Asia-Pacific Economic Cooperation

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NETWORK VIRTUALIZATION, DISAGGREGATED NETWORKS, AND OPEN TELECOMMUNICATIONS ARCHITECTURE IN APEC

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KEY TERMS

4G *(Fourth Generation)*	Describes technologies that fulfill the International Telecommunication Union's International Mobile Telecommunications Advanced (ITU's IMT-Advanced) specifications such as Long Term Evolution (LTE). 4G technologies have flexible channel bandwidths; peak speeds of 100 Mbit/s when mobile and 1.5 Gbit/s when fixed; high spectral efficiency; smooth handoff between different network types; and a flat, all-IP network architecture. In practice, 4G is also used to describe technologies that nearly meet these requirements such Mobile WiMax and LTE.
5G *(Fifth Generation)*	Used to describe networks that use the IMT-2020 standard. 5G networks are expected to have 1-10 Gbps connections to endpoints in the field, as well as 1 millisecond end-to-end round-trip delay (latency).
5G New Radio *(5GNR)*	Refers to the air interface that was developed to replace LTE. It is through this new radio air interface that the advances associated with 5G are achieved.
5G Non-standalone	Refers to a 5G system that uses a 5G radio access network with a 4G/LTE Evolved Packet Core instead of a 5G Next Generation Core Network.
5G Standalone	Refers to a 5G system that uses both a 5G radio access network and a 5G Next Generation Core Network.
Base station	Refers to the equipment that provides and manages the connection between mobile phones and the cellular network.
FDD *(Frequency Division Multiplexing)*	The technique of using one spectrum band for transmission and a second band for reception. This ensures that the two bands do not interfere with each other. LTE can use FDD in which case it is referred to as FD-LTE.
LTE *(Long Term Evolution)*	The 3GPP standard, generally branded as 4G, that uses an all-IP flat network architecture and is capable of peak downlink speeds 100 Mbit/s and uplink speeds of 50 Mbit/s when deployed in a 20 MHz channel, and even higher rates if used with multiple-input multiple-output (MIMO) to deploy LTE in multiple channels. LTE is generally a frequency division duplex (FDD), but also has a time division duplex (TDD) version.
MIMO *(Multiple-Input Multiple-Output)*	A technique/technology for using multiple (typically more than 8) transmit and receive antennas.
MNO *(Mobile Network Operator)*	An entity that provides mobile telephony and data services. The term implies that the entity "operates" a radio network, though this may not necessarily mean that it owns the infrastructure.
Network (Function) Virtualization	NFV is an initiative to transfer the network functions from dedicated hardware devices to virtual machines in order to allow those functions to be virtualized on commodity hardware. Typically enables operators to be more flexible, cost-effective and deploy new services.
Open RAN	Refers to a new set of technologies that are about building networks using a radio access network solution based on open interfaces that runs on commercial, off-the-

	shelf hardware (COTS) with open interfaces, whose standards are developed by a global specifications setting organization using technology neutral principles.
Radio	The equipment typically deployed on top of cell towers near the antennas that provide the analog transmission to and from mobile phones and the mobile network.
Radio Access Network	The collection of base stations for a cellular network. Provides the RF connection to the end user device. Abbreviated RAN.
TDD *(Time Division Multiplexing)*	The technique of using one spectrum band to transmit and receive by dividing the band into alternating time slots. LTE can use TDD in which case it is referred to as TD-LTE.

EXECUTIVE SUMMARY

Open RAN (Radio Access Network) technology provides a compelling approach to building telecom infrastructure through the use of vendor-agnostic software and hardware. This approach utilizes equipment that runs on RAN software and commercial, off-the-shelf hardware (COTS), allowing an "open" network in which different vendors can work together in an interoperable system. Growing in demand as government leadership globally, and increasingly in APEC member economies, seeks to build safe, secure, and affordable digital infrastructure, this model allows mobile network operators flexibility while avoiding vendor lock-in. Open RAN is a relatively new approach to network architecture that shows strong potential.

Potential benefits of Open RAN include:

- The use of cutting-edge hardware and software components from multiple vendors rather than restricted use of hardware and software from a singular vendor.
- Reducing capital maintenance expenses by driving the (emergent) competition across the multiple vendors in the hardware and software supply chain
- Making network maintenance open to a wider range of service providers through existing IT processes and procedures.
- Enabling competition by diversifying the ecosystem of vendors from which MNOs can procure network equipment leads to lower network structuring cost, supply stability and enhanced security.
- Reducing the amount of physical infrastructure required at cell sites, though it obviously does not eliminate the need for antennas.

Potential challenges to adoption, include:

- Open RAN may require greater security monitoring because of its open interfaces and functionality.
- Network integration could be more difficult, requiring operators' workforces to have higher level and more diverse skills.
- Open RAN is provided by different manufacturers with different components such as RF and baseband, which could make component optimization challenging.
- In the short-term, hardware and underlying software suppliers may be limited.
- Energy consumption with Open RAN systems may be higher, again in the short- to medium-term.

Open RAN technology may have numerous potential benefits for consumers and enterprise customers. Because Open RAN uses COTS hardware and software, the cost of deploying a mobile network could be lower than a similar network deployed using traditional RAN hardware. This cost flexibility may increase the potential to reduce the "rural mobile internet gap", which is currently up to 40 percent in low- and middle-income economies; those living in rural areas were 40 percent less likely to use the mobile internet than those in urban areas [1]. Through the use of Open RAN-based solutions, a multi-economy organization could provide cellular coverage and increased capacity to areas traditionally too expensive to deploy a network using traditional RAN equipment. Finally, if the network costs less to deploy and operate, the multi-economy organization can provide service to its customer base for less, increasing access to a broader range of consumers and businesses.

All of these benefits can help close the global digital divide while supporting 5G-related investment and critical economic growth. According to the most recent ITU State of Broadband report, mobile operators will invest approximately USD 1.3 trillion worldwide in mobile capital expenditures between now and 2025, of which over 75 percent is estimated to would be spent on 5G networks (the forecast was made before COVID-19.) And, online service providers have become major investors in digital infrastructure (data centers, submarine cables and other facilities). This supply chain shift would also allow increased participation by local vendors from emerging markets, strengthening local tech ecosystems and diverting procurement from a select few global incumbents that currently dominate the market. This diversification could help open the market and strengthen workforce development of hardware and service providers in developing regions, as local tech ecosystems become more competitive with increased global demand for diversified ICT expertise and technology solutions. This opportunity could be further capitalized upon by APEC members to drive critical technology development and job creation programs, increasing female representation in the local tech ecosystem and diversifying their domestic workforces.

The 2019 ITU State of Broadband report suggests a correlation between broadband access and gross domestic product (GDP) growth:

- An increase of 10 percent in fixed broadband penetration yields an increase of 0.8 percent in GDP based on econometric modeling,
- An increase of 10 percent in mobile broadband penetration yields an increase of 1.5 percent in GDP.
- In more developed economies, the economic impact of fixed broadband is greater than in less developed economies.

In a post-COVID-19 world, many multi-economy enterprises will be seeking to strengthen and diversify their supply chain on a global scale. These companies require wired and wireless networks in order to extend their supply chain into different economies. An economy with strong networks and multi-economy enterprises (or other entities) willing to move quickly to deploy those networks may well be better positioned to capture manufacturing and/or logistics business of a multi-economy enterprise.

