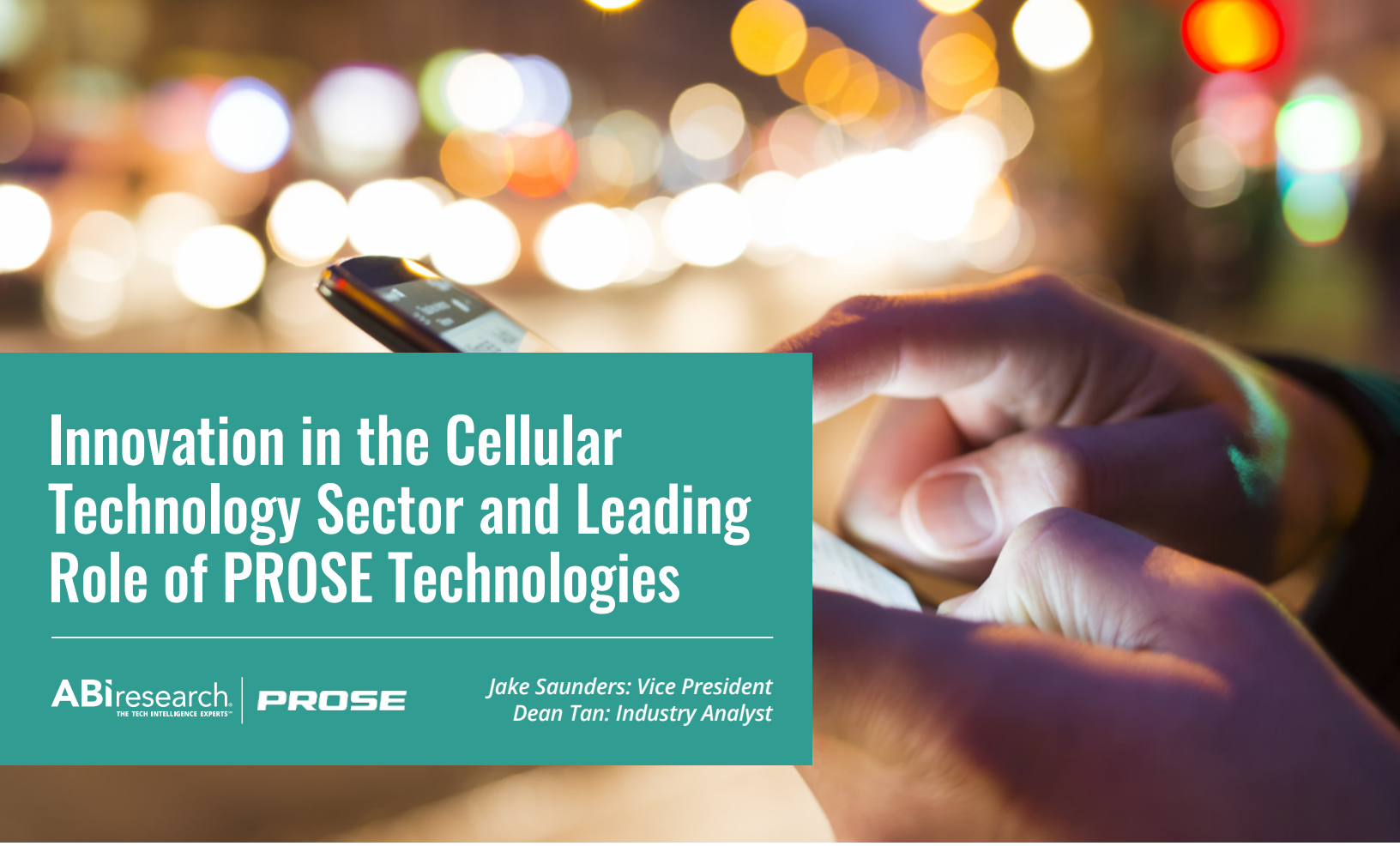

Innovation in the Cellular Technology Sector and Leading Role of PROSE Technologies

ABIresearch | PROSE

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EXECUTIVE SUMMARY

5G was first launched in 2019 and it has been almost 3 years since then. Globally, based on a Global mobile Suppliers Association (GSA) report in June 2022,[1] a total of 205 operators in 80 countries have launched 5G mobile services. With 5G being more widely available, consumer and enterprise applications are expected to drive the traffic demand for 5G. Each of these has a separate requirement for the network to deliver to work best. Applications include Extended Reality (XR), cloud gaming, immersive video, and 5G + Artificial Intelligence (AI) for industrial monitoring and sensing, autonomous vehicles and robotics, and remote operations, which are some examples, among many others. Data traffic from the top 30 markets is expected to grow and reach about 3.23 zettabytes by 2026 with 5G representing more than 50%.

To meet these future data traffic demands, there is a need to upgrade the mobile infrastructure with a trusted, innovative, and leading company for both outdoors and indoors. An ideal vendor will be one that is able to move ahead of the current developments and charter a path of Research and Development (R&D) to help Communication Service Providers (CSPs) prepare for the future. The vendor should be focused on finding the most innovative and cost-effective solutions to help CSPs transit and reach the next stage.

1 *5G-Market Snapshot June 2022*

The current key developments include The 3rd Generation Partnership Project's (3GPP) Release 17 and Release 18, the first 5G-Advanced branding, and the Open Radio Access Network (RAN), which is set to continue disrupting the market. Release 17 and Release 18 are set to enhance 5G and further improve its ease of adoption and technological advancement. For example, the enhancement in the XR space, expected to come in Release 18, will help drive greater adoption of XR in both consumer and enterprise markets.

Based off Europe, PROSE Technologies (Previously Rosenberger) is a leading global equipment vendor with cutting-edge solutions for both outdoor and indoor connectivity. The company has demonstrated over the years not only its ability to innovate and push the boundaries of technologies, but also to execute its go-to market strategy successfully. Catering to both outdoors and indoors, PROSE Technologies' product portfolio provides a comprehensive suite of solutions for CSPs to overcome their network deployment challenges. PROSE Technologies' ability to keep a finger on the pulse of the demands of CSPs and its established history of innovation are expected to continue propelling the company forward.

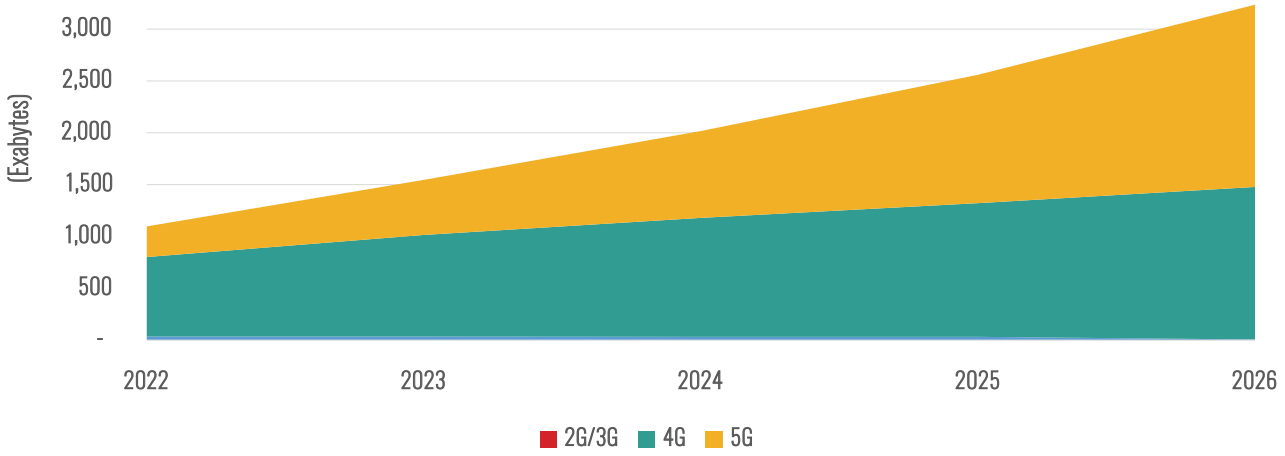
PRIMARY DRIVERS OF 5G ADOPTION

OVERVIEW

5G was launched just at the time that the COVID-19 pandemic put the world into a lockdown. Yet, it has not stopped the CSPs' investments in and deployments of 5G. Globally, based on a GSA report in June 2022,[2] a total of 205 operators in 80 countries have launched 5G mobile services. With the deployment of 5G mobile networks, CSPs and the telecommunication industry have made huge progress in exploring and commercializing both consumer and enterprise 5G use cases.

Chart 1: Network Data Traffic by Technology and Year (Top 30 Markets)

(Source: ABI Research)



Based on ABI Research's data, by 2026, 5G data traffic is expected to grow to 1.76 zettabytes,[3] representing more than 50% of all data traffic. This increase in data traffic is expected to be driven with increasing 5G use cases being commercialized in the market for both consumers and enterprises.

2 *5G-Market Snapshot June 2022*

3 *1 zettabyte equals 1 billion terabytes or 1 trillion gigabytes*

CONSUMER 5G ADOPTION

Consumer data traffic forms the bedrock for CSPs in the earlier cellular technology generations. While in the 5G era, enterprise-related use cases have generated lots of attention as the new markets, for CSPs, the consumer market continues to showcase its market growth and potential. The word "metaverse" was first used by Neal Stephenson in his 1992 novel, Snow Crash, describing a virtual environment in which users gained access to the virtual world through Virtual Reality (VR) goggles. No one, in the past, would have imagined the word to be hugely popular and widely used today.

There are a few key applications for the concept of the metaverse today, namely: 1) immersive video, 2) cloud gaming, and 3) XR. These applications are some of the cornerstones to a successful development of the metaverse. 5G will also be a key technology to support the metaverse development by enabling higher bandwidth, lower latency, and a massive number of devices.

METAVERSE APPLICATIONS

IMMERSIVE VIDEO APPLICATIONS

Immersive video, also known as volumetric video, delivers video with a 360° viewing angle, a key differentiation to traditional video content. It allows viewers to interact and change their viewing areas, whereas traditional video allows only for a single viewing angle captured by the videographer. It provides the perception of being in the actual environment due to the way the content surrounds the user. It is important to note that immersive videos are also used in conjunction with the VR technology, which will be covered in greater depth in Section 2.2.1.3 under Extended Reality.

For an immersive video experience, typical 1080p High Definition (HD) will not make the cut. To deliver an acceptable experience, 4K is needed and, even then, it can be grainy. While an immersive video is captured in 4K, its viewing angle is but a small slice of the 4K video that typically translates to 720p video quality. Therefore, for a quality experience, the immersive video needs to scale beyond 4K and even 8K. For reference, streaming a 4K video is estimated to consume up to an average 14 Gigabytes (GB) per hour, more than 4X the data consumed for 1080p video.

