LEGACY VERSUS OPEN RAN: POWER CONSUMPTION IN 5G RADIOS

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EXECUTIVE SUMMARY

Open Radio Access Network (RAN) is picking up traction and commercial interest in 2023, with multiple operators actively considering the new technology for their new and existing 5G networks. In the meantime, 5G deployments have matured in consumer markets and mobile operators are looking toward the next wave of monetization, given that 5G today provides a blanket of nearly ubiquitous and consistent mobile broadband connectivity across most developed markets.

At the same time, sustainability is becoming a critical topic and is now part of the criteria for vendor selection. Trying to live up to the hype of both 5G performance standards (super-fast speeds, higher throughput, lower latency, enhanced security) and sustainability standards (running a green network, while optimizing energy efficiency) can sometimes be at odds. The entire telecoms supply chain is now aiming to optimize power consumption of all equipment, with the RAN being the most power-hungry part of the network, due to its distributed and technical nature.

In the 5G RAN, the radio itself consumes most of the energy, often 70% to 80% of total RAN energy expenditure according to many European mobile operators. This is a prime area for optimization, where multiple initiatives have been designed and implemented to reduce its impact. Early vendor equipment that was released 3 to 5 years ago was far less efficient than the current generation, and it is very likely that many early 5G networks still operate on this equipment because the depreciation, and thus replacement period often takes up to 10 years in cellular network infrastructure.

The past few years have seen Open RAN equipment being developed and becoming commercially available, but the topic of energy consumption has not been explicitly discussed so far, perhaps due to the dominance of legacy infrastructure vendors and Open RAN radios not yet deployed in large scale, in parallel with legacy radios. Following on from a previous study ABI Research completed, titled Is **Open RAN Power Efficient?**, which focused solely on the baseband layer, this study focuses on the radio layer, aiming to compare like for like in both radios (Remote Radio Units (RRUs)), and Massive Multiple Input, Multiple Output (mMIMO) units (Active Antenna Units (AAUs)).

ABI Research has designed a network deployment model for a Western European market, where 5G is densely deployed in both high-density and low-density urban areas. The research team has also collected power consumption data, while understanding that these data are the most sensitive, confidential, and competitive information in the market currently. Our model indicates that as far as RAN-power-consumption is concerned, Open RAN radios and active units perform better than legacy RAN across typical network RAN usage ranges observed in any mature network, which is likely throughout the forecast period. In case of extremely high network RAN usage though, which may not be a typical representation of commercial RAN network operating range, legacy RAN radios may perform better, which may not be attributable to any Open RAN-related shortcomings. It may also be noted that the superior power consumption performance of the specific units we have profiled—within the Open RAN family of products—also depends on other factors like differential efficiency of the silicon vendor, difference in their implementation techniques, and difference associated with their choice of process node and hardware design.

In addition to the results compiled in this study, which compare like for like and show "vanilla" radio performance, there are qualitative improvements that all legacy vendors implement, including putting radios in "sleep" mode during the night. At the same time, Open RAN radios promise additional energy optimization through the RAN Intelligent Controller (RIC) and xApps/rApps, which will create more opportunities for vendor-agnostic innovation from third parties and startups in the next couple of years.

5G MARKET OVERVIEW

In the last few years, the telecoms industry has witnessed mixed challenges related to 5G deployments, including COVID-19, geopolitics, and the energy crisis, while at the same time, it continues to remain the backbone of national infrastructure by providing fixed and mobile connectivity. In fact, the ongoing geopolitical challenges and market uncertainty accelerated investment in telco networks and created renewed interest in cellular networks, including 5G-Advanced and 6G, which are now part of national agendas for many countries globally.

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At the same time, several developments in the 5G RAN, cloud, and chipset markets have accelerated competition within the telecoms industry. These include Open RAN and Virtualized RAN (vRAN), both of which aim to open the mobile infrastructure supply chain to new entrants, while allowing infrastructure to use common processing platforms and not custom silicon necessarily. On the other side, the cloud and accelerator infrastructure market has become more competitive with silicon vendors starting to gain mobile vendor partnerships. During 1H 2023 silicon vendors have started to develop super and integrated chipsets to provide full-stack acceleration, including complex Layer 1 (L1) processing for mMIMO configurations for RAN without requiring external accelerator cards.

NETWORK INFRASTRUCTURE MARKET TRENDS

The advent of vRAN and Open RAN promises to help the telecoms industry recover from these conditions by providing operators the flexibility to choose suppliers. vRAN enables virtualized baseband processing with commoditized hardware that depends on proprietary interfaces, software, and purpose-built hardware in the Radio Frequency (RF) domain that still restricts vRAN from delivering interoperability and openness. The concept of Open RAN promises to make RAN virtualized, software-defined, and disaggregated, as well as connected via open interfaces to enable RAN reconfigurability, intelligence, and interoperability between different vendors, allowing operators to leverage equipment and chipsets from different vendors. Combining the two concepts of Open RAN and vRAN results in Open vRAN, which allows operators to migrate from custom-built Baseband Units (BBUs) to standard software running on Commercial Off-the-Shelf (COTS) hardware.

The telecoms market is now working toward 5G-Advanced and 6G, doing research on the next wave of mobile network technology, while trying to build platforms for future generations.

In the radio domain, Open RAN allows operators to mix and match between baseband (Centralized Unit (CU)/Distributed Unit (DU)) and Radio Unit (RU) vendors, while the integration of Open RAN radios allows for additional efficiency due to the design of these units.

5G started to become more pervasive across several geographical areas and industries by handling advanced use cases and applications that require higher throughputs, coverage, a greater number of antennas, and more frequency bands. This may result in higher energy consumption that affects the environmental impact of 5G networks. Due to the increasing concerns related to environmental sustainability and increased energy costs, the network Operational Expenditure (OPEX) has become a major issue in many European markets, accounting for approximately 25% of the total operator cost. Mobile operators have started to find different ways to save energy costs such as switching off 5G radios during off-peak night hours. Moreover, mobile operators have started to optimize their networks by retrofitting new infrastructure or completely replacing existing base stations and network equipment.