Note, too, that these networks are not just about connecting people, but also about connecting machines – the Internet of Things (IoT). Machine-to-machine and machine-to-human connectivity will be a large driving force of future mobile growth, and an increasingly critical component of global supply chains, requiring a more flexible network architecture than ever before. While this report focuses on Open RAN, a technology-neutral approach should not exclude the development of other relevant technologies in the future.

Open RAN trial activity and deployments are currently also underway in several APEC economies, including Japan; Indonesia; Korea; Mexico; Peru; Singapore; Thailand; and the United States.

In February 2021, US-SEGA held a Workshop on Network Virtualization, Disaggregated Networks, and Open Telecommunications Architecture in APEC during the first Senior Officials Meeting. During the workshop, authors shared the findings of this report with policy makers and private sector guests from across the region, encouraging the sharing of experiences and emerging practices in the adoption and deployment of Open RAN in APEC economies. A summary of the workshop, including feedback on the report's findings and proposed next steps, is attached to this report as Annex A.

BACKGROUND

APEC's 10th Ministerial Meeting on Telecommunications and Information endorsed the APEC Telecommunications and Information Working Group (TELWG) Strategic Action Plan for 2016-2020, which specifically calls for "develop[ing] and support[ing] ICT innovation; promot[ing] regional economic integration; and enhanc[ing] the digital economy and the internet economy." To support the operationalization of the Strategic Action Plan, the United States, joined by Japan, Korea, and Mexico, launched a project under TELWG to analyze the benefits of network virtualization and disaggregated networks, as well as open architecture, in next generation telecommunications networks. These efforts also contribute to key focus areas highlighted in the APEC Internet and Digital Economy Roadmap implemented by the Digital Economy Steering Group, namely: (i) development of digital infrastructure; (ii) promotion of interoperability; (iii) promoting coherence and cooperation of regulatory approaches affecting the Internet and Digital Economy; (iv) promoting innovation and adoption of enabling technologies and services; and (v) enhancing inclusiveness of Internet and Digital Economy.

Several APEC economies have already begun deploying virtualized and/or disaggregated telecommunications networks, as well as open architecture specifications in Radio Access Networks (RAN). These approaches have the potential to improve competition in telecommunications markets, which could lead to increased connectivity. Furthermore, these approaches have the benefit of broadening the supplier base, which contributes to a more resilient and adaptable system in the event of an exogenous shock, proven to be paramount by the COVID-19 pandemic. Yet, there is an opportunity to deepen the understanding of these approaches and their broader economic implications among regulators and policymakers in the region.

This paper—a key deliverable of the United States' self-funded project—reinforces the TELWG's mandate to advance the development of information and communications technology (ICT) infrastructure and services in the Asia-Pacific region, and promote cooperation, information sharing and the development of effective ICT policies and regulations. In producing this paper, the United States seeks to present information, approaches, and case studies from the APEC region on emerging ICT infrastructure practices, including network virtualization, disaggregated networks, and open telecommunications architecture. By articulating the application and use of these emerging technologies, this paper ensures that balanced information is shared on the regulatory environment for all APEC economies.

AN INTRODUCTION TO MOBILE NETWORK ARCHITECTURE

HOW ARE NETWORKS BUILT TODAY?

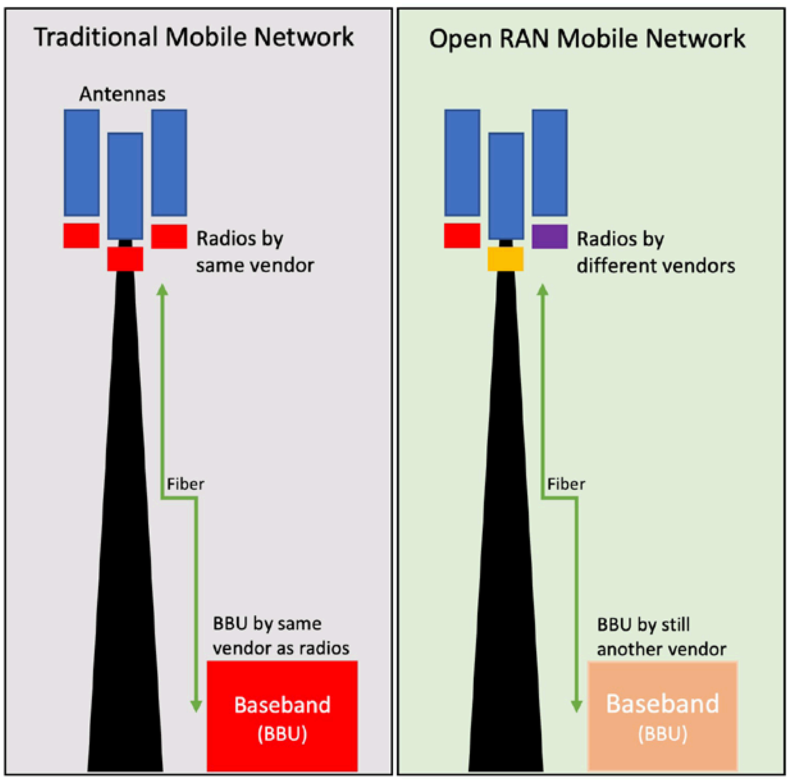
Mobile networks are key to global communications. Cellular/mobile service is typically provided via towers and antennas installed at cell sites, sometimes called macrocell sites. Note, too, that cellular/mobile service is increasingly being provided via small cells which cover a smaller geographic footprint. These small cells can be deployed indoors or outdoors, to provide both coverage and/or capacity increases. In most world regions, licensed Radio Frequency (RF) spectrum is used to provide that service. There are many different frequency bands each with different (but similar) propagation characteristics; each RF band has different (but similar) capabilities with respect to "carrying" mobile voice/data traffic.

RF spectrum is scarce, so mobile network operators (MNOs) try to use it efficiently and there are many different technical ways to do so. Deploying, maintaining, optimizing and operating mobile networks requires a great deal of (highly) skilled labor – everything from construction expertise to networking and RF engineering.

The key components of cell sites relevant to this paper are illustrated in Figure I: the radios which transmit and receive the radio signals to and from the end user device and the baseband processing units (BBUs) which, manipulate the digital portion of the voice and/or data stream before the radio converts that digital stream back to analog for transmission via the antennas. Originally, the radio and BBU were housed together in a base station transceiver (BTS). Over time, that architecture has changed such that the radio was moved to the tower top while the BBU stayed at the base of the tower.

Figure I also illustrates the basic difference between a traditionally built Radio Access Network (RAN) and an Open RAN-based network. That is, the key components shown here in the gray panel are all built by the same equipment vendor. In an Open RAN-based mobile network, those same key components can all be built by different equipment. This is the essence of what OpenRAN means.

Figure I - Traditional versus OpenRAN Mobile Networks



Source: *iGR*, 2020

How OpenRAN ends up working is a detailed, highly technical discussion. There are many other components to cell sites: routers, power supplies, cabling, backup generators and batteries, etc. And beyond the cell site is the mobile core network which in LTE is referred to as the evolved packet core (EPC). It is comprised of many different components as is 5G New Radio (NR), which introduces an entirely new Service Based Architecture (SBA) in the 5G core network (5GC).

On a related note, there are many other network technologies – e.g., fiber optics, hybrid fiber coaxial (HFC) cable, digital subscriber line (DSL), and, of course, Wi-Fi. These examples, along with all radio frequency spectrum, are "Physical Layer" transmission mediums per the seven layer Open Systems Interconnection (OSI) model. The radio is a fundamental part of the mobile network, but it does not interconnect directly with those other physical transmission mediums. Per the OSI model, data transfer between different networks happens at the Network Layer.

