First Uplink on massive MIMO is most critical, and then speed capability is critical as well as energy effiency/saving." "First NTN satellitemight be on of the most important parts of Rel.18. Then, further development of RAN disaggregation. Next physcial layer optimization based on AR/AI and operational efficiency, automation and sustainability in terms of minimizing energy consumption."	"First enhance network performance to support increasing eMBB traffic then meet the future service demands, such as XR applications and third explore new market opportunities, such as: full-duplex with lower latency, passive IoT for ultra-low cost IoT and Joint Communication and Sensing (JCAS)." "First, low and RedCap devices then symmetrical on demand for bandwidth uplink/downlink and then network slicing."

As the figure shows while N. American and European operators are looking for Uplink and Massive MIMO – two key capacity enhancers - and a couple like Non-Terrestrial Networks (NTN), Chinese and S.E Asian operators however focus on new performance enhancements for eMBB, XR, low cost IoT and JCAS. One operator sees a combination of RedCap, Uplink and Network Slicing as the top three technology drivers.

Putting all our sources and analysis together we identified three top Feature/ Technology Drivers :

B1. Enhanced RAN and MIMO performance, capacity and reliability

B2. Beyond Smartphone - 5G IoT devices for low latency, localized positioning and low cost UEs

B3. Beyond connectivity - new applications and device driven use cases

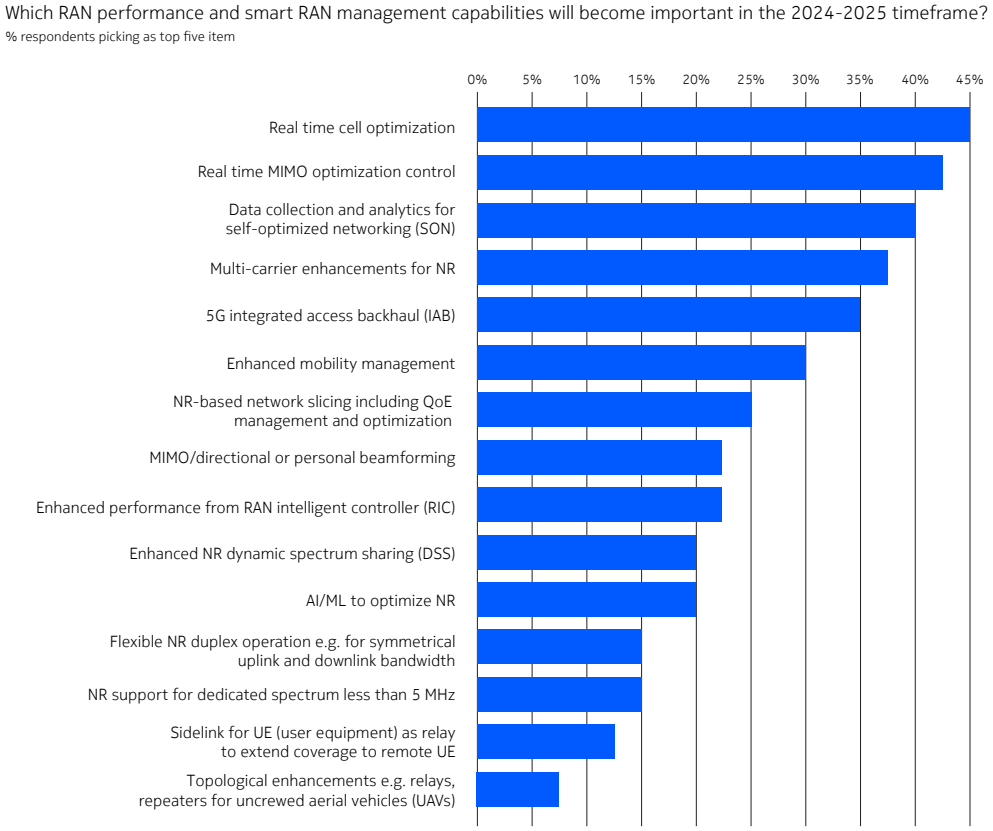
Many of the adoption decisions for these three 5G-Advanced capabilities will be driven by very specific operator requirements for particular features. The three categories are discussed in detail below.

B1. Enhanced RAN and MIMO performance, capacity and reliability

Enhanced RAN functionality is a key technology that was mentioned in multiple interviews. Capabilities in 5G-Advanced include Enhanced Massive MIMO, Full Duplex Option with Symmetrical Uplink capacity as required, Advanced Power saving, AI/ML for RAN management, Spectrum Aggregation and Optimized Radio Interface for XR.

Massive MIMO now enables RAN Access to match Multi-Gbps Fiber or Coax throughput in many situations e.g. on the factory floor and is now capturing significant attention from enterprise users especially where hundreds of LAN access points have become too complex to manage and can be replaced by a few distributed 5G Remote Radio Heads (RRHs) and a centralized CU/DU base station. 5G-Advanced technology could finally reposition wireless as a high throughput, high reliability, almost 'deterministic' low latency transport technology. In addition the availability of CBRS and C-Band frequencies around the world are removing the licensed spectrum barrier for low power use and made it far simpler to operate indoor, private or campus 5G wireless networks.

Figure 29 Top RAN Performance and Smart RAN priorities in 2024-25 timeframe



Source: TechInsights Online Survey

As the figure above indicates Cell and MIMO optimization top the chart with over 40% of operators putting them in their top five, followed by Analytics for Self-Optimized Networking (SON), Multi-carrier for New Radio (NR) and Integrated Access Backhaul (IAB).

The figure also shows some relatively low rankings for some key capabilities specifically - Enhanced Mobility Management which enables many of the other important 5G-Advanced capabilities and NR Based RAN Slicing are sixth. and seventh .respectively. MIMO personal beamforming is ranked eighth alongside RAN Intelligent Controller (RIC) performance with 23% of respondents listing them in their top 5. Enhanced Dynamic Spectrum Sharing (DSS) and AI/ML for NR both get 20% with NR Duplex down at 15%. Sidelink UE relay only got 13% and Topological enhancements for UAVs only 8%. The very low responses for some of important 5G-Advanced features – NR Duplex and Sidelink probably reflect the importance of the higher rated capabilities and the narrower specificity of those use cases. The quotations from operators shed some additional light on their top priorities i.e. smarter RAN and MIMO - see below.

Figure 30 Essential RAN and MIMO functionality to improve current network performances

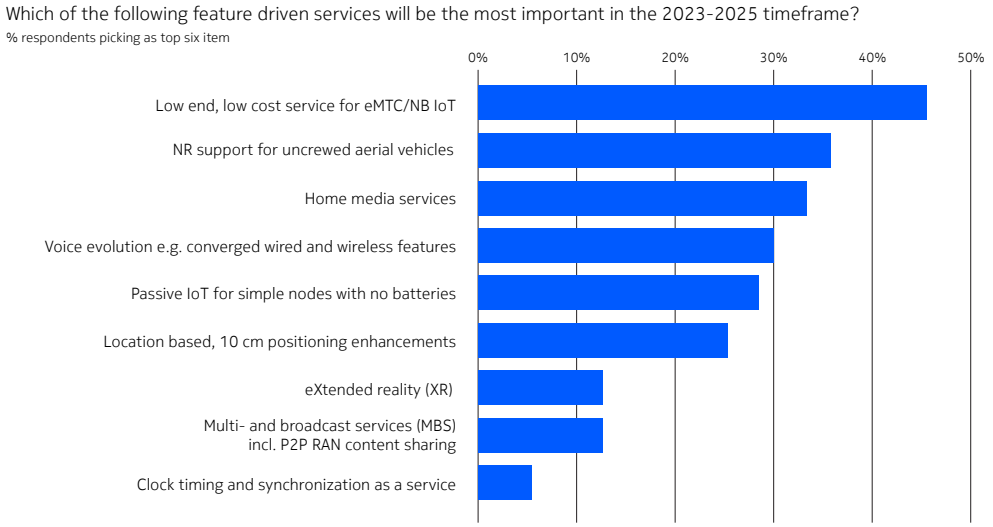
Topic	Key highlights by region	Key quotes for North America and Europe	Key quotes for China and SE Asia
RAN performance enhancements	All operators are looking for smarter, better RAN solutions. Massive MIMO is mentioned by many operators with 9 references to need for MIMO enhancement. Multiple requests for Uplink for consumer applications and a couple for Open RAN and RIC. Very specific feature priorities from Chinese operators, see quote.	"Uplink is really important and dynamic partitioning of the radio resource will be key." "We have a strategic plan for centralising and cloud RAN that is easier to coordinate." "More work needed to optimise the radio interface for XR application." "GPS timing server over 5G network." "We expect the next very big move to be Open RAN." "Uplink and O-RAN very critical."	"Support all enhancements of the existing 5G features, such as MIMO enhancement, coverage enhancement, etc., to meet the growing eMBB traffic. Particularly pay attention to full-duplex to reduce the latency of industrial applications." "RAN priorities in order are: Uplink coverage, flexible duplexing, evolution of NR duplex operation, NR dynamic spectrum sharing (DSS), AI/ML for NR Air interface, enhanced performance from RAN intelligent controller, NR network-controlled repeaters, topological enhancements (e.g. relays, repeaters, uncrewed aerial vehicles or UAVs), mobile integrated access backhaul (IAB), artificial intelligence (AI)/machine learning (ML) for NG-RAN."

