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TIP OpenRAN: Toward Disaggregated Mobile Networking

A Heavy Reading white paper produced for the Telecom Infra Project



TELECOM INFRA PROJECT

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WHY OPEN, DISAGGREGATED RADIO ACCESS NETWORKS?

Mobile networks serve more than 9 billion connections and generate almost \$1 trillion in service revenue annually, according to research firm Omdia.* And with millions of cell sites deployed globally, this makes radio access networks (RANs) the most important distributed network infrastructure in the world.

As operators enter the 5G era, the RAN is increasingly software-driven and based on open implementation and open interfaces. Some of the largest equipment vendors are migrating from integrated single-vendor systems to more modular, open platforms. In parallel, a new wave of challengers is adopting software-centric design principles to develop disaggregated, virtual RANs (vRANs) optimized for cloud deployment and operation.

This paper profiles the work of the Telecom Infra Project (TIP) OpenRAN Project Group. TIP is an industry initiative focused on advancing open telecom networking through disaggregation, open interfaces, and the development of reference implementations. The TIP OpenRAN Project Group is one of the foremost open RAN initiatives in the industry. It is focused on collaborative working, reference implementations, interoperability, field trials, and developing pathways to commercial deployment of OpenRAN solutions.

This paper identifies and explains the key achievements of the project group and looks ahead to the next phases of OpenRAN development. It places the work of the group in a wider industry context to illustrate how OpenRAN helps operators and the wider ecosystem advance their goals for low cost, high performance mobile connectivity. In terms of RAN interfaces, TIP has recently announced a liaison agreement with the O-RAN Alliance and will use O-RAN interfaces in OpenRAN implementations, test programs, and so on.

RAN market overview and drivers for OpenRAN

The mobile RAN equipment market (covering active base station equipment and antennas, but excluding power supplies, cable, install costs, civils, passive antennas, etc.) was worth about \$33 billion in 2019, according to Omdia,[†] and is forecast to grow to \$36 billion in 2023. After almost two decades of consolidation, the top three vendors now have a combined revenue market share of approximately 80%. The market share of the top five vendors is higher than 95%. Among the reasons for this consolidation are the investment in R&D required to compete in the RAN; the need for high product volumes to sustain profit margins; and the need for geographically distributed field employees. TIP OpenRAN must address all these issues to be successful.

The concentration of market share has advantages, but for operators that buy and operate RAN equipment, there are also downsides. These disadvantages can be summarized as follows:

- **Limited availability of suppliers and reduced competition:** In some important markets, this is now a critical problem that has been exacerbated by geopolitical issues, especially relations between China and some Western nations.

* Omdia's World Information Series Service Provider Data and Forecasting Service

[†] Omdia's *Radio Access Network Forecast: 2019–24*

- **Monolithic RAN products:** Large vendors favor integrated products under their exclusive control. This can mean customers are held hostage to big company development timelines. Innovative subsystem suppliers are also buried beneath the large OEM brand.
- **Lack of software control and feature development:** It can be hard for operators and independent software developers to gain control over RAN equipment due to proprietary interfaces and licensing restrictions.

The open RAN movement, in general, and TIP OpenRAN, specifically, are a reaction to the limitations of the current model. They also represent recognition that “open” practices in adjacent industries like those used in open compute and cloud networking can be applied to telecoms to deliver cost-effective solutions and faster innovation cycles. The three primary drivers for open RAN are the following:

- **Vendor diversity and ecosystem:** There is a strategic need for greater diversity and choice in the supply chain. Diversity and competitive innovation at the module level would also be welcome; for example, there is a good chance that a competitive market in white box radios will emerge from TIP OpenRAN.
- **Cloud technologies and economics:** This is about disaggregation and moving functionality to modular software that runs on high volume general-purpose hardware. The cloud operations model, characterized by extreme automation, is also fundamental to the OpenRAN business case.
- **Open interfaces and programmable RAN:** Open interfaces between RAN centralized unit (CU), distributed unit (DU), and radio unit (RU) subsystems enable operators to create best-of-breed solutions. In an open RAN architecture, specialist software developers can gain near-real-time control of radio resources and improve system performance through novel algorithms.

