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# Exploring the Opportunities, Benefits & Challenges of Open RAN Deployments

Oghenekevwe Kofi, Oluwatobi Allen
*LM Ericsson Nigeria Limited*

***Abstract***
*Open RAN is a brewing transformation force within the telecommunication industry, characterized by the virtualization and disaggregation of network architecture. Opening up interfaces and disaggregating hardware from software in Open RAN expands the possibilities of competition from non-traditional suppliers. The facilitation of multi-vendor collaboration and reduction in operational expenditure make the entire concept adaptive and cost-effective compared to proprietary networking. The main element constituting this technology involves active RAN services, harmonized radios, and software-defined mobile networking.*
*Open RAN certainly provides benefits, mainly relating to capital and operational expenditure reduction, scalability, and innovation. Yet challenges still remain. Chief among these are multi-vendor interoperability issues that may lead to potential integration problems and delays. In addition, there are regulatory and security concerns about the openness of the multi-vendor architecture. After all, with all these challenges, Open RAN represents enormous potential for revolutionary changes in the field of telecom and supports a better competitive and innovative environment, especially with developments towards 5G and beyond.*
*This is why the future of Open RAN seems so bright because of continuous progress related to artificial intelligence and cloud-native technologies-one thing that would lead to enhanced network management and service delivery, opening new vistas for business models and network optimization.*

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## I. Introduction to Open RAN Deployments

Open RAN is now a hot topic in the telecom industry. Operators can no longer ignore this new software-centric, virtualized, and disaggregated technology that appears to offer lower costs, a new competitive ecosystem with more suppliers, and provides a platform that offers the scope for innovation from non-traditional suppliers to infiltrate their value chains. Open RAN combines the use of open interfaces throughout the network. It aims to disaggregate hardware and software to provide highly capable interoperable components that deliver the same or better services as proprietary and single-vendor mobile networks. This paper provides insight into Open RAN: exploring Open RAN use cases or opportunities, why it is beneficial to deploy the technology, and the main challenges that still need to be addressed for deployment to become widespread practice. We examine the limitations of current mobile networks and argue that Open RAN can offer a real solution to these difficulties. Even if one considers the many challenges ahead for Open RAN, it remains an active area for innovation. We also present some ideas on what might come next. Central to Open RAN is the concept of creating a collaborative ecosystem, an opportunity that Open RAN supporters believe is hard to ignore. Such a cooperative approach to development is expected to result in a series of innovations that can assist with the transition to full 5G, but also have applications with existing LTE networks. If pursued, proponents argue that the Open RAN paradigm could provide a veritable cornucopia of agile technologies that can update current mobile technology. Over the last few decades of mobile telecommunications, the architecture of the networks that provide these services has been closed, proprietary, and vertically integrated, controlled primarily with a BSS/OSS and network-and-slice-based orchestrator. Consequently, software and hardware innovation and supply mostly fell to a few large suppliers, resulting in the same few companies dominating the main RAN and core network markets.

## II. Understanding Open RAN Technology

In 4G and 5G networks, Open RAN disaggregates the traditional RAN built upon small cells and macro cells to separate hardware and software components composed according to open and interoperable interfaces and integrated by multiple vendors. Since the virtualized network function in the base station is mainly implemented by software, this technology has the potential to facilitate competition from software vendors, including not only information and communication technology vendors but also new industry vertical vendors, and to provide a new network option. In this case, ICT and industry vertical vendors can supply and develop virtual RAN platforms and applications that run on a common data center pool of hardware resources and that are executed by appropriate computational and storage resources at the network edge instead of supplying the closed BBU hardware and software stacks in the corresponding domain. This paper illustrates the composition and implementation of Open RAN and discusses the relevant applications and communication and computation offloading services, which help to attract open applications and industrial users as well as virtual network operators to select virtual BBU racks and guarantee that the technologies and implementations of such racks are suitable for the open and diverse applications and services in the industrial edge domain.

### 2.1. Key Components of Open RAN

Open RAN focuses on opening up the RAN to a diverse ecosystem of supplier companies. Simply put, these key components together in a disaggregated RAN create Open RAN. However, when we start discussing how to change the RAN through the standards, it may not be simple, as there are eight key, tightly coupled system components that each have to work together harmoniously to achieve the goals of Open RAN. If all eight of these components are not carefully considered and well-coordinated, we will not see the economic benefits achieved from over commercial low-cost Ethernet. Instead, we will be left with high-cost RAN deployed anywhere with a one-size-fits-no-one solution.

