Open RAN Integration: *Run With It*

White Paper
April 2020

Table of Contents

Executive Summary

The Open RAN concept and movement is not new – mobile operators and network and technology vendors have been developing solutions, conducting trials and deploying networks for the last few years. The important point is that Open RAN networks are being deployed today by major operators around the world – this is no longer a science experiment.

The Open RAN concept is about disaggregating the RAN functionality by building networks using a fully programmable software-defined mobile network solution based on open interfaces – radios, base stations, etc. – that runs on commercial, off-the-shelf hardware (COTS) with open interfaces.

There are two main organizations driving Open RAN:

- OpenRAN refers to the project group that is a part of the Telecom Infra Group (TIP) whose main objective is the deployment of fully programmable RAN solutions based on GPPP/COTS and disaggregated software.

- The O-RAN Alliance is the other main driver of the Open RAN concept, focused on efforts to standardize interfaces. The alliance was founded in 2018 by AT&T, China Mobile, Deutsche Telekom, NTT DOCOMO and Orange.

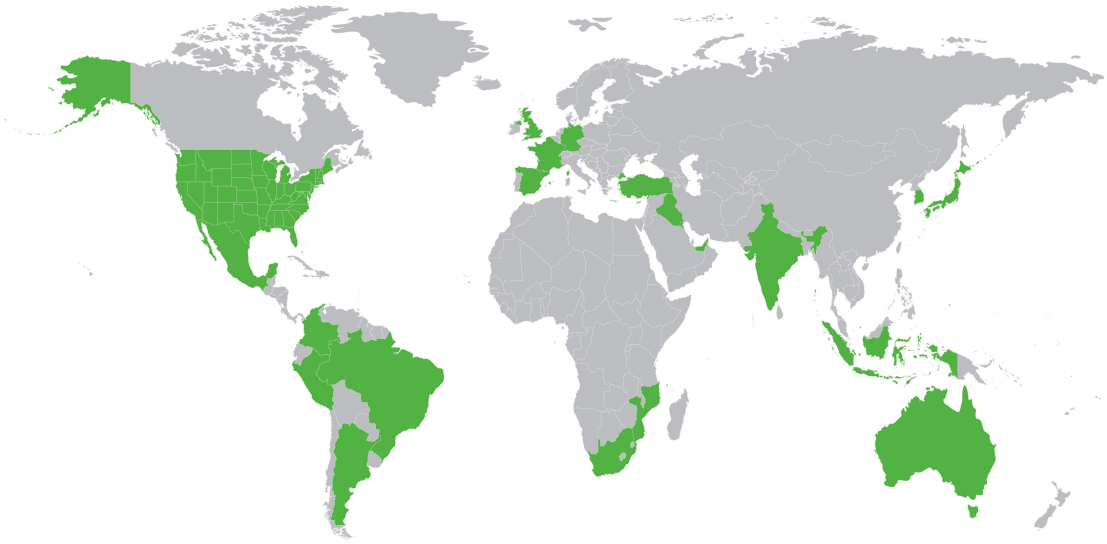
A recent important step in the development of the Open RAN ecosystem was an alliance agreement between the two organizations. The new agreement allows the two groups to share information, reference specifications and conduct joint testing and integration efforts.

Open RAN software and hardware vendors have been developing network solutions for the last few years. As part of the research for this paper, *iG*R identified 22 publicly announced MNOs around the world using equipment from multiple vendors, including Altiostar, Mavenir and Parallel Wireless, who had deployed Open RAN in *commercial* networks. These MNOs have collectively just over 1.199 billion subscribers in their commercial networks and operate in countries or regions with a total population of more than 2.4 billion.

This means that these operators are responsible for 21.8 percent of the world's mobile subscriber base. Furthermore, assuming the current trials convert to commercial deployments, *iG*R estimates that by 2024, Open RAN will be used by MNOs that collectively are responsible for 47.2 percent of the global subscriber base.

As a visual example of how widespread Open RAN is becoming, consider the following map: this shows the Open RAN announced commercial network deployments around the world, from the research iGR conducted in preparing this white paper.

Figure 1: Open RAN commercial deployments



Source: *iG*R; company reports; 2020

Clearly, Open RAN is no longer a regional solution, nor one that only applies to greenfield operators or MNOs in developing regions of the world. Open RAN has been deployed to support legacy 2G and 3G network technologies, as well as 4G LTE and 5G. It has been deployed in the most developed and competitive markets in the world, supporting some of the fastest growing regions.

These MNOs have realized significant savings in CapEx and OpEx and many have discussed this publicly. The benefits of deploying Open RAN are real. Consider:

- Accenture stated that 5G deployments that used COTS hardware and Open RAN software had seen CapEx savings of 49 percent compared to traditional deployment options.

- Senza Fili estimated the savings for a cloud RAN deployment to be 37 percent over five years, compared to a DRAN deployment. Specifically, the study showed a 49 percent savings in CapEx in year one and a cumulative 31 percent savings in OpEx over the five years.

- Strategy Analytics modelled the TCO of Open RAN over a five-year period. This model showed 40 percent lower CapEx and 34 percent lower OpEx compared to a legacy RAN.

