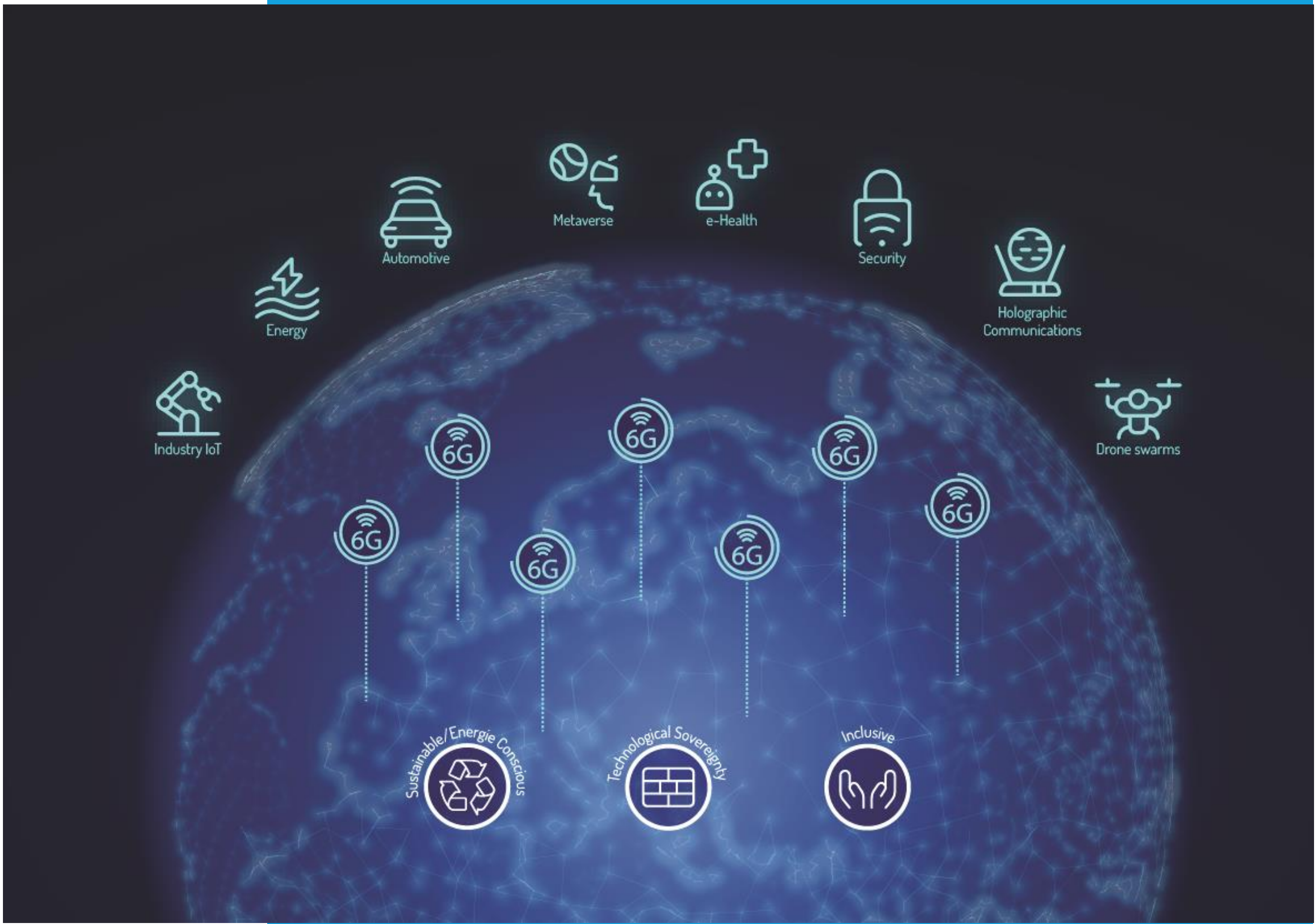
6G Smart Networks and Services Industry Association (6G-IA)



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White paper

OPEN RAN AND 6G FUTURE NETWORKS DEVELOPMENT

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C2 General

EXECUTIVE SUMMARY

The development of 6G networks represents an exciting opportunity to advance the capabilities of wireless communications. The design and deployment of these networks will require new approaches to network architecture that can efficiently accommodate the diverse needs of different deployment strategies and use cases in the future. Open (in the sense of opening new interfaces) and disaggregated network architectures promise flexibility in selecting and optimizing network functions and services. This white paper explores the potential benefits and challenges of such architectures in the context of radio access networks (RAN).

Open RAN refers to the disaggregation of radio access network (RAN) components, assembled using **open interface** specifications between elements, such as open fronthaul, and enabled by software **virtualization**. This approach allows for implementation on vendor-agnostic hardware and software-defined technology, leveraging open interfaces and collaboratively developed standards. Furthermore, Open RAN incorporates **intelligence** through artificial intelligence/machine learning-based (AI/ML) open platforms to optimize network performance and enhance the user experience.

Open and disaggregated network architectures are expected to offer several benefits for 6G networks. Firstly, they promise for greater flexibility in selecting and optimizing network components and services. This flexibility can potentially help to meet the diverse needs of various use cases. Open RAN is a specific example of such an architecture that allows for network functions to be moved into the cloud, looking for greater efficiency and scalability. Secondly, the definition of new interfaces on top of the already defined open interfaces in 3GPP, as Open RAN proposes, increases flexibility in the market and potentially leads to more competition in the telecoms supply chains. Finally, open and disaggregated network architectures can facilitate a smoother transition to 6G by allowing multi-vendor network components to be reused where possible, while new components can be added to support 6G scenarios, which could impact positively in a more efficient total cost of ownership management potentially.

Open RAN architecture may also present several challenges. Security risks associated with the use of open interfaces and the management of multiple vendors, are a well-known issue, as well as managing the lifecycle, the integration of different platforms on top like RAN Intelligent Controller (RIC) and Service Management and Orchestration (SMO) components and their coordination with different vertical use cases can be a significant challenge. Finally, one of the key challenges is the complexity of the network, and more specifically the integration of different vendor components which can be difficult to address the mix and match approach of the E2E solution. Integration of Open RAN components will create considerable cost and personnel efforts which could lead into just few multi-vendor Open RAN solutions being tested and deployed, limiting large-scale multi-vendor interoperability.

To address the potential key issue of limited multivendor combinations testing, a common regime for certification of Open RAN solutions needs to be set up which focuses on few

widely used interoperability profiles, streamlines the process around integration and enables industry players to develop their solutions towards agreed test plans. This challenge should not be solely tackled in other areas of the world - Europe needs to play a leading role in the certification of Open RAN solutions to retain leadership in telecommunications.

This document proposes in its final section (chapter 5) a list of recommendations to European Commission to foster the maturity of open Network aiming at facilitating the future transition to 6G networks in the future.

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1. OPEN RAN

Currently, there are 3 main new components discussed in the context of Open RAN. Firstly, hardware and software should be decoupled targeting to run telco software on 3rd party hardware and in the cloud infrastructure. Secondly, the radio components should be decoupled from the baseband components targeting increased deployment flexibility and competition . Thirdly, new interfaces and corresponding functions should be introduced targeting improved network control through end-to-end AI/ML powered automation and optimization.

Existing open interfaces such as RAN-Core and others, providing benefits in today's cellular networks, e.g. mobility, roaming, etc. should of course be kept also in the future. However, interfaces of legacy systems that were proven not to be beneficial and just complicate standardization and implementation, should be consolidated in the next generation.

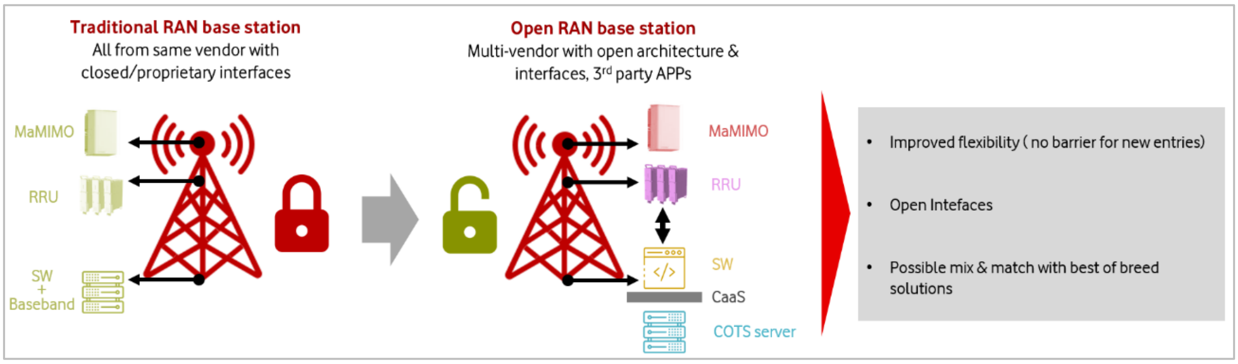

Figure 1: Traditional RAN vs Open RAN

Open RAN promises benefits in comparison to traditional integrated solutions; however, challenges need to be assessed as well. In this chapter benefits and challenges associated with Open RAN networks are summarised.

1.1. POTENTIAL BENEFIT OF OPEN RAN

Increased competition

Currently the traditional RAN supplier's ecosystem is based on integrated solutions s. This creates a lack of flexibility to replace selected RAN elements with other suppliers' equipment/components since some RAN-internal interfaces are proprietary. This makes it costly to incorporate RAN products from a different vendor since all RAN kit would need to be replaced on the same site.

Open RAN breaks this paradigm and resides not only in disaggregating hardware and software but also in adding new open interfaces among RAN elements, as well as introducing a new level of intelligence in the network.

Thanks to a set of new open interfaces and virtualization of the software, Open RAN´s goal is to enable a diverse vendors ecosystem to provide components that can interoperate and work together seamlessly. This would allow network operators to select the best components for their specific needs and requirements, and to integrate them into the overall RAN architecture. This may bring additional opportunities to a wide range of potential new vendors, what would be a common scenario in the development of 6G future networks.

