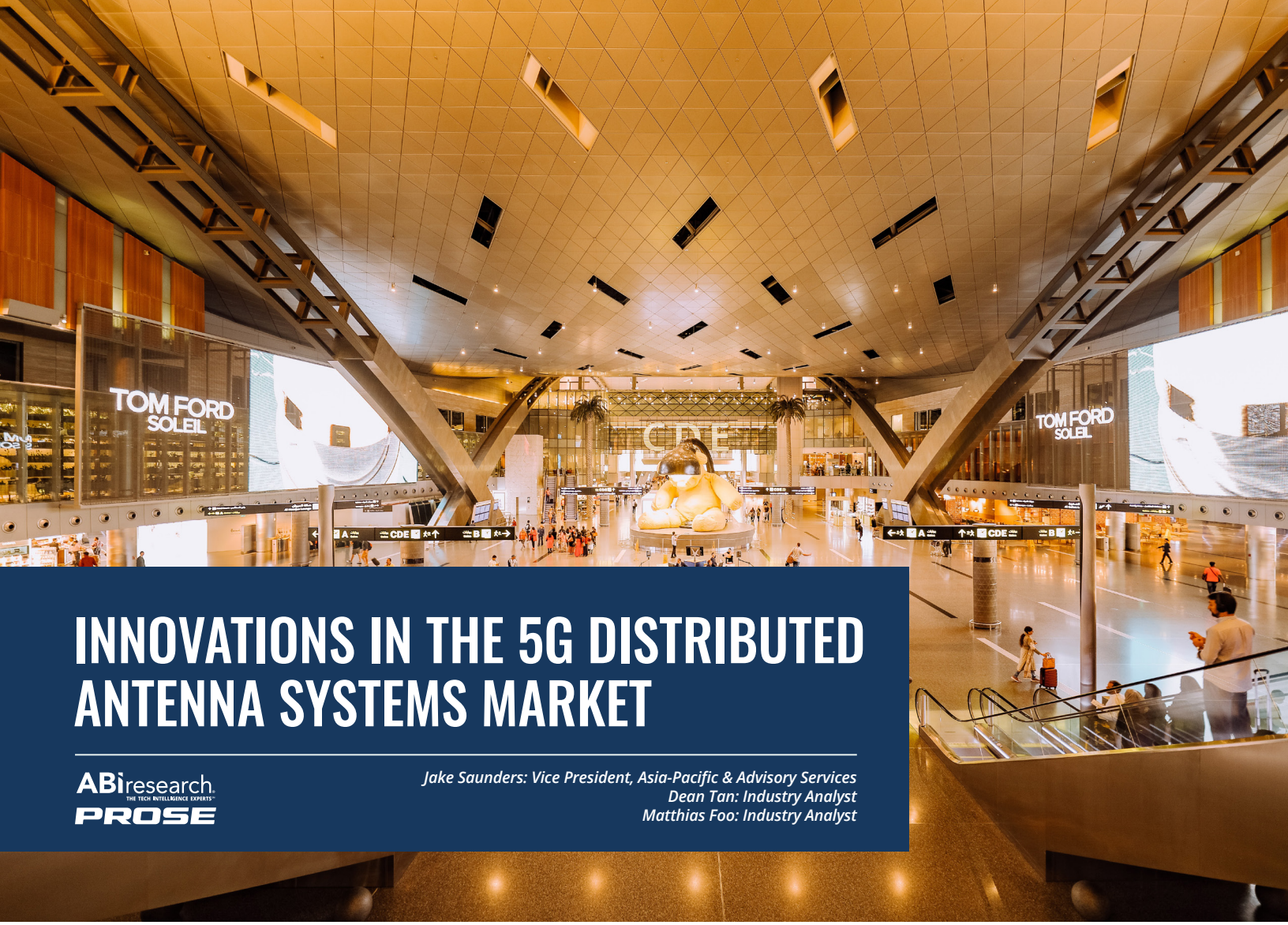

INNOVATIONS IN THE 5G DISTRIBUTED ANTENNA SYSTEMS MARKET

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THE TECH INTELLIGENCE EXPERTS
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EXECUTIVE SUMMARY

5G data traffic is expected to increase significantly over the next 5 years in both Europe and North America. By 2027, the total amount of 5G traffic is expected to reach approximately 900 exabytes[1], representing a Compound Annual Growth Rate (CAGR) of about 62%. To prepare for this increase, it is not sufficient only to upgrade the outdoor mobile network infrastructure. Outdoor-to-Indoor (O2I) solutions for 5G will fail to bring about the revolutionary capabilities promised by 5G and future wireless communication standards. As importantly, the indoor mobile network infrastructure will need its due attention and investment. However, Communication Service Providers (CSPs) continue to struggle with monetizing their 5G mobile networks. This creates a challenging situation for CSPs to support the necessary investment for indoor mobile network coverage. In order to deliver effective performance, landlords and CSPs will need to select the right solutions and optimize their investment to meet their end-user expectations.

[1] *1 Exabyte = 10^{18} Bytes*

A Distributed Antenna System (DAS) is one solution that enables CSPs and, increasingly, landlords that wish to offer neutral hosts within their premises a way to deploy indoor mobile infrastructure efficiently. ABI Research forecasts that the investment in global indoor DAS equipment will grow at a CAGR of 18% through 2027, reaching US$16 billion. Within this growth, Active DAS is expected to make up 80% of the total equipment spending. There are several advantages that Active DAS provides compared to a traditional or Passive DAS. For example, its ability to support 5G capacity enhancement, such as higher orders of Multiple Input, Multiple Output (MIMO) and its simplified deployment architecture based on fiber instead of coaxial cables.

The importance of indoor connectivity and the challenges faced by CSPs with their Capital Expenditure (CAPEX) has spurred the growth of alternative business models in the market. One such model is the **neutral host model** where an independent infrastructure company invests to build the indoor wireless infrastructure and leases it out to CSPs. This transforms the rollout of indoor deployment from a CAPEX model to one that is based on a more cashflow manageable Operational Expenditure (OPEX) model.