The point here is this: Even with Open RAN deployment on the rise, and 5G networks being deployed all over the world, data will still – and perhaps always – flow over different physical layer transmission mediums.

However, the focus of this paper is on the cellular radio access network and the integral role it plays in connecting users to one another via voice and data.

WHAT IS THE RADIO ACCESS NETWORK (RAN)?

The RAN is often used to refer to the physical equipment via which MNOs provide cellular service – antennas, radios, BBUs, etc. The radio itself is one of the most important components in a mobile network since it provides the link between the subscriber and the network. Everywhere there is an antenna on a tower today there is usually also a radio, though there are exceptions. In the 5G future, this basic architecture may well be different.

Originally, operators primarily used proprietary, closed radio networks systems purchased from the traditional RAN vendors. These systems could be expensive (depending on the size of the network and the maturity of the product) and were purchased as a whole package, which meant that operators could be getting features they did not need or want. At the time, these systems were all that were available. Recall, too, that computing technology and the Internet itself were in their infancy at the same time the cellular industry was born (the early 1980s). The major difference between cellular and computing, however, is that the latter matured much more rapidly than cellular. That maturity is, in part, why the conversation is now about Open RAN.

Open RAN is about building networks using equipment that separates the vendor-specific software and vendor-specific hardware associated with the vast majority of radio access network (RAN) equipment that is available today from a handful of cellular equipment vendors. Open RAN, then, uses RAN software on commercial, off-the-shelf hardware (COTS). In this case, being "open" means that there are reference designs and standards for hardware and software such that there are open interfaces exposed such that Open RAN-compliant software/hardware from different vendors can work together.

Consider this comparison: Apple's Mac OS X versus Microsoft's Windows 10. Without taking special steps, an application coded for the Mac OS will not run on a Windows-based machine even though the underlying hardware in both cases is Intel x86-based (at the time of this writing). In a conceptually similar fashion, an established Vendor A's RAN product would not work with Vendor B's. The interfaces between solutions and/or equipment were proprietary and (mostly) non-interoperable. It was possible to make the different solutions directly work together, but in many of those cases some functionality was lost. Note that this does not refer to a voice/data originating on Carrier A's network, which runs Vendor A's products, terminating on Carrier B's network which runs Vendor B's products. That is a different level of interoperability. What is being discussed here is RAN equipment from Vendor A not interfacing with RAN equipment manufactured by Vendor B – even though that equipment performs the exact same role in the RAN.

Not only have the traditional RAN vendors provided radio solutions that are proprietary, but sometimes these systems were siloed for each air interface generation. For example, upgrading from 3G to 4G LTE meant, in some cases, the MNO had to "rip out" their existing RAN equipment and replace it with 4G-capable RAN equipment. In more recent years, this rip-and-replace cycle has largely been mitigated such that "older-generation" radios can be software upgraded to new versions of the current air interface generation and, in some cases, to the next air interface generation. For example, an MNO with a 4G LTE RAN might only need to push a software update to their radios to enable 5G NR communications on that same equipment.

Moreover, any introduction of new services relied on the hardware/software provided by the vendor. Not only did the operator have to rely on the vendor but there was little differentiation among the operators since it was most cost-effective for the vendor to build features that every operator could use. Over the last decade, the number of RAN vendors has shrunk to only a few. Open RAN-based solutions help give MNOs more options when building and/or upgrading their cellular networks.

Several organizations are driving the Open RAN movement. OpenRAN (written as one word/acronym), which refers to the project group that is a part of the Telecom Infra Project (TIP), seeks to deploy RAN solutions based on general purpose processing platforms (GPPP) / commercial off-the-shelf (COTS) equipment and disaggregated software. Doing so, according to OpenRAN, will help operators and vendors benefit from the flexibility and faster pace of innovation capable of software-driven development.

The O-RAN Alliance, founded in 2018 by AT&T, China Mobile, Deutsche Telekom, NTT DOCOMO and Orange, aims to foster the development of reference designs and specifications 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 Open RAN Policy Coalition represents a group of companies formed to promote policies that will advance the adoption of open and interoperable solutions in the Radio Access Network (RAN) as a means to create innovation, spur competition and expand the supply chain for advanced wireless technologies including 5G.

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RELATED TRENDS

In addition to the overarching, Moore's Law scaling of computing power, Open RAN is indebted to several other trends.

For example, this paper mentioned earlier how the radio processing was moved from the base of the tower to its top. This was done to minimize the losses associated with sending RF traffic up and down coaxial cable from the antenna to the base station – the BTS or eNodeB, as it is called in LTE. The radio at the tower's top was (and is) called the remote radio unit/head (RRU/RRH) and was connected to the BBU at the tower's base via fiber optic cable.

The natural next step forward was taken by the Cloud RAN (CRAN) movement that began several years ago. It was the first shot across the bow of the established equipment vendors. Essentially, CRAN allows the operator to locate all of the cell site functionality except the radio itself in one centralized place. When full 5G NR networks are deployed, MNOs will even be able to distribute some of the radio functions across locations.

Indoor and outdoor small cells are another key trend. Small cells involve placing small base stations close to end users – e.g., in stadiums, hotels, light posts, etc. These devices improve the coverage and capacity experienced by mobile subscribers while also offloading that traffic from the "umbrella" macrocell which frees up its coverage/capacity for other mobile subscribers.

The introduction of multi-access edge computing (MEC) or, more simply, edge computing, goes hand-in-glove with both macrocells and small cells. MEC is a server that can be collocated at the macrocell tower or with a small cell. This allows data content – video, web pages, applications, and more – to be cached physically closer to the mobile end user. Furthermore, edge compute processing functions can be handled at the edge rather than in the cloud or the core network. This helps reduce latency and improve throughput.

Physical proximity to the end user is shorthand for the "edge" of the RAN, but it is likely that the actual RAN edge will vary based on the application(s) supported. Applications and/or use cases require some combination of throughput and latency. An emergency service responder (fire, ambulance, police, etc) might need extremely low latencies while a commuter streaming audio/video might tolerate higher latency in return for high throughput rates.

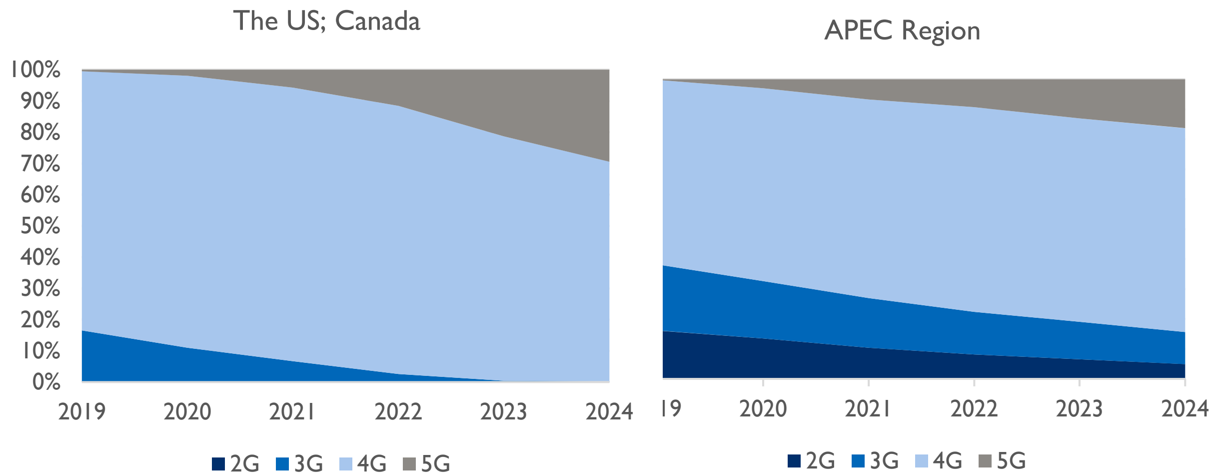
RECENT TRENDS IN MOBILE NETWORK CONNECTIONS

Figure 2 shows *iG*R's forecast for the percentage of the North American geographic region's mobile connections by air interface technology generation (2G through 5G). *iG*R defines a cellular connection as any device that connects to the mobile/cellular network. This includes smartphones, tablets with cellular modems, machines, IoT devices, etc. This forecast does not explicitly include Wi-Fi, but many devices with cellular modems also have Wi-Fi modems.

