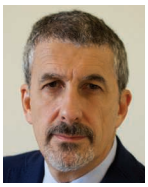
Claudio Casetti



Mobile Milestones: Speed Breakthroughs and Network Tweaks

Remember the days when 1 Gb/s was the gold standard in mobile networks? As the industry is pushing past those boundaries, new speed records are being advertised on a weekly basis. A notable achievement in the sub-6-GHz spectrum has set a new benchmark with an unprecedented 7.5 Gb/s downlink speed. In parallel, extended range tests and the use of reconfigurable intelligent surfaces (RISs) and new interleaved antenna systems are challenging our current notions of range and speed. On the application front, the potential of the 5G standalone (SA) network slicing is being harnessed, promising a transformative gaming experience, while a recent collaboration has paved the way for an innovative feature in Voice over New Radio (VoNR). Join us in this issue's column as we navigate through these groundbreaking developments.

THEY ENABLE FUTURE-READY DEVICES SO MORE DEMANDING DATA APPLICATIONS, SUCH AS VIDEO STREAMING AND DOWNLOADS, ONLINE GAMING, AND MORE, CAN RUN MORE SMOOTHLY THAN EVER, FOR MORE USERS.

Simultaneous Uplink/Downlink Carrier Aggregation Test

On 8 September 2023, Qualcomm Technologies, in collaboration with Samsung Electronics, announced that the companies had successfully executed the world's first simultaneous 5G 2× uplink and 4× downlink carrier aggregation (CA) for the frequency division duplex (FDD) spectrum.

The test was completed using a mobile phone form factor test device powered by the Snapdragon X75 5G modem and Samsung's 5G dual-band and triband radios supporting advanced CA technology.

The demand for increased uplink capacity has grown due to more consumers using increasingly higher uplink-heavy applications such as video uploads, video conferencing, social media sharing, and cloud applications. This achievement increases flexibility for operators with fragmented FDD spectrum assets, bringing faster upload speeds to more consumers across a multitude of markets and networks. Previously, uplink CA has been accomplished by combining FDD + time division duplex (TDD) or TDD + TDD configurations.

New Speed Record on Sub-6-GHz Spectrum

A related piece of news featuring the Snapdragon X75 5G modem was reported by Qualcomm Technologies on 9 August 2023, announcing that it set a new world record on the sub-6-GHz spectrum, achieving a 7.5 Gb/s downlink speed. Conducted through device testing using a 5G SA network configuration, this speed was reached by leveraging a total of 300 MHz of spectrum, using 4× CA with four TDD channels in one downlink connection, and 1024 quadrature amplitude modulation (QAM).

The aggregation of four TDD channels enables operators to combine their diverse spectrum assets to achieve higher data rates. In addition, 1024 QAM improves spectral efficiency by incorporating more data into each transmission, in comparison with 256 QAM, ultimately allowing for increased data throughput and improved spectrum efficiency.

These two Snapdragon X75 capabilities, and the modem-RF system's ten other world firsts, empower better user experiences, faster download speeds, increased network capacity, and improved spectrum efficiency. They enable future-ready devices so more demanding data applications, such as video streaming and downloads, online gaming, and more, can run more smoothly than ever, for more users.

New Speed Record in Extended Range Tests

On 26 June 2023, Nokia announced it had achieved sustained average downlink speeds of over 2 Gb/s using the millimeter-wave (mm-wave) spectrum and 5G fixed wireless access (FWA), over a distance of

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10.86 kilometers. This milestone download speed, the fastest recorded worldwide to date, was accomplished using Nokia's 5G extended range mm-wave solution at the OuluZone test facility in Oulu, Finland.

The test utilized Nokia's AirScale baseband and AirScale 24-GHz (n258 band) mm-wave radio and Nokia's FastMile 5G proof-of-concept customer premises equipment (CPE). Testing involved eight component carriers in the downlink, aggregating 800 MHz of mm-wave spectrum. This enabled a top downlink speed of 2.1 Gb/s and an uplink speed of 57.2 Mb/s.

This achievement, which builds on a previous world record announced by Nokia in 2021, demonstrates the reach and connectivity speeds that 5G mm-wave can deliver. It also lays the foundations for high-quality Internet connectivity solutions delivered via FWA to areas where wired connections are not always possible.