TIP OpenRAN initiatives

There is activity to develop open RAN architectures and specifications by several industry bodies. This includes work within the 3GPP (the major industry standards body), the O-RAN Alliance, the Small Cell Forum, and the OpenAirInterface Software Alliance. TIP distinguishes itself by focusing on the collaborative development of technical reference implementations and routes to commercial deployment. In the mobile network area, and radio access specifically, TIP has a broad range of activities underway, as outlined in **Figure 1**.

Figure 1: TIP project groups focused on mobile RAN

Project Group	Description
OpenRAN	An initiative to define and build 2G, 3G, and 4G disaggregated RAN solutions on general-purpose vendor-neutral hardware and software-defined technology.
vRAN Fronthaul	Developing and validating non-ideal transport solutions for fronthaul to enable virtualized RAN deployments where fiber is unavailable or unaffordable.
OpenCellular	A publicly available RAN solution tailored for rural connectivity.

Project Group	Description
OpenRAN 5G NR	To define an open and disaggregated white box platform for a 5G NR base station that is easy to configure and deploy.
CrowdCell	Developing LTE relay architectures to extend indoor coverage with reduced capex and opex investment.
Non-Terrestrial Radio Access	A project group focused on satellite, drone, balloon, and aircraft access providing cellular connectivity focused on solutions for coverage extension and emergency relief.
Disaggregated Cell Site Gateways (DCSG)	A project to develop an ecosystem of disaggregated cell site transport solutions that allow a mix-and-match of different software and off-the-shelf hardware platforms; first commercial deployments are live.

Sources: Heavy Reading, TIP

Operator OpenRAN activity

Operators worldwide are interested in TIP OpenRAN, and there are several examples of commercial, multi-vendor deployments. These are relatively small scale at this stage; however, the OpenRAN concept has been proven and there are now strong demand signals in the market to encourage ongoing development and larger-scale deployment. Specifically, in relation to TIP, several operator members have announced trials and commercial pilots of OpenRAN systems. Three of the highest profile are the following:

- **Rakuten:** A new member of TIP, joining in November 2019, Japan's Rakuten Mobile launched the world's largest vRAN network covering 4,000+ cell sites in April 2020, with plans to extend nationwide in the coming years. Rakuten is a cloud-native online services company and does not consider itself a traditional mobile operator.
- **Vodafone:** A co-chair of the OpenRAN Project Group, Vodafone is also one of the most active trialists of OpenRAN solutions, with activity in Turkey, the UK, Ireland, Mozambique, South Africa, and the Democratic Republic of Congo (DRC) on public record. It recently announced an open request for proposal for its vast European RAN estate (greater than 100,00 cell sites) that it hopes will be attractive to OpenRAN suppliers.
- **Telefónica:** Has one of the most significant OpenRAN projects in the industry and is deeply engaged with the TIP OpenRAN. It has a live deployment in Peru with several hundred sites live. It also hosts one of the TIP's interoperability testing labs focused on implementing a continuous integration (CI)/continuous delivery (CD) framework for OpenRAN at its R&D labs in Madrid, Spain.

Momentum for OpenRAN is also building elsewhere, helping to drive investment in silicon, software, and systems integration. Operators that have publicly announced trials or deployments of TIP OpenRAN systems are found in the following geographic regions:

- In **Indonesia**, Indosat Ooredoo and Smartfren will conduct the first OpenRAN field trials in the Asia Pacific region.
- In **Malaysia**, edotco, the tower arm of Axiata Group, is collaborating with Celcom Axiata to conduct lab trials, with a view to field trials in the near term.
- In **Russia**, MTS has joined the OpenRAN Project Group as a contributing member.

- In the **Middle East**, Etisalat has committed to OpenRAN in the United Arab Emirates and will extend trials of OpenRAN solutions to more operating countries later in 2020.
- In **North America**, Sprint has completed its request for information (RFI) evaluation and will begin trials of OpenRAN 5G NR technologies in its TIP Community Lab.
- In **Germany**, Deutsche Telekom is expanding its TIP Community Lab and will launch a European Open Test and Integration Center that will work on validating O-RAN-compliant RU-DU solutions to be used in the upcoming Open Fronthaul TIP PlugFest. It is also a member of the new Evenstar program to develop a white box radio.