As the figure suggests, 4G LTE is important through 2024 and for many years after. 5G connections start becoming a significant percentage of the total about halfway through 2022.

The following figure shows the same split for the APEC member region and the economies contained within it. As the forecast shows, 2G and 3G are relevant for much longer than they are in the United States. 4G LTE as a percentage of total connections is lower in the APEC economies. 5G connections begin at the same time (2019) but the forecasted growth rate is slower. Note, too, that the vast majority of those 5G connections are in just several APEC economies: Australia; China; Japan; Korea; and Singapore.

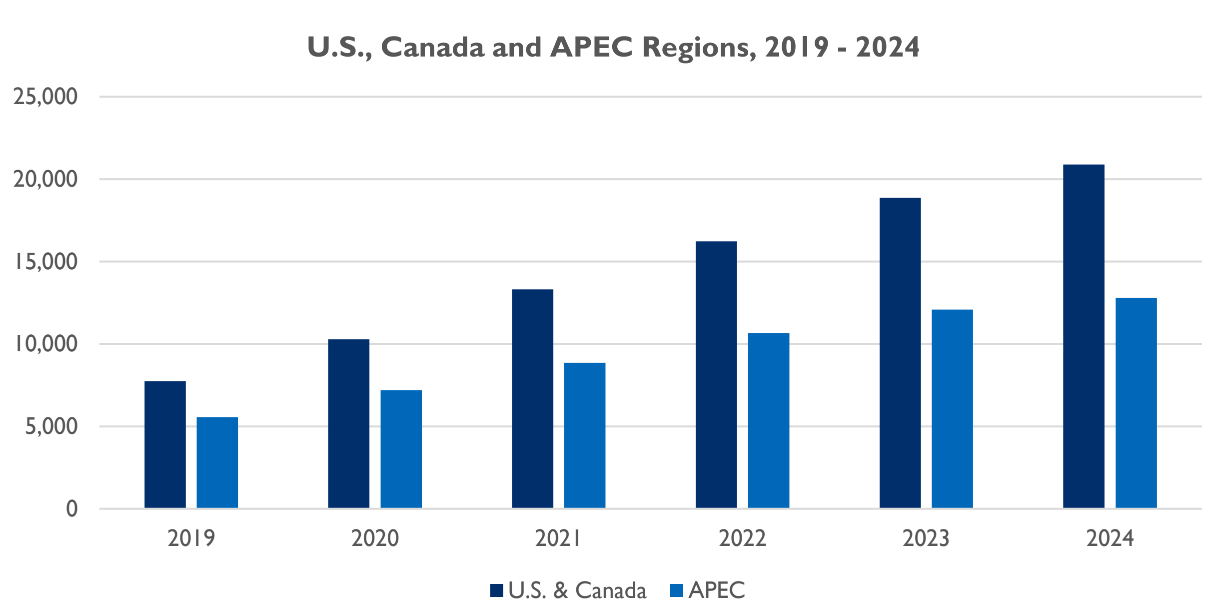
Figure 2 - Comparative cellular connections by tech generation (2019-2024)



Source: *iGR*, 2020

As the mix of air interface technology generations change over time so too does usage of the mobile network. Figure 3 shows how in the U.S. and Canada average mobile data usage (megabytes per month) per connection increases from approximately 7,700 MB/month in 2019 to more than 20,000 MB/month by 2024. The following figure shows how in the APEC economies' average mobile data usage (megabytes per month) per connection increases from approximately 5,500 MB/month in 2019 to nearly 13,000 MB/month by 2024. A great deal of this mobile data usage occurs in the economies with 4G LTE and/or 5G networks.

Figure 3 - Comparative average mobile data usage per connection per month (2019-2024), MB



Source: *iGR*, 2020

Regardless of where users are in the world, people tend to use networks in the same ways – voice/text/video communication, web browsing, social networking, consuming and creating video content, gaming, etc. One of the bottlenecks to greater cellular adoption is the cost of building, operating, maintaining and then upgrading the radio access network.

There are many economy-level trends behind the ongoing upgrade from 2G to 3G to 4G LTE and from there to the deployment of 5G New Radio (NR) Non-standalone (NSA) and Standalone (SA). The two major current trends with respect to the enhanced mobile broadband use case of 5G involve creating:

- Coverage where none exists and extending coverage to greater swathes of the population.
- Capacity, and building more capacity, so that the network provides useable throughput over time as demand for mobile data increases.

One major problem is that MNOs in some economies/regions have a lower ceiling with respect to the average revenue per user they can generate relative to other economies. However, those companies still have to build a cellular network that covers the population and provides sufficient capacity. Given that lower revenue ceiling, the cost of equipment (and deployment in general) is critical since these are typically for-profit companies.

In the past, regions that deployed new mobile technologies later in the product cycle have benefited from the cellular technology adoption and advancement in the early-adopter markets. For example, with 4G LTE, as deployment volumes ramped in the first regions to deploy LTE, unit costs fell. Moreover, expertise regarding deployment methodology, etc., was earned and then shared. This has led to lower costs toward the middle/end of the 3G/4G cycle which has benefited carriers in those regions that waited to move to 4G LTE. The same will be true with 5G.

OPEN ARCHITECTURE AND NETWORK VIRTUALIZATION

As mentioned earlier, Open RAN involves building networks using a fully programmable software-defined radio access network solution based on open interfaces that runs on commercial, off-the-shelf hardware (COTS) with open interfaces. This is similar to how data centers are run – various types of software are run on general-purpose computing equipment.

Today, there are many Open RAN-related work centers developing reference designs for hardware that can be used to run cellular telecom equipment. The purpose of the reference designs is to standardize the hardware so that any vendor (software or hardware) can build equipment that interoperates with all the other relevant parts of the cellular network. The main goal is to keep the interfaces open, so that hardware and software will interoperate no matter which company creates it. Note that the existence of open interfaces does not preclude the use of proprietary techniques deeper within the hardware/software solution.

There are a great many moving parts in these standardization efforts, along with technical “showdowns” among different groups pushing different ideas that will become standards. Usually, support coalesces around a handful of these competing proposals, and one becomes the standard. In the end, there is a diversity of approaches to implementing the given standards in reference designs. This results in different products targeted at different performance, power and cooling levels.

This allows MNOs to build the network that best fits their budget and/or customer base.

WHAT DOES "OPEN" RADIO ACCESS NETWORK ARCHITECTURE MEAN?

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

Openness does not mean that all hardware and software will be 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. "Open" also does not mean simple – RANs are complex with many moving parts.

WHAT IS VIRTUALIZATION?