Open RAN has the possibility to facilitate the entry of new suppliers in the RAN ecosystem as the disaggregation of hardware and software plus new open interfaces among RAN elements bring down the barrier for new players products adoption, widening the options for operators to choose their provider for each RAN element.

With a richer vendor ecosystem, competitive pricing for individual RAN components may be further stimulated.

Software-based design

Open RAN's software-based architecture allows network operators to run network functions on commercial-off-the-shelf servers (COTS servers) in the cloud rather than on purpose-built hardware. This may result in lower costs since software can be more easily modified and updated. Efficiency may increase since network operators can dynamically allocate compute resources on demand. However, running computationally heavy computing processes on general-purpose processors may limit network/energy performance such that specialized hardware accelerators will have to be integrated into the cloud platforms.

Innovation fostering

One of the main drivers of Open RAN is innovation. By facilitating that any supplier can be incorporated to the multivendor ecosystem, innovative products will have the chance to be introduced by operators in their networks. A diverse ecosystem of suppliers could accelerate the development of new technologies and solutions. Mobile operators can adopt these innovations directly, ensuring their networks remain at the cutting edge of performance and user experience.

RAN Automation with RAN Intelligent Controller (RIC)

One particular area of innovation in Open RAN is the RAN Intelligent Controller (RIC) framework which can improve the application of AI/ML automation control of RAN elements. Developers will be able to create external application to be run in RICs (rApp and xApp).

xApps are focused on implementing use-case specific logic and optimizations, while rApps concentrate on the control and management of the RAN infrastructure. The objective is that operator will have an option to select the best rApps and xApps from (3rd party) developers to run in RIC and to enhance network functionality, performance, and management, facilitating the adoption of new technologies and solutions, ensuring their networks remain at the cutting edge of performance.

Impact on Total Cost of Ownership

The above-described factors of virtualization/cloudification, increased competition, and AI-based automation of cellular networks are expected to lead to reduced Total Cost of Ownership (TCO).

However, that achievement would be the product of a wider multivendor ecosystem, implement innovative technology roadmaps in silicon and product evolution, AI/ML differentiation through RIC use case (enhancing efficiency and performance) and orchestration and automation (reducing time in network operations tasks).

Lowering RAN's cost may also help in combatting the digital divide, by enhancing the business case of RAN deployments in low-population density areas.

1.2. CHALLENGES

Traditional RAN offers are based on fully tested and integrated RAN solutions, where software and hardware are compatible and fully deployable. In Open RAN although operators will have more flexibility in choosing best of breed network components to build their RAN network, it comes with some challenges to deal with, especially in system integration and operation management areas.

Multiple vendors coordination

One of the main challenges for operator in Open RAN is the increase in complexity for managing and operating in a multivendor environment. Now the different RAN components can be provided by different providers (physical servers and infrastructure, SW virtualization layer, SW functionality, orchestration…). This could lead to unfulfilled SLAs and accountability problems with operators' customers due to ping-pong effects among the providers (i.e., who is really the responsible for fixing a fault?).

System Integration

Open RAN demands a new role to manage diverse complexities that were transparent for operators in traditional RAN; this role is defined as “system integrator”.

In traditional networks, vendors make transparent to operator the delivery of E2E solutions for which interoperability, conformance and performance of RAN elements are addressed, and life cycle is managed. On the contrary, in Open RAN, operators/System Integrators will have to deal with a more complex multivendor RAN environment and, therefore having a key role assuring the interoperability of the E2E, including conformance, software life cycle management, KPI assurance, service management, and so on and so forth.

In some cases, operators are aiming to run system integrator tasks internally, whilst others may rely on 3rd party companies’ assistance.

For the establishment of open ecosystems industry collaboration in areas such as interoperability testing would be necessary.

Operational Management

The integrated Open RAN solution presents important challenges due to its multivendor nature. The simple fact of having multiple vendors would make more complicated the management of alarms, commissioning, fault resolution, monitoring, etc. compared to single vendor environments. To reduce the complexity in operating a network based on Open RAN, the Service Management and Orchestration (boosted with AI/ML technology) will be necessary.

When an unexpected alarm or KPI degradation occurs, troubleshooting needs to be coordinated among all suppliers for root cause analysis and solution fix. If processes related to engineering support and escalation are not well defined, this may result in a stale mate between operators and vendors.

System integrator working together with Open RAN vendors and operators could be an option to assist operators in managing their network in a more efficient way.

Service Management and Orchestration (SMO) platform and Automation tools will be needed to facilitate operations and to manage complexity:

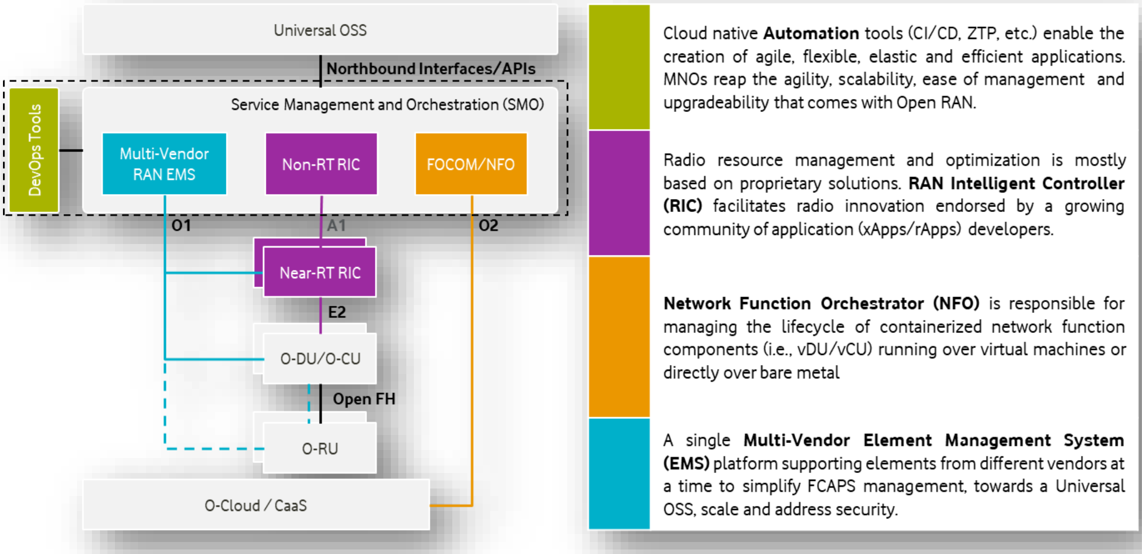

Figure 2: Functional diagram for cloud native network functions management

RAN Intelligent Controller Apps conflict mitigation

Current AI/ML solutions are usually applied to a single network layer (e.g., RAN), and aim for a single network intelligent task (e.g., energy saving). As the 5G and beyond network becomes AI native, a massive number of AI models will be deployed, likely in a distributed fashion at various components of the networks, addressing different network KPIs independently or simultaneously. The AI/ML models may be deployed according to the various operational or business objectives and requirements, identified by the network operator and/or AI model providers. In O-RAN Alliance specifications, the AI models that aim to address given network optimisation and management intelligent tasks, are named xApps and rApps. When deployed independently, xApps/rApps may be configured in such a way that they result in conflicting actions, for example, when the total requested resources by different AI models exceed the available system resources.

[1]In order for the multiple AI/ML models to work together without generating negative performance impact to the network, it is necessary to have unified control and management (including lifecycle management) of the AI/ML models.

The network is serving as a platform to host the various AI/ML models, that should collectively support the continuous integration and delivery (CI/CD) of AI/ML models, including the management of various stages in their lifecycles, such as configuration, validation, and deployment, as well as the orchestration of various AI/ML models iteratively, according to the different network contexts and requirements at the time. Such a platform should ideally support open APIs and open data accessibility, to realise the vision of an AI-native network in the 6G era.

"Additionally, anticipating a future requirement for AI/ML models harmonization, the mentioned RAN AI models should be aligned with other models and decisions that would happen across the network in a transversal manner, using, for instance, approaches like NWDAF.

Cross layer optimization

O-RAN Alliance is studying various RAN optimization use cases, utilizing AI agents deployed as xApps or rApps that, based on various data from the UE and the RAN functions, can trigger policies, modify RAN configurations, as well triggering other actions to optimize the RAN performance. Although promising there is also number of challenges related to LCM (Life Cycle Management), access to data, conflict handling, etc. that needs to be solved to realize the vision of xApps/rApps for RAN optimization. These challenges are also an important research area for future network going beyond 5G where it is expected that E2E optimized cross layer and cross domain is expected to be more important.

Critical dependencies

Disaggregation and interoperability are key pillars of O-RAN architecture allowing for the creation of multiple strategies and mechanisms with the aim of introducing more flexibility to the network and promoting a richer ecosystem of solution providers. However, Open RAN architecture does not eliminate critical dependencies, which can still be present when hardware or software becomes deeply integrated into the operators' network, harming the possibility of switching to an alternative solution. An example of these limitations is present in the required hardware acceleration to perform some wireless processing operations such as forward error correction.

Security risks

Open RAN introduces new security concerns when compared to monolithic, traditional RAN solutions due to its disaggregated architecture and increased reliance on software. Some of them are not exclusive to Open RAN but to any virtualized RAN network. However, Open

RAN has brought about new infrastructure, functions, and interfaces, with the potential to make future networks the most secure network generation so far, provided they are carefully configured and securely operated. To ensure the security of telco-specific functions and interfaces, 3GPP and the O-RAN Alliance have established a base blueprint and design principles. However, vendors and operators must implement additional security controls to achieve higher levels of protection against cyber-attacks, particularly for the IT and cloud systems that support modern networks. Adhering to these best practices is crucial for maintaining a secure, reliable, and efficient network while reducing the attack surfaces exposed by the overall architecture.