One of the most important capabilities is the use of Artificial Intelligence (AI) and Machine Learning (ML), which started entering the mobile network in the upper layers of the network stack, mainly in Business Support Systems (BSSs) that handle subscriber, marketing, and commercial data. The BSS has been a relatively straightforward domain for AI/ML because it deals with large amounts of data and is running on common Information Technology (IT) platforms. However, AI/ML is now expanding well beyond this domain to all areas of the network, reaching as far as the radio domain where network optimization has traditionally been vertically integrated in a closed and well-guarded field due to the complexity of network operations. Many initiatives are now addressing multiple areas of the network, including the RIC, the Service, Management, and Orchestration (SMO) element, network orchestration, and many others. It is important to note that the RIC has been designed to address Open RAN deployments and not traditional RAN networks, because it is principally designed for open interfaces. The RIC also offers significant advantages over Self Optimizing Networks (SON), which targets traditional RAN deployments, including the capability to do user-based optimization.

Finally, the telecoms market is now working toward 5G-Advanced and 6G, doing research on the next wave of mobile network technology, while trying to build platforms for future generations. This is now filtering to current market developments, which are focusing on deploying horizontal platforms, rather than vertical architectures that were the mainstream choice the previous years. This is certainly the case in radio networks as well.

EVOLUTION OF LEGACY RAN TOWARD OPEN RAN

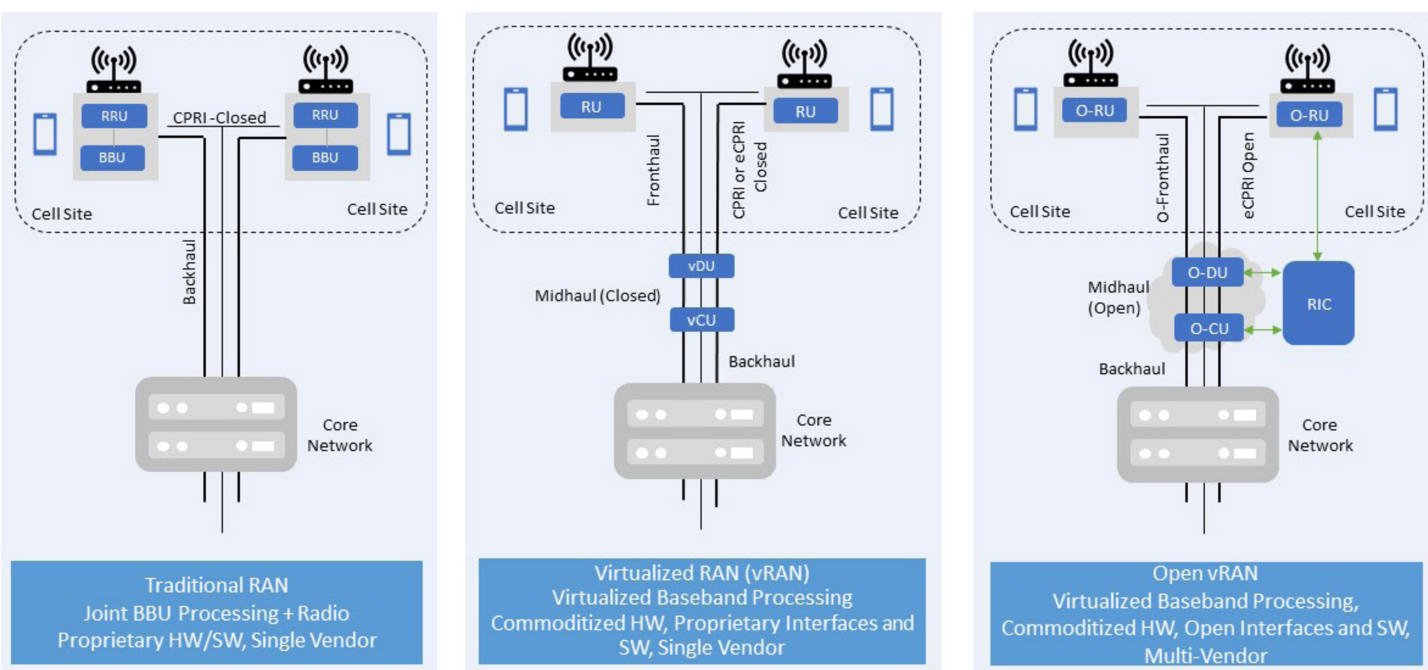
Radio networks have traditionally been deployed through monolithic units following a black-box approach that implements the full protocol stack. In the case of 4G, this means a RRU, which translates electronic signals to RF and, in the case of 5G, mMIMO AAUs, which are more complex network elements, capable of beamforming and consisting of hundreds of RF chains. The traditional RAN market has been one of a closed nature, meaning that the market was dominated by a handful of large suppliers.

In the radio domain, particularly in the fronthaul domain, closed interfaces meant that BBUs and RUs were not interchangeable between vendors, which restricts operators from leveraging RAN reconfigurability, limiting coordination between network nodes and equipment from multiple vendors. The concept of Open RAN was initiated exactly to solve the shortcomings of traditional RAN and to enable interoperability and openness into the radio domain. This could be achieved by the 7-2x fronthaul interface defined by the O-RAN Alliance, that splits the PHY layer (L1) processing between Open DU (O-DU) and Open RU (O-RU). A 7-2x fronthaul interface provides a fair trade-off between the simplicity of interface and O-RU design, meaning that it requires fewer parameters to configure and requires a lower data rate for the fronthaul transport compared to higher layer split options. But this is not as simple when mMIMO AAUs are deployed at the RU, which is a key feature that 5G introduced to the market. The distribution of protocol stack functions is different in 5G mMIMO due to the increased number of RF chains and the requirement of exchanging more information with the O-DU. Therefore, the complexity of AAUs increases with the number of antennas and RF chain, resulting in increased computational complexity of mMIMO due to intensive L1 processing at the AAUs.

Figure 1 illustrates the transition from traditional RAN to vRAN and Open RAN.