Virtualization is the logical separation of hardware and software by abstracting the software application from the underlying hardware. For example, Solution A is broken down into component parts by first splitting the hardware from the software. Think of the hardware as a personal computer (PC). It can be configured (almost) however one wants – motherboard, processor, memory, video card, hard drive, etc. – using parts from any vendor. All of those hardware parts interoperate.

The resulting PC can be built for a variety of tasks: gaming, general use, etc. There is a wide range of components across all those tasks and within each type of task (e.g., high, medium and low-end video cards) just as there is a wide range of PC vendors who target certain niche users with pre-built PCs. Even with a given PC vendor's portfolio there is a wide range of SKUs that target different use cases.

Now, consider the software. Obviously, there is different software for different tasks (and even software choice for the same tasks). Some software could take advantage of certain hardware capabilities – e.g., advanced visual features in video games – but that software will (likely) run on any gaming PC. The analogy breaks down a bit, but the fundamental point is that the software and hardware are not built together nor does one require the other or vice versa.

So, with all that in mind, a RAN can be:

- Not open and not virtualized: this is the state of most commercial mobile networks today. Vendor-specific software (that implements cellular standards) runs on vendor-specific hardware.
- Not open and virtualized: i.e., the software and/or the hardware could be proprietary, but the software will only "talk" to other specific applications
- Open and virtualized: not only is the software running on generic hardware, but the hardware and software will also interface with any other platform

BENEFITS OF OPEN RAN

Some of the benefits of adopting the Open RAN model include:

- The opportunity to use cutting edge hardware and software components rather than be restricted to using both the hardware and software provided by a single RAN vendor – this expands the supply chain for RAN solutions, thereby diversifying the ecosystem of vendors from which MNOs can procure network equipment. A wider ecosystem of vendors increases competition, drives innovation, and lowers pricing by reducing vendor lock-in, though the intermediate supplier ecosystem for some components like semiconductors and software may not change in the short- to medium-term.
- Making network maintenance open to a wider range of professionals through existing IT processes and procedures.
- Enabling competition among vendors and leading to lower network structuring cost, and supply stability.
- Open RAN can reduce the amount of physical infrastructure needed at cell sites, though it obviously does not eliminate the need for antennas.

Open RAN also has numerous benefits for consumers and enterprise customers in APEC economies. Because Open RAN uses COTS and software, the cost of deploying a mobile network is likely to be lower than a similar network deployed using traditional RAN hardware – this is, of course, assuming that the Rakuten deployment proves to be the rule rather than a potential exception. Should Open RAN-based networks truly prove to be less expensive to deploy, then there is the potential to reduce the "rural Internet gap", which was 40 percent in low- and middle-income economies; those living in rural areas were 40 percent less likely to use the Internet than those in urban areas.

For example, by using Open RAN-based solutions an MNO could provide cellular coverage/capacity to areas where it would have been too expensive to deploy a network using traditional RAN equipment. Those companies that build Open RAN-based networks can deploy them more quickly. Finally, because the network potentially costs less to deploy and operate, an MNO can sell the service to consumers and businesses for less than using traditional mobile architectures, which makes it more likely that more people can afford access.

Due to the open interfaces and standardized hardware, the network software will run on COTS and interface with hardware and software from other vendors. This expands the supply chain for RAN solutions, thereby diversifying the ecosystem of vendors MNOs can procure network equipment. A wider ecosystem of vendors increases competition and lowers pricing.

Finally, because Open RAN is software based (though it does include antenna selection), many Open RAN functions could reside in the cloud (a data center). The cloud could be:

- Owned and operated by the MNO

- Owned and operated by a third-party data center provider.

IMPACTS FOR END USERS

In this instance, the term "end users" refer to consumers and enterprise users. Consider the following:

- According to the ITU, Asia & the Pacific geographic region has an estimated Internet user penetration of 47 percent (2018 data). In 2018, the "rural mobile internet gap" was 40 percent in low- and middle-income economies; those living in rural areas were 40 percent less likely to use the mobile internet than those in urban areas.

- According to the September 2019 ITU State of Broadband report [1], 43.5 percent respondents in low-income economies cited poor connectivity as a barrier when trying to use the Internet, compared to only 34.6 percent of those in upper middle-income and 25% in high-income economies.

- Japan's Rakuten has estimated that its capital and operational costs are lower with Open RAN compared to a traditional network. Given that, it is reasonable to suggest that by using Open RAN an MNO could potentially deploy a RAN over a large coverage area or network capacity for a given amount of capital. Note that there are likely to be differences in this regard between "greenfield" and "brownfield" deployments.

The impacts of Open RAN for end-users go further:

- The MNO could provide coverage/capacity to areas where it would have been too expensive to deploy a network using traditional equipment. Several of the leading Open RAN solutions support multiple air interface technologies (2G, 3G, 4G, 5G) in a single package. This is also possible with radios from traditional vendors, but the point is raised here because it demonstrates how Open RAN is, in this respect, on par with traditional solutions. It is beneficial to support multiple air interfaces in a single product because it allows the MNO to use the same equipment as it implements the newer air interfaces which they do because the later technologies are more efficient than older technologies. That is, operators can do more with the same amount of spectrum.

- Because an Open RAN-based network may cost less to deploy, the MNO can sell the service for less which makes it more likely that more people can afford access.

Note that at the time of this writing, Rakuten in Japan was the only MNO to deploy an Open RAN-based network with radios that all had the same specifications. Rakuten's experience suggests that deployment costs with Open RAN are likely to be lower, but this may not prove true in all geographies and in all situations.

IMPACTS TO ECONOMIES

According to the September 2019 ITU State of Broadband report [1], capital investment in the global communications industry had continued to rise (in the pre-COVID-19 world, at least). That report also stated that capital expenditure growth was driven by increases in emerging economies which have rapidly increasing Internet user bases and demand for data consumption. This is the same trend *i*GR forecasts illustrated.

The ITU report went on to state that mobile operators will invest approximately USD 1.3 trillion worldwide in mobile capital expenditures between 2019 and 2025 of which more than 75 percent would be spent on 5G networks. (Their forecast was made before COVID-19.) Online service providers have become major investors in digital infrastructure (data centers, submarine cables and other facilities).

It is no secret that foreign direct investment can help economies grow. Open RAN is software-based (aside from the antennas and other necessary physical components) and the hardware is COTS. This means that more companies than just the few, large established RAN vendors can participate in developing solutions. In Japan, the government, mobile network operators and solution vendors see Open RAN as a major business opportunity.

Open RAN can help create a competitive environment in which entrepreneurs and/or existing small- and medium-sized enterprises have a greater opportunity to develop products/services for mobile networks. Policy decisions could further incentivize enterprises to move toward building Open RAN-based solutions. Moreover, an existing Open RAN company, or even an MNO in the given economy that moves forward with Open RAN technologies, could be incentivized to transfer that knowledge into the given economy. This can be used to develop and encourage specific parts of the workforce such as women and workers retrained from older, obsolete industries.

The September 2019 ITU State of Broadband report [1] suggests a correlation between broadband access and gross domestic product (GDP) growth:

- An increase of 10 percent in fixed broadband penetration yields an increase of 0.8 percent in GDP,
- An increase of 10 percent in mobile broadband penetration yields an increase of 1.5 percent in GDP.
- In more developed economies, the economic impact of fixed broadband is greater than in less developed economies.

The government of Japan has developed tax incentives for 5G investment, introduced on August 31st, 2020. Corporate taxes are deducted for carriers that have confirmed they will deploy 5G networks by vendors that meet three main requirements: security and trustworthiness; supply chain stability; and openness. Openness is set as one of the requirements in order to promote multi-vendor solutions.

