EVOLVING 4G TO 5G
INNOVATION IN DISTRIBUTED ANTENNA SYSTEMS

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KEY HIGHLIGHTS

5G will offer tremendous data throughput, low latency, and ultra-reliability benefits to enterprise customers, Small and Medium Enterprises (SMEs), and end users, According to the International Mobile Telecommunications 2020 (IMT-2020) standard, indoor wireless infrastructure should deliver 20 Gbps for eMBB and traffic density of 10 Mbps/Square Meter (m^2). Thus, Thus, 5G will also require a substantial increase in improved indoor coverage by Mobile Network Operators (MNOs) and landlords since it is estimated that approximately 80% of all smartphone activity is generated indoors. According to Ericsson Mobility Report (June 2020), mobile video is expected to represent 76% of monthly mobile traffic by 2025, up from 63% in 2019.

Distributed Antenna System (DAS) solutions are effective at addressing the needs of indoor traffic management by enhancing coverage and capacity typically supporting different Radio Access Technologies (RAT) and multi operators' deployments. However, DASs have transitioned from the passive RF domain (in which the infrastructure widely adopted feeder cable) to the fiber/ Category 6 cable domain (in which the cabling infrastructure is replaced by fiber and CAT6 cable) to add advanced features and flexibility to the delivery of indoor wireless. The table below summarizes different features of Active DASs.

Table 1: Features of Active Distributed Antenna System (DAS)

(Source: ABI Research)

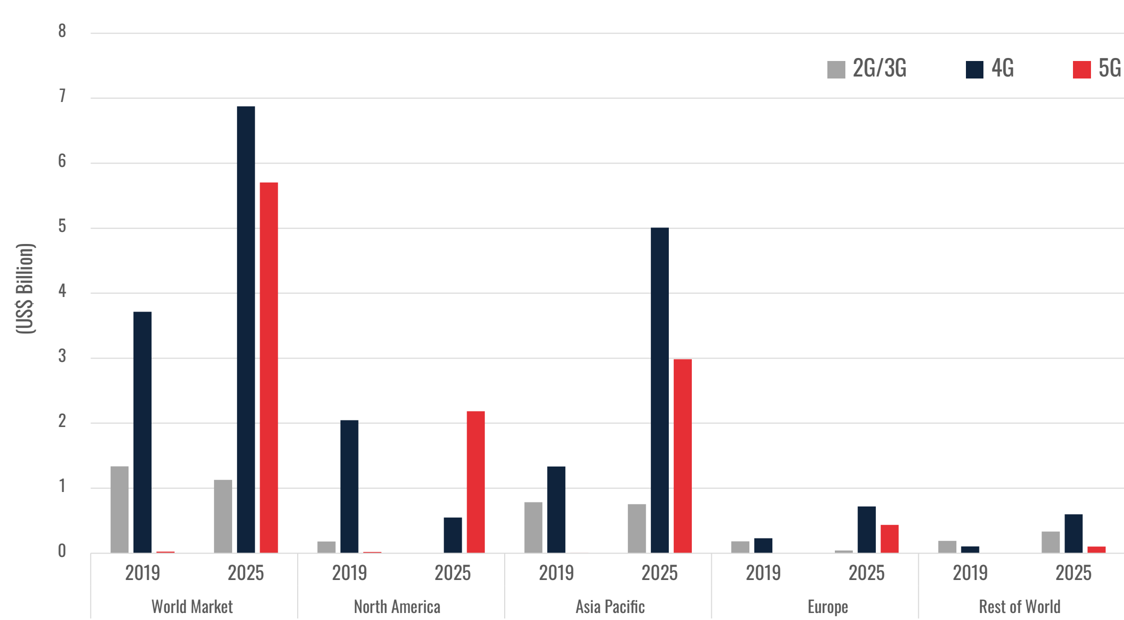
FEATURE	DESCRIPTION
Neutral Host	DAS is able support multiple operators' networks for indoor wireless coverage.
Transmission over Optical Fiber or HFC	This type of cabling infrastructure enables a rapid implementation of 5G systems onto LTE networks and provides a future-proof infrastructure. With fiber solutions, the fronthaul will be able to support higher data rates, spectrum and technology evolution.
Cell Splitting	This feature can be achieved in many commercialized active DAS solutions. While passive DAS will require manual intervention and reconstructive engineering to allow capacity steering.
Common Public Radio Interface (CPRI)	This feature allows the communication between the head-end and the remote units located elsewhere. Some systems specify the data packet with destination address allowing a more flexible approach to handle varying level of capacity demand in the building.