The eight key components are: Active RAN Service, Harmonized Radio, Intelligent Controller, Open Compute Platform, Radio Unit/Remote Radio Unit, Software Defined Mobile Networking, System Software, and Hardware Abstraction Layer. Defining Open RAN in this manner does require an increase in what most of us have thought of in terms of a definition for RAN in the past. In the past, our concept of RAN has at the highest level, been one of two parts: the network infrastructure and the AIs. The network infrastructure included the policy and subscriber charging systems. With Open RAN, the network infrastructure includes the three new parts of Open RAN plus the Active RAN SDN, the old Active RAN, RAN Baseband, and Remote Radio Head systems.

## III. Benefits of Open RAN Deployments

One of the key advantages of embracing Open RAN deployments is that it promotes efficiencies in operations. Adopting and advancing established open standards will aid in operating and maintaining networks in an agile and flexible manner. In addition to this, lowering the barriers to entry for new vendors and solutions will prevent buy-in from a single vendor. Leveraging open standards through Open RAN will enhance competition and the overall market, providing opportunities and potential solutions from multiple vendors. Inherent to open arrangements, Open RAN fosters innovation. Service providers have the capability to look to new technologies and solutions that can be added to their Open RAN infrastructure from various companies promoting differing technologies. In addition to operational advantages, the concept of being able to extract more infrastructure resources and grow service offerings from one set of assets promotes capital efficiency. Through innovation, companies like service providers can look at new business models and services that can be underpinned by Open RAN efficiencies. Similarly, Open RAN introduces scalability and flexibility into infrastructure, thus enabling the ability for resources to scale up or down depending on need and potential cost savings. Furthermore, Open RAN deployments are designed and constructed on modular and disaggregated technology on open backhaul. The idea of this predictable environment means non-significant changes can be deployed more quickly. Time-to-market will be a distinct advantage in a market space where technological advances are occurring so rapidly. In conjunction with rapid deployment, moving away from a one-size-fits-all technology promotes innovative solutions for creating resilient and adaptive networks. Hyperscalers have identified the powerful capabilities cloud technology offers for resilience and agility, and with Open RAN, we will see more coordinated cloud development which makes networks function more as a utility. This utility approach spreads processing and networks far more dynamically across a network, not worrying about infrastructure limitations.

### 3.1. Cost Reductions

Disaggregating the RAN and opening the specifications of every component can lead to significant financial benefits for telecom operators. Once software is decoupled from hardware, it becomes less expensive to procure, deploy, and maintain. Open RAN promises a reduction in CapEx and OpEx thanks to the use of cheap, low-power general-purpose hardware managed by rich software, and by leveraging solutions from various vendors, thus avoiding lock-in. Besides the high-level promise of savings, various Open RAN cost models have been developed to clearly detail where any savings occur. One analysis found a RAN lifecycle cost reduction of 42% compared with a traditional RAN across 2G, 3G, 4G, and 5G services over a 10-year period. Most of those savings are to be found in OpEx, with 62%.

Open RAN is cheaper because it dismantles the radio box and builds the software necessary to communicate with equipment from many different suppliers; the biggest cost comes from controlling software development. The deep integration between software and hardware in legacy monolithic RAN designs creates OpEx maintenance and support expenses directly proportional to the amount of equipment within the network and almost null interoperability among the entire equipment. The deployment of Open RAN architectures is also simpler from an operational viewpoint due to the improved interoperability between the disaggregated devices and platforms, thus lowering support and service maintenance costs. Lifecycle costs from a high-level perspective show Open RAN can make significant savings compared to traditional RAN, even if the initial deployment and organization have higher costs.

## IV. Challenges in Open RAN Deployments

There are multiple likely challenges along the way from vendor integration to widespread Open RAN deployment. Integrating technologies, systems, and teams from multiple suppliers at the RAN/Transport solution, and especially at the VNF level, is a significant challenge. This is one of the reasons why the traditional end-to-end vendor ecosystem has been so popular. The fact is that traditional RAN has always been multi-vendor at the baseband level. For many years, Mobile Network Operators have been able to use either multi-standard RRHs based on their own methodologies or deploy cleverly placed enablers such as DAS, RRUs, sometimes repeaters, and other techniques such as Frequency Domain Coexistence along with antenna technologies to deploy multiple vendors.