The Open Radio Access Network (O-RAN) Alliance and its members are promoting Open Testing and Integration Centre (OTIC) to facilitate integration and interoperability testing of multi-vendor solutions. Led by the Ministry of Internal affairs and Communications (MIC), operators and vendors are coordinating to establish an OTIC in Japan.

Cellular is not just about connecting people. It is also about connecting machines – the Internet of Things (IoT). Machine-to-machine and machine-to-human connectivity is important both in 4G and 5G. In fact, much of the forthcoming mobile connections growth is due to IoT rather than people/subscribers. Consider a multi-economy enterprise that only wants a smart supply chain using IoT. The mobile network built out to support that use case. Cellular networks can provide the connectivity necessary and is likely to be architected differently in the beginning than one that has to support human communications.

Finally, Open RAN-based solutions when deployed by operators can help facilitate improved connectivity in a region. Consider that not only can cellular do everything a wired network can (provide fixed broadband connectivity, Internet access, streaming entertainment, etc), but it can do so at (potentially) less cost. Depending on the wireless network architecture used, a cellular network can be deployed using wireless backhaul (so a fiber connection does not have to be trenched to a cell site). Small cells can also be mounted on existing buildings, towers, or street furniture. Both of these aspects can reduce the cost of deployment.

Cellular can also be deployed more quickly, it provides inherent security at the air interface and SIM card level while also delivering mobility both within the region if not globally. A 4G solution deployed today can also be software-upgraded to 5G. Unlike the original analog cellular systems from the early 1908s, today's 4G and 5G network protocols are encrypted and also use spread spectrum technologies, making interception and decryption extremely difficult. This is not to suggest that cellular networks are more secure than their wired counterparts, but rather that cellular networks are not inherently insecure simply because they are wireless.

Cellular spectrum can also be used for fixed wireless access (FWA). The network is architected differently, but wireless point-to-multipoint broadband services to homes or businesses are available today in many economies. The deployment cost of FWA is also low compared to a wired network, particularly as FWA is ideal for rural areas.

OPEN RAN IN APEC: LESSONS LEARNED AND POTENTIAL BARRIERS

As with other parts of the world, implementing Open RAN remains a challenge for telecommunications carriers within APEC. Perhaps the foremost reason is that Open RAN is relatively new and relatively unknown. The approach requires the commitment, knowledge base and confidence to integrate the disparate parts of the RAN. In the short term, it is much easier and faster (if potentially more expensive) to implement the RAN solutions provided by the traditional RAN equipment vendors.

New approaches to telecommunications architecture naturally involve a degree of ongoing progression and maturation. The same is of course true for Open RAN (Open RAN has been in development for some years), with some posing questions on aspects like performance characteristics, technical security, or energy usage. These are worthy of further study, and will be addressed as there are more trials, a phased introduction, and further optimization over the next few years. While Open RAN continues to develop, economies can take a technology-neutral approach that does not exclude the development of other relevant secure technologies in the future. Open RAN networks will be deployed alongside traditional architectures, which will allow for direct comparisons, and a rapid maturation of the new architectures.

This discussion is also occurring against the backdrop of standardization and coordination efforts in bodies such as the O-RAN Alliance and Telecom Infra Project. These bodies are continuing to develop technical solutions and push the standards forward, thus addressing current concerns, as well as encouraging new vendors into an expanding ecosystem.

For APEC, there is an unprecedented opportunity to play a valuable role facilitating the adoption and development of Open RAN architecture. This could be done simply by constructively sharing information among member economies and other stake holders to remove barriers and understand the Open RAN ecosystem.

Some challenges to Open RAN deployment include:

- By virtue of their established base of traditional mobile operator radio infrastructure, the established traditional RAN 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.

- While 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 critical for the success of the Open RAN movement.

- Deploying and maintaining/optimizing traditional networks requires a lot of manual labor and results in potentially higher labor costs. 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. It is worth noting that traditional network vendors have also been promoting the deployment of network automation as well.

- Security has been raised as a potential issue for Open RAN networks and is a topic that requires further analysis. The level of security deployed in a mobile network depends on many factors and is not only impacted by the level of openness or virtualization implemented, but also by the level of maturity of the vendors and features deployed in a 5G system. Open RAN may in fact offer important security-related benefits like enhanced transparency into network functioning, and AI-enabled security and measurement tools; it is important to continually reassess such benefits as the market matures.

- Open RAN standards-related activity must take security appropriately into account. Some feel that Open RAN networks could be exposed to a higher level of malicious activity due to the expected expansion of the number of nodes (device connections) in a 5G network, as well as a higher level of virtualization, thus expanding attack opportunities. Others believe that these dynamics may affect 5G networks generally, and that the increased visibility and monitoring available through Open RAN will be helpful in addressing them.

- If Open RAN proves successful and saves on expenditures, the workload of compatibility testing could also increase. This will require personnel with a deep, technical understanding of the technology. This may prove a challenge that could necessitate vendors testing and certifying the compatibility of their equipment, rather than putting the responsibility on MNOs, especially smaller service providers.

- The MNOs that have deployed Open RAN to date have seen significant decreases in deployment and operational costs. Determining vendor responsibility for component failures or interoperability problems could also affect the savings in deployment and operational costs, and potentially lengthen the amount of time to restore service in the event of a failure in part of the network. WOn the other hand, the increased visibility inherent in Open RAN may make it easier to locate the source of potential issues, and Open RAN's use of interoperable components could facilitate replacement of faulty components. In short, more Open RAN deployments are needed to understand the potential savings on a global scale. Reliable metrics on the operational costs of Open RAN are therefore not yet available.

While there are already examples of Open RAN architectures in APEC member economies and more planned, several factors impact the pace at which the approach will be deployed in the region:

- Economies may consider it more important to get the technology/network rolled out than it is to implement a relatively immature set of products compared to what can be bought and installed from the established RAN equipment vendors.

- The MNOs in those economies are perhaps already contractually committed to a deployment plan with an established RAN equipment vendor. That capital is earmarked and that investment needs to be depreciated. Over time, as these traditional agreements expire, those MNOs may choose to expand/upgrade their networks with Open RAN elements.

- The population of those economies may have a relatively small workforce with the IT skills necessary to install, operate and/or maintain Open RAN. Obviously, many within a given economy have IT skills, but it is likely those individuals are already employed in IT firms/functions. Over time, the IT workforce can of course be expanded through training and education. The software driven approach of Open RAN will require shifting worker skillsets away from hardware to software deployment and maintenance.

- Regulators / government officials in developing economies may be more focused on other issues besides what is admittedly a more technical argument for how mobile networks can (or should be) deployed. Other economies in APEC can offer assistance to each other with respect to building knowledge about Open RAN.

CASE STUDIES: OPEN RAN APPROACHES IN APEC ECONOMIES

There are several examples of Open RAN deployments in the APEC member economies – in fact, this region has more examples of Open RAN deployments than elsewhere in the world. Each Open RAN deployment differs, both in terms of scale and schedule, but also with regard to the vendors used and the level of integration, if any, with existing mobile architectures. The below case studies reflect what individual companies have announced, but APEC economies should take into consideration factors related to network buildout, quality, deployment, user development and business conditions.

This section discusses the progress of several Open Ran deployments with: Rakuten; NTT DOCOMO; IpT Peru; and Dish Network. Note that some of the operators studied are greenfield operators, whose experiences might be different than brownfield operators.

RAKUTEN

In early 2020, Rakuten launched a multi-vendor, Open RAN, using products from Altiostar, Airspan, Nokia and others. To make this happen Nokia (one of the few established RAN vendors) opened its interfaces to support Altiostar's software solution which runs on COTS hardware from Quanta in a virtualized environment from Cisco.