Enhanced Massive MIMO is viewed as the key 5G-A RAN upgrade by many operators. Dynamic or Expanded Uplink is mentioned by many operators and Open RAN by a few. Asian operators were very specific in their RAN requirements as shown in the rightmost column above.

B2. 5G IoT devices are broad driver for low latency, localized positioning and low cost UEs

IoT devices and solutions are 'exploding' everywhere. Tracking location within a few meters (release 17) is viewed as very important e.g. for asset tracking. Under 10 cm. positioning (Rel. 18) occupies a much smaller 'niche' e.g. for robot control or factory production line applications. Similarly the opportunities for passive IoT and the use of 5G timing to replace GPS are not yet widely appreciated but could take off fast as App. Developers demonstrate the potential. The figure below shows the range of features that will be important to different operators in 2024-25. Low cost service for eMTC/NB-IoT (as operators think of it today – possibly to become 5G NR-Light) tops the list; and Passive IoT comes in fifth just ahead of 10 cm location positioning. It is important to note that respondents were picking from a list of 17 items.

Figure 31 Top Feature Driven Services that will be most important in the 2024-25 Timeframe



Source: TechInsights Online Survey

B3. New applications and device specific features will drive CSP choices

The advent of new devices and smartphones with intelligent UE software and User Equipment (UE) intelligence will not only open doors for new use cases but also allow operators to differentiate their services and increase their brand visibility on the user device – as they did long ago in 1980s. New Devices will actually drive or accelerate the development of new applications.

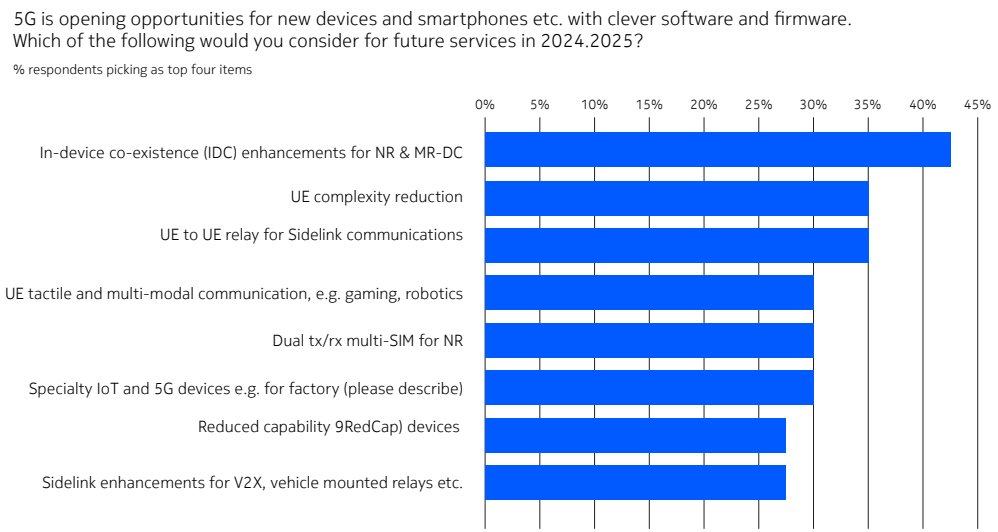
Examples of unique 'niches' that can leverage new types of UEs include NR for UAV, XR, Uplink with 5G NR Duplex, Edge Apps., Sidelink and Non-Terrestrial Networking (NTN).

- **5G NR for Uncrewed Aerial Vehicles (UAVs)** also known as Drones – UAVs will likely trigger a large family of new mobile and control applications. Drones represent a burgeoning market that is racing ahead of the standards in part because of their usefulness for everything from military attacks to consumer video capture and package delivery. 5G-Advanced will bring new relevant features that can be combined with NR to create completely new UAV solutions e.g. Intelligent UE on board the UAV for intelligent real time command and control with 10 cm positioning for precise doorstep drop off
- **XR, Uplink with 5G NR Duplex.** XR enabled devices are already stimulating a vast range of applications – both extensions and highly integrated. XR applications and market focus vary significantly by operator with some CSPs being highly consumer focused on broad mass market enhancements like XR for gaming or 'Uplink Bandwidth on Demand' including 5G NR Duplex for Stadium Apps. and User Originated Video content, while others focus on XR applications for business – Digital Twins for Manufacturing, Video for Telemedicine, immersive VR for Architects etc..
- **Uplink** is a major capacity enhancer for Both B2C and B2B. Entertainment and Hospitality enterprises are interested in Uplink for both User Generated Content upload and for Video Monitoring and Surveillance. Technology and Communications businesses are looking for Uplink to enhance capabilities for airplane and fast moving vehicle communications.

- **Edge Apps.** Other operators - especially those with large manufacturing customers - are more enterprise focused and looking to the B2B market as a profitable source of revenue. Manufacturing sites - see Enterprise interviews in Section 5 - expect significant benefit from on-premise or 'far edge' Apps. to control robots, track assets, enhance security and data backup and reduce the cost of fixed WAN transport to the Cloud. Top verticals mentioned for B2B applications in the near term are Manufacturing, Automotive, Supply Chain/ Logistics and Healthcare.

As the figure below shows there are a wide variety of features that will stimulate new applications at different operators. One operator for example was also very interested in multicast and broadcast features of 5G-Advanced, while Sidelink is of great interest to first responders and Non-Terrestrial Networking for both consumers and enterprises in very remote locations.

Figure 32 New Devices and Smartphones with Clever Software and Firmware



Source: TechInsights Online Survey

Although the top rated device capabilities were for in device multi-radio co-existence and reduced complexity, Sidelink UE to UE relay was also chosen by 35% of respondents followed by UE tactile and multi-modal devices. Sidelink enhancements for V2X just made the list in 8th. Place – possibly soured by earlier 'hype'.

So, based on their market focus therefore, different CSPs will have very different sets of 5G-Advanced device enabled priorities – especially for features that are very context or use cases specific.

- **Sidelink.** For example Sidelink is expected to be initially important for first responders at emergency sites where 'over the horizon' 5G extensions are required on demand. Today, however, UE device based relays for expanded coverage seem to a 'hard sell' even for remote rural locations that are willing to consider 5G Fixed Wireless Access (FWA) or Integrated Access Backhaul (IAB). Recent concerns have been raised about unpredictable latency for Sidelink responses, but as experience grows and 'Smart UEs' can manage issues transparently confidence in Sidelink should increase.
- **5G NTN.** 5G with Satellite connectivity – NTN was included very favorably by two European operators but completely rejected by several others and by many enterprise respondents. One enterprise respondent with remote hospitality locations was however, experimenting with Starlink and ViaSat. In several countries there appears to be a lack of understanding of new low latency satellite options i.e. Low Earth Orbit (LEO) and Medium Earth Orbit (MEO) – as well as the potential for data only User Plane Functions (UPF) from the Satellite direct to the handset or device UE. Satellite adoption remains a challenge as end users remember the long history of high latency stationary satellites and many operators are only just beginning to hear about 5G Non-Terrestrial Networking (NTN) direct to the UE device or smartphone.