5G SA Slicing for Gamers

On 21 August 2023, Ericsson and Vodafone reported the completion of a live network trial at Coventry University that successfully demonstrated the positive impact an optimized 5G SA network slice could have on enhancing the mobile gaming experience for consumers. Network slicing allows for multiple virtual network slices across the same physical network, with each slice able to be isolated from other network traffic to give a dedicated performance, with the features of the slice tailored to the use case requirements.

Using network slicing, a major function of a 5G SA network that will allow Vodafone to customize connectivity services for specific customers and use cases, the trial participants were able to experience more consistent gaming connectivity with a 270% increase in throughput, a 25% decrease in latency, and 57% less jitter, as well as smoother graphics rendering. The trial at Coventry University featured 15 gamers of varying degrees of experience (from first-time mobile gamers to enthusiasts) and a broad age demographic (18–65 years old).

Trialists were asked to play cloud-based mobile gaming under two different connectivity scenarios. Scenario A simulated the performance of an existing public mobile network. Scenario B was an isolated 5G SA network slice that was optimized for cloud gaming. Scenario B's network configuration had higher download speeds, lower latency, reduced jitter, and no risk of network congestion.

Research conducted by Bryter, an independent gaming insights and consultancy agency, confirmed the success of the live 5G SA network slicing trial:

For scenario A, 63% of trialists ranked satisfaction between 0 and 5 out of 10, with only 13% ranking satisfaction above 8 out of 10. Frustrations included longer loading screen times, sound and visual issues, and increased latency.

For scenario B, 88% of trialists ranked satisfaction above 8 out of 10. The better gaming experience was due to improved game loading, smoother graphics rendering, and reduced latency and jitter.

Focus groups following the trial suggested mobile gaming enthusiasts would be highly interested in the 5G SA gaming experience as the benefits of faster loading and reduced latency and jitter would give them an advantage over other players.

The trial demonstrates the importance of 5G SA and network slicing to deliver new 5G use cases and experiences for consumers and businesses, with higher scalability and enhanced quality-of-services management enabling new business models across all verticals and creating new revenue opportunities for operators. Ericsson's network slicing report estimates that 25%–30% of potential 5G use cases will require network slicing as an enabler.

New Feature for VoNR

On 24 August 2023, Telstra and Ericsson announced Australia's first implementation and validation of the next evolution of 5G technology, using Ericsson's precommercial Reduced Capability (RedCap) software on Telstra's 5G commercial network using a MediaTek RedCap testing device. Telstra and Ericsson utilized one of the new 5G features, VoNR, where a voice call was made using a MediaTek RedCap testing device. The VoNR call on FDD was made in Box Hill, Victoria, and signaled the start of ongoing testing and validation of this new 5G capability on Telstra's network.

RedCap is a new 5G capability that builds on the industry progress of 4G Internet of Things (IoT) technologies such as narrowband IoT. The new benefits delivered by RedCap include reduced device chipset cost, complexity, and power consumption while supporting higher data rates and key 5G service enablers delivered via 5G SA.

This Australian-first VoNR call using RedCap on Telstra's commercial 5G network shows how the new software can enhance the functionality of wearables such as smartwatches. RedCap will also enable a number of new service capabilities such as longer battery life, augmented/virtual reality (AR/VR) functionality, and enhanced video monitoring.

RISs for mm-Wave

As reported by ZTE on 29 August 2023, the company has successfully partnered with Thailand's leading telecommunications operator, Advanced Info Service (AIS), to accomplish the world's first dynamic RIS trial in an mm-wave network at the A–Z Center in Bangkok.

This groundbreaking collaboration explores new possibilities in the field of mm-wave communication, offering a low-cost, low-carbon solution for deploying mm-wave networks at scale.

RIS is an innovative multiantenna technology that utilizes electromagnetic metamaterials. RIS enables the extension of base station coverage by intelligently reflecting or

transmitting base station signals, resulting in improved coverage at a low cost and with low carbon emissions. By incorporating dynamic functionality, ZTE's dynamic RIS technology achieves beam sweeping and user tracking, effectively enhancing the coverage range of base stations and ensuring an optimal user experience, even when the user is on the move.

