Spirent

2025

It's Halftime for 5G

Progress, Key Plays, and Future Prospects

A Spirent Report

Huddle Up

5G: Ready to Win

Stakeholders are eager for action.
End users want to be wowed. It's time for 5G to deliver.

By all accounts, 5G has faced its share of trials as it works to find its footing in complex, global markets. Now we stand at the midpoint of the 5G era—with 6G coming into view for 2030—making this a true halftime moment.

5G has proven it can achieve real transformation. As 5G Standalone (SA) deployments continue to grow and 5G-Advanced starts to take off, telecom is poised to deliver the true capabilities of 5G that meet industry needs.

Our confidence in 5G as an enduring growth driver remains strong as demand-side momentum builds.

With refined strategies coming into focus, it is 5G's moment to power new capabilities, revolutionize industries, and unlock revenue opportunities.

From Fixed Wireless Access (FWA) and private networks to emerging stars like 5G RedCap and 5G V2X, the marquee players are set to deliver real value. Combined with advancements in network APIs, AI-driven infrastructure, the low-altitude economy, and non-terrestrial networks, the second half of the 5G game promises to be action-packed.

Halftime means there is still a long way to go. Despite the preparation and proof points, our industry still faces complexity, fierce competition, and economic uncertainty.

Winning in 2025 will mean staying resilient, delivering peak performance at scale, and capitalizing on the hard work conducted to date. On this front, Spirent is proud of its track record, supporting over 3,500 5G engagements globally.

As the game progresses, we'll see 5G achieve a level of gameplay we've long known was possible but that remained elusive for many years.

We're excited to share our latest annual 5G outlook report—offering the clarity and strategies you need to make the second half of the 5G journey a success.

Eric

ERIC UPDYKE
Spirent CEO, Executive Director

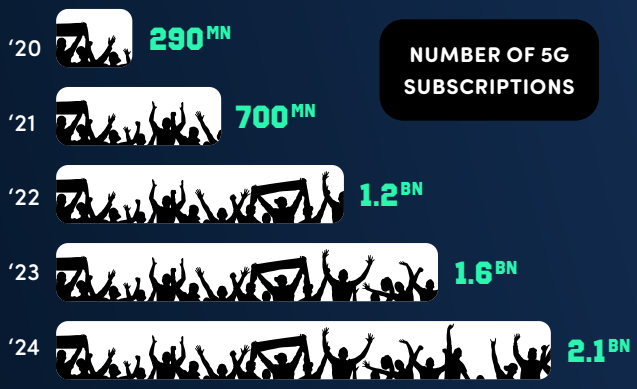
What's Inside

LET'S CHECK THE

Halftime Scores

NUMBER OF 5G COMMERCIAL LAUNCHES

NUMBER OF 5G SUBSCRIPTIONS



Note: 5G is the fastest growing mobile technology to date. It took 5G 5 years to reach 1.6bn subscriptions, 4G took 7 years, and 3G 10 years.

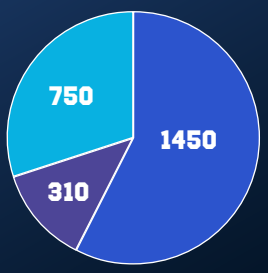
5G POPULATION COVERAGE BY 2024

China	96%
Japan	96%
North America	96%
Germany	96%
France	95%
Brazil	94%
Spain	92%
United Kingdom	86%
India	80%
South America	50%

MOBILE 5G POSTPAID MONTHLY ARPU

BEFORE 5G		AFTER 5G	
$45.8	US Operator	$48.8	▲
¥47.4	China Operator	¥51.0	▲
£17.9	UK Operator	£18.5	▲
€18.4	German Operator	€17.7	▼
JPY4230	Japan Operator	JPY3930	▼

NUMBER OF 5G DEVICE TYPES



CAPITAL INVESTED ON 5G SPECTRUM BY 2024

North America	$122BN
Europe	$26.9BN
India	$31.3BN

2024 5G FWA MONTHLY ARPU (AVERAGE):	United States	Western Europe	Middle East	India
	~$46	~€32	~$70	~$12

Source: Spirent Market Insights

FROM THE EXECUTIVE VICE PRESIDENT

5G Standalone Scouting Report

Commercial Deployments to Accelerate in 2025

Global momentum headed into 2024 was promising though macro-economic uncertainties and technology complexity ultimately impacted operator 5G Standalone (SA) deployment goals.

However, lack of visible commercial deployments in the field doesn't tell the whole story. The real action unfolded behind the scenes, where progress toward large-scale SA rollouts continued at a rapid pace and new 5G-Advanced plays kicked off.

In the past year alone, Spirent engaged with more than 50 CSPs, NEMs, and hyperscalers on 5G SA testing. Key drivers spanned performance, security, resilience, lifecycle management, and service-based testing.

We view the priority and focus being placed on testing as an encouraging indicator of accelerated 5G SA and 5G-Advanced deployments in 2025.

It's Go Time

The global telecom community needs 5G SA's performance and capabilities to power a range of growth initiatives. The motivation behind what is being tested highlights the range of offerings we can expect out of the gate as these powerful networks are finally turned up and positioned to become revenue growth generators.

Let's break down the key testing categories to better understand what comes next for 5G services.

Manuel

MANUEL ZEPEDA
Spirent, EVP

NEW ENGAGEMENTS IN 2024

415

UNIQUE CUSTOMERS

138

Testing Priorities Highlight 5G SA and 5G-Advanced Potential

The testing efforts undertaken during 2024 by global telecom stakeholders underscore the priorities for future 5G networks.

Security and resilience. Vendor 5G Core networks were being validated against 3GPP's Security Assurance (SCAS) specifications, while resilience testing zeroed in on how cloud-native network functions (CNFs) perform and recover across diverse cloud infrastructures. These efforts are building confidence that 5G SA will be able to handle complex, real-world demands and deliver service continuity.

TOP 5G PLAYS OF THE YEAR

DISRUPTIVE TESTING FOR 5G CLOUD-NATIVE NETWORK RESILIENCE

A major North American MVPD wanted to rigorously test the resilience of its pre-deployed 5G SA core network by validating 5G cloud-native architecture robustness. Spirent engaged in chaos-based testing via the Spirent Landslide CNF Resiliency Test Solution, which introduced disruptive network failure scenarios like storage connection loss and infrastructure resource depletion to gain critical insights into recovery mechanisms, QoE, and automated response effectiveness. This work was conducted as part of an expansive initiative with Spirent to refine test automation, ensure 5G core network robustness, and scale future deployments.

Automation and lifecycle management. Continuous Integration and Continuous Deployment (CI/CD) practices got a boost from automated continuous testing integrated into the pipeline. Demand is growing for subscription-based test libraries that assess functional and non-functional testing, including compliance, capacity, performance, resilience, and security, which are all foundational for seamless lifecycle management and a seamless lab-to-live process for operators. **Advanced services and features.** A variety of advanced use cases will define the 5G SA era as testing gets underway to validate them, including:

- 5G Core's readiness to handle millions of RedCap (Reduced Capability) devices that must coexist with traditional smartphone networks.
- Verifying large-scale roaming scenarios such as home-routed and local breakout setups for 5G roaming.
- Assessing 5G Core's ability to support Mission-Critical Push-to-Talk (MCPTT) services with voice, video, and data functionality, especially in large-group scenarios.
- Testing IEEE Time-Sensitive Networking (TSN) in private networks for precision-driven applications, as well as 5G Local Area Networking (LAN) functionality.

