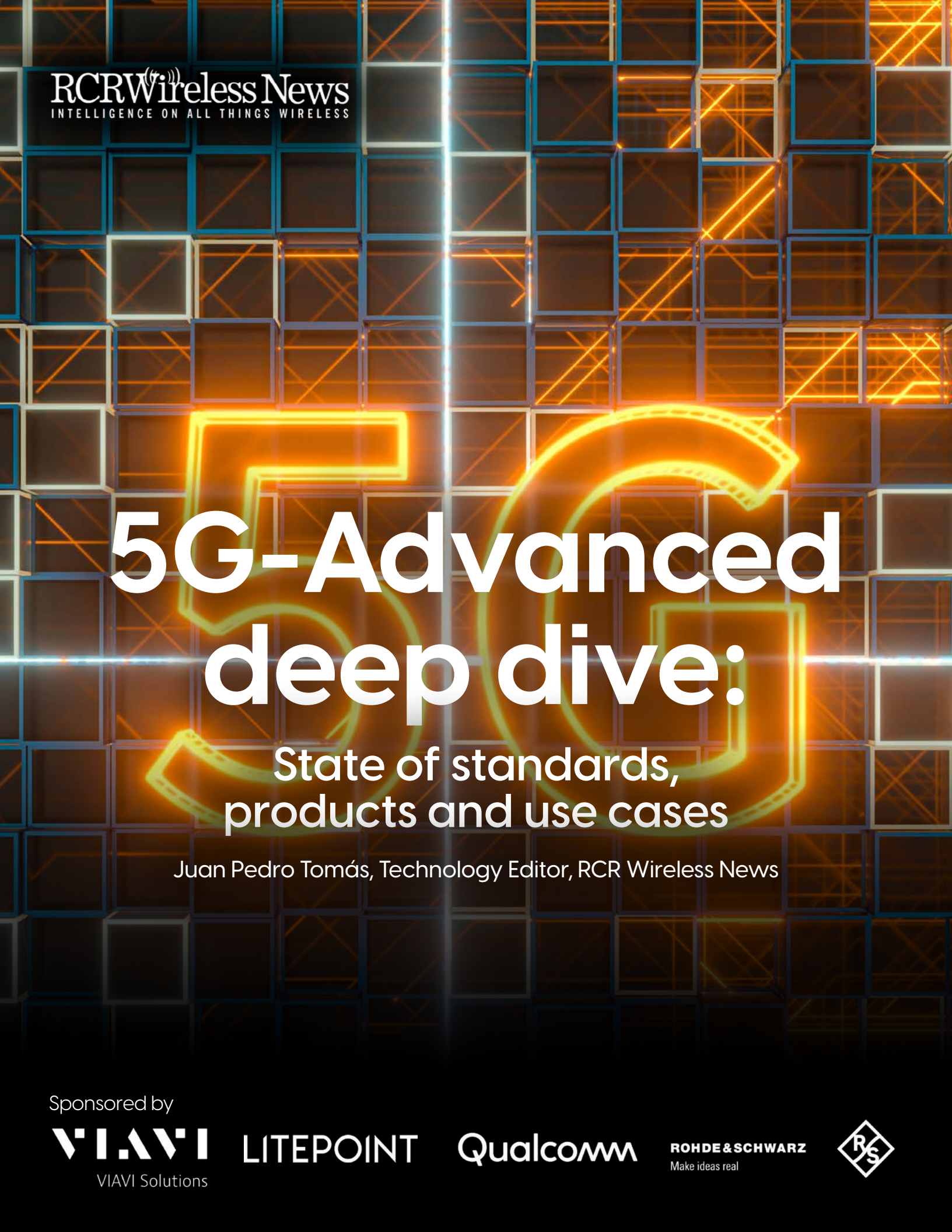


5G-Advanced deep dive:

State of standards, products and use cases

Juan Pedro Tomás, Technology Editor, RCR Wireless News

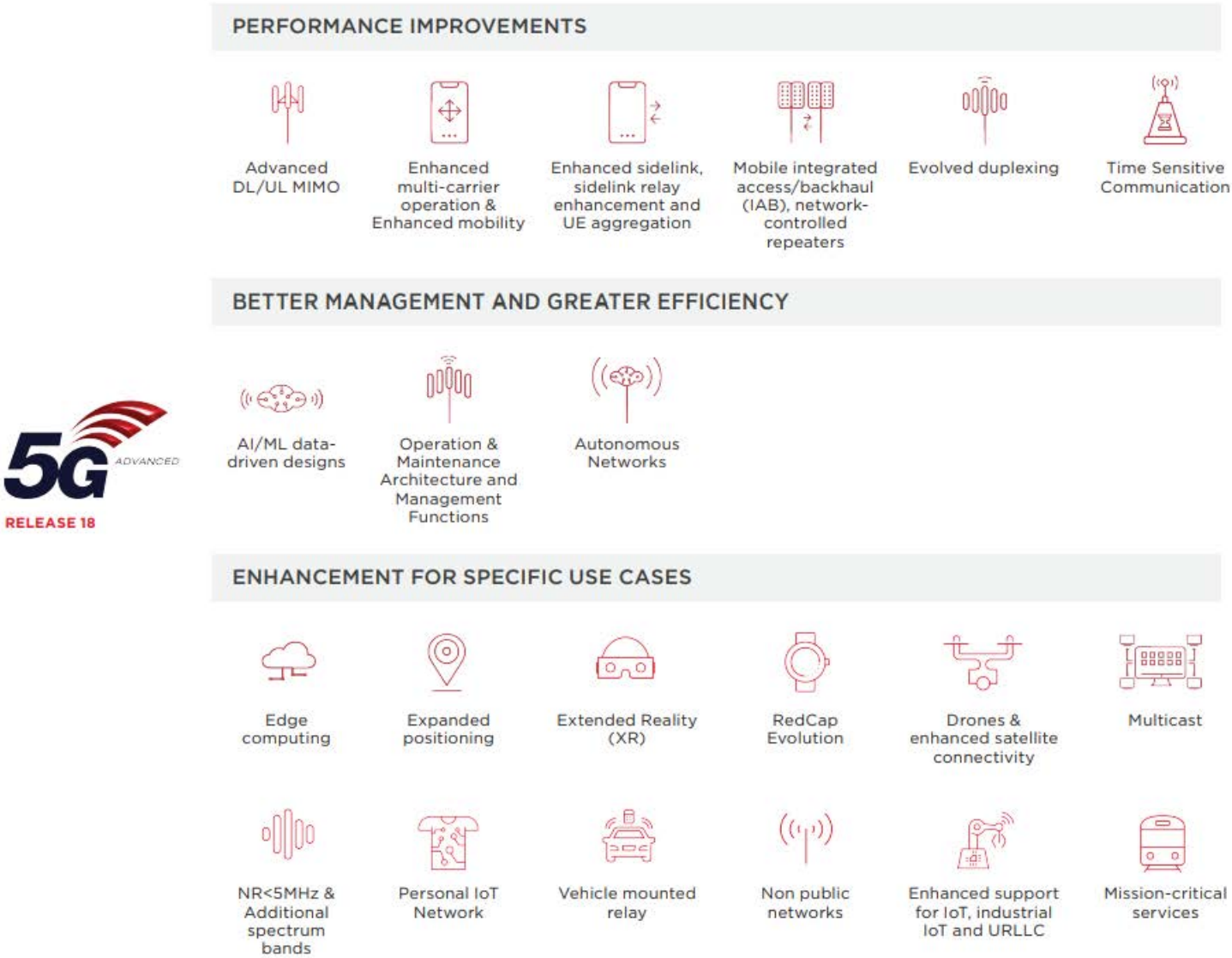
INTRODUCTION

3GPP Release 18 marks the start of 5G-Advanced, which builds on the 5G baseline defined by 3GPP in previous Releases 15, 16 and 17. 5G-Advanced will be specified by 3GPP Releases 18, 19 and 20, after which 3GPP's work will focus on 6G, expected to hit the market around 2030.

There is wide consensus in the industry that 5G-Advanced will bring new enhancements to current mobile network capabilities and use case-based support to help mobile operators with 5G commercialization, long-term development of artificial intelligence (AI) and machine learning (ML) and network energy savings for a fully automated network.