Wider Open RAN, in the context of integrating diverse Radio Units and potentially diverse E2 interfaces connected to a virtualized central implementation, is a significantly different challenge. Some RAN engineering team members have argued that the integration of diverse RUs is excruciatingly painful and now, fundamentally limits the Open RAN testing program. It is also the case that moving from traditional RAN to Open RAN will be a huge challenge. Its potential success extremely depends on the outcome of a fundamentally destructive internal discussion. The 'RAN integrated' camp will likely push back aggressively no matter how tightly the vendor has engaged operators. This means that agile network design will require a close relationship between tech vendors and operators, allowing the former group to influence both decision-making as they collectively wade through a business and regulatory swamp in this nascent marketplace. What we may witness is disrupters and incumbents making 'manufactured' go-to-market decisions supported by grants, semi-soft loans, and attractive terms and conditions designed to skew market dynamics.

### 4.1. Interoperability Issues

Interoperability issues play a prominent role when it comes to ORAN networks. It is the major hurdle operators see while deploying ORAN. To communicate between different elements made by different vendors, there needs to be a set of open or standard interfaces that all vendors must adhere to. However, introducing elements from different vendors may result in interoperability difficulties. This introduces a risk of delay because, in case of any compatibility issues, most of the proof of concepts fail. Moreover, it is not feasible to run two networks – a separate open RAN network and the traditional RAN network – side by side, and as such, anyone deploying these architectures will want to avoid this scenario. Further, different parts of the network may also introduce incompatibility, as combining new functions and components into existing, previously installed infrastructures can open further issues. Emerging technologies often bring with them a bundle of incompatibilities in the initial stages. These situations are common and are by no means limited to ORAN networks. For instance, when IP phones emerged, the protocols used in these phones were not very well supported by the Internet Service Providers. Similarly, when cable modems were introduced, configuration protocols were not widely supported either. These issues were resolved over time as the technologies were embraced by the industry and were not limited to IP phone manufacturers to work on for resolution. In both cases, the technology was based on principles ultimately rooted in open-source tools, giving the broader industry visibility and a hand in guiding the technology to larger acceptance. Historically, interfacing different equipment using protocols has been invaluable. In the wired networking world, Data Over Cable Service Interface Specification provides that interface. In many ways, the underlying principles that guide open or standard interfaces are very similar, as they imply interoperability. Past examples of interface standards include the 5ESS and DPNSS in the fixed network for the provisioned networks. In xDSL services, ADSL recommendations were created for the interfaces between the line cards to facilitate interoperability. When working with interworking functions, like providing Wi-Fi for a mobile device or when giving dynamic fixed mobile convergence services, standard or open interfaces are valued. In today's ORAN world, while this approach is fascinating, it requires widespread adherence to the standard transfers, and if this is not achieved, situations such as the current lack will arise. Considering the industry's long assertion and convention of the importance of widely deployed open or standard interfaces, this is a noteworthy departure.

## V. Opportunities in the Open RAN Ecosystem

The content in this section reflects upon the myriad opportunities presented by the Open RAN ecosystem for leading telecom operators and technology providers.

The Open RAN ecosystem presents a significant upgrade opportunity for operators, allowing innovation at a rapid pace. Modern technology providers can become new collaborators or ecosystem enablers. More established companies can continue integrating provided software and hardware, forming a unique strength in their products and building a distinctive business around it.

Communication as a business needs to expand to new horizons and economic spheres. The Open RAN ecosystem may disrupt the mature market, just as OTT players did earlier. Cost will be a detractor in mature markets. Open RAN democratizes technology and will reduce barriers in communications. A global market and community of technology providers will push the Open RAN market to new frontiers. A small-sized company doesn't have to give away its contracts and business to monopolistic and oligopolistic companies anymore. Multilateral relations among companies in the technology providers' ecosystem can open a spate of new opportunities for business partnerships and collaborations. Open ecosystems provide a platform for developing new businesses and credibility for new entrants. Established brands can also take advantage by collaborating with newcomers through partnerships, investments, or mergers to create new business models and infuse growth engines. Newer mid-sized companies in emerging economies can leverage opportunities to expand into mature markets.