Network slicing and API enablement. Network slicing got close attention, with operators validating UE Route Selection Policy (URSP) and testing slice-specific authentication mechanisms (NSSAI) to pave the way for vertical industries to authenticate users or devices with their own identity management systems. Additionally, we are seeing increased demand for Common API Framework (CAPIF) testing, which securely exposes network capabilities to third-party developers.

TOP 5G PLAYS OF THE YEAR

SPEEDING 5G LIFECYCLE MANAGEMENT AND COMPLIANCE IN THE FACE OF COMPLEXITY

To meet new compliance standards, **a major UK mobile network operator** needed to reduce network vulnerability testing time from months to two weeks while grappling with 5G disaggregation complexity. It implemented automated testing and lifecycle management via Spirent's Landslide, Velocity, and VisionWorks solutions, achieving rapid code validation and "test to deployment" times measured in hours instead of weeks. Full end-to-end deployment will be completed within the first half of 2025, allowing continuous testing in lab and live environments based on integration of tools like GitLab and Jenkins, ensuring regulatory compliance and network reliability while continually speeding new features to market. The operator plans to expand this pioneering initiative to international markets for its Non-Standalone (NSA) and SA networks.

ENSURING NETWORK RESILIENCE IN EMERGENCY SCENARIOS

A Turkish telecommunications and digital services provider with more than 40 million subscribers wants to ensure robust emergency connectivity in an earthquake-prone region as it preps a nationwide 5G deployment. It is relying on Spirent Landslide to help enhance core network resilience when the network is overwhelmed with voice calls, replicating high-stress scenarios by simulating peak emergency traffic and ensuring performance under controlled, disaster-like conditions. While this type of testing is usually reserved for lab environments it is being conducted successfully in the live network following government and regulatory approval.

Winning with a Better Customer Experience

Operators are intently focused on service quality, identifying the experience they want to deliver and working backwards to ensure they are not falling short.

5G SA and 5G-Advanced are poised to significantly enhance consumer and enterprise services via 5G-powered Voice over New Radio (VoNR), Video over New Radio (ViNR) and location-based services with assisted GPS (A-GPS). These services need to seamlessly deliver enhanced performance and quality of experience (QoE), which kept operators busy conducting drive testing and benchmarking to ensure they are ready to deliver as expected.

QoE benchmarking also extended to services like Fixed Wireless Access, which needs to meet demanding data, video streaming, and gaming QoE requirements, multi-access edge computing (MEC) to assess throughput and latency, and nationwide competitive benchmarking of all services.

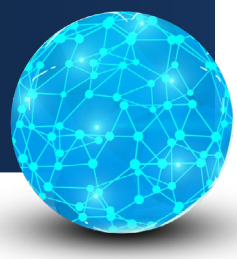
TOP 5G PLAYS OF THE YEAR

COMPARING 5G EDGE COMPUTING PERFORMANCE TO HYPERSCALER CLOUD

A major UK mobile operator wanted to measure performance of its 5G multi-access edge computing (MEC) network against a cloud-based hyperscaler solution under real-world scenarios. It engaged with Spirent to gather granular application, location, and network path data across multiple cities to understand latency, throughput, and application performance down to the region and SIM level. The project validated edge-based low latency benefits but exposed network routing irregularities like unexpected latency variations between sites, revealing a requirement for optimized traffic pathing. Empowered by a clearer understanding of MEC's limitations and potential in its network infrastructure, this pioneering initiative is helping the operator strategically expand into additional regions with robust and responsive 5G services.

DIALING IN 5G AUDIO QUALITY TESTING TO MEET NEW CARRIER STANDARDS

A global mobile phone manufacturer in China needed to meet stringent 5G VoNR audio quality standards in its role as a key handset supplier to operators in the country. It used Spirent's Umetrix Voice to perform complex audio quality testing and precise channel modeling in its own labs, streamlining certification processes and supporting sophisticated R&D testing. This capability helps maintain a competitive edge in a dynamic market while positioning the company as a global leader in 5G and next-generation audio quality assurance.



Assuring Boundary-Pushing Network Performance

Active testing for service assurance has gained increased focus due to the rollout of 5G SA commercial deployments. This shift is driven by the need to proactively monitor the new mobile core and specific services, such as VoNR.

Additionally, there has been a continued emphasis on live 5G over-the-air (OTA) testing, where autonomous field devices generate realistic traffic scenarios to proactively verify the QoE delivered to end users. This approach aligns with a growing trend among leading operators to prioritize end-user experience as a strategy for driving revenue growth and reducing churn.

TOP 5G PLAYS OF THE YEAR

VALIDATING AN EXPANSIVE NETWORK VENDOR OVERHAUL

A UK government mandate prompted **a mobile operator** to swap single-vendor, core network equipment with a new cloud-based, multi-vendor environment. The complex transition spanned 4G, 5G NSA and SA architecture, requiring extensive pre-production and production validation with Spirent Landslide for core network test and Spirent VisionWorks for active assurance amid integration challenges. A phased service activation approach validated each upgrade with real customer loads in segregated parts of the network to ensure it could support six million subscribers per migration iteration, eventually reaching a full scale of 30 million subscribers. Spirent solutions successfully identified potential design flaws along the way, mitigating major issues and avoiding costly live network outages. Reliable, scalable 5G services for this lab-to-live initiative have been achieved in production, supported by continuous testing capabilities that have reduced network operations escalations and increased operational stability.

Laying the Foundations for Long-Term Success

Deeper into the network, we are seeing operators continue Massive-MIMO testing, including 32 transmitter configurations for mid-band spectral efficiency. There is early interest for Frequency Range 3 testing in the "golden band" of 7-8 Ghz range, which promises to deliver enhanced capacity and coverage to support the growing demands of advanced 5G use cases.

On the IP Transport front, 400G router and switch validation for IP Core refreshes among large operators is underway in response to 5G traffic growth and anticipation of 5G SA demands. 400G is of high interest given its higher speeds per port while simultaneously decreasing energy consumption and rack space requirements.

At the same time, operators are turning focus to 10G, 25G, and 100G IP Transport fabric to support 5G RAN deployments. This directly addresses the higher capacity demands driven by MIMO radios and edge aggregation. eCPRI's 25G capacity requirements are in the spotlight as operators seek to support massive MIMO's data-intensive demands and 100G testing continues to ensure robust performance at edge aggregation sites.

Finally, Segment Routing (SRv6) is a growing focus given its support for custom traffic paths for user equipment (UEs), including 5G slices. SRv6 simplifies network management by reducing routing hops and improves reliability with fast traffic rerouting. It has emerged as a vital enabler of next-generation network performance and scalability.

Overall, Spirent views the backroom work commenced in 2024 as setting the scene for operators to deliver strategic 5G plays during 2025 with a focus on quality and ROI.

TOP 5G PLAYS OF THE YEAR

RIGOROUS CORE AND MPLS TESTING TO MEET NEW MARKET DEMAND

One of India's fastest-growing **network equipment manufacturers** is meeting significant operator and government demand by embarking on an ambitious 5G core project, deploying over 10,000 nodes for MPLS/VPN services. It is relying on Spirent's Landslide and TestCenter solutions to replicate high-demand, real-world conditions that help validate 4G and 5G Core offerings with rigorous testing to ensure high performance and reliability in global markets. Network node control and data planes are being validated in lab environments with Layer 3, MPLS, and Segment Routing (SR) features being assessed via comprehensive testing under varying network conditions, building pre-deployment confidence.