5G-Advanced will also bring system-level enhancements to the 5G NR standard, while also optimizing capabilities for specific vertical industries and applications. Some of these innovations include AI-enabled, end-to-end communications, support for new spectrum bands, wide-area IoT evolution, private networks and more. 5G-Advanced will also provide stepping stones in areas that will influence the future 6G systems, thus bridging 5G with 6G.

This report explores the progress of 5G-Advanced in terms of standardization, as well as the new features and use cases it will enable.



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WHEN WILL 5G-ADVANCED HIT THE MARKET AND HOW WILL IT HELP TELCOS TO MONETIZE 5G INVESTMENTS?

Dimitris Mavrakis, senior research director at ABI Research, said that the first 5G-Advanced features and applications could be expected to be commercially available by the end of next year, with additional commercialization in 2025 and after.

"5G-Advanced introduces many new features that can indeed help operators monetize their 5G networks. These include advanced support for extended reality — such as virtual reality, cloud gaming and augmented reality — better performance for existing networks, advanced positioning capabilities, enhanced sidelink [device-to-device communications] and new device types that include sensor-based devices [NB-IoT], more advanced capabilities [RedCap] and industry-specific devices," said Mavrakis.

Peter Merz

Meanwhile, Peter Merz, VP and head of Nokia Standards, explained that the first release of the 5G-Advanced Standard, Rel-18, will be completed by 3GPP in the first half of 2024, adding that he expects the initial commercialization from 2025 onwards. "It is important to remember that Standalone architecture is required to capture all business and technical benefits of 5G-Advanced," he said. "5G-Advanced will provide major enhancements, allowing us to reach the full potential of 5G. New value-adding features will further accelerate the monetization of 5G investments by facilitating the simultaneous delivery of services requiring a mix of high data rates, low latency or a massive number of devices."

> "5G-Advanced will provide major enhancements, allowing us to reach the full potential of 5G." - Peter Merz, VP and Head of Nokia Standards

Also, according to Barbara Pareglio, senior technical director and smart mobility lead at GSMA, the initial work on the inaugural release of 5G-Advanced started in 2022, with the target for commercialization from the second half of 2024 onwards. Pareglio added that 5G-Advanced will enable the creation of new monetization business models that do not currently exist. "While the exact models and features that will make it to market remain to be seen, industry collaboration, such as GSMA Open Gateway, will unlock opportunities in the 5G enterprise market. By working together on a framework of common network Application Programmable Interfaces, mobile operators and hyper-scalers, will help create new business opportunities in partnership with third-party application developers and vendors," she continued.

Pareglio went on to say that the range of new business opportunities that will emerge with 5G-Advanced will provide mobile operators with a strong opportunity to monetize their previous investments in 5G by striking partnerships and educating enterprises about how to address current challenges, as well highlighting the competitive advantages new technologies, enabled by 5G-Advanced, will have over Wi-Fi technology. "In summary, 5G-Advanced will enhance both existing commercial 5G

networks and open up new opportunities for new B2B business models," she said.

Commenting on the potential timing for the launch of initial 5G-Advanced applications, Hiroyo Masuda, senior architect at Fujitsu's 6G infrastructure Strategic Planning Division, Advanced Technology Development Unit at Japanese tech firm Fujitsu, said that the market introduction of any feature will be possible with user equipment (UE) that is compatible with the functions of all releases. "It takes six months to a year after specifications are completed, but it may take longer to deploy features for new use cases of 5G-Advanced," Masuda said.

"Although the Abstract Syntax Notation One [ASN.1] freeze of Rel.18, which is the first version of 5G-Advanced, is planned for March 2024, it will take another three to six months for the specifications to become stable. Taking this into account, we assume that 5G-Advanced will be introduced to the market around 2026," Masuda added.

Masuda believes that the introduction of 5G-Advanced services will have the potential to expand beyond consumer services to other markets such as enterprise markets, which will likely contribute to monetization of communication service providers.

Wanshi Chen, 3GPP RAN chair, noted that the package of Rel-18 projects was approved in December 2021, with the specification work starting from the second quarter of 2022. "We are now finishing the Rel-18 specification, targeting June 2024 for the official freeze of the so-called ASN.1. Subsequently, commercialization of these new features and enhancements will follow," he said

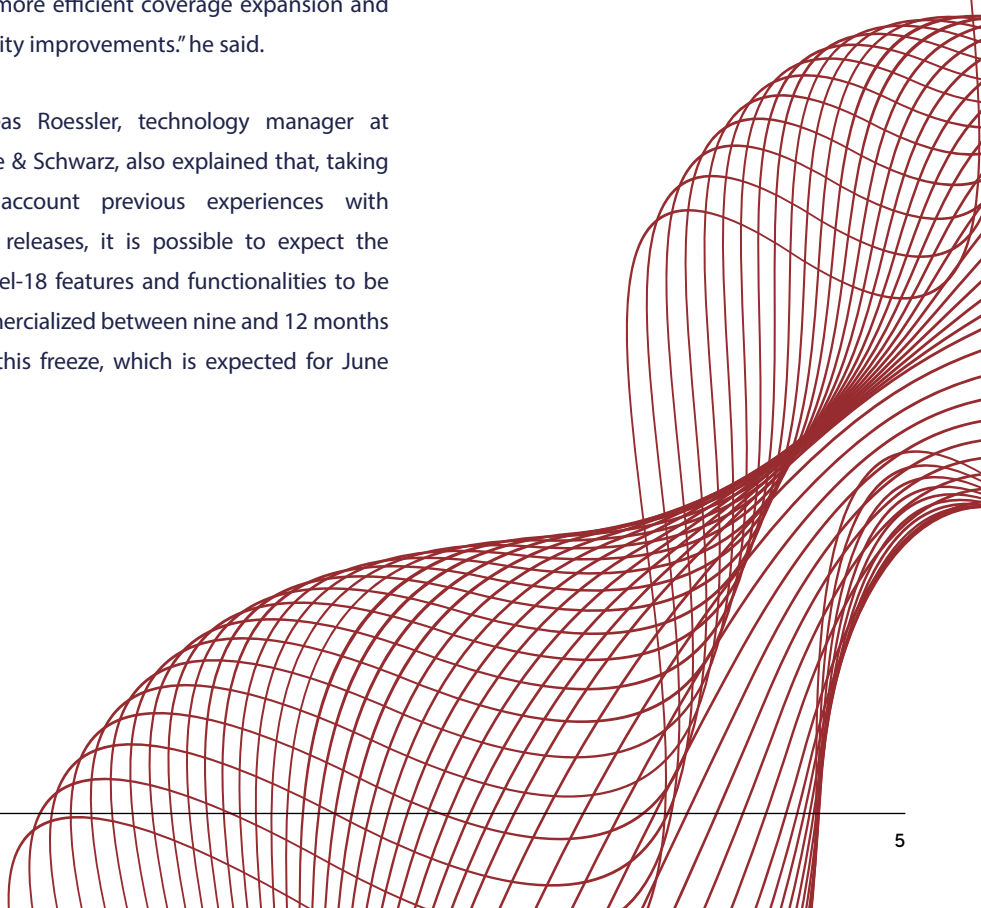
Chen also stressed that the industry expects that 5G-Advanced will unlock the full potential of 5G, delivering new and enhanced capabilities for the end-to-end 5G system: "It will further improve mobile experiences supporting higher speeds, lower latency, better mobility, improved coverage and more, as well as further expand into new use cases and verticals, such as extended reality (XR) and low-cost 5G IoT devices."