Vodafone shared network performance information from its OpenRAN deployment in Turkey. Vodafone stated that the network has achieved 96 KPIs in both 2G and 4G networks; achieved QoS levels that are already acceptable (as of October 2019); and that, as of October 2019, that network optimization was

ongoing, and they expected to achieve all of the target KPIs soon. And in April 2020, Vodafone Idea announced that OpenRAN has been deployed on multiple cell sites and has been carrying commercial traffic since December 2019.

Rakuten is considered to be a text book example of how Open RAN can support a nationwide mobile operator. In 2019, the Japanese carrier was the first to implement a multi-vendor RAN, using products from Altiostar, Airspan, Mavenir, Nokia and others. Nokia opened up their radio interfaces to Altiostar's BBU which was running on a Cisco virtualization platform. Other functions within the network were also multi-vendor such as the EPC from Cisco, and IMS and RCS applications from Mavenir. Rakuten's network began as an LTE network consisting of both macro and small cells. The company has said it will evolve its network to 5G NR in 2020.

In April 2020, just as the research was being finalized, Dish Network announced the first vendor selection (Mavenir) for its 5G Open RAN nationwide network deployment, using spectrum Dish has acquired over the last few years.

This shows how cloud, virtualization, openness and vRAN architectures and practices can be applied to a new network deployment. With Rakuten, a legacy vendor opened their interfaces to support Open RAN radios and baseband units from other vendors. Rakuten's CTO Tareq Amin has said the Open RAN framework has proved approximately 40 percent less expensive than traditional telecommunications infrastructure (Source: Light Reading; SDX Central, 2020). According to press reports, Rakuten deployed lean cell sites, with only antenna and remote radio heads, easing site acquisition and reducing deployment costs, and uses virtual RAN (vRAN) for baseband processing.

The takeaway here is that Open RAN is real; Open RAN can be, and is being, deployed in commercial networks today; the Open RAN community is coalescing and coordinating to move deployments along; the cost savings are being realized; and operational performance requirements and KPIs are being met.

What is Open RAN?

Fundamentally, the Open RAN concept is about building networks using a fully programmable software-defined radio access network solution based on open interfaces – radios, base stations, etc. – that runs on commercial, off-the-shelf hardware (COTS) with open interfaces. Traditionally, mobile networks have been built with closed, proprietary software and purpose-built hardware. But today, mobile networks can be disaggregated and based on the Open RAN concept.

In this context, disaggregation means separating the hardware from the software. The 3GPP introduced this concept in Release 14 of its specification with the Control and User Plane Separation (CUPS) of evolved packet core (EPC) nodes and the O-RAN Alliance produced the Open RAN specifications. With 5G New Radio (NR) in 3GPP Release 15 and beyond, this split is continued with the Service Based Architecture (SBA). 5G NR further abets disaggregation by continuing the split between control and user plane all the way down into the 5G base stations and radios with the central unit and distributed unit.

The main reasons to move away from the old, vertically integrated model to the Open RAN concept are those that drive virtualization of data centers and enterprise networks and the disaggregation of hardware and software:

- Take better advantage of the rapid advances in computing power delivered by Moore's Law. The data center industry experienced a similar disruption back in the 2000s.

- Use software components to not only implement core network, radio and base station functionality, but also introduce new capabilities as they are developed.

- Use best of breed components and software in architecting building the infrastructure for the network.

- Reduce capital and operational/maintenance expenses since there is competition among many different layers of the hardware and software supply chain. Operation and maintenance of an Open RAN system is simplified because the hardware is standardized, standardized interoperable interfaces and open APIs are used, DevOps approaches can be utilized, and the software does not rely on purpose-built components.

- Enabling edge centric architecture – multiple mini data centers can be built closer to subscribers, especially in high population areas, to serve subscriber needs, support low latency connectivity for 5G applications and provide scalability for both devices and applications.

- Expand the supply chain for RAN solutions, thereby diversifying the ecosystem of vendors from which MNOs can procure network equipment.

The Open RAN ecosystem

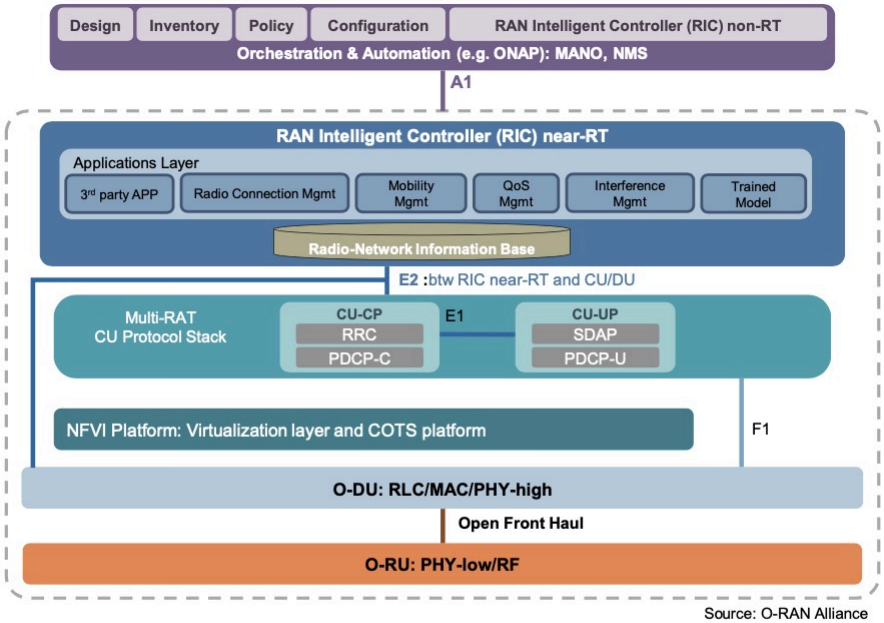
There are two main organizations driving Open RAN movement:

- OpenRAN refers to the project group that is a part of the Telecom Infra Group (TIP). The main objective is the deployment of fully programmable RAN solutions based on GPPP/COTS and disaggregated software so that operators and vendors can benefit from the flexibility and faster pace of innovation capable with software-driven development.

- The O-RAN Alliance is the other main driver of the OpenRAN concept, especially the efforts to standardize interfaces, in addition to the TIP. Founded in 2018 by AT&T, China Mobile, Deutsche Telekom, NTT DOCOMO and Orange, the O-RAN Alliance's goal is to foster the development of reference designs and standards such that current and future RANs can be built with "virtualized network elements, white-box hardware and standardized interfaces that fully embrace O-RAN's core principles of intelligence and openness." (Note: The O-RAN Alliance was created by merging the C-RAN Alliance and the xRAN Forum.)

The following graphic summarizes the components of the O-RAN Alliance's reference architecture.

Figure 2: O-RAN Alliance Architecture



CP: Control Plane
MAC: Media Access Control
MANO: Management and Orchestration
NFVI: Network Functions Virtualisation Infrastructure
ONAP: Open Network Automation Platform
PDCP: Packet Data Convergence Protocol
PHY: PHYsical layer
RAT: Radio Access Technology
RF: Radio Frequency
RLC: Radio Link Control
RRC: Radio Resource Control
SDAP: Service Data Adaptation Protocol
UP: User Data Plane

Source: O-RAN Alliance, 2019

A recent important step in the development of the Open RAN ecosystem was an alliance agreement between the two organizations to ensure they were in alignment in developing interoperable, disaggregated and Open RAN solutions. The new agreement allows the two groups to share information, reference specifications and conduct joint testing and integration efforts.

Inherent in Open RAN is support for existing radio access networks in addition to 5G Nonstandalone (NSA) and Standalone (SA) networks. There are many parts of the world where all of these various technology generations must be supported; Open RAN actually allows that to happen on the same infrastructure.

To achieve this goal, the Open RAN movement helps enable a broader and vibrant open ecosystem of complete solutions and solution components that take advantage of the latest capabilities of GPPs, both at a software level and also using readily available programmable offload mechanisms such as field-programmable gate arrays (FPGA), and open interfaces.

Virtualization and openness

It is important to understand that virtualization and openness are not the same thing. Virtualization is disaggregation of hardware and software by abstracting the software application from the underlying hardware. A RAN can be virtualized but not be open – i.e., the software and/or the hardware could be proprietary, or the interfaces could be closed.

Being truly "open" means that there are reference designs and standards for hardware and software such that there are open interfaces with no proprietary interfaces and/or hardware in the RAN. For example, a COTS remote radio head/unit (RRH/U) from Vendor A will be able to talk via open interfaces to (proprietary) software running on a COTS server with (virtualized) network functions from Vendor B.

Note that openness does not mean that all hardware and software will be the identical for all mobile networks. Vendors will compete to produce all of the hardware and software such that operators will have a broad selection in terms of scale, scope, features and cost. Due to the open interfaces and standardized hardware, the network software will run on COTS and talk to hardware and software from other vendors. This will lead to a wider procurement ecosystem from different vendors.

Open RAN components

The goal of this paper is not to describe in detail the technologies involved in Open RAN – the various technologies and architectures are complex and difficult to cover in a short white paper. There is a range of network architectures that are needed to address the specific needs of different mobile operators around the world and it is expected that vendors will interoperate to create customized solutions to meet these requirements.

Moving forward into the world of 5G NR which, in 3GPP terms are Release 15 and beyond, the specifications require the RAN to become a new, disaggregated grouping of functional elements (as has been discussed earlier in this paper). The 5G base station, known as the gNB (as opposed to the eNodeB or eNB in LTE), is comprised of several functional units:

- The radio unit (RU) which comprises the RF chain, to transmit or receive the over-the-air signal and provide corresponding transformation of the analog radio signal and the digital signals.