MONETIZATION

Meet Today's 5G Revenue Stars and Future MVPs

Early revenue expectations for 5G were tempered following deployment and demand challenges. Notable successes like 5G FWA underscore long-term opportunity for sustainable growth.

At the halfway mark, it is now clear that 5G monetization will be a team sport, with a range of revenue stars combining to comprise a strong foundation for growth. Let's meet the key players, break down how they've performed and look ahead at what to expect from the most promising future winners.

STEPHEN DOUGLAS
Spirent, Head of Market Strategy

★ ★ ★ STAR PLAYER ★ ★ ★

5G FWA

With average revenue per user (ARPU) approaching $50 per month across 30 million global subscriptions, 5G Fixed Wireless Access is proving its ability to win share against cable broadband and high-speed offerings in rural areas.

As deployments expand beyond 160 rollouts in more than 70 countries, including emerging markets such as India, Brazil, and sub-saharan Africa, service quality improvements like 140Mb/s download speeds are making it possible to replace unlimited offerings with speed-based tariffs. Frequency band sharing, and CPE device and location issues can occasionally hamper performance, and customer equipment remains pricey. These challenges can be addressed in part via network congestion and load management, more window-mounted device options, and streamlined installation processes.

SECOND HALF OPPORTUNITIES AND STRATEGIES

Expand consumer footprint by upselling subscribers and adding new ones, marketing speed boosts for services like gaming and SLAs for performance-sensitive apps like video conferencing, multi-view experiences, and use cases like home security.

Target enterprise users with SLA-based offerings guaranteeing availability, reliability, and performance, including SMEs that want a fiber alternative, connectivity in remote or temporary locations, or continuity support for mission-critical industries and military applications.

Offer a supercharged 5G SA tier using network slicing to capture premium audiences that want the best performance for transformative and lucrative use cases like cloud gaming and extended reality.

Serve multi-occupancy buildings like condos and offices, which are often underserved by high-cost, legacy broadband offerings.

TOP 5G PLAYS OF THE YEAR

VALIDATING 5G FWA PERFORMANCE IN COMPETITIVE MARKETS

A top U.S. mobile operator offering high-speed home internet via 5G-powered FWA wanted to ensure it was delivering advertised speeds and performance levels. It worked with Spirent to measure data, video, and gaming performance with comprehensive, competitive field testing in several major cities for insight into how mobility, peak usage times, and varied spectrum strategies affect reliability. It also used the granular data collected, like specific 5G link performance metrics, to identify optimization opportunities and develop strategies for further enhancing user experiences as it plans a 2025 expansion into additional cities.

★ FUTURE GAMECHANGER

PRIVATE NETWORKS

Promising enterprise ROI and benefits like reduced downtime and increased productivity, efficiency, and safety are driving consistent but conservative adoption, as initial deployments remain in the low hundreds of devices for use cases like enhanced coverage and workplace communications. Manufacturing, energy and mining, transport and logistics, and government and military lead rollouts. Challenges remain around high deployment costs, integration complexity, lack of industrial devices and 5G R17 and R18 feature support, with still-to-be proven value for operators.

SECOND HALF OPPORTUNITIES AND STRATEGIES

Incorporating enhanced network slices into dedicated environments can be a step toward enterprise hybrid public/private network acceptance in the face of security, privacy, and performance concerns.

Cost and integration challenges can be solved via enhanced 5G capabilities like RedCap and access traffic steering switching and splitting (ATSSS), especially in brownfield environments where Wi-Fi coexistence is required.

Increase value and boost enterprise ROI potential by integrating Release 17 and 18 features like enhanced location performance and positioning accuracy, expanded support for Time-Sensitive Networking (TSN), and advanced mobility management for connected drones.

INTEGRATING RELEASE 17 AND 18 FEATURES EXPAND SUPPORT FOR TIME-SENSITIVE NETWORKING

TOP 5G PLAYS OF THE YEAR

5G LAN POWERS A PIONEERING SMART MANUFACTURING TRANSFORMATION

A major APAC-based global data center solution provider saw Wi-Fi struggling in advanced industrial environments, spurring a three-year, 5G-powered smart manufacturing innovation initiative for uninterrupted communication among robotic arms, automated guided vehicles (AGVs), and other workstation devices. Supported by 5G LAN-enhanced Ultra Reliable and Low Latency Communications (URLLC), Spirent Landslide is enabling seamless data exchange from sensors, PLCS, dashboards, and ERP systems without requiring traditional cabling – a defining aspect of "lights-out" manufacturing that lets facilities operate autonomously without human intervention. The new private network infrastructure introduces AI and ML-driven manufacturing advancements, enabling data slicing between production lines for optimized workflows and scalability. This next-generation, efficient, manufacturing model showcases 5G LAN's ability to transform industrial production, paving the way for similar initiatives globally.

★ FUTURE GAMECHANGER

RedCap

Introduced in Release 17, RedCap (Reduced Capability) provides a "light" 5G experience to cut complexity for IoT device connectivity, reducing 5G NR module costs by 80% and power consumption by more than 30%. China leads the pack of over 15 countries trialing or implementing RedCap with three of its largest operators already deploying the first wave of devices, including dongles and terminals for IoT sensor aggregation.

SECOND HALF OPPORTUNITIES AND STRATEGIES

Position to support large-scale implementations, taking advantage of favorable economics to serve smart grid, smart city, and smart manufacturing demands.

Explore lucrative opportunities in consumer electronics wearable devices and eHealth markets.

Prepare to capitalize on Release 18 and 19 RedCap capabilities that increase value and addressable market opportunity, including improved positioning and advanced power saving.

★ FUTURE GAMECHANGER

5G V2X

Increased road safety and smart traffic demand and regulations are finally starting to focus adoption timelines as countries like China roll out initiatives like its C-NCAP requirements, seeking to move vehicle-to-everything (V2X) beyond trials and urban corridor projects. Necessary capabilities are being introduced in R16-R18, including NR Sidelink and relay, but challenges remain around roadside infrastructure readiness, 5G maturity and geographic coverage, high costs for automakers, and lack of globally aligned regulatory clarity as V2X adoption gradually takes off.

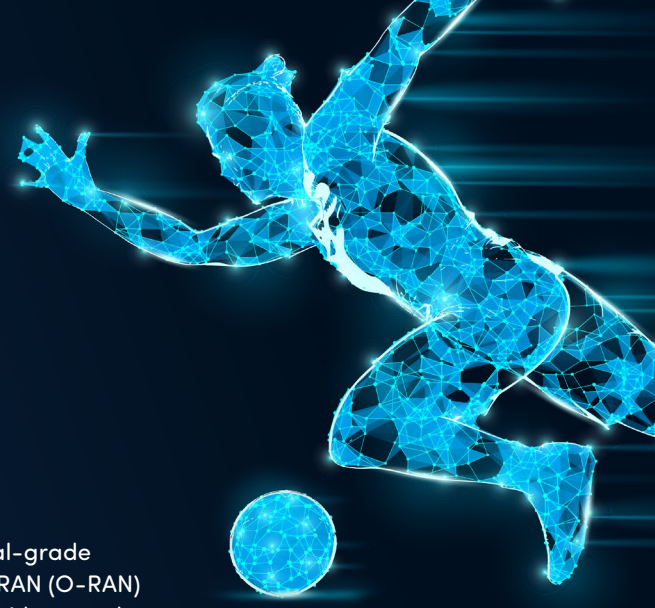
SECOND HALF OPPORTUNITIES AND STRATEGIES

Watch for initial deployments in countries like China, Germany, Japan, South Korea, and the United States, which have strong automotive sectors, advanced 5G infrastructure, and government support.