For consumers looking to run immersive video applications, the increase in data consumption will need an upgraded tariff with a higher data limit. Not only do 5G plans typically have higher data caps for subscription plans, but 5G is much more suitable with its higher frequency bands (e.g., the 3.5 Gigahertz (GHz) band) to provide the Enhanced Mobile Broadband (eMBB) experience and lower latency.

CLOUD GAMING APPLICATIONS

Cloud gaming allows players to access gaming titles on demand. By hosting game titles in the cloud, players are not limited solely by the physical hardware capabilities. This is because the computing needs can be performed at a data center located kilometers away from the end player. This reduces the need for expensive and high-performance hardware to support the gaming experience, allowing hardware to be less expensive, sleeker, and more compact.

By having the computation performed kilometers away, the network will need to be able to handle large amounts of data and provide low-latency capabilities for an optimal gaming experience, while supporting multiple players accessing the game or platform simultaneously in a similar location (e.g., during events or when playing Pokémon Go). Today, a few mainstream cloud gaming services include GeForce NOW, PlayStation Now, and Google Stadia.

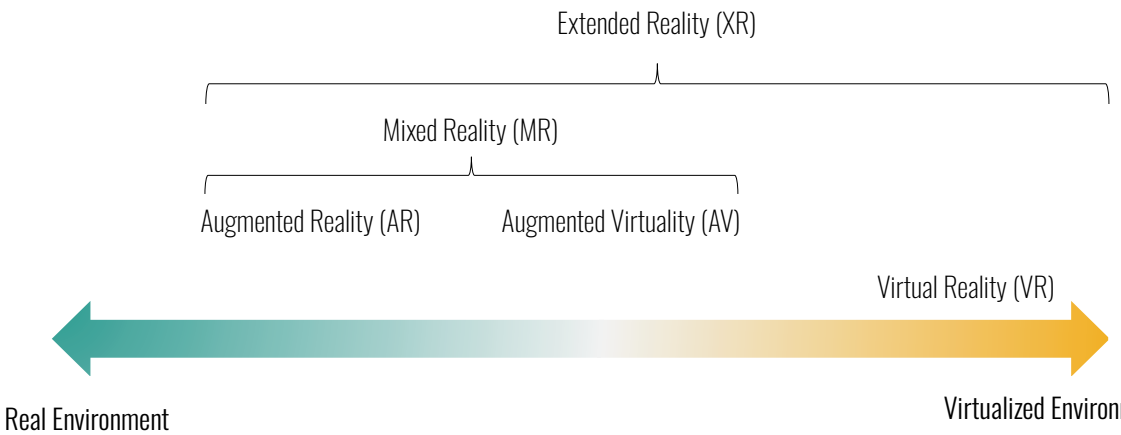
While the potential of cloud gaming sounds attractive for gamers, there could be significant consequences when the gaming application experience, the network infrastructure, and the data centers are not properly optimized. For cloud gaming to work and be a good substitute for a locally stored game on hardware, the latency issue needs resolving, and the mobile network needs to support the large amount of data communicating through the network. Certainly, any company launching cloud gaming services needs to have its own cloud strategy, while complementing the 5G technology available to deliver a quality gaming experience.

EXTENDED REALITY

XR is an umbrella term for Augmented Reality (AR), VR, and Mixed Reality (MR). It encompasses all types of real and virtual environments in which human-machine interactions are performed. XR has been primarily used in the entertainment and gaming industry, but increasingly in industries like tourism, retail, and education, among others.

Figure 1: Extended Reality Plotted along Milgram & Kishino's Reality-Virtuality Continuum

(Sources: ABI Research, Milgram & Kishino (1994))



XR plotted onto the original Milgram and Kishino's Reality- Virtuality Continuum (1994).

Other barriers to adopting XR are constrained mobility for consumers, lack of alternative wireless technologies, need for high computation power, and data storage. The lack of alternative wireless technology capable of delivering the data throughput, while providing sufficient low latency, is one reason for cybersickness. There have been studies by researchers identifying latency as a contributor to cybersickness and that a good VR experience requires latency of less than 20 milliseconds.

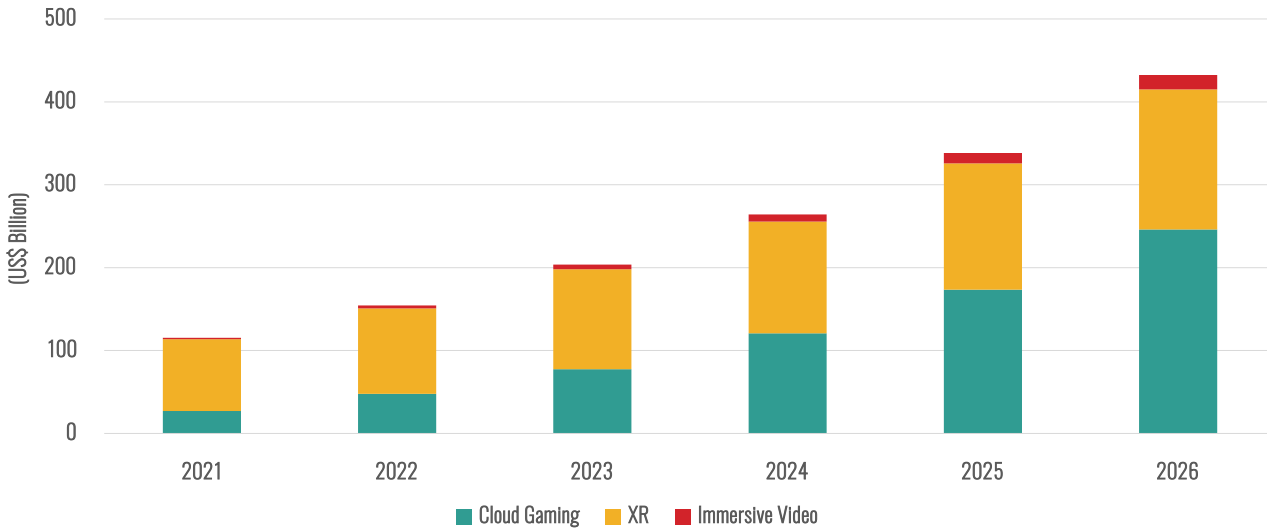
This is where 5G plays a role and provides close to real-time XR content delivery, while reducing the weight of the Head-Mounted Displays (HMDs). 5G can provide higher data throughput and lower latency to better support XR applications. A peripheral development with 5G is the deployment of edge computing, also known as Multi-Access Edge Computing (MEC), in the network. MEC enables the XR industry to benefit from a lower overall latency and to offload computing requirements to the cloud. Offloading can reduce the weight of HMDs, thereby enhancing the appeal of XR to end users.

METAVERSE APPLICATIONS WORLDWIDE OUTLOOK

The following dataset is part of ABI Research's Consumer Metaverse: Digital Content, Services, and Advertising market data, (MD-NGCS-102), Augmented and Mixed Reality Market Data: Devices, Use Cases, Verticals, and Value Chain market data (MD-ARMR-106), Virtual Reality Market Data: Devices, Verticals, and Value Chain market data (MD-VR-111). Immersive video subscription revenue is expected to grow from US$103 billion in 2022 to US$168.9 billion in 2026. Immersive video is already commercialized today and will grow further as other technologies (e.g., VR) develop and grow in adoption.

Chart 2: Metaverse Applications Revenue by Application and Year

(Source: ABI Research)



For the XR forecast, only consumer-related verticals, such as media & entertainment, tourism, and sports & fitness, have been taken into consideration to generate the forecast. Global consumer XR revenue is estimated to reach about US$91 billion by 2026 at a Compound Annual Growth Rate (CAGR) of 52% from 2022 to 2026. By 2026, AR/MR will make up the bigger share of 64% of the global XR revenue. ABI Research forecasts that global cloud gaming revenue will reach US$17 billion by 2026, growing at a CAGR of 48.3% from 2022 to 2026.

COMMERCIAL ENTERPRISE 5G ADOPTION

Consumer applications are not the only drivers for 5G adoption and demand for wireless technologies. A big part of the 5G market lies in the enterprise market where 5G is set to enable Industry 4.0 and help companies go through digital transformation. With the three key capabilities of 5G (eMBB, Massive Machine-Type Communication (mMTC), and Ultra-Reliable Low Latency Communication (URLLC)), many applications exist in the market that 5G can support and industries can adopt.

KEY APPLICATIONS

5G + AI

5G + AI is being used commonly in the department of quality control and assurance. This is crucial, especially in the manufacturing industry, and forms an integral part for a successful product. Quality control and assurance remains a task that requires experienced staff's involvement. However, with the introduction of 5G, companies can use high-resolution 4K or 8K videos coupled with machine vision to detect defects or sub-quality production with the help of experienced staff. This will help companies sort out faulty products more accurately and reduce the time required for visual quality inspection. 5G will be needed to provide a robust and reliable network capable of handling the numerous production lines where 5G + AI is implemented.

AUTONOMOUS VEHICLES AND ROBOTICS

Other popular 5G use cases are autonomous vehicles and robotics, which include Automated Guided Vehicles (AGVs) and Autonomous Mobile Robots (AMRs). These are observed in logistics and transportation industries, as well as in manufacturing. Observable benefits include reduced cost of operations from fewer workers on a shift, reduced fatigue of workers, and improved operational efficiency. To enable these key uses cases, 5G's ability to handle high data rates and low latency is essential. Autonomous operation will need to react in near real time in case of any safety breach or to prevent accidents. Alternative wireless technologies, such as Wi-Fi, will face the challenge of spotty coverage, unable to handle high data throughput requirements and higher latency rates. Thus far, this has limited the adoption of autonomous vehicles and robotics.

REMOTE OPERATIONS FOR VEHICLES AND EQUIPMENT

Remote operations help increase efficiency and allow an experienced worker to attend to different equipment in a shorter amount of time. Typically, a single piece of equipment will have a single experienced worker operating it. To move from one piece of equipment to another requires time and effort, in addition to the rest time. Through remote operations, an experienced worker could pivot much faster from one piece of equipment to another, allowing the individual to increase productivity. For example, in the mining industry, remote haulage operations could not only drive productivity, but also keep workers safe from harsh environments and, in the case of an accident, safe from injury.

WORKPLACE OF THE FUTURE

The COVID-19 pandemic accelerated the need for digital collaboration, sparking a new trend of remote working and the ability to tap into talent globally. The workplace of the future is one in which people can be working from different locations, yet able to connect with team members. This means that workers in remote locations can seamlessly connect and tap into needed capabilities easily.

For example, in manufacturing, this helps reduce the production downtime when issues arise. Using 5G to support 4K/8K video streaming and AR allows remote engineers to help on-site staff resolve issues without the need to travel to the factory floor. In product design, a team can work and discuss 3D digital assets in real time without requiring all personnel to be on-site. This also increases the level of engagement, as team members can interact with the digital object via XR.

The metaverse will not only impact the future of the broader communications and collaboration market, but will also impact how companies approach planning, design, analyzing/assessing, and work. All of these new opportunities will require the development and continued maturation of key enabling technologies like AR/VR, cloud/edge computing, and 5G/5G-Advanced/6G.