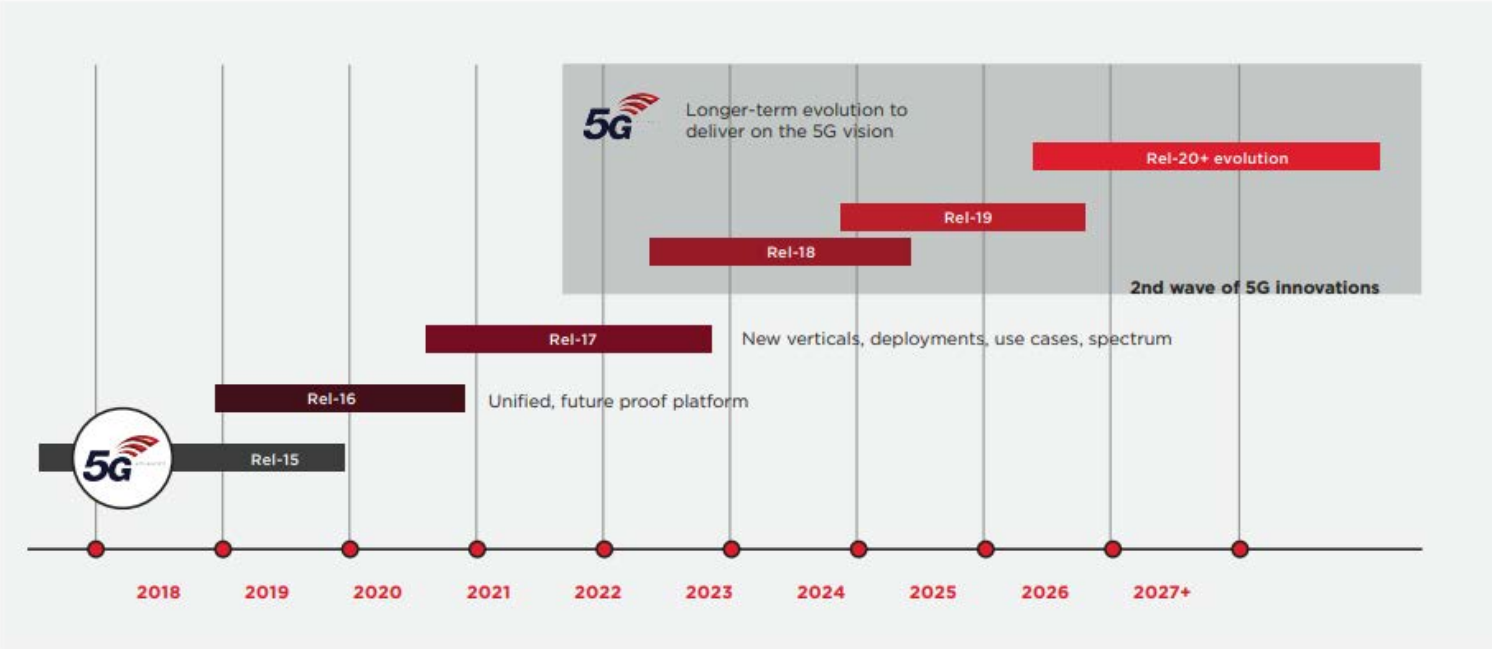
From an operator's point of view, Tomohiro Sekiwa, SVP and chief network officer at Japanese carrier SoftBank, considered that 5G-Advanced technology will gradually be implemented into commercial network equipment after 2025. "With 5G-Advanced, the deployment of services that truly embody 5G features will become easier with more efficient coverage expansion and capacity improvements." he said.

Andreas Roessler, technology manager at Rohde & Schwarz, also explained that, taking into account previous experiences with other releases, it is possible to expect the first Rel-18 features and functionalities to be commercialized between nine and 12 months after this freeze, which is expected for June 2024. "That, of course, depends on the feature itself and its complexity," said Roessler.

The executive said that it is necessary to assess the current status of global 5G deployments before analyzing the 5G-Advanced feature sets and define which ones may help monetize 5G from an operator perspective.

"According to the latest public figures released by GSA, we have, for example, 259 operators in 102 countries investing in 5G, but only 35 service providers in 24 countries transitioned to Standalone [SA] mode. Only with SA mode the 5G RAN is connected to the 5G core network, where the operator can take advantage of network slicing, which provides the basis in 5G to offer specific Quality-of-Service profiles and flows and ultimately enables the operator to monetize these slices. This will also be a prerequisite for features like deploying, for instance, Rel-17 RedCap functionality or Non-Terrestrial Network [NTN] support, some hot topics right now within our industry," Roessler added.





Adam Smith, director of marketing at LitePoint, believes that the initial rollout of some initial 5G-Advanced features and applications will start to happen next year. "When I talk about 5G-Advance, I talk about stuff like NTN, RedCap and additional carrier aggregation scenarios and it's also probably some AI working its way into the modem," Smith said.

"I expect that we could start to see some form of that technology hitting the market as early as 2025. In terms of operators and monetizing previous investments, I think that one of the key things with 5G-Advanced will be an increase in the adoption of AI/ML to enhance RAN performance. It could also help to reduce Opex for operators. An example of this would be the network energy saving," said Paul Harris, Principal Wireless Architect of the CTO Office at VIAVI Solutions.

"I think there will be an opportunity for AI to be helping further tailor and optimize networks for private deployments in specific verticals, increasing the overall attractiveness of a 5G solution for more markets. And I think another key development would be the NTN enhancements coming in 5G Advance." Harris said.

Paul Harris

"One of the key things with 5G-Advanced will be an increase in the adoption of AI/ML to enhance RAN performance. It could also help to reduce Opex for operators." - Paul Harris, Principal Wireless Architect, CTO Office, VIAVI Solutions.

According to Huawei, 5.5G will be the technology that will support mobile communications networks over the next five to eight years. 5.5G is Huawei's brand name for advancements in areas like integrated sensing and communication, Level 4 autonomous driving, "all-scenario IoT" concepts and green ICT.

"5.5G increases 5G's network capabilities by a factor of 10, realizing 10 Gbps connectivity. It also provides much stronger IoT capabilities, which can enable advanced manufacturing from end to end. Thanks to its large bandwidth and low latency, 5.5G allows us to embrace the metaverse, the Internet of Vehicles [IoV] with harmonized communication and sensing, and space-air-ground integrated networks," said John Gao, president of Huawei's 5.5G domain.

"5.5G provides stronger network capabilities, higher cost-effectiveness and smarter, simpler network operations, while supporting a wider range of business scenarios. Without a doubt, the commercial use of 5.5G will enable more industry applications and create more opportunities and capabilities for operators to monetize their investments," he added.

John Gao

"5.5G increases 5G's network capabilities by a factor of 10, realizing 10 Gbps connectivity. It also provides much stronger IoT capabilities, which can enable advanced manufacturing from end to end." - John Gao, President of Huawei's 5.5G domain

THE MAIN FEATURES OF 5G-ADVANCED

According to Mavrakis of ABI Research, 5G-Advanced will introduce new network management and deployment capabilities, including enhanced coverage, network performance and most importantly, the capability to utilize AI to manage the network.

"The new features of 5G-Advanced can be categorized around four areas, which we call the '4 Es:' enhanced experience through services; the extension of the geographical and vertical reach of networks; the expansion of 5G beyond connectivity; and excellence in operation of services. Among other features, 5G-Advanced will provide improved uplink performance, XR boosting, higher energy efficiency, more

Barbara Pareglio

accurate location, timing resilience, the possible introduction of AI/ML in the radio and extension in core and further optimization for IoT devices and Non-Terrestrial Networks," said Nokia's Merz

Pareglio of the GSMA noted that 5G-Advanced will enable performance Improvements, enhancing multi-carrier operations, time-sensitive communication and mobile integrated access as well as better management and greater efficiency, such as AI/ML data-driven designs and autonomous networks and enhancement of specific use cases. It will also provide enhanced support for IoT technology, she said.

"In addition, 5G-Advanced will extend 5G technology to all connected devices virtually, supporting a new generation of business opportunities in areas such as smart mobility, industrial automation, metaverse and extended reality, blurring the lines between physical and digital worlds with virtual reality and augmented reality for consumers and workforces alike," Pareglio added.

"5G-Advanced will extend 5G technology to all connected devices virtually, supporting a new generation of business opportunities in areas such as smart mobility, industrial automation, metaverse and extended reality." - Barbara Pareglio, Senior Technical Director and Smart Mobility Lead at GSMA

According to Masuda of Fujitsu, the introduction of 5G-Advanced technologies will enable two main features: AI/ML implementation and the introduction of personal IoT. "5G-Advanced will enable efficient collection of information on devices that cannot be directly connected to the network, such as sensor information," he said.

Chen of the 3GPP said that Release 19, which will be the second release of 5G-Advanced will enable wireless AI/ML to further improve system performance and efficiency, network energy savings to reduce overall power consumption, optimization for XR for more capacity and improved latency, as well as expanded 5G IoT support with enhanced NR-Light/RedCap.