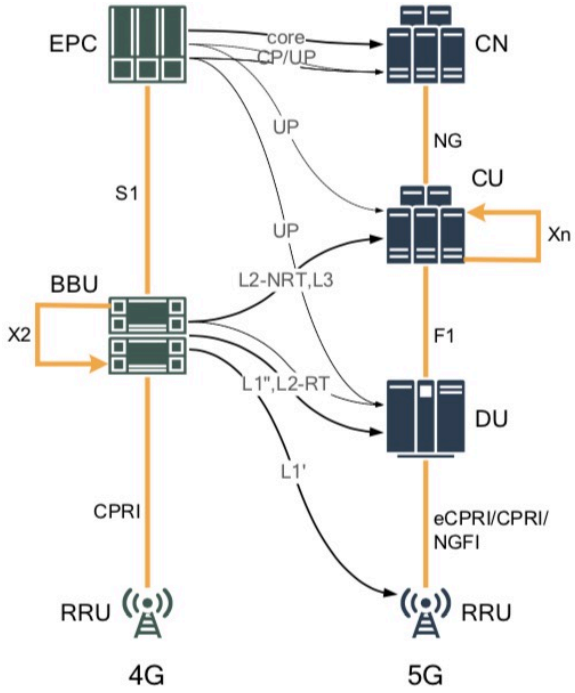
- The distributed unit (DU) which handles the lower layers of the baseband processing up through the PDCP layer of the protocol stack. In legacy systems, this runs on a proprietary hardware appliance, but today's software (which runs on COTS) allows this function to be virtualized. Since it is virtualized, this gives flexibility in terms of placing the processes at different locations which may include the cell site, far edge locations and/or the centralized locations. These functional splits are defined in the 3GPP specifications and their placement is selected based on type of transport available to the cell sites.

- The centralized unit (CU) handles all higher layer functions of the protocol stack from PDCP and above.

As has been stated, the goal of Open RAN is to create open interfaces so that the hardware and software from different vendors can interoperate and talk to each other. One key initiative is the TIP Evenstar program which has developed a Remote Radio Head (RRH) that will be available in the second half of 2020. The Evenstar RRH decouples the base components of the RRH and will support the O-RAN Central Unit-Distributed Unit (CU-DU) architectural split known as 7.2. Beyond this, other vendors including MTI, Gigatera Communications, NEC, Airspan and Fujitsu have announced that they plan to provide radios in various configurations which will adhere to Open RAN specifications.

The following graphic shows the 4G RAN and core network as compared to the 5G RAN and core.

Figure 3: 4G RAN and the CU-DU Split in the 5G RAN



Source: Transport network support of IMT-2020/5G, ITU-T Report, February 2018

Note that in 5G, the BBU function from LTE is split between the CU and DU and this depends on which path the mobile operator is taking toward 5G, as there are many options that accommodate incumbent 2G, 3G and 4G networks, as well as the level of integration between the current network and a new 5G network.

The 3GPP defined multiple deployment options for carriers that are migrating to 5G NR from LTE. Two of the most likely paths are:

- **Option 1 to Option 3x to Option 7x to Option 4a to Option 2:** This path assumed that the operator already has an extensive RAN and a core network (EPC) that it wants to leverage before introducing a 5G core. The current roadmap assumes that Option 3 is already deployed, that Option 2 will be deployed when ready, and that the two configurations will coexist for some time. This path involves using multiple radio access technologies.

- **Option 1 to Option 3x to Option 4a to Option 2:** This path also assumes the existence of a RAN and core, but the move directly to 4a implies that 5G RAN coverage gets built out, the 5G core introduced and then the operator moves directly to 4a or Option 2.

It is *iG*R's understanding that the main differences between these two routes involve the extent of the changes and how long the process takes. These options enable operators to leverage the existing EPC that they have in their networks and allow for a migration path towards 5GC. It appears that both Option 3 and

Option 7, regardless of the sub-type, are interim steps and the amount of time the operator spends in either option will depend on many external and internal variables.

And consider that regardless of how quickly mobile operators might want to move in the migration, they will likely be required to support multiple radio access technologies (RATs) for at least 10 years if not longer due to market and regulatory demands. Thus, the ability to support incumbent network technologies cost-effectively becomes even more important.

Industry challenges that drive Open RAN

The legacy RAN vendors have provided solutions that are proprietary and siloed for each air interface generation. By virtue of their established base of traditional mobile operator radio infrastructure, these vendors may position themselves to provide some of the benefits associated with virtualization and they may comply with the 3GPP release specifications, but they are not required to open up their hardware/software interfaces to other equipment vendors.

Therefore, they continue to promote and provide only closed, proprietary systems that are only in their best interests and not creating a future-proof network for their operator customers, although it is completely within their capabilities today. In some cases, the legacy OEM's reluctant decision to open up any part of their hardware/software architectures has been driven by the requirements of some of their incumbent mobile operator customers.

In part, one of the drivers for Open RAN has been the need to expand the radio ecosystem – the reality is that there are relatively few radio vendors available today. The radio is one of the most important components in a mobile network, it provides the link between the subscriber and the network and is therefore widely deployed. Growing the radio ecosystem is therefore seen as important for the success of the Open RAN movement.

Deploying and maintaining/optimizing traditional networks requires a lot of manual labor and results in high cost. This can be addressed with the automation/DevOps approach in Open RAN solutions. DevOps has been defined as the practice of development and operations and engineers (hence DevOps) working together from the service design all the way through the development process to production support. And by introducing Continuous Integration/Continuous Development (CI/CD) models from the cloud domains of the IT industry, operational costs can be reduced significantly, and new features can be rolled out faster.