Expect urban and high-traffic corridor rollouts among smaller, tech-forward nations like Singapore and innovative EU countries that are poised for promising adoption.

Experiment with 5G monetization models that span subscription-based services for automakers and fleets, data-as-a-service for city planners and insurance companies, connected car services for consumers, edge computing for ITS providers, emergency service prioritization slices, and first responder networks.

Leverage RedCap in support of advanced driver assistance systems (ADAS), including to replace 4G Cat 4 infrastructure currently supporting lower-level ADAS use cases, such as improved location accuracy, TSN support, and advanced mobility management for drones, to offer increased value and ROI potential for enterprises.



★ FUTURE GAMECHANGER

OPEN RAN

A slowdown in the overall RAN market, vendor struggles to achieve commercial-grade readiness, and limited operator operational preparedness, challenged Open RAN (O-RAN) progress throughout 2024. Recent momentum has been promising, however, with several major operators revealing plans to adopt O-RAN within the next few years. To prepare, stakeholders are advancing beyond basic interoperability testing with a focus on achieving higher technology readiness levels defined by performance, security, and resilience.

SECOND HALF OPPORTUNITIES AND STRATEGIES

Help brownfield operators modernize and expand existing 5G networks as part of 5-6 year refresh cycles with an aim to reduce vendor lock-in, optimize cost structures, and foster innovation via multi-vendor ecosystem participation.

Deliver cost-effective, flexible, and scalable solutions for private networks with vendor diversity that supports tailored deployments for enterprise-specific needs and reduces reliance on proprietary systems.

Leverage RIC-enabled and embedded AI-RAN convergence to enhance O-RAN performance and scalability through AI-driven automation, real-time optimization, fault prediction, and improved energy efficiency with a focus on strengthening reliability, interoperability, and multi-vendor network adaptability.

Address non-terrestrial network (NTN) deployment challenges with O-RAN's software-defined radio approach, enabling lightweight, scalable SATCOM solutions for use cases like direct-to-device communications, IoT connectivity, remote coverage, and disaster recovery.

Future 5G Monetization MVPs Waiting in the Wings

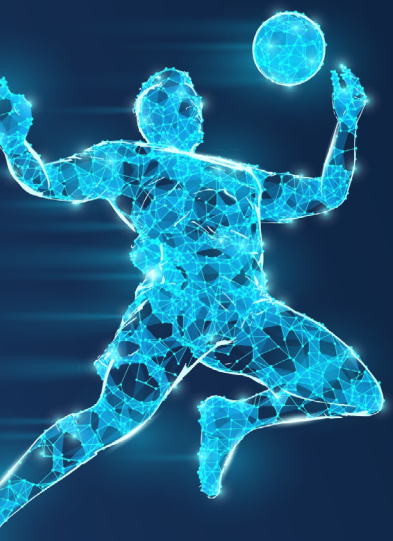
When it comes to additional potential standout monetization stars, 5G has considerable bench depth demonstrating promising signs of real revenue readiness. Let's meet these future MVPs and learn more about how they will impact future 5G strategies.

★ SUPER SUB

NETWORK APIs

Giving developers access to 5G capabilities can unlock new markets and business models while transforming industries and digital experiences as research firm Omdia predicts global network API revenue will reach $8.7 billion by 2029[1]. Number verification and SIM swap APIs will lead early growth as attempts are made to reduce fraud and support secure digital transactions. Looking further out, exposing 5G advanced capabilities like VoNR, network slices, ATSSS, and enhanced indoor and outdoor positioning could help significantly expand projected revenue predictions.

1. https://omdia.tech.informa.com/pr/2024/oct/omdia-forecasts-global-telecoms-network-api-revenues-of-9bn-dollars-in-2029



★ SUPER SUB

NON-TERRESTRIAL NETWORKS

Operators are set to deliver an expanded array of emergency, IoT, voice and data services that expand connectivity in rural, remote, sea and air environments for consumer, industry, government and military customers. 3GPP has progressively laid the 5G non-terrestrial networks (NTNs) groundwork since Release 17, integrating satellite and high-altitude platform communications with terrestrial networks, even extending to Direct-to-Device (D2D) communications to ordinary smartphones—potentially a $100 billion market by 2032, according to Analysys Mason. Future 3GPP releases will bring architecture enhancements and support for higher band, RedCap and network slicing devices.

TOP 5G PLAYS OF THE YEAR

REMOTE 5G CONNECTIVITY REACHES NEW HEIGHTS WITH NTN

One of **Japan's largest mobile operators** wanted to expand 5G coverage with Non-Terrestrial Networks (NTNs) in support of the National Institute of Information and Communications Technology (NICT)'s Beyond 5G/6G initiative. High-altitude platform systems (HAPS) were chosen to deliver enhanced connectivity to remote regions and improve resilience in disaster scenarios versus traditional approaches. Spirent Vertex 5G channel emulation enables realistic testing with dynamic signal strength and delay variation, which is crucial for feeder links from ground stations and service links between HAPS and user devices. The ability to emulate multiple channel types simulated a more realistic wireless propagation environment to ensure performance in dynamic, real-world conditions. The project sets a precedent for operators, national defense entities and other institutions in Japan and beyond as NTN application exploration continues.

★ SUPER SUB

LOW-ALTITUDE ECONOMY

Drones, urban air mobility applications, remote inspections, and other aerial services, all stand to receive a boost from the emerging ecosystem of businesses and services delivering 5G connectivity via low-altitude airspace, with countries like China anticipating a $2.7 billion market by 2030. Related operator revenue streams could soon span connectivity services and subscriptions for use cases like drone-based delivery and logistics, fleet management solutions like real-time tracking and route optimization, and edge computing services for processing real-time data generated by drones, including video.

★ SUPER SUB

XR & AI ASSISTED VIDEO

5G's high-speed, low-latency capabilities combined with AI-enhanced video processing is yielding immersive extended reality (XR) experiences like augmented reality (AR), which is set for mass-market adoption within the next 18 months. This shift positions mobile operators to monetize premium 5G data plans optimized for AR, new advertising revenue streams, sponsored AR content, and new enterprise offerings like AR-as-a-Service (ARaaS). Supporting this evolution hinges on R17 and R18 capabilities, such as NR XR, XR + Media Services, URLLC enhancements, and device compatibility.

★ SUPER SUB

NETWORK INFRASTRUCTURE AS A SERVICE FOR AI (NIAAS)

AI's rise represents an expanding opportunity to provide multitenant, scalable, and secure networking and hosting solutions that can help better monetize a range of telecom connectivity services. While many organizations, like SMEs and governments, lack the infrastructure to support AI's burdensome performance requirements, they are primed to take advantage of NIaaS offerings that provide on-demand, lower-cost access to optimized networking capabilities. These capabilities could initially include ultra-low latency high throughput network connections, dedicated secure network slices combined with wireline slices to meet privacy and data sovereignty-driven AI inference requirements, and secure communications that combine 5G with Zero Trust Network Access (ZTNA), Security Service Edge (SSE), and Quantum secure and private edge distributions.