Meanwhile Sekiwa of SoftBank explained that the main features of 5G-Advanced would include further improvements in the fundamental performance aspects of 5G, such as coverage, capacity and mobility, as well as the efficient integration of diverse devices expected to proliferate in the future, such as sensors, XR terminals and UAVs into the network and the further development of Non-terrestrial Network (NTN) and their seamless integration

with terrestrial networks (TN). Additional features of 5G-Advanced will enable the optimization of communication quality and energy consumption through the adoption of AI/ML and operational cost reductions through automation, he said.

Roessler of Rohde & Schwarz noted that one promising feature set to help service providers start monetizing 5G and secure their previous investments into this technology is the investigations on eXtended Reality (XR) to optimize the 5G network, including the air interface to support this service and its applications. The executive highlighted that the initial investigations started with Release 17 and continued with Release 18. "Until then, no dedicated study items in 3GPP focused on XR as, technically, this service exists between the main application scenarios of enhanced Mobile Broadband (eMBB) and ultra-reliable low latency communications (URLLC). It, therefore, requires a combination and balance of key performance indicators, such as throughput, low latency, high reliability and low power consumption," he said.

Adam Smith

Litepoint's Smith noted that the main features of 5G-Advanced would be NTN, RedCap, network slicing and AI. "You're going to see an AI push pretty heavily in 5G-Advanced networks. These are the kind of buzzwords that people are typically talking about when they're talking about 5G-Advanced. We've been doing some work already with the chipset companies around NTN, adding NTN to the bench of tests that are done when a cellular device is validated," the executive said.

"There are actually two buckets of features. One of the buckets is more a fundamental technology enhancement that will benefit all the use cases. For example, we have machine learning for NR air interface and we also have AI-assisted RAN network optimization. So these are very generic technology enhancements that will help everyone. It doesn't matter if we're talking about enhanced mobile broadband, existing services or new services. It's going to make the overall technology better. Full duplex is another example of this generic enhancement. These features are not part of 5G. They are distinctively 5G-Advanced. This is foundational technology that's being introduced in 5G-Advanced," said Tingfang Ji, VP of engineering at Qualcomm Technologies

"The second bucket of features that we're introducing in 5G-Advanced targets specific use cases," the executive said, adding that some key features in this group include positioning, RedCap and NR-Light, a new class of 5G technology that fills the gap in between high-speed mobile broadband devices and extremely low-bandwidth NB-IoT devices. "So there are quite a few new features that allow 5G to expand the market. I will say that RedCap will allow you to substantially lower the cost of the modem and enable data connectivity for some very low-cost devices," Ji said.

Gao noted that another main feature of 5G-Advanced is harmonized communication and sensing. "Sensing services for the broader transportation sector rely on capabilities like detecting and identifying a target's location, height, distance and speed. With technologies like high-isolation large-scale antenna arrays, ultra-large bandwidth, compute sensing and network sensing, it will be possible to achieve target detection and identification using less than 10% of the spectrum resources that were previously required," Gao said.

Gao also noted that space and terrestrial integrated networking will expand network coverage to provide signal for all people in all parts of the world, adding that phones will be able to directly connect to satellite networks.

"You're going to see an AI push pretty heavily in 5G-Advanced networks. These are the kind of buzzwords that people are typically talking about when they're talking about 5G-Advanced." - Adam Smith, Director of Marketing at LitePoint

NEW USE CASES ENABLED BY 5G-ADVANCED TECHNOLOGY

Merz believes that as 5G-Advanced is adopted, it is possible to expect plenty of new use cases to emerge, especially those that require a combination of high data rates, bounded-latency and/or massive connectivity.

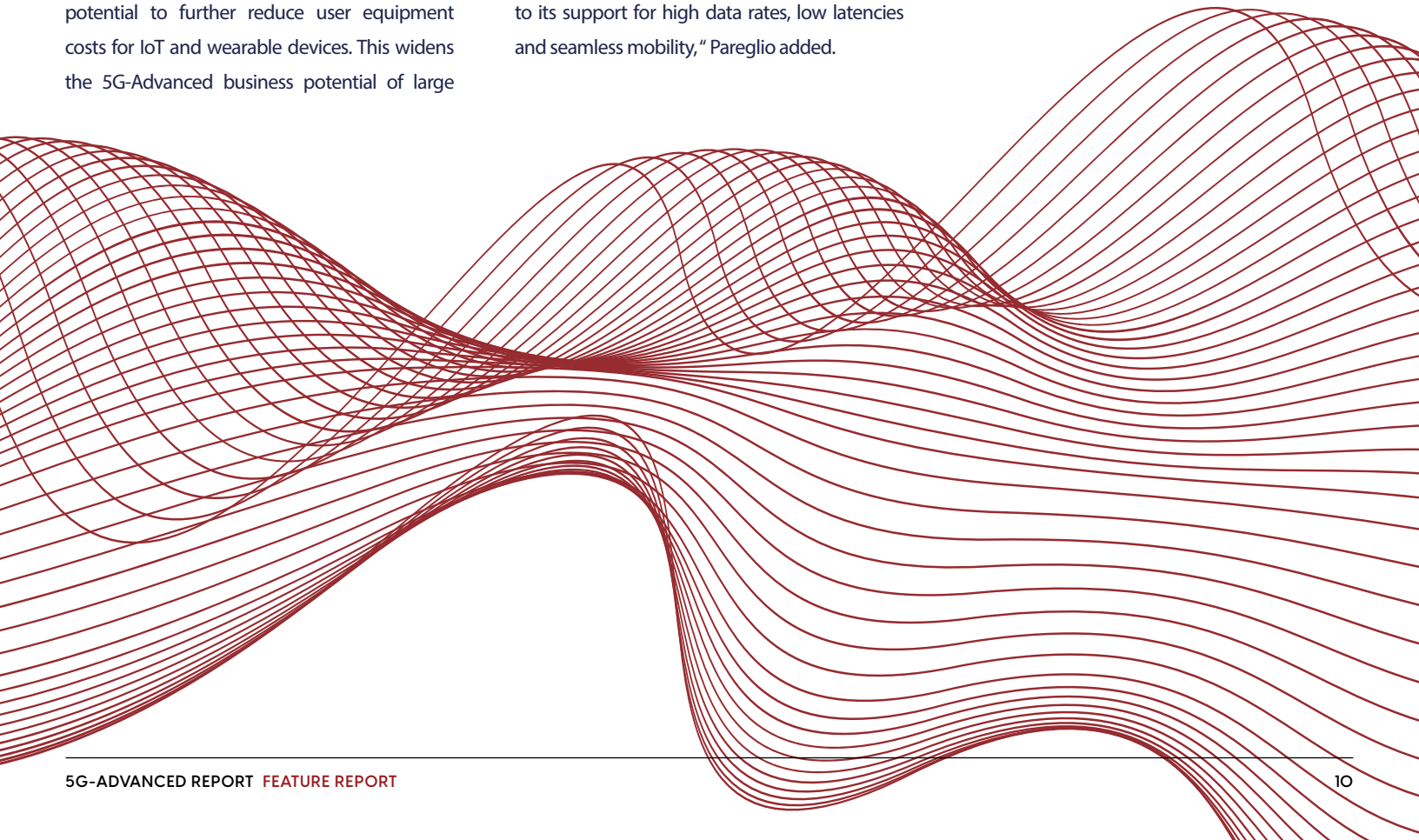
"XR, RedCap, NTN, UAVs, positioning and synchronization are some of the key use cases. 5G-Advanced will enhance today's XR experience by expanding the reach of VR and immersive AR applications and the cloud gaming experience. It will offer enhancements in terms of cellular-based positioning, for both indoors and outdoors scenarios," Merz said.

Merz also highlighted that thanks to accurate positioning and RedCap, 5G connected tags for asset tracking can be implemented. "Finally, 5G-Advanced evolves 5G RedCap, with the potential to further reduce user equipment costs for IoT and wearable devices. This widens the 5G-Advanced business potential of large 5G NR coverage investments toward device categories formerly only addressed with 4G technologies." he stated.

5G-Advanced will help to build on the achievements made possible with the rollout of 5G technology, while also facilitating new applications in areas such as smart transportation, smart cities and entertainment, said Pareglio.