In our interviews – see below - some leading edge Enterprise executives already see several Use cases for Satellite Communications for both Access and Backhaul. Specifically:

- One Manufacturer is using Starlink in beta in several locations although their preferred provider is ViaSat. Enterprise is trying Starlink out for “those (remote) locations that have nothing or next to nothing.”
- Use of fixed wireless and satellite backhaul for non-durable manufacturing or hospitality in very remote locations
- Satellite backhaul combined with high speed Uplink for data connectivity to fast moving vehicles – drones, trains and even airplanes.

Top business and feature/technology drivers address key trends

To see how the specific business drivers and features specifically address the key global trends described in Section 1, we charted how each of the seven priorities support the 15 specific trends as shown in the figure below.

Figure 33 Key trends and key business and feature/technology priorities that address them

15 Strategy analytics trends	A1 Energy efficiency	A2 AI/ML and network automation	A3 New and enhanced services	A4 Multi-access convergence to a common 5G 5A core	B1 Enhanced RAN and MIMO performance, capacity and reliability	B2 Neyond smartphone - 5G IoT devices foe low latency, localized positioning and low cost UEs	B3 Beyond connectivity - New applications and device driven use cases
Working from anywhere and rural migration	■		■	■	■		■
Gig economy and flexible working			■	■	■		■
Sharing economy	■		■	■		■	
Smarter healthcare	■		■	■	■		■
Metaverse		■	■	■	■	■	■
Spatial internet		■	■		■	■	■
Environmental handprint	■			■			
Environmental footprint	■	■	■				
Technology sovereignty		■					■
Beyond smartphones			■	■		■	■
Dedicated devices for verticals			■			■	■
Network modernization (new architecture)	■		■	■	■		
Cloud intelligence		■	■				■
Edge cloud	■	■	■	■	■	■	■
Road to 6G		■	■	■	■		■

Source: TechInsights

The chart above shows how the seven business and feature/technology priorities identified above will address the fifteen major trends. Some of the seven address many trends:

- **A3** New and Enhanced Services will address all the trends except Environmental Handprint and Technology Sovereignty.
- **A4** Multi-Access Convergence to a Common 5G SA Core addresses nine of the trends - Working from Anywhere, Sharing Economy, Smarter Healthcare. Metaverse, Environmental Handprint, Beyond Smartphones, Network Modernization and Road to 6G

One trend – Edge Cloud is addressed by all seven priorities; and the Metaverse is addressed by all but one –Energy Efficiency. Working from Anywhere, Smarter Healthcare, Spatial Internet and the Road to 6G are addressed by five of the seven priorities.

'Trends gap' – areas not addressed

There are several trends that are not well addressed by the priorities identified in the research. We call this the 'Trends Gap'

Unfortunately eight of the trends are not expected to be directly addressed – at least initially - by Energy Efficiency priorities – Gig Economy, Metaverse, Spatial Internet, Technology Sovereignty, Beyond Smartphones, Dedicated Devices for Verticals, Cloud Intelligence and Road to 6G. Beyond Smartphones and Dedicated Devices are likely to be further fleshed out over time as new types of specialized devices emerge.

Some trends, however, are only partly addressed by one or two of the business and feature priorities i.e. Environmental Handprint and Footprint as well Technology Sovereignty. Those trends may require additional features and technologies that are not yet included in the 3GPP or 5G-Advanced roadmap.

Significant 5G-Advanced opportunities not highlighted as priorities

There are several important 5G areas that received minimal or less than expected interest in the research. These areas may be need better exposure or information. We call these the 'Priority Gap;

'Priority Gap' or Areas not mentioned
Based on the current research there were important 5G and 5G-Advanced capabilities that may not be getting sufficient attention. We summarize a few of these below. They are:

- **Security - lack of information and awareness** of the competitive advantages of 5G inherent security e.g. for edge compute or at enterprise server locations where firewalls cannot be deployed. Although ranked third in figure 22 as 'Top Business Driven Service' 'Security and Privacy for Edge access services' is not yet associated directly with 5G and 5G-Advanced. It would appear that 5G security is the victim of poor marketing.
- **V2X -** The unrealistic hype over fully autonomous driving in the near future appears to have caused a backlash against V2x among some operators. Many V2X features will come with Release 17 but operators may find that there are multiple simpler Apps. that 5G-Advanced brings e.g. collision avoidance and location assistance with GPS over 5G, Intelligent in-vehicle UEs for safety recalls etc. Sidelink for V2X relays made the new device priority list – See figure 31 above.

These two major market areas may warrant additional awareness campaigns on the capabilities and benefits of 5G-Advanced.

State of 5G standalone (SA) – prerequisite for 5G-Advanced

The In depth Service Providers Interviews that Strategy Analytics completed in late 2022 with 16 Service Providers who are implementing 5G. 5 were based in N. America, 6 in Europe, and another 6 in Asia. 5 were purely Mobile Operators, 9 were Converged Fixed and Mobile Operators and 2 were Cable Companies that offer 5G.

In addition to the topics covered in Section 4, we asked about their current 5G Standalone (SA) status and commercial deployment plans since fully operational 5G SA is an essential pre-requisite for 5G-Advanced features to operate fully.

The following sections presents key quotes from the Service Provider In Depth Interviews (IDIs) on the state of 5G Standalone (SA) .

State of 5G SA commercial deployment

In the online survey with respect to 5G SA deployment many operators claimed current or near term commercial deployment within 18 months i.e. mid 2024 – 65% in Europe, 82% in Americas and 60% in Asia Pacific (APAC). Even 50% of the African operators who responded expected to have 5G SA deployed by 2024. The IDIs summarized below provide additional insights on the state of 5G SA.

Widespread 5G SA commercial deployment was probably delayed at least two years by the pandemic and the challenges of adopting the new processes and developing the tools needed for a cloud native Service Based Architecture.

Figure 34 Is 5G SA currently deployed 5G SA with 3GPP Release 16?

Topic	Key highlights by region	Key quotes for North America and Europe	Key quotes for China and SE Asia
Current 5G SA	Many European and North American operators are finally deploying Commercial 5G SA systems. SA deployments of Release 16 may have been slowed by pandemic and lack of chipsets. China and many Asian operators are allready offering.	"In the process of deploying 5G core in various EU countries. Started some years ago and now doing the test integration and hope to have commercial networks from 2022-2023." "Will deploy commerically within 1 year. It's not available now, but we're network ready."	"Already deployed for commercial use."

Source: TechInsights In-Depth Operator Interviews

Plans for 5G SA commercial deployment

A realistic appraisal of the state of 5G SA commercial deployment is critical for 5G-Advanced deployment. Plans for commercial 5G SA rollout were delayed by the Pandemic which made it hard to develop new team processes and software tools for cloud native operations. Current plans may unfortunately be slowed by the 2023 economic slowdown – even though 5G SA Network Operations costs with LTE /4G Radio and RAN interoperability may be as much as 50 percent lower than the costs of running 5G NSA and LTE/4G as a hybrid network today. A conservative estimate is that by 2025 about 40 percent of mobile operators will have deployed 5G SA on a fully commercial basis across a large part of their footprint – see below.

There are still recalcitrant doubters who are not sure of the value of 5G SA but they will catch up as they see the commercial, success of others in 2024.

Figure 35 If not 5G Standalone Yet, When?

Topic	Key highlights by region	Key quotes for North America and Europe	Key quotes for China and SE Asia
Timing of future 5G SA	2023 will see increased deployment in North America and Europe if that is not slowed by the Recession. By early 2025 when 5G-Advanced arrives we would expect significant commercial deployment at over 40% operators.	"In 2023, that's the plan, but exact timelines are not available. Reason is uncertain of value we can generate from customers." "It's a lot about optimization and efficiency. All else has slowed down, due to everything being harder than expected, lack of use/ demand, economic."	Note: Chinese and several other advanced S.E. Asian operators skipped 5G NSA and directly deployed 5G SA. Smaller operator outside China "Not sure when."