The Open RAN ecosystem signals potential for small-sized technology providers and developers to join the platform and disrupt the industry. It helps create new, innovative, and disruptive business models. Companies can create virtualized, AI/ML-driven Open RAN solutions that specifically address the 5G challenges in an efficient and productive manner. Solutions crafted to provide network slicing in 5G Open RAN technology will certainly make inroads. These network slicing mechanisms will also become valuable technological tools for telcos to navigate the value chains while providing services such as managing applications. As capital expenditure moves towards Open RAN AI/ML integrated network slicing mechanisms, operators can convert OPEX budgets into profitable incomes. These might be significant cost-heavy projects for companies initially, but over time, as more operators monetize their efficient network slicing projects through the Open RAN ecosystem, this adjacent service will spur the expansion of the 5G business into service markets. When operators deploy 5G Open RAN and network slices, companies can continuously optimize and provide managed services based on evolving artificial intelligence/machine learning sensing, insights, and root cause analysis.

## VI. Regulatory Considerations for Open RAN Deployments

Regulatory considerations influence Open RAN adoption across the globe. The policies and regulations to be followed by telecom operators and Open RAN solution vendors vary from country to country or even within a country. In Open RAN solutions, the telecom operator and Open RAN vendor jointly need to ensure compliance with various frameworks and principles laid out by their respective governing bodies and industry associations. Initiatives also propose regulations for the same. There are also some regulators that can potentially put hurdles in the growth of the Open RAN domain by offering significantly different and/or more stringent conditions and creating an uneven playing field. Given the ongoing debates on matters related to national security and privacy, there are also concerns regarding open innovations and privately governed initiatives by large corporations, including data management practices. Several working groups are actively collaborating with the government to draft the regulations and guidelines for Open RAN deployment. In the future, organizations may come out with regulatory compliance guidelines for technologies like Open RAN. With the right direction and approach by regulatory bodies today, the possibility of increasing competition in markets is high for both large and niche markets. But adaptability will be critical as changes in technology may result in the transformation of these regulations, since running regulations through various iterations becomes a necessity with open ecosystems. This poses both benefits for operators and early challenges for Open RAN architecture and standards for compliance.

## VII. Case Studies of Successful Open RAN Implementations

To showcase and promote the tangible and realistic deployments and results of Open RAN, we present case studies for Open RAN operations that span across various markets. These studies highlight different combinations of the importance of Open RAN integration, from cost reduction in remote island deployments, improving operational efficiency and redundancy in urban markets, deployment of a greenfield network, and the rollout of commercial, trial, and pre-commercial networks in various regions. These case studies show the benefits, lessons learned, real-world use cases, and applications of Open RAN technology in rural, non-densely populated areas as well as in dense, urban areas.

1. Rakuten Mobile (Japan): Rakuten's launch of a fully virtualized Open RAN network in Japan is often cited as one of the first large-scale commercial deployments of Open RAN. By leveraging software-defined networking (SDN) and cloud-native technologies, Rakuten was able to reduce network costs and speed up deployment timelines. The flexibility of Open RAN allowed them to use multiple vendors for different parts of the network, lowering dependency on single vendors and enabling competitive innovation.
2. Dish Network (USA): Dish is building a 5G network in the U.S. entirely based on Open RAN architecture. They aim to disrupt the traditional telecom model by using cloud-native and software-defined networks. This deployment focuses on reducing capital expenditure (CAPEX) and operational expenditure (OPEX) while enabling better customization and faster rollout of services.
3. Telefónica (Germany and UK): Telefónica has been one of the major telecom operators to adopt Open RAN in Europe. They have conducted successful trials in Germany and the UK to improve coverage in rural and underserved areas. The flexibility and cost-effectiveness of Open RAN allowed them to increase connectivity in regions where traditional networks would be too expensive to implement.
4. Vodafone (UK and Europe): Vodafone has deployed Open RAN technology across various sites in Europe, notably in the UK. Their pilot project in rural areas helped connect previously unserved regions, and they are now looking to scale this across their network. Vodafone's use of Open RAN has proven that the technology can work at scale in both urban and rural environments, helping to enhance coverage and reduce costs.
5. MTN (Africa): MTN has embraced Open RAN technology to expand its network in African countries. By adopting Open RAN, MTN has been able to lower the cost of deployment in rural and low-income areas while improving access to high-speed networks. Open RAN has also enabled MTN to modernize its network infrastructure more flexibly and cost-effectively.