During the trial, ZTE adopted the dynamic RIS product in the AIS mm-wave network with a 400-MHz bandwidth. This implementation led to a substantial enhancement in mm-wave signal coverage. Users were able to consistently maintain a peak downlink rate of over 1.6 Gb/s and an uplink peak rate of over 260 Mb/s while moving within an office room larger than 400 square meters. This performance was achieved, which is more than three times that achieved without RIS under obstructed circumstances.

As a crucial frequency range in 5G networks, mm-wave offers the advantages of large bandwidth and capacity. However, due to its transmission characteristics, it encounters significant challenges in terms of long-distance transmission and penetration through obstacles. Through the collaboration between ZTE and AIS, dynamic RIS technology has been successfully implemented in mm-wave networks. This technology effectively overcomes propagation obstacles and enhances coverage range and transmission speed.

This collaboration represents an important milestone in the field of mm-wave communication, signifying a significant stride in the commercialization of dynamic RIS technology. The implementation of this groundbreaking technology will usher in revolutionary changes to the global communication industry, establishing a stronger network foundation for the development of future smart cities, industrial IoT, and other domains.

This announcement came on the heels of a previous report by ZTE about the successful completion of a trial of mm-wave SA (5G SA architecture) technology at the A–Z Center in Bangkok. This achievement not only positions Thailand as a leader in the Association of Southeast Asian Nations region regarding mm-wave explorations but also marks a significant step toward commercializing mm-wave in the country, meeting the diverse requirements of consumers and industries.

During the trial, 5G mm-wave SA technology showcased unparalleled downlink speeds of 7.04 Gb/s under the DDDSU frame structure, impressive uplink speeds of 2.12 Gb/s under the DSUUU frame structure, and end-to-end latency of less than 4 ms. Recall that in frame structure jargon, "D" means a downlink subframe is transmitted, while "U" indicates uplink, and "S" indicates a special subframe. These exceptional results were achieved using a single CPE prototype powered by the Snapdragon X65 5G modem-RF system from Qualcomm Technologies, along with ZTE's latest mm-wave active antenna unit network infrastructure equipment. The high throughput and minimal data transmission delay offered by this cutting-edge technology enable users to experience immediate responses during critical applications such as online gaming, virtual reality, and autonomous vehicles. With seamless connectivity between users and their devices, this advancement opens up a world of possibilities for both businesses and consumers.

In comparison with E-UTRAN New Radio Dual Connectivity (EN-DC) or New Radio Dual Connectivity (NR-DC), mm-wave SA was implemented using four 200-MHz carriers in the downlink and two 200-MHz carriers in the uplink, all operating solely at 26 GHz. This approach significantly simplifies the network architecture and eliminates the need for "anchoring" cells in EN-DC or NR-DC, thereby avoiding additional capital expenditure.

New Antenna to Increase 5G Capacity and Coverage

On 18 July 2023, Ericsson and Vodafone began the deployment of a compact active–passive antenna in the United Kingdom to bring greater 5G capacity, coverage, and performance without adding to the antenna footprint.

Ericsson's interleaved antenna-integrated radio (AIR) 3218 combines a radio and multiband passive antenna technology in one single enclosure, meaning additional high-performing 5G capacity can be added with no additional antenna footprint. The interleaved AIR 3218 is powered by the latest Ericsson silicon technology enabling high performance and energy efficiency, among other benefits. AIR 3218 will contribute toward sustainability enhancements and the transmission of more gigabytes per watt of energy utilized (GB/W) compared with 4G. Indeed, to reduce the environmental impact, the growing data traffic needs to be managed with energy-efficient hardware, combined with the use of energy-saving network features to break the trend of increasing energy usage in mobile networks.

The interleaved AIR also lowers the total antenna footprint on site, reducing the need for antenna reinforcements and reducing site rent expenses.

The interleaved AIR 3218 utilizes beam-through technology where an arbitrary active antenna can be placed behind the passive antenna reducing the overall footprint in terms of size, weight, and wind load. The key enabling technology for beam-through is frequency-selective surfaces tuned to serve as a reflector for the passive antenna, while being transparent for the underlying massive multiple-input multiple-output (MIMO) radio.