Source: TechInsights In-Depth Operator Interviews

In addition to Network Operations savings there are many reasons for operators to deploy 5G Service Based Architecture to grow revenues and improve margins. They include the ability to:

- Enable Telco Cloud with distributed processing anywhere for Edge Services or with a Hyperscaler partner
- Facilitate real time End to End (E2E) Network Domain Management and Slice Allocation on Demand
- Adopt open APIs for trusted 3rd. parties to use 5G-Advanced features

Additional research and practical experience will be needed to fully understand the long run impact of 5G SA and the new opportunities it creates in conjunction with 5G-Advanced for service provider innovation and new services on the path to 6G.

Key takeaways for CSPs from enterprise interviews

This section identifies the key takeaways and provides quotations from in-depth interviews that were conducted in late 2022 with '5G Aware' Enterprise CTOs and CIOs etc. It represents important responses from multiple industries even though it is not a statistically representative sample; and is skewed towards advanced users. Of the 15 companies interviewed 6 were in N. America, 6 in Europe (including UK and Israel) and 3 were in Asia Pacific.

The 15 industry executives interviewed came from the following six categories of manufacturing and service sector companies.

Manufacturing

- Five Durable Manufacturers of:
  - High volume automotive vehicles (B2C)
  - Low volume racing cars (B2B)
  - Premium automotive OEM sub-systems (B2B)
  - Cable/optical fiber (B2B)
  - Battery (large scale backup power) (B2B)
- Three non-durable manufacturers (small equipment & food processing
  - Small tool manufacturer (B2C and B2B for small and medium enterprise (SME))
  - Computer printing equipment manufacturer (B2C and B2B)
  - Food manufacturer (B2C)

Services (B2B2C and B2C)

- Two select consumer services
  - Hospitality and event management
  - Insurance
- Two healthcare and medical
  - Hospital
  - Medical diagnostics
- Two technology service providers
  - Data center service management
  - Telecommunications and software ecosystem conglomerate
- One utility
  - Leading water company

Important findings from the enterprise market interviews

5G has gained major recognition as a reliable and fully capable Broadband solution for fixed and mobile connectivity. Potential enterprise customers – like CSPs themselves - want 5G to fully meet its original objectives of performance, reliability, cloud native compatibility and security/privacy in the 2024/25 timeframe.

Private or Managed 5G is now viewed as competitive alternative to WiFi – especially in the factory where it is viewed as more reliable, secure and easier to manage than thousands of LAN access points connected with hard to move Ethernet Cable.

However, while enterprise IT and telecommunications executives are very familiar with 5G's high bandwidth and low latency capabilities they have very limited awareness of its superior security, distributed processing and inherently flexible resource allocation on demand.

Even as Edge Processing takes off – driven by the Hyperscaler Cloud Providers (HCPs) – CSPs must demonstrate the value that 5G and 5G-Advanced will add to the HCPs with dynamic load management and strong access security at the Edge where firewalls are impractical. Edge processing from CSPs also leverages new capabilities that complement the HCPs i.e. distributed real time processing and storage optimization with easy to manage End to End (E2E) Network Slicing that supports seamless fixed and mobile VPNs and RAN slicing to guarantee service quality and reduce transmission costs.

Some of the 5G-Advanced Features are currently viewed as 'niche' applications. Potential use cases for broad applicability of Sidelink, Uplink, RedCap devices and smart UEs need to be demonstrated with live applications early in 2025 to ensure profitable device and chipset volumes in 2026/27.

Key takeaways

We identified fourteen key findings from the Enterprise in depth interviews. They are:

Business requirements

1. System integrator (SI) plays a key role
2. Reliability is critical for enterprises to assure ICT infrastructure
3. Cloud is key for digital transformation.
4. CSP's must respond to pressure from Hyperscalers and leverage extensive CSP network expertise
5. Enterprise customers have a strong preference for Private LTE and 5G over Public Network

Feature and technology requirements

6. Enterprise customers want 5G basic features first - Bandwidth, Performance and Low Latency
7. Security is critical
8. Industry 4.0 transition is driving demand for 5G and 5G-Advanced
9. 'Sidelink' adoption
10. Reduced Capability (RedCap) devices must meet basic functionality requirements
11. Uplink Bandwidth 'On Demand'
12. Secure Local Edge Processing
13. Remote Location Coverage and Bandwidth issues
14. 5G is preferred to Wi-Fi in factory

Detailed comments from interviewees are summarized for each topic below with interview quotations as figures.

Business requirements for 5G enterprise users in 2024/25

System integrator (SI) plays a key role

Systems Integrators are viewed as expensive. Most Interviewees would not turn to CSP for Systems Integration beyond Radio Access and Network Connectivity. They are most likely to do the systems integration themselves or turn to one of the global Systems Integrators (SIs)- Accenture, Bearing Point, Cap Gemini, Deloitte, IBM/Kyndryl, KPMG, PWC etc. See comments in figure below.

Figure 36 Who fills the Role of Systems Integrator for Enterprise 5G?

Topic	Enterprise overall	Other MFG. (food)	Telecoms software and data center ops
System integrator also plays a role, but often very expensive. Most interviewees would not turn to carrier for systems integration beyond radio access and network connectivity.	Most enterprises use some 3rd party systems integrator but it is not usually a CSP or a cloud provider. For manufacturing they often need very specialized integrators e.g. for machine tool protocols.	"We have also a system integrator." "It's not really the main partner." "It's [the company] that is leading this."	"Neither carriers not cloud hyperscalers are very interested in customization for unique situations. Accenture, IBM etc. offer very expensive customization" "Need to leverage 5G composability and open APIs to make customization easier for in-house ICT personnel."

Durable Manufacturing often requires a highly specialized expert integrator who is familiar with machine tool protocols; and some leading edge companies are willing to do their own systems integration 'in house'. Open APIs are very important for in-house ICT staff.

Reliability is critical for enterprises to assure ICT infrastructure

Reliability is key for supply chain management and to assure reliable path to the Cloud.

Figure 37 Enterprise Expectations for Reliability

Topic	Enterprise overall	Durable Mfg. and OEM suppliers	Other Mfg. (Food)	Healthcare and medical
Reliability critical for enterprises for ICT infrastructure, for supply chain and to assure reliable path to the cloud.	IT executives expect far higher reliability from their communications service providers than they do from the internet i.e. high reliability 'path to the cloud'.	"If we have and outage or slow performance at our edge computing strategy that cost us £1,000,000 per production session."	"I'm expecting that... we can use 5G as a backup."	"As we move into more and more cloud having reliable communications is more important because... if my communications path is down, I'm sort of down, and that impacts the entire operation. So... communications vendors are becoming a much more critical path, more than ever."

Enterprises expect very high reliability from Carriers who support their ICT and Cloud infrastructure – much higher in fact than that they expect from the Cloud Hyperscalers. They see Communications Service Provider reliability as 'Business Critical'.

Cloud is key for digital transformation

Figure 38 Enterprises assume Cloud as part of Digital Transformation

Topic	Enterprise overall	Durable Mfg. and OEM suppliers	Other Mfg. (Food)	Healthcare and medical
Could is key for digital transformation	Cloud is a given for advanced enterprise CIOs/CTIOs as a key part of corporate digital transformation.	"Because of the nature of our adoption of cloud, ... we have partnerships with AWS, GCP and IBM." "Cloud journey for any enterprise in S. Asia is a very mixed journey... you have hybrid cloud.	"My goal is to eventually migrate more and more into the cloud."	"Cloud is becoming a game changer or game driver in this space."

Digital Transformation is already a 'given' for these advanced enterprise respondents; and they expect support for hybrid cloud operations to be part of standard operating procedure. For global manufacturers multiple cloud partners may be required to achieve coverage, while for healthcare the cloud partner may be more strategic as a 'game changer' for operations in a particular area.

CSP's must respond to pressure from hyperscalers and leverage extensive CSP network expertise

Figure 39 Enterprises demand CSPs and Hyperscalers work together

Topic	Enterprise overall	Durable Mfg. and OEM suppliers	Healthcare and medical	Utility
CSP's must respond to pressure from hyperscalers, coordinate with them and leverage extensive CSP network.	Enterprises are looking for CSPs that will work with any ISP or Cloud provider i.e. Hyperscaler neutral. CSP should be a neutral 3rd party that supports hybrid cloud and adds value with reliable network access.	"Current and new network integration should be ISP neutral. Because irrespective of the location, I do not want to be married to a specific ISP. So if that is coming from a hyperscaler as a bundled solution, then it is something which is going to be very interesting." "Work with telecoms provider to consume the experience of other partners and peers in automotive."	"Really have to work much more closely with cloud provider."	"Because we're so geographically spread, we rely heavily on public carrier services."

