LIGHTCOUNTING

Why Open vRAN is Fully Vindicated – July 2021

A Reality Check on How Open vRAN Delivers on its Promises and is the Perfect Fit for this 4G/5G Investment Cycle

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Produced in association with Altiostar

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Key Takeaways

In the mobile industry, 2020 will certainly be remembered as THE year of actual Open RAN commercial deployments for both 4G and 5G. The remarkable combination of the TIP initiative kicked off in 2016, followed by the launch of the O-RAN Alliance in 2018 and the Open RAN Policy Coalition in 2020 with the unabated US campaign to warn mobile operators worldwide against using Chinese RAN equipment in their network created a perfect storm for Open RAN, including vRAN when RAN functions are deployed as VNFs and applications run on COTS hardware automated by cloud operating systems such as OpenStack and Kubernetes.

2020 saw the emergence of high-profile newcomer Rakuten Mobile, Japan's fourth mobile operator, which rapidly became the world's largest Open vRAN network supplied by pioneer Altiostar. In each of its quarterly reports, the company shared astonishing achievements including dramatic capex and opex reductions compared with traditional RAN, and network performance equal to or better than traditional equipment.

As Rakuten Mobile fueled the Open RAN momentum, large communications service providers such as DISH, Etisalat, STC, Telefónica and Airtel joined the bandwagon. Airtel successfully completed its first O-RAN Alliance Plugfest in September 2020 while Telefónica invested in Altiostar, signed a partnership with Rakuten Mobile and presented an ambitious Open vRAN 2022-2025 deployment plan. These events are significant developments because they demonstrate the viability and feasibility of adding an Open vRAN platform to an existing traditional RAN footprint. Consequently, the proven cost-to-performance ratio of Open vRAN as well as its agility, flexibility, scalability, and reliability make this innovative technology a formidable candidate for the upcoming U.S. FCC-driven "rip and replace" campaign and the coexistence with existing 2G and 3G networks.

Open vRAN delivers on its 4G/5G promise, is the perfect fit for "rip and replace," and will co-exist with 2G/3G

The concept of network function (NF) disaggregation that defines the evolution of NFs from proprietary hardware and software sourced from a single vendor towards truly decoupled open network elements (NEs) with open interfaces is not new. However, it is just now being applied to radio access networks (RANs), which have long been well guarded by a handful of vendors that continue to enjoy an oligopolistic market situation.

However, current market forces, including a large and lingering 2G/3G global footprint, the ramping migration from 4G to 5G, and geopolitics are prompting many communication service providers (CSPs) to reconsider their RAN supplier, and are opening the door to open virtual RAN (Open vRAN) platforms. Since the beginning of this century, CSPs have gone through many challenges such as the rise of the web-scale companies that have rapidly built agile networks easily upgradable at the power of just a click or two. Now CSPs understand that Open vRAN provides that agility at a lower cost and eliminates the traditional vendor lock-in while preserving their multi-generational RAN footprint. So far, two distinct types of Open vRAN deployments are happening in parallel and provide valuable insights for future deployments to come:

- **Greenfield**: deploying a new mobile network from scratch with no legacy elements (e.g., Rakuten Mobile, DISH and 1&1 Drillisch)
- **Brownfield**: adding an Open vRAN platform to an existing traditional RAN footprint (e.g., Airtel, STC, Telefónica, and Vodafone). A Brownfield CSP could deploy Open vRAN either as an overlay on top of existing RANs or in a geographically segregated cluster of sites

FROM DAY 1, RAKUTEN MOBILE'S 4G/5G NETWORK DELIVERS SIGNIFICANT COST SAVINGS

When Japan's government authorized Rakuten Mobile to become the fourth mobile operator in April 2018, the newcomer knew it had to architect its network in a radically different manner to successfully get a share of the pie of this lucrative and yet saturated market. By embracing an end-to-end cloud-native network architecture approach, Rakuten Mobile made a bold move that quickly caught the world's attention, especially when it selected Open vRAN pioneer Altiostar as its sole RAN supplier.