"The increased power efficiency enabled by the technology will strengthen support for cost-efficient devices and/or power-sensitive applications, such as industrial wireless sensor networks, smart watches, smart eyewear and other wearables. Elsewhere, interactive applications, such as virtual reality, augmented reality and extended reality, will benefit thanks to its support for high data rates, low latencies and seamless mobility," Pareglio added.

"In the transport domain, 5G-Advanced will help to overcome connectivity issues by ensuring a user's experience isn't affected when on a high-speed train or plane. The technology will also provide communications support for uncrewed aerial vehicles (UAVs), satellites and HAPS operating as non-terrestrial networks with full seamless interworking with terrestrial networks. In turn, UAVs will offer new types of smart transportation solutions, while satellite and HAPS connectivity are a good complement to terrestrial connectivity for the maritime industry, IoT use cases and to fill coverage gaps," she added.



Chen stressed that 5G-Advanced will continue to expand into use cases beyond mobile broadband, such as boundless XR, including augmented reality, virtual reality and cloud gaming, adding that 5G-Advanced will also enable expanded IoT enhanced RedCap as a continuation of RedCap in Rel-17.

Sekiwa said that 5G-Advanced technology will enable the advancement of XR services and promote the widespread adoption of XR devices. It will also facilitate the utilization of UAVs, the progress of Cyber-Physical Systems (CPS / Digital Twins) through the proliferation of low-cost, low-power 5G IoT devices and the seamless integration of NTN with TN, he said.

Meanwhile, Peter Linder, head of 5G Marketing North America at Ericsson, said that 5G-Advanced "will enable 5G connectivity to more price sensitive devices making it a viable connectivity for the type of devices we have seen scaling on 4G since 2018."

"5G-Advanced will also improve Extended Reality use cases on smartphones as well as location based services where the precision in determining the location is essential for the use case," Linder said.

Peter Linder

"5G-Advanced will also improve Extended Reality use cases on smartphones as well as location based services where the precision in determining the location is essential for the use case." - Peter Linder, Head of 5G Marketing North America at Ericsson

Smith believes that 5G-Advanced will enable telecom operators to generate additional revenue streams with use cases applied for enterprise or industrial customers. "My opinion on 5G-Advanced is that the carriers are trying to figure out how to go beyond the enhanced mobile broadband use case. It's hard to squeeze more revenue out of the existing subscribers, so they got to find a way to move into industrial or enterprise applications. 5G-Advanced theoretically opens up some ways for them to provide value added services. One of the features will be network slicing for private networks, which will enable operators to sell certain things in the network to an end customer, whether that's maybe guaranteed latency or guaranteed data rate or maybe edge computing. So I think these are kind of non-consumer related use cases that 5G-Advanced would open up," Smith said.

"Another thing would be NTN. If you look at 5G-Advanced, another use case would be enhancing industrial tracking. NTN could provide real time coverage and real time positional accuracy for example for truckers moving out of the urban, cellular coverage ranges," he added.

Smith also highlighted that the deployment of small cells will be essential as the industry moves to 5G-Advanced as he believes there's not enough spectrum allocated to satisfy every use case that will emerge in the coming years. "So I think spectrum reuse is 100% going to be a part of 5G-Advanced. So the only way I know how to do spatial reuse is to go to smaller cell sizes. I think small cells are absolutely going to be part of the network build out as small cells are one of the keys to creating capacity in the network."

Ji of Qualcomm highlighted that a high-end use case would be Extended Reality, which is an umbrella term for different types of realities such as Virtual Reality (VR), which aims at giving the user the feeling of being physically and spatially there, Augmented Reality (AR), which provides a user with additional content overlaid upon their environment, and Mixed Reality (MR), which is an advanced form of AR where some virtual elements are inserted and can be interacted with. 3GPP has extensively studied the support of XR services in several working groups and the previously approved Rel-18 work items will introduce the first mechanisms that these studies have identified as beneficial.

"So in terms of power saving, in terms of capacity increase and in terms of mobility handling, there are many new features introduced in 5G-Advanced specifically for this XR technology," he said.

PUSHING THE LIMITS OF 5G

On the verge of 6G ?

While the optimization of networks and early 5G devices is ongoing, researchers are already discussing the future beyond 5G and the next generation of wireless communication. Rohde&Schwarz is following these discussions and is working with its partners and customers with the aim of adapting its existing solutions to support this initial phase of research on what might be ultimately called 6G.

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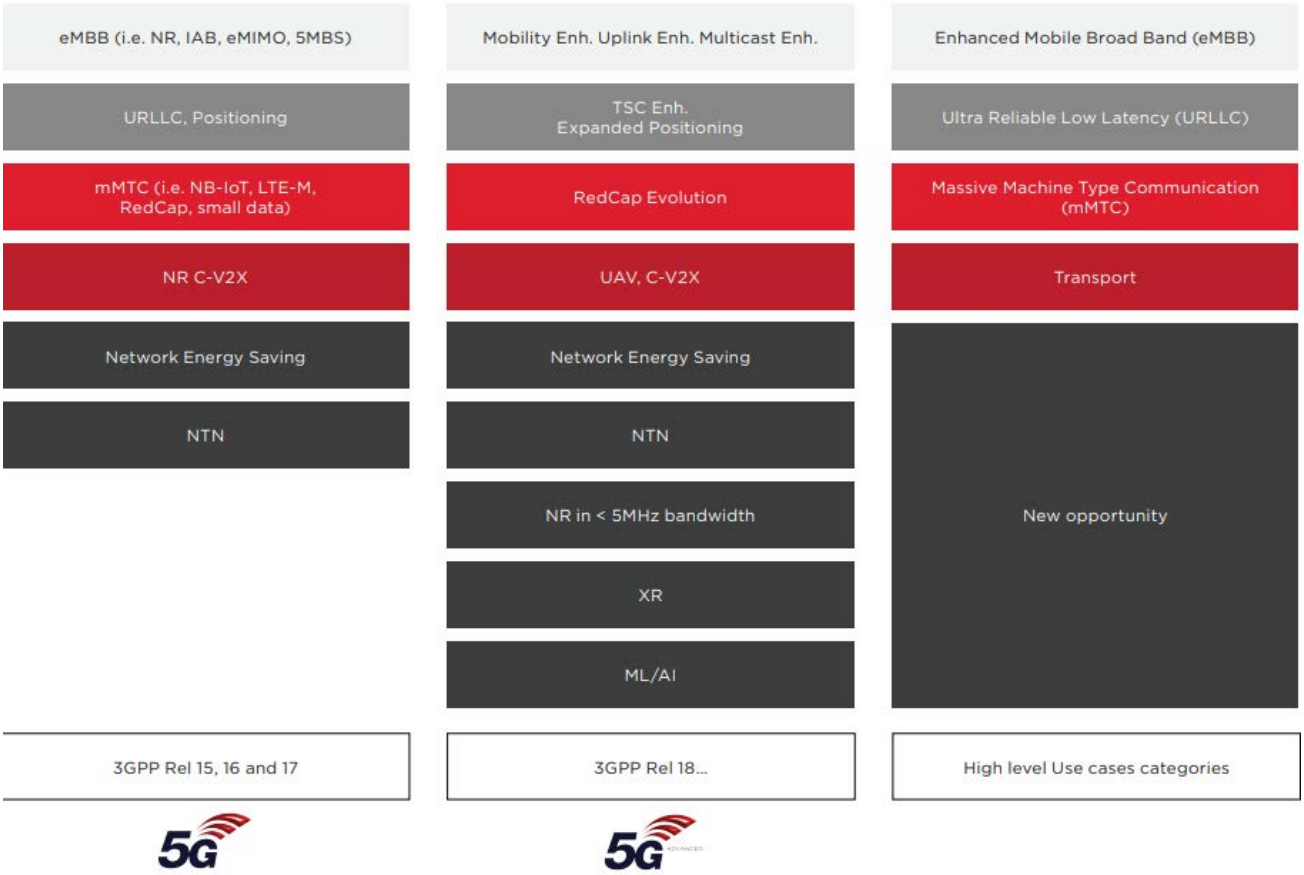