Enterprises are looking to work with communications and Cloud providers but also expect their CSP providers to work with the Cloud Hyperscaler of their choice. Many enterprises do not appear to be looking for a single vendor solution. The reason for choice of a specific Cloud provider varies. For Automotive manufacturers it may depend on which Cloud provider their suppliers and partners use. For healthcare providers it may be driven by local support, while for utilities it is determined by regional coverage of public cloud access.

Enterprise customers have a strong preference for private LTE and 5G over public network

Figure 40 Enterprises Prefer Private Networks

Topic	Enterprise overall	Durable Mfg. and OEM suppliers	Utility
Preferences for private and public network favor private 5G	Leading enterprises in durable manufacturing and utility companies want private 5G but are considering doing it themselves due to the anticipated cost of managed service from CSP.	"We're probably not going to be talking to a carrier about that because they tend to be very expensive." "5G extranet (hybrid private and metro-area) with secure VPNs is one area that can be a definite potential use case for us, offering it to our close suppliers, if not at all."	"Our thinking is to build out a local area network potentially using 5G" where "it's difficult to convince carriers it's a good idea to invest in coverage."

CIOs have a strong 'need for control' and although they accept Managed services for Private LTE and 5G radio networks they need to be convinced that part of their service could also depend on the Public Network as a Hybrid PNI-NPN solution. SDN and 'perceived control' as well as Secure Private Network Slices can play a major role in helping Enterprise users to accept Hybrid Public private 5G solution. Both Manufacturers. Their OEMs and Utilities see Private Networks as preferrable 'on site' but are willing consider Hybrid solutions with Secure VPN for 'off site' and metro area requirements.

Enterprise requirements for features and technology

5G-Advanced Features are important for broad 5G adoption but vary by Industry Segment and Use Case

Enterprise customers want 5G basic features first - bandwidth, performance and low latency

Figure 41 Enterprises expect 5G basics as foundation for high performance and low latency

Topic	Enterprise overall	Durable Mfg. and OEM suppliers	Other Mfg. (food)	Utility
5G basics first - especially high throughput and low latency	High bandwidth, high performance and low latency for basic 5G come first. 5G-Advanced features will follow.	"Latency is becoming a critical parameter for ourselves. So the 5G is the only solution for us." "What's offered by 5G are significant performance improvements, significant support to out edge computing strategy and significant cost reductions as we go over the next decade." "Our biggest challenge at this point is so much more of our equipment has to have an adapter for special protocols to work with 5G and we need the machine tool companies to do that." "We lack the technical capability to architect a transition strategy that will allow us to really effectively take on 5G."	"We are going to discuss the 5G-Advanced and all these things in a secind step."	"What's driving us towards 5G is the size of the bandwidth, particularly for CCTV." Uplink for video surveillance.

The good news is that Enterprises are convinced that 5G can match the best wired connectivity. The bad news is that they expect very high throughput and low latency as part of their baseline 5G service. For Durable Manufacturers and their OEMs very low latency is key but many must also deal with machine tool protocols that do not work with 5G today. Other sectors are waiting.

Security is critical

Although Security is critical for almost all interviewees, many are not aware of the inherent advantages of 5G for Security and corporate Privacy – especially in combination with 5G Network Slicing.

Figure 42 Security is 'must have' for enterprise – but 5G is under appreciated

Topic	Enterprise overall	Durable Mfg. and OEM suppliers	Other Mfg. (food)	Utility
5G basics first - especially high throughput and low latency	High bandwidth, high performance and low latency for basic 5G come first. 5G-Advanced features will follow.	"Latency is becoming a critical parameter for ourselves. So the 5G is the only solution for us." "What's offered by 5G are significant performance improvements, significant support to out edge computing strategy and significant cost reductions as we go over the next decade." "Our biggest challenge at this point is so much more of our equipment has to have an adapter for special protocols to work with 5G and we need the machine tool companies to do that." "We lack the technical capability to architect a transition strategy that will allow us to really effectively take on 5G."	"We are going to discuss the 5G-Advanced and all these things in a secind step."	"What's driving us towards 5G is the size of the bandwidth, particularly for CCTV." Uplink for video surveillance.

While 5G is viewed as more secure and private than WiFi most enterprises are unaware of the truly superior inherent security of 5G SA solutions. Significant marketing effort is required to increase Enterprise awareness of 5G Network.

Slicing as an alternative for Secure Private VPNs. 5G Security at the Edge and for Cloud access is potentially a major differentiator for CSPs. Security is the 'elephant in the room' when customers consider off-site shared 5G connectivity.

Industry 4.0 transition is driving demand for 5G and 5G-Advanced
i.e. Ultra-Reliable Low Latency (URLLC), Multi-Campus Nets, Location of Assets within 10 to 20 cm.

Figure 43 Industry 4.0 is a major trigger for manufacturers to adopt 5G-Advanced

Topic	Enterprise overall	Durable Mfg. and OEM suppliers	Other Mfg. (food)
Industry 4.0 transition is driving demand for 5G and 5G-Advanced URLCC, multi-campus nets, precise location of assets within 10-20 cm	Industry 4.0 is a key driver for 5G adoption	"Some of the funds we use are financed by the state." "We're ina bit of a downturn right now. We've got a shift from strategic Industry 4.0 to more tactical in the near term." 5G gives "Ability to reconfigure production line rapidly for different products."	"We had an Industry 4.0 project with a huge tax incentive from the government to invest in the factory with a new production line."

Industry 4.0 is real and happening at many leading manufacturers. 5G is viewed already as a key enabler for Industry 4.0 and it is important for CSPs to seize this opportunity. Wherever Industry 4.0 goes 5G should be there.

'Sidelink' adoption
Sidelink is likely to come first for real-time coverage expansion.

Figure 44 Where will Sidelink be adopted?

Topic	Enterprise overall	Hospitality/events and insurance
'Sidelink' adoption likely to come first for real-time coverage expansion	Interviewees with remote sites like the idea of UE relays to extend coverage 'over the hill' but current 5G coverage for originating UE is not there yet.	"Sidelink could be great for the first responders and emergency coverage as needed."

Highest initial interest in 'Sidelink ' is for emergency response and coverage extension. Elsewhere, Sidelink applications will need to emerge to gain more widespread adoption. Dependency on the availability Handset UE relay capabilities for Sidelink is also a concern – creating a 'chicken and egg problem'.

Reduced capability (RedCap) devices must meet basic functionality requirements
Figure 45 Where are Reduced Capability (RedCap) Devices needed?

Topic	Enterprise overall	Durable Mfg. and OEM suppliers	Other Mfg. (food)
Reduced capability (RedCap) devices need to meet basic functionality reqquirements	'Lower cost devices' for 5G were requested by several interviewees, especially for non-voice IoT or remote sensor or asset tracking applications. Need for very application-specific RedCap UE could slow adoption.	"We would require very App. Specific RedCap device/UEs" "Important extension of IoT device options"	Concerned about possible loss of 'standard' functionality or even simple App. Programmability on low end devices.

Customers want lower cost devices but then immediately express concerns about basic functionality limitations – so finding the 'sweet spot' for RedCap will be very important.

Uplink bandwidth 'on demand'

Symmetrical or On Demand Uplink that matches Downlink throughput on 'as needed' basis is a very attractive option for Enterprise users.

Figure 46 Which Enterprise Applications need symmetrical Uplink bandwidth?

Topic	Enterprise overall	Durable Mfg. and OEM suppliers	Hospitality/ events and insurance	Healthcare and medical	Telecoms software and data center ops
Symmetrical uplink bandwidth/ capacity useful to match downliink on 'as needed' basis.	Several enterprise interviewees see an occasional need for high bandwidth uplink. Others see regular need for entertainment and video surveillance at large events.	"Only very local 'uplink' to the nearest Edge server (either in on premise private LTE or 5G network or very nearby public network) for backup and data filtering to reduce traffic volume and fixed throughput costs to reach the cloud data center."	"Uplink capacity is very important for major events." Examples: UE generated video sharing, video surveillance. "We have several use cases where we're deploying cellular service for transactional (i.e. as needed) basis. So we'll set up basically a pop-up network using 5G or 4G to be able to cover an event maybe in a parking lot at one of our stadiums or in one of our university campuses. So we've been doing quite a bit with that especially over the past several years.	"Healthcare applications and remote diagnostics may need high bandwidth for very short periods."	"Uplink - especially (combined with)...satellite for land to air, or directly to the handset... will be a huge win." "Good for fast moving airplanes, helicopters, air ambulance." "In remote areas for farming... Uplink will play a major role."