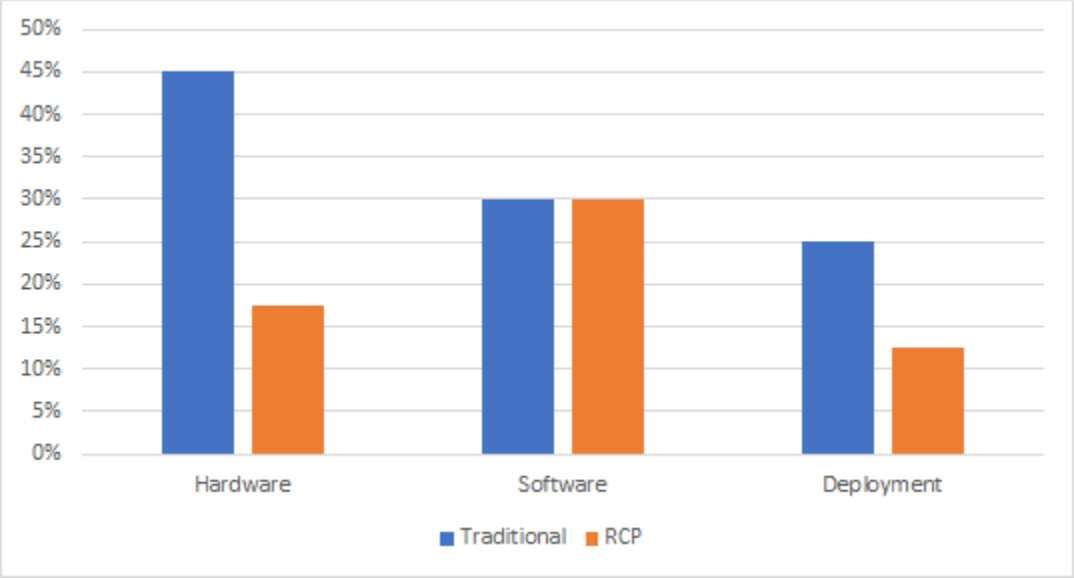
RAKUTEN MOBILE IS BUILDING A HIGH PROFILE 5G AND 4G OPEN VRAN MOBILE NETWORK

As of the end of May 2021, Rakuten Mobile had 22,500 4G vRAN sites on air carrying live traffic and covering more than 75% of the Japanese population and became the world's largest Open vRAN network as ranked by number of vRAN sites. In addition, the company had over 1,000 sites in all 47 prefectures and said its 4G buildout was ahead of plan with an average of 100 to 200 sites installed each day with no RF engineers and no drive test needed as the process is fully automated. Eager to share its operational findings so far, the company did not miss a chance to provide insights into its innovative network architecture and the performance it has delivered so far.

RAKUTEN MOBILE'S OPEN VRAN CAPEX IS 40% LOWER THAN THAT OF A TRADITIONAL RAN

When deploying a network from scratch, there are upfront costs related to the purchase of needed hardware and software, which are categorized as capital expenditures (Capex). Figure 1 illustrates the Capex difference between the build out of a traditional RAN and an Open vRAN based on Rakuten's experience. Total Open vRAN build-out capex was 40% lower than that of traditional RAN.

Figure 1: Rakuten Mobile Open vRAN Capex Analysis



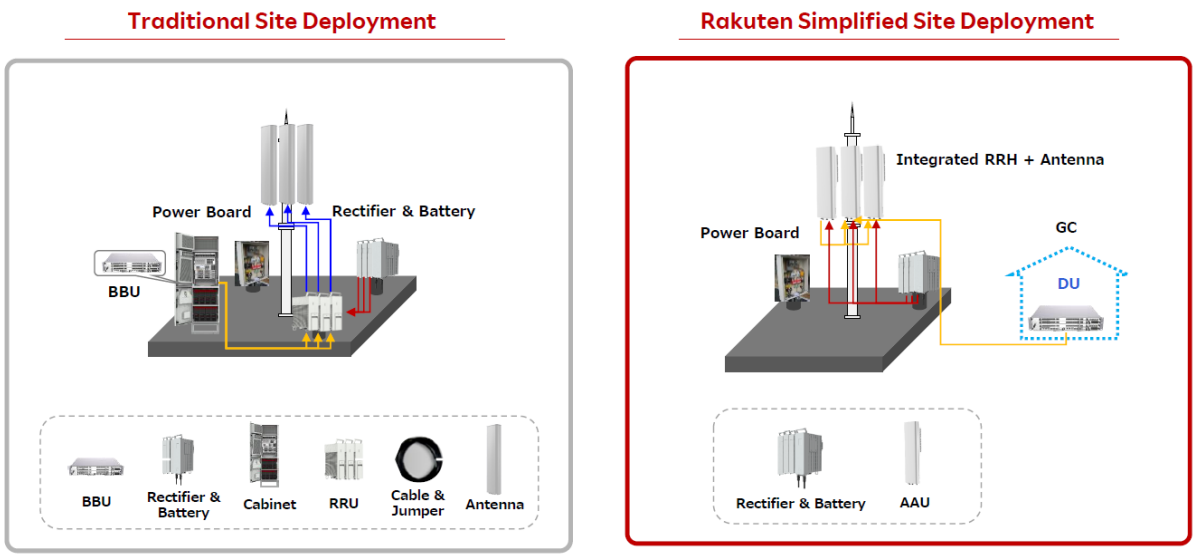
Source: Rakuten Mobile data, LightCounting

As expected, the most significant Capex saving, 60%, comes from the reduction of hardware needed in the Open vRAN architecture, which uses Altiostar's software platform which is

disaggregated from hardware and runs baseband unit functions (BBUs)—split into a virtual central unit (vCU) and a virtual distributed unit (vDU)—both of which run on Intel® architecture-based commercially available off-the-shelf (COTS) hardware (Figure 2).