Implementing a multi-operator deployment model is not a radically new idea. However, challenges like the need for a technical solution, which fits the requirements of all operators, and an intermediary, who can guarantee an equitable multi-operator environment, have limited its adoption. New business models, such as a "**neutral host**," resolve the challenge of the intermediary and enable indoor wireless deployment to support an optimal multi-operator environment. With The 3rd Generation Partnership Project (3GPP) Release 15, a new flexible architecture emerged for 5G Radio Access Network (RAN)—Open RAN. Open RAN increases the diversity of indoor wireless solutions in the market, giving both CSPs and neutral hosts greater choice in terms of equipment. Open RAN, alongside virtualization of network functions, can reduce the physical components and equipment required through the use of Commercial-Off-The-Shelf (COTS) equipment. These developments help CSPs to not only optimize their investments, but also to expand coverage (*e.g.*, in rural areas) and enhance performance in urban areas.

PROSE

To help neutral hosts and building owners optimize their indoor 5G networks, PROSE Technologies offers a range of highly scalable Active and Hybrid DAS solutions, thereby setting the foundation for future networks and technologies. PROSE's DAS solutions support increased power output for better performance, low latencies to support critical operations, reduced energy consumption, and remote monitoring capabilities for efficient Operations and Maintenance (O&M) works.

Indoor wireless connectivity is expected to be of great importance as 5G end-user adoption ramps up and 5G-Advanced starts to be rolled out. With the advent of 5G, alongside the other key drivers, such as Open RAN and technological advancements in DAS solutions, it is essential for both CSPs and the industry to adopt new business models and deploy future-proof indoor connectivity solutions.

IMPORTANCE OF INDOOR CONNECTIVITY SOLUTIONS

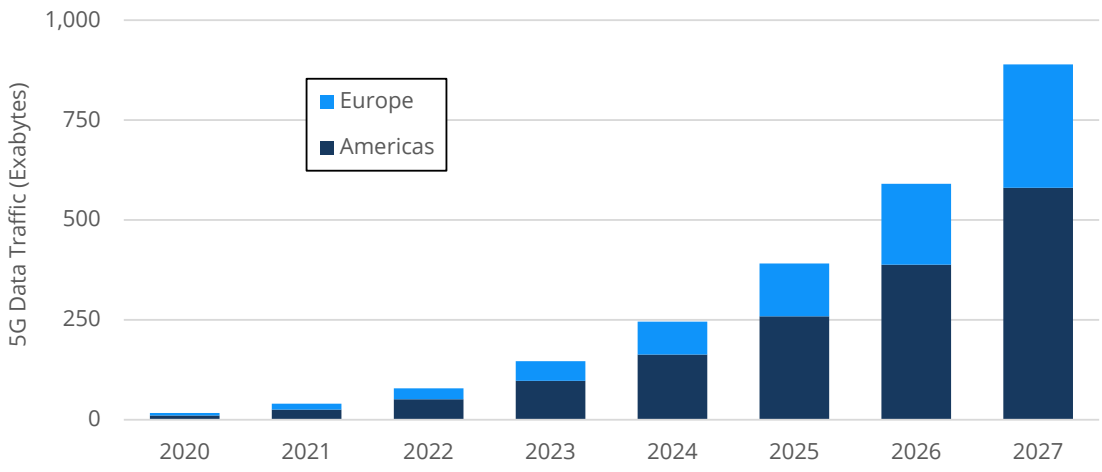
This section explores the growing importance of DAS solutions in meeting the indoor coverage requirements of 5G.

5G BRINGING ABOUT INCREASED DEMANDS FOR DATA

The advent of 5G has brought about a new digital age for consumers and enterprises alike. One of the key changes observed is in the way data are being consumed. Based on ABI Research's forecasts, 5G data traffic in the Americas and European regions are expected to increase from 78 exabytes in 2022 to approximately 900 exabytes by 2027. This represents a CAGR of ~62% and more than a 4X increase in total data traffic over this period.

Chart 1: 5G Traffic (Americas & Europe): 2022 to 2027

(Source: ABI Research)



The indoor environment (*e.g.*, office buildings, shopping malls, train stations, *etc.*) is where most of the data traffic is being generated. It is estimated that the proportion of data traffic generated indoors can go up to 70% or 80% of total data traffic on operators' networks. This is especially true in urban environments or metropolitan cities where more time is spent indoors than outdoors. With the expected increase in data traffic, CSPs need to ensure their mobile cellular infrastructure is ready. This is true for both the outdoor and the indoor infrastructure.

The proportion of data traffic generated indoors can go up to 70% or 80% of total data traffic on operators' networks

LIMITATIONS OF O2I SOLUTIONS FOR 5G

O2I solutions offer CSPs a quick and affordable way to extend outdoor coverage into buildings. However, one of the key issues faced by O2I connectivity is signal attenuation challenges due to the walls or office features (*e.g.*, metal cabinets and computer equipment), which impacts the ability

of O2I solutions to ensure extensive and robust coverage of the indoor environment. This limitation becomes even more evident with 5G, where the higher frequency bands (i.e., C-Band and the Millimeter Wave (mmWave)) used to meet increased data throughput requirements also come with limitations in their ability to penetrate reinforced concrete, building walls, and metalized glass windows. As a result, O2I solutions are generally not suitable to meet the requirements for deep and ubiquitous indoor 5G coverage, particularly for larger buildings.