TIP OPENRAN PROJECT GROUP

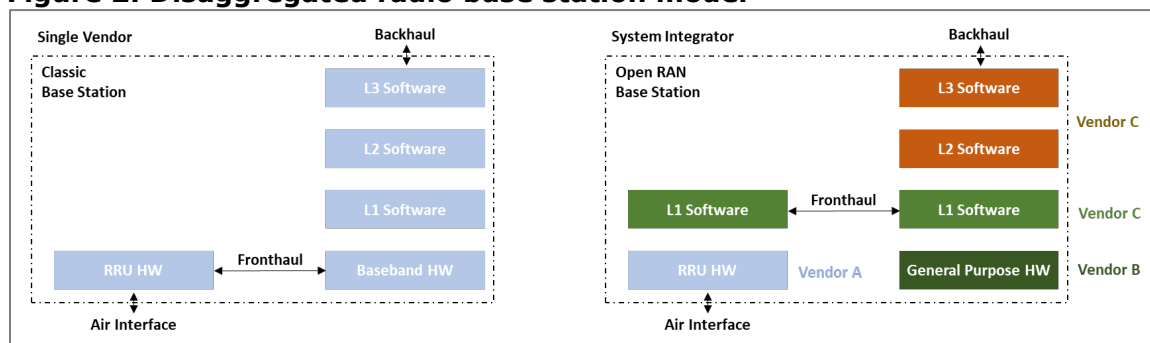
The TIP OpenRAN Project Group was chartered in 2017 at a time when vRAN was widely discussed but considered impractical to implement and deploy for commercial traffic. The intent of the project group was to demonstrate a multi-vendor, “production-grade” software-based RAN that can run on general-purpose hardware and be modified, in software, to support different use cases (e.g., urban and rural networks). In keeping with TIP practice, the project group was “sponsored” by operator members—in this case, Vodafone and Telefónica, along with the co-chair of the Project Group (Intel)—and approved by the TIP technical committee. A broader target of helping to stimulate the wider open RAN ecosystem outside TIP was also identified as an important objective.

A software-first RAN ecosystem

A requirement of the OpenRAN charter was to develop programmable baseband software that can run on general-purpose processing platforms (GPPPs). In principle, this can be any capable off-the-shelf processor type. It is anticipated that, over time, there will be several hardware options available. Depending on the use case, additional silicon options may be considered, such as field-programmable gate arrays (FPGAs) for Layer 1 acceleration.

Figure 2 compares the classic, single-vendor base station model (left) with the new, disaggregated radio base station (right). In the OpenRAN model, different vendors can supply different parts of the system, with a systems integrator to combine the elements into a working system.