★ SUPER SUB

5G MISSION-CRITICAL PUSH-TO-TALK

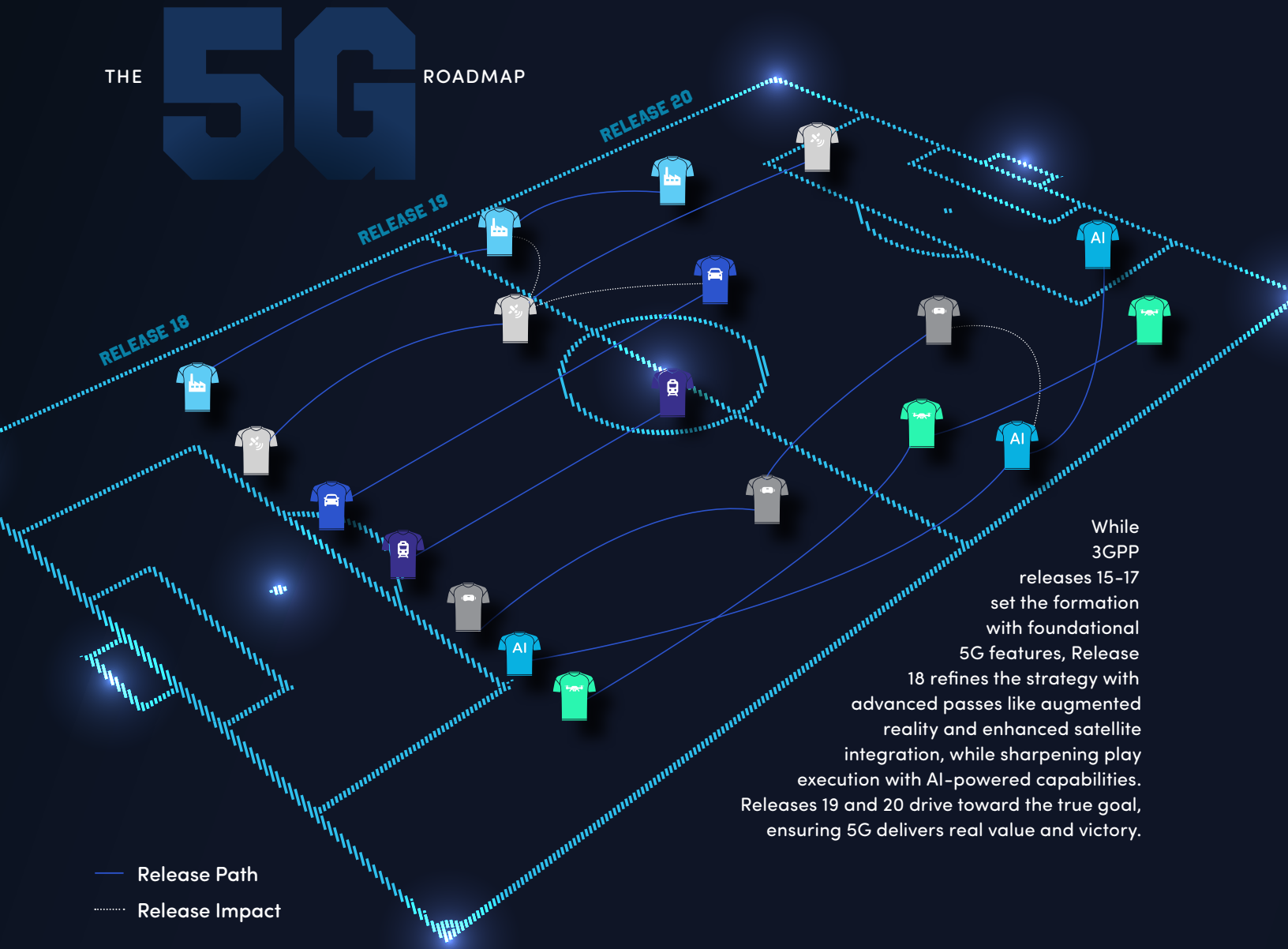
Prioritizing messaging, voice, video, group communications, and location sharing for mission-critical industries via low latency services powered by 5G Mission-Critical Push-to-Talk (MCPTT) represents a major potential revenue opportunity. This capability is central to planned initiatives like the Future Mobile Communications System for real-time communication between train operations teams, as Global System for Mobile Communications -- Railway (GSM-R) will be obsolete by 2030. Other industries like public safety and utilities and energy are all set to capitalize on MCPTT capabilities, especially as compatible device ecosystems become commercially available.

How do YOU plan on scoring goals with 5G? Answer our poll question and see what others think.*

*Poll will remain open until June 2025

CLICK FOR POLL

THE 5G ROADMAP



While 3GPP releases 15-17 set the formation with foundational 5G features, Release 18 refines the strategy with advanced passes like augmented reality and enhanced satellite integration, while sharpening play execution with AI-powered capabilities. Releases 19 and 20 drive toward the true goal, ensuring 5G delivers real value and victory.

	R18 Q2 2024	R19 Q4 2025	R20 Q1 2027
	Low Power High Accuracy Positioning (LPHAP) for industrial IoT, eRedCap devices for further complexity reduction, and slice enhancements incl. temporary & area of service	Edge computing for industrial scenarios (security, digital twins) Ambient IoT (study item)	Integrated Sensing and Communication 5G Femto cells Ambient IoT
	NTN Transparent mode enhancements incl. L & S bands	NTN Regenerative mode, enhanced DL/UL & RedCap support	NTN further enhancements (Store & Forward, UE-SAT-UE)
	NR Sidelink evolution (CA, unlicensed spectrum, relay)	NR Sidelink multi-hop relay	
	Interconnection and Migration Aspects for Railways (FRMCS)	FRMCS Phase 5, smart stations (study item)	
	XR+Media enhancements for traffic awareness & QoS	XR+M enhancements for Metaverse	XR+M enhancements (multi-modality, UP latency reduction)
	NR support for UAVs	Architecture enhancements for UAVs (security)	UAV enhancement (NEF for C2, no-transmit zones..)
AI	AI/ML for NG-RAN incl. data collection & signaling support	AI/ML for NG-RAN enhancements (beam mgt, positioning) AI/ML for NR air interface, mobility & slicing (study items)	AI/ML enhanced mobility

R15-17

Foundation for AI/ML focussing on network automation, analytics, and RAN intelligence.

Release 15: Introduced the **Network Data Analytics Function** (NWDAF), providing analytics to 5G Core network functions and OAM.
Release 17: Added NWDAF logical functions for AI/ML:

- **Analytics Logical Function**: Handles inference, analytics derivation and service exposure.
- **Model Training Logical Function**: Manages AI/ML model training.

Release 17 (RAN): Study establishing a functional framework for AI-driven RAN intelligence and use cases including **network energy saving, load balancing** and **mobility optimization**.

R18

Builds on previous AI/ML foundations, introducing:

WORK ITEM

- **AI/ML for NG-RAN**: Enhances data collection and signaling for energy saving, load balancing, and mobility optimization.

STUDY ITEMS

- AI/ML Model Transfer: Downloading AI models to UE based on traffic and performance requirements.
- AI/ML Management: Focuses on deployment and inference phases of the lifecycle.
- AI/ML for NR Air Interface: Early evaluation of CSI feedback, beam management, and positioning.
- Security and Privacy: Addresses privacy-sensitive exposure in AI/ML-based services and applications.