With the rapid transition from 4G to 5G, indoor mobile networks are facing several challenges in meeting 5G network requirements, namely: higher capacity and data throughputs as well as enhanced spectrum efficiency. For passive DAS, the upgrade path towards 5G require a transition to digital or analogue DAS with virtualization playing an important role.

According to ABI Research's Mobile Network Infrastructure Market Data (MD-INF-104) worldwide, DASs are expected to grow at a Compound Annual Growth Rate (CAGR) of 19.4% from 2019 to 2025 worldwide. The investment in 5G DASs is expected to expand from US$ 23.13 million in 2019 to US$ 5.7 billion by 2025. This trend is led by Asia-Pacific and North America. 4G DAS deployments are expected to grow by 1.9X from US$3.71 billion in 2019 to US$ 6.87 billion by 2025.

Figure 1: Indoor DAS Revenue by Radio Access Technology, World Markets, Forecast: 2019 and 2025

(Source: ABI Research)



INDOOR DEPLOYMENT CHALLENGES

In the 5G era, many legacy DASs are facing several limitations to incorporate 5G and increase the overall capacity of the system. These limitations are mainly associated with two factors: (i) new frequency bands in which 5G typically operates (mid-band and mmWave); and (ii) major infrastructure works needed to increase the capacity of the legacy system. Some of these limitations can be described as follows:

- The frequency range of legacy passive components span from 700 Megahertz (MHz) to 2700 Megahertz (MHz). Thus, if an upgrade to incorporate 5G in 3.5 GHz band is required, all passive components for main and MIMO channels will require replacement to comply with the new frequency range.
- Narrow beam formed at high frequencies and ultra-low latency needed for mobile 5G implies that indoor wireless systems using millimeter wave spectrum will resemble a small cell architecture. Hence DAS will cater mainly for sub 3 GHz frequency bands.
- A redesign and additional installation work (i.e., more antennas and feeder cable) will be required in order to provide ubiquitous coverage in the 3.5 GHz band, because propagation conditions are very different compared to existing lower frequencies.
- Major upgrade works involve new active equipment, passive components, cabling infrastructure, and antenna swap. In addition, a dedicated link budget analysis will typically need to be carried out so that main and MIMO channels are well balanced.

UPGRADE PATH FOR DAS

While legacy DASs remain popular where low deployment cost is a main concern, the upgradability and cost to scaling will be of primary concern with the introduction of new higher frequency bands and 2x2 or 4x4 MIMO configurations.

There are four strategies for landlords and MNOs to deploy 5G in venues with existing legacy DASs: (i) Migration towards Active Distributed Antenna Systems, (ii) Virtualized RAN, (iii) Spectrum Re-farming Strategy and (iv) System Overlay. ABI Research believes that virtualization and Active DAS has a large role to play in aiding the transition towards 5G for Active DAS. This will allow allocating resources where it is required based on the dynamic flow of traffic.