Figure 2: Disaggregated radio base station model

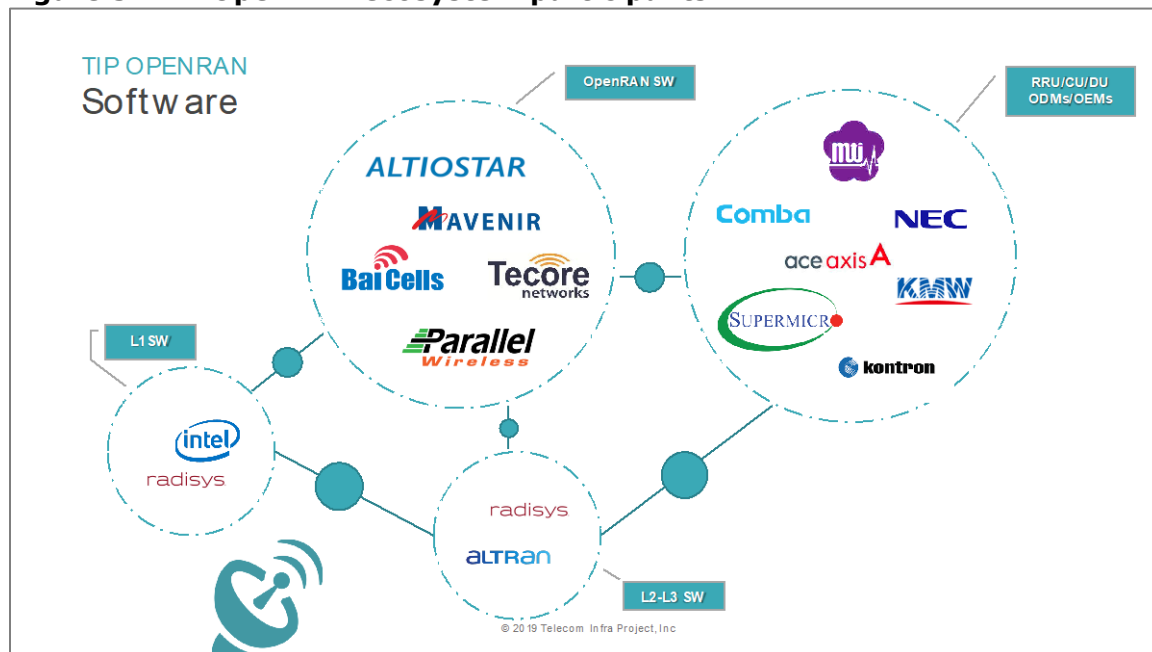


Sources: Heavy Reading, TIP OpenRAN

The OpenRAN Project Group draws on the expertise of several different participating companies. The participants are shown in **Figure 3**, grouped according to which part(s) of the system they contribute. They are generally nontraditional RAN technology vendors and typically smaller companies. In some cases (e.g., Intel and Commscope), they are well-established base station subsystem suppliers with sizable revenue.

The baseband hardware used in the project is based on GPPPs. To date, this has been an Intel Xeon processor, which serves as a common baseline on which different software can be deployed. In the future, it is anticipated that newer Intel silicon and non-x86 processor architectures will be used. Intel also provided a reference Layer 1 (L1) software called FlexRAN to kick-start the project and shorten development time. FlexRAN showcases how to write the L1 software using CPU instruction sets (specifically, the AVX instruction sets) and CPU architecture building blocks (e.g., Cache). FlexRAN enables L1 on an Intel GPP CPU while meeting real-time RAN requirements. Note, however, this is a reference L1 implementation and is not intended for commercial operation “as is.” As shown in **Figure 3**, reference implementations of L2 and L3 software were provided by Radisys and Altran, enabling “demo class” digital baseband units (BBUs) to be created.

Figure 3: TIP OpenRAN ecosystem participants



Source: TIP OpenRAN Project Group

In addition to discrete Layer 1, 2, and 3 software implementations, independent software vendors—Altiostar, Mavenir, Parallel Wireless, Baicells, and Tecore Networks—also provided complete L1/L2/L3 baseband software to run on the reference hardware. These baseband software stacks *are* intended for commercial deployment and have been developed, hardened, and tested accordingly. This software has been used in OpenRAN field trials and in live commercial deployments. Performance and features vary by vendor.

A critical part of a radio base station is the RU, also known as the remote radio unit (RRU), which radiates the downlink signal and receives the uplink. The radio includes functions such as analog-to-digital conversion, filters, power amplification, and so on. The RU

accounts for more than half the bill of materials for a radio base station. It is, therefore, critical to OpenRAN that there is a competitive market for these products. Ace Axis, Baicells, Benetel, Comba, Commscope, KMW, Kontron, MTI, and Supermicro have been involved in the OpenRAN Project Group to date. There are also several other active RU suppliers in the market, but they are not yet part of TIP OpenRAN.

Across the industry, operators wish to see a competitive white box radio market. Generally speaking, RUs use integrated hardware/software and are not “disaggregated” in the classic sense, but rather in the sense of open interfaces to connect to BBUs. The Evenstar program by Vodafone, Deutsche Telekom, Mavenir, Parallel Wireless, MTI, AceAxis, Facebook Connectivity, and additional partners is designed to address this through the development of a white box reference design. The intention is to contribute the proposed solution to TIP’s OpenRAN Project Group to help accelerate adoption. This is discussed in more detail in the **Next phases for TIP OpenRAN** section below.