2. OPEN RAN STATUS

2.1. STAKEHOLDERS OF THE OPEN RAN ECOSYSTEM

2.1.1. MANUFACTURES

Open RAN focused small and medium enterprises / startups

Open RAN is the birthplace of a multitude of small new manufacturers, either spinning off universities or larger manufacturers. Those new companies often focus on a single product whose implementation or architecture differs considerably from the ones used by traditional vendors. While taking the risk of a business failure, those small manufacturers drive the pace of innovation where others may choose to be more conservative, yet secure development options. Resulting from their limited staff size, the new kids on the block are not able to heavily contribute to standards and thus fully rely on the ecosystem to mature the interface specifications. Particularly, in the area of xApps and rApps, many specialised software companies can feel attracted to develop innovative enhancements to operator´s networks.

IT players aiming at new business

The purpose of Open RAN is not only to create open interfaces, but also to foster cloudification and automation of the RAN. By that, it attracts companies which grew large in the IT space by development and sales of infrastructure and software solutions. These manufacturers aim to provide the servers and Container-as-a-Service (CaaS) software components required for cloudified RAN. Moreover, few companies even reach out into entirely new areas, offering radio intelligent controller (RIC) or the distributed unit (DU) and centralized unit (CU) software components. Outfitted with large research and development (R&D) budgets, the new market entrants can rapidly develop complex products and bring them to maturity. They can also contribute considerably to standardization and global plugfests to strengthen their position at operators with whom they already maintain long-term relationships.

A different category of such manufacturers are the producers of semiconductor chipsets. While these companies supplied traditional vendors with chips for their equipment already before the advent of Open RAN, they become the suppliers of old and new network equipment providers (NEPs) offering Open RAN radios or server infrastructure. The huge invest required to develop and manufacture leading-edge dedicated chipsets has been one of the reasons which let only a few traditional RAN vendors survive. Now chipsets with integrated hardware acceleration can be sourced from semiconductor manufacturers, lowering the barrier to become a RAN equipment manufacturer. Virtualised RAN solutions (not exclusive for Open RAN) have suffered from lagging in performance and energy consumption. Time will tell if the technical advancements of the semiconductor manufacturers in virtualised solution chipsets can be closing that gap.

Traditional manufacturers of RAN solutions

The first impulse of traditional RAN manufacturers to some of the aspects of Open RAN has been to safeguard decades of investments and well-established business models. With growing interest by operator in commercial Open RAN solutions coupled with investments by new entrants and traditional suppliers into their roadmaps, to ensure that Open RAN in brownfield and greenfield deployments meets expectations in terms of performance, feature parity, etc.; traditional manufacturers seek to evolve their portfolio towards Open RAN without compromising network performance. Transformation paths are unique per manufacturer and influenced by the varying perception of future business opportunity represented by Open RAN, however it is matter of fact that cloudification and RAN intelligence are progressing quite fast.

Nevertheless, European suppliers of traditional RAN solutions are some of the top major contributors to standardization and specially in O-RAN Alliance specifications definitions for Open RAN.

The European view on the RAN manufacturer ecosystem

Europe is facing a complex situation resulting from the Open RAN uptake. The greater number of the newly established Open RAN ecosystem comprises of vendors originated in the United States (RAN SW, IT, cloud platform, and semiconductor companies) or south-east Asia (radio equipment providers and RAN SW), building from ICT technological strengths in AI, cloud, virtualization, and semiconductors supported by a strong research, science and infrastructure deployment policies to develop and advance technologies to build or re-build technology leadership including maintaining or developing new national champions. European manufacturers are world-leading in traditional RAN and, although adapting their business to Open RAN in line with operators requirements, that adaptation needs to accelerate to improve their relevance worldwide. Traditional companies as well as new entrants need to ensure that performance expectations and challenges identified in Section 2 meet operator's expectations, to be able to succeed commercially. Furthermore, traditional vendors are decisively contributing to the technical work in ORAN-Alliance to ensure that technical specifications are in place to achieve Open RAN objectives.

2.1.2. INDUSTRY ORGANIZATIONS

Industry organizations such as 3GPP, O-RAN Alliance, ONAP, ONF, Telecom Infra Project (TIP), and others play a crucial role in the development of open network and service architectures. These organizations work in defining standards -or guidelines for the interoperability of network technologies, enabling innovation, and fostering the development of open networks.

Third Generation Partnership Project (3GPP)

Third Generation Partnership Project (3GPP) is a collaboration between telecommunications standardization organizations that develop cellular networks. It plays a pivotal role in defining the standards for all generations of cellular technologies. 3GPP specifications cover cellular telecommunications technologies, including radio access, core network and service capabilities, which provide a complete system description for mobile telecommunications. The 3GPP specifications also provide hooks for non-radio access to the core network, and for interworking with non-3GPP networks.

O-RAN Alliance

The O-RAN Alliance is a collaborative group made up of telecom service providers as members and vendors, academics, and other industry participants as contributors. The main objective is to create more intelligent, open, virtualised and fully interoperable Radio Access Networks (RAN).

O-RAN Alliance's work complements and enriches 3GPP specifications. It is organized into eleven working groups which are focused on defining various network functions, open interfaces and protocols, and four focus groups, being the most relevant the Open-Source Focus Group (OSFG), responsible for developing open-source software of O-RAN network functions and Test and Integration Focus Group (TIFG), responsible for conformance, interoperability and interface compliance of O-RAN products and solutions.

Telecom Infra Project (TIP)

The Telecom Infra Project (TIP) is a collaborative project between telecom service providers, equipment vendors, and other industry participants. It aims to create an open ecosystem for the telecom industry by promoting the collaboration, market requirements definition and interoperability testing of different vendor solutions. TIP's work focuses on creating open hardware and software designs that enable interoperability between different network components.

Within TIP, there are several project groups working on open network concepts: Open RAN, Open Core Networks, Open Optical & Packet Transport, Open Automation, etc.

6G Smart Networks and Services Industry Association (6G-IA)

The 6G Smart Networks and Services Industry Association (6G-IA) is the voice of European Industry and Research for next generation networks and services. Its primary objective is to contribute to Europe’s leadership on 5G, 5G evolution and SNS/6G research.

The 6G-IA represents the private side in both the 5G Public Private Partnership (5G-PPP) and the Smart Networks and Services Joint Undertaking (SNS JU). In the 5G-PPP and SNS JU, the European Commission represents the public side.

The 6G-IA brings together a global industry community of telecoms & digital actors, such as operators, manufacturers, research institutes, universities, verticals, SMEs and ICT associations. The 6G-IA carries out a wide range of activities in strategic areas including standardization, frequency spectrum, R&D projects, technology skills, collaboration with key vertical industry sectors, notably for the development of trials, and international cooperation.

Linux Foundation Networking (LFN)

Linux Foundation is a collaborative project that brings together open-source communities to build and support software-defined networking (SDN) and network functions virtualization (NFV) platforms. LFN is also contributing to the development of Open RAN solutions, particularly through its Open Network Automation Platform (ONAP) project, which aims to provide a common platform for managing network services and resources across multiple domains, including RANs.

Linux Foundation is working together with the O-RAN Alliance. The O-RAN Software Community (OSC) supports the creation of open-source software for the RAN, aiming to develop reference software components based on 3GPP and O-RAN Alliance specifications. Additionally, the OSC Community Lab is a testing and integration lab for Open RAN software. The lab is designed to speed up the development and adoption of Open RAN solutions by providing a common platform for testing and validation.

Open Network Automation Platform (ONAP)

The ONAP (Open Network Automation Platform) is an open-source platform that provides a common platform for orchestration and management of network services. It enables the automation of service delivery, provisioning, and assurance across different network technologies and vendors. ONAP brings together several open-source projects and standards bodies to create a unified platform that enables network automation.

ONAP is currently being integrated by the O-RAN Alliance`s Open Software Community (OSC). Some Service Management and Orchestration (SMO) functions partly leverage and extend some existing infrastructure from ONAP.

Open Networking Foundation (ONF)

The ONF (Open Networking Foundation) is an organization that focuses on promoting the adoption of open networking technologies. It defines open interfaces and protocols that enable the integration of different network components and promotes the use of open-source software. ONF also works towards ensuring the interoperability of different network technologies.

ONF`s SD-RAN project is building open source near-real-time RIC (nRT-RIC) and a set of xApps for controlling the RAN, leveraging the O-RAN Alliance architecture.

Open RAN Policy Coalition (ORPC)

The Open RAN Policy Coalition /ORPC) promotes policies that will advance the adoption of open and interoperable solutions in the Radio Access Network (RAN)

Small Cell Forum:

The Small Cell Forum is an industry organization that is focused on the development and deployment of small cell solutions for mobile networks. The forum is also contributing to the development of Open RAN solutions, including the development of specifications for small cell interfaces and integration with RANs.

OpenAirInterface Software Alliance (OAI):

The OpenAirInterface Software Alliance is an open-source community that is focused on developing and promoting open-source software for wireless communication systems, including RANs. The alliance is contributing to the development of Open RAN solutions by developing open-source implementations of RAN interfaces and protocols.

In a recently signed Memorandum of Understanding, OAI and O-RAN ALLIANCE agreed to co-operate on open Radio Access Network issues, open-source software development, and 5G as well as next-generation platforms for demonstrating O-RAN technology. Implementation of these high-level principles has still to be defined.

2.1.3. OPEN ECOSYSTEM COOPERATION

To foster the development of open networks, these organizations must collaborate with each other on developing common standards, interoperability testing, open-source development, and policy advocacy. For instance, O-RAN Alliance complements and enriches 3GPP work (avoiding fragmentation) to ensure that 4G/5G networks are interoperable. O-RAN leverages the work done by ONAP to create an open and automated platform for network service orchestration. ONF works with these organizations to ensure that open interfaces and protocols are defined, enabling the integration of different network components. ORPC collaborates with these organizations to promote policies that support open networks, spur competition and expand the supply chain. TIP works towards creating open hardware and software designs that enable interoperability between different network components. Open Air Interface Software Alliance and the O-RAN Alliance have agreed to jointly develop open-source software for the 5G (and next generation) Radio Access Network. In summary, industry organizations such as 3GPP, O-RAN Alliance, ONAP, ONF, ORPC, TIP, and others play a critical role in promoting open networks. These organizations work towards defining standards and guidelines for the interoperability of network technologies, enabling innovation, and fostering the development of open networks. Collaboration between these organizations is crucial to ensure that open networks are created and adopted widely.