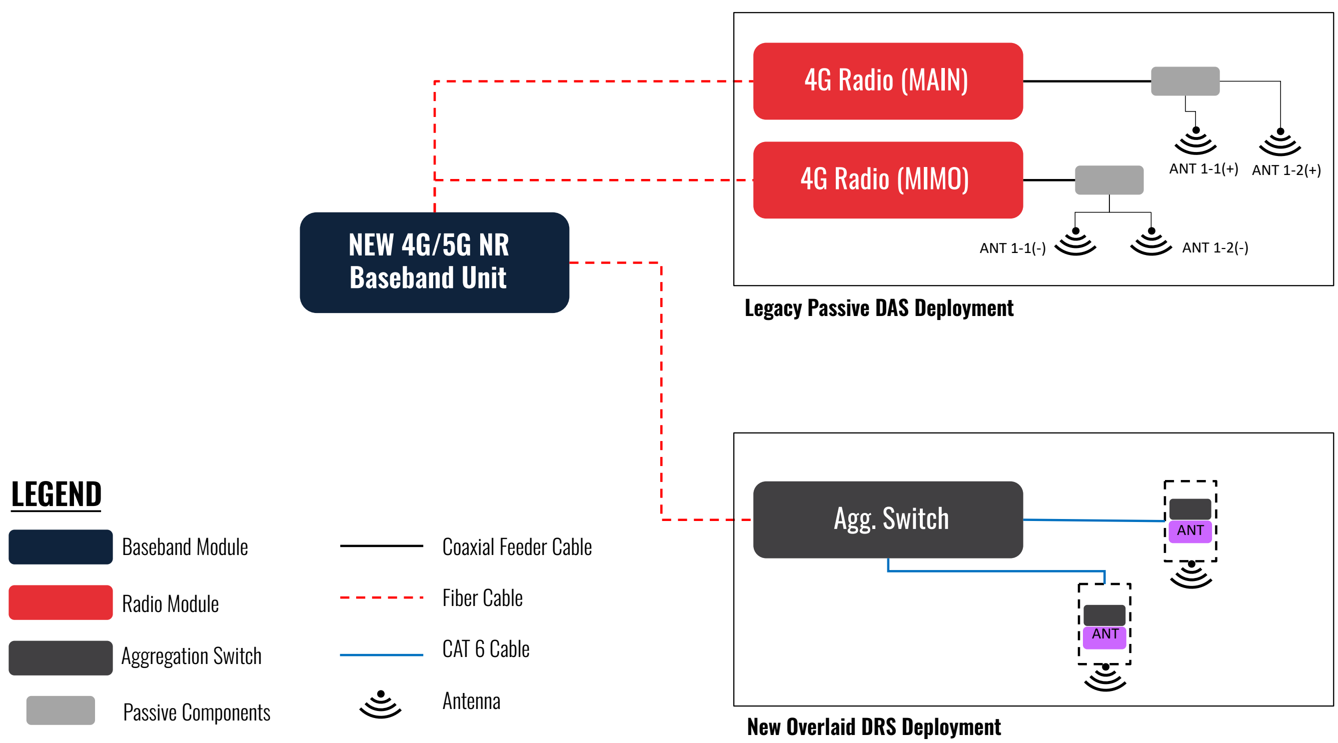
- **Migration to Active DASs**: Passive or legacy DAS has limitation in scalability as well as the need to increase antenna and cable in order to achieve an optimal coverage area and performance. By migrating to Active DAS, the in-building networks will be more suitable for 5G due to their zero losses advanced features, architecture and cabling infrastructure which will enable the system to support higher data throughputs.
- **Virtualization**: This will help to reduce the CAPEX and OPEX for operators. It also allows for radio resources to be dynamically allocated ensuring greater efficiency and optimal usage to meet data traffic demands.
- **Spectrum Re-Farming Strategy**: The spectrum re-farming technique allows MNOs to easily deploy 5G in legacy DASs, as long as the platform can support the new frequency bands. For instance, in Hong Kong, China, MNOs re-farmed a 3G 10 MHz at 2.1 GHz for 5G. The operator used the 2.1 GHz band in legacy DASs for 5G and overlaid a new Distributed Radio System solution to introduce 50 MHz of 5G spectrum in the 3.5 GHz frequency band. However, it is to be noted that refarming using existing bands do not give adequate capacity for 5G due to limited bandwidth. In some cases, existing bands are also concurrently supporting LTE networks.
- **System Overlay Strategy** - The system overlay technique has also been adopted by several MNOs. With this approach, legacy DAS systems have been left in place without any major changes for 3G/4G. Instead, the legacy 4G infrastructure has been used to work as an “anchor band” for the deployment of 5G in Non-Standalone (NSA) configuration. In the Figure below, there is an example of how the overlaid

upgrade could be carried out by deploying DRS systems. Firstly, a new baseband module capable of supporting 4G and 5G technologies needs to be deployed, thus replacing the legacy 4G baseband unit. Secondly, the new DRS infrastructure is deployed to provide 5G coverage in the target areas as shown in the figure below

In the upgrade path towards 5G, virtualization plays a big role for Active DAS in adapting to the fluctuation in traffic demand. In addition, through adopting a multipoint-to-multipoint fronthaul topology, it will also allow the system to handle the dynamic selection for both frequency and carrier for the various radio nodes. As such, radio resources can be allocated much more efficiently based on varying levels of traffic demand and thereby reduce the TCO. These types of systems also ease scalability because additional resources can be added centrally or incrementally and distributed virtually to any connected radio node within the network

Figure 2. An Overview of an Overlaid 5G Deployment

(Source: ABI Research)