Working processes and output

The OpenRAN Project Group is open to all TIP members. Led by the co-chairs from Vodafone and Intel, the group collectively defined performance targets for the OpenRAN reference system, with benchmarks for factors such as bandwidth, MIMO rank, number of users, setup success rates, handover performance, and so on. Different benchmarks were developed for different deployment scenarios (e.g., rural vs. urban).

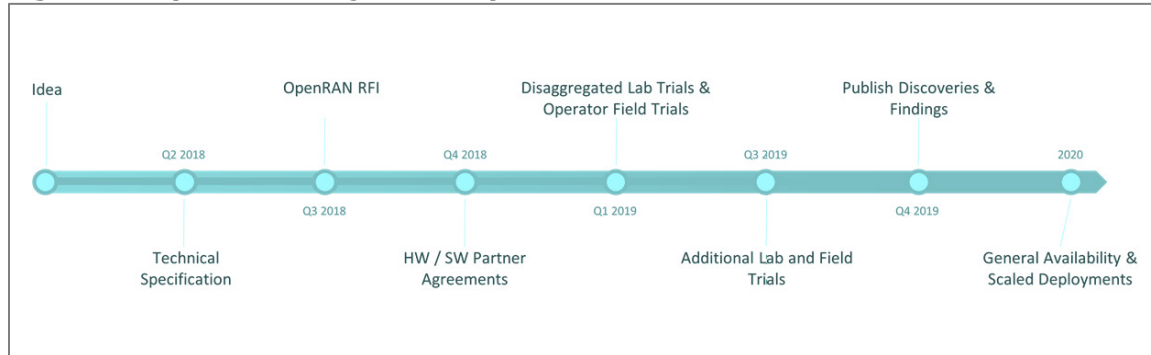
These system-level key performance indicators (KPIs) were codified in a test plan developed by the project group in association with the TIP Community Labs’ teams. The demo systems were then tested against the criteria and the results shared with group participants. This working model helps each participant learn from best practices and from other companies’ errors. Smaller companies can benefit from greater scale in the development process and system improvements can be made more quickly. This collaborative working model is at the heart of the TIP OpenRAN project.

In terms of deliverables, the OpenRAN Project Group is focused on activities that encourage ecosystem development and accelerate deployment. Think of the following as products of the working group:

- Statements of requirements for OpenRAN implementations, adapted for different deployment scenarios.
- Establishment of collaborative working processes that can accelerate future work. The same model could be adapted for developing an open 5G RAN.
- Reference integration documents for multi-vendor RAN base stations validated by TIP Community Labs; these are not reference designs as such, but offer a baseline for commercial products. Documentation is shared in the project group online workspace.
- The OpenRAN RFI issued jointly by Vodafone and Telefónica in 2018 and the subsequent field trials were informed by work in the Project Group.
- Field trials of OpenRAN systems, creating a pathway to commercial deployment, which is probably the key achievement of the group: to have contributed significantly to developing and demonstrating commercially viable software-based RANs. (More on this in the next section.)

Figure 4 shows the OpenRAN Project Group timeline from inception in late 2017 to the current situation of trials and commercial deployments. The group expects its work to contribute to commercial deployments later in 2020.