Rakuten's Open RAN – i.e., the Rakuten Communications Platform (RCP) – began as an LTE network consisting of both macrocells and small cells. As of June 2020, Rakuten had more than 5,700 base stations on air and another planned 7,500 sites with contracts signed. By October 2021, the operator's 4G network had 94.3 percent of Japan's population covered.

Reportedly, these consist of the minimal physical equipment required to provide cellular service. Rakuten Mobile has less than 10 SKUs, recently announced only 2 SKUs in order to enable infrastructure standardization, leading to not only economies of scale in procurement, but also reduced operational complexity. These sites are made operational via a cloud-based, virtualized RAN. Rakuten's RAN uses a carrier-grade core network for operations.

Rakuten's CTO Tareq Amin has been quoted many times as having said that the Open RAN framework has proved approximately 40 percent less expensive than traditional telecommunications infrastructure. More specifically, Rakuten has stated that it has realized:

- 40 percent lower capital expenditures compared to traditional networks largely because RCP needed less site equipment due to virtualization and pooling of capacity/resources.

- 30 percent reduction in operational spending largely due to less site equipment that required less total footprint and resulted in lower total power consumption. This has also helped reduce the cost of the company's field maintenance.

From a customer experience standpoint, Rakuten has stated that its data volume per subscriber is 0.5 GB per day, its network serves more than two million videos per day and that its rich communication service (RCS) call volume (which incorporate video) is more than 2.5 times higher than its Voice over LTE (VoLTE) call volume.

NTT DOCOMO

In September 2019, NTT DOCOMO announced that along with Fujitsu, NEC and Nokia, it had achieved world's first multi-vendor interoperability across a variety of 4G and 5G base station equipment based on O-RAN Alliance's open interfaces, namely open fronthaul and open X2. This equipment was deployed in its pre-commercial 5G service. The same equipment, with software upgrades, are used to provide its commercial 5G services launched in March 2020.

In September 2020, NTT DOCOMO further announced expansion and enhancement of multi-vendor activities using O-RAN's open interfaces including: new 5G baseband unit (5G-CU/DU) developed by NEC and Samsung, 5G radio units (5G-RU) for macro-cells and fronthaul multiplexers (FHM); and realization of 5G mmWave commercial service from September 2020 and world's first carrier aggregation on 5G sub6 GHz bands in a multi-vendor RAN. Carrier aggregation on 5G sub6 GHz bands provides maximum downlink data rates of 4.2Gbps, and is available for commercial service since December 2020.

NTT DOCOMO is building its 5G network fully based on multi-vendor interoperable base station equipment supporting O-RAN's open interfaces. It is providing 5G services in all 47 of Japan's prefectures, has deployed 10,000 base stations as of June 2021, and has announced plans to have 20,000 base stations deployed by the end of March 2022.

In February 2021, NTT DOCOMO agreed with 12 companies, including Dell Technologies Japan Inc., Fujitsu Limited, Intel K.K., Mavenir, NEC Corporation, NTT DATA Corporation, NVIDIA, Qualcomm Technologies, Inc., Red Hat, VMware K.K., Wind River and Xilinx, Inc. to cooperate towards a "5G

Open RAN Ecosystem" with the objective to further accelerate Open RAN by developing virtualized RAN with vendors for global operators.

IPT PERU

In Peru, the ISP Internet para Todos Perú (IpT Peru) launched in May 2019. It is owned by Telefónica, Facebook, IDB Invest and CAF banks. IpT Peru has deployed hundreds of new mobile sites using the Parallel Wireless virtualized and automated Open RAN architecture along with several other equipment vendors. IpT has stated that all new radio units are automatically configured by the software, which reduces the need for manual intervention (and thus lowers costs). IpT Perú, Telefónica and Parallel Wireless have also developed an operating model that helps to streamline the adoption of new network functionality and features. This helps to further reduce operational expenses and accelerate product cycles. While IPT Peru previously replaced 150 of its Open RAN base stations when it was undergoing network expansion, the company has since continued to tout the effectiveness of Open RAN to bringing 4G solutions to rural Peru.

DISH NETWORK

DISH Network is a U.S.-based connectivity company. Through its subsidiaries, the company provides television entertainment to over eleven million customers with its satellite DISH TV and streaming SLING TV services. In 2020, the company became a domestic U.S. wireless carrier through the acquisition of Boost Mobile.

DISH has invested over $20 billion in wireless spectrum assets to enter the wireless industry and is currently building the United States' first cloud-native, Open RAN-based 5G broadband network. DISH recently launched their first Open RAN 5G radio and antenna trial cell site in Littleton, Colorado. As they continue to build-out their Open RAN network, DISH is expected to cover 20% of the U.S. population by June 2022 and 70% of the U.S. population by June 2023.

DISH has participated in every FCC spectrum auction since 2008. Its spectrum acquisitions include: the FCC's 2008 700 MHz auction; a 2011 acquisition of two satellite service companies with AWS-4 spectrum holdings; the FCC's 2014 H Block auction; the FCC's 2017 600 MHz Incentive auction; the FCC's 2019 24/28 GHz auctions; and the FCC's 2020 Citizens Broadband Radio Service (CBRS) auction. Utilizing Open RAN cloud-native wireless architecture, DISH plans to use its spectrum to deploy the economy's first virtualized, standalone 5G broadband network. DISH has hired several leading wireless industry executives and has been growing its wireless workforce while also announcing major vendor agreements for partners in its network buildout.

Unlike legacy networks, DISH will not carry the burden of maintaining legacy technology. By bringing together innovations such as the distributed cloud, edge computing and network slicing, DISH's software-based network will provide customers with customizable, secure solutions that stand to be more cost-effective than legacy, vertically-integrated, hardware-reliant alternatives.

The following table shows DISH's announced vendor partners.

Network Element	Vendor
RAN hardware	Fujitsu
RAN management software	Altiostar, Mavenir
RAN silicon and software architecture	Intel
RAN platforms	Qualcomm
Core	Nokia
Cloud orchestration	VMWare
MVNO enablement	Tucows
Network intelligence and automation	Blue Planet (Ciena)

REFERENCES

[1] ITU: The State of Broadband: Broadband as a Foundation for Sustainable Development, September 2019

ANNEX A

WORKSHOP ON NETWORK VIRTUALIZATION, DISAGGREGATED NETWORKS, AND OPEN TELECOMMUNICATIONS ARCHITECTURE IN APEC
February 24, 2021

BACKGROUND & OBJECTIVES

Network virtualization and open and interoperable interfaces enable economies to move to "open" or "disaggregated" telecommunications networks, removing the need for specialized hardware and allowing networks to integrate "best of breed" software and hardware from different vendors. The resulting architectures can contribute to a more robust, open, cost-effective, and competitive telecommunications ecosystem, potentially enabling firms, including SMEs, to establish themselves as more globally competitive vendors. With the proliferation of these newer approaches, opportunities arise for APEC economies to realize greater transparency, interoperability, and efficiency in markets.

On February 24, 2021, the United States, with co-sponsors Japan; Korea; and Mexico, organized a workshop on Network Virtualization, Disaggregated Networks, and Open Telecommunications Architecture in APEC, gathering APEC economy policymakers and regulators who have authority to advance policies related to network virtualization and open architectures, as well as industry stakeholders in this space.