With the need to further improve 5G coverage indoors, solutions such as Distributed Radio Systems are also expected to gain greater market participation in the longer term. In the immediate and mid-term, solutions such as Active DAS will serve to build capacity and expand indoor coverage for 5G with practical solutions at viable TCO profiles. For example, an indoor Active DAS deployment in French operators (Orange, Free, SFR, and Bouygues Telecom) in 2020 has 60% of the deployment being Active DASs. ABI Research anticipates mobile operators will then take a system overlay approach as a stepping-stone for the deployment of 5G. Thus, ABI Research envisions the delivery of indoor wireless solutions to rely on three different layers depending on the capacity density of the venue and specific use cases as illustrated in Table 2.

Table 2. Three-Layer Delivery of Indoor Wireless
(Source: ABI Research)

COVERAGE LAYER	TECHNOLOGY AND FREQUENCY BAND	DESCRIPTION
1	Sub-3 GHz	Voice and data coverage with carrier aggregation capabilities for good data throughputs and good signal coverage.
2	5G New Radio (NR) in mid band	To add capacity densification and provide eMBB services
3	5G NR in mmWave	To provide ultra-high throughput in high-density venues, such as stadiums and conference rooms, or to address high-bandwidth applications, such as VR and AR

The sub-3 Gigahertz (GHz) may be provided by legacy DAS, which has been primarily passive deployments. In the mid-band of 3.5 GHz, a multi-operator Active DAS solution can be adopted for a ubiquitous coverage while taking in consideration the cost effectiveness. Finally, in the mmWave band, small cells hotspots may be added to address the ultra-high bandwidth requirement.

DAS SOLUTIONS TAKING ON ADDITIONAL FEATURES

DAS vendors are working towards a more flexible ecosystem that allow mobile operator and landlords to maximize their Return on Investment (ROI) from their DAS deployments.

ABI Research has evaluated the level of innovation and capabilities of 11 different DAS vendors taking into account commercial inbuilding products, compiled the following assessment, as shown in Figure 3. With the advent of 5G, vendors are innovating quickly to meet the changing demands for indoor wireless and as such the ranking below is subjected to changes.

Figure 3. Innovation Ranking of Vendor DAS Solutions
(Source: ABI Research)