The next biggest savings is site deployment, which costs 50% less for vRAN deployments. This reduction of site deployment Capex is driven by the need for fewer sites achieved through the combination of virtualization and pooling of capacity and resources. Figure 2 shows the contrast between the RAN systems needed at a traditional versus an Open vRAN site.

Figure 2: Traditional 4G RAN versus Rakuten Mobile's Open vRAN Site



Source: Rakuten Mobile

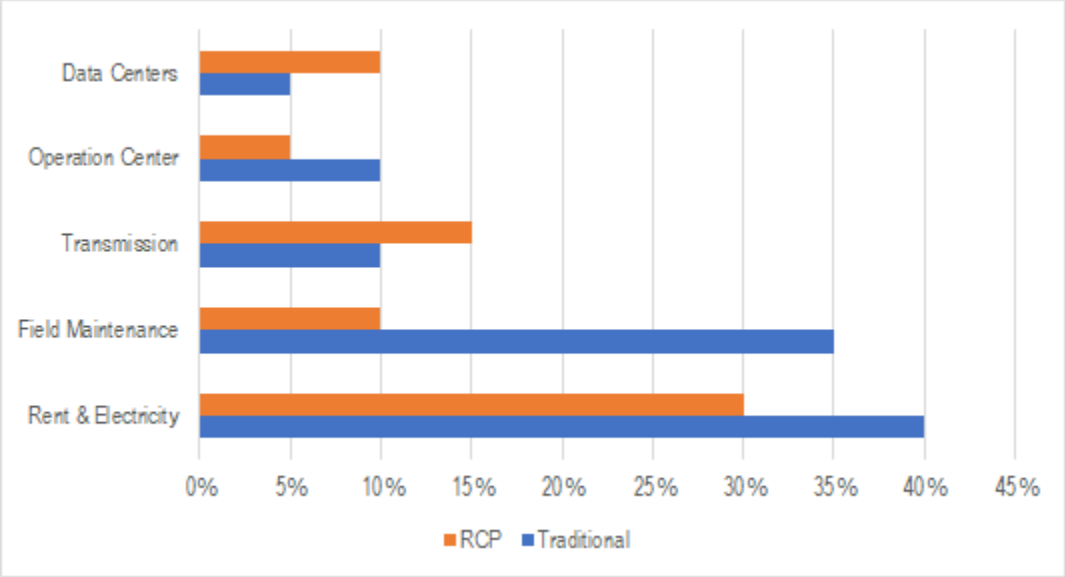
OPEX IS 30% LOWER

Figure 3 indicates that although data center and transmission operational expenditures (Opex) rose, field maintenance Opex dropped significantly, and rent and electricity Opex decreased moderately. The explanations are as follows:

- **Field Maintenance** (-70%): as mentioned in the capex analysis, Rakuten Mobile has fewer sites and less equipment on site and has implemented heavy automation through its use of Webscale technology
- **Rent & Electricity** (-25%): fewer sites result in footprint reduction and less overall power consumption
- **Operations Center** (-50%): centralization of the resources and automation
- **Transmission** (+50%): the increase comes from the use of edge locations and transmission

- **Data Centers** (+100%): edge locations deployed to reduce the latency drove the bump