Different verticals see different potential for symmetrical Uplink bandwidth and Hospitality, Events and Healthcare especially enthusiastic. Others see very local or high mobility applications as special opportunities.

Secure local edge processing

Edge compute is most likely first on premise and then for metro area or multi-location Apps. at the 'far edge' of the Cloud closest to customer. Edge processing taking off, but some still see any off premise processing as risky. Many enterprises are unaware of the inherent Security that 5G offers at the Edge.

Figure 47 Where will Enterprises adopt Edge Processing and Services?

Topic	Enterprise overall	Durable Mfg. and OEM suppliers	Other Mfg. (food)	Telecoms software and data center ops
Edge processing taking off... but some still see it as risky	High reliability and low latency are critical for Edge processing. Many enterprises prefer Edge resources to be 'on premise' e.g. for manufacturing process control. One non-durable equipment manufacturer saw Edge as an important way to monitor and service its own customers' equipment. Edge cloud is very important for filtering data and reducing transmission bandwidth costs to the cloud.	"We have a low risk tolerance for Edge (and while there) are multiple benefits from it, we still haven't had the appetite to think about industrial Edge (for integration of the factories... the use of automation, (and) the use of robots... in production... to work out our sense to cloud strategy and our requirements around smart sensors."	"We launched our printers as a kind of an edge device. We've done 30 million of them, but then we also launched a formal edge offering earlier this year and that's one of the reasons we're exploring 5G ... ultimately even though you are processing the edge, the edge ... needs to get also connected to the cloud, and for retraining of the AI."	"Edge devices and the communication will be the future... especially (for) video... Edge network to the local network or the near vicinity network with the Edge will be the future." Edge "will play major role" fpr processing for "devices and the protocols."

Enterprise users are enthusiastic about Edge Processing where it is performed on premise, but view it as risky when located at the nearest network access. Nonetheless some enterprises are planning new business wide uses e.g. for monitoring their customers' equipment from their own edge servers. Experienced software and data center based businesses expect edge devices and services to play a major role.

Remote location coverage and bandwidth issues

Remote Access is only partly solved by 5G.

Figure 48 Where will 5G Fixed Wireless be Used? Remote Access? Private 5G Backhaul?

Topic	Enterprise overall	Durable Mfg. and OEM suppliers	Hospitality/events and insurance	Telecoms software and data center ops
Remote location issues only partly solved by 5G. Interest in remote coverage (FWA, sidelink relay)	5G integrated access backhaul and fixed wireless access seen as robust solutions where available, but 5G coverage is not available in remote ares in my countries yet. Satellite viewed as 'last resort' by several interviewees in developed countries, largely due to long rememebred delays from geostationary satellites. [Limited awareness of LEOs and MEOs].	"There is not one solution that fits all locations." "Backhaul for 5G at remote sites is still a challenge." "5G fixed can be viewed as substitute for fixed broadband but is not always available."	"We are using Starlink and in beta in sveral locations and our preferred provider is till ViaSat. But we've been trying Starlink out for those (remote) locations that have nothing or next to nothing."	"Uplink - especially (combined with) ... satellite for land to air, or directly to the handset...will be a huge win." "Good for fast moving airplanes, helicopters, air ambulance." "In remote areas for farming etc. Uplink will play a major role."

Fixed Wireless Access (FWA) is becoming accepted for private enterprise wireless backhaul (IAB), but only where other fixed connectivity is not available. 5G coverage itself is often not available in many remote areas and only a few enterprises are willing to experiment with Low Earth Orbit (LEO) or Mid-Earth Orbit (MEO) satellites. Use of fixed wireless and satellite backhaul for non-durable manufacturing or hospitality is very situation and geography dependent.

However. High speed Uplink – see 11 above – combined with satellite backhaul was seen by data center and communications companies as a major opportunity for data connectivity to fast moving vehicles – drones, trains and even airplanes.

5G is preferred to Wi-Fi in factory

5G is viewed as more flexible and practical to manage in the factory, but that is less of an advantage in the office.

Figure 49 Where will WiFi be used vs. 5G?

Topic	Enterprise overall	Durable Mfg. and OEM suppliers	Other Mfg. (food)
5G addresses key Wi-Fi issues in the factory, but is less necessary in the office.	Consistent response from many manufacturing companies that 5G was preferable to Wi-Fi on the factory floor (a) to eliminate thousands of calbed up access points (b) to delivery more 'deterministic' latency (c) to allow continuous flexible reconfiguration of movable production machinery in new process flows."	"Wi-Fi has problems, we have problems with coverage." "Prefer 5G to thousands of Wi-Fi access points on the factiory floor."	"We have standard defined by the group. The standard is Cisco."

5G has gained significant credibility as an alternative for connectivity on the factory floor. The relatively few base station control units and radio heads make it far preferable to hundreds of LAN access points connected with Ethernet cable and a controller in the Cloud. Factories that frequently reconfigure their production line equipment view 5G as a massive advantage. Many enterprises saw little advantage, however, for 5G vs. WiFi in the office environment

Key findings

The key findings of the report are summarized below.

Although may service providers have been slow to deploy 3GPP Release 16 and 5G Standalone (SA) upon which 5G-Advanced depends – see Section 6 - almost all operators have plans to deploy 3GPP Releases 17 and 18, – see figure 5 and Section 4.1 - although the timing may overlap and the two releases will likely arrive very close together.

The most important overall finding for 5G-Advanced deployment is that service provider decisions are being driven first by the need to improve Performance, Coverage and Capacity followed closely by the urgent requirement to Optimize RAN Energy Costs and Reduce the Cost of Network Operations through Automation and AI/ML. See figure 12.

Top seven priorities for service providers

Based on both in depth interviews with 16 service providers and an online survey of 40 operators around the world we concluded that the following are the top four CSP business priorities for 5G-Advanced – see Section 4.2 for details :

A1. Energy Efficiency

A2. AI/ML and Network Automation

A3. New and enhanced services

A4. Multi-Access Convergence to a Common 5G SA Core.

And these are the top three feature/technology priorities – see Section 4.3 for details:

B1. Enhanced RAN and MIMO performance, capacity and reliability

B2. Beyond Smartphone - 5G IoT devices for Low Latency, Localized Positioning and Low Cost UEs

B3. Beyond Connectivity - New Applications and Device Driven Use Cases

These seven priorities reflect the service provider objectives of saving money in the near term and – growing service revenues on an ongoing basis.

In the 2023 and 2024 CSPs may be most interested in the Cost Savings with Revenue growth increasing in importance as 5G-Advanced arrives in late 2024 and 2025.

Broader findings from the study

The research looked into both broad and highly focused requirements from 5G-Advanced and two key messages emerged.

Operators are determined to complete 5G Vision in the 2024 – 25 time period.

One of the most important messages to the industry that we heard from the CSPs is their strong desire to see the fulfilment of the original vision in the original 2015 White Paper.

By 2024-25 5G-Advanced will help to complete many of the original Radio design objectives shown at the top left in the figure below including multi-RAT co-ordination, massive MIMO and dynamic radio topology. With 5G SA the common composable core, the CU function split and the RAT agnostic core could meet the Network design objectives in the upper middle. Similarly automation and carrier grade network cloud orchestration are within sight for Operations and Management – shown at the top right - in the next two years.