Ms. Jaisha Wray, Associate Administrator for International Affairs at the U.S. National Telecommunications and Information Administration (NTIA), provided a keynote address highlighting potential benefits of industry's development of open, interoperable networks. These include increased competition, enhanced supply chain resilience, and lower prices for operators and consumers. Lower barriers to entry in the telecommunications equipment market would also unlock economic opportunities for innovative companies and entrepreneurs around the world.

The workshop then featured panel sessions — with iGR, authors of this report; the Open RAN Policy Coalition; the Telecom Infra Project; and private sector telecommunications firms from Japan (NTT DOCOMO and Rakuten Mobile) and the United States — to facilitate information sharing on the adoption and application of network virtualization and open architectures in APEC economies. These discussions between panelists and thoughtful questions from workshop participants facilitated enhanced positive engagement with innovative new approaches while also encouraging cross-border policy exchange and coordination.

Closing remarks were provided by Adam Lusin, Director of the Office of International Communications and Information Policy at the U.S. Department of State's Bureau of Economic and Business Affairs, who emphasized the role that further innovations in open telecommunications architecture and associated policy could play in bridging the digital divide, by rebalancing market dynamics and expanding opportunities for innovative small and medium enterprises, creating competition that lowers costs and expands network reach.

The workshop was attended by 75 participants from 15 APEC economies, the private sector, and the APEC Secretariat; 39 percent of workshop participants identified as female.

REPORT FINDINGS: NETWORK VIRTUALIZATION AND DISAGGREGATED NETWORKS IN APEC

Prior to this workshop, the United States circulated the *Network Virtualization, Disaggregated Networks, and Open Telecommunications Architecture in APEC* report to APEC Telecommunications and Information Working Group (TELWG) members for review and comment. This workshop served as an opportunity for APEC economies to discuss the report's themes and provide suggestions to finalize the report and develop future activities.

The report's author provided an overview of findings, first discussing the benefits of open telecommunications architectures. In part because Open Radio Access Networks (Open RAN) use commercial off-the-shelf (COTS) hardware, the cost of deploying a mobile network is likely to be lower, which increases the potential to reduce the "rural mobile internet gap." In addition, a broadening of the supply chain could allow for increased participation by local vendors from emerging markets, which could in turn help to expand the market and support workforce development within the hardware and service communities. APEC economies can further capitalize upon these benefits to drive critical technology development and increase representation of women and marginalized communities in the local technology ecosystem.

Despite these benefits, APEC economies may experience challenges that impact the extent and pace of Open RAN deployment. Open RAN is a relatively recent development that involves commitment, knowledge, and confidence on the part of industry players to integrate different components into a network. Decisionmakers may default to established RAN solutions to the extent they are easier to implement in the short term, despite the demonstrated benefits of Open RAN systems.

ADDRESSING POTENTIAL CHALLENGES

Subject matter experts discussed their experiences in fostering an enabling environment that allows for technical proliferation, sharing considerations that may be helpful as economies seek to address potential challenges. The Open RAN Policy Coalition presented its Open RAN Policy Roadmap, a resource that economies can use to connect policy tools to specific Open RAN objectives and learn how other economies have used policy approaches to achieve similar goals. Following this presentation, the Telecom Infra Project shared insights from an Indonesia case study on digital transformation, advocating for public-private partnerships to validate technology, provide solutions in the field, build awareness, promote innovation, and develop the local talent pool.

Subsequently, industry representatives from NTT DOCOMO, Rakuten Mobile, DISH Network, and AT&T discussed their experiences with Open RAN in their economies and took questions from workshop participants. The four operators stressed the advantages of Open RAN, including lower capital costs, which could help extend connectivity to remote areas and close the digital divide. In response to questions, panelists discussed the steps they take to ensure robust network security in Open RAN deployments, emphasizing that potential vulnerabilities are minimized with early risk detection, intrusion detection, and isolation capabilities associated with Open RAN, an improvement over legacy systems. U.S. and Japanese operators said this increased system transparency and flexibility to swap out component parts offered security advantages. When addressing potential challenges to Open RAN deployment, panelists recommended that economies consider phased and localized approaches, building technical expertise in COTS products and facilitating information exchange opportunities to promote knowledge sharing on solutions and innovations. Panelists also acknowledged the role of public-private dialogue in creating a forward-looking regulatory environment and facilitating cross-border information exchange in the region.

In response to a question on whether Open-RAN will encourage supply chain diversity given that some hardware elements may presently be provided by a smaller number of vendors, the panelists stated that the shift to whitebox vendors is in fact incentivizing entry by more hardware suppliers and that they are already seeing increased participation by vendors from more economies. The event moderator and participants discussed challenges about other aspects of Open RAN networks as well, such as scalability and the need for regulatory certification.

FUTURE ACTIVITIES

Following the workshop, economies provided feedback to inform future capacity building activities on network virtualization, disaggregated networks, and open telecommunications architectures. Participants indicated an interest in the economics of Open RAN, requesting further details on the costs associated with Open RAN rollout, as well as further insights on the development opportunities and economic gains for emerging economies. Participants also suggested a series of deep-dive events to promote more robust information sharing on the opportunities and challenges of Open RAN, building on the themes covered in this introductory workshop. Participants proposed additional topics for capacity building programming and economy-level technical assistance, including telecommunications standards and regulations; workforce development and Open RAN upskilling; strategies to accelerate broadband penetration; and demonstrations of technology, technology adaptions, and sample use cases.

AGENDA

Workshop on Network Virtualization, Disaggregated Networks, and Open Telecommunications Architecture in APEC

February 24, 3:00p – 6:00p NZDT *(February 23, 9:00p – 12:00a USEST)*

TIME (NZDT)	DESCRIPTION
3.00p – 3.05	Welcome Remarks Adam Murray, Acting Deputy Director, International Communications and Information Policy, Department of State, United States
3.05 – 3.15	Keynote Jaisha Wray, Associate Administrator, Office of International Affairs, National Telecommunications and Information Association (NTIA), United States
Panel 1 3.15p – 3:45	Report Findings: Network Virtualization and Disaggregated Networks in APEC *This panel will feature iGR, author of the US' self-funded report on Network Virtualization and Disaggregated Networks in APEC, to discuss the key findings from the research.* Iain Gillott, CEO, iGR *Questions and Answers*
Panel 2 3.45p – 4:30	OpenRAN Enabling Environment Landscape *The ORAN Policy Coalition and the Telecom Infra Project will present on their experiences in fostering an enabling environment that allows technological proliferation.* Moderator: John Garrity, US-SEGA Panel: • Alex Botting, International Programs Director, ORAN Policy Coalition • Vishal Mathur, Global Head of Engagement, Telecom Infra Project (TIP) *Questions and Answers*

Panel 3 4:30 – 5:45	Case Studies: OpenRAN Technology Deployment *Industry representatives will discuss their experiences deploying Open RAN in their economies in a moderated discussion led by the moderator.* Moderator: John Garrity, US-SEGA Panel: • Masafumi Masuda, Director, Radio Access Network Development, NTT DOCOMO, Japan • Dr. Tsunehiko Chiba, Head of Standards, Technology Strategy Headquarters Standardization, Rakuten Mobile, Japan • Jeffrey Blum, Executive Vice President, External and Legal Affairs, DISH Network, United States • Chris Boyer, Vice President for Global Security and Technology Policy, AT&T, United States *Questions and Answers*
5.45p – 6.00	Closing Remarks Adam Lusin, Director, Office of International Communications and Information Policy, Department of State, United States

APEC project: TEL 03 2020S

Produced by
US-Support for Economic Growth in Asia

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APEC#223-TC-01.1