Figure 1: Traditional to vRAN to Open RAN Evolution

Source: ABI Research

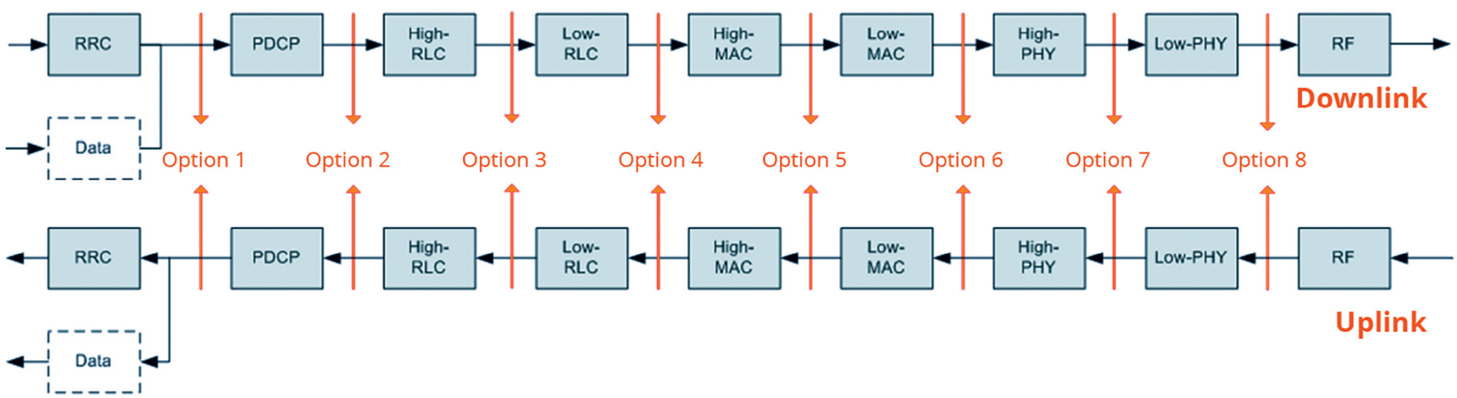


OPEN RAN FUNCTIONAL SPLITS AND 7.2X

When Open RAN was initially discussed and the concept was being developed, there were several "functional splits" aiming to split the functionality and processing capabilities of the CU, DU, and RU, respectively. Figure 2 illustrates potential functional splits that were considered during the design of Open RAN in the O-RAN Alliance.

Figure 2: 5G Functional Splits

Source: O-RAN Alliance



For typical 5G areas in urban and dense urban locations, the O-RAN Alliance chose Option 7.2x that splits the Physical (PHY) layer between O-RU and O-DU to conform to stringent latency and high throughout requirements. This split represents a good compromise between fronthaul and processing requirements, and the Open RAN ecosystem has designed products that use this split extensively. In traditional RAN, radios consume more energy due to complex PHY layer processing performed at these units, as compared to Open RAN that splits the PHY layer processing between O-DU and O-RU, where processing may even be pooled. This creates significant energy savings, which scales further with centralization of the O-DU.

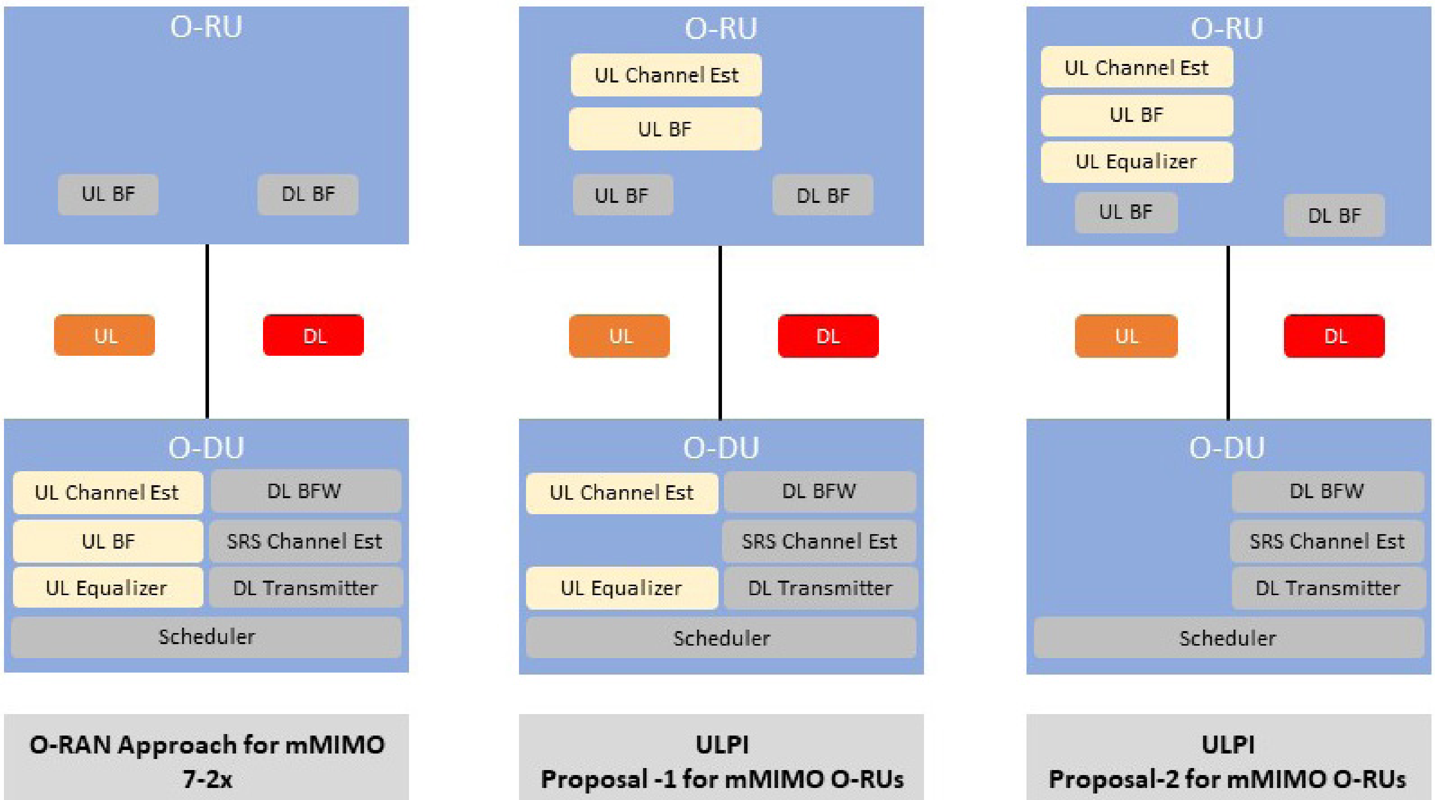
AAU ELEMENT COMPARISON BETWEEN LEGACY AND OPEN RAN

mMIMO is a foundational technology for 5G and critical for the next generations of RAN to change wireless communication with unprecedented coverage, capacity, and speeds. Massive-scale antenna arrays can provide diversity gains and beamforming opportunities, but one major bottleneck in achieving these targets is the requirement of a fronthaul data rate that depends on compression techniques and availability of a functional split used between O-DUs and O-RUs. The fronthaul data rate scales up with the number of AAUs; therefore, laying out high-speed optical fiber may increase the operational cost for operators, as sending IQ samples from AAUs to BBUs in 64-antenna configuration will require significantly higher data rates.