2.2. STATUS OF WORLDWIDE OPEN RAN

2.2.1. TRIALS AND DEPLOYMENT

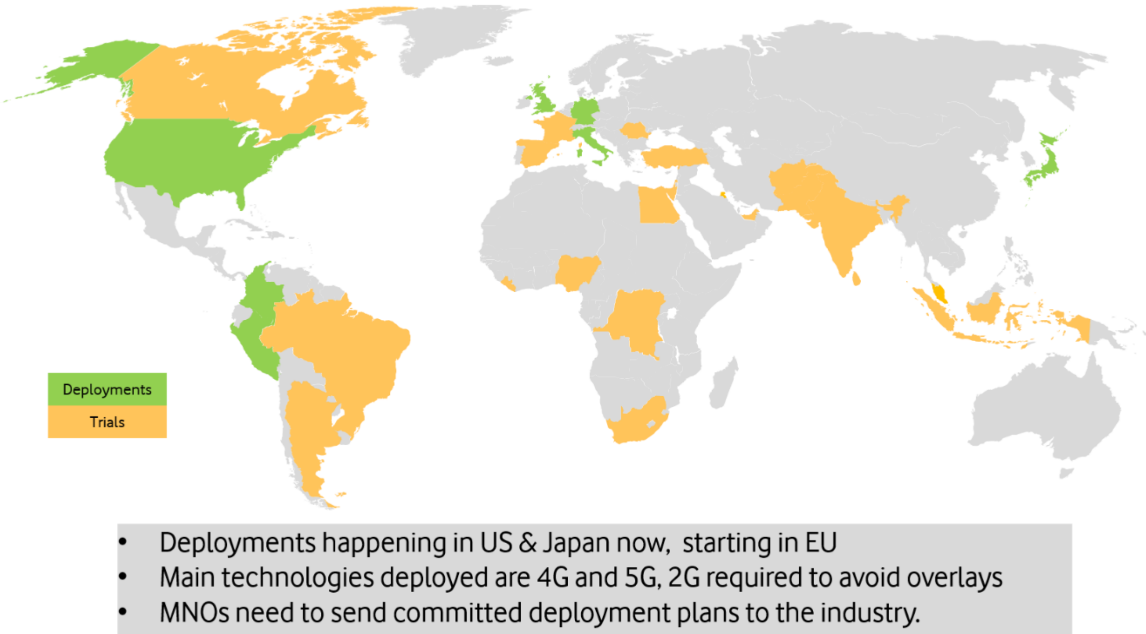

Figure 3: Deployment and trial zones

- Trials
    - *DT trials (O-RAN Town in Germany) [2]*
    - *Vodafone conducted trials in EU in UK, Spain, Germany [3] , Turkey and Ireland. [4]*
    - *Telefónica is conducting tests and trials in Germany, Spain, UK and Brazil.[5]*

- Greenfield deployments:
    - *Rakuten deploying early stage multi-vendor RAN in Japan [6] – not really O-RAN compliant as standards are not mature, but showing to which levels of automation and IT procedures a RAN can go*
    - *Dish leveraging public cloud capabilities (AWS) to deploy RAN in the US [7]*
    - *1&1 being the first service provider to set up carrier-grade RAN in IT-like manner [8]*

- Brownfield deployments:
    - *All green-field trials benefit from reduced feature need (e.g. 5G only)*

- *Brownfield deployments are much more complex and need to integrate with existing networks, thus ramping up slower*
- *Brown-fielders need to follow their modernization cycles to first write off their recently ordered 5G equipment, thus more traction expected in late 2020s*
- *Verizon deployed more than 8,000 vRAN cell sites, rapidly marches towards goal of 20,000 [9]*
- *NTT DoCoMo deployed over 20.000 sites in Japan [10]*
- *Vodafone is deploying Open RAN in rural and urban areas, targeting 2500 sites in UK by 2027. [11]*
- *Deutsche Telekom begin deployment of multi-vendor Open RAN network in Germany [12]*
- *AT&T's Open RAN investment in partnership with Ericsson plan is for 70% of its wireless network traffic by late 2026 [13]*

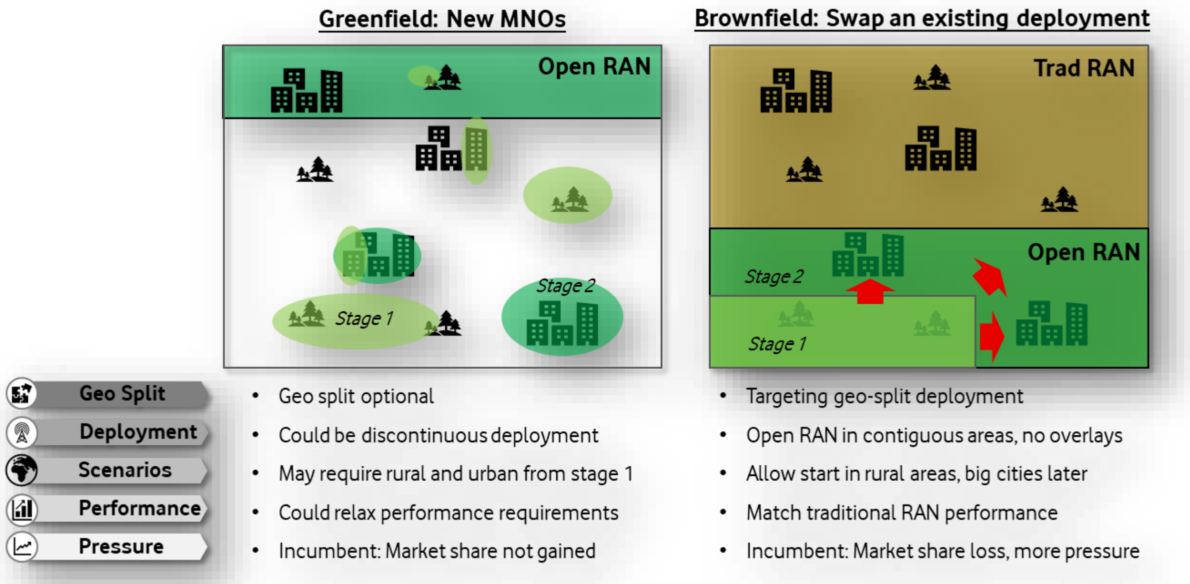

Figure 4: Deployment scenarios

2.2.2. LAB ECOSYSTEM

Additional information about existing facilities for Open RAN testing and evaluation, have been included in the document. Available in chapter 8.

2.2.3. STANDARIZATION

Third Generation Partnership Project (3GPP)

3GPP's open standards ensure interoperability on the air interface (with the corresponding open interfaces Uu and PC5), between the RAN and the Core network (Ng, S1), between different radio base stations, e.g., for mobility or dual connectivity (Xn, X2), and seamless connectivity between different networks, e.g., for roaming. Open interfaces between the network functions of the 3GPP core network are standardized using a cloud-friendly service-based architecture. Further open interfaces are standardized that allow to connect the 3GPP system externally to the data network (the internet), to voice/video/message systems (IMS), to application layers, to network management, business and operations support systems, or even to non-3GPP networks (WiFi).

O-RAN Alliance work group status

Specification activities within O-RAN Alliance embrace virtualization, use of open standardized interfaces and intelligent controllers. Each O-RAN Alliance work group (WG) deals with specific aspects of the O-RAN architecture and their activity can be summarized thus far as follows:

- WG1 O-RAN architecture Task Group (TG) has delivered multiple versions of the "O-RAN Architecture Description" document, which de facto specifies the overall O-RAN architecture and points to specifications developed within the O-RAN WGs for each architectural component or interface. WG1 is also responsible for high level descriptions of O-RAN use cases, the requirement of which drive the specification work in the related work items (see, e.g., massive MIMO or Energy Saving use case).
- WG4 Open Fronthaul specification activity has been continuously evolving the open fronthaul "7-2x split" specifications that include, amongst the others, CUS-Plane, M-Plane and conformance/ interoperability tests. The maturity level of such specifications has led to initial multi-vendor deployments where O-RU and O-DU products from different vendors connect via O-RAN OFH. Further evolution of current split might include enhancements related to uplink performance in massive MIMO scenarios, as per the ongoing work item in WG4.
- WG2 and WG3 deal with non-RT and Near-RT RIC, respectively, including their internal Architecture and external interfaces (A1, E2). WG2 has provided a complete version of A1 specifications, with Stage-3 A1 Type Definition (TD) that supports different use cases; the work on non-RT Internal architecture description has identified the main modules of non-

RT RIC whereas the R1 service API (used by rApps running on top of non-RT RIC) are at their infant stage. From WG3 perspective, E2 interface specifications are implementable with specified E2 Service Models (E2SMs) supporting different Near-RT RIC use cases; Near-RT RIC internal architecture describes in detail the general principles of interaction between xApps and RIC platform functions whereas the xApp API specification only covers a subset of the listed services.

- WG6 covers cloud architecture and its orchestration aspects via standardization of orchestration use cases for virtualized deployment of network functions, O2 interface allowing SMO to manage cloud HW and SW, and Acceleration Abstraction Layer (AAL) interface between workload and underlying cloud. The work on O2 interface mainly focuses on general design principles whereas the detailed signalling is partially available for, e.g., cloud infrastructure management aspects and profiles for Kubernetes.
- Overall management architecture and O1 design/protocol principles are under WG10's purview. Protocols and general design of O1 generally follows 3GPP specifications whereas the work on management data models is not complete and do not cover all network functions.
- WG11 is responsible for the security architecture and requirements and made great strides in developing corresponding specifications. These revolved around Threat Modelling, Security Requirements (including interface protocols), Security of O-RAN applications Lifecycle Management, and also security test specifications.
- O-RAN has also set up an interest group, MVP-C (Minimum Viable Plan), that is tasked to define which features would be part of the upcoming O-RAN release as well as coordinating the efforts across all WGs involved in the specification of a certain feature.