Figure 3: Rakuten Communications Platform (RCP) 4G Open vRAN Opex Analysis



Source: Rakuten Mobile data, LightCounting

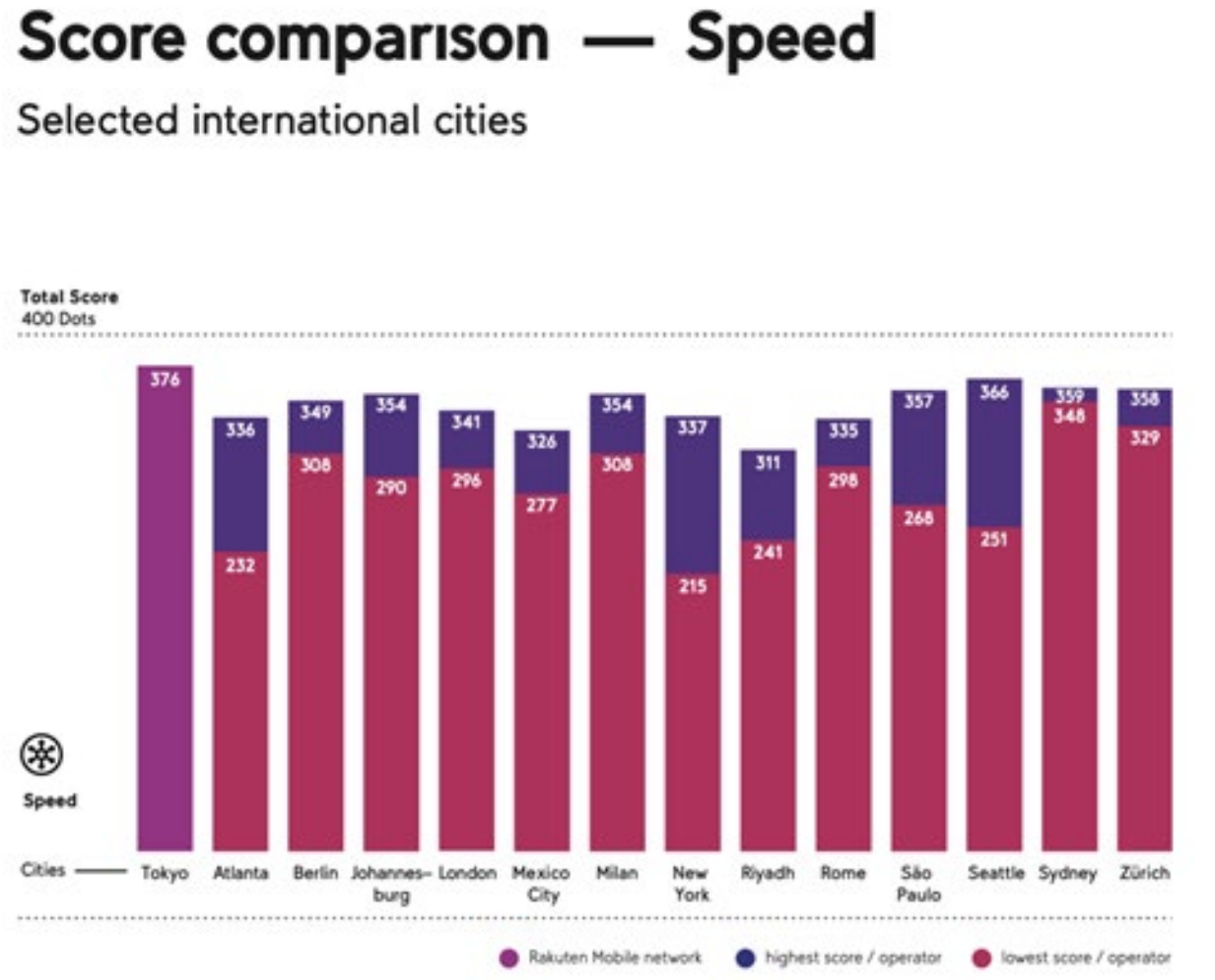
RAKUTEN MOBILE'S OPEN VRAN NETWORK DELIVERS SOUND PERFORMANCE

Since Day 1, Rakuten Mobile's nationwide network has achieved both high performance (number one in upload speed in Japan at 16.8Mbps, per OpenSignal) and network availability (99.7%), despite having only 1/6 of the spectrum of competing operators in the market.

Rakuten Mobile's 5G mmWave network has demonstrated impressive performance for end users, with realized download speeds of 1.77 Gbps, according to measurements revealed by Rakuten Mobile. This compares favorably to data from Ookla, which detailed speed test results for Japan in Q3 2020, where the fastest 10% of users realized an average download speed of 719.42 Mbps.

Rakuten Mobile is the world's first and currently the only nation-wide commercial-scale network built entirely on Open RAN standards. A recent report by independent analyst firm umlaut addresses performance questions head-on by comparing Rakuten Mobile's performance to that of tier-1 operators in major cities in Europe with the outcome decidedly positive. In terms of network speed, Rakuten Mobile's network in Tokyo achieved the highest rating among operators in the cities compared in the report (see Figure 4).

Figure 4: Rakuten Mobile's 4G Network Performance - June 2021



Source: Umlaut, June 2021, Audit Report - First Open Ran Network Rakuten Mobile

TELEFÓNICA PARTNERS WITH RAKUTEN MOBILE TO CREATE AN OPEN VRAN CHAMPION BEFORE KICKING OFF A PHASED ROLLOUT

Telefónica, which like Rakuten invested in Altiostar (10/17/2020), signed a Memorandum of Understanding (MoU) on September 16, 2020 to work with Rakuten Mobile on Open RAN, operation support systems (OSS) and 5G core technologies. The partners will conduct trials of Open vRAN architectures, including vCUs, vDUs, remote radio units (RRUs), and other necessary network equipment and software components. In addition, they will also jointly develop proposals for the role of artificial intelligence (AI) in the RAN.