NETWORK REQUIREMENTS

5G applications have differentiated network requirements in terms of latency, reliability, and throughput.

Figure 2: 5G Industrial Use Cases Network Requirements

(Source: Ericsson)

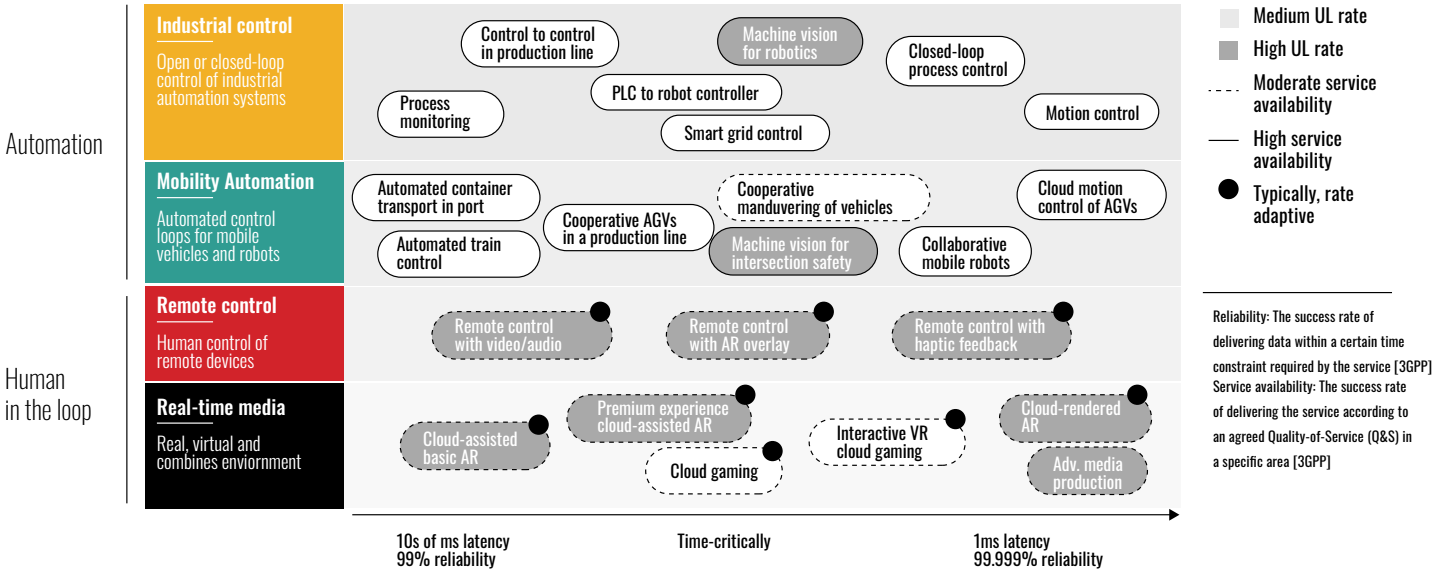


Figure 2 provides a snapshot of the network requirements for different 5G use cases. Some use cases (e.g., factory automation or AGVs) need to achieve latency as low as 1 millisecond (ms) in order for it to be acceptable, while others (e.g., process automation) do not. It should be noted that the final requirements of each 5G application can vary depending on the project specifications and the budget of the project.

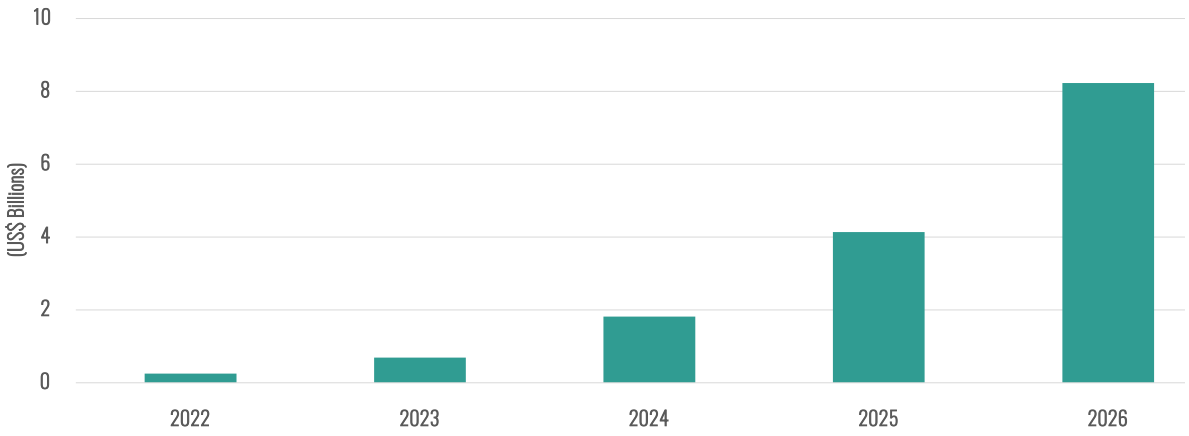
ENTERPRISE 5G APPLICATIONS WORLDWIDE OUTLOOK

The following dataset is part of ABI Research's 5G Network Slicing and Industry Verticals market data, (MD-SLIC-103), which covers the market opportunities for CSPs from 5G network slicing deployments and offers a more detailed methodology and discussion.

A key driver of 5G network slicing centers around 5G's capability to offer differentiated connectivity products. With previous cellular generations, connectivity was the same product for every consumer or enterprise, independent of the device and use case. A differentiated and dedicated slice of the network can be provided to the enterprise as and when it needs the service.

Chart 3: Network Slicing Revenue (Conservative Forecast) by Year

(Source: ABI Research)



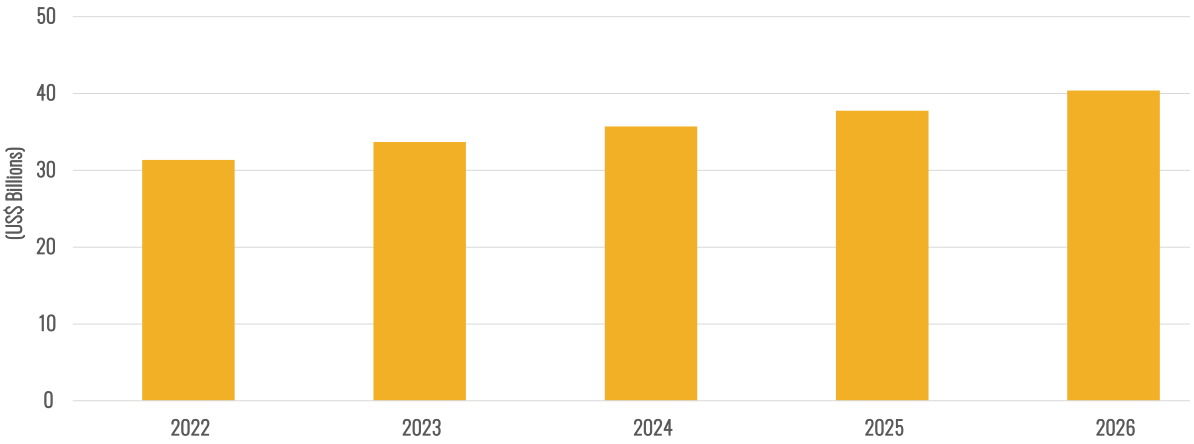
By 2026, 5G network slicing is expected to increase from about US$250 million to US$8.2 billion, representing a CAGR of 139.6% from 2022. Industrial manufacturing remains the largest market for 5G network slicing, making up about 24% of the global total 5G network slicing revenue.

Workplace Collaborative Revenue

The following dataset is based on ABI Research's Enterprise Metaverse: Future of Work market data, (MD-EVED-101), focusing on the buildup of the metaverse across collaborative work in the enterprise space. This is no light switch event, but one that requires time to develop, evolve, and grow. Based on ABI Research's forecast, by 2026, the enterprise collaborative revenue is expected to reach about US$40 billion, at a CAGR of about 6%. The revenue consists of two key components, namely: 1) the collaboration and related cloud services and 2) the hardware required to support video conferencing.

Chart 4: Enterprise Collaborative Revenue by Year

(Source: ABI Research)



SUMMARY CONCLUSION

5G networks and services, as of June 2022, are available in 80 countries from 205 CSPs. ABI Research expects 5G traffic to continue growing and will form the majority of data traffic by 2026. This growth is driven by 5G technology adoption for both consumer and enterprise use cases.

While 5G has the ability to help industries transform and develop, it also enables new use cases and technologies in the consumer space. Applications such as immersive video, XR, and cloud gaming have already been commercialized and will see further growth and adoption. 5G is one key technology enabling these applications to see further growth with its higher throughput, lower latency, and ability to connect a massive number of devices.

It cannot be denied that much of the attention of 5G is on its enablement of enterprise use cases. Based on ABI Research's insights, there are several enterprise use cases being more widely trialed and adopted for 5G enterprise use cases. These include 5G with AI (e.g., machine vision), autonomous vehicles and robotics, and remote operations of equipment and vehicles. The workplace of the future is a concept of an enterprise metaverse in which technologies like XR are used for workplace functions (e.g., meetings for design and remote working collaboration).

RADIO ACCESS NETWORK DEVELOPMENTS

IMPACT OF 3GPP RELEASE 17 DEVELOPMENTS AND RELEASE 18

Release 17 is set to support new 5G use cases by providing ubiquitous connectivity in different deployment scenarios. Additionally, it will also be supporting URLLC in an unlicensed spectrum environment and will set up a framework to support time-sensitive communications.

The updates in Release 17 set out to help CSPs attain the tools to meet current and future use cases and services. This is achieved by providing greater flexibility and higher scalability for 5G, allowing it to meet a multitude of scenarios with different requirements. Work on Release 18 is ongoing and will see the technology evolve to 5G-Advanced. 5G-Advanced is set to bring the next step in maturing the technology.RAN SLICING

5G RAN slicing is part of the End-to-End (E2) network slicing capability for a 5G Standalone (SA) network. 5G RAN slicing enables CSPs to manage their network's RAN resources. This is important, as a 5G network slice needs to go through not only the core network, but also the RAN to achieve a predictable Quality of Service (QoS) and Service-Level Agreement (SLA).

The key objective of RAN slicing is to provide flexibility to 5G network slicing capability in various scenarios. For example, where a resource shortage is identified for a current slice at a target cell, other slices or cells could ensure service continuity without changing the Single-Network Slice Selection Assistance Information (S-NSSAI); S-NSSAI is used to identify a unique network slice.

FURTHER ENHANCED MMIMO

Massive Multiple Input, Multiple Output (mMIMO) uses many antennas to deliver increased transmission gain and spectral efficiency through highly directional beamforming techniques. In Release 17, 3GPP seeks to enhance the capabilities of mMIMO in four key areas: 1) enhanced multi-beam operation, 2) enhancement of Multiple Transmission and Reception Point (multi-TRP) deployments, 3) Sounding Reference Signal (SRS) improvements, and 4) improvement to Channel State Information (CSI) measurement and reporting. These enhancements seek to help mMIMO achieve greater efficiency, higher reliability, and reduced latency.