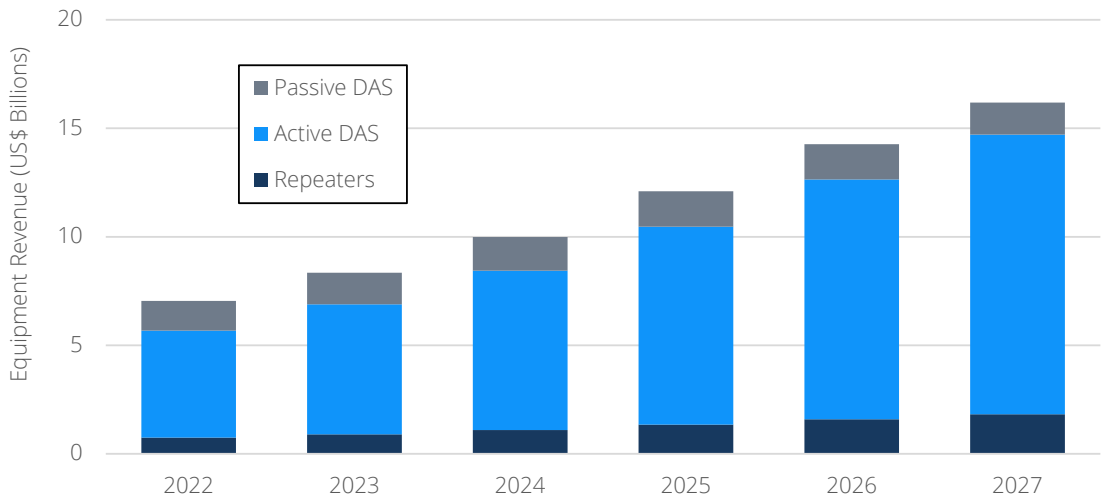
GLOBAL MARKET TRENDS FOR 5G INDOOR COVERAGE

DAS is increasingly being used to deliver 5G indoor connectivity globally. In France, Orange's subsidiary TOTEM has opted for DAS to provide connectivity on the metro line. This deployment will provide 5G indoor connectivity for all 15 "Sud" lines of the Grand Paris Express metro with over 1,000 active antennas. Aside from providing indoor connectivity for the metro, TOTEM has also deployed a DAS solution at the Orange Vélodrome stadium. Increasingly, DAS and indoor connectivity are seen as key growth drivers for tower companies. Cellnex, a Europe-based Tower Infrastructure Company (TowerCo), sees the need to further enhance their competitiveness by becoming more than just a TowerCo, focusing also on in-building connectivity and DAS solutions

This development of DAS deployment is not limited to the region of Europe. In the United States, DAS solutions are being deployed in hotels and resorts to ensure robust and reliable coverage for guests and staff. Boingo, a DAS service provider, undertook the deployment of a neutral host cellular DAS network for the Omni Professional Golfers' Association (PGA) Frisco Resort, USA, for both Long Term Evolution (LTE) and 5G connectivity. Accordingly, ABI Research foresees global indoor DAS equipment investment as growing from US$7 billion to more than US$16 billion between 2022 and 2027 (at a CAGR of ~18%), of which Active DAS is expected to constitute 80% of the equipment spending in 2027.

Chart 2: Indoor DAS Equipment Investment: 2022 to 2027

(Source: ABI Research)



SHUTDOWN OF 3G CELLULAR NETWORKS

Around the world, many countries, such as the United States, the United Kingdom, Spain, Germany, and Italy, and many more, have shut down or announced plans to shut down their 3G networks. In light of this trend, DAS solutions need to not only be able to meet today's coverage requirements, but need to also cater to future deployments of new technologies and spectrum bands. It is crucial that CSPs prepare by adopting and deploying future-proof solutions and ensure competitiveness.

SUMMARY CONCLUSIONS

DAS solutions need to not only be able to meet today's coverage requirements, but also cater to new technologies and spectrum deployments

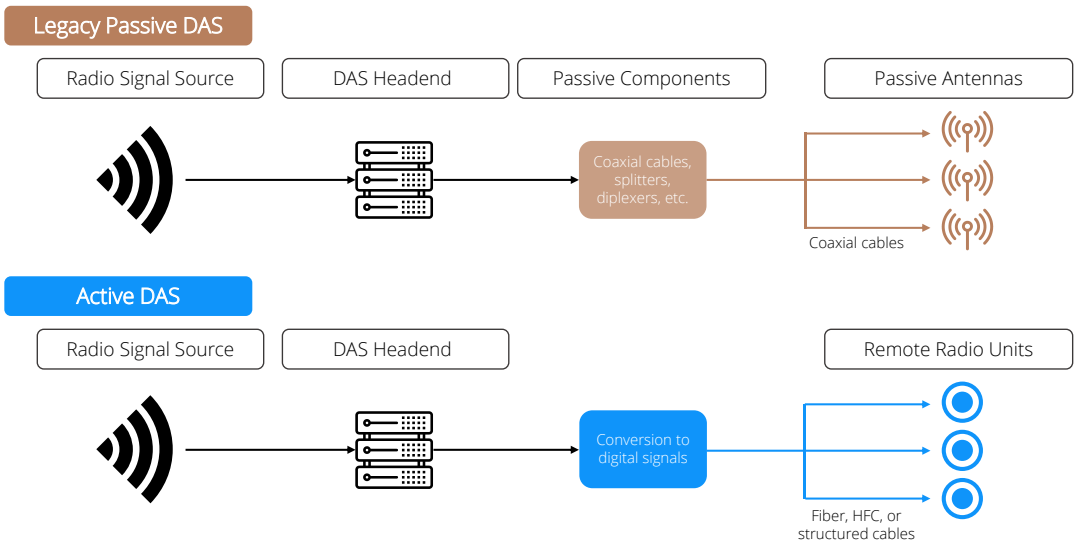
In the 5G era, data traffic generation is expected to increase tremendously in both Europe and the Americas. Most of the data traffic is being generated indoors, with as much as up to 80%. Hence, the mobile network infrastructure has to cater to both outdoor and indoor environments. However, O2I solutions are unable to meet the deep coverage needed for indoor scenarios. As a result, ABI Research anticipates that investments in indoor DAS solutions will increase rapidly to meet the indoor coverage requirements of large space environments, such as office blocks, hotels, shopping malls, *etc.*

PASSIVE OR ACTIVE DAS FOR INDOOR COVERAGE?

This section explores the advantages that Active DASs can bring about when compared to traditional Passive DAS solutions.