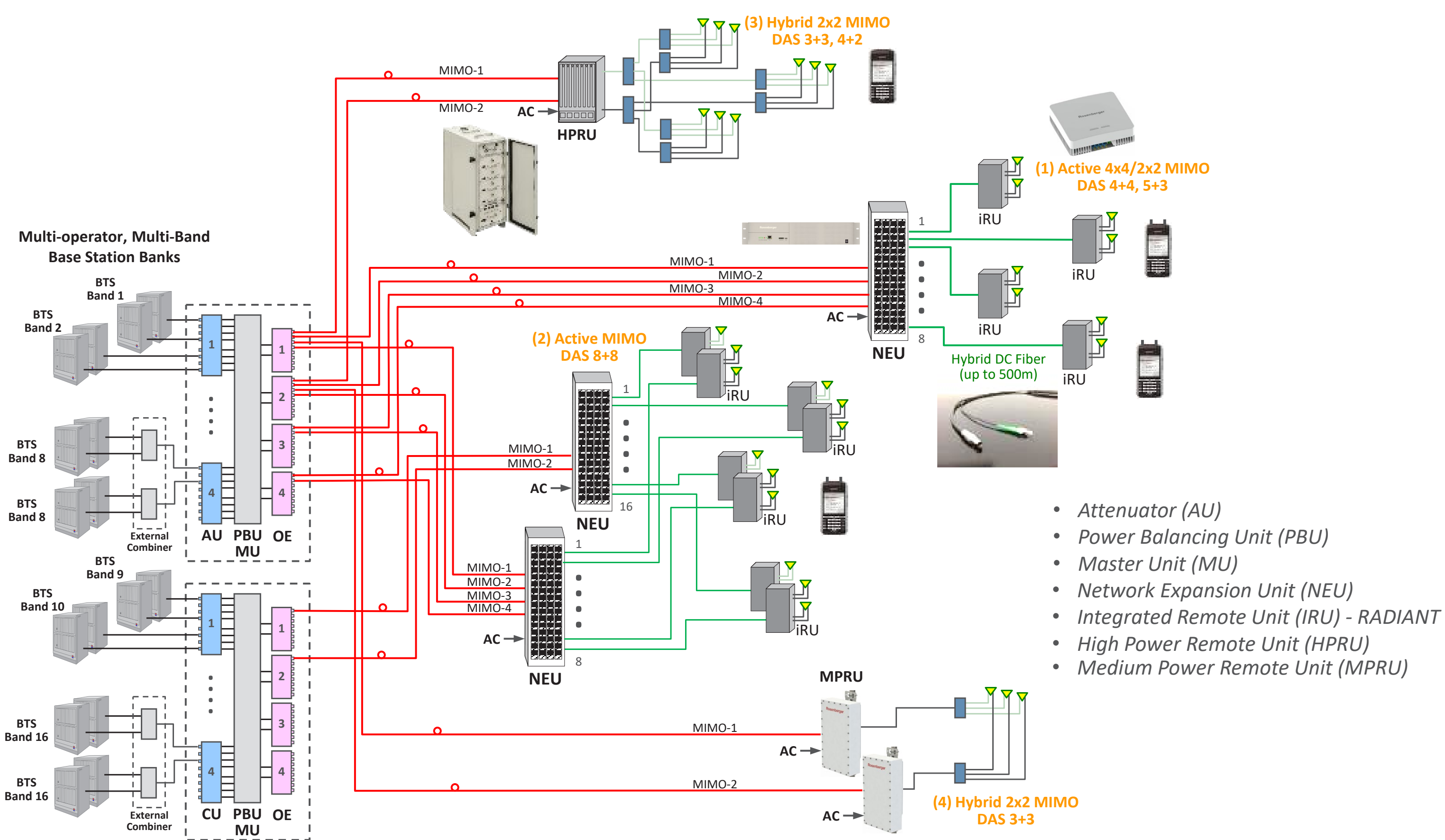
CommScope, Corning, and JMA Wireless have a number of incumbent positions with telcos, but competition is ratcheting up and they are squeezed by a number of Tier 2 and Tier 3 vendors. Tier 2 and 3 vendors have had to ensure their solutions are price competitive and focus on reducing maintenance and overall total cost of operations to secure contracts. This is being reflected in multi-regional deployment wins and in the size of deployments. To date, many vendors are actively investing in DRSs, such as Advanced RF Technologies (ADRF), CommScope, Corning, Ericsson, Huawei, JMA Wireless, Nokia, Rosenberger, and SOLiD.

OVERVIEW

Rosenberger's Smart DAS is the latest DAS system that is multi-operator, multi-band, and multi-technology operating from 698-3800 MHz. The platform supports both hybrid (high-power remote unit) and active (low-power remote unit) and supports up to four operators per band. In the NR C-band, the system can support 400 Megahertz (MHz) Instantaneous Bandwidth (IBW) and 4T4R with one of the smallest footprints in market. It can support various MIMO configurations (e.g., Single Input, Single Output (SISO), 2x2 MIMO and 4x4 MIMO) with up to six bands per RU for a high-power solution and 8 bands for a low-power RU.

Figure 4: Smart DAS Diagram Supporting Active (1, 2) and Hybrid DAS (3, 4)

(Source: Rosenberger)



The headend unit consists of the following components:

- **Attenuator Unit (AU)**: The AU consists of eight wideband 698-3800 MHz Radio Frequency (RF) input ports from the operators' Base Transceiver Stations (BTSs) and performs fixed RF power attenuation. Up to four AUs will be needed to support eight bands in a 2x2 or 4x4 MIMO configuration.
- **Power Balancing Unit (PBU)**: The RF attenuated signals of the base stations are power balanced in the PBU, which consists of individual variable attenuators per port controlled remotely by the Network Monitoring System (NMS).
- **Master Unit (MU)**: The MU combines up to four ports per band after power balancing and provides additional variable attenuators for uplink and downlink paths. The uplink attenuator provides noise padding to control the noise increase at the BTS.
- **Optical Electrical (OE) Module**: The OE module converts the RF signals from the 698-3800 MHz band to optical with eight optical ports per OE module. There are four OE modules in the system, which can be configured as SISO (32 optical ports), 2x2 MIMO (16 optical ports per path), or 4x4 MIMO (8 optical ports per path).

Once the RF signals have been converted to optical, they can be routed to High-Power Remote Units (HPRUs) for implementation as a hybrid DAS solution, or to low-power remote units as an active DAS solution.