With accelerating 5G deployments, ever-increasing data traffic, and subscriber growth, mobile networks require new levels of site flexibility, spectrum efficiency, and

energy savings. Using a single antenna footprint and massive MIMO technology, the larger bandwidth of the midband spectrum will be leveraged to increase 5G capacity and deliver enhanced mobile broadband experiences. Combining the technologies into a single unit also helps improve network efficiency and reduces deployment complexity.

Additionally, the combination of radio and antenna in one single unit brings an optimized modular form factor and easy rooftop, tower, wall, and pole mounting, meaning that site upgrades and acquisitions will be simplified and 5G deployment accelerated in areas previously constrained by building regulations or planning law. AIR 3218 is forecast to be deployed across 50 sites within the Vodafone U.K. network in 2023, with a 30% savings in site acquisition and build time expected.

Beginning of the 5.5 Era

On 29 June 2023, Huawei announced they will launch a complete set of commercial 5.5G network equipment in 2024 at the 5G Advanced Forum during the Mobile World Congress in Shanghai in 2023. Huawei's Director and President of Information and Communication Technology (ICT) Products & Solutions Yang Chaobin, who made the announcement, said the company intends for this launch to mark the beginning of the 5.5G era for the ICT industry.

The 5G deployment has progressed rapidly over the past four years and is already yielding significant financial gains. Today, there are more than 260 commercial 5G networks worldwide, serving over 1.2 billion users, and there are already 115 million gigabit fifth-generation fixed (F5G) network users. With service models and content continuously evolving, breakthroughs in technologies like glasses-free 3D are creating unprecedented immersive experiences for users. However, these new services continue to require stronger 5G network capabilities. The industry has widely agreed that 5.5G will be a key milestone in 5G evolution and that it is fast approaching.

Huawei proposed the concept of a "5.5G era," based on an end-to-end solution that integrates comprehensive evolved technologies including 5.5G and F5.5G. This solution would protect operators' previous investments in 5G, while also improving network performance by 10 times. This 5.5G era would feature 10-gigabit peak downlink speeds and gigabit peak uplink speeds to meet increasingly diverse service requirements. It would also refresh the industry vision by using new technologies like passive IoT to unlock a market of 100 billion IoT connections.

As an advocate for end-to-end 5.5G solutions, Huawei has been working with multiple players across the industry on R&D and verification of key 5.5G technologies. Significant progress has been made in this verification process, specifically for the extremely large antenna array, which underpins 10-gigabit downlink; flexible spectrum access, which helps realize gigabit uplink; and passive IoT, which can enable 100 billion IoT connections. The 50G passive optical network is another key technology that can enable 10-gigabit speeds for F5.5G ultra-broadband networks and is expected to be extensively used in homes, campuses, and productions in the future. Huawei has worked with over 30 operators around the world on technological verification and application pilots for these technologies.

In addition to the development of key technologies for 5.5G wireless and optical access networks, Yang announced that the company has been working on applying artificial intelligence (AI)-native technologies to 5.5G core networks to continuously enhance network capabilities and availability. This would allow AI capabilities to be delivered to the very ends of networks, so that they can better serve numerous industries.

The industry is still in its earliest stages of developing a vision for 6G and only just beginning related research into key technologies. This is why many have turned to 5.5G as their milestone for future development. The 10-fold improvement in network capabilities in the 5.5G era is set to enable numerous industries to unleash the productivity of digital technology.

New Solutions for Virtualized Radio Access Network

On 8 August 2023, Samsung announced the company is expanding its collaboration with Intel through a new product innovation agreement, allowing the companies to continue advancing the virtualized Radio Access Network (vRAN) for enhanced performance and capacity.

As part of this expanded collaboration, Samsung will integrate its vRAN 3.0 software with 4th Gen Intel Xeon Scalable processors with Intel vRAN Boost to deliver advanced vRAN solutions. Offering increased capacity, Samsung's enhanced vRAN will be able to support more cells with the same number of servers, which would bring the benefits of power savings and cost efficiency to network operators.