Figure 4: OpenRAN Project Group timeline



Source: TIP OpenRAN Project Group

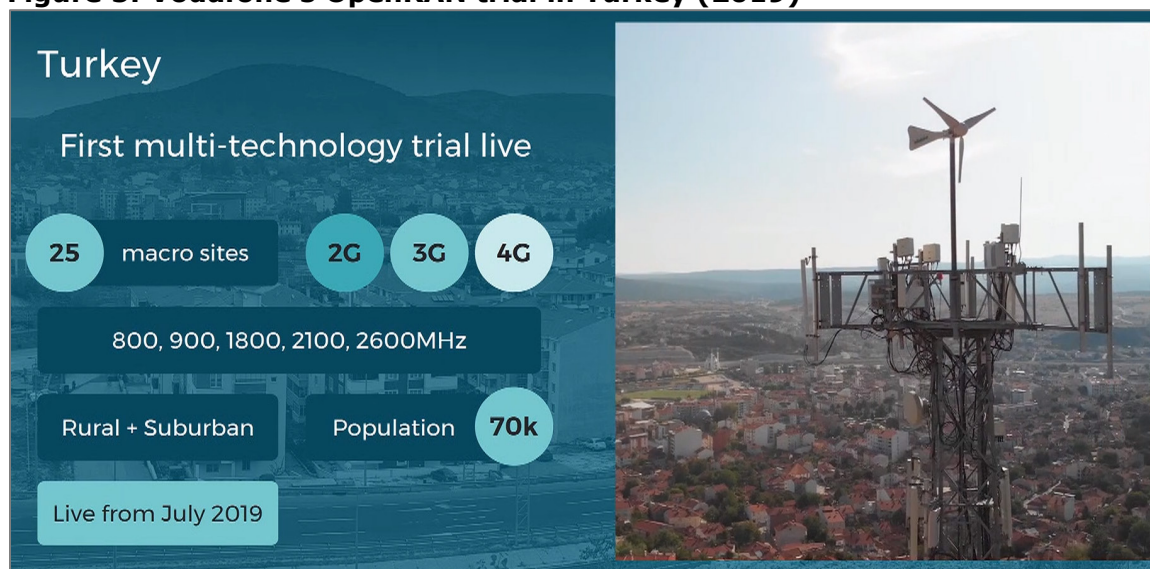
OPENRAN FIELD TRIALS AND PATH TO COMMERCIALIZATION

After the proofs of concepts and lab trials, the project group moved on to field trials, some of which have already led to commercial deployments. Two of the TIP-endorsed field trial programs were led by Vodafone and Telefónica. The results were presented publicly at the TIP Summit 2019 in Amsterdam.

Vodafone trials: Turkey

Vodafone has announced OpenRAN trials in several markets, including the UK (the first in Europe), Ireland, DRC, Mozambique, Ghana, South Africa, and Turkey. Its trial in Turkey started in February 2019, with results presented at the TIP Summit in November 2019. The trial, which is ongoing, covers a suburban district of a small city. Vodafone deployed 25 OpenRAN macro sites with 2G, 3G, and 4G access across five different frequency bands to provide coverage to a population of 70,000. This is shown in **Figure 5** below.

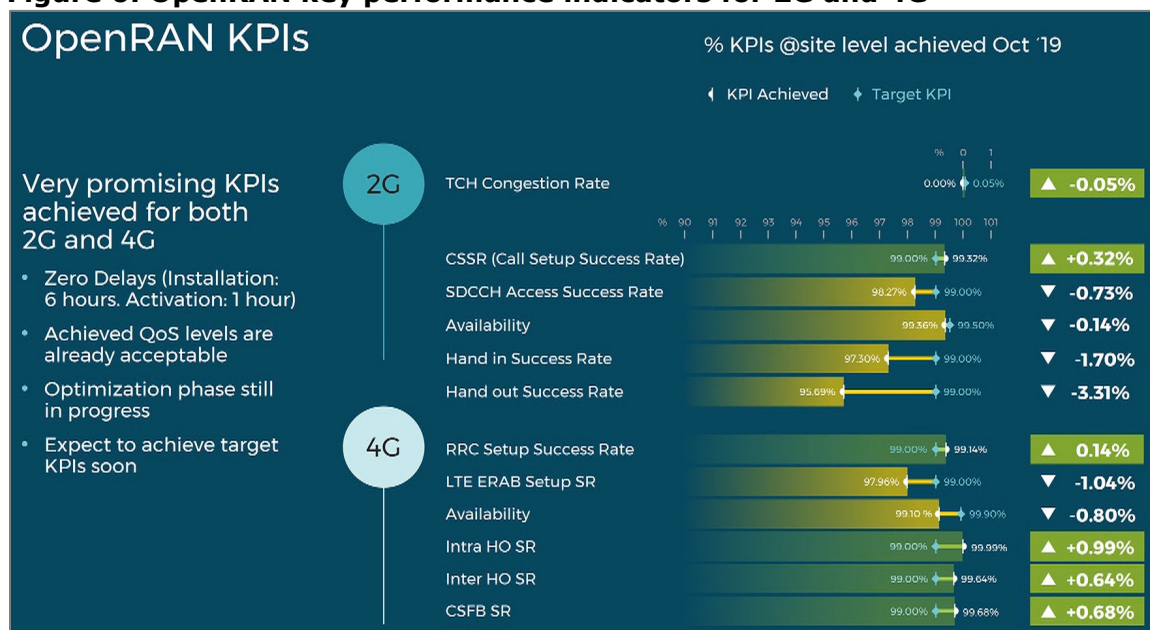
Figure 5: Vodafone's OpenRAN trial in Turkey (2019)