Figure 50 Original 5G design principles

Radio	Network	Operations and management
Leverage spectrum - Exploit higher frequencies and unlicensed spectrum - C/U-path split, UL/DL split, multiple connectivity **Enable cost-effective dense deployments** - Integrate third-party/user deployments - Automate configuration, optimization and healing - Enhance multi-RAT coordination - Support multi-operator/shared use of infrastructure **Coordinate and cancel interference** - Build-in massive MIMO and CoMP - Exploit controlled non-orthogonal interference **Support dynamic radio topology** - Moving cells, relays, hubs, C-RAN, D-RAN - D2D (e.g. for latency, disaster relief)	**Create common composable core** - Minimize number of entities and C/U-function spit, lean protocol stack - No mandatory U-plane functions - Minimize legacy internetworking - RAT-agnostic core - Fixed and mobile convergence	**Simplify operations and management** - Automation and self-healing - Probeless monitoring - Collaborative management - Integrated OAM functionality - Carrier-grade network cloud orchestration

Embrace flexible functions and capabilities	Support new value creation
- Network slicing - Function variance - Flexible function/service/application allocation - Leverage NFV/SDN - State-disintegrated functions - Graceful degradation	- Exploit big date and context awareness - Expose radio and network APIs - Facilitate XaaS - Build in security and privacy - Extend C-plane security (e.g. HetNets) - Ensure location privacy and identity protection from (unlawful) disclosure

Source: Strategy Analytics based on NGMN 5G White Paper 2015

But progress on the value creators at the bottom of the figure above has been painfully slow. A primary objective for all Service Providers should be to complete the 5G vision of leveraging flexible functions and capabilities – Network Slicing, Function Variance etc – new value creation – data and context awareness, network APIs and XaaS – and Security and Privacy extensions in the 2024 -25 timeframe. This implies adopting a broader view of 5G design and systems level requirements – as shown in the Chart above - to create End to End (E2E) service solutions rather than simply sets of features and capabilities to be bundled as needed.

In particular, three key 5G-Advanced solution enablers are needed to complete the NGM design vision and assure revenue growth with improved margins in 2024 and beyond. They are Software Defined Networking (SDN), Edge Compute and Network Slicing. We summarize these enablers in Appendix A.

Operators will leverage 5G-Advanced features to finally focus on 5G as a Service Revenue Generator.

Operators often state that they are focused on creating new revenue generating services, but in fact many spend much of their investment on better networks that will deliver more bandwidth at lower cost/GB. This is exemplified in figure 15 responses above. At heart they are 'Network Operators' before they are 'Service Providers' and their shareholders are getting impatient with slow revenue growth and flat ARPU.

Fortunately 5G-Advanced will help them to become even more efficient Operators and to grow their long awaited 5G Service Revenues.

5G-Advanced does bring in new features that will enhance performance and scalability at lower cost such as Massive MIMO, Energy Efficient RAN and RAN Optimization, large scale, low cost and passive IoT, and AI/ML and Automation to

reduce Network Costs, but it also introduces new capabilities that can rapidly become service revenue generators. For example Uplink and other types of Bandwidth On Demand enable new kinds of Interactive Video, Video Content Upload and RAN Peer to Peer (P2P) Content creation and Streaming alongside XR for Gaming and other pre-cursors of the Metaverse.

For business 5G-Advanced immediately enables V2x and NTN use cases and new applications for Industry 4.0, Digital Twins and Private 5G as it integrates 5G NR with a fully fledged SA Core that supports new and enhanced services whether on site or across the public network. In parallel as noted above new devices and Intelligent UEs will likely trigger a flood of new applications and services, e.g. smart UEs for Uncrewed Aerial Vehicles(UAVs) that will leverage a multitude of new drone solutions.

SDN, Edge and Network Slicing will accelerate adoption of many 5G-Advanced solutions including:On Demand Uplink to satellite, Optimized Network Slice Selection, Mobility Management, NR Duplex management with Edge Server backup for retransmission. Very precise Timing Services – independent of GPS – and Intelligent User Equipment (UE) are all ushered in with 5G-Advanced.

The outlook for CSP revenue from 5G-Advanced is looking good.

Note on key enterprise survey findings

One of the major sources of new 5G revenue growth is expected in 2024 – 25. to come from Enterprise customers for Private 5G, Network Slicing and Edge Services businesses. So let's examine their priorities from our recent survey.

Note: Although enterprise customers are looking for the same high reliability, high performance 5G services that the operators are trying to deliver they have a somewhat different perspective. Based on our recent interviews Enterprise priorities are focused on the impact of the 5G-Advanced capabilities on their business and IT operations efficiency in 14 priority areas as shown below. These are grouped by Enterprise Business and Feature/technology Requirements just as the CSP priorities were. They are:

Enterprise business requirements

1. System integrator (SI) plays a key role
2. Reliability is critical for Enterprises to assure ICT infrastructure
3. Cloud is Key for Digital transformation.
4. CSP's must respond to pressure from Hyperscalers and leverage extensive CSP network expertise
5. Enterprise customers have a strong preference for Private LTE and 5G over Public Network

Enterprise feature and technology requirements

6. Enterprise customers want 5G basic features first - Bandwidth, Performance and Low Latency
7. Security is critical
8. Industry 4.0 transition is driving demand for 5G and 5G-Advanced
9. 'Sidelink' adoption
10. Reduced Capability (RedCap) devices must meet basic functionality requirements
11. Uplink Bandwidth 'On Demand'
12. Secure Local Edge Processing
13. Remote Location Coverage and Bandwidth issues
14. 5G is preferred to Wi-Fi in factory

Detailed descriptions of survey responses for each category are in Section 6 above.

The challenge for operators therefore is to align their Network operations goals with their Consumer and Enterprise customers' priorities to leverage 5G-Advanced for 5G Service Revenues in 2024-2025.

Recommendations

To speed the adoption of 5G-Advanced in 2024-2025 Operators must respond promptly to key triggers.

Operators must respond promptly to key triggers that will allow them to both reduce costs and generate new revenues in the 2024 – 25 timeframe.

The figure below shows some of the top triggers that will influence the timing for 5G-Advanced deployment.

Figure 51 Top Triggers for 5G-Advanced in terms of Cost Savings and New Service Revenues

Select trigger categories	Specific 2024/25 trigger for action	CSP priority addessed	CSP benefit	Related systems also triggered
'Save money' - examples of top cost savings triggers for 2023-25				
Energy cost/Net zero	Achieve 30-40% reduction in energy cost per GB	Energy efficiency per GB	Cost reductions of 30-40% $ per GB	New open vRAN interfaces
	Reduce RAN energy costs	Over the air energy savings	5G capacity expansion	MIMO upgrades
Operations/OPEX cost	Simplify RAN management	ML/AI and automation for intelligent RAN	Enhanced 5G performance and profitability	5G SA OSS and orchestration
	Scale 5G RAN	Enhanced RAN and MIMO performance, capacity and reliability	5G capacity expansion	MIMO upgrades
'Make money' - examples of top service revenue triggers for 2024-25				
Increased coverage requirements - rural and indoor	Expand remote and indoor coverage as needed	RAN coverage with beamforming, integrated access backhaul (IAB) and Sidelink	Network expansion satisfies Government broadband goals	Integrated fixed wireless access (FWA) and Wi-Fi integration
Completion of NGMN 5G service vision	Need for new 2025 revenue growth	New and enhanced services for select verticals based on SDN, Edge cloud and network slicing	Application-specific solutions	Open 3rd party APIs for Industry 4.0 developers
	Industry 4.0 transformation	New applications and UE/device-driven use cases		
New intelligent UE/Device-enabled services	Device diversity	Intelligent differentiated UEs and specialty devices	Return of CSP-branded UE and device options in firmware	UE cloud hosted apps
Foundation for next generation services/6G and Metaverse	Spatial internet, digital twins	5G custom UEs and URLLC for low latency app. specific services	App enabler for next generation services	Insight on cloud and network elements for Web 3.0/Metaverse

Source: TechInsights, Networks and Service Platforms

As the figure above indicates the need for energy cost savings will trigger opportunities to enhance RAN efficiency and reduce Cost per GB. The need to simplify and scale 5G RAN while reducing OPEX, will likewise trigger both AI/ML and automation in parallel with enhanced RAN and MIMO performance.

New Revenue triggers will be created in parallel, not only by requirements for Rural as well as Indoor coverage but also by the growing need for CSPs to grow revenues in 2025 and to respond to 'demand pull' for private and hybrid 5G that is being driven by Industry 4.0. These in turn will stimulate expanded coverage and new application specific solutions for specific verticals e.g. manufacturing and healthcare. The emergence of specialized devices for these verticals will in turn trigger new applications that create a revenue opportunity for operators to create custom firmware and embedded software for intelligent 'branded' UEs.