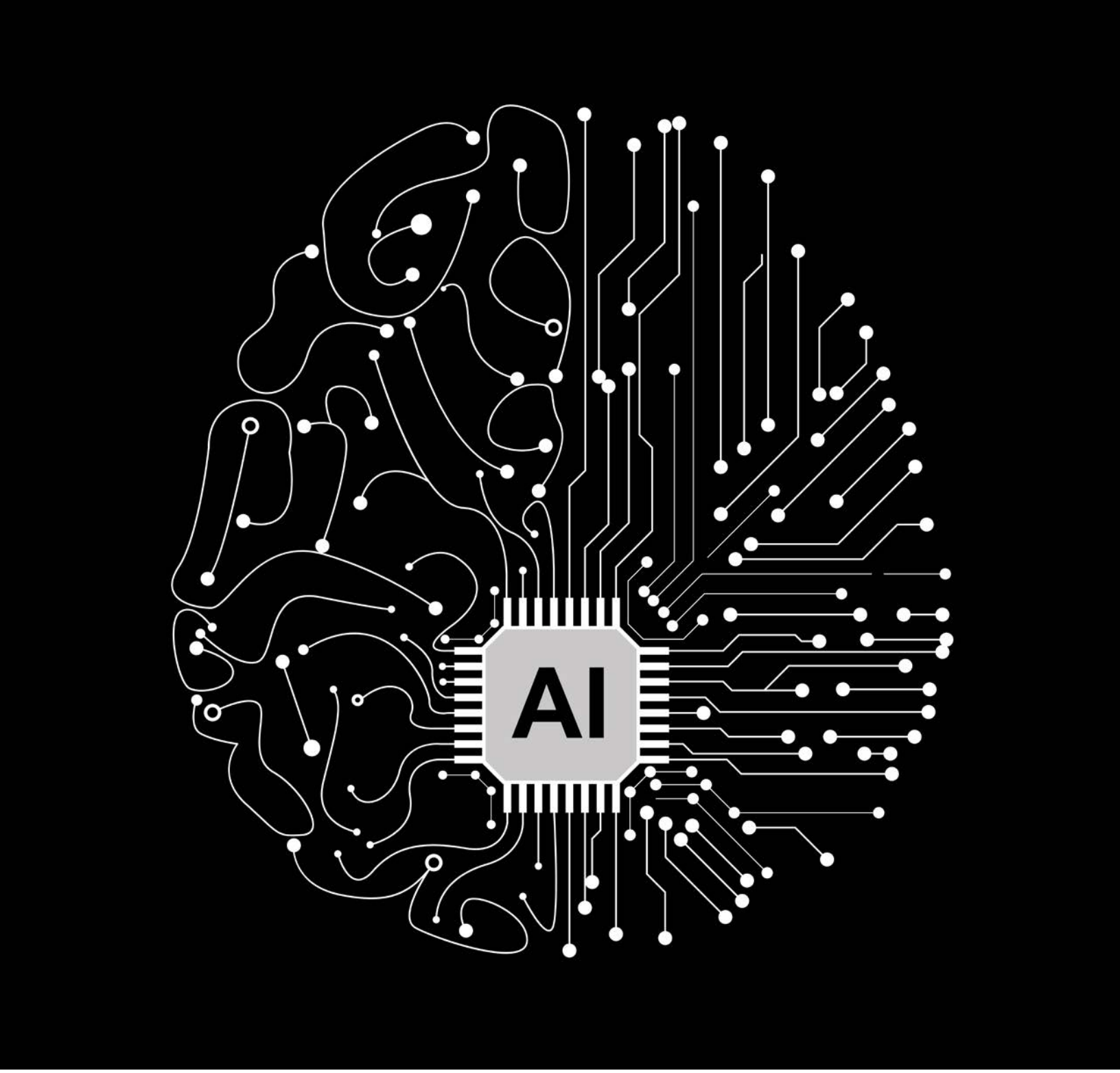
THE ROLE OF AI AND ML IN FUTURE 5G-ADVANCED NETWORKS

According to Mavrakis, the use of AI/ML to manage the network would be one of the key points of future 5G-Advanced networks, as these technologies will provide a more flexible, automated and cost-effective way to manage the network and improve performance and costs. "In terms of innovations, we still need to wait for commercialization of Rel-18 which will happen in 2-3 years, but several vendors are already developing AI/ML 5G network management tools," Mavrakis said.

"AI/ML is already part of 5G systems, but today it is mostly applied to network automation. With 5G-Advanced, we might see an advanced implementation of AI/ML in the RAN and radio interface. Eventually, those AI/ML capabilities will expand to the RAN, Core and the device, creating a foundation for future releases, including 6G," Merz said.

The Nokia executive added that the potential benefits of AI/ML in the network will be significant as it will boost the performance of the radio interface, reduce power consumption and greatly improve the end-user experience. "AI/ML will also play a big role in 5G-Advanced data collection and management. Finally, there is a need to standardize certain interfaces and signaling between Core, RAN and devices, in order to allow for adoption of AI/ML solutions in an interoperable way, which is the direction 3GPP is moving. In short, AI/ML will help find a better performing network parameterization faster," Merz added.

Both AI and ML will be instrumental in the evolution of the network and as an enabler



of autonomous networks for an always-connected and sustainable future, according to Pareglio. "5G-Advanced will harness artificial intelligence and machine learning to enable efficient network configuration, operation and optimization in a sustainable way, thereby improving the user experience while minimizing the energy consumption of.

Meanwhile, Masuda believes that the adoption of AI/ML is very important in the sense that it will be a trial for the full introduction of AI/ML in future 6G networks. "For 5G-Advanced, there is the possibility that the adoption of AI/ML will only lead to a partial optimization, as it will be applied to already built networks, but we think that the effects of the introduction can be measured and the results fed back to 6G. We thus expect innovation through the application of AI/ML to 6G networks, rather than innovation in 5G networks," he said.

Hiroyo Masuda

"For 5G-Advanced, there is the possibility that the adoption of AI/ML will only lead to a partial optimization, as it will be applied to already built networks, but we think that the effects of the introduction can be measured and the results fed back to 6G." - Hiroyo Masuda, Senior Architect, 6G infrastructure Strategic Planning Division, Advanced Technology Development Unit at Fujitsu

Chen explained that artificial intelligence and machine learning over-the-air was completely new to 3GPP when the Rel-18 work got started in May 2022, although 3GPP started AI/ML related work for network data collection earlier. He went on to say that there were a lot of uncertainties and doubts at that time regarding how AI/ML could be incorporated into the 5G NR air interface framework in 3GPP and, conversely, how the 5G NR air interface could exploit the benefits of non-transparent AI/ML operations.

"We now have a much better and clearer understanding of the interaction of AI/ML vs. 5G air interface, after the dedicated and thorough study involving all working groups in 3GPP RAN. In Rel-18, the study shows that AI/ML will bring not only performance enhancements for aspects such as channel adaptation, beam management and positioning, but also increased system operation efficiency such as overhead reduction and energy consumption savings," Chan said.

He added that Rel-19 is expected to continue AI/ML in a more expanded and comprehensive manner. "As a continuation of Release study, specification for AI/ML air interface is expected. In addition, additional study for new use cases, such as mobility management, is very likely to occur," Chen said, adding that the work in Rel-18 and Rel-19 on AI/ML will lay a solid foundation for future AI-native 6G in 3GPP.

Sekiwa considers that there will be a widespread adoption of AI/ML in various aspects, such as optimizing communication quality and energy consumption and reducing operational costs through automation, while Ericsson's Linder noted that AI/ML are essential for making network more dynamic and adjusting capabilities and network workloads to actual demand for network resources. He also said that AI/ML also introduces new tools in the network for optimizing energy consumption.

"As we all know, artificial intelligence and machine learning are the buzzwords of our time. But doing machine learning for the sake of machine learning makes no sense. It is, therefore, very important to identify the use cases where applying AI/ML makes sense. So with Rel-18, 3GPP did exactly that and identified three pilot use cases around CSI feedback enhancement, beam management and positioning accuracy to start studying and ultimately defining a general framework for augmenting the 5G NR air interface functionality to support AI/ML-based algorithms to enhance performance and reduce complexity and overhead," said Roessler. "As the topic is very complex, there is, at the moment, a strong debate with 3GPP RAN1 on how to continue with these studies in 3GPP Rel-19, when the initial study item transitions to a work item. Some companies believe more studies are required; some believe the current results justify changing and updating the impacted technical specifications," Roessler added.

"The impact [of AI] will be not only just the performance getting better, but it will also allow the 5G-Advanced technology to evolve faster," Ji said.