Samsung and Intel have been collaborating on vRAN innovation since 2017, and the companies have already proven the performance of their integrated solutions in Tier One operators' commercial networks in the United States, the United Kingdom, and Japan. In these networks, Samsung's vRAN software integrated with 3rd Gen Intel Xeon Scalable processors (Intel's previous generation processor) has been delivering performance optimization and power-saving capabilities to operator networks.

Along with its ecosystem partners, Samsung continues to deliver advanced virtualized network solutions powered by its latest vRAN 3.0 capabilities, such as 200-MHz three-cell support for 64T64R massive MIMO radios, power-saving features, and improved automation. This paves the way for operators to

deploy an exceptional and versatile RAN solution. In addition to its enhanced features, Samsung's vRAN also supports multiple radio access technology, across 2G, 4G, and 5G, for greater flexibility in network operation.

The combination of Samsung's vRAN 3.0 and 4th Gen Intel Xeon Scalable processors with Intel vRAN Boost will provide operators with a solution that allows them to meet their demanding capacity, coverage, quality, and total cost of ownership requirements while underpinning their networks on a modern, fully virtualized architecture.

The companies have successfully completed interoperability tests, accomplishing a first call on Samsung's vRAN running on the 4th Gen Intel Xeon Scalable processors with Intel vRAN Boost.

Intel and Samsung have a longstanding collaboration with a shared commitment to deliver highly integrated, vRAN solutions. This new agreement will deepen that collaboration, enabling both companies to jointly speed up operators' vRAN deployments at scale and to deliver a strong combination of flexibility, performance, and power efficiency. This enhanced vRAN offering is expected to be commercially available in the second half of 2023.

Connectivity for Refugees

On 4 July 2023, the United Nations High Commissioner for Refugees agency (UNHCR), together with the International Telecommunication Union (ITU), launched a transformative agenda to connect refugees around the world.

Together, UNHCR, ITU, and GSMA (the trade association for mobile operators, nowadays no longer restricted to GSM) seek to ensure that all major refugee hosting areas have available and affordable connectivity by 2030, advancing the digital inclusion of over 20 million forcibly displaced people and local host communities.

Wrapping up a joint visit to Ethiopia in early July 2023, ITU's Secretary-General Doreen Bogdan-Martin and UNHCR's Deputy High Commissioner Kelly T. Clements witnessed how digital connectivity is providing a lifeline and solutions for refugees and displaced people, helping them access mobile money, online health services, and connected education and as an avenue to employment in the digital economy.

They issued an urgent global call to action to increase investment and establish an enabling regulatory framework for providing connectivity to forcibly displaced and stateless people and the communities that host them. A joint letter signed in 2021 between the two agencies outlined a shared vision of a connected society that leaves no one behind, in line with the Sustainable Development Goals.

"In Ethiopia, we've witnessed the ingenuity of refugee communities in finding whatever path they can to stay connected with society," said ITU's Bogdan-Martin, following a visit to a cybercafé in Bokolmayo, in the Melkadida refugee camp. "These communities are asking all stakeholders to do their bit to expand access to meaningful connectivity so that they can enjoy a safe, satisfying, enriching, and productive online experience at an affordable cost. ITU's Partner2Connect Digital Coalition and the Global Refugee Forum can serve as important entry points for interested organizations and investors to pursue connectivity for all, including displaced people and their hosting communities."

UNHCR, ITU, and GSMA have developed an ambitious pledge around refugee connectivity that seeks to mobilize investments and further policy commitments to include refugees into national frameworks and objectives around digital access for all through universal connectivity. This includes fostering an enabling policy and regulatory environment for both expansion of infrastructure and lifting regulatory barriers to individual access for displaced people.

The three organizations will lay the foundation for advancing meaningful connectivity as both a community need and a cornerstone of digital transformation in the humanitarian sector. Driven by data and promising practices and through piloting new business models, their work will devise pathways for new sustainable solutions to get displaced communities online.

To achieve this, they are seeking at least US$20 million in core support, with at least US$200 million in direct investment and contributions to advance the refugee connectivity agenda. Further detailed planning is underway in these areas, including in Ethiopia.