COVERAGE ENHANCEMENTS

Release 17 aims to enhance the capability of 5G uplink coverage in urban and rural areas. The rationale for the enhancement comes as 3GPP foresees the Physical Uplink Shared Channel (PUSCH) to be a potential bottleneck. Thus, Release 17 introduced enhancements, such as increasing the maximum number of repetitions and supporting dynamic repetitions for better uplink reliability. Release 17 also includes specifications to support Demodulation Reference Signal (DMRS) bundling across repetitions. These enhancements are applicable to both 5G FR1 (Sub-7 GHz) and FR2 (Millimeter Wave (mmWave)), as well as to non-terrestrial networks, such as satellite communications.

SPECTRUM ASSEST EXPANSION

To further bolster the capacity and meet future new use cases and demand, 3GPP has expanded the mmWave spectrum range. It extended the existing 5G mmWave spectrum range from 24.25 – 52.6 GHz up to 71 GHz. This new extended range is also called the FR2-2 (Frequency Range 2 – 2) to distinguish from the original mmWave spectrum range. mmWave spectrum is a new high-frequency band available in 5G that has much more bandwidth. With its bigger bandwidth, it can deliver ultra-high throughput, low latency, and capacity enabling use cases in both consumer and enterprise settings.

ENHANCED INTEGRATED ACCESS BACKHAUL AND SIMPLE REPEATERS

Integrated Access Backhaul (IAB) is a new capability introduced in Release 16, offering a new way of providing wireless backhaul and strengthening the transport network to handle network densification. Another key development in Release 17 is the introduction of enhanced and simple repeaters.

IAB will see additional support provided through enhancements to simultaneous transceivers inter-donor migration, handover, and multi-hop efficiency. Release 17 introduced simple repeaters, without adaptive beamforming capability, which can operate in the sub-7 GHz, both Time Division Duplex (TDD) and Frequency Division Duplex (FDD)), and mmWave bands.

RELEASE 18

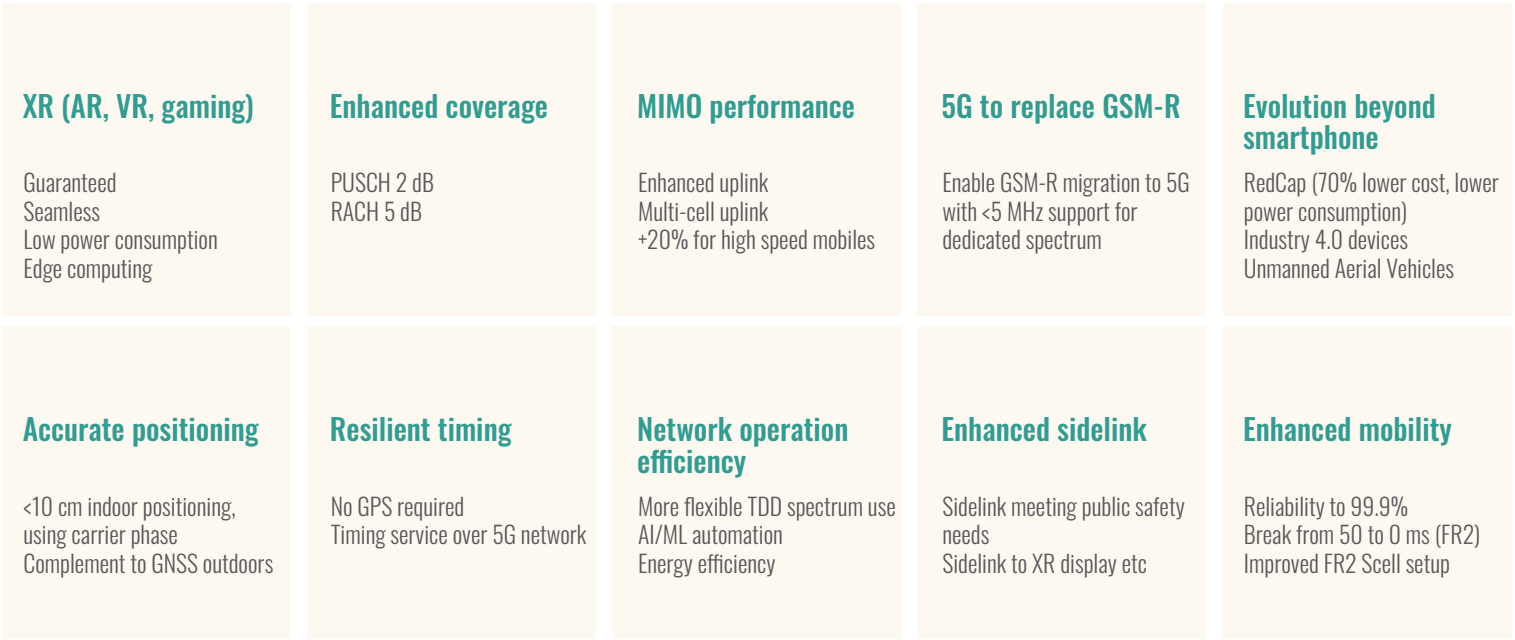
Release 18 will be the first official release of the 5G-Advanced standard, according to 3GPP, expected to be available at the start of 2024. Release 18 is expected to deliver key enhancements in both eMBB and non-eMBB use cases, and will focus on achieving network energy efficiency and tapping into the full power of AI.

For eMBB enhancements, these include evolving 5G MIMO performance and efficiency, further increasing the 5G uplink capability and power efficiency, and optimizing the mobility management of 5G devices in both the sub-7 GHz and mmWave bands. Additionally, for non-eMBB enhancements, Release 18 also seeks to investigate requirements for efficient traffic management, efficient radio resource allocation, and energy efficient user equipment, which meets XR data and latency needs.

Both eMBB and non-eMBB use cases can include the use of AI/Machine Learning (ML) in the physical layer and for RAN enhancements. Lastly, Release 18 lays the foundation for the future of full duplex, allowing data transmissions in both receiving and transmitting on a single carrier in the TDD band.

Figure 3: Release 18 Enhancements

(Source: Nokia)



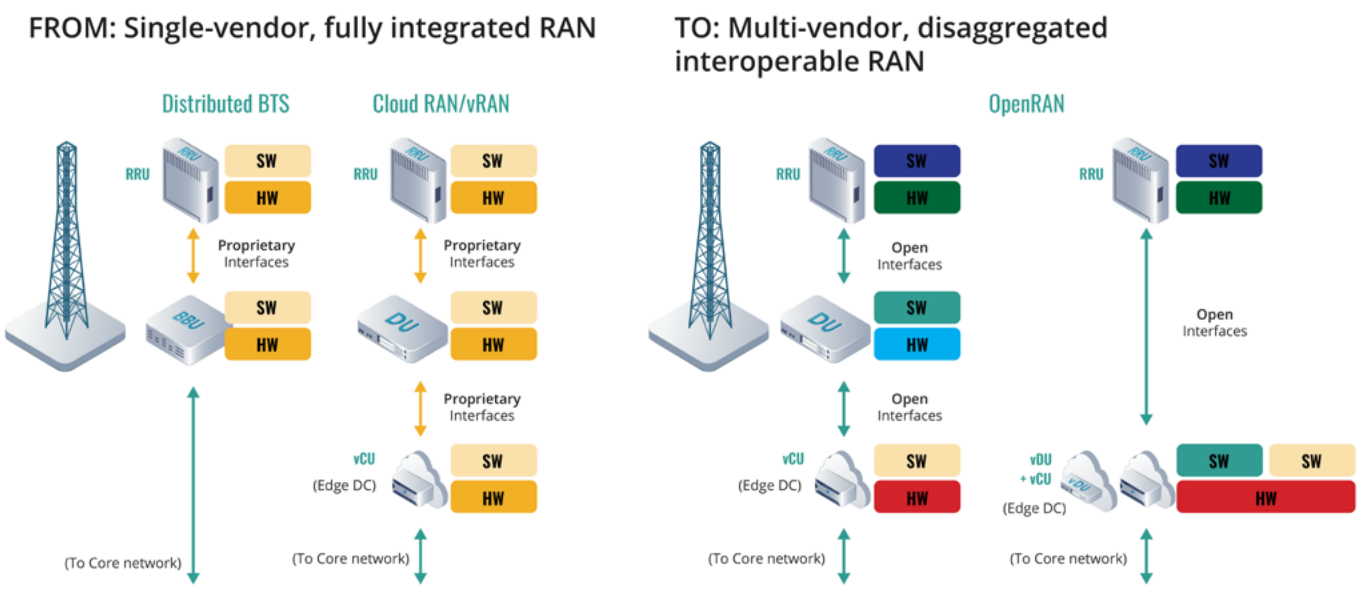
THE IMPACT OF OPEN RAN

WHAT IS OPEN RAN?

Open RAN is a set of industry standards that opens the previous proprietary interfaces and functions in the RAN. The O-RAN Alliance is the international standard organization, established in 2018 by international CSPs, which focuses on setting Open RAN specifications and standards. Aside from the O-RAN Alliance, the Meta-led (previously Facebook) Telecom Infra Project (TIP) is another industry alliance working to drive the development and deployment of open, disaggregated, and standards-based technology in the mobile network.

Figure 4: Single Vendor versus Multi-Vendor (Open RAN)

(Source: Telecom Infra Project)



Open RAN ultimately delivers the disaggregation of RAN functionality via open and interoperable interfaces between the three building blocks. The equipment for the RAN can be supplied by multiple vendors, instead of a single vendor with proprietary technology. One key benefit for Open RAN is to increase the number of equipment vendors that can supply the CSPs, which has been reduced to a handful at the start of 5G.

MOBILE TELCO EXPECTATIONS

For the CSPs, key objectives for Open RAN include resolving the challenge of vendor lock-in and lack of alternative vendors to supply their network infrastructure. Open RAN with its disaggregation will bring in more vendors, thus encouraging competition for the best-of-breed solution in the different parts of the RAN. These would help bring about a more innovative and efficient telecommunication industry supply chain. In the long term, CSPs have expectations that Open RAN solutions will become more cost effective than traditional RAN equipment. This comes as an effect of the increasing number of suppliers, a maturing Open RAN ecosystem, and wider-scale adoption of Open RAN.

WHAT ARE THE STANDARDS AND INTERFACES?