Andreas Roessler

"AI and ML are the buzzwords of our time. But doing machine learning for the sake of machine learning makes no sense." - Andreas Roessler, Technology Manager at Rohde & Schwarz

WILL 5G-ADVANCED BOOST PENETRATION OF PRIVATE NETWORKS?

According to Merz, several features of 5G-Advanced are aimed at private networks. The executive believes that the enhancements in the uplink will meet the more symmetrical connectivity demands of enterprises and industries. Also, he considers that 5G-Advanced will bring highly accurate localization and timing resilience, which will be key for a broad range of applications from factory automation and logistics to financial services. "Verticals like electrical utilities and railways that have small blocks of spectrum will be able to take advantage of 5G-Advanced's support for small-bandwidth connections. Finally, through RedCap enhancements, 5G-Advanced will pave the way for new classes of 5G devices with lower power consumption and cost, bolstering private network adoption," he said.

"Given that 5G-Advanced will serve a wide variety of industries with different ecosystems and enable a plethora of new business models, there is a very good chance 5G-Advanced will indeed boost the penetration of private networks in vertical markets, particularly for industries such as manufacturing, fintech and smart mobility," said Pareglio.

"Furthermore, 5G-Advanced will further enhance the management of what 3GPP calls the Non-Public Network, which also includes private networks, but has also slightly different models. We believe this will definitely help the use of private networks in combination with public networks," the GSMA executive said.

Masuda considers that 5G-Advanced will also enable many improvements of already existing functions, adding that a number of companies in vertical markets are also participating in studies toward the introduction of 5G-Advanced. "We expect that their needs and demand will speed up the introduction of Advanced 5G," he stated.

Chen explained that 5G private networks was defined and enabled as part of 3GPP Release 16, while 5G-Advanced will continue to bring fundamental system enhancements, such as the ability to improve XR performance and experiences, which will be critical for many private network use cases. "The enhanced support for multiple SIMs, part of Rel-18, will also bring closer integration of 5G public and private networks. Extension of time-sensitive communication [TSC] to deterministic networking [DetNet] in Rel-18 will enable new capabilities that are important to industrial automation/IoT use cases," Chen said.

Wanshi Chen

"Extension of time-sensitive communication to deterministic networking in Rel-18 will enable new capabilities that are important to industrial automation/IoT use cases." - Wanshi Chen, 3GPP RAN Chair

Sekiwa noted that the key to the proliferation of private networks lies in the provision of cost-effective and high-quality 5G networks, as well as a wide range of 5G-IoT devices and their integration with various applications used by businesses. He also said that 5G-Advanced offers features that contribute to the spread of private networks, such as high-speed uplink transmission expected in many use cases and the realization of low-cost RedCap/eRedCap.

"I think that via the introduction of AI for the first time in the network, there's good potential there for providing an increase in intelligent network automation. I think that this could help increase the attractiveness of private 5G solutions and boost adoption.

I also think that there's an opportunity for AI/ML to better tailor aspects of private deployment to address vertical markets as well," Harris said. Ji believes that the introduction of 5G-Advanced technology will pave the way for a massive expansion in the IoT field.

"From day one, we have been saying that 5G was not just all about enhanced mobile broadband but also about Massive IoT and Critical IoT. "In the first five years of 5G, the enhanced mobile broadband use case will drive the ecosystem and drive the cost down to enable the economies of scale," Ji said.

"In many private network industrial settings, you really don't need a very beefy modem that gave you 10 gigabits per second. That's not what the market is looking for. The market is looking for something that can give them an advantage in terms of both performance and cost. So 5G-Advanced is not only advancing fundamental wireless technology, but it will offer specific solutions for that market," Ji added.

"The market is looking for something that can give them an advantage in terms of both performance and cost. So 5G-Advanced is not only advancing fundamental wireless technology, but it will offer specific solutions for that market." - Tingfang Ji, VP of Engineering, Qualcomm Technologies

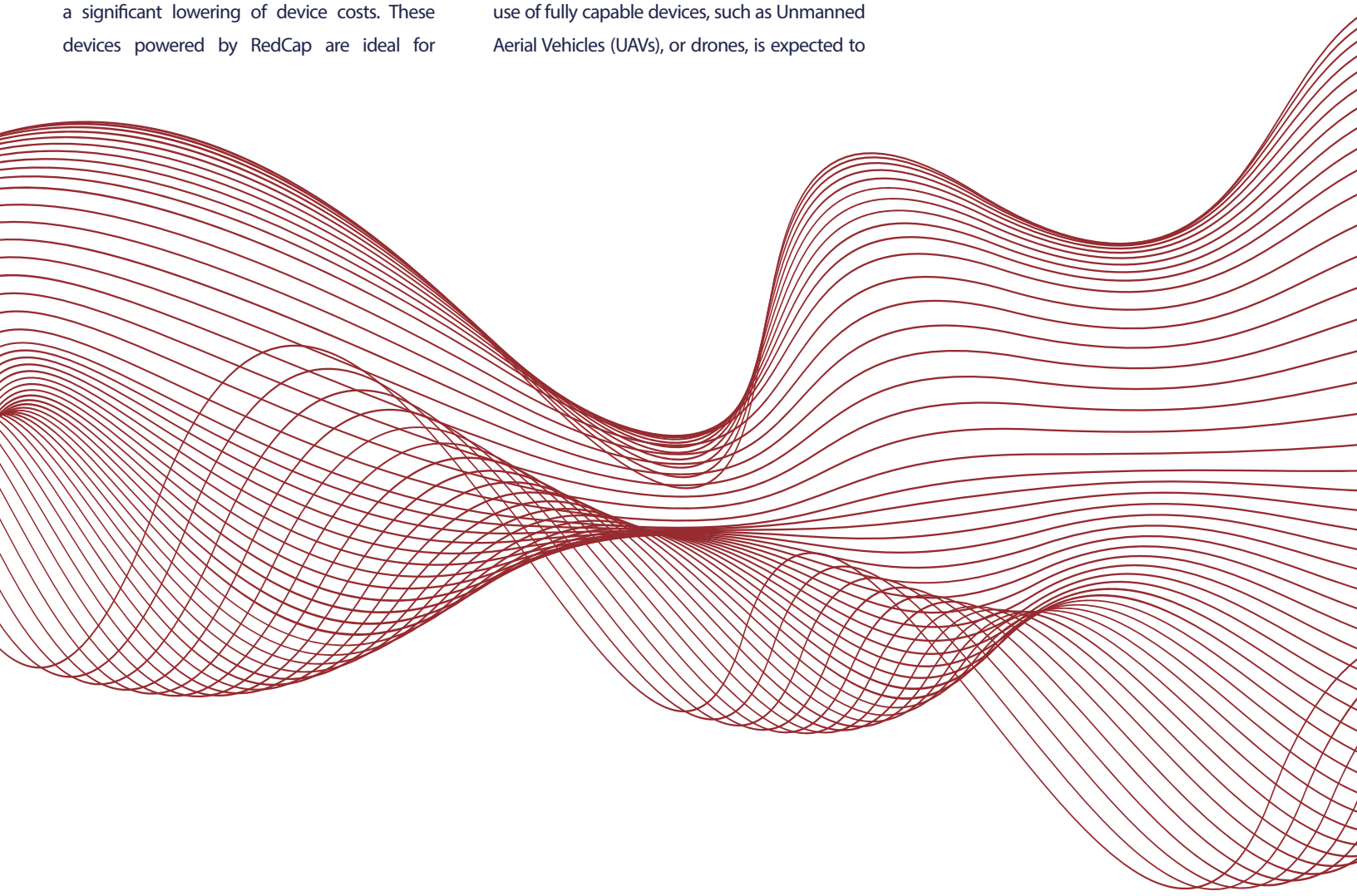
Tingfang Ji

5G-ADVANCED AND ITS IMPACT IN THE IOT FIELD

The introduction of 5G-Advanced networks will pave the way for the implementation of network management using AI/ML, which will make it easier for operators to manage their IoT products and network capabilities, according to Mavrakis.