R19

In Release 19, as CSPs prioritize network performance and prepare for 6G, AI/ML remains a focus in four key areas:

Enhancements for NG-RAN: Improved AI/ML capabilities for RAN performance.
NR Air Interface: Continued development of AI/ML for Channel State Information (CSI) feedback and beam management.
5GS Enhancements: Advancing AI/ML functions within the 5G System (5GS).
Mobility Optimization: New study on proactive AI/ML mechanisms for Layer 3 handovers with a focus on high-density micro-cells, replacing existing reactive approaches.

5G PLUS AI

R20

Release 20 looks set to expand AI/ML capabilities in 5G-Advanced while laying the groundwork for 6G use cases and requirements:

5G-Advanced: Further enhancements of AI/ML capabilities.
6G: Study items on use cases and requirements, with AI/ML as an integral component combining distributed learning and deeply embedded AI.

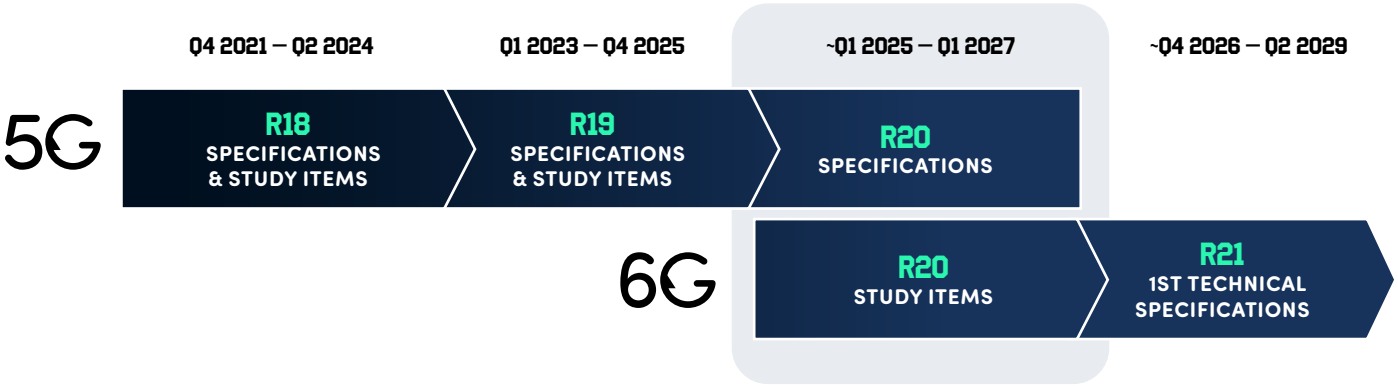
EXTRA TIME

6G: Is it 5G Overtime or a Whole New Game?

5G still has plenty of time left on the game clock, but 6G is already warming up on the sidelines. The real question is whether this marks a gradual evolution between generations or the start of a whole new game.

Studies for 5G's predecessor are already set to begin next year in 3GPP Release 20 with 6G normative work commencing in Release 21. As stakeholders prepare to conduct this preliminary research and exploration of 6G concepts and features, and begin writing and adopting standards, we could see the first set of 3GPP technical specifications by Release 21, which will be finalized before 2030. Unlike 5G's first release (R15), which was introduced incrementally, Release 21 is expected to be delivered in a single phase.

Estimated timeline



The 6G timeline targets a commercial rollout around 2030 with research and standardization efforts recently accelerating. 5G-Advanced (3GPP Releases 18–20) serves as a solid foundation as 6G is poised to enhance network efficiency, integrate AI, and power new use cases for a seamless progression to more transformative capabilities.

The International Telecommunications Union—Radio Sector (ITU-R) is shaping the 6G vision and requirements via the International Mobile Telecommunications set of standards. It has identified core use cases, which will continue to evolve through 2030 in alignment with global telecommunications needs.

IMMERSIVE COMMUNICATIONS

Multi-sensory interactions between physical and digital worlds.

Examples in action: Holographic telepresence, tactile internet, and ambient awareness.

MASSIVE COMMUNICATIONS

Extends 5G's Massive Machine-Type Communications (mMTC) capabilities with even higher connection density, security, and reliability.

Examples in action: Smart cities, logistics, environmental monitoring, and energy.

UBIQUITOUS CONNECTIVITY

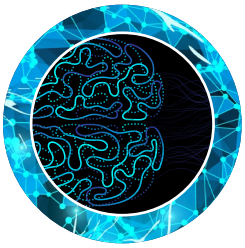
Support digital inclusion initiatives, reaching underserved or scarcely connected areas.

Examples in action: Enhanced access to healthcare, education, remote working, public safety, and disaster management.

INTEGRATED SENSING AND COMMUNICATION

Multi-dimensional sensing that provides spatial information about unconnected objects, connected devices, and the movements and surroundings of these devices.

Examples in action: Autonomous transportation, immersive augmented reality, and smart cities.



AI AND COMMUNICATIONS

Distributed computing for AI applications and advanced capabilities from integrating AI and computational functionalities directly into 6G.

Examples in action: Autonomous networks, personalized content, and immersive experiences, enhanced security, and advanced industrial automation.

HYPER-RELIABLE AND LOW-LATENCY COMMUNICATION

Extends 5G's ultra-reliable low latency communications (URLLC) capabilities to support specialized use cases with stringent performance requirements.

Examples in action: Machine interactions, emergency services, monitoring for electrical power transmission, and distribution.

Building on 5G and Looking Beyond

5G is being fine-tuned in alignment with market needs and revenue opportunities. For many of the feature sets finally being monetized or prepped for prime time, 6G will enhance these capabilities rather than attempt to change the game entirely. Let's run down the anticipated advancements:

1	PEAK DATA RATE	50–200 Gbps per device under ideal conditions.
2	USER-EXPERIENCE DATA RATE	300–500 Mbps available ubiquitously across the coverage area to mobile devices.
3	SPECTRUM EFFICIENCY	1.5x to 3x greater than 5G for average data throughput per unit of spectrum resource and per cell.
4	AREA TRAFFIC CAPACITY	30–50 Mbit/s/m^2 total traffic throughput served per geographic area.
5	CONNECTION DENSITY	Targeting 10^6–10^8 devices per km^2.
6	MOBILITY	Maximum speed of 500–1000 km/h for seamless connectivity during high-speed movement.
7	LATENCY	As low as 0.1–1 ms over the air interface.
8	RELIABILITY	Target reliability of 10^{-5} to 10^{-7} over the air interface.
9	SECURITY AND RESILIENCE	Enhanced beyond 5G system capabilities.

Looking beyond supercharged 5G capabilities, 6G is anticipated to introduce a range of transformative capabilities:

SENSING-RELATED FEATURES
New radio interface functionality spanning range, velocity, and angle estimation, as well as object detection, localization, imaging, and mapping.

AI-DRIVEN INNOVATIONS
Advanced functionalities like distributed data processing, distributed learning, AI computing, AI model execution, and AI model inference.

SUSTAINABILITY
Improved energy efficiency (bits per joule), minimized energy consumption, and optimized resource utilization as capacity increases.