A couple of solutions are available to make mMIMO economically feasible for operators: a compression technique to reduce the fronthaul load, and a functional split to split the processing between units. In a non-mMIMO case, the Open RAN does not impact the analog processing of radio, meaning that the RF paths and functions remain the same, including analog-to-digital and digital-to-analog conversions, analog beamforming, and RF Front End (RFFE). Whereas, in case of mMIMO, the distribution of the protocol stack is not simple due to the increased number of RF chains, complexity of PHY L1 functions, and the requirement of exchanging more information to the DU. Beyond this constraint, there is the ongoing debate whether option 7-2x provides optimal performance in terms of stable interoperability and reduction in fronthaul transport cost. To address this issue, the O-RAN Alliance has initiated a new work item to complement the existing 7-2x interface to improve the performance of mMIMO in the uplink scenario. To accelerate this development, there are proposals submitted by several companies as shown in Figure 3. The O-RAN Alliance has selected two proposals to proceed with further development and testing. In the first proposal, the idea is to move functions (e.g., equalizer) from O-DU to the O-RU, whereas in the second proposal, the idea is to keep the O-RU simpler, while achieving the performance advantage by implementing complex equalization processes at the O-DU.

Figure 3: O-RAN Approach for Uplink mMIMO O-RU

Source: ABI Research



MODELING RRU/AAU POWER CONSUMPTION

Apart from performance and cost comparison for any new deployment, energy consumption is becoming a key indicator when considering a new deployment. ABI Research has thus created a network model to assess how the power consumption of Open RAN compares to Distributed RAN (DRAN), in a real-life network scenario. For this model, ABI Research selected a developed Western European market for several reasons: 5G is well deployed in this region, and there is healthy traffic demand from both consumers and enterprises, while the energy crisis is pushing network operators to optimize their power consumption profiles throughout the network. It should be noted that this model is fully applicable to other markets as well, including Asia-Pacific and India, in particular. In fact, the model assumptions in this Western European case are arguably stringent, as the network parameters below are very high-end. This translates to a very high traffic demand, which in turn, requires a dense mMIMO deployment to ensure that there is significant capacity in the network throughout the forecast period. In developing markets, these requirements will likely be lower, giving more flexibility to network planners.

ABI Research has explicitly selected urban and dense urban environments in Western Europe due to the aggressive traffic nature that requires high capacity and coverage, and it is likely to consume the most energy throughout the region compared to suburban and rural areas that are likely to generate less traffic and consume much lower amounts of energy throughout the day. On top of that, dense urban and urban cell sites are more active throughout the day; therefore, ABI Research has selected a busy hour dimensioning window of 12-hours per day, meaning that the network is well used throughout most of the day, so network planning and dimensioning take into account that cell sites remain busy throughout the day.

ABI Research modeled two scenarios to reflect a typical and realistic 5G RAN deployment to include two types of radios: mMIMO AAUs and RRUs that consist of 32T32R and 4T4R configurations, respectively. These radios will typically be deployed in completely different scenarios and the following sections describe these model assumptions in more detail.

RADIO MODELING ASSUMPTIONS

4T4R RRU NETWORK MODELING ASSUMPTIONS

These units are deployed at 2.1 Gigahertz (GHz) in non-dense areas to ensure that urban areas without stringent traffic requirements have 5G coverage. The configurations for this model are described in Table 1.

Table 1: Network Model Parameters for Non-mMIMO Traditional and Open RAN

Source: ABI Research

5G Network Parameter	Value
mMIMO configuration	4T4R
Frequency and bandwidth	15 MHz at 2.1 GHz
4T4R RRUs are deployed in:	Ultra-high density: 0% of cell sites High density: 50% of cell sites Low density: 100% of cell sites
Sectorization	80% of sites have 3 sectors 10% have 6 sectors 10% have 9 sectors
Average monthly traffic per 5G user	20 GB in 2020 50 GB in 2027
Effective sector spectral efficiency	5 bps/Hz
Effective sector capacity	75 Mbps
Busy hour dimensioning window	12 hours/day
Network elements considered	RRUs
Transmit power	4x40 W

MMIMO NETWORK MODELING ASSUMPTIONS

mMIMO units are much more powerful than 4T4R and allow more advanced features, including beamforming and spatial multiplexing, thus increasing the sector spectral efficiency to a significantly higher level. Table 2 describes the network parameters used for the mMIMO model.

Table 2: Network Model Parameters for mMIMO Traditional and Open RAN

Source: ABI Research

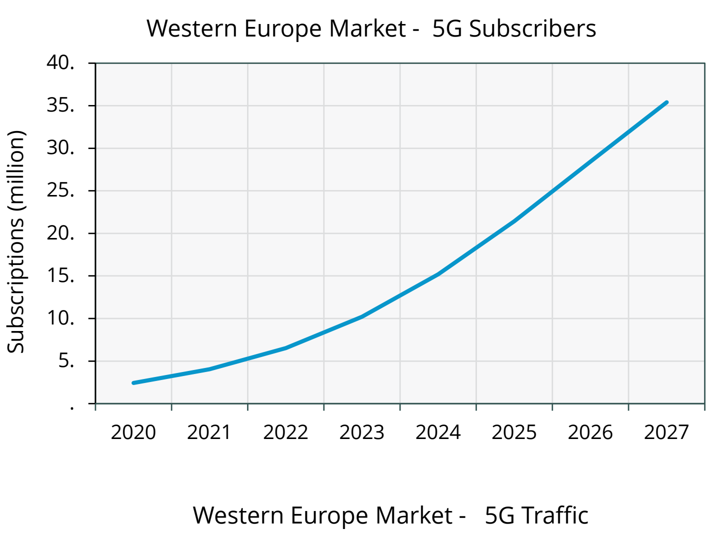
5G Network Parameter	Value
mMIMO configuration	32T32R
Frequency and bandwidth	90 MHz at 3.5 GHz
mMIMO AAUs are deployed in:	Ultra-high density: 100% of cell sites High density: 50% of cell sites Low density: 0% of cell sites
Sectorization	80% of sites have 3 sectors 10% have 6 sectors 10% have 9 sectors
Average monthly traffic per 5G user	20 GB in 2020 50 GB in 2027
Effective sector spectral efficiency	15 bps/Hz
Effective sector capacity	1.5 Gbps
Busy hour dimensioning window	12 hours/day
Network elements considered	AAUs
Transmit power	320 W