Relation to standards developing organizations (SDOs)

The O-RAN architecture builds upon 3GPP architecture and protocols, which are properly referenced in the O-RAN specifications. This also led to exchange of liaison statements between the two organizations – e.g. WG10 and 3GPP SA5 on management aspects – with the aim to report on WG progress or request alignment between specifications. The same applied to other standardization bodies or organizations such as ITU (e.g. synchronization aspects) and ETSI (ZSM, NFV).

The collaboration agreement with ETSI also resulted in O-RAN submitting its own specifications to ETSI according to the ETSI Public Available Specification (PAS) process. Once approved via a thorough review process, ETSI PAS documents are adopted and ultimately published as official ETSI specifications. One example of that is the publication of "O-RAN Fronthaul Control, User and Synchronization Plane Specification v7.02" as ETSI document ETSI TS 103 859. The overall goal of ETSI PAS submissions is to enable broad adoption of Open RAN, with an additional level of recognition from commercial and public sector entities in a range of countries.

O-RAN Alliance will benefit if its processes and governance fully adapt to the WTO/TBT Principles for the Development of International Standards [14] , improving openness in participation (e.g. not only operators as members with rights to vote), consensus and impartiality in decision-making (e.g. reducing the role of the five founding members: AT&T, China Mobile, Deutsche Telekom, NTT DOCOMO and Orange).

Gaps and requirements to support multi-vendor open RAN

The following areas require additional efforts to ensure multi-vendor deployment of open RAN:

- Reference internal architecture of SMO with a clear definition of the different functionalities and their interaction with non-RT RIC and onboarded rApps. This is key to ensure that rApp intelligence can be thoroughly harnessed when enabling automation use cases.
- Progress needed on xApp APIs and rApp R1 services to ensure that 3rd party app providers can efficiently be run on RIC platforms. E2 interface requires more detailed test definitions and profiling to ensure multi-vendor interoperability.
- O2 interface standardization requires more efforts on Stage-3 orchestration aspects for what concerns cloud infrastructure management and workload lifecycle management. The same applies to AAL API and its applicability in a multi-vendor environment.
- More progress needed in all WGs regarding definition of test specifications (e.g. conformance and inter-operability test cases) for O-RAN interfaces. Release of O-RAN badges based on specified test cases can certainly speed up integration of O-RAN products on the field.
- O-RAN security focus group should finalize security threat analysis related to open FH as well as additional functionalities such as onboarding of xApps/rApps on RIC platform, AI/ML services and O-Cloud security.

3. BEYOND 5G / TOWARDS 6G OPEN NETWORKS EVOLUTION

The current open RAN solutions are built on the RAN architecture as defined by 3GPP and enhanced with work from the O-RAN Alliance. The consensus from the mobile industry indicates that 3GPP will remain the major driving force and standard body to define the 6G architecture. As the industry calls for a single global standard for 6G, we strongly believe that the open RAN evolution path will be tightly aligned with, if not largely merged into, the 3GPP mainstream. The 3GPP development roadmap shows its 6G (IMT-2030) standardization process may not be started before 2025. 6G use cases, requirements and considerations regarding architecture principles and key 6G enablers are intensively researched. The O-RAN Alliance has kicked a pre-6G study work. It provides industry the opportunity to evaluate different technical evolution paths and offer the ground to seek for early consensus on key 6G enablers. Based on the ongoing open RAN research and pre-standard work, we discuss the open RAN evolution in this section, with a focus on requirements, main drivers and action plan.

3.1. VISION OF THE MOBILE NETWORK EVOLUTION

It is expected that the trend towards network horizontalization i.e., separation HW / SW, management, exposure etc. will continue in future mobile networks (see example in Figure 5). In 6G there is an opportunity to re-design / evolve the functional architecture as standardized by 3GPP to be better suited for network horizontalization. That includes harmonization of infrastructure, management, tools, orchestration across RAN and Core network. These areas have been the key development areas targeted by open RAN. Cloudification and orchestration, open fronthaul interface to support flexible RAN disaggregation, and network exposure through new interfaces and control components from the current O-RAN design provide competitive architecture options to realize the network horizontalization in the 6G era. 6G networks are intended to serve even diverse use cases to meet the increasing needs for ubiquitous connectivity from society and industries. Extreme diverse requirements drive the network to be more open and intelligent while keeping the sustainability and sufficient simplicity. We see the network horizontalization as the trend to further converge conventionally separated technology domains, for instance, the telecom domain, information technology domain, and industry operation domain, to a unified service platform. The openness, not only for the component/system interoperability, but also for system efficiency and service innovation, is expected to be the crucial element to support the 6G evolution.

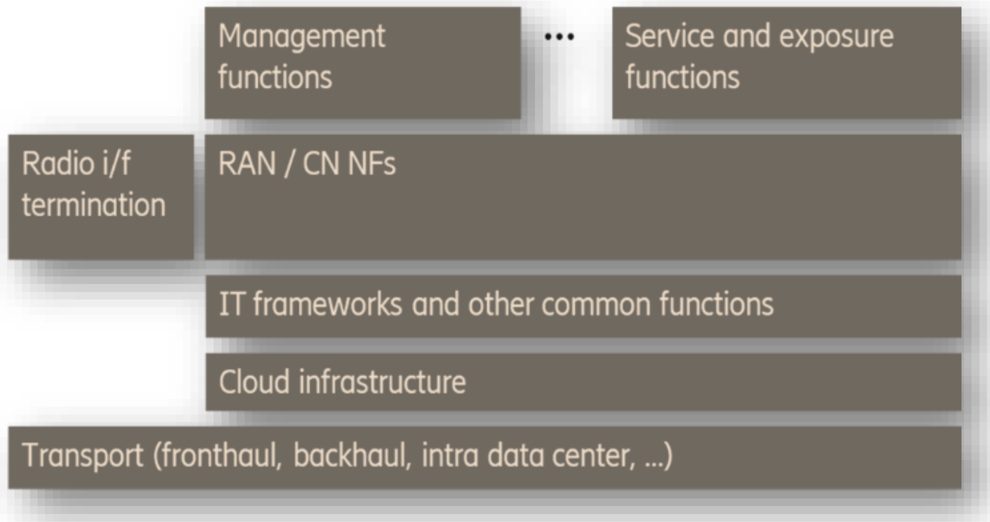

Figure 5: Key elements of future mobile networks

A key area in 6G that will be impacted by the O-RAN architecture is the support for Non-Terrestrial Networks (NTN). In addition to necessary adaptations in the physical layer that are being addressed by 3GPP, a native integration of NTN in the 6G system brings about many RAN control and management challenges that can benefit from the introduction of O-RAN RAN Intelligent Controllers (RICs). Example challenges include: i) UE mobility procedures that are impacted by base station mobility in NGSO constellations, ii) base station mobility challenges introduced by regenerative architectures, iii) interference mitigation between TN and NTN cells, and iv) the need for new mechanisms to steer traffic between TN and NTN cells under flexible per-device policies. The O-RAN architecture allows to introduce dedicated radio applications (x/rApps) operating at different time scales to address the previous challenges.

NTN integration also requires aligning the context of the NTN mission, e.g. planned orbits and payload activities, with the mobile network requirements. O-RAN includes mechanisms to inject information external to the RAN into the RIC allowing to account for the operational context of the satellite mission inside the RAN.

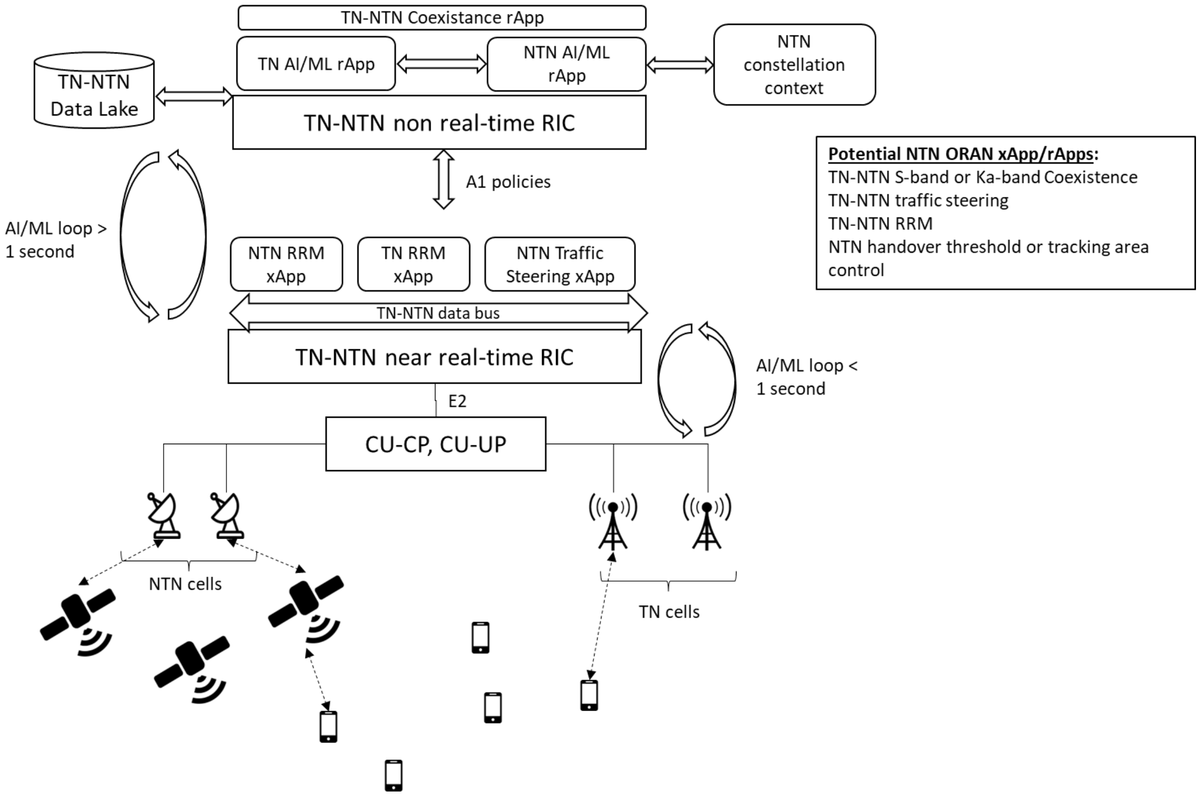

Figure 6: ORAN architecture extended to control TN and NTN under a common RIC

3.2. REQUIREMENTS

While open RAN has been first deployed by greenfield operators (Rakuten, Dish, 1&1) in macro networks, private networks and small cells markets seem to be now of strong interest for open RAN solutions and ecosystem, as the technical performance requirements are more achievable compared to macro networks requirements.