Meanwhile, Merz said that it is possible to anticipate a plethora of new IoT devices beyond smartphones, as well as devices that do not need to implement every aspect of 5G's performance portfolio. "This allows for a significant lowering of device costs. These devices powered by RedCap are ideal for use cases such as video surveillance, process monitoring, sensing and asset tracking," the executive said. "For instance, we can design smart wearable electronics with a small form factor that has long-lasting batteries. Or in industrial process monitoring and quality control scenarios, we can implement inexpensive, low-power sensors that frequently transmit small data packets but utilize only minuscule network resources," he added.

The Nokia executive also emphasized that the use of fully capable devices, such as Unmanned Aerial Vehicles (UAVs), or drones, is expected to grow with applications ranging from search and rescue to parcel delivery and aerial displays. "Not only drones but also autonomous vehicles, robots and Automated Ground Vehicles (AGVs) will benefit from 5G-Advanced networks that are designed to ensure reliable communications with base stations," he said. "Moreover, new types of devices called ambient or passive IoT, which in theory do not require any electricity source or battery, are now being studied."



Meanwhile, Pareglio stated that 5G-Advanced will provide enhanced support for IoT, industrial IoT (IIoT) and Ultra-Reliable Low Latency Communications (URLLC). She added that in use cases requiring small and infrequent data packet transmissions, the battery lifetime for user equipment can be extended by removing the need to execute the whole session setup procedure. "The small data transmission feature will enable the sending of data packets and signaling messages, extending battery lifetime, side link support and narrow band positioning. As the rollout of 5G-Advanced develops, ambient IoT technologies could make sensor networks far more economical, while dramatically increasing the efficiency of warehouse stock taking and other industrial processes," Pareglio added.

Chen explained that there are multiple workstreams in 5G-Advanced currently focusing on IoT. The executive explained that RedCap evolves to bring down the cost further while enabling even more capabilities, such as the support for sidelink (mesh networking), positioning and power saving for lower throughput applications.

Chen also said that Ambient IoT is being studied for Rel-19, which will target even higher energy efficiency and lower-complexity applications. "Further enhancements in positioning and sidelink can enable new IoT use cases," he added.

Meanwhile, Sekiwa believes that with 5G-Advanced, the proliferation of various IoT devices through UAVs and RedCap/eRedCap, as well as the further development of IoT-NTN, will enable the expansion of deployment areas, thus enabling new diverse use cases. "Furthermore, the efficient integration of various sensors with features such as wireless charging and low power consumption into the network through Ambient IoT is expected to foster the further advancement of CPS."

Harris noted that the main improvements in this field would be enabled by the NTN enhancements to be included in Rel-18:"I think these enhancements would help to drive increased adoption of technologies like NB-IoT and really tackle those areas where deploying terrestrial networks previously just wasn't practical or there wasn't a good business case for it. So I think that's something that could drive market adoption." he stated.

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5G-ADVANCED AS A BRIDGE CONNECTING 5G WITH FUTURE 6G SYSTEMS

Mavrakis agrees with the fact that 5G-Advanced networks will act as a bridge connecting current 5G networks with future 6G networks. He noted that 6G will be developed on AI/ML and automated network capabilities, which will also play a key role in 5G-Advanced networks. "Other capabilities that include Sidelink and positioning will also help the industry understand what vertical markets need, and these will surely feed into the discussions for 6G standardization," the analyst said.

Dimitris Mavrakis

"However, we should expect that 5G and 5G-Advanced will remain in the market for many years to come, and 6G is not likely to replace them, but augment them," Mavrakis added.

Merz explained that 5G-Advanced will lay several foundations for 6G, as there are a few areas where we can see 5G standardization acting as a bridge or "prior art," including topics like AI/ML in air interface and in the network domains, ISC (Integrated Sensing and Communication) and Ambient IoT. "These functionalities are being studied and specified in 5G-Advanced and will provide a basis for further 6G planning and implementation," the Nokia executive said.

> "We should expect that 5G and 5G-Advanced will remain in the market for many years to come, and 6G is not likely to replace them, but augment them." - Dimitris Mavrakis, Senior Research Director, ABI Research

Pareglio, of the GSMA, stated that while 6G applications are yet to be defined, this new generation aims to reach global connectivity, sensing connectivity, immersive communications and critical services along with several other potential use cases throughout a hybrid and diverse technology approach.

"As the roll-out of 6G will be gradual, 5G-Advanced will play an important role in bridging from 5G to 6G with new features that were previously not standardized in 3GPP. Many of the 5G-Advanced technology components and innovations will be viewed as precursors to some of the 6G building blocks. Indeed, MNOs could of course jump directly to 6G, but the foundations for the majority will be through 5G-Advanced," she said.

Pareglio stated that XR is a clear example of this, as this technology will gradually evolve into immersive communication for human-machine interaction and may be reliant on 6G to provide an even better experience. "AI/ML will also play an important role in the fully data-driven architecture of 6G and the intelligent network platform of the future," she added.

Also, Masuda noted that some of the services expected in the 6G field are already under consideration in 5G-Advanced. "Since the adoption of AI/ML is promoted not only in 5G-Advanced but also in the whole industry, we believe that networks using AI/ML will be available from the beginning of 6G systems and architectures can be planned accordingly."

Chen also agrees with the idea of 5G-Advanced as a connector between the 5G world and future 6G systems. "Many projects in 5G-Advanced will become the foundation of the 6G platform. We have observed a similar trend in the 4G to 5G transition, where many LTE-Advanced features got further enhanced and widely deployed as part of 5G."

He went on to say that some possible examples of such possible 5G-Advanced features could be AI-based air interface, green networks, full duplex, support for upper mid-band (7-15 GHz) and integrated sensing and communication (ISAC), among others. "Indeed, the newly completed Rel-19 workshop envisions that Rel-19 can also serve as a bridge to 6G, as witnessed by strong interest to initiate some studies, such as channel modeling for new spectrum such as 7-24GHz and ISAC," Chen added.

Tomohiro Sekiwa

"We believe that 5G-Advanced will introduce some of the technologies that are expected to see widespread adoption in the 6G era. Through the use of AI/ML, network communication quality and energy consumption will be optimized, enabling cost reductions through automation," Sekiwa said.

"An important characteristic of the 3GPP model is that all releases build on each other. The role of releases in the second half of a mobile generation is to deliver on the full scope of a generation and bridge to the next one. The stepping-stones are often of an architectural nature, like the transition from virtualized to cloud-native cloud infrastructure, hardware and software disaggregation for RAN, etc.," said Linden, of Ericsson.

Roessler, of Rohde & Schwarz, also agrees with the idea of 5G-Advanced as a connector between the 5G and 6G worlds. "There are two main examples I can think of right now. First, the Rel-18 study item on AI/ML for the air interface will transition into a work item for Rel-19 and will, therefore, become part of the technical specifications. 3GPP will lay the foundation for supporting AI/ML functionality on the 5G NR air interface, which, ultimately, any 6G standardization efforts will build upon as many researchers and industry experts believe 6G will support AI natively for the air interface."

"The second example is that at the recent RAN plenary meeting in September, 3GPP approved a new study item for Rel-19, which is the second release for 5G-Advanced, on investigating the frequency range between 7 and 24 GHz by the means of doing channel sounding and subsequent modeling. This frequency range is better known by its unofficial title, "FR3". Many consider "FR3", besides sub-THz frequencies, as a frequency range that a future 6G standard will support," he added.

"I think it will be a bridge for sure. I think the most crucial stepping stones from my perspective are NTN and AI, I think that NTN provides a path towards complete global coverage, unifying satellite and terrestrial networks for the first time to kind of enable a single device to keep you connected wherever you are on the planet. And I think that's quite an incredible vision really. And then we've all seen the potential that AI has in various forms, and 5G-Advanced will be our first foray into leveraging that potential in the mobile network. So that will definitely lay the foundations for a 6G network that can be more AI native by design," Harris said.

"We believe that 5G-Advanced will introduce some of the technologies that are expected to see widespread adoption in the 6G era." - Tomohiro Sekiwa, SVP and Chief Network Officer at SoftBank,

CONCLUSION

5G technology still has a long way to go in order to deliver on all of the promises and use cases anticipated by the industry. Many of these advances, however, will be a reality with the development of 5G-Advanced services and applications in the coming years. These applications and use cases enabled by 5G-Advanced, where artificial intelligence and machine learning will start playing a key role, will also set some initial stepping stones that will influence future 6G systems, which are expected to be commercially launched around 2030.

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