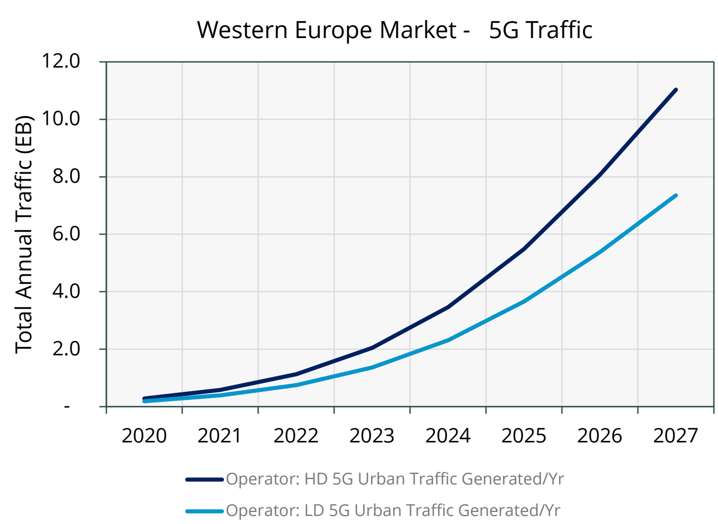
5G SUBSCRIBER AND TRAFFIC PROFILES

ABI Research has considered one of the biggest and most advanced markets in Western Europe, and one of the first to launch 5G and a hub for one of the biggest multinational operators around the world. Figure 4 illustrates historical data and ABI Research projections for the number of 5G subscribers in this market, and the expected amount of 5G traffic throughout the forecast period of 2020 to 2027.

Figure 4: Western European Market Subscriptions and Traffic Forecasts

Source: ABI Research





Although traffic has been split between ultra-high-density, high-density, and low-density urban areas, these are treated in the same way in the network model, especially when dimensioning the RUs. It is also necessary to note that the network modeling and dimensioning process was performed using average values throughout the network, i.e., the traffic is assumed to be spread throughout the network uniformly in terms of time and space. This was assumed to make the deployment process easier, rather than treating each individual area in a different manner. In a real network, each area and even each site needs to be treated separately, but this is not possible in a network modeling or simulation exercise.

ABI Research has concluded that this is a reasonable approximation to make for a network model. For example, a cell site will experience varying amounts of traffic throughout the day, such as it may be used at 80% at peak time, while experiencing near 0% usage during the night. ABI Research's model assumes 30% usage throughout the entire day to factor in this variation.

5G BASE STATIONS AND SECTORS

The above parameters allow the deployment of a 5G radio network, including numbers and forecasts for cell sites, sectors, AAUs and non-mMIMO radios. Figure 5 represents the parameters used for this urban and dense urban 5G network throughout this developed market. It should be noted that cell sites have been split between two main categories:

- **Macro Cells:** These are typically deployed on masts or large poles that cover large areas. These sites are typically high-power, high-capacity sites and consist of 3, 6, or 9 sectors to improve capacity. Given the fact that the Western European market we are modeling is in the relatively early stages of 5G rollout—with deployment driven by coverage needs, not capacity—most sites are 3- sector. This is the reason ABI Research assumed mMIMO—32T32R in this modeling scenario—and it also provides a significant capacity boost compared to previous generations, something that end users will take years to adapt to and ultimately congest.
- **Rooftop Cells:** These cells are deployed on top of buildings to cover dense urban areas. These sites are typically 3- or 4-sector and are not considered for cell splitting in our model. These are usually deployed on low-rise buildings to cover busy street areas and not considered for additional capacity upgrades, given that the current deployment model for 5G in this market is coverage-driven.

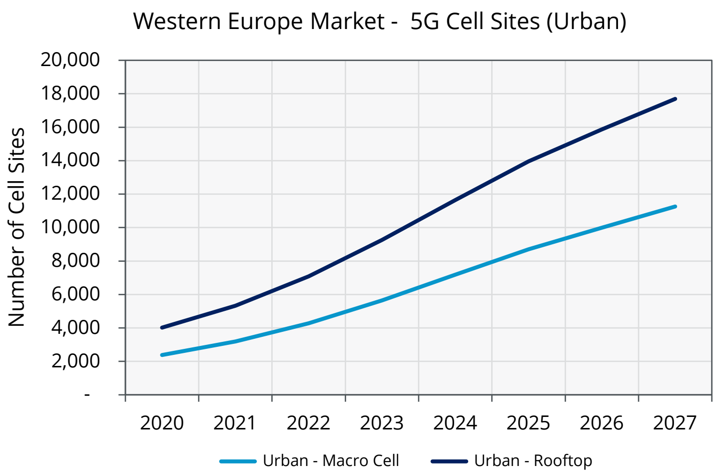
In addition to this segmentation, ABI Research has segmented cell sites to these three sub-categories:

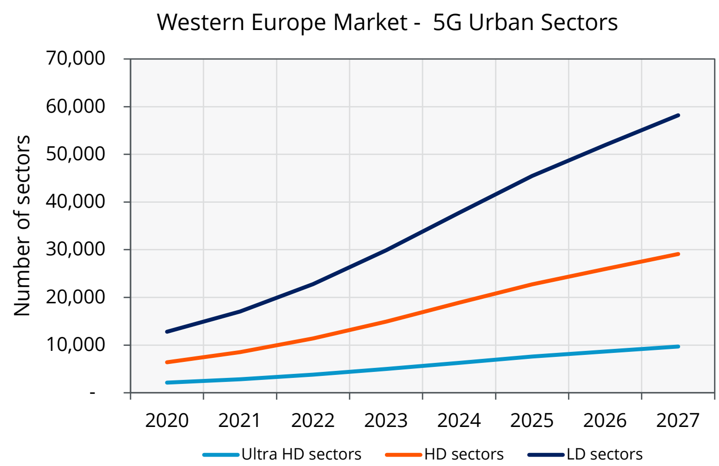
- **Ultra-High-Density Sectors:** These are typically deployed in very dense urban areas, which handle the most amount of traffic in a typical deployment.
- **High-Density Sectors:** Typical urban areas, which also carry a significant amount of traffic, but not as high as Ultra-high-density sectors.
- **Low-Density Sectors:** Low-density urban areas, where coverage will likely be a priority, not capacity for a new network deployment.