According to analysts [15], and likely to be arising from verticals' needs, use cases beyond 5G will require huge resources at the edge for local processing.

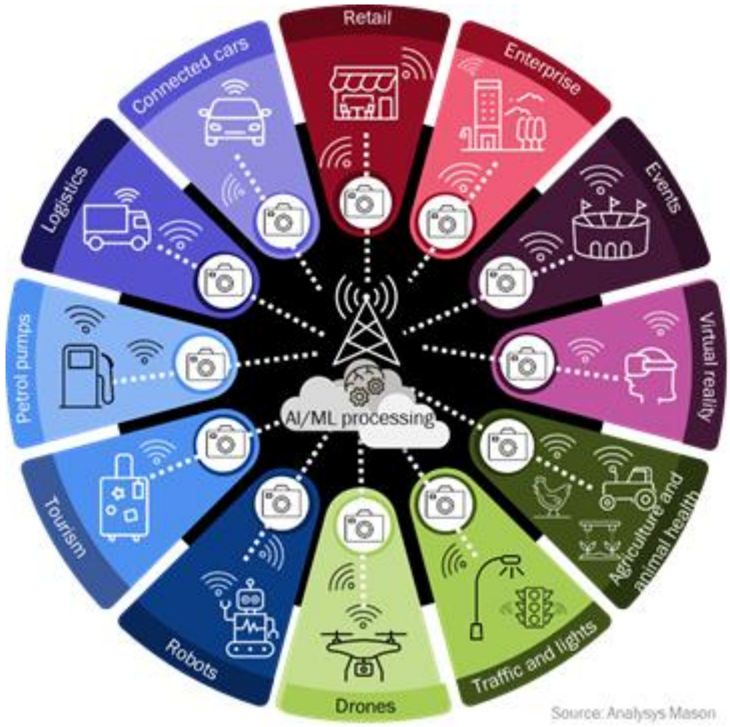

Figure 7: Use cases beyond 5G will need local processing at the edge

The by-design disaggregated architecture of the open RAN approach makes it fully adapted to those upcoming use cases: an O-DU, which embeds the most resources hungry part of the RAN, could be deployed near to/in the end user premises, and then a joint use of computation resources between RAN and other applications could be considered.

The adoption of open RAN solutions is heavily driven by the market and business needs. Public and private network markets have shown an increasing demand/interest for open RAN solutions. It solves the need to develop the RAN vendors ecosystem and offer the open innovation through flexible network exposure, control programmability, and horizontal and vertical integration. These points will remain important in the 6G era. On a longer-term perspective, the open RAN innovation at infrastructure, interfaces, system integration, services, and energy efficiency levels will eventually help bringing down the CAPEX and OPEX and create new revenue streams for mobile operators and infrastructure owners. This is expected as the key driving forces for the success of open RAN in the 6G era.

Open RAN evolution must address innovation and future proofness of open networks. For instance, to get more DevOps way of working in cellular network there is a need to ensure that the standards allow innovation on top of the standards (avoiding slow standardization cycle).

Clearly, open RAN solutions must also address the common 6G technical requirements. The areas that could be explored in 6G time frame include:

- How to reduce the complexity of the network. Incl. reducing duplicated functionality, unnecessary options and procedures, re-thinking existing requirements.
- How to ensure higher network performance for better end user experience. Including things like signalling performance for critical procedures, the usage of HW acceleration, energy performance etc. in Open networks.
- How to enable cross layer and cross domain AI. What are the different control / automation / SW delivery loops? How to minimize or deal with conflicting actions?
- How to address flexibility and scalability. How to address new deployment scenarios, meeting needs from industry / verticals e.g. on redundancy, on-prem processing, automation? Scaling from single cell to global network.
- How to enable network exposure and beyond communication capabilities. Incl. APIs, federation, …
- How to address increasing needs for security and privacy. New regulatory requirements, secure and private identifies, AI agents getting access to user data, usage of public infrastructure, …

3.3. DRIVERS

The main technical drivers for the developing of Open RAN are:

- Interoperability: Open RAN solutions are designed to allow true interoperability, giving the possibility to the mobile operators to avoid vendor lock-in and stimulate a more competitive marketplace.
- Flexibility: as a consequence of previous point, Open RAN allows mobile operators to choose solutions among different alternative products. This can enable mobile operators to easily evolve and expand the network quickly adapting to customer demand.
- Innovation: Open RAN paradigm encourages competition among the solution providers. This will stimulate the ability to introduce innovation in the proposed solutions in order to be more competitive and differentiate them in the market.
- Cost Reduction: the increased number of solutions available in the market and associated higher competition will help the operators to get solution at lower costs and deploy current and next generation networks in a more sustainable way.
- Open new interfaces: The possibility to develop RAN solutions opening new interfaces, on one hand as already stated allows to consider different vendors to work together seamlessly. On the other hand, looking at the management systems, it can help to simplify network management reducing the complexity and integration burden for mobile

operators. A management system with a defined interface and open standards can contribute to reduce the timing and complexity in the integration.

- Energy efficiency and carbon footprint reduction towards Europe Green objectives and network sustainability. The transition from 4G to 5G is incurring 10 times energy consumption, due to increased density of cells and that of antennas, despite a greater energy efficiency per bit. With 6G going towards higher spectrum (such as Terahertz or THz) and thus resulting in even denser networks and smaller cells, energy consumption will become a big hurdle on the way to 6G success. A dramatic reduction of the energy consumption per bit is one of the drivers towards 6G solutions since it promise (for energy efficiency):
    - System on Chip solutions, generating very little heat.
    - More efficient power amplifiers (now they represent more than 60% of the total mobile network consumption)
    - The deep sleep software functionality (up to 70% of the Massive MIMO radios' consumption reductions during low traffic hours) and M Micro-Sleep TX (switching off component e.g., Power Amplifiers when no transmission is required)
    - Moving traffic to the most energy efficient bands
- Societal benefits: O-RAN is not just a different way of doing the same things, but a way to improve them, starting with performance. Just think of the role that the application of AI and ML will play in typical connectivity use cases such as traffic steering/load balancing and optimization of active antennas. Furthermore, the greater flexibility of the new networks, together with the creation of new application use cases generated by the development model based on the "application store", represents a key factor that will favour the meeting of supply and demand in the area. So, a social driver is certainly that of finally being able to implement new services, which were previously unthinkable, especially due to the prohibitive costs of implementation and customization. Therefore, thanks to greater flexibility, integration with AI / ML and lower cost for radio coverage, more services that will benefit from 5G and B5G / 6G will be implemented.

For example, there will be great progress in the development of solutions for industry 4.0. this will have a strong impact on citizens. Furthermore, the big savings and new revenues that the manufacturing companies that will adopt the Industry 4.0 enabled by 5G and increased by O-RAN solutions will allow end customers, therefore all citizens to have products at lower prices, without giving up on the quality. It´s important to highlight that the factors or drivers mentioned above for Open RAN would contribute to facilitating the entry of both European and non-European suppliers into the ecosystem. By reducing the barriers for new entrants, there is potential for an increase in the presence of European suppliers, thereby enriching the European ecosystem which is an important goal.

3.4. ACTION PLAN

Open RAN technologies show great potential to enable mobile network evolution towards 6G. However, any new technology adoption will face challenges and need a strong action plan backed by the stakeholders, including, but not limited to, industry, academia and government funding agencies. Open RAN technologies are currently defined by O-RAN Alliance and implemented by the RAN industry. We expect O-RAN Alliance to remain the main industry association driving the evolution of open RAN towards 6G. Indeed, O-RAN Alliance has established a 6G research group to facilitate the O-RAN 6G studies. As 3GPP will remain the major standard body to ratify 6G technologies, it is critical to synchronize the technical path with 3GPP on the 6G development. It is too early to say how open RAN concepts and key technologies will be adopted by 3GPP, as 3GPP is driven by technical consensus from the members. Therefore, it is important to align the 6G vision and requirements among 6G pre-standard bodies around the world and achieve the early consensus on the technical evolution path. Undoubtedly open RAN will evolve based on current open RAN technologies. As the first step in the action plan, it is important to analyse the technical gaps, identify key use cases, requirements, and technical enablers that have direct impact on open RAN evolution, research key technical topics, and come up with open RAN vision towards 6G. Open RAN industry associations will take the natural position to define and communicate this vision.