Benefits of Open RAN

From the mobile operator's point of view, benefits of Open RAN include:

- Lower costs – both CapEx and OpEx

- Lower deployment times – Using virtualized RAN, benefits like automation can reduce the average time for deploying a site. And a virtualized RAN combined with centralization can be deployed faster than a traditional architecture since the only site installation required is for the radio and power. The remainder of the installation uses remote software loads managed through central operation center which do not require an additional site visit.

- Upgrade options from multiple vendors to future-proof the network evolution. MNOs do not have to depend on the roadmap evolution of a single vendor to roll out new features.

- Minimizes the danger of vendor lock-in - the incoming Open RAN vendor's equipment will work with the incumbent and future vendors' solutions

- Easier to scale because disaggregating hardware from software can enable carriers to respond more quickly and in a more targeted fashion when they need to increase/decrease or relocate capacity

- Ability to add massive scale if needed using web scale approach.

The last bullet highlights one of the main architectural benefits of Open RAN networks. Since edge computing is being deployed by mobile operators around the world, the edge compute architecture can be used for Open RAN – containers can be used to push changes (using automation) to the network, using the DevOps model. This means that the RAN is essentially following the same development curve as the data center did, with the corresponding benefits.

In addition, to further support mobile operators as they transition to 5G, Open RAN also supports legacy 2G, 3G and 4G LTE network technologies.

Moving forward, the need to continue supporting LTE while also transitioning to 5G adds more complexity to an already complex RAN. Not only will carriers be introducing new frequency bands (such as mid-band/CBRS and mmWave), layering in new carrier aggregation schemes, adding small cell sites, adding capacity to macrocells, coordinating capacity among small cell sites and macrocells, swapping out old antennas for new, they will also need to support edge computing solutions and new applications – VR/AR, IoT, etc.

Opening up the RAN so that operators can introduce comparatively less expensive COTS and best-of-breed software can help operators' future proof their networks and become more flexible in their operations. This model leverages well established practices from the cloud domain in the IT world and is applying them into the mobile telecom space.

Open RAN integration

Open RAN is being deployed in multiple markets by multiple MNOs around the world. They are large scale deployments in some of the largest countries in the world.

It is important to understand there are two levels of integration required when discussing Open RAN networks:

- Open RAN ecosystem integration includes the hardware, software, systems integrators, data centers and MNOs. In this case, the systems integrator will be responsible for integrating across the entire solution including integrating open radios. To ensure the ecosystem thrives and performs as required, the SI must be impartial and not aligned or associated with a specific hardware or software vendor.

- System integration of the Open RAN software on COTS hardware. This level of integration is similar to what occurs in the data center environment. In fact, many of the same tools and principles are used, which further eases Open RAN adoption.

- In addition to this, multiple vendors from the ecosystem can come together to self-integrate and certify their solutions to create a blueprint that mobile operators can use directly into their networks.

Systems integration can be provided by a variety of companies and can be provided by one vendor if needed. This situation is similar to what the MNOs use today – there is no reason that Open RAN cannot be as simple and easy to integrate and deploy as the RAN is today.

Despite this activity, many of those critical of the open network movement and trying to preserve proprietary systems still present arguments against Open RAN – these are old arguments that were leveled in the past but are no longer relevant. The following table discusses those arguments and why they no longer apply.

Table 1: Easy to Counter – the arguments against Open RAN integration

	OLD ARGUMENT	DETAIL	CURRENT SITUATION
1	MNO will need to integrate Open RAN solutions themselves	• Since multiple vendors are required for an Open RAN deployment, solution is not integrated • MNO will therefore be responsible for the cost of integration	• Numerous Open RAN deployments in live MNO networks • Multiple vendors have developed their Open RAN solutions specifically to be integrated onto hardware and with other software • Systems Integration can be done by vendors or operators

	OLD ARGUMENT	DETAIL	CURRENT SITUATION
		• This will lead to higher overall costs and delayed time to market	• Hardware and software vendors have followed data center integration best practices which are well established in the IT world • MNOs that have deployed Open RAN have said integration costs are no higher than with the traditional single-vendor approach • Note that traditional approach to deploying RAN also requires integration between different vendors – for example, for OSS/BSS, EPC and RAN and there are associated service agreements with each vendor
2	High risk for network reliability	• Since network elements are from different vendors, network reliability will be compromised • Identifying network issues will be more complex due to the solution using multiple vendor software and hardware	• Open RAN network deployments have demonstrated ability to support large subscriber bases and meet network performance KPIs • Network management tools have been developed for Open RAN, meaning that any issues can be quickly identified and resolved • Modularity will help operators audit and determine problems with their network faster.
3	Lower overall network performance	• Since network elements are from multiple vendors, the overall network performance will be compromised • Disparate network elements cannot be integrated to maximize performance	• Real world Open RAN network deployments have demonstrated ability to support large subscriber bases and meet network performance KPIs. • Vodafone shared KPIs from its Open RAN deployment in Turkey that are comparable to KPIs from the legacy vendors • Software-based RAN allows for more rapid deployment of upgraded features, thereby allowing the operator fine tune performance features for their network and roll out advanced new features like carrier-aggregation to boost performance. • DevOps approach with CD/CI can push updates quickly to many different sites, all automated and orchestrated
4	Lower CapEx solution cost savings not realized	• Use of disparate RAN vendors results in higher initial costs, since overall volumes are lower than	• Actual Open RAN network deployments by multiple MNOs have resulted in significantly lower costs – both CapEx and OpEx (40 percent according to Rakuten)