Given the above assumptions, the following results in Figure 5 illustrate the number of cell sites and sectors in our model.

Figure 5: Western European Cell Site and Sector Forecasts

Source: ABI Research





Macro cells typically represent a smaller fraction of cell sites in this market and most developed markets, but the percentage of macro sectors is higher due to 6- and 9-sector macro sites. It should be noted that historical population, subscription, traffic, cell site, and sector numbers for 2020 and 2021 were validated with the mobile operator this model is approximating. Moreover, the coverage targets assumed in this model approximate what this operator has announced and are in line with Western European 5G coverage targets.

The coverage area of ultra-high-density sectors is typically smaller and usually, which is typically confined to very busy city centers. This translates to fewer ultra-high-density sectors throughout the forecast period. On the other hand, low-density areas are much larger in terms of geographical size, meaning that more must be deployed for these sectors.

It should be noted that the network planning, dimensioning, and deployment model considered here is high level and relatively simple compared to a real-life scenario, which will factor in cell site availability, backhaul/fronthaul restrictions, landlord concerns, and many other external factors. However, these issues do not affect the model, because it is designed to compare between two similar deployments—between legacy and Open RAN that both must operate in the same environment. The input assumptions do not matter as much as calculating the energy consumption of each one individually.

RRU AND AAU DIMENSIONING AND POWER CONSUMPTION

Power consumption for 4T4R and 32T32R radios is one of the most confidential, protected, and competitive topics in the industry at the moment, and one of the key performance indicators for mobile operators to select a 5G RAN vendor. ABI Research has conducted extensive research to estimate power consumption numbers for both legacy and Open RAN vendors, but cannot disclose any of these numbers throughout this study. These numbers have been validated with several key industry stakeholders, including operators, and indicate that they approximate what is being used currently. The list below presents a few caveats and findings from the collection of these power consumption parameters from the industry:

1) The most power-hungry network element in both RRUs and AAUs is the power amplifier, but technology has progressed enough for both legacy and Open RAN vendors to be compared.

2) Open RAN radio with its 7.2x split has more functions on the RU compared to a traditional RAN RU with split 8. Still, Open RAN AAUs and RRUs perform better for lower usage scenarios due to the advanced technologies deployed.

3) However, there seems to be an inflection point, after which legacy RAN AAUs perform slightly better than Open RAN. This crossover point varies depending on the specific models for each of Open RAN AAUs and traditional RAN AAUs. Networks are not expected to reach this crossover point, except in very high traffic areas. However, Open RAN AAUs perform significantly better for lower and live field typical usage, due to the factors discussed in point 2.

4) Current mMIMO and RRUs deployed in the field will not be the latest generation, especially in Western European markets where 5G deployments started few years ago. ABI Research has not considered these units, instead considering the latest generation of equipment offered by both legacy and Open RAN vendors to be able to compare like for like.

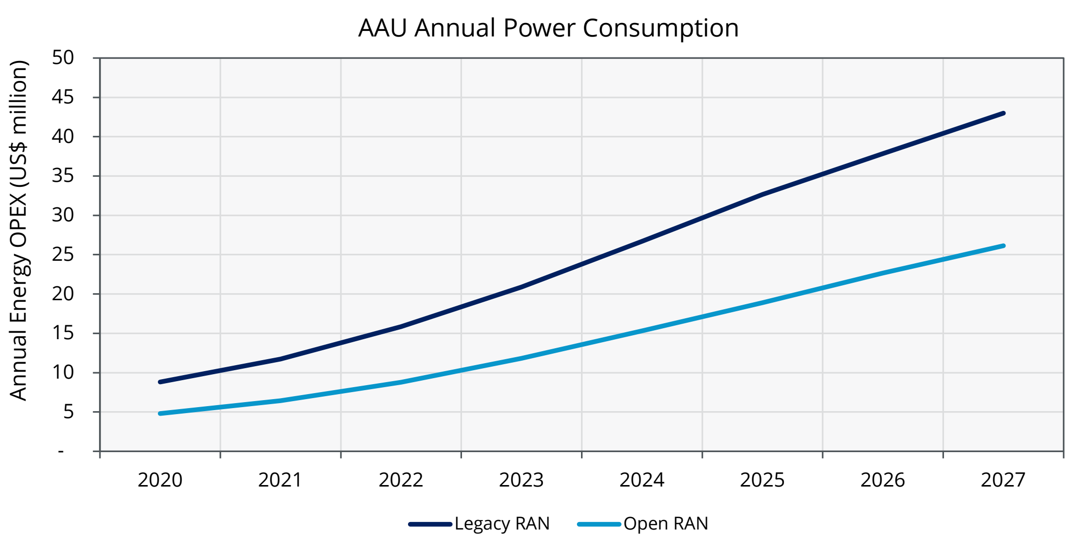
Taking into account these assumptions and data collected from primary and secondary research, ABI Research could compare the energy consumption performance of legacy and Open RAN directly.

POWER CONSUMPTION RESULTS

The assumptions listed in the previous sections enable the power consumption calculation for the entire network. Figure 6 compares the energy consumed per year for DRAN and Open RAN, assuming that the wholesale energy price in the market we are considering costs US$400/Megawatt Hour (MWh).