Figure 1: Legacy Passive versus Active DAS Infrastructure Logical Diagram

(Source: ABI Research)



LEGACY PASSIVE DAS

Widely used in previous generations for indoor coverage, a Passive DAS has no integrated active components (*e.g.*, the Radio Unit (RU)) that are being deployed throughout the building. Instead, it uses components like coaxial cables, splitters, and diplexers to distribute the signal received from the base station unit. However, the emergence of 5G has presented a number of issues for Passive DASs, such as:

- **Power Loss**: The higher frequencies that 5G typically operates present higher power losses in the feeder, and result in higher deployment costs (due to additional infrastructure required), reduced coverage footprint, and poor performance. For example, at 3.5 Gigahertz (GHz), link loss numbers of 15 Decibels (dB) at 100 Meters (m) using "400-type" or ½-inch connectors are common. These losses mean that the coverage area and performance of the system are both reduced without adding additional antenna and cable runs.
- **High Cost for Upgrades to Meet 5G Capacity Needs**: Many Passive DASs have been deployed in a Single In, Single Out (SISO) antenna configuration. Upgrading to 2X2 or 4X4 MIMO would require significant investment, including new MIMO antennas and additional coaxial runs from each of the antenna elements back to the signal source.
- **Support for 5G Frequency Bands**: Passive components, such as combiners and power splitters, used by many traditional DASs are unable to support frequencies above 3 GHz, thereby limiting the use of C-Band frequencies for 5G indoor coverage.

Upgrading a Passive DAS to 5G is not a scalable proposition, with its use generally confined to small and medium-sized venues.

The evolution toward 5G indoor connectivity requires a higher level of flexibility, as well as capabilities for capacity expansion and higher data throughputs. In light of the above, ABI Research has concluded that upgrading a Passive DAS to 5G is not a scalable proposition, with its use generally confined to small and medium-sized venues.

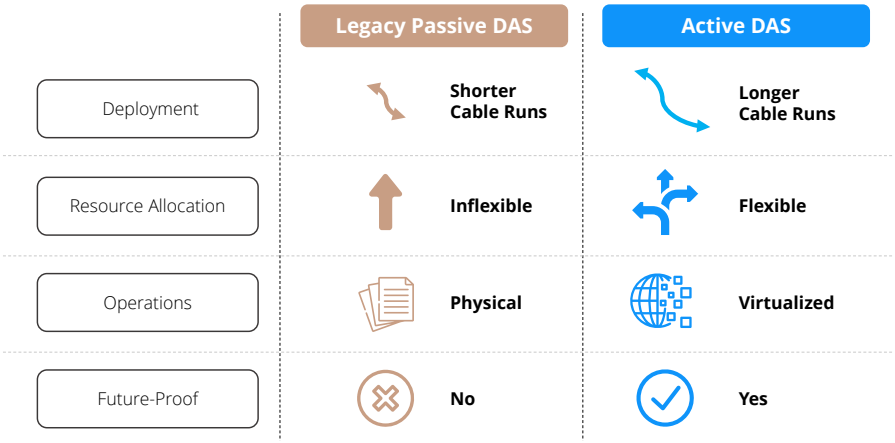
ACTIVE DAS

An Active DAS consists of a headend unit and Remote Radio Units (RRUs) that are deployed throughout the building. The former receives analog Radio Frequency (RF) transmissions from the signal source and converts them to a low level optical or electrical signal, best suited for easy and reliable transport to the RRUs via the in-building transport network. This can be fiber based, HFC or structured cable. The RRU then converts this transport signal back to the original RF-signal for coverage and connectivity to the end-user devices. The latest 5G indoor solutions, such as Active DASs, are expected to see greater deployment in the market. Advantages that Active DAS can deliver over Passive DAS include:

- **Flexible Deployments**: Components in Active DASs can be connected *via* fiber cables, which are less complex to install as compared to coaxial cables. Additionally, signal attenuation in fiber cables is low, thereby giving CSPs the flexibility to deploy RRUs in locations farther away from the headend unit.
- **Flexible Resource Allocation**: Active DASs support flexible capacity adjustment, allocating resources according to the traffic needs. In contrast, Passive DASs do not allow for capacity steering without reconstructive engineering.
- **Virtualized Functions**: Active DASs support virtualized O&M platforms that enable real-time monitoring and prompt fault identification in the network.
- **Supporting 5G Capacity Requirements**: Active DASs support the use of higher-level MIMO configuration, such as 4x4 MIMO or even 8x8 MIMO, without the need for added passive infrastructure, thereby meeting the increased capacity requirements needed for 5G deployments.

Figure 2: Advantages of Using Active DAS over Passive DAS

(Source: ABI Research)



HYBRID DAS

Another possible deployment mode is the Hybrid DAS, which leverages both active and passive components. In this arrangement, similar to the Active DAS, the headend unit receives analog RF transmissions from the signal source and converts them to a transport signal before transmitting the signals to the RRUs via the in-building transport (*e.g.*, fiber, HFC, or structured cable). At this stage, however, the RRUs do not broadcast cell signals, but instead convert the digital signals back to analog and send them out to distributed antennas *via* passive infrastructure, such as coaxial cables, splitters, *etc.*

Hybrid DAS presents itself as a middle point solution between its Active and Passive DAS counterparts, providing greater performance compared to Passive DASs, and at a lower cost compared to Active DASs.

SUMMARY CONCLUSIONS

Flexible solutions with advanced features and capabilities, such as Active DASs, are expected to see greater deployment in the market

Active DASs' ability to support advanced features and capabilities make them the preferred method to support 5G indoor coverage and capacity requirements. Consequently, as shown in Chart 2, ABI Research expects Active DAS equipment investment to grow from US$4.9 billion in 2022 to US$12.9 billion in 2027 and make up almost 80% of total DAS equipment spend.

5G INDOOR WIRELESS BUSINESS MODELS

This section explores how new wireless business models, multi-operator deployment models, and Open RAN DAS architectures can create new value for CSPs, neutral hosts, System Integrators (SIs), and landlords.

INDOOR WIRELESS BUSINESS MODELS ENABLED BY 5G

The importance of indoor connectivity is increasingly being recognized by industry. This, coupled with the release of new spectrum access initiatives (*e.g.*, Citizens Broadband Radio Service (CBRS) in the United States or Local Access License (LAL) in the United Kingdom & other European countries) for enterprises has spurred new business models. New types of wireless service providers adopting different types of business models, such as "neutral host," SI, and landlord-based deployments, have also emerged.