The 6G development has been heavily pushed by the public investment in different regions of the world. In Europe the Smart Network and Service Joint Undertaking is the major funding program to support 6G early research and development. The programme already today supports multiple actions related to Open RAN and Open Networks as exemplified in table below:

SNS Project	**Topic/Stream**	**Open RAN relation**
ImagineB5G	Stream D, trials with verticals	Project includes Open RAN components in the trial platform and aims at advancing the development, integration, and validation of the Open RAN components, including newly developed xApps solutions from third parties, in the project.
HORSE	Stream B, security	security framework addressing some of the security challenges of the O-RAN specification with special focus on securing the interfaces as well as ensuring a secure O-RAN operation in untrusted clouds. (TEE)
BeGREEN	Stream A, B5G	Extending chipset availability through accelerators for ARM environment; AI/ML at RIC level to support energy efficiency.
6G BRICKS	Stream C, experimental platforms	Delivery of an open and programmable O-RAN Radio Unit (RU) for 6G networks, termed as the OpenRU, based on an NI USRP-based platform, integration of the RIS concept into the OAI; delivery of

		breakthrough experimentation tools, going beyond the current Testing as a Service (TaaS) capabilities of current initiatives, and allowing experiments also on devices via O-RAN compliant xAPPs.
6GREEN	Stream A, B5G	Testbed extended with a complete Open RAN (O-RAN) prototype with split Option 2 and 7.2 in the context of energy efficiency improvements
6G XR	Stream C, experimental platforms	Nodes of the experimental facility adopt Open RAN architecture to study the virtualised distributed function splits in the RAN. Different RAN functionalities are managed and monitored by the near-time and non-real-time Radio Intelligent Controller (RIC). The controlling and monitoring aspects of O-RAN enable AI algorithms for RAN optimisations and the energy-efficiency RAN control. Virtualised RU functionalities run on SDR platforms providing up 140 MHz radio links and MIMO schemes.
6G SANDBOX	Stream C, experimental platforms	Target experimental platform includes validation capabilities at relevant layer of the IoT- connectivity-service provision value chain, covering at least innovative components and microelectronic capabilities, fixed/multi radio access (including NTN), backhaul, core network, and service technologies and architectures, covering disaggregated scenarios like Open RAN, Core, or blurred RAN/core scenarios. It includes end-to-end virtualisation and network slicing as key components to support multi-tenant environments, integration of private/non-public and public networks and multiple vertical use cases.
SEASON	Stream A, B5G	integration of the transport and RAN control-planes at the edge, between the O-RAN Near-RT RIC and the disparate transport SDN controllers are researched and demonstrated, including the exploration of AI/ML driver xApps to automate and optimise this interaction, for QoS SLA validation of network slicing and integration of innovative optical technologies into an Open RAN architecture.

Table 1: SNS Call 1, main Open RAN related projects

As the public investment is expected to play a key role to support the open RAN development and the evolution towards 6G, these ongoing activities may require expansion in the future. It is important to fund the Research on key architecture aspects and enabling technologies to understand needs, benefits, limitations of different technical solutions before the 6G standardization starts. The joint research by the public investment is the most effective way to accelerate the technical development and reach early consensus. Several regions have already taken the strategy move and planned significant public funding for open RAN research and technical adoption. However, not all regions treat open RAN as equally important in their 6G development plan.

Once a technology reaches the sufficient maturity, it is important to validate it first through proof-of-concept and later in a large-scale testbed. 6G research platforms for open RAN technologies are highly important for idea validation and performance evaluation and need to be available at the early stage of the open RAN 6G development. There are more compatibility and integration tests to be done in open RAN systems. Open testbeds supported by the public investment will provide great support to open RAN research and development.

The time plan of open RAN evolution to 6G is illustrated in the Figure 8

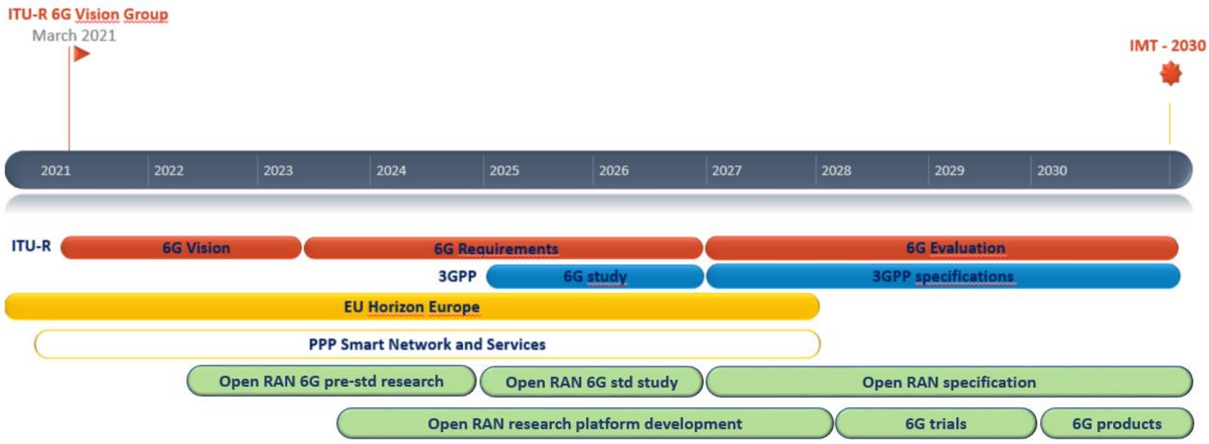

Figure 8: Open RAN evolution time plan

4. CONCLUSIONS & RECOMMENDATIONS

Conclusions

Open Radio Access Network (Open RAN) development maturity in the next years is crucial for future mobile networks, such as beyond 5G and 6G networks. Future networks should connect a vast range of different devices and services, and for that, open interfaces to allow interoperable functions are essential. The main reasons why the evolution of the RAN networks are expected to be based on open RAN principles are:

1. Increased Flexibility and Interoperability: Open RAN is designed to be more flexible and interoperable than currently mainly deployed network architectures. That capability allows network operators to choose from a range of vendors for each component of the network, enabling them to mix and match technologies and product solutions to suit their specific

needs. However, the overall complexity of 6G will be a critical factor and the granularity of interfaces needs to be on a reasonable level.

2. Enhanced Innovation and Faster Time-to-market: Open RAN can help to leverage innovation and reduce the time-to-market in the mobile network industry. By allowing multiple vendors to contribute to the development of network components and AI/ML solution, Open RAN can create a more competitive ecosystem that encourages innovation and the introduction of new technologies. However, too many interfaces may lead to a large standardization overhead and in turn limited speed of innovation.

3. Lower Costs: Open RAN has the potential to reduce the costs of mobile networks, thanks to the possibility for mobile operator to select the best-of-breed solutions from a range of vendors. Wider range of vendor options can lead into a higher competition and drive down costs as a result.

However, although Open RAN's standardized and modular approach could make it easier to deploy new services and technologies, it may increase multi-vendor integration costs as well. Advances in chipset development will have to decrease the performance and energy gap between general purpose and dedicated processors. Finally, secure and resilient supply chains need to be ensured by ensuring interoperability and openness with cloud platform and semiconductor players.

4. Support for Diverse Use Cases: 6G networks are expected to support a wide range of use cases, including ultra-high-speed data transmission, low-latency communication, massive machine-type communication, and more. Thanks to flexibility and modularity implicit in Open RAN the support of diverse use cases will be easier, by enabling network operators to choose the best components and solutions for each specific use case.

5. Additionally, Open RAN brings some new challenges that need to be addressed properly, such as security, due to open interfaces (nevertheless zero trust by design approach is considered), more complex multi-vendor integration environment and operational management (orchestration is pivotal to mitigate that complexity).

6. Finally, Open RAN, the same way that the traditional radio solutions, must align with global trends on energy efficiency to avoid the exponential growth of energy consumption when transitioning from 5G to 6G. This means including energy related metrics as one of the fundamental KPIs when designing new Open RAN solutions.

In conclusion, the principles of Open RAN are becoming increasingly important for the coming 6G network. Open RAN can be the foundation of efficient and innovative mobile networks for the future.

Recommendations

In order to build broader operator and ecosystem confidence and allow acceleration on Open RAN based deployments, Europe needs industry effort to play a leading role of Open RAN solutions on the evolution of open networks towards 6G. The Open Smart Network and Service (Open SNS) working group under the 6G-IA has agreed on a number of recommendations on the context of developing Open RAN to set the foundations for 6G introduction in the future:

1. The Smart Network and Services Joint Undertaking (SNS-JU) initiative is the correct mechanism to enhance the cooperative nature of European research and innovation and already significantly support Open RAN technologies. There is a need to further foster an environment that supports open SNS solutions for R&D and trials in the future, through funded collaboration between European stakeholder (universities, vendors, operators, industry verticals, etc) to present and discuss innovations, specific test cases and blueprint of interest, creating a joint (probably multi-party) solution roadmap and executing the validation and integration of those transversal cases and innovations toward commercial applicability.

2. To enhance the European open labs landscape, which cover voluntary large-scale testing of O-RAN Alliance compliant - Open RAN products and systems promoting the development of open European solutions and its ecosystem towards maturity and readiness, also supporting SMEs with the aim to foster a rich ecosystem of rAPPs developers in thematic areas such as automation, AI/ML, energy efficiency while adhering to openness principles defined in O-RAN alliance specifications.

These European labs may need additional funding to invest in equipment and staff, particularly to overcome the commercial risks of open labs during the early development phase of their services and business models. Moreover, these labs could be the foundation to define and evaluate the different use cases and advance functionalities required by the European industry, while becoming the European authority on new technology testing and connecting the industry communities in that regard.

3. To secure the involvement of multiple European stakeholders from different sectors, throughout the entire process, encourage large scale investments in high-performance and future proof infrastructure and thereby fostering the development of innovative solutions and services.

4. To ensure regulatory level playing field regarding security, energy efficiency, certification and presumption of conformity in accordance with EU law (ex CRA), such requirements and assessments should apply equally to any RAN solution. To assure the compliancy to the mentioned requirements, the relevant testing could be performed in the open labs mentioned in point 2 of the recommendations.

Furthermore, technology neutral regulation and funding for broadband deployments should continue to be the norm ensuring technological competition.

5. To align on international level for the achievement of harmonization of validated requirements, test cases, document standards and results formats between European and other regions open labs for better efficiencies and coordination.