TELEFÓNICA IS DEPLOYING OPEN VRAN PILOTS IN ITS CORE MARKETS

The Spanish giant is deploying 5G pilots in Brazil, Germany, Spain and the UK between the end of 2020 and the beginning of 2021. The company's objective in these pilots is to create a new RAN vendor ecosystem that comprises a specific consortium with better chances to deliver Open RAN successfully. To do so, Telefónica is working to develop the technology through strategic collaboration with Altiostar, Gigatera Communications, Intel, Supermicro and Xilinx. In December 2020, Telefónica O2 Germany added NEC as a full-service system integrator for its first Open RAN pilot in Germany. As such, NEC will customize the Open RAN architecture to meet Telefónica's requirements and will coordinate the overall design of the end-to-end service delivery platform.

BETWEEN 2022 AND 2025, TELEFÓNICA EXPECTS 50% OF ITS FOOTPRINT TO RUN ON OPEN VRAN

That's the objective set at the time of the MoU signing with Rakuten Mobile and to get there Telefónica plans to deploy Open vRAN in 3 phases:

1. Phase 0 / 2020 – 2021: Pilots
2. Phase 1 /2021 – 2022: Initial deployments
3. Phase 2 / 2022: Massive deployments in Brazil, Germany, Spain and the U.K.

AIRTEL'S EARLY INVOLVEMENT IN TIP LED TO THE ADOPTION OF ALTIOSTAR'S OPEN VRAN FOR 4G AND 5G

As a member of both the O-RAN Alliance and Facebook's Telecom Infra Project (TIP), India's Airtel has been active in standardization efforts, which gave the company a leading innovative edge to make rapid decisions about how to move its mobile network to the next stage and stay competitive by adopting Open vRAN in its small cell network footprint as a start. Airtel's story conveys a powerful message to the CSP community: get involved in TIP developments and reap the benefits of cutting-edge disaggregated technologies.

The move paid off as Airtel become totally involved in all TIP developments and found that Open vRAN would be the quickest and most cost-effective way to expand the reach of its networks with a competitive advantage. Airtel is the first operator in India to deploy a vRAN-based 4G network, leveraging Altiostar's Open vRAN solution across multiple major cities in India:

1. Indoor FDD small cells mainly for residences (2x125mW)
2. Indoor TDD small cells mainly for enterprises (2x250mW)
3. Outdoor TDD small cells mainly for capacity

IN SEPTEMBER 2020, AIRTEL SUCCESSFULLY HOSTED ITS FIRST O-RAN ALLIANCE PLUGFEST

Held at Gurgaon and Bengaluru locations, the India O-RAN Plugfest put 10 companies together to showcase O-RAN Open Fronthaul multi-vendor interworking, O-DU system validation, O-RAN open X2 interface, and Radio Intelligent Controller (RIC) use cases with O-RAN O1 and E2 interfaces for network performance optimization, combining machine learning (ML) and radio intelligence.

Among the 10 companies, Airtel, Altiostar and NEC teamed up to demonstrate the world's first fully virtualized interoperability testing and integration of massive MIMO radio units (O-RU) and virtualized distributed units (O-DU) running on COTS servers. The project featured a commercial end-to-end Open Fronthaul interface utilizing O-RAN specifications. This demonstration was comprised of control, user, synchronization and management plane protocols, including 3GPP RCT and performance cases.

OPEN VRAN IS THE PERFECT FIT FOR "RIP AND REPLACE"

Led by the U.S., a major "rip and replace" market is shaping up. This is by far the largest opportunity for Open RAN and vRAN rollouts: removing Chinese vendors' old legacy RAN and replacing it with Open RAN or Open vRAN.

THE FEDERAL COMMUNICATIONS COMMISSION (FCC) IS MOVING FAST AND ADDING FUEL TO OPEN RAN

In October 2020, the FCC voted to establish a fund of up to $9 billion in federal support for rural 5G build-outs and precision agriculture. Adopted at the FCC's open meeting in late October 2020, the Report and Order sets up the 5G Fund for Rural America that includes up to $8 billion in Universal Service Fund (USF) dollars to be awarded in the first phase of a multi-round reverse auction for 5G build-outs over 10 years. These are focused on parts of the country that lack unsubsidized 4G LTE or 5G mobile service. Of that, $650 million is allocated for providers that plan to serve Tribal lands. The second phase provides at least $1 billion for deployments of precision agriculture technologies and areas remaining after Phase 1. The FCC called out the following components of the new 5G Fund:

- When determining eligible locations, it appears the FCC will exclude areas where T-Mobile committed to deploy 5G service as part of its merger-related agreement approval of its Sprint deal. That includes covering 90% of rural Americans within 6 years. The FCC says this will avoid overbuilding and wasting resources.
- The reverse auction will factor in and adjust for areas that are particularly expensive to deploy or don't have a good business case, because of things like rugged terrain or low population, to ensure they can compete in the auction.