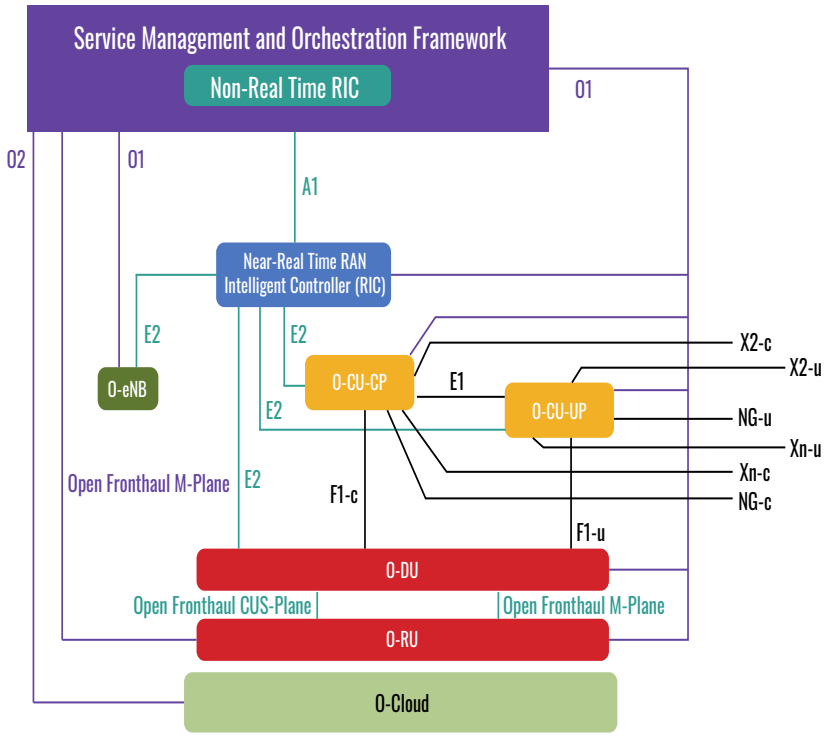
3GPP's Release 15 defines an architecture with the split of the Baseband Unit (BBU) into a Centralized Unit (CU) and a Distributed Unit (DU). On the other hand, the O-RAN Alliance focuses its standardization efforts on the Split Option 7.2x fronthaul specification between Open RAN Distributed Unit (O-DU) and Open RAN Radio Unit (O-RU). On the other hand, the Small Cell Forum (SCF) focuses on Split Option 6.

For Open RAN interfaces, a number are at work within the Open RAN architecture. These include the Open Fronthaul interface, A1, O1 & O2, X2 & Xn, NG, E1 & E2, and F1. All interfaces play a part in ensuring the workings of Open RAN and its success. This section covers a few of the prominent interfaces for Open RAN in 5G.

The X2 interface is an important one, as it forms the link between different base stations or Evolved Node B (eNB). It performs important tasks, such as X2-based handovers and Coordinated Multi-Point (CoMP) transmission or reception, among others. X2 is an optional interface under 3GPP's standards; however, for a multi-vendor network, the X2 interface needs to be open. With an open X2 interface, the CSP then can manage the multi-vendor network and avoid being locked into a single vendor.

Figure 5: Open RAN Architecture Interfaces Standardized by the O-RAN Alliance

(Source: O-RAN Alliance)



The other interface is fronthaul, which uses the Common Public Protocol Interface (CPRI) protocol that typically has a vendor-specific implementation. Open RAN-focused organizations aim to replace the use of CPRI in the fronthaul with other open alternatives. The O-RAN Alliance aims to overcome this by creating open alternatives, such as the Enhanced CPRI (eCPRI) with Split 7, for example. Additionally, eCPRI can be compatible with the 4G mobile network and provide CSPs with the flexibility to implement open protocols and interfaces.

OPEN RAN DISTRIBUTED ANTENNA SYSTEM

A Distributed Antenna System (DAS) is a set of equipment targeted to provide better indoor wireless signals and coverage. The DAS has worked well through the 2G to 4G era; however, with 5G, its network performance degrades significantly with multiple operators involved. Traditionally, a DAS also faces

challenges with new frequency bands and a significant number of deployments to bolster the network capacity. Higher frequency bands imply increased power losses experienced in the feeder, which leads to poorer network performance and efficiency.

Venues like shopping malls or high-capacity stadiums will increasingly need a strong connectivity layer to support emerging metaverse applications. However, for all passive or active DASs, a Radio Frequency (RF) signal source is required to enable connectivity in the 5G era. This RF signal will come from either the Base Transceiver Station (BTS) or from a high-powered Remote Radio Unit (RRU). In order to bring 5G capabilities indoors, CSPs will need to invest in new equipment, which adds to the total cost of deployment and creates a greater negative environmental impact.

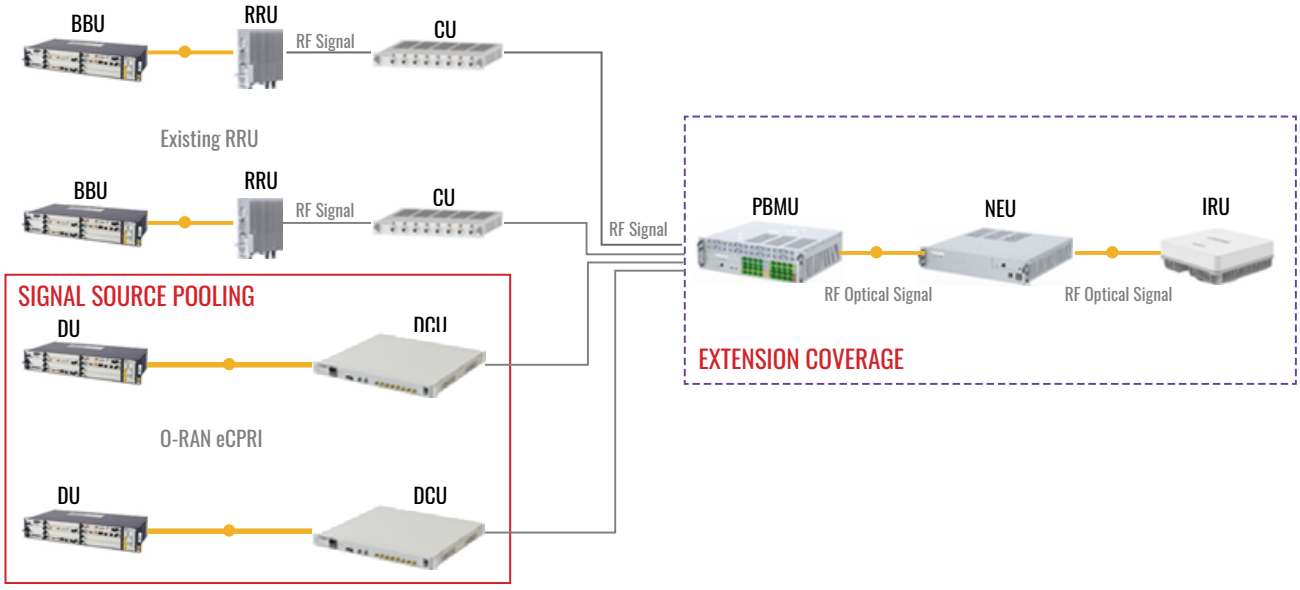
Having the fronthaul interface opened enables bypassing the RRU and connecting the DAS directly to the DU. This will likely be done through the O-RAN Alliance's specification of a 7.2 split. Open RAN reduces the number of high-powered RRUs needed to drive the DAS, which helps CSPs manage Total Cost of Ownership (TCO) for both capital goods and energy consumption.

PROSE TECHNOLOGIES SOLUTIONS

The Open RAN trend is here to stay and has the potential to grow over time. Hence, as a technological leader, PROSE is developing a leading O-RAN active DAS. The new O-RAN active DAS will leverage PROSE's active DAS, which can support 4x4 MIMO capability with up to 1,600 Megahertz (MHz) of bandwidth and supports transmissions in the 3,330 – 3,800 MHz range. To ensure ease of deployment, the solution comes in a compact 19 inches in a single rack unit.

Figure 6: Comparison of Traditional versus O-RAN Active DAS

(Source: PROSE Technologies)

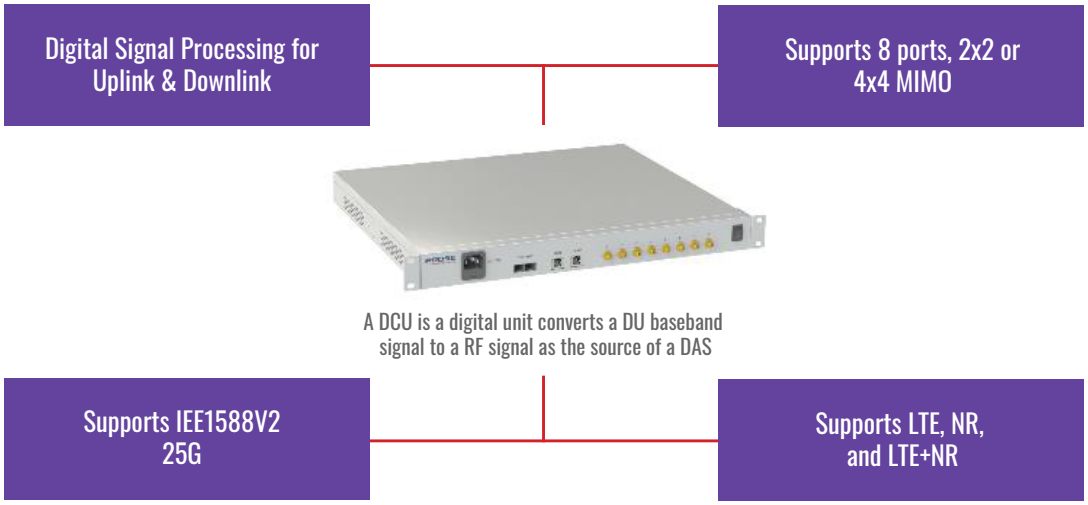


- PBMU can be connected by traditional and ORAN solution
- Extension Coverage includes PBMU, NEU and IRU, it supports multiple operations
- Flexible networking

Figure 6 depicts the use of a traditional high-power RRU, followed by an attenuator (CU; Combiner Unit) before feeding to the active DAS *(Power Balance Master Unit (PBMU)), Network Extended Unit (NEU), and Integrated Remote Unit (IRU)).* This is extended by PROSE's O-RAN-compliant 7.2 split interface module DCU that feeds directly to the active DAS without involving high power handling.

Figure 7: PROSE Technologies' DCU Solution

(Source: PROSE Technologies)



THE VERSATILITY OF A DAS

SINGLE AND MULTIPLE OPERATOR TENANCY

For indoor wireless infrastructure, there are two distinctive tenancies: a single operator tenancy and a multiple-operator tenancy. A single tenancy implies that the infrastructure only supports a single CSP's frequency bands and services, while the other allows services from multiple CSPs to be supported. In a multi-operator scenario, the cost of deployment could be shared among the parties. This helps make it more cost effective for deepening coverage and providing better QoS.

With indoor connectivity, landlords and building owners will need to assess the profile of the users within. For example, the assessment could include whether the users are from a single CSP or from different CSPs. This will determine the type of indoor wireless connectivity solution that best suits the needs of the users, while balancing the cost of deployment.