The low-power solution, also known as RADiAnt (Rosenberger Active DAS with Integrated Antenna), has the following components:

- **Network Expansion 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 MU path 1 and path 2 optical modules, and splits into 16 pairs of optical outputs. In a 4x4 MIMO system, the number doubles.
- **Hybrid Cable**: The hybrid cable consists of a DC cable and two or four fiber strands. It connects from the NEU to the Integrated RU (iRU). The hybrid cable is available in lengths of 50 Meters (m) to 300 m with connectorized fibers, so installation will be greatly simplified.
- **Integrated Remote Unit (iRU)**: The iRU is 2.5 liters with a size of 200x200x70 Millimeters (mm) and weighs less than 2.5 Kilograms (kg). Each iRU can support eight bands from 698-3800 MHz, with options to support SISO, 2x2 MIMO (for LTE and NR) or 4x4 MIMO (NR only). Each path has a composite power of 24 Decibel Milliwatts (dBm) for the high band (1700-3800 MHz) and 21 dBm for the low band (<1000 MHz), excluding the antenna gain. Various band combinations and MIMO capabilities are available to support:
  - 4x NR3500 (4T4R, 1600 MHz total RF bandwidth)
  - 2x NR3500 (4T4R, 800 MHz total RF bandwidth) + 4x 4G (dual band 2T2R)
  - 4x NR3500 (2T2R, 800 MHz total RF bandwidth) + 4x 4G (dual band 2T2R)
  - 2x NR3500 (4T4R, 800 MHz total RF bandwidth) + 4x 4G (2T2R) + 4x 2G + 4x 3G
  - 4x NR3500 (2T2R, 800 MHz total RF bandwidth) + 4x 4G (2T2R) + 4x 2G + 4x 3G

The RADiAnt system can support up to 64 iRUs in 2x2 MIMO and up to 256 iRUs in 4x4 MIMO. An additional iRU can be installed to support more bands, giving a total of 16 bands. Options for an external antenna is also available.

In the high-power solution, the optical modules in the headend unit connects directly to the modular high-power remote, which supports up to six bands (698-2700 MHz) and up to four bands (3300-3800 MHz) per unit. Bands can be changed by replacing the amplifier modules, with each amplifier delivering a composite power of 43 dBm (698-2700 MHz) or 46 dBm (3300-3800 MHz). The passive DAS components support from 698-4000 MHz, allowing it to support existing technologies and the new 5G band. A medium-power hybrid DAS solution is also available with three bands per unit, delivering 33 dBm per band.