Source: Vodafone at the TIP Summit, November 2019

Vodafone has reported that the pilot is progressing well. **Figure 6** shows some of the target KPIs the operator set for the trial. The green boxes indicate the performance target has been achieved and the arrows and percentage values show the extent of the over- or under-performance. 4G performance, particularly, is close to commercial grade. Vodafone is using a “DevOps” model, enabling it to work with vendor partners to make rapid updates to the equipment via new software loads or configuration changes. This is part of the reason it is confident the KPI thresholds will be achieved quickly. Vodafone plans to extend this OpenRAN network to serve denser, more urban parts of the city later in 2020.

Figure 6: OpenRAN key performance indicators for 2G and 4G



Source: Vodafone at the TIP Summit, November 2019

Turkey is also the first market where Vodafone, or any other operator, will trial OpenRAN small cells in the field. This is a TIP initiative known as a CrowdCell and is intended to extend coverage and capacity at cell edge locations.

Telefónica trials: Peru

Telefónica is one of the foremost advocates of open networking in the telecom industry and was the first major operator to deploy the disaggregated cell site gateway technology, developed within TIP, in a large commercial network (O2 Germany). The operator is a sponsor of the OpenRAN Project Group, has trialed the technology in the field, and has deployed it in commercial networks. It is positive about the outlook for OpenRAN in general.

At the TIP Summit 2019, Telefónica shared information on its OpenRAN project in Peru, where it is one of the leading mobile operators. The network is run by a company called Internet Para Todos (which translates into “Internet for All”), a provider set up to serve people in under-connected areas of the country. It acts as a wholesale operator that works with Peruvian mobile operators to extend their coverage to hard-to-reach regions.

The network covers 800,000 people with 650 macro sites and has accumulated 450,000 subscribers in the six months since it launched in May 2019, which has been a roaring success. More than half of the 650 sites were built using OpenRAN technology and based on equipment from vendors that performed well in the 2018 OpenRAN RFI. This makes it probably the largest commercial OpenRAN deployment worldwide to date. To build and operate the network, Telefónica relied on a combination of in-house resources and a systems integrator with a major local presence. The operator has also adopted a DevOps-style CI/CD operating model to be able to rapidly deploy and evolve the network.

NEXT PHASES FOR TIP OPENRAN

When the TIP OpenRAN Project Group was formed in 2017, there was widespread interest in the technology but skepticism that it could meet commercial requirements of advanced operators. In the intervening period, sentiment has turned more positive thanks to activities such as TIP OpenRAN showing the technology and the associated “cloud-inspired” operating models can be competitive.

While it is not yet the case that programmable, software-based RAN deployed on general-purpose hardware is ahead of proprietary solutions in performance or economics, the gap is closing fast, and there is a real possibility that software-centric RAN will become a mainstream deployment option in the next few years. Operators worldwide are ramping up investment in trials, developing vendor relationships, and thinking about how their operating models must change to take the most advantage of OpenRAN. The technology is now hitting its stride and there are many areas where TIP can make further contributions to OpenRAN.

TIP OpenRAN PlugFest

One major activity for the project group in 2020 will be to host an interoperability PlugFest. This will be a multi-party test event that will

- Help vendors improve interoperability.
- Reduce the need for individual vendors and operators to replicate tests.
- Signal to the market that multi-vendor software RAN works and is viable.