- Winning bidders of the 5G Fund must deliver 5G mobile broadband speeds of at least 35 Mbps downloads and 3 Mbps uploads, and meet deployment benchmarks starting in the third year, and reach the final milestones by the end of year six
- Carriers that get legacy mobile high-cost support must start spending an increasing portion of their $368 million in funds to deliver 5G in rural areas that are considered more expensive to support.

In late December 2020, $1.895 billion was appropriated to carry out the Secure and Trusted Communications Networks Act of 2019. The funding was earmarked as part of the **Consolidated Appropriations Act, 2021**. In conjunction with this legislation, the FCC has created a reimbursement program to compensate CSPs for costs incurred in removing, replacing and disposing of communications equipment that poses an unacceptable risk to national security.

And in July 2021, the FCC set October 29, 2021, as the date CSPs can start applying for reimbursement funds for ripping and replacing Huawei and ZTE equipment from their networks. And it also expanded the pool of companies that can get reimbursed to include CSPs with 2M to 10M customers.

"RIP AND REPLACE" IS NOT ONLY ABOUT 5G, FOR RURAL AREAS, 4G NEEDS TO BE CONSIDERED AS WELL

Although everywhere in the world the focus is on 5G, the industry needs to focus separately on 4G coverage because 5G alone may not fully meet the needs of rural communities in the Americas, EMEA, and Asia.

Most rural customers' needs can be served with current generations of mobile technology (i.e. 4G) deployed in Open vRAN configurations for cost efficiencies, agility, flexibility, scalability and reliability as presented earlier in this whitepaper. In order to truly address the digital divide, there is a great need for affordability and accessibility for both infrastructure and devices, and Open vRAN is the perfect fit.

CONSEQUENTLY, REPLACING LEGACY RAN WITH OPEN VRAN SHOULD BE A NO BRAINER

As all mobile networks have been built so far with the traditional RAN approach based on proprietary technology, CSPs are left with the sole option of ripping and replacing the equipment. Had they built their RAN with at least an Open RAN approach, they would have been able to simply remove specific old components and replace them with new updated ones. In addition, they would have been able to select the components from different vendors to mix and match the best products and services offered in the Open RAN ecosystem. And as

networks are evolving toward end-to-end virtualization through an open architecture, Open vRAN is a fundamental building block of the whole network architecture.

THE NEW NETWORKS WILL HAVE TO BE AGILE, FLEXIBLE, SCALABLE AND RELIABLE TO SUPPORT A LARGE VARIETY OF UNKNOWN USE CASES

A CSP that faces the challenge of removing a legacy proprietary RAN should embrace the opportunity to deploy an Open RAN platform and future-proof its mobile network. Until now, mobile broadband for consumers has been THE use case that started on 3G networks and moved to 4G, which since has become the de facto universal mobile broadband platform (see Figure 6 at the end showing LTE, LTE-Advanced and 5G networks in the world). As 5G has been designed to support use cases grouped in 3 categories, including enhanced mobile broadband (eMBB), ultra-reliable low latency communications (uRLLC) and massive machine type communications (mMTC), a flexible and agile RAN is required such that it enables future unknown use cases fitting the three categories without requiring forklift scale changes to the architecture. At the same time, the network design should lead to web-scale operations to minimize Opex as seen in the Rakuten Mobile Open vRAN deployment.

- **Agility**: RAN transitions from traditional hardware-centric design to software-intensive design, with RAN functions implemented in software
- **Flexibility**: disaggregation of hardware from software with open interfaces and use of standardized commodity hardware that can be independently procured and upgraded to take advantage of Moore's Law
- **Scalability**: standardized hardware shared across multiple workloads increasing the utilization through statistical multiplexing gains
- **Reliability**: application load for single cell sites distributed across multiple virtual network functions (VNFs) providing high resiliency in the event of failure of a single VNF