Figure 6: Legacy versus Open RAN Annual Energy OPEX Forecasts—mMIMO 32T32R AAU

Source: ABI Research

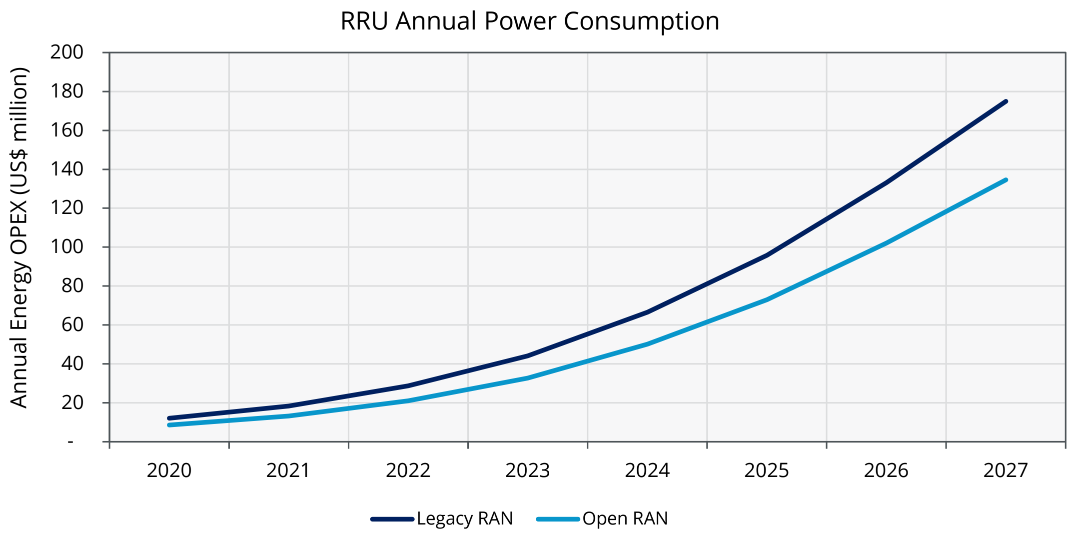


Open RAN performs better than legacy RAN due to the overall lower usage assumed throughout the network. Maximum usage of AAUs in the modeling scenario was 30%, which translates to better performance for Open RAN. This is due to the uniform distribution of traffic throughout the network in ABI Research's model, and a sensitivity analysis for higher traffic loading is illustrated in the following section.

For 4T4R RRUs, power consumption performance is closer for the two different technologies as shown in Figure 7.

Figure 7: Legacy versus Open RAN Annual Energy OPEX Forecasts—4T4R RRUs

Source: ABI Research

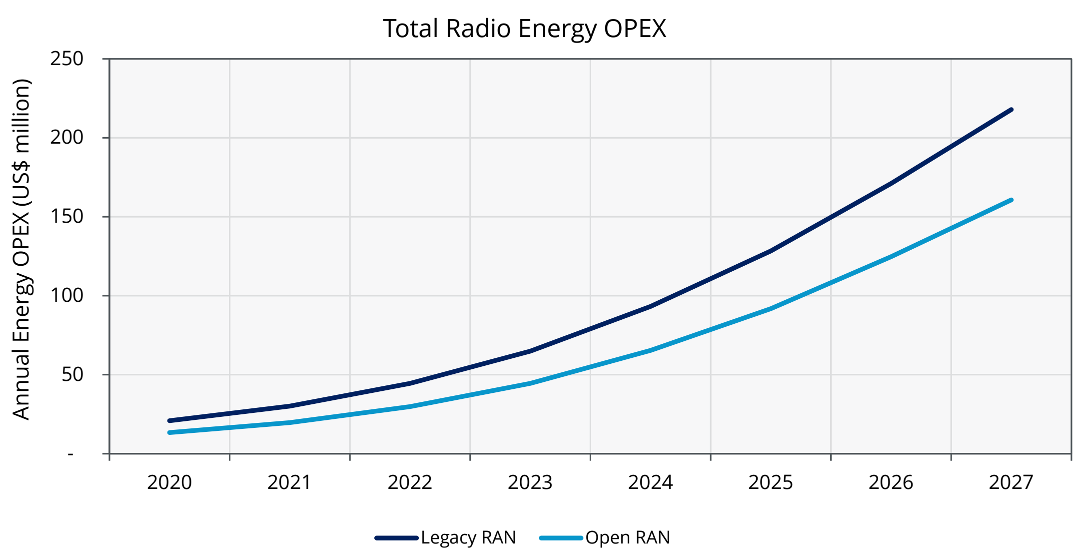


4T4R RRUs illustrate much higher energy OPEX due to the larger geographical coverage area they need to cover: low-density and parts of high-density areas are much bigger than dense urban areas, which consist of ultra-high-density areas.

The overall energy OPEX for radios, including AAUs and RRUs, is shown in Figure 8.

Figure 8: Legacy versus Open RAN Annual Energy OPEX Forecasts for vRAN (both AAUs and RRUs)

Source: ABI Research



Open RAN performs better than legacy RAN, again due to the overall lower usage of the radio network and because signal processing components are removed from the RRU/AAU and placed into the DU.

SENSITIVITY ANALYSIS: HIGH TRAFFIC LOAD

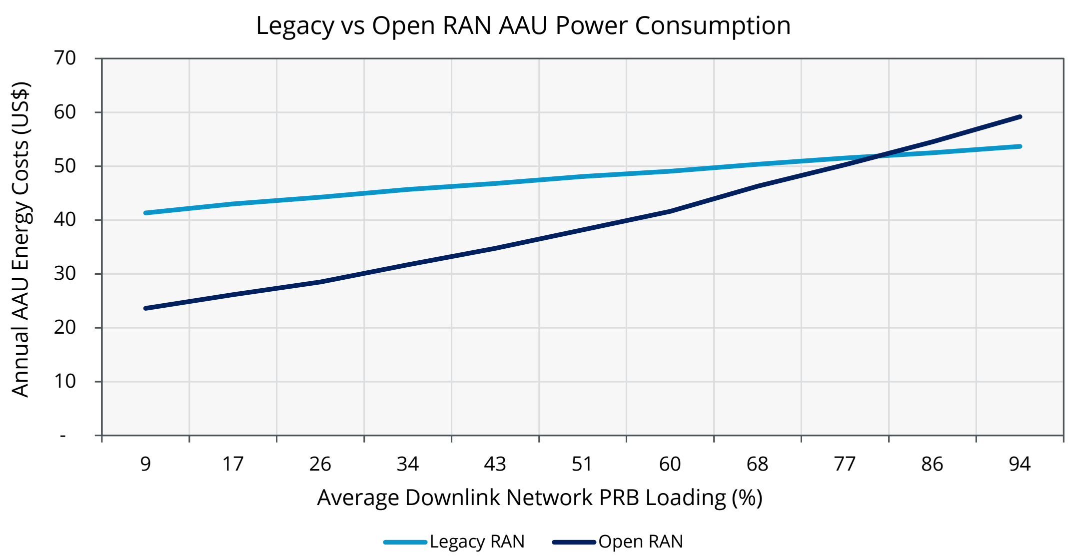
It was mentioned earlier that Open RAN performs better due to the lower usage of the RRUs/AAUs throughout the forecast period, which approximates what takes place in real networks. mMIMO units, even 32T32R, are capable of spatially multiplexing multiple layers, meaning that the spectral efficiency and effective throughput they can offer is much higher than what is needed today. This is also shown in the model discussed above, illustrating that mMIMO AAUs have no problem catering to traffic needs throughout the forecast period.