DAS VERSUS SMALL CELLS

A DAS is a system of small-sized antennas distributed across the venue or building to provide coverage. The DAS feeds off a centralized RF signal connected via fiber, coax cable, and/or Cat 6 cable. It can support thousands of users, and is suitable for office towers, stadiums, airports, and other large venues. With 5G, new types of digital DASs, such as the Digital Radio Solution (DRS), which is an integrated radio antenna solution, have been released to meet capacity demand.Small cells are cellular radio access equipment categorized by output power range. A small cell with an

output power of <1 Watt (W) is defined as a "femtocell" class small cell. Small cells with output power between 1 W and 5 W are "picocell" class small cells, and those with output power between 5 W and 10 W are "microcell" class small cells. For indoor coverage, the small cells are typically in the femtocell or picocell categories.

Table 1: Types of Small Cells by Output Power Range

(Source: ABI Research)

CHARACTERISTICS	FEMTOCELL (RESIDENT)	PICOCELL (ENTERPRISE)	FEMTOCELL (STREET LEVEL)	PICOCELL (STREET LEVEL)	MICROCELL (ROOFTOP)	MACROCELL
Characteristics	Femtocell (Resident)	Picocell (Enterprise)	Femtocell (Street Level)	Picocell (Street Level)	Microcell (Rooftop)	Macrocell
Output Transmit Power (W)	10 mW to 100 mW	100 mW to 250 mW	900 mW to 1 W	1 W to 5 W	5 W to 10 W	10 W and above
No. of Users	4 to 8 Users	8 to 16 Users	16 to 64 Users	16 to 128 Users	100+ Users	1,000+ Users
Coverage Radius	10 m to 100 m	250 m to 500 m	500 m to 750 m	0.5Km to 1.5Km	1 km to 3 km	1 km to 25 km
Typical Deployment Scenario	Indoor Consumer	Indoor Consumer & Enterprise	Indoor/Outdoor on Public Infrastructure (e.g., Street Lamps)	Indoor/Outdoor on Public Infrastructure (e.g., Street Lamps)	Building Façade, Rooftops, Utility Poles	Tower Masts, Rooftops, Outdoor

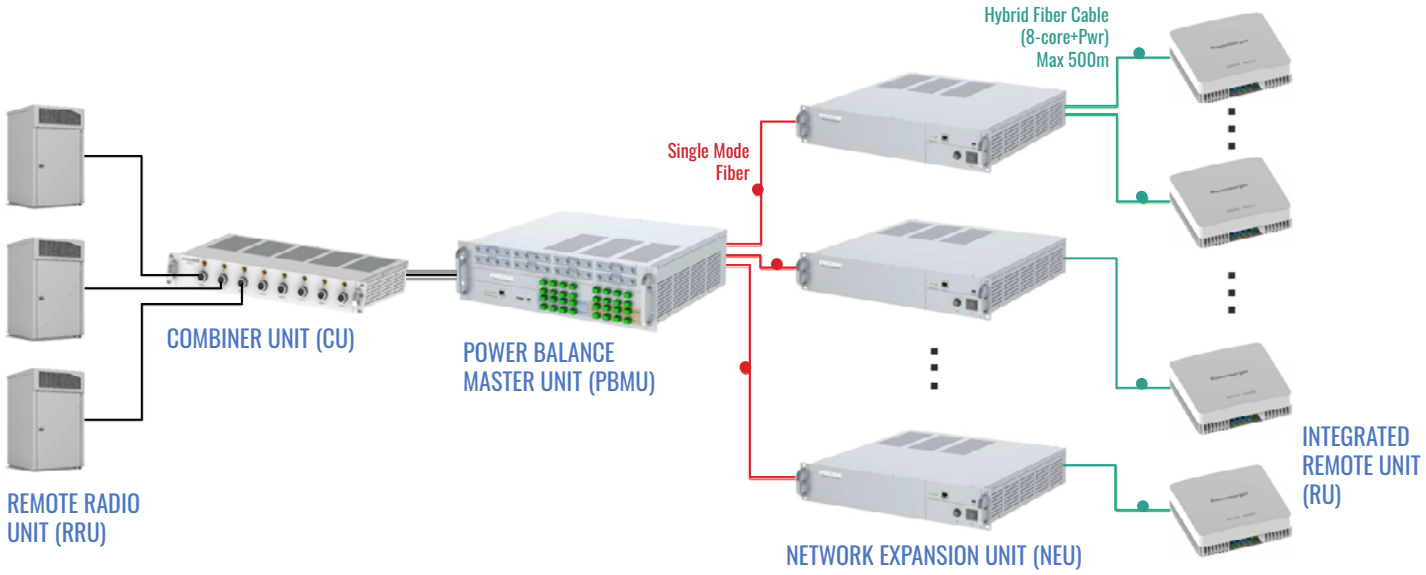
While small cells and DASs are both indoor wireless connectivity solutions, there are a few reasons why a DAS is still a go-to option today. In venues with thousands of users and the need to support different operators' frequencies, a DAS deployment can be the more cost-effective choice. For futureproofing, a legacy DAS can be upgraded to an active DAS, which allows it to work with new frequency and higher-order MIMO configurations. Other strategies include virtualization, spectrum refarming of legacy bands for 5G, and performing a system overlay.

PROSE TECHNOLOGIES SOLUTION

In the 5G era, the 3,300 – 3,800 MHz band is the sweet spot for CSPs. It delivers enhanced capacity compared to the legacy bands (<3 GHz bands) and better coverage than the mmWave bands. However, legacy DASs are not equipped to support higher frequency bands and have limited MIMO capability. While the industry has a DAS solution capable of supporting up to the 4,000 MHz range with 4x4 MIMO, the cost and high losses profile resulted in its low adoption.

Figure 8: Active DAS Architecture Supporting 4x4 MIMO

(Source: PROSE Technologies)



To meet these challenges and ensure competitiveness, PROSE developed a cost-effective active DAS platform supporting multi-operators, multi-band, and 2x2 & 4x4 MIMO capabilities for the 5G era. This provides an instantaneous bandwidth of more than 1800 MHz per integrated remote unit. Additionally, CSPs can also benefit from a more cost-effective solution by overlaying the 4x4 MIMO active DAS onto the existing passive infrastructure to enable 5G connectivity.

INNOVATION IN THE MOBILE CELLULAR ANTENNA SECTOR

One of the key pieces of equipment in a RAN, connecting end-user devices and the communication network, is the base station antenna. The base station antenna is a sophisticated piece of equipment transmitting and receiving thousands of radio signals and data traffic each day. With the launch of 5G, alongside new frequency bands, base station antennas need to cater to additional spectrum and adopt new features to meet data traffic demands. Base station antennas are also subjected to huge amounts of stress due to their exposure to weather and the environment.

Today's base station antennas consist of an extensive list of features, such as multi-band, multi-port, multi-beam, active-passive integration feature, and mMIMO (a.k.a. an active antenna). There are two main types of base station antennas—passive antennas and active antennas.

PASSIVE ANTENNA

Traditionally, almost all of the macro base station antennas mounted on poles or masts are passive in nature. The passive base station antennas contain the antenna array or diploe, the reflector or side walls, and feeding network in its radome. While the history of passive base station antennas goes back to the 1990s, they have seen many innovations breaking into the market.

With each new generation of mobile cellular technology, more frequency bands are made available for CSPs to deploy. Base station antennas need to evolve and cater to these demands by

having multi-band/multi-port capabilities. Today, passive base station antennas can have as many as 30 ports. ABI Research posits that a growing number of base station antennas have more than 10 ports and support 5 or more frequency bands.

FDD + TDD hybrid antennas are also one of the innovations that allows CSPs to deploy both FDD and TDD frequency bands with a single antenna, thus saving on space and rental costs. Space constraint is also a key challenge for antennas with more frequency bands; to meet these challenges, innovations like the interleaved antenna dipole design are key. With an interleaved antenna dipole design, both a low band (< 1 GHz) and a high-band (e.g., 1 GHz – 3 GHz) can fit neatly together and meet the space constraints.

Base station antennas need to meet the strict requirement of handling wind load. Wind load is an important parameter for designing base station antennas, as it affects the performance, reliability, and safety of the mobile network infrastructure. Therefore, base station antennas today have incorporated the dimpled golf ball design to create smaller wake and reduce the wind load on the antennas.

The arrival of 5G has introduced new frequency bands, as well as new products, such as the active antenna, which is covered in the next section. To help mitigate the increase in cost of deployment, antenna vendors created the active-passive antenna platform solution, allowing active antennas to be mounted at the back of the passive antennas. The active-passive antenna platform is a cornerstone solution to help CSPs overcome deployment challenges.

ACTIVE ANTENNA

An active antenna is an evolutionary product, which derived from the higher frequencies and the need for higher capacity and performance. Today, active antennas support 32T32R or 64T64R mMIMO.

The key differences between an active antenna and a passive antenna lie in the components encapsulated within the radome. An active antenna is the result of integration between a passive antenna array and the RU. For an in-depth discussion on the differentiation between active antennas and passive antennas, please see ABI Research's Clarifying the Role and Relationships of Passive and Active Antennas and Their Innovation Roadmaps whitepaper.

A key feature of active antennas is the ability to create highly directable narrow beams for each end user. These narrow beams allow active antennas to generate multiple beams, while balancing constructive interfaces between each beam. This enhances the spectral efficiency for CSPs, while improving overall performance of the mobile network, as each user could obtain a dedicated beam.