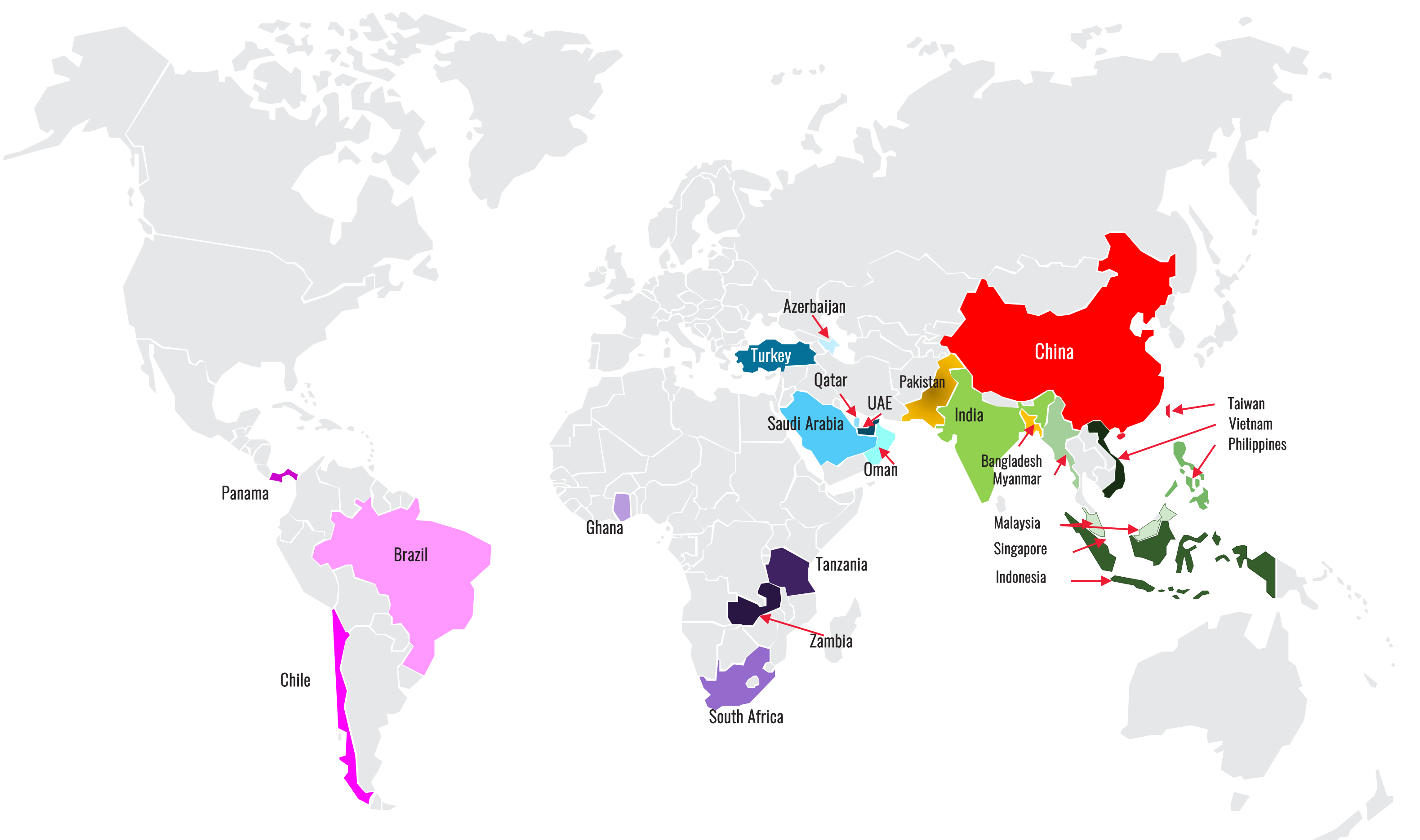
TECHNICAL MERITS

The active DAS solution has several technical merits that makes it ideal for deployments involving 5G, or 5G with other technologies:

- **Zero DAS Loss**: Delivers higher Effective Isotropic Radiated Power (EIRP), particularly in higher frequency bands like 2600 MHz and 3500 MHz. With higher downlink EIRP, a better downlink Signal-to-Noise-Plus-Interference Ratio (SNIR) can be achieved up to 256 Quadrature Amplitude Modulation (QAM) in s larger percentage of coverage.
- **Consistent Output Power**: To meet coverage Key Performance Indicators (KPIs) with output power balance for each iRU set remotely.
- **More Bands and MIMO Reduces Operator Operational Expenditure (OPEX)**: The system supports up to eight bands per iRU, which can be configured to support from 2G to 5G, with different MIMO capabilities for 4G and 5G.
- **Low Latency**: At less than 1 micro-second end-to-end latency, the active DAS can support all 5G Ultra-Reliable Low-Latency Communications (URLLC) applications.
- Higher RU output power significantly decreases iRU quantity and Capital Expenditure (CAPEX) investment.
- Compact RU design is reliable and has extremely low power consumption, using natural air cooling.

Figure 5. Locations of Rosenberger DAS Deployments

(Source: Rosenberger)



SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

Legacy DASs will face challenges with upgrading to 5G. However, solutions from vendors like Rosenberger will enable operators to deploy indoor 5G in a cost-effective way and avoid rip-and-replace scenarios. ABI Research does not expect major upgrade work to be carried out in legacy DASs to incorporate 5G, as these could be expensive and time-consuming. Instead, it is recommended for techniques, such as spectrum re-farming, to improve the capacity and performance of the system.

Flexible solutions with advanced features and capabilities like low power Active DASs are disrupting the market. Innovative solutions from vendors like Rosenberger are changing the way traditional DASs are designed and installed due to their simplified and future-proofed architecture. ABI Research believes that indoor wireless will be delivered in 3 layers dependent on the venue and use case. Legacy DASs will also evolve from the Centralized RAN architecture towards Virtualized RAN, reducing the Total Cost of Ownership (TCO). These trends will have the effect of reducing system costs so that DASs can be economically deployed in smaller floor area buildings than before.

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