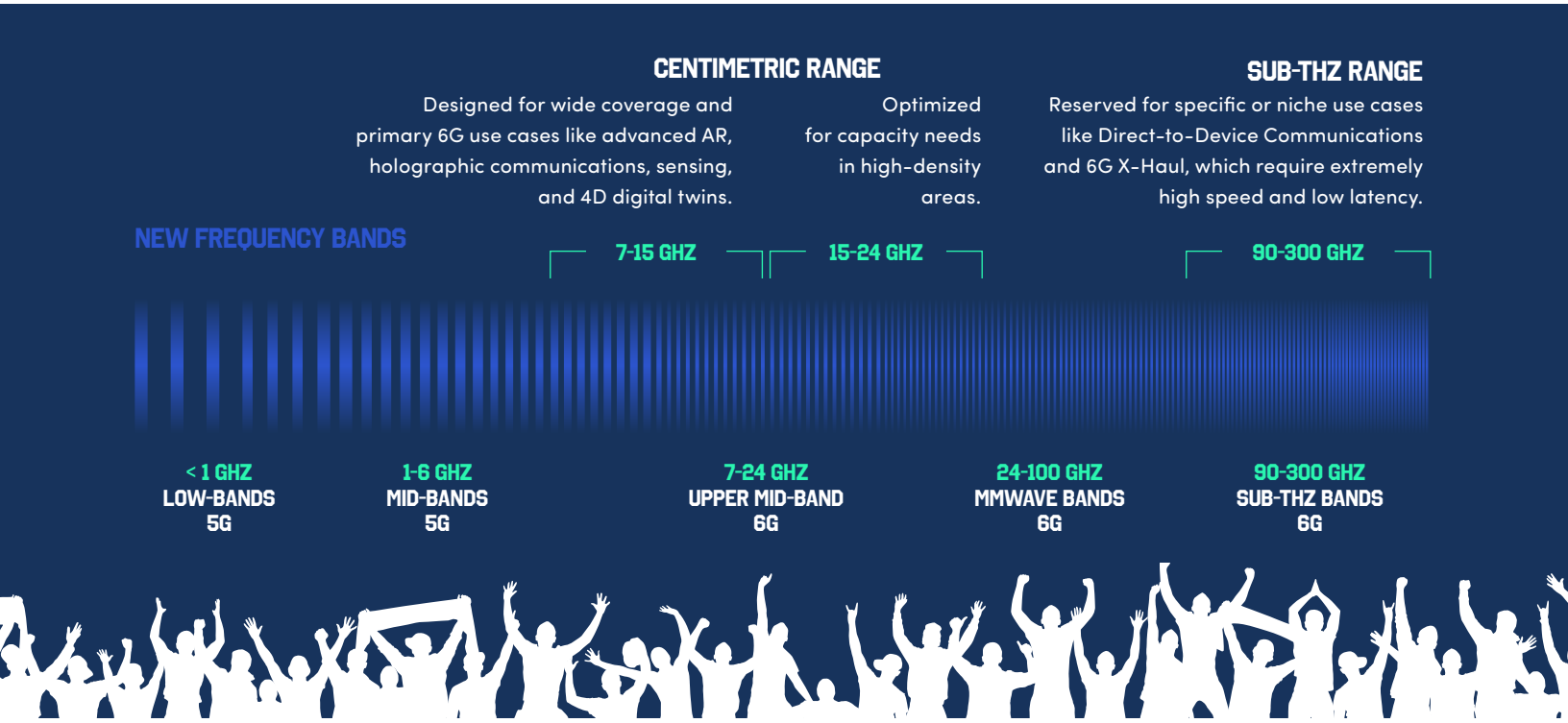
INTEROPERABILITY
Enhanced radio interface inclusivity and transparency for seamless functionality between different entities and suppliers.

POSITIONING
Precision accuracy ranging from 1 to 10 cm.

COVERAGE
Extended coverage versus 5G, including greater cell-edge distances.

Exploring 6G's Network Technology Enablers

6G won't just be defined by what it can do but how it accomplishes new technical feats. When it comes to pushing the limits of mobile connectivity, next-generation networks will be powered by a range of new technology enablers. Let's break down the emerging tech currently being explored.



AI-NATIVE NEW AIR INTERFACE

AI-powered performance and energy efficiency enhancements for radio functions like mobility, symbol detection and decoding, channel estimation, beam management, and interference mitigation. Automated intelligence lets radios decide between spectrum bands and reconfigure signal paths and modulation schemes as required.

EXTREME MASSIVE MIMO

Significant expansion of MIMO technology leveraging high volumes of antennas to achieve unprecedented spatial multiplexing, energy efficiency, and 6G network capacity. This increased antenna density introduces challenges like higher signal processing complexity, increased hardware costs, and greater physical space requirements.

DISTRIBUTED MASSIVE MIMO

Network performance is enhanced by deploying multiple, spatially separated antennas that work collaboratively versus Extreme Massive MIMO's high-density antenna approach concentrated in a single location.

DIGITAL TWIN NETWORKS (DTN)

Real-time replication and interactive mapping of the physical network into a virtual twin network that can help efficiently and intelligently verify, simulate, deploy, and manage 6G networks.

QUANTUM SECURITY

6G networks are incorporating advanced quantum security mechanisms to counter growing threats to traditional cryptographic systems, particularly from quantum computers. Key technologies include Quantum Key Distribution (QKD), Post-Quantum Cryptography (PQC), quantum-enhanced authentication (e.g., digital signatures), and Quantum Random Number Generation (QRNG).

RECONFIGURABLE INTELLIGENT SURFACES (RIS) UTILIZING META-MATERIALS

Engineered surfaces composed of metamaterials embedded with programmable elements, such as antennas, that dynamically manipulate electromagnetic waves to optimize wireless communication. These surfaces can reflect, refract, and amplify signals to enhance signal strength, coverage, and energy efficiency. RIS enables advanced functionalities like seamless urban connectivity, improved indoor coverage, and energy-efficient network densification, reducing the need for high-power transmitters.

EVOLUTION VS REVOLUTION

Competing interests and demands from across telecom's vast worldwide markets are slowly forming 6G's playing field.

It remains to be seen how the opportunity to pursue transformative innovation will be balanced against desire for pragmatic deployments devoid of complexity, spiraling costs, and long timelines.

IT BEGS THE QUESTION: WILL 6G BE AN EVOLUTION OR A REVOLUTION?