New types of wireless service providers adopting different types of business models, such as "neutral host," SI, and landlord-based deployments, have emerged

- **Neutral Host Model**: A neutral host business model involves an independent infrastructure company (*e.g.*, a TowerCo like America Tower) investing in the indoor mobile network infrastructure and leasing its infrastructure to CSPs.
- **System Integrator Model**: SIs can now become service providers by providing indoor network connectivity *via* the use of lightly licensed (General Authorized Access (GAA)) and licensed spectrum (Priority Access Licenses (PALs)) in the CBRS band, or even *via* the leasing of spectrum from CSPs.
- **Landlord-Based Model**: These privately-owned networks are customized, designed, and built by the building owners themselves to meet their own connectivity requirements (*e.g.*, enterprise, public venues, *etc.*).

BENEFITS OF MULTI OPERATOR DEPLOYMENT MODELS

The neutral host, SI, and landlord-based deployment models all support multi-operator environments, which can bring about a host of benefits for CSPs.

First, the multi-operator models unlock funds from CAPEX and convert it into an OPEX model through leasing from the independent infrastructure company/building owner, or *via* roaming on SI networks. Lower upfront CAPEX increases the flexibility of fund management for CSPs.

Second, besides saving on the CAPEX needed to deploy optimal indoor mobile infrastructure, the multi-operator model helps CSPs tackle deployment scenarios in both rural and high-density urban areas.

- **Rural Areas**: Indoor coverage of buildings located in rural areas can be extended at a fraction of the cost if the CSPs were to each deploy their own indoor networks. This is particularly important due to the likely lower Return on Investments (ROIs) expected due to lower customer density in rural regions.
- **Urban Areas**: In urban areas where data traffic demand and consumption are high, CSPs can tap into the already deployed multi-operator infrastructure to quickly expand indoor coverage for their subscribers. This reduces the time CSPs need to bring their service to the market.

Third, another key benefit for CSPs with multi-operator deployment models is the reduced operational burden that CSPs have to bear when deploying their own infrastructure. This will now be in the hands of the independent infrastructure company, SIs, or building owners to manage and maintain the infrastructure.

CHALLENGES OF TRADITIONAL MULTI-OPERATOR DEPLOYMENT MODELS

Despite the many positives, multi-operator deployment models also bring about several challenges that CSPs will need to take into consideration.

First, given that CSPs will need to lease infrastructure from neutral host/building owners or roam on SI networks, CSPs may have limited control over the End-to-End (E2E) visibility and control over their network performance for their customers.

Second, CSPs are also typically still required to install their own networking equipment at the building premises, thereby limiting the amount of CAPEX savings that such multi-operator deployment models can bring about. This also creates challenges to scalability, as CSPs have to undertake numerous projects to ensure quality indoor coverage.

ADDRESSING CHALLENGES WITH OPEN RAN DAS

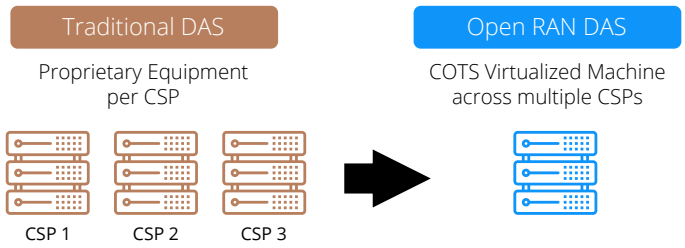
Tier One operators like Orange have promoted the evolution of DAS toward Open RAN, with open interfaces between the RUs, and vRAN functions operating on cloud infrastructure

3GPP Release 15 standardized a "split" for the RAN to reduce the burden of high data rates on 5G fronthaul networks caused by increased network densification, wider spectrum bandwidths, and implementing Massive MIMO (mMIMO) technology. Two functional splits are supported by the industry (Split 7.2 by the O-RAN Alliance and Split 6 by the Small Cell Forum). Tier One operators like Orange have promoted the evolution of DAS toward Open RAN, with open interfaces between the RUs, and Virtualized RAN (vRAN) functions operating on cloud infrastructure. Some of the key features of Open RAN DAS deployments include:

- **Reduced Complexity for Multi-Operator Environments**: Running multiple CSP networks on vRAN architecture can result in a reduction of the number of transmitter elements and the related power consumption required, leading to shorter deployment times and CAPEX/OPEX savings.
- **Maintain E2E Visibility of Networks**: With virtualized network functions, CSPs can maintain E2E visibility of their network performance and also quickly deploy configuration changes to their networks *via* software upgrades.
- **Greater Flexibility**: Open RAN development can introduce greater flexibility for upgrading indoor wireless communication infrastructure by increasing the diversity of indoor wireless solution vendors in the market.

Figure 3: Open RAN DAS Architecture

(Source: ABI Research)



SUMMARY CONCLUSIONS

Adoption of Open RAN DAS architecture is expected to bring about a range of benefits for CSPs, neutral hosts, SIs, and building owners alike

The shift to 5G has brought about new business models for indoor wireless deployments. Moving toward virtualized and open configurations can help address some of the issues plaguing traditional DAS deployments, which, in turn, can lead to increased savings, faster deployments, and better network management and visibility.

PROSE Technologies' Solutions

This section explores how PROSE Technologies' DAS solutions are well-positioned to provide a future-proof and scalable 5G solution for CSPs, neutral hosts and building owners.