	OLD ARGUMENT	DETAIL	CURRENT SITUATION
		from using a single RAN vendor	• Numerous TCO studies also prove and support similar CapEx and OpEx savings (up to 40 percent) • COTS hardware is generally lower cost, due to massive scale spread across enterprise IT, data center industries etc • Software can be developed and scaled quickly and at lower cost using modern tools and practices such as DevOps, etc leading to lower operational costs.
5	Overall costs higher than traditional	• Even allowing for a lower software-based RAN solution on COTS, argument is that the overall deployment cost (including integration) will be higher	• Actual Open RAN network deployments by multiple MNOs have resulted in significantly lower costs – both CapEx and OpEx (40% Rakuten) • Some MNOs have stated that Open RAN integration costs have actually been lower than for the traditional approach
6	Systems integration lacking	• Open RAN solutions have not been integrated • Argument is that software solutions are not integrated, and that software is not integrated onto hardware	• Multiple MNO deployments show that different software components have been integrated • Rich ecosystem of vendors for radios, baseband hardware and software are already working together to ensure integrated solutions are available to the market
7	Less secure	• Lack of integration, argument is that Open RAN deployments are inherently less secure than the traditional single-vendor approach	• Open RAN deployments have followed data center, private cloud, and enterprise IT integration and security best practices • More auditable interfaces for an MNO to take control of their own security versus a black box approach by traditional vendors • Security is a joint responsibility across the vendors and the MNO versus a single vendor
8	Ecosystem not developed to support MNOs	• Since Open RAN is so new and untested, there is no developed ecosystem of vendors to support the national MNO • Therefore, the MNO will be responsible for many installation, maintenance	• Open RAN now supported and deployed by some of the largest hardware and software vendors in the world. For example, Rakuten is using an IMS from Mavenir, and Open RAN architecture from Cisco, Altiostar and Nokia to create an E2E cloud architecture. IpT and Vodafone deployments also utilize components from different vendors

	OLD ARGUMENT	DETAIL	CURRENT SITUATION
		and operational tasks themselves	• Also, now a wide range of specialist RAN software vendors developing and deploying solutions • Multiple vendors in the ecosystem who are coming together to create blueprints that will ensure the solutions are not only available but well tested. • Many companies in the ecosystem such as Intel, Cisco, Fujitsu, MTI, VMware, Qualcomm, Airspan, NEC, Dell, Red Hat, Quanta, Gigatera Communications, Xilinx, Sercomm, Supermicro and others have announced that are building or contributing to Open RAN. • The radio hardware ecosystem is rapidly developing with TIP leading the Evenstar hardware development.
9	Only suited to greenfield MNO deployments	• Open RAN does not integrate well with the existing legacy 2G and 3G deployments • The number of actual deployments, and therefore the scale, is therefore limited to greenfield MNOs only	• Multiple MNO deployments show that Open RAN can support legacy technology networks as well as new 4G LTE and 5G deployments • Some of the largest MNOs are deploying Open RAN for their running legacy architecture networks

Source: *iG*R, 2020

Open RAN Case Studies

Open RAN software and hardware vendors have been developing network solutions for the last few years (the OpenRAN Project Group was launched by the TIP at the TIP Summit in November 2017). After several trials, there are a number of commercial deployments with many more in the pipeline, as well as numerous trials by major national and multi-national MNOs.

As part of the research for this paper, *iG*R identified 22 publicly announced MNOs around the world using equipment from multiple vendors, including Altiostar, Mavenir and Parallel Wireless, who had deployed Open RAN in commercial networks. These MNOs have collectively just over 1.199 billion subscribers in their commercial networks and operate in countries or regions with a total population of more than 2.4 billion.

This means that these operators are responsible for 21.8 percent of the world's mobile subscriber base. Furthermore, assuming the current trials convert to commercial deployments, *iG*R estimates that by 2024, Open RAN will be used by MNOs that collectively are responsible for 47.2 percent of the global subscriber base.

Clearly, Open RAN is no longer a science experiment or a regional solution, nor one that only applies to greenfield operators or MNOs in developing regions of the world. Open RAN has been deployed to support legacy network technologies, as well as 4G LTE and 5G. It has been deployed in the most developed and competitive markets in the world supporting some of the fastest growing regions.

These MNOs have realized significant savings in CapEx and OpEx – many have discussed this publicly. Other studies point to similar savings:

- Accenture stated that 5G deployments that used COTS hardware and Open RAN software had seen CapEx savings of 49 percent compared to traditional deployment options (Source: Accenture Strategy, 2019).