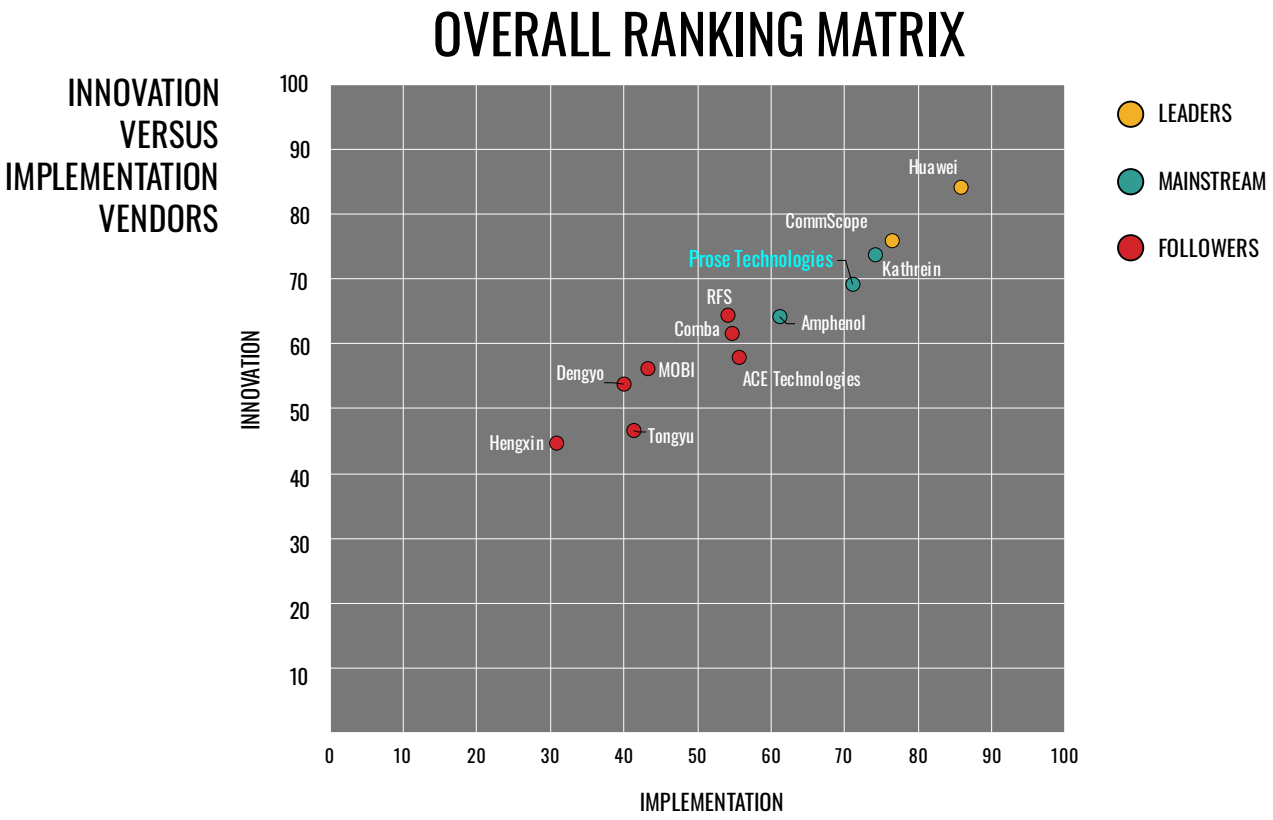
RAN vendors, such as Ericsson and Huawei, have already launched 64T64R mMIMO that weighs approximately 20 Kilograms (kg) or even less. Ericsson launched a 20-kg unit, while Huawei launched one that weighs 19 kg. Aside from weight, the number of antenna arrays, between 192 and 384 antenna elements, and the number of frequency bands have also increased, with the latest supporting triple bands.

COMPETITIVE ASSESSMENT SNAPSHOT

ABI Research conducts a regular competitive assessment study, the "Cellular Base Station Antenna Market" competitive assessment (CA-1326), which was published in June 2021. PROSE Technologies, formerly Rosenberger, was assessed as one of the top five vendors in the passive base station antenna market based on ABI Research's annual vendor matrix assessment. The vendor matrix assessment assesses each vendor based on two major categories—innovation and implementation.

Chart 5: Passive Base Station Antenna Vendor Matrix (2020)

(Source: ABI Research)



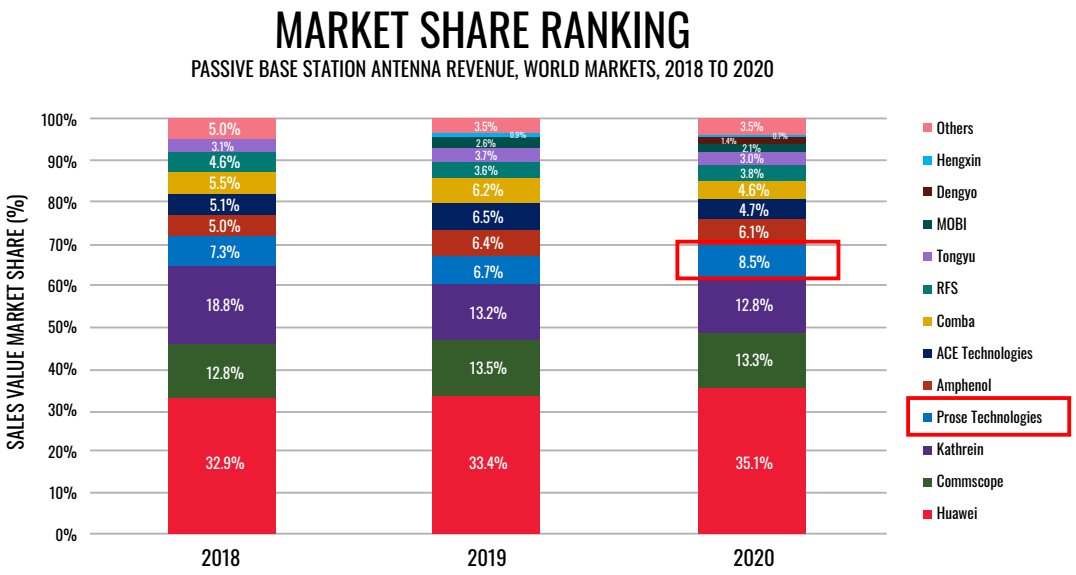
PROSE Technologies is a market challenger and has risen up the ranks to become one of the leading base station antenna vendors globally. In ABI Research's latest competitive assessment, PROSE Technologies ranked in fourth position, four ranks higher compared to 2016. Over the years, PROSE Technologies has continued strengthening its R&D capabilities to ensure its products meet the stringent demands of CSPs in different regions of the world.

MOBILE CELLULAR ANTENNA MARKET SHARE

Based on ABI Research's latest passive base station antenna competitive assessment, the "Cellular Base Station Antenna Market" (CA-1326), almost 70% of the market, based on revenue, was captured by the top four vendors in 2020. These vendors include Huawei, CommScope, Ericsson Antenna System (previously Kathrein Mobile Communications), and PROSE Technologies. PROSE Technologies is one of the antenna vendors that has emerged over the years, capturing 8.5% of the global market in 2020.

Chart 6: Passive Base Station Antenna Market Share Ranking (2020)

(Source: ABI Research)

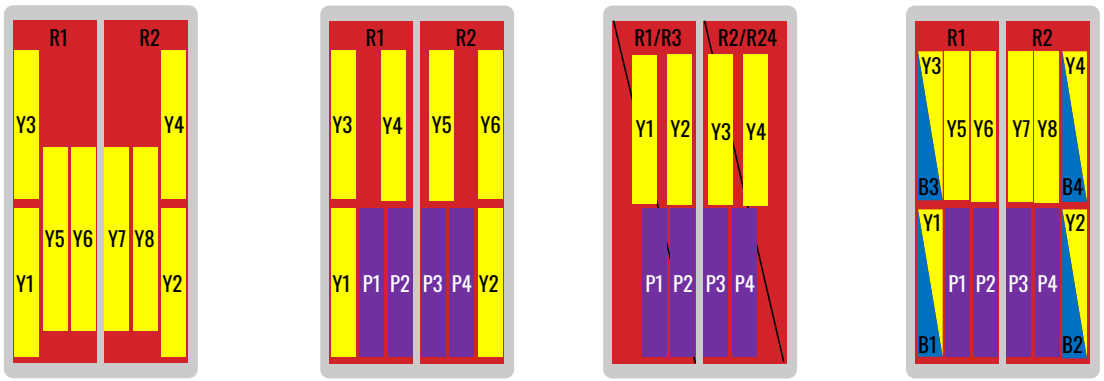


PROSE TECHNOLOGIES SOLUTIONS

While mMIMO active antennas have been touted as essential for deploying 5G, particularly in the n78 band (3,330 – 3,800 MHz), passive base station antennas remain the foundation for CSPs. Passive base station antennas have seen innovations over the years and there is increasing demand for an optimal solution capable of delivering coverage and capacity. The 8T8R (8 transmitters and 8 receivers), with its beamforming capabilities, is one solution that allows CSPs to scale up network capacity, while balancing cost of deployment, a perfect alternative option to deploying mMIMO.

Figure 9: TDD + FDD Antenna Developments Example

(Source: PROSE Technologies)



2L4H + 2.6G TDD
498mm width
20 Port - 2.0&2.7m

2L6H + 2.3-3.8 TDD
448mm width
24 Port - 2.0&2.7m

4L4H + 3.5G TDD
498mm width
24 Port - 2.0&2.7m

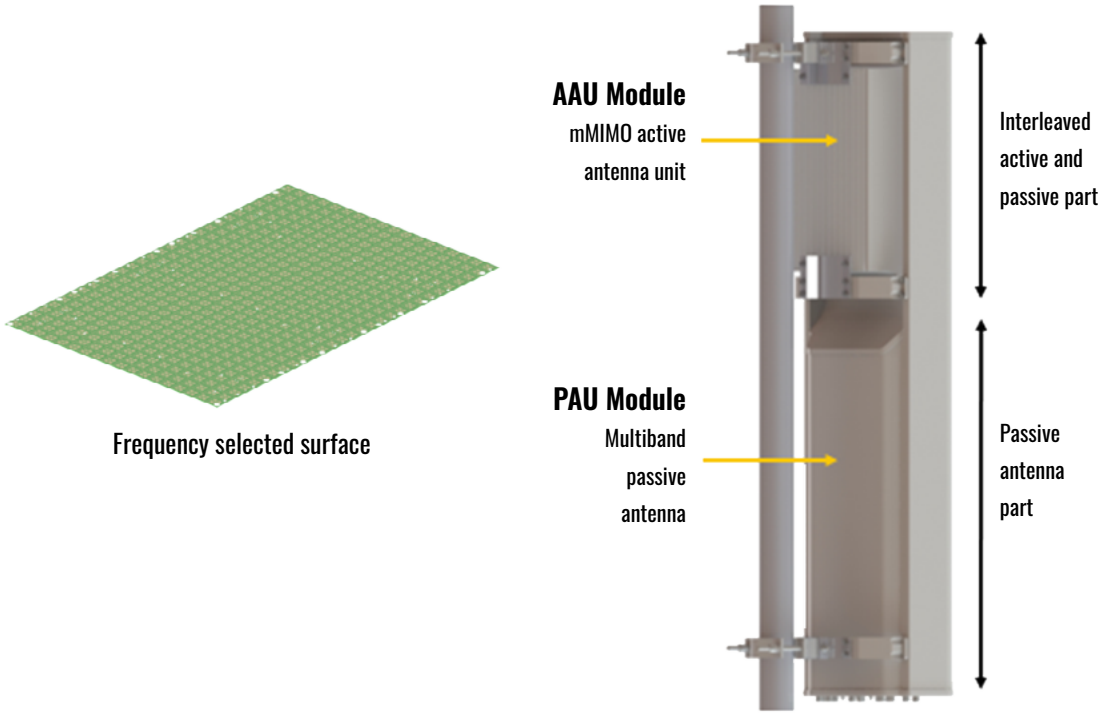
2L8H + 2.6&3.5G TDD
498mm width
36 Port - 2.0&2.7m

PROSE Technologies has TDD + FDD antenna solutions to overcome space constraints on masts, while increasing capacity. Figure 9 shows some of PROSE Technologies' innovative solutions. For CSPs uncertain about the Return on Investment (ROI) for 5G mMIMO, the TDD + FDD antenna is one of the most cost-effective solutions to introducing 5G and upgrading the network.