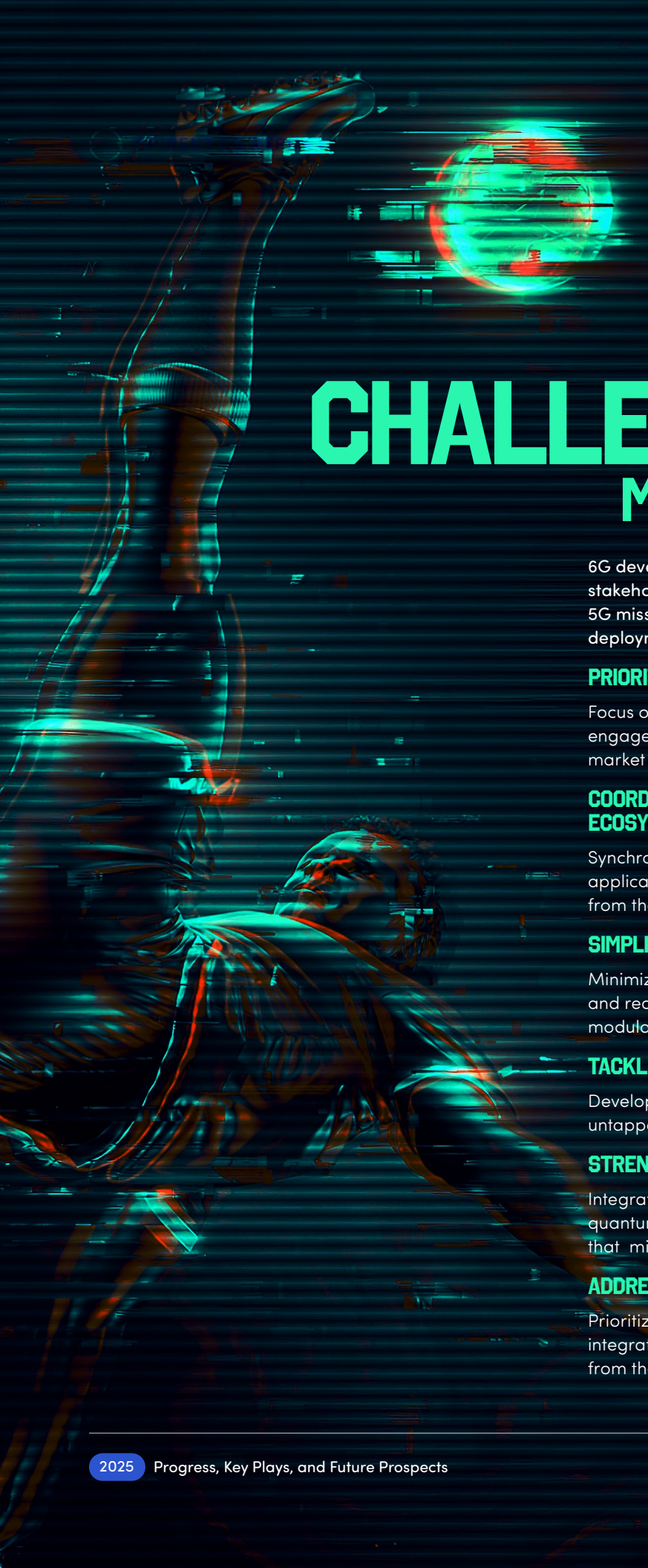
With expanded 5G revenue opportunities just starting to materialize, there is a desire to allow ample runway to monetize existing investments before introducing competing pressures. It is also unclear what the consumer appetite will be for next-generation services with unproven demand. If the industry overpromises service possibilities, it risks ultimately underwhelming users.

What is most evident is an eagerness to pursue a path toward seamless integration with legacy systems to support smoother ROI. This includes cost-efficient upgrades versus rip-and-replace overhauls that could bruise budgets for years.

WE ARE LIKELY TO SEE A HYBRID APPROACH THAT IS PART EVOLUTION, PART REVOLUTION.

Initial evolutionary enhancements based on 5G-Advanced and the first technical specifications of 6G will leverage 5G investments to improve efficiency and maintain cost discipline. Longer-term, the industry will integrate revolutionary technologies into progressive 6G standards, laying the groundwork for transformational applications.

This phased strategy could ultimately strike the necessary balance between financial sustainability and innovation, aligning operator and equipment vendor interests.



LEARNING FROM THE MOST CHALLENGING MOMENTS OF 5G

6G development can leverage the lessons learned from 5G. 6G stakeholders have an opportunity to proactively avoid repeating 5G missteps by leveraging six learnings that can help streamline deployments and aid successful adoption:

PRIORITIZE USE CASES WITH CLEAR ROI.

Focus on high-value, deployable use cases via early industry engagement to ensure offerings are aligned with actual market demand.

COORDINATE NETWORK ROLLOUT WITH DEVICE AND ECOSYSTEM READINESS.

Synchronize technology development across devices, applications, and networks so supply meets demand from the outset.

SIMPLIFY DEPLOYMENT AND OPERATIONS.

Minimize 6G design complexity by supporting self-optimization and reducing deployment costs through automation and modular design.

TACKLE SPECTRUM CHALLENGES AT THE ONSET.

Develop an early global spectrum strategy that explores untapped bands like terahertz and satellite spectrum.

STRENGTHEN SECURITY BY DESIGN.

Integrate security as a core 6G architecture component using AI, quantum-resistant cryptography, and other advanced measures that mitigate risks.

ADDRESS ENERGY AND SUSTAINABILITY CHALLENGES.

Prioritize energy-efficient designs and renewable energy integration, leveraging AI for dynamic power management from the start.

Team Spirent

Spirent has the vendor-neutral expertise and innovative solutions to unblock the path to 5G Standalone (SA), unlock new cost efficiencies, and unveil new revenue-generating services.

Service providers can choose from many different starting points and goals as they migrate to 5G SA and 5G Advanced. Some are greenfield operators, while others are taking the next step after 4G or 5G Non-SA. Some service providers are inclined to use a single vendor to simplify deployments, while others will integrate solutions from multiple vendors.

Spirent has already supported more than 65 service and cloud providers as they select vendors, test, and commercially launch 5G SA with the new cloud-native core network. Based on our experience, we describe 5G SA success as a journey with five key steps. The journey begins with 3GPP compliance, capacity, and performance validation, moving to security and validating cloud-native network functions. The final step incorporates automated, continuous testing across lab and production networks.

Regardless of your progress on the journey to 5G SA or 5G Advanced, Spirent has the vendor-neutral test, assurance, and automation solutions to help you unleash the potential of 5G and deliver a new generation of revenue-generating services.

Spirent is the trusted authority in vendor-independent 5G test, assurance, and automation, with a proven track record for driving innovation and achieving industry benchmarks.

- 5G/4G CORE NETWORK TEST & EMULATION
- TELECOM LAB AUTOMATION AND TRANSFORMATION
- 5G SERVICE ASSURANCE (ACTIVE TEST)
- 5G SERVICE EXPERIENCE TESTING AND BENCHMARKING (VONR, VINR, LBS, XR)
- NAVIGATION & TIMING (PNT) TEST AND SIMULATION

Spirent's cutting-edge experience enables us to continually deliver first-to-market solutions in areas such as:

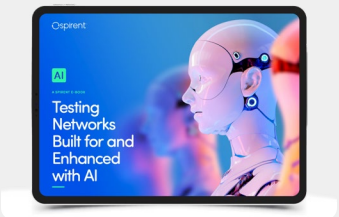
- CONTINUOUS TESTING
- CLOUD NATIVE RESILIENCY VALIDATION
- END-2-END AUTOMATED O-RAN TEST
- LEO SATELLITE TEST & ORBITAL SIMULATION

About Spirent

Spirent Communications plc. (LSE: SPT) is the leading global provider of automated test and assurance solutions for networks, cybersecurity, and positioning. The company provides innovative products, services, and managed solutions that address the test, assurance, and automation challenges of a new generation of technologies, including 5G, edge computing, cloud, autonomous vehicles, and beyond. From the lab to the real world, Spirent helps companies deliver on their promise to their customers of a new generation of connected devices and technologies. For more information visit: www.spirent.com.

LEARN MORE IN THE AI EBOOK:

Read Spirent's eBook to understand how AI is impacting current and future networks and how to address AI adoption challenges and validate use cases.



How do YOU plan on scoring goals with 5G? Answer our poll question and see what others think.*

*Poll will remain open until June 2025

CLICK FOR POLL

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About Spirent Communications
Spirent Communications (LSE: SPT) is a global leader with deep expertise and decades of experience in testing, assurance, analytics, and security, serving developers, service providers, and enterprise networks.

We help bring clarity to increasingly complex technological and business challenges. Spirent's customers have made a promise to their customers to deliver superior performance. Spirent assures that those promises are fulfilled.

For more information, visit: www.spirent.com

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