In all these cases, the success of these deployments is down to the ability of the different components and elements to function together cohesively. This, in turn, is possible due to the extent of collaboration not only between the different working groups within Open RAN, but also between the vendors of the different components to test and integrate the RAN solution. Nevertheless, it should be stressed that these results and deployments show high confidence in the capability and commercial readiness for Open RAN. Management and operational aspects for new, innovative, and open technologies are, however, expected to remain a hurdle towards large-scale deployment. Possible solutions on this are described in the following sections.

## VIII. Security Aspects in Open RAN Deployments

Exploration of the security aspects becomes important in the context of Open RAN deployment due to the fact that it adopts a multi-vendor architecture, and each component of the multi-vendor solution adds its unique vulnerabilities to the security risk. Although conventional security measures including cryptography, encryption, and user authentication can be enabled in Open RAN, it is believed that these classical measures do not fully guarantee the security of the system, especially in the context of an open and software-defined environment. In general, the critical security aspects pertinent to Open RAN deployments are:

(a) data identity and trust verification,
(b) ownership and privacy protection for users and operators' data,
(c) network integrity and trust verification for critical, protected, licensed, or societal services,
(d) light data load security with illness information,
(e) device and user authentication based on verified identity,
(f) balanced trust levels with respective domains and networks, and
(g) secure updates of frequent and shared software.

Moreover, even though compliance with common security standards becomes mandatory, these individual components expand the security risk in Open RANs. In this perspective, Open RANs require an additional security framework to mitigate and handle the emerging security risks, potentially different from the traditional security systems. Applications of AI and ML-based smart security for continuous monitoring and threat assessment are imperative to counter potential security threats. Considering this, cooperation among diverse technology providers in order to develop and follow a robust security framework is mandatory. Even though detailed realization of the disintegrated system for security in Open RAN is still in its infancy, the regulatory compliance also plays a decisive role in carving the individual security norms to ensure the privacy and protection of the subscribers. Emerging security threats in an open RAN environment can jeopardize service delivery and consumer confidence, ultimately leading to revenue losses. Although Open RANs enable the integration of diverse access networks, they raise important security challenges. Conventional approaches that focus on the protection of service and user data may need to be re-envisioned in light of the broader and more complex vulnerabilities. In fact, infrastructure theft through reprogramming of remote radio units is a concern for operational networks. Besides, regulatory controls have to be in place for end-to-end service level and user agreements that are specifically addressed in Open RAN architectures to ensure privacy and protection of individual subscribers. Even though critical telecom services need to be provided with a security interoperable framework, it needs to be analyzed further in a competitive landscape. Regulatory norms and cross-verification requirements should provide multi-level compliance processes combining data source authenticity, network access, and service capability-to-authenticate route to check security at the policy enforcement level and flow through to a security assurance level.

## IX. Future Trends and Innovations in Open RAN Technology

Artificial intelligence, based on technologies like machine learning, is expected to play a major role in Open RAN evolution towards self-organized networks (SONs) where optimization problems are formulated as AI models with applications in network management and configuration. Traditional SON use cases could be improved in Open RAN either during the AI model training phase with the inclusion of RAN resource constraints and specific policy rules, or in the inference phase, with implementations running across the functional layers at the node, central space, or even leveraging distributed computing. It has also been proposed that AI models deployed in SON may collaborate with the radio controller for traffic management with predictive congestion avoidance and scaling for improved service resilience. Looking further ahead, the evolution from Open RAN towards Cloud-Native Open RAN is to be expected within this next decade, with operators moving from a 'virtualized' infrastructure to a Cloud-Native infrastructure built with microservices, containers, and orchestration technologies. This evolution is motivated by the improved ability to break down architectural silos, and hence realize 5G innovation opportunities with other industries, through the provision of low-latency policies to enable Edge Services. On one hand, players from the IT industry are expected to bring fresh innovation and competition to the RAN domain. With the improved ability to innovate from the cloud, the verticals will drive the network slicing capability to create innovative SLAs and business models. Through further scale and market share, operators' requirements, however, could have significant influences in the evolution of the cloud-native architectures and the way intelligence is implemented in Open RAN networks.

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