The Role of Churches in Rural OpenRAN Deployment

On 27 July 2023, Vodafone reported that it has partnered with mobile coverage services specialist Net CS to install new mobile technology in 11 Church of England parish churches across the United Kingdom to provide strong and reliable 4G coverage to the nearby rural communities.

The first two churches, the Blessed Virgin Mary in Brompton Regis, Somerset, and St. Michael's & All Angels in Ewyas Harold, Herefordshire, are now live. A further nine sites are planned to go live in the coming months.

Churches have long been seen as an important part of delivering mobile coverage to rural and urban areas, often located in central, elevated sites within a community. The 11 sites will deliver Vodafone 4G to areas that have historically struggled to receive good quality and reliable mobile coverage.

The project has been made possible through innovative mobile technology called OpenRAN, which is a radio access network system that allows interoperation among cellular network equipment provided by different vendors. Some of the many benefits are that OpenRAN

installations occupy a smaller physical footprint and require less power than traditional single-vendor systems. Net CS has designed the church installations using a neutral host format, so they can be connected to multiple network operators.

White Paper on Multiaccess Edge Computing Support for Edge Native Design

On 22 June 2023, ETSI released a new white paper, "MEC Support Towards Edge Native Design" [2], written by members of the ETSI Industry Specification Group on Multiaccess Edge Computing (ISG MEC). This white paper provides an overview and vision about the edge native approach, as a natural evolution of cloud native.

It explains in detail the concept of "edge native," describes what edge native means for edge developers to build their applications, and introduces how ETSI ISG MEC and other organizations support this edge native design paradigm. In particular, the white paper guides developers in the principles and specific requirements of edge computing and how they can combine them with the modern architectural approach introduced by cloud native. It also gives insight into the general technical community interested in ETSI MEC solutions or edge native application design concepts.

MEC is a promising technology that brings applications and services closer to the end user, thus providing lower network latency, better data privacy, and other benefits that are critical for business scenarios such as vehicle-to-everything, AR/VR, and Industry 4.0.

MEC enables a flexible environment for deploying and managing edge applications by adopting cloud-based technologies, e.g., virtualization, service-based management, and heterogeneous hardware management. However, the edge environment has a few key characteristics that distinguish it from the traditional cloud environment, leading to specific requirements for both the edge applications and the edge system. For example, the edge environment usually has limited resources and is geospatially distributed, and users/clients are likely to move while using the edge services. These characteristics led to the emergence of the edge native concept. Edge native, which is inspired by cloud native, refers to building and running edge applications that take the above-mentioned edge environment characteristics into account and can best utilize the edge environment capabilities.

THE 10-FOLD IMPROVEMENT IN NETWORK CAPABILITIES IN THE 5.5G ERA IS SET TO ENABLE NUMEROUS INDUSTRIES TO UNLEASH THE PRODUCTIVITY OF DIGITAL TECHNOLOGY.

Since its foundation in 2014, the ETSI ISG MEC has been focusing on the definition and standardization of the MEC system, taking into consideration the unique challenges of the edge environment. In addition to ETSI, other organizations such as Eclipse and Linux Foundation are also working in this area, e.g., by studying how to enable the edge native design and provide tools and guidelines for the application developers. This white paper gives a summary of the existing works in the industry and their support for the edge native design.

The authors of the white paper conclude that the ETSI MEC standard [synergized with 3rd Generation Partnership Project (3GPP) specifications] can offer a footprint for interoperability, API basic design principles to ensure universal adoption, and possibly also some guidelines for API abstraction, complementing the work of open source projects. Therefore, to fully exploit edge capabilities and for the adoption of edge native design principles from application development communities, joint efforts from open source and standards will be needed.

"This effort is also aligned with the plans in ETSI MEC to transition toward the next MEC Phase 4 from 2024 to 2026," said Dario Sabella, chair of ETSI ISG MEC. "In fact, the recently approved MEC Terms of Reference include topics for the MEC evolution toward the support cloud native communication systems and edge native design for application developers (also with container support). These are key technologies that are expected to play a role for the future of MEC."

Network Applications for 5G and Beyond

On 28 August 2023, the 5G PPP Software Network Working Group (WG) and most of the ICT-41 projects published version 2.0 of the white paper "Network Applications: Opening Up 5G and Beyond Networks" [1].