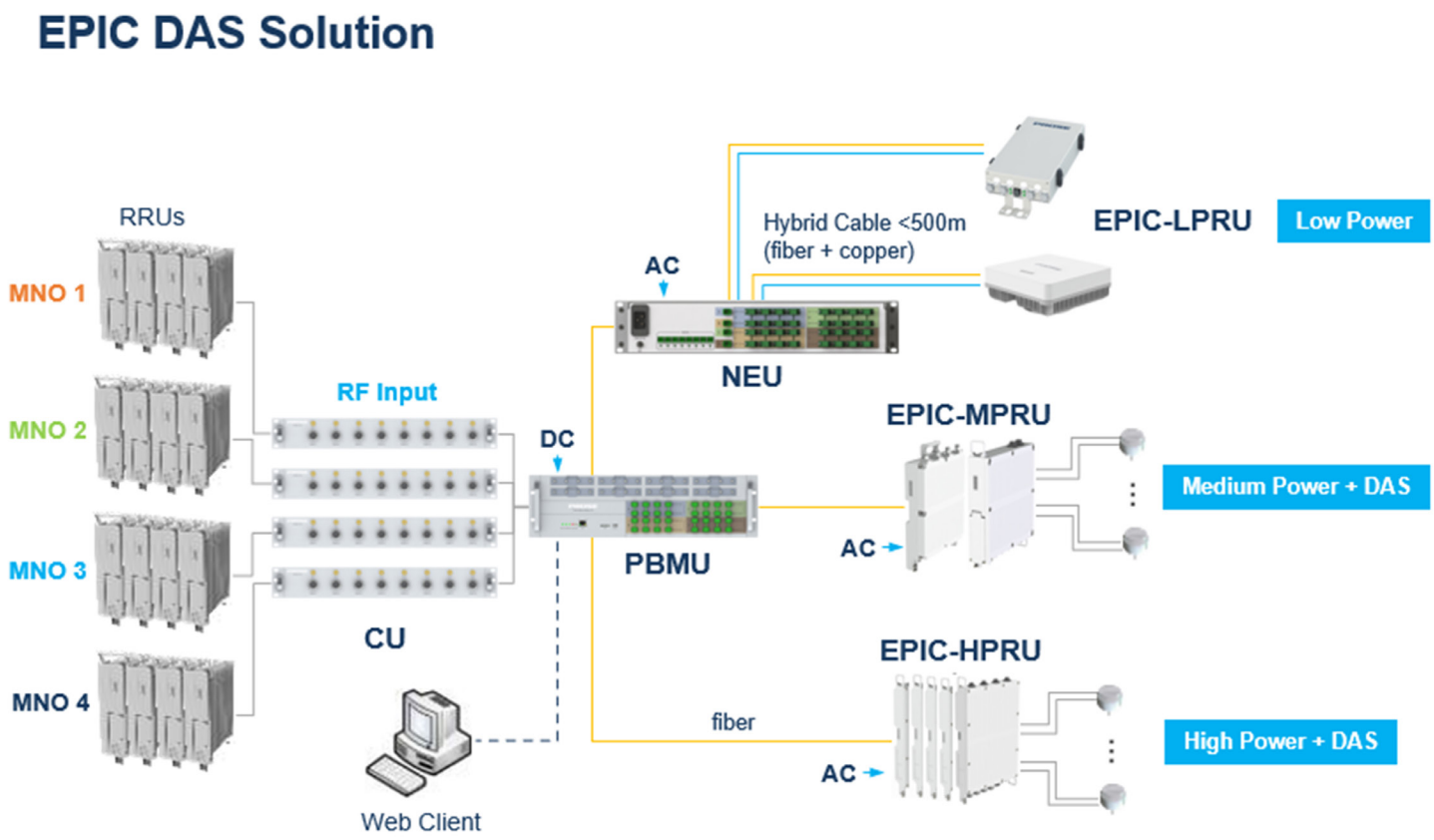
PROSE's EPIC DAS is its latest multi-operator, multi-band, and multi-technology active/hybrid DAS solution that covers spectrum ranging from 617 to 4,200 MHz.

OVERVIEW

PROSE's EPIC DAS is its latest multi-operator, multi-band, and multi-technology active/hybrid DAS solution covering spectrum ranging from 617 to 4,200 MHz. The platform supports both hybrid (blade high-power remote unit) and active (low-power remote unit) DAS deployment modes and supports up to four operators per band. In the New Radio (NR) C-band spectrum, the system can support 400 MHz Instantaneous Bandwidth (IBW) and 4T4R with one of the smallest footprints in the market. It can also support various MIMO configurations (*e.g.*, SISO, 2x2 MIMO and 4x4 MIMO) with up to 8 bands/channels for a blade high-power RU or low-power RU.

Figure 4: PROSE's EPIC DAS Solution

Source: PROSE Technologies



- **Power Balance Master Unit (PBMU)**: The RF attenuated signals of the base stations are turned to be balanced in the PBMU, which consists of individual variable attenuators per port and controlled remotely by the Operation Maintenance Center (OMC). The PBMU combines up to four ports per band after power balance and provides additional variable attenuators for uplink and downlink paths. The uplink attenuator provides noise padding to control the noise level into the BTS.
- **A medium-power DAS solution (EPIC-MPRU)**: will be also available very soon. Same as EPIC-HPRU, there are NR EPIC-MPRU and Sub-3G and NR modular EPIC-MPRU. EPIC-MPRU's output power is between EPIC-HPRU and EPIC-LPRU. EPIC-MPRU has the similar features and the same Ingress Protection level as EPIC-HPRU but smaller size and lower power consumption.

Once the RF signals have been converted to optical, they can be routed to Blade High-Power Remote Units (HPRU) for implementation as a Hybrid DAS solution, or to Low-Power Remote Units (LPRU) as an Active DAS solution with integrated antennas.

LOWER POWER ACTIVE DAS SOLUTION – EPIC-LPRU

The low-power solution, also known as EPIC-LPRU, has the following components:

Figure 5: NEU

- **Network Extender Unit (NEU)**: The NEU performs optical splitting and provides Direct Current (DC) power to the low-power remote units. In a 2x2 MIMO system, the NEU accepts two optical inputs from the Power Balance Master Unit (PBMU) A/C and B/D optical modules, and splits into 16 pairs of optical outputs (2x16). In a 4x4 MIMO system, the NEU accepts four optical inputs from the PBMU optical modules, and splits into 8 pairs of optical outputs (4x8).

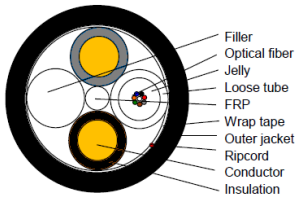


Figure 6: Hybrid Cable

- **Hybrid Cable**: The hybrid cable consists of a DC cable and four or eight fiber strands. It connects from the NEU to the Integrated RU (iRU). The hybrid cable is available in lengths up to 500 Meters maximum (2.5 (Millimeters) mm² DC wires) for fibers and DC feed, so installation will be greatly simplified without any need for local power supply.