We encourage Service providers to seize these opportunities to deploy 5G-Advanced for both cost savings and revenue growth as they are triggered by major trends and CSP business imperatives over the next few years.

Appendix A: 5G solution enablers and references

Three key Service Enablers that do not all exclusively depend on 5G-Advanced but that are essential to complete the 5G NGMN vison in 2024/25 are Software Defined Networking (SDN), Edge Compute and Network Slicing. Based on additional secondary research we summarize these three major solution enablers below.

A.1 Software defined networking (SDN)

- SDN. Several Global operators are already focused on Global Cloud Data VPN connectivity for large multi-national corporations (MNCs) combined with Software Defined Networking to give large customers visibility and control of pre-configured service activation. Others have picked a few industries where they have developed solutions that are common to 80 percent or more of the customers in the same vertical market to avoid costly customization. Still others are partnering with Systems Integrators to deliver expensive custom B2B solutions for large clients with special privacy and security requirements. The trick for 5G-Advanced is to leverage SDN to:
- Capture new revenues by bringing mass customization to VPNs and Industry Clouds/Extranets in conjunction with 5G
- Enable On Demand activation of 5G-A features such as Sidelink and symmetrical Uplink
- Allow UEs and End Users to trigger access to 5G Core services via Fixed (WiFi, Ethernet, Wireless) or Satellite as required.

A.2 Edge service enablers

- Most operators we interviewed have indicated that they are deploying Edge Compute resources over the next couple of years – at Data Centers, Base Station sites, or even at Edge Routers. By 2025 5G SA and AI/ML will make it feasible for CSPs to offer on demand data filtering, backup and forwarding at part of 'Edge Cloud as a Service'. As a key solution enabler for 5G-Advanced Edge capabilities were highlighted in response to multiple questions.
- Edge featured three times in figure 22 responses on 'Top Business Driven Services that will be most important in the 2024-25 Timeframe' i.e. as:
- Security and Privacy for Edge access services
- AI/ML for Load Management at the Edge
- Low latency enablers at the Edge
- In figure 26 'Most Important 5G-A Innovations in Architecture, technology and Services', Edge was one of three high level innovations - "Telco cloud, edge and automation of networks" that operators are demanding for 5G-Advanced
- Figure 31 responses on 'Features/Technologies that are New and Enhanced Service Drivers identified Metaverse enablers for Edge Services
- In addition both Operator and Enterprise Interviews identified 'on-premise' or 'far edge' CSP managed Apps. to control robots, track assets, enhance security, data backup and reduce the cost of fixed WAN transport to the Cloud. That last capability – where filtering and storage at the edge massively reduces data uploads to the central Cloud Data Center - may turn out to be a 'killer app.' for CSP distributed metro area edge services sold to enterprise customers.

A.3 Network slicing

- Almost all the interviewees indicated a renewed interest in Network Slicing to allow a diverse range of applications/services to have guaranteed Quality of Service (QoS) while sharing the common pool of virtualized network resources. See forthcoming TechInsights publication 'Capacity and Cost Savings from Dynamically Shared Network Resources with Network Slicing and Virtualization'. Release 18 will finally make it possible to dynamically assign new service flows from multiple users to a shared pre-provisioned slice that guarantees a particular Class of Service. This will dramatically improve the profitability of Network Slicing which today is largely 'nailed up' physically just like a dedicated leased line. With Release 18 CSPs will realize that Network Slicing is the key to profitably managing a wide range of VPN and SD-WAN requirements across a range different markets and applications that share the virtualized pool of network resources. Savings of 30 – 40 per cent cost per VPN could open this market to Small and Medium Enterprises (SMEs).

Privacy and Security are also two key drivers for Network Slicing that can reduce Enterprise concerns about remote Cloud access and concentrate traffic to lower leased line and carrier Ethernet transmissions.

As Network Slicing lowers costs it brings Private Network VPN capabilities - that large corporations have long enjoyed - to small and medium enterprises (SMEs) who will soon be able to leverage standardized lower cost versions of the 'managed connectivity' services '.

A3.1 Special note on network slicing in releases 17 & 18

Dynamic Network Slicing Standards finally arrive in Releases 17 and 18

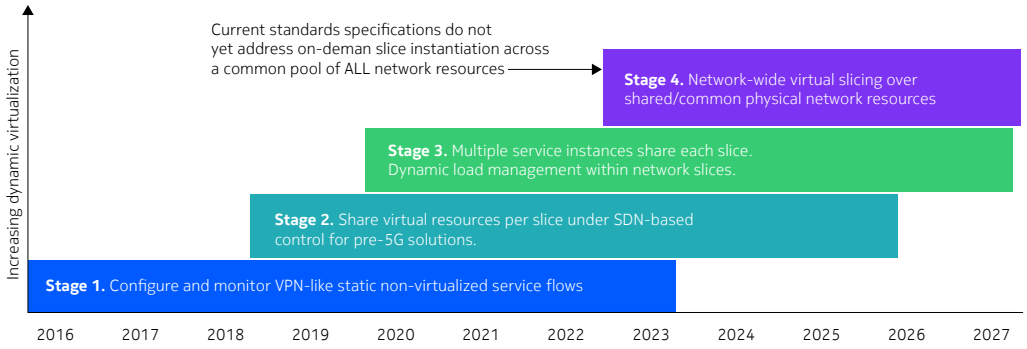
Critical enhancements for Network Slicing standards are in process to facilitate dynamic assignment of multiple UEs and UE service flows to available/active/ pre-configured slices and make Network Slicing on Demand far easier to implement. Specifically:

- Release 18 starts to enable multiple UEs and UE Service Flows/ Sessions to Share a Common Slice (subject to Security and Corporate VPN limitations) See TR 33.886 V0.2.0 (2022-10) Study on enhanced security for Network Slicing Phase 3 Section 4.3 Network slice admission control (NSAC)
- In Process 3GPP Release 17 TS 32.255 Proposal for Multi-Tenant Network Slice charging based on 5G Data Connectivity makes it possible to create a business case for Slice Sharing,
- Evolution of NPN (Non-Public Networks) (both Private and Publicly Hosted) will start to enable End to End Multi- Access Shared Slices. See 3GPP News Dec 2022- 3GPP Non-Public Networks (NPN).
- See Extract below:

"Release 18…3GPP is also studying to enhance management and security of NPNs. The management study includes end-to-end network management, including RAN and CN (Core Network) domains, in NPN scenarios, cooperation between 3GPP and non-3GPP management systems, and management of capability exposure for various types of NPNs. In the security perspective, security implications of the new NPN features are being studied. For example, support for mobility between Standalone Non-Public Networks (SNPNs), support for non-3GPP, and enabling of localized services for NPNs.

Below is TechInsights projected Roadmap for Network Slicing evolution. Note that operators have only just entered Stage 4 in 2022.

Figure A1 Projected Roadmap for Evolution of Network Slicing



Source: 'HPE, Intel Sponsored Report '5G Network Slicing – Management and Orchestration Aspects' 2019

Based on the evolution of standards described above and expected implementation of solutions, we anticipate that 5G-Advanced will usher in the full range of Network Slicing and Virtualization solutions.

These will be based – among other capabilities – on 5G Standalone (SA) Service Based Architecture, NPN and End to End Multi-Domain Network Slice management and orchestration as well as 5G Intelligent UE requests for IoT and other Network Slicing – that will eventually allow protocols for special purpose Devices – Drones, Robots etc.

Between 2025 and 2028 the full NGMN vision of Network Slicing and Resource Virtualization should be steadily completed in Releases 18 through 20.

A4. References

See additional reports on SDN, Edge and Network Slicing:

- Overcoming Barriers to Large Scale SDN/NFV - Design, Deployment, DevOps and Digital Dollars
- Edge Services do not need 5G but 5G needs Edge in 2021 – Winning vendors will offer Distributed resources
- Adding Communications Service Provider (CSP) Value to 'Edge Cloud
- Two Revenue Generating Use Cases Leverage New Network and Service Orchestration: I. Managed SD-WANs, II Multi-Domain, Multi-Cloud Network Slicing
- Multi-Domain Orchestration makes 5G Network Slicing Real for Non-Public Networking (NPN) in 2021

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