- Goldman Sachs has also published some cost savings for Open RAN: 50 percent CapEx and 35 percent OpEx savings; and efficiency gains from taking 10 minutes to deploy a virtualized radio site (Source: Goldman Sachs Global Investment Research, 2019).

- Senza Fili estimated the savings for a cloud RAN deployment to be 37 percent over five years, compared to a DRAN deployment. Specifically, the study showed a 49 percent savings in CapEx in year one and a cumulative 31 percent savings in OpEx over the five years. The CapEx savings mainly come from reduced equipment costs in the virtualized BBU. (Source: *How much can operators save with a Cloud RAN?* White paper, 2017)

- Strategy Analytics modelled the TCO of Open RAN over a five-year period. This model showed 40 percent lower CapEx and 34 percent lower OpEx compared to a legacy RAN. Strategy Analytics stated Open RAN cost savings of $93.852 per macrocell site excluding cell site costs and $204,390 per macrocell site including cell site costs. (Source: Strategy Analytics, 2019).

This section details some of the major Open RAN deployments around the world.

Vodafone

Vodafone has been heavily engaged in Open RAN efforts from the start of the initiative. The multi-national operator has stated that it has three main goals for its Open RAN involvement:

- To spur innovation through building an ecosystem,
- To enable supplier diversity and,
- To reduce deployment and maintenance costs.

Vodafone recently noted that "the global supply of telecom network equipment has become concentrated in a small handful of companies over the past few years. Vodafone has claimed that a greater choice of suppliers will safeguard the delivery of services to all mobile customers, increase flexibility and innovation and, crucially, can help address some of the cost challenges that are holding back the delivery of internet services to rural communities and remote places across the world. Vodafone has been trying to do something about this lack of choice by accelerating Open RAN development and deployment through TIP. For example, in Turkey, Vodafone was able to modernize its network with Parallel Wireless using the Open RAN architecture.

Vodafone has deployed Open RAN in rural and low ARPU markets as well as more urban and higher ARPU markets. For example, Vodafone has used Parallel Wireless to help run live traffic in Turkey, in the Democratic Republic of Congo (DRC), and in Ireland and Mozambique (Mavenir).

At the TIP Summit in Amsterdam, Netherlands, in 2019, Vodafone shared network performance information from its OpenRAN deployment in Turkey. Vodafone stated that:

- Achieved 96 KPIs in both 2G and 4G networks
- Achieved QoS levels are already acceptable (as of October 2019)
- In the 2G network, KPIs were exceeded with the TCH congestion rate and the call set-up success rate

- For 4G LTE, KPIs were exceeded on the RRC set-up success rate, the interRAT handoff success rate, the intraRAT handoff success rate and the circuit-switched fall back success rate.

Vodafone stated that, as of October 2019, network optimization was ongoing, and they expected to achieve all of the target KPIs soon.

Rakuten

In 2019, Rakuten was the first to implement a multi-vendor RAN, using products from Altiostar, Airspan, Nokia and others. Rakuten's network began as an LTE network consisting of both macro and small cells. The company has said it will evolve its network to deploy 5G NR using radios from NEC and a container-based solution from Altiostar.

Rakuten's network is a text book example of how cloud, virtualization and vRAN architectures and practices can be applied to a new network deployment. In this case, Nokia opened their interfaces to support the baseband solution from Altiostar. In this network, Altiostar has virtualized the CU and DU to run on commercially off-the-shelf hardware from Quanta in a virtualized environment from Cisco. Rakuten's CTO Tareq Amin has publicly stated that the Open RAN framework has proved approximately 40 percent less expensive than traditional telecommunications infrastructure.

According to press reports, Rakuten deployed lean cell sites, with only antenna and remote radio heads, which is making it easier to find appropriate cell sites. By using virtualized RAN, Rakuten is able to deploy hundreds of sites in a few weeks, leveraging cloud-scale automation.

Rakuten's network uses a carrier-grade telco cloud for all virtualized applications from RAN to core which includes a common orchestration layer on top. Central and regional software-defined data centers will be capable of tens of terabits of capacity, horizontal scale, automation and analytics.

Rakuten has the ability to host a variety of services and applications at various central or far-edge locations along with the RAN workloads. This enables various types of network slices to be enabled, forming the basis for how applications will be deployed in 5G. The mobile network is using a Control and User Plane Separated packet core, along with its distributed telco cloud, to enable mobile edge computing for both infrastructure functions and a variety of low-latency services.

Rakuten Mobile Network has less than 10 SKUs in order to enable infrastructure standardization, leading to not only economies of scale in procurement, but also reduced operational complexity.

IpT

Internet para Todos Perú (IpT Peru) launched in May 2019. The company is owned by Telefónica, Facebook, IDB Invest and CAF banks. IpT Peru has deployed hundreds of new mobile sites in Peru using the Parallel Wireless virtualized and automated Open RAN architecture.

With the Parallel Wireless OpenRAN Controller, IpT has created a multi-vendor, multi-operator, open ecosystem of interoperable components for the various RAN elements and from different vendors. All new radio units are self-configured by the software, which reduces the need for manual intervention. The self-optimization capability automates optimization across different RANs in IpT Peru's network, utilizing available RAN data from all RAN types (macros and small cells). This functionality has allowed IpT to create a business model where MNOs can partner with local companies that focus on rural coverage.