But what if traffic profiles were significantly higher, meaning that these very same mMIMO units were pushed to nearly 100% usage? Relevant assumptions have been introduced in the network model presented above, specifically to increase monthly traffic consumption for every smartphone user by 5X. This translates to every single 5G smartphone user consuming 200 Gigabytes (GB) every month throughout the Western European country we are modeling. Effectively, this is pushing 5G networks to their limit and nearly 100% usage and congestion.

Using these parameters, the energy OPEX for AAUs is shown in Figure 9.

Figure 9: Legacy versus Open RAN Annual Energy OPEX Forecasts for AAUs with Respect to Average Individual AAU Loading

Source: ABI Research



Note: PRB stands for Physical Resource Block

Our analysis indicates that legacy vendor AAUs will perform better in the high average, individual AAU utilizations because they are more efficient near saturation and 100% loading. However, this scenario will not likely be implemented in any market, because mobile operators will likely act on this well before their networks reach saturation and will deploy more sites, split existing sites, or add more capacity through other means, such as adding spectrum or small cells. Regardless, this scenario illustrates a suitable sensitivity analysis to validate ABI Research's conclusion that Open RAN behaves better than legacy RAN below a sufficiently high usage rate that is realistic.

QUALITATIVE ANALYSIS OF OPEN RAN ENERGY SAVINGS

Open RAN has the potential to prove itself as a catalyst for energy efficiency. Its open architecture provides several energy efficiency features, including intelligent control using a RIC (non-Real-Time (RT) RIC and near-RT RIC), fronthaul optimization via functional split 7-2x, and use of COTS hardware. Moreover, other approaches like sleep mode, including symbol shutdown, mMIMO carrier shutdown, and RF channel reconfiguration, can be used in conjunction with Open RAN features to eliminate the underuse of spectrum resources and to achieve better levels of energy efficiency for the sake of reduced operational cost and environmental sustainability.

INTELLIGENT CONTROL VIA RIC

One of the key features of Open RAN is the RIC, which has the ability to control and optimize RAN elements (O-CU, O-DU, and O-RU) via fine-grained data collection and intelligent decisions over the southbound (E2) interface. One of the key components of a RIC are rApps and xApps, that are plug-and-play units designed to run on the non-RT and near-RT RICs, respectively, to define custom logic for RAN. RICs can process intensive data by leveraging AI/ML algorithms to provide policy-based guidance for the RAN to optimize radio resource management, RAN slicing, traffic steering, the handover process, interference management, beamforming optimization, scheduling, and last but not least, the power management to achieve higher energy efficiency in the RAN. Optimizing all of these features will significantly increase the spectral and energy efficiency in the RAN.

Open RAN has the potential to prove itself as a catalyst for energy efficiency.

CARRIER AND CELL SWITCH-ON/OFF VIA RIC

The use of multiple frequency layers/carriers is commonly used by operators to cover the same service area. During off-peak times, when the traffic load is lower (mainly at night), a considerable amount of energy can be saved by switching off one or more carriers without compromising user experience. A network operator can save significant OPEX and energy by using a carrier switch-off/on mechanism. This also depends on their network deployment, including cell configuration, traffic load, and hardware selection. However, switching on/off carriers is not an easy task due to the dynamic behavior of traffic that may change over time. The non-RT RIC and near-RT RIC can control carrier switch-off/on decisions that may result in a considerable amount of energy savings, instead of local optimization. The AI/ML-based models deployed on non-RT RICs and near-RT RICs can predict user mobility, future traffic, resource usage, and expected energy saving enhancements to enable policy-based guidance for RICs to take more informed and intelligent decisions.

RF CHANNEL RECONFIGURATION VIA RIC

RF channel reconfiguration or MIMO/mMIMO sleep mode refers to the deactivation of a number of antenna arrays during low traffic periods. During the low load when the traffic and the numbers of connected users are lower than the expected threshold, the concept of channel reconfiguration can be adopted to achieve energy savings by switching off certain Transmit (Tx)/Receive (Rx) arrays at the RRU and AAU. For example, in the case of 8x8 or 4x4 MIMO, the RRU can be reconfigured to 2x2 MIMO mode. In the case of mMIMO 64T64R, 32 arrays can be switched off, which requires modifying a number of spatial streams and AAU Tx power. All these decisions can be made by AI/ML-based models deployed at the non-RT RIC and near-RT RIC. All the relevant Key Performance Indicators (KPIs) are collected by the RIC from E2 nodes and RRUs/AAUs for the xApps and rApps to execute the RF channel reconfiguration process.

CONCLUSIONS AND RECOMMENDATIONS

Open RAN is a relatively new market that is still evolving, with protocols and specifications still being fine-tuned. The new technology has a lot to offer and even traditional infrastructure vendors have committed to adopting the new concept in the future. Open RAN promises more supply chain diversity, more vendors, and, in the long term, better equipment in terms of performance and energy efficiency.

Our study indicates that the discussion on RAN energy efficiency needs to expand and take place on even terms between Open RAN and legacy radios. In the current state of the industry and 5G deployments, legacy mMIMO radios are widely deployed, and their performance, optimization, and energy efficiency are well understood. This is not the case with Open RAN, so further network tests, studies, and comparisons need to take place to fully understand their live performance on the field.

ABI Research's study further suggests that there are significant energy savings to be had with Open RAN AAUs and RRUs. The assumptions in this study are simplified on purpose and aim to compare like for like between legacy and Open RAN radios, while exactly the same scenario is tested for both cases. The Open RAN radios seem to perform better than legacy RAN across typical network RAN usage ranges observed in any matured network, which is likely throughout the forecast period. In case of extremely high network RAN usage though, which may not be a typical representation of commercial RAN network operating range, legacy RAN radios may perform slightly better, which may not be attributable to any Open RAN-related shortcomings. It may also be noted that the superior power-consumption performance of the specific units ABI Research profiled—within the Open RAN family of products—also depends on other factors like differential efficiency of the silicon vendor, differences in implementation techniques, and differences associated with the choice of process node and hardware design.

Legacy vendors have arguably spent significant efforts and capital to develop their mMIMO units, but Open RAN vendors are now quickly catching up. Our modeling indicates that both Open RAN mMIMO and non-mMIMO radios have a lot to offer in terms of performance, as well as in the energy efficiency domain, and mobile operators need to realize that Open RAN is now becoming a viable choice for their radio networks.

Published November 2023

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