Network applications are seen as full-potential enablers for future vertical industries beyond current deployment. Therefore, they must be considered along with other 6G enabling technologies in the next-generation network architecture. The white paper focuses on the different technical aspects of network applications, new business models for all stakeholders, experimental facilities to support network applications, and new network intelligence solutions that can be enabled by using network applications.

This white paper is the second published by the Software Network WG, and it goes into the implementation details of the two major network applications: as-a-service (aaS) and hybrid models. This paper closes the plan of the Software Network WG in the 5G PPP era. In the 6G Industry Association/Smart Networks and Services Joint Undertaking, the working group's name becomes "Reliable Software Network WG," grouping topics like AI/machine learning; security; development, security, and operations; distributed orchestration; and more.

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ubiquitous computing. He is a fellow of the Institution of Engineering and Technology and the European Alliance for Innovation.

Pan Hui (panhui@ust.hk) is a chair professor at the Hong Kong University of Science and Technology, Hong Kong. He is also the Nokia Chair in Data Science and a professor at the University of Helsinki. His works have covered a wide spectrum of topics, including augmented reality, mobile computing, and networking. He is a Fellow of IEEE, an international fellow of the Royal Academy of Engineering, and a distinguished scientist of the Association for Computing Machinery.

Appendix: Related Articles

[A1] X. Yu et al., "When connected and automated vehicles meet mobile crowdsensing: A perception and transmission framework in the metaverse," *IEEE Veh. Technol. Mag.*, vol. 18, no. 4, pp. 22–34, Dec. 2023, doi: 10.1109/MVT.2023.3320865.

[A2] M. Xu et al., "Sparks of generative pretrained transformers in edge intelligence for the metaverse: Caching and inference for mobile artificial intelligence-generated content services," *IEEE Veh. Technol. Mag.*, vol. 18, no. 4, pp. 35–44, Dec. 2023, doi: 10.1109/MVT.2023.3323757.

[A3] Y. Kang, Q. Song, J. Song, F. Pan, L. Guo, and A. Jamalipour, "How does a digital twin network work well for connected and automated vehicles: Joint perception, planning, and control," *IEEE Veh. Technol. Mag.*, vol. 18, no. 4, pp. 45–55, Dec. 2023, doi: 10.1109/MVT.2023.3328107.

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MOBILE RADIO

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5G Nonterrestrial Networks

Satellites can enhance 5G networks by solving coverage and challenging use cases beyond ground-based infrastructure. On 4 July 2023, 5G Americas, the voice of 5G and beyond for the Americas, unveiled the white paper "Update on 5G Non-Terrestrial Networks" [3], which provides an update on current developments in the growth of partnerships and technologies relating to nonterrestrial network (NTN) integration with 5G networks, building on a previous white paper on this subject (as we reported in the June 2022 issue of the magazine).

By mid-2023, NTNs are a thriving market with diverse technical and commercial strategies. The 5G NTN delivers high-speed wireless access to remote areas, utilizing satellites on the mobile network's access side to provide ground users with mobile services.

"Update on 5G Non-Terrestrial Networks" examines the growing ecosystem of providers and partnerships between NTN service providers and ground-based cellular providers. In addition, it highlights satellite constellations operating in three key domains: broadband and Internet services, IoT connectivity, and direct-to-cell applications.

Some key topics surrounding NTNs in this 5G Americas report include

- current status of NTNs
- architectural paradigms update
- 5G NTN standardization in 3GPP
- New Radio and IoT support
- NTN in release 17
- NTN enhancements in 3GPP release 18
- potential for new services with 3GPP NTN solutions
- Federal Communications Commission activities related to NTNs
- recommendations and conclusions.

Luiz Abud, head of emerging business and partnerships at Nokia, said, "Today, the integration of 3GPP smartphones with NTN paves the way for exciting advancements in 5G NTN standards. These developments within 3GPP hold tremendous potential to amplify the efficiency and capabilities of LEO satellites, presenting a wealth of opportunities for emerging 5G NTN ecosystems. By revolutionizing Earth's communication landscape with unprecedented reliability, these advancements not only bridge the digital divide but also safeguard lives in challenging scenarios while optimizing global supply chain systems."

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