Figure 7: iRU

- **Integrated Remote Unit (iRU)**: The iRU is 2.6 liters with a size of 200x200x71 mm and has a weight of less than 2.6 Kilograms (kg). Each iRU can support eight channels from 617 to 4,200 MHz, with options to support SISO, 2x2 MIMO (for LTE and NR) or 4x4 MIMO (NR only). Each path has a composite power of 31dBmi for the high band (3,300 to 3,800 MHz), 27 dBmi for the medium band (1,700 to 2,700 MHz) and 18 dBmi for the low band (<1,000 MHz), excluding the antenna gain. Various band combinations and MIMO capabilities are available to support:
  - 4 operators NR3500 (4T4R, 1,600 MHz total RF bandwidth)
  - 4 operators NR3500 (4T4R, 1,600 MHz total RF bandwidth) + 4 operators 4G (dual band 2T2R)
  - 4 operators NR3500 (2T2R, 800 MHz total RF bandwidth) + 4 operators 4G (triple band 2T2R)
  - 4 operators NR3500 (4T4R, 1,600 MHz total RF bandwidth) + 4 operators 4G (single band 2T2R) + 4 operators 2G (single band 1T1R) + 4 operators 3G (single band 1T1R)
  - 4 operators NR3500 (2T2R, 800 MHz total RF bandwidth) + 4 operators 4G (dual band 2T2R) + 4 operators 2G (single band 1T1R) + 4 operators 3G (single band 1T1R)

The EPIC-LPRU system can support up to 64 iRUs in 4x4 MIMO and 96 iRUs in 2x2 MIMO configurations. An additional iRU can be installed to support more bands, giving a total of 16 channels. Option for an external antenna is also available.

HIGH POWER HYBRID DAS SOLUTION – EPIC-HPRU-P

The Blade high-power solution, also known as EPIC Blade High-Power Remote Unit Pro (HPRU-P), has the following deployment options:

Figure 8: NR HPRU-P

Figure 9: Sub-3G LPA (Modular)

Figure 10: NR LPA (Modular)

Figure 11: Sub-3G and NR MCU (Modular)

- **NR HPRU-P**: The HPRU-P connects to the PBMU through two optical fiber cores with the following features:
  - Quad-channels for N78 band (3,300-3,800MHz)
  - 2T2R with DPD (Digital Pre-Distortion) linearity technology
  - 46 dBm composite power per each 200MHz sub-band
  - Size: 357x600x144 mm, 24 kg (include handle and connectors)
- **Sub-3G and NR Modular HPRU-P**: The HPRU-P consists of plug-and-play Linearity Power Amplifier (LPA) and Master Control Unit (MCU) modules. The MCU accepts two optical inputs from the PBMU, performs optical-electrical signal conversion and provides monitoring control to the LPA module. The HPRU-P has following features:
  - Each MCU supports up to four LPAs (617 to 4,200 MHz)
  - Each LPA supports single band 2T2R or two bands SISO
  - Support 4 Sub-3G band 2T2R or 3 Sub-3G band 2T2R + 1 NR band 2T2R
  - 43 dBm composite power per Sub-3G band, and 46 dBm composite power per NR band
  - MCU size: 357x600x80 mm, 12 kg (include handle and connectors)
  - LPA size: 357x600x80 mm, 15 kg (include handle and connectors)

The EPIC-HPRU-P solution supports both integrated and modular set-ups. The integrated solution will typically be deployed in 5G overlay scenarios, whereas the modular solution will be better suited for new site deployments which require both NR and legacy bands since difference bands can be deployed easily by replacing the LPA modules. The EPIC HPRU-P is a Fan-less solution that can be deployed in both outdoor and indoor environments as it comes with excellent Ingress Protection 67 (IP67) and operational temperature ranges of between -40 to +55 Degrees Celsius. External RF combiners can also be deployed to support flexible SISO/MIMO combinations for HPRU-P.

OTHER DAS SOLUTIONS

PROSE also offers passive DAS components which support 617 to 4,200 MHz wide band with low Passive Intermodulation (PIM), thereby allowing customers to combine existing technologies with new 5G bands in one system. A medium-power DAS solution, EPIC-MPRU, will also be available soon.

PROSE's EPIC DAS solutions have several technical merits that makes it ideal for 5G and multi-technology deployments.

TECHNICAL MERITS

PROSE's EPIC DAS solutions have several technical merits that makes it ideal for 5G and multi-technology deployments.

- **Zero DAS Loss**: Delivers higher Effective Isotropic Radiated Power (EIRP), particularly in higher frequency bands such as 2,600 MHz or 3,500 MHz. With higher downlink EIRP, a better downlink Signal-to-Noise-Plus-Interference Ratio (SNIR) can be achieved enabling up to 256 Quadrature Amplitude Modulation (QAM) and covers a larger area.
- **Consistent Output Power**: To meet coverage Key Performance Indicators (KPIs) with output power balance for each RU managed remotely.
- **More Bands and MIMO Reduces Operator OPEX**: The system supports up to eight independent bands/channels per RU, which can be configured to support all technologies ranging from 2G to 5G in different MIMO capabilities.
- **Low Latency**: At less than 1 Microsecond (µs) E2E latency, the active DAS can support all 5G Ultra-Reliable Low-Latency Communications (URLLC) applications. With the low intrinsic system delay, there will not be negative impact to the TDD (Time Division Duplex) timing considerations.
- **Higher RU output power**: Significantly decreases RU quantity and CAPEX investment.
- **Compact RU design**: High reliable design with extremely low power consumption and natural air cooling feature.
- **High stability of system**: -40 degrees to +55 Degree Celsius operational temperature and IP67 protection ensure that the HPRU-P can withstand the harshest environments and provide reliable network performance.
- **Flexibility on RF Sources**: EPIC can be fed with RF signals from high-power (46 dBm) down to low-power (24 dBM), and even base-band signals from sources such as ORAN.
- **Redundancy function**: Power supply, fiber optical and amplifier module backup and redundancy ensure the integrity of the network signals and stable coverage.