IpT Perú, Telefónica and Parallel Wireless have also implemented an operating model built on the principles of the data center with continuous integration and continuous delivery (CI/CD) that helps to accelerate taking new functionalities to market faster and safer than ever before, in an easy and automated way. This approach has helped to establish a new operating model to reduce IpT Perú's OpEx, to be able to manage much faster product lifecycles and to speed up the deployment of new applications for coverage and capacity scenarios.

MTN

MTN plans to deploy Open RAN technology at more than 5,000 rural sites in Africa across their 21 operations in order to bring mobile connectivity to those regions. MTN has partnered with Parallel Wireless, VANU and NuRAN Wireless.

According to MTN, the company concluded field trials in Zambia in 2018 and had begun deploying commercial sites from the beginning of 2019. As of October 2019, MTN deployed 200 commercial rural sites across its footprint using Open RAN.

MTN has stated that Open RAN offers cost savings of up to 50 percent on the network systems compared with the cost of "traditional" radio access network equipment.

Open Test and Integration Center

In September 2019, the Open Test and Integration Center (OTIC) initiative was launched by a group of global operators, vendors and systems integrators. The group includes China Mobile and Reliance Jio along with participation from China Telecom, China Unicom, Intel, Radisys, Samsung Electronics, Airspan, Baicells, CertusNet, Mavenir, Lenovo, Ruijie Network, Inspur, Sylincom, WindRiver, ArrayComm, and Chengdu NTS.

The OTIC was founded to facilitate OEM and other open source products and solutions to be functionally compliant to the specifications of the O-RAN Alliance, through verification, integration and testing of disaggregated RAN components and to deliver the desired architecture that supports a plug-n-play model.

The initial focus is to ensure that RAN components from multiple vendors support standard and open interfaces and can interoperate in accordance with O-RAN test specifications. Additional partners will be invited to join over time.

The ultimate goal is to develop an ecosystem with many different solutions from which operators can choose. And having gone through the OTIC process, these solutions will be assured to work together. Systems integrators can also select from these solutions to build product portfolios that they can bring to the operator market.

Vendor profiles

This paper was sponsored by Altiostar, Mavenir and Parallel Wireless. A brief overview of each company is provided here. See each company's website for more details.

Altiostar

Altiostar provides a 4G and 5G virtualized RAN software solution that supports open interfaces and disaggregates the hardware from the software to build an open multi-vendor web-scale cloud-based network. This solution supports macro and small cells, indoor and outdoor, enabling interference management, carrier aggregation and dual reception to improve the efficiency of the network and enhances the Quality of Experience for the user while providing broadband speeds.

For more details, go to www.altiostar.com.

Mavenir

Mavenir accelerates and redefines network transformation for Service Providers by offering a comprehensive product portfolio across each layer of the network infrastructure stack — from 4G/5G application/service layer to the 4G/5G RAN and packet core. Through its industry first VoLTE, VoWiFi, Advanced Messaging, Multi-ID, vEPC and Cloud RAN solutions, Mavenir's platform enables service providers to successfully deliver innovative new services, lower costs and realize new revenue streams. Mavenir offers a fully virtualized end-to-end portfolio of Voice/Video, Messaging and Mobile Core and Access solutions.

For more details, go to www.mavenir.com.

Parallel Wireless

Parallel Wireless is a U.S.-based company challenging the world's legacy vendors with the industry's only unified ALL-G (5G/4G/3G/2G) software-enabled Open RAN solution. Its cloud-native network software reimagines network economics for global mobile operators in both coverage and capacity deployments, while also paving the way to 5G. The company is engaged with 50+ leading operators (Vodafone, IpT/Telefonica, MTN, Zain, Etisalat, Cellcom, Inland Cellular, OptimEra, Optus publicly announced) worldwide. Parallel Wireless's innovation and excellence in multi-technology, open virtualized RAN solutions have been recognized with 72+ industry awards.

In February 2020, Parallel Wireless won two GLOMO awards. The first was "best mobile infrastructure for global Open RAN deployments with Vodafone and TIP for its solutions deployed in Turkey and the Democratic Republic of Congo (DRC). Vodafone will now roll out the Parallel Wireless solution across Europe. The

second award was for its Open RAN Controller and Network Software Suite as best network software breakthrough.

For more details, go to www.parallelwireless.com.

About *iG*R

*iG*R is a market strategy consultancy focused on the wireless and mobile communications industry. Founded by Iain Gillott, one of the wireless industry's leading analysts, we research and analyze the impact new wireless and mobile technologies will have on the industry, on vendors' competitive positioning, and on our clients' strategic business plans.

A more complete profile of the company can be found at http://www.iGR-inc.com/.

Disclaimer

The opinions expressed in this white paper are those of *iG*R and do not reflect the opinions of the companies or organizations referenced in this paper. All research was conducted exclusively and independently by *iG*R. This paper was supported by Altiostar, Mavenir and Parallel Wireless.