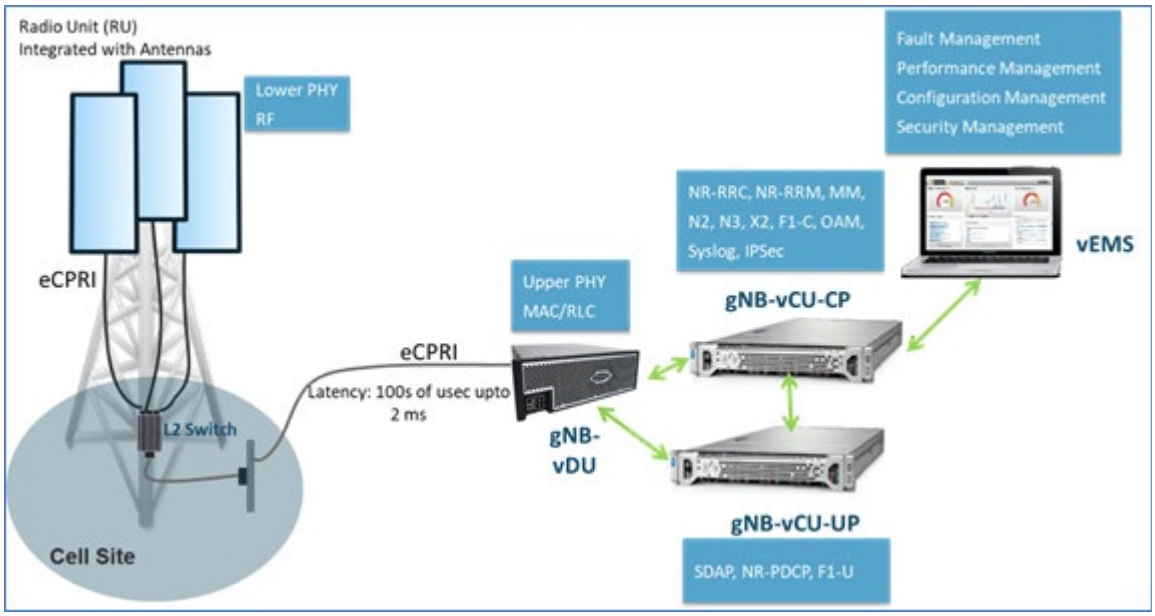
THE VNFS THAT POWER OPEN VRAN ENABLE AGILITY, FLEXIBILITY, SCALABILITY AND RELIABILITY

All this leads to a better capital utilization efficiency. Further, the use of open-source cloud platforms with open APIs in NFV brings a high degree of operational automation including auto-provisioning, and resiliency against failures, which in turn reduce Opex as confirmed by Rakuten Mobile's operational data presented at the beginning of this paper. As illustrated in Figure 5, Open vRAN is based on a split architecture with standards-based open interfaces, which is driven by the 3GPP and by the operators through the O-RAN Alliance. As already mentioned, RAN applications are running on COTS infrastructure and automated by a Cloud OS such as OpenStack, OpenShift or Kubernetes.

The use of open interfaces gives operators flexibility to mix and match vRAN software and hardware components from different vendors, which in turn leads to the deployment of best of breed products for high quality innovative network architectures. Figure 5 also shows the implementation of control user plane separation (CUPS) on dedicated vCUs (e.g., vCU CP and vCU UP) such that the control plane and the user plane traffic are scaled independently.

And as BBU functions are deployed as VNFs (e.g., vDU, vCU-CP, vCU-UP), the resulting vRAN platform is programmable and various operational tasks such as new cell site integration (auto-commissioning), detection and automated recovery from failures (self-healing) are automated and drive Opex down.

Figure 5: Open vRAN Architecture



Source: Altiostar

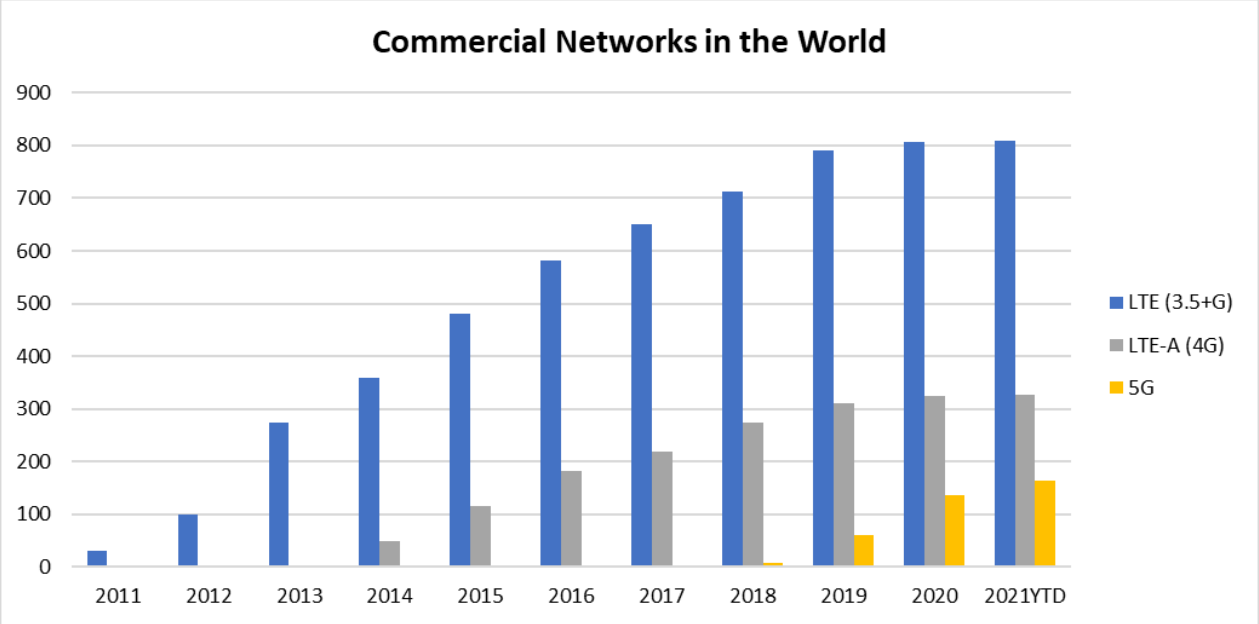
LASTLY, OPEN VRAN WILL CO-EXIST WITH 2G AND 3G