The specifics of the PlugFest are still being developed, but it will be conducted in TIP member Community Labs and is expected to cover two major areas:

- **Interworking between RU-DU-CU functions:** This is to test compatibility with interfaces already standardized for the DU-CU and RU-DU by 3GPP and the O-RAN Alliance. These base station components should be plug-and-play across vendors.
- **Site solution validation:** In practical terms, operators think in terms of a complete site solution. There is a need for the OpenRAN ecosystem to industrialize site deployment, including aspects such as install, power supply, redundancy, cabling, antenna systems, transport interfaces, and so on.

Evenstar open radio program

The radio module, known as an RU in 5G and an RRU in 4G, makes up a significant part of a base station bill of materials, has a major impact on site deployment and operations, and affects system performance. The Evenstar program, recently launched by Vodafone, Deutsche Telekom, Mavenir, Parallel Wireless, MTI, AceAxis, Facebook Connectivity, and additional partners, aims to create open RRU reference designs that can be implemented by independent commercial suppliers. The intention is to encourage competition and innovation in the RRU market. Evenstar is being contributed to the TIP OpenRAN Project Group.

Classic RRUs are sold integrated with the base station and manufactured by the base station vendor, or a subcontractor, to its own design. They connect to vendor-specific BBUs over a quasi-proprietary Common Public Radio Interface (CPRI) standard. This combination makes it difficult for operators to source each component separately.

Evenstar will create a common, open reference design that uses the O-RAN 7.2 open interfaces to connect the RRU to BBUs provided by independent suppliers. This is a critical interface for open RAN systems. Since it supports packet-based Ethernet fronthaul, it also provides greater flexibility in deployment.

The first Evenstar RRU design is a frequency-division duplexing (FDD) product supporting Band 3 (1800MHz), 4T4R, and 160W (40W per port). Other bands are under consideration for the future. Products should be commercially available from several suppliers by 2H20. The target cost is \$1,000 per unit/sector, which is significantly below market price today. At this price point, with adequate performance density (including power efficiency), commercial-off-the-shelf RRUs will be an important enabler for software-based OpenRAN.

Next steps: 5G OpenRAN, next-gen silicon, and edge cloud

The OpenRAN Project Group has, to date, focused on 2G, 3G, and 4G access. This covers the majority of the market today. However, with 5G buildouts underway and scaling rapidly, there is now also a need for 5G OpenRAN. Without this, OpenRAN can only sell into a declining market (albeit a very large one) and operators will be limited in how much they can adopt OpenRAN. This is exacerbated because 4G and 5G RANs are now, and will continue to be, tightly integrated.

TIP is addressing 5G in the OpenRAN 5G NR Project Group. This work is focused on macro and small cell applications and developing white box platforms. The OpenRAN 5G NR Project Group has developed and released the technical requirements to define an open and disaggregated platform based on commercial off-the-shelf components that can meet the needs of 64T64R, 16T16R, and 4T4R base stations. In addition, extending the TIP CrowdCell Project Group, which currently focuses on LTE relay architectures to extend indoor coverage to 5G, is under consideration.

Elsewhere, Heavy Reading expects to see progress in the GPPPs used to run RAN software. This has the potential for very substantial performance improvements, particularly for radio signal processing (essential for higher order MIMO, massive MIMO, and beamforming), but also to address density, power consumption, and cost. This expectation of higher performance, off-the-shelf silicon capable of running 4G/5G baseband is already driving the big RAN vendors with proprietary, integrated products to accelerate their vRAN developments. While not yet certain, there is potentially a route to this becoming the dominant model over the longer term, and larger established vendors are wise to be up to speed.

A number of interesting considerations remain to be determined: What type of GPPP will be used? Will these always be x86, or will ARM, GPU, or some other architecture also be used? What will be the implications for software developers? And what physical platforms and which deployment models will prevail? Classically, baseband is deployed at the cell site; however, OpenRAN provides an opportunity to run RAN as an application on multipurpose edge cloud infrastructure. These questions are, arguably, out of scope for TIP OpenRAN, but clearly have an impact on RAN software developers and the operators deploying the technology.