KEY TAKEAWAYS AND RECOMMENDATIONS

Through investigating the capabilities of different DAS solutions, the impact of 5G growth and end-user needs, and the emergence of new business models, ABI Research has distilled some of the key insights that both building owners and CSPs should consider when deploying indoor connectivity solutions.

FOR BUILDING OWNERS

- **Enterprises must leverage new active DAS solutions to overcome their indoor coverage and capacity challenges**. Enterprises can engage with DAS vendors, SIs, neutral hosts, and CSPs to address their coverage needs. These solutions now offer flexibility for future upgrades to incor porate 5G that will enable enterprises and businesses to benefit from enabling 5G enterprise use cases.
- **Due to the high volumes of data generated indoors and increasing demand for indoor wireless solutions, building owners must future-proof their building infrastructure**. Building owners must start deploying fiber in vertical and horizontal cabling, enabling a rapid deployment of cellular services with reduced costs and disruptions.
- **Connectivity will play a crucial role in retaining high value, commercial tenants, increasing satisfaction of tenants and visitors, and implementing smart technologies**. Landlords must deploy indoor connectivity to improve the attractiveness of their venues for their tenants and customers (*e.g.*, visitors to malls) alike.

COMMUNICATION SERVICE PROVIDERS

- **CSPs must assess indoor deployments in parallel with outdoor ones, especially when allocated 5G frequencies are above 3.5 GHz**. By doing so, CSPs will reduce customer churn as competitiveness in 5G coverage and capacity is often the deciding factor between CSPs.
  End users expect to have a reliable and rich data user experience both indoors and outdoors.

- **CSPs should be open to trials with DAS vendors working on Open RAN and vRAN products that can drive innovation in wireless solutions for indoor deployments**. Through trials, CSPs can test and identify Open RAN and vRAN solutions that bring greater value and flexibility to their indoor networks.
- **For new cellular indoor wireless deployments, CSPs should start adopting future-proof, 5G-ready platforms**. Active DASs will support rapid adoption of 5G and future technologies. Active DAS platforms can be upgraded through software, and the cabling infrastructure solutions, such as fiber and CAT6, provide the system with flexibility for future upgrades, reducing costs associated with hardware decommissioning and replacement, as well as minimizing downtime of the system during upgrades.

GLOSSARY

ACRONYM	DESCRIPTION	ACRONYM	DESCRIPTION
BTS	**Base Transceiver Station**: Equipment used to facilitate wireless communication between end user devices and networks.	CAPEX	**Capital Expenditure**: Resources used to purchase assets.
CBRS	**Citizens Broadband Radio Service**: 150 MHz of spectrum (3.55 – 3.7 GHz) that can be used for private mobile networks in the United States.	COTS	**Commercial-Off-The-Shelf**: A standard product that can be procured from third-party vendors and be modified to address specific requirements.
CSP	**Communication Service Provider**: An enterprise that focuses on offering connectivity services to its subscribers.	DAS	**Distributed Antenna System**: A connectivity architecture in which multiple remote nodes are connected to a radio signal source *via* a transport network.
EIRP	**Effective Isotropic Radiated Power**: Measurement of the radiated output power of an isotropic antenna.	E2E	**End-to-End**: A full process from beginning to end.
GAA	**General Authorized Access**: Lightly licensed spectrum within the CBRS band, USA.	HFC	**Hybrid Fiber-Coaxial**: Combines optical fiber and coaxial cable.
IBW	**Instantaneous Bandwidth**: Refers to the frequency boundaries of the allocated frequency band.	IP67	**Ingress Protection 67**: Measurement of protection against water and dust.
KPI	**Key Performance Indicator**: Measurement of performance against a particular quantifiable objective.	MIMO	**Multiple Input, Multiple Output**: A technology that uses multiple transmitters and receivers to increase data throughput capacity.
mmWave	**Millimeter Wave**: Radio frequencies between 30 GHz and 300 GHz.	NR	**New Radio**: Radio access technology developed by 3GPP for 5G mobile networks.
O&M	**Operations & Maintenance**: A combination of management, monitoring, and upkeep of a facility to ensure proper functioning of equipment.	OPEX	**Operational Expenditure**: Expenses required to maintain work operations.
Open RAN	**Open Radio Access Network**: A new network architecture that supports the use and interoperability of non-proprietary equipment in different parts of the network.	O2I	**Outdoor-to-Indoor**: The provision of indoor network coverage using outdoor base stations.
PAL	**Priority Access License**: Consists of 10 MHz channels within the 3550 – 3650 MHz band (CBRS) that receives protection from GAA users, USA.	PIM	**Passive Intermodulation**: Refers to interference experienced when two or more signals pass through passive components.
QAM	**Quadrature Amplitude Modulation**: A method of using both phase and amplitude modulation of radio frequencies.	RAN	**Radio Access Network**: Connects end-user devices to the core network *via* radio links.
RF	**Radio Frequency**: Refers to the range of 3 Kilohertz (kHz) to 300 Gigahertz (GHz) in the electromagnetic spectrum.	ROI	**Return on Investment**: A measure of profitability by comparing the final value generated by a product against its initial cost.
RRU	**Remote Radio Unit**: A remotely located radio transceiver.	SI	**System Integrator**: An enterprise that brings together multiple subsystems to develop a complete solution.

ACRONYM	DESCRIPTION	ACRONYM	DESCRIPTION
SISO	**Single In, Single Out**: A simple system where one antenna is used on both sides of the wireless link.	SNIR	**Signal-to-Noise-Plus-Interference Ratio**: Measurement of signal quality by comparing the strength of desired signal against undesired interference and noise.
TowerCo	**Tower Infrastructure Company**: An enterprise that manages passive telecommunication infrastructure.	URLLC	**Ultra-Reliable Low Latency Communications**: Concept focusing on reducing latency and increasing reliability of 5G mobile networks.
vRAN	**Virtualized Radio Access Network**: Refers to the running of baseband unit functions as software, as opposed to hardware.	-	**Headend Unit**: Consists of RF modules that provide signal filtration, amplification, and facilitates signal distribution to RRUs.
-	**Split**: Refers to the division of functions across 5G baseband unit logical nodes, namely the Central Unit (CU), Distributed Unit (DU), and Radio Unit (RU).		

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