The two cases of Rakuten Mobile and Airtel tell the world that Open vRAN is a perfect fit for 4G and 5G as it delivers on its promises of cost savings and network performance. But that is not the whole story, as the world remains blanketed with 2G and 3G networks that continue to deliver consumer and machine-to-machine (M2M) connectivity services. Although more CSPs are shutting down their 3G networks and re-farming their spectrum for 4G, 2G is less likely to be turned off because of a large installed base of M2M connectivity that is generating a lucrative business.

ALTHOUGH 5G ROLLOUTS ARE GOING GANGBUSTERS, LTE REMAINS PREDOMINANT

Looking at the global LTE, LTE-Advanced and 5G NR footprint worldwide, Figure 6 indicates the number of LTE networks has reached a plateau at around 800, which means the planet has reached the stage of having all live cellular networks migrated to LTE, which is a radio access technology (RAT) that can be migrated to Open vRAN, and is ready for 4G LTE-Advanced (LTE-A) upgrades to pave the way for 5G. As long as the RAT is LTE (E-UTRAN), it qualifies as a candidate for the move towards Open RAN providing the RU is O-RAN option 7.2 split compliant. In the meantime, the shutdown of 2G and 3G networks is not happening overnight and therefore, 2G/3G services will need to be supported for some time to come. It is worth noting that 2G and 3G network spending peaked in 2008 and 2009, respectively, and have been steadily declining since the LTE spending peak in 2015; by 2025, LightCounting expects 2G/3G spending to totally disappear. And since these networks are fully deployed and will soon be sunset, they do not need to be ripped and replaced with an Open RAN architecture.

Figure 6: Number of Commercial Networks – LTE/LTE-A/5G NR



Source: Global mobile Suppliers Association (GSA), LightCounting

HUNDREDS OF CSPS FACE TOUGH GENERATIONAL MIGRATION QUESTIONS AND DECISIONS

Although 2G has already been shut down in Australia, Japan, Singapore, South Korea and the U.S., to cite a few countries, the 2G versus 3G shutdown agenda varies across regions. For

instance, Europe is more likely to sunset 3G first while Asia, Oceania and North America are shutting down 2G. Key factors for consideration before making the end-of-life decision include:

- Number of devices alive on the network and level of revenue generated
- Geographic coverage
- Regulatory environment
- Operation and maintenance costs
- Network depreciation status

For example, after finding in 2015 that very few 2G devices were active on their nationwide network, AT&T decided to shut down 2G as of January 1st, 2017.

ALTHOUGH O-RAN SPECIFICATIONS DO NOT COVER 2G/3G, OPEN VRAN MUST CO-EXIST WITH THESE TECHNOLOGIES

As there is no need to retrofit older networks to Open RAN, traditional 2G/3G networks can continue to co-exist with newer 4G/5G Open RAN. LightCounting's regular discussions with CSPs indicate that when they make the decision to shut down 3G, they re-farm the spectrum for 4G to beef up their 4G network services offering. For example, Telenor Norway made the decision to shut down its 3G network last year and expects to complete the process by year end. The 900 MHz 3G spectrum was shut down by the end of 2019 and is now supporting 4G. The 3G devices that could not support 4G fell back on the 2G network. Overall, given the imminent sunsetting of 2G/3G networks across the globe, it makes no business sense to invest in Open RAN for 2G/3G.

BOTTOM LINE: OPEN VRAN IS RIPE FOR BOTH GREENFIELD AND BROWNFIELD NETWORKS

There is no shortage of evidence to prove that running BBU functions on software as VNFs with open interfaces creates a programmable Open vRAN platform that enables a great degree of agility, flexibility, scalability, reliability, and automation. Backed by fresh Rakuten Mobile operational data for 4G and 5G networks, we see that all of this leads to lower Capex and Opex, which is excellent news in this era of stagnant or low-single digit revenue growth.

And seeing Airtel and Telefónica jumping on the Open vRAN bandwagon, among other leading CSPs, provides a strong rationale to believe that Open vRAN meets the operational cost and the network performance expectations required of Brownfield deployments.

What are those CSPs who are either expanding their 4G networks, building a 5G network, facing a rip and replace or considering a 2G/3G sunset situation waiting for?