To help CSPs upgrade their network smoothly, PROSE Technologies also has its active + passive platform solution. This solution has seen increasing interest among CSPs as they look to deploy mMIMO on cell sites without needing additional construction or poles. To ensure high performance, PROSE Technologies' active + passive antennas are equipped with a Frequency Selected Surface (FSS), which allows 5G transmissions to pass through the passive antenna elements with little loss.

Figure 10: Active + Passive Antenna Platform with Frequency Selected Surface

(Source: PROSE Technologies)



To further improve the performance of PROSE's antenna solutions, a low-loss stripline structure that replaces the traditional RF cables is used in antennas. According to PROSE Technologies, this can provide up to about 1.5 Decibels (dB) higher gain compared to antennas using traditional RF cables. The use of a low-loss stripline structure can also help CSPs save up to 30% of the cost of base station sites. Other key innovations from PROSE Technologies include an antenna radome design to minimize wind load and materials innovation to reduce the weight of antenna mounting brackets by up to 70%.

BACKHAULING WITH MICROWAVE ANTENNAS

In the RAN infrastructure, the backhaul, also known as the transport network, is an indispensable part. The backhaul connects the access network to the core network, typically via copper or fiber, or through microwaves and satellites. With the increasing amount of mobile data traffic expected to be generated with 5G, CSPs need to upgrade their backhaul infrastructure as much as they are upgrading the core and access networks. There are key developments in the backhaul market, such as Cross Polarization Interference Cancellation (XPIC), the availability of E-band (71 – 76 GHz, and 81 – 86 GHz), and the bonded channels or multiband microwave.

ABI Research forecasts that the total number of macro cell links will increase from around 8.1 million links in 2021 to 11.1 million links in 2027, while the number of small cell backhaul links will increase from 1.6 million links in 2021 to 6.1 million in 2027 at a CAGR of 25.8%.

ROLE OF XPIC

XPIC is a signal processing technique used on carrier-grade microwave links to drive higher capacity and spectral efficiency. XPIC potentially doubles the amount of capacity a microwave link can achieve through enhanced spectral efficiency by propagating two signals horizontally and vertically over the same frequency channel.

IMPACT OF THE E-BAND

The E-band is a frequency band covering 10 GHz of spectrum ranging from 71 – 76 GHz and from 81 – 86 GHz bands. Its full duplex bandwidth capacity can reach up to 25 Gigabits per Second (Gbps) and has a longer range than the V-Band (57 – 70 GHz), as the E-band is not readily absorbed by oxygen.

The beamwidth of the E-band is very narrow, making it highly suitable for Point-to-Point (PTP) Line-of-Sight (LoS) transmission. Due to its narrow beamwidth, and thus less likely chance of interference, multiple E-band radios can be deployed on a single cell site. Additionally, the narrow beamwidth and the need for PTP LoS transmission make it more difficult for a security breach, as it requires the intercepting radio to be placed between the transceivers.

THE VERSATILITY OF BONDED CHANNELS/MULTI-BAND

Just as the access network taps into multiple frequency bands to provide superior performance, backhaul can do the same. Bonded channels tap into different frequency bands in order to achieve a good balance between throughput and distance of hops. Traditional microwave frequency bands, such as 7 GHz, perform much better when traveling through longer hops. While the higher frequency bands, such as the E-band, perform much better in delivering the capacity to meet heavy traffic, they suffer from higher attenuation. By leveraging the advantages of different frequency bands, CSPs can benefit from increased flexibility in deployments.

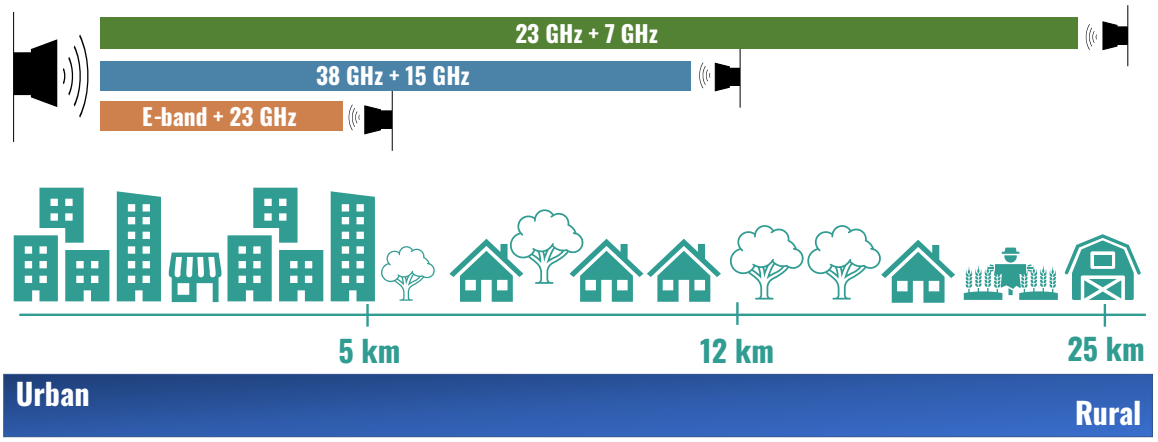
KEY BENEFITS OF BONDED CHANNELS

Traditional microwave bands have much less bandwidth (28 – 56 MHz), as compared to the E-band (500 – 2,000 MHz). This restricts the throughput achievable by the traditional microwave bands. By tapping into different combinations of the E-band and the traditional microwave bands, for example,

CSPs can boost the performance of backhaul significantly. Through bonded channels, CSPs can improve throughput and the distance covered between each hop to meet network demands.

Figure 11: Examples of Multi-Band Microwave Backhaul Configurations (not to scale)

(Sources: ABI Research, Ericsson)



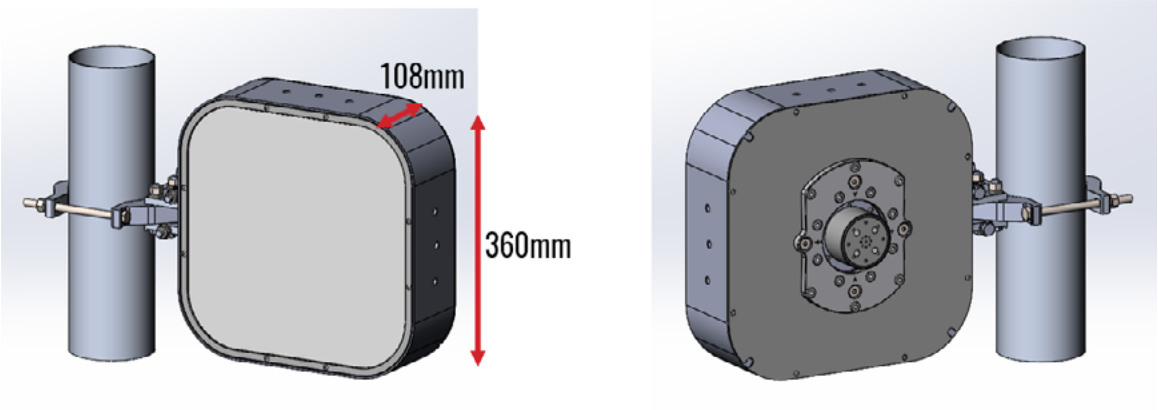
PROSE TECHNOLOGIES SOLUTIONS

PROSE Technologies has a suite of microwave antenna solutions that meets the current and future demands of CSPs. PROSE's current microwave antennas come in the range of 0.3 meters (m) up to 3.0 m, supporting 6 – 80 GHz bands. These microwave antennas can support single or dual-band for CSPs with either a single or dual polarization capability compliant with ETSI Class 3 or Class 4 Standard.

Given the importance of the E-band, besides the 0.3/0.6 m conventional reflector E-band antenna, PROSE Technologies also offers its E-band Flat Planar Antenna (FPA) with up to 43 dBi gain Decibel Relative to Isotropic Radiator (dBi) to meet the demand from CSPs for various scenarios.

Figure 12: E-Band Flat Panel Antenna

(Source: PROSE Technologies)



SUMMARY CONCLUSION

To support 5G use cases as detailed in Section 2, there are a few important trends and initiatives ongoing in the industry. To enhance cellular communication technologies, 3GPP has since worked on Release 17 and Release 18. Newly introduced capabilities, such as RAN slicing, enhancing mMIMO, and new spectrum assets are some of the study and work items within 3GPP. Release 18 is set to be the first official release of 5G-Advanced scheduled to be completed by the end of 2023, bringing upgrades to both eMBB and non-eMBB use cases.

At the same time, the industry is also in the midst of driving the development of Open RAN with the aspiration of transforming the telecommunications supply chain. A diminishing number of vendors in the market and demands for a more innovative and competitive supply chain are a few reasons for using Open RAN. With these enhancements, the mobile network infrastructure has to keep pace to meet the standards and deliver new capabilities. This includes both indoor connectivity in the DAS domain and outdoor connectivity in the RAN (both base station antenna and microwave antenna) domain. Each of these has its own unique circumstances and challenges to overcome.

PROSE Technologies is a leading global equipment vendor with cutting-edge solutions for both outdoor and indoor connectivity. The company has demonstrated over the years not only its ability to innovate and push the boundaries of technologies, but also to execute its go-to-market strategy successfully. PROSE Technologies' ability to keep a finger on the pulse of the demands of CSPs and its established history of innovation is expected to continue propelling the company forward.

GLOSSARY

GSA	Global Mobile Suppliers Association	MEC	Multi-Access Edge Computing
XR	Extended Reality	mMTC	Massive Machine-Type Communications
AI	Artificial Intelligence	QoS	Quality of Service
5G	The fifth-generation technology standard for cellular networks.	URLLC	Ultra-Reliable Low Latency Communications
VR	Virtual Reality	5G-Advanced	The next evolution milestone of 5G technology
eMBB	Enhanced Mobile Broadband	RedCap	Reduced Capability
AR	Augmented Reality	MR	Mixed Reality
RAN	Radio Access Network	HMD	Head-Mounted Display
3GPP	The 3rd Generation Partnership Project	PTP	Point-to-Point
FPA	Flat Planar Antenna	DRS	Distributed Radio System
mMIMO	Massive Multiple Input, Multiple Output	PBMU	Power Balance Master Unit
IRU	Integrated Radio Unit	NEU	Network Expansion Unit
CU	Centralized Unit	PUSCH	Physical Uplink Shared Channel
TCO	Total Cost of Ownership	CSI	Channel State Information
eNB	Evolved Node B	Multi-TRP	Multiple Transmission and Reception
EMRS	Demodulation Reference Signal	S-NSSAI	Single Network Slice Selection Assistance Information
IRU	Integrated Radio Unit		

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