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6. ABBREVIATIONS AND ACRONYMS

Acronym	Explanation
3GPPP	Third Generation Partnership Project
5G-PPP	5G Public Private Partnership
6G-IA	6G Smart Networks and Services Industry Association
AI/ML	Artificial Intelligence – Machine Learning
AAL	Abstraction layer
API	Application Programming Interfaces
CAPEX	Capital Expenditure
CaaS	Containers as a Service
COTS	Commercial-off-the-shelf
CI/CD	Continuous Integration/Continuous delivery
CP	Control Plane
CU	Centralized Unit
CRA	Cyber Resilience Ac
DU	Distributed Unit
DT	Deutsche Telekom
EC	European Commission
E2E	End-to-end
ETSI	European Telecommunicats Standards Institute
EU	European Union
FH	Front-haul
HW	Hardware
ICT	Information and Communication Technology
IMT	International Mobile Telecommunications
IT	Information Technology
ITU	International Telecommunication Union
JU	Joint Undertaking
KPI	Key Performance Indicators
LCM	Life Cycle Management
LFN	Linux Foundation Networking
MIMO	Multiple Input Multiple Output
MVP-C	Minimum Viable Plan
NEP	Network Equipment provider
NFV	Network functions virtualization
nRT-RIC	Near-real time RAN Intelligent Controller
NTN	Non-Terrestrial Network
NWDAF	Network Data Analytic Function
OAI	OpenAirInterface Software Alliance
ONAP	Open Network Automation Platform
ONF	Open Networking Foundation
O-DU	Open RAN Distributed Unit

O-RAN	ORAN Alliance
OPEX	Operational Expenditure
ORPC	Open RAN Policy Coalition
OSC	O-RAN Software Community
OSFG	Open-Source Focus Group
PAS	ETSI Public Available Specification
rApps	Non real-time application
R&D	Research & Development
RAN	Radio Access Network
RIC	RAN Intelligent Controller
RU	Radio Unit
SDN	Software-defined networking
SME	Small and Medium Enterprise
SMO	Service Management and Orchestration
SNS	Smart Networks and Services
SW	Software
TBT	Technical Barriers to Trade Agreement
TCO	Total Cost of Ownership
TIFG	Test and Integration Focus Group
TIP	Telecom Infra Project
TN	Terrestrial Network
TX	Transmission
UE	User Equipment
UP	User Plane
WTO	World Trade Organization
xApps	Near real time applications

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8. LIST OF LABS AND OPEN RAN TESTING FACILITIES

Testbed/Lab name	**Vodafone Open Lab UK**
Institution and location	Vodafone / Newbury (UK)
Projects starting from January 1st, 2020.	
Summary	Testing for Open RAN systems, involving multiple configurations and vendors.
Areas of testing	RAN, Transport.
Scope of the Lab	E2E testing, System Integration
Provide in-orbit validation /demonstration (only NTN sub-domain)	No

Is it an Open Lab?	No
Plans for supporting open networks.	Yes

Testbed/Lab name	**European OTIC in Berlin (** info@i14y-lab.com)
Institution and location	i14y lab / Winterfeldtstrasse 21, 10781 Berlin
Projects starting from January 1st, 2020.	
Summary	The European OTIC in Berlin is a part of the Integration Lab hosted by Deutsche Telekom. We provide subsystem, system and interoperability testing in a laboratory environment as well as field setups. The quality and performance of new products during design and development can be also verified and checked in this OTIC. The expert support includes results interpretation, troubleshooting, root cause analysis and consultancy services. The services can also be customized and combined.
Areas of testing	RAN, Transport.
Scope of the Lab	E2E testing, Subsystem IoT
Provide in-orbit validation /demonstration (only NTN sub-domain)	No
Is it an Open Lab?	Yes
Plans for supporting open networks.	Yes

Testbed/Lab name	**European OTIC in Madrid**
Institution and location	OTIC, Distrito Telefónica, Sur-3, pl. 0 – Ronda de la Comunicación s/n, 28050 Madrid
Projects starting from January 1st, 2020.	
Summary	The European OTIC in Madrid is hosted by Telefonica. It primarily focuses on Transport equipment (Xhaul testing), to assess the feasibility of deployment scenarios based on different technologies and topologies. This OTIC contributes to the commitment of Telefonica on open solutions, as key driver of the industry in the forthcoming years. The activities and focus areas are coordinated with other European OTICs to be complementary among them and offer wide range of services to partners and clients in Europe.
Areas of testing	Transport.
Scope of the Lab	Perform system and interoperability testing, including multi-layer, multi-technology and multi-vendor scenarios. The tests can cover both functional and performance testing.
Provide in-orbit validation /demonstration (only NTN sub-domain)	No
Is it an Open Lab?	Yes
Plans for supporting open networks.	Yes

Testbed/Lab name	**European OTIC in Torino** (https://www.gruppotim.it/en/innovation/technology/research/accredited-testing-laboratory.html)
Institution and location	TIM (host & Sponsor). Via G. Reiss Romoli n. 274, Torino, ITALY, 10148

Projects starting from January 1st, 2020.	
Summary	This OTIC lab will be hosted in TIM laboratories in Torino where currently almost all equipment (radio and core), network solutions and new services are tested before deploying them in the commercial network. Some lab activities are dedicated also to UE testing (i.e. internal device certification activities), management systems and network automation and SON as well. Testing lab is the place where TIM check all the solutions internally made and provided by vendor, with the final goal to check E2E interoperability. So the OTIC activities will rely on the infrastructure, equipment, tools and experience of TIM in radio access and core network testing
Areas of testing	RAN
Scope of the Lab	Subsystem, interoperability and End2End testing (including security aspects) of O-RAN based solution
Provide in-orbit validation /demonstration (only NTN sub-domain)	No
Is it an Open Lab?	Yes
Plans for supporting open networks.	Yes

Testbed/Lab name	**European OTIC in Paris (** otic.paris@orange.com)
Institution and location	Orange (host & Sponsor). 44 Avenue de la République, Châtillon, France, 92320
Projects starting from January 1st, 2020.	
Summary	In its OTIC, Orange will offer testing capabilities to RAN vendors who would need to test the conformance of their O-RAN products and the interoperability to third party vendors' products. Orange may also help vendors for the integration of their solution in E2E 5G SA/NSA chains deployed in our lab. This lab will help the RAN vendors' ecosystem to develop and to get products being on par with the traditional approach.
Areas of testing	RAN
Scope of the Lab	Conformance, interoperability and E2E testing (as well as security tests) of O-RAN based solution
Provide in-orbit validation /demonstration (only NTN sub-domain)	No
Is it an Open Lab?	Yes
Plans for supporting open networks.	Yes

Testbed/Lab name	**Auray OTIC and Security lab (**https://www.auray.com.tw)
Institution and location	7F.-1, No. 286, Sec. 1, Gaotiezhanqian W. Rd., Zhongli Dist., Taoyuan City 320016, Taiwan (R.O.C.)
Projects starting from January 1st, 2020.	
Summary	Auray OTIC and Security Lab, the main business of Auray Technology Corp., which is a SME contributor of O-RAN ALLIANCE, is a third-party test laboratory focusing on communication technology with cross-disciplinary expansion and integration services in Taiwan. Auray Technology Corp. is registered as an independent institute, offering services such as open radio network testing, information transforming integration and testing, test case development, and O-

	RAN validation. As an independent third-party laboratory, our test and measurement equipment include UE/UEs emulators, O-RU emulators, O-DU emulators, and emulated core and signal generator/analyzers.
Areas of testing	RAN
Scope of the Lab	Subsystem, interoperability, performance and E2E system testing
Provide in-orbit validation /demonstration (only NTN sub-domain)	No
Is it an Open Lab?	Yes
Plans for supporting open networks.	Yes

Testbed/Lab name	**Asia&Pacific OTIC in PRC** (http://zgc-xnet.com/OTIC_EN.html)
Institution and location	1402, Courtyard 8, Xitucheng Road, Haidian District, Beijing, China
Projects starting from January 1st, 2020.	
Summary	The Asia&Pacific OTIC in PRC is a part of the Integration Lab hosted by ZhongGuanCun (ZGC) Academy of Mobile Communication Innovation (ZAMI), a construction of China's national science and technology innovation center in Beijing, where O-RAN ALLIANCE's founding member China Mobile is one of the founders providing support and guidance to ZAMI. Following the vision of ZAMI, Asia&Pacific OTIC Lab in PRC will focus on cutting-edge technology research in the field of information and communication and actively promote the R&D and industrialization of 5G Open RAN. Meanwhile, A&P OTIC Lab in PRC will be a vendor independent, open and qualified physical facility providing a collaborative, open and impartial working environment.
Areas of testing	RAN
Scope of the Lab	PoC, test & verification
Provide in-orbit validation /demonstration (only NTN sub-domain)	No
Is it an Open Lab?	Yes
Plans for supporting open networks.	Yes

Testbed/Lab name	**Kyrio O-RAN Test and Integration Lab** (www.kyrio.com/otic)
Institution and location	858 Coal Creek Cir, Louisville, CO 80027, USA
Projects starting from January 1st, 2020.	
Summary	The Kyrio O-RAN Test and Integration Lab is hosted by CableLabs, a member of O-RAN ALLIANCE since 2018. CableLabs together with its subsidiary Kyrio, provide subsystem, system, interoperability, and performance testing services in a laboratory environment.
Areas of testing	RAN
Scope of the Lab	Subsystem, interoperability, performance and E2E system testing
Provide in-orbit validation /demonstration (only NTN sub-domain)	No

Is it an Open Lab?	Yes
Plans for supporting open networks.	Yes

Testbed/Lab name	**NEC OpenRAN Lab UK**
Institution and location	NEC Europe / Ruislip (UK)
Projects starting from January 1st, 2020.	
Summary	NEC OpenRAN LAB is offering Lab As a Service for a E2E ORAN Full Functional testing, E2E regression testing, E2E performance testing, Radio variant validation, Inter-Operability & Development testing, Security & Vulnerability testing, Beamforming testing and Life Cycle Management testing
Areas of testing	E2E ORAN systems
Scope of the Lab	E2E ORAN Lab As a Service facilitating European Operators a pre-certified E2E ORAN solution
Provide in-orbit validation /demonstration (only NTN sub-domain)	No
Is it an Open Lab?	Yes
Plans for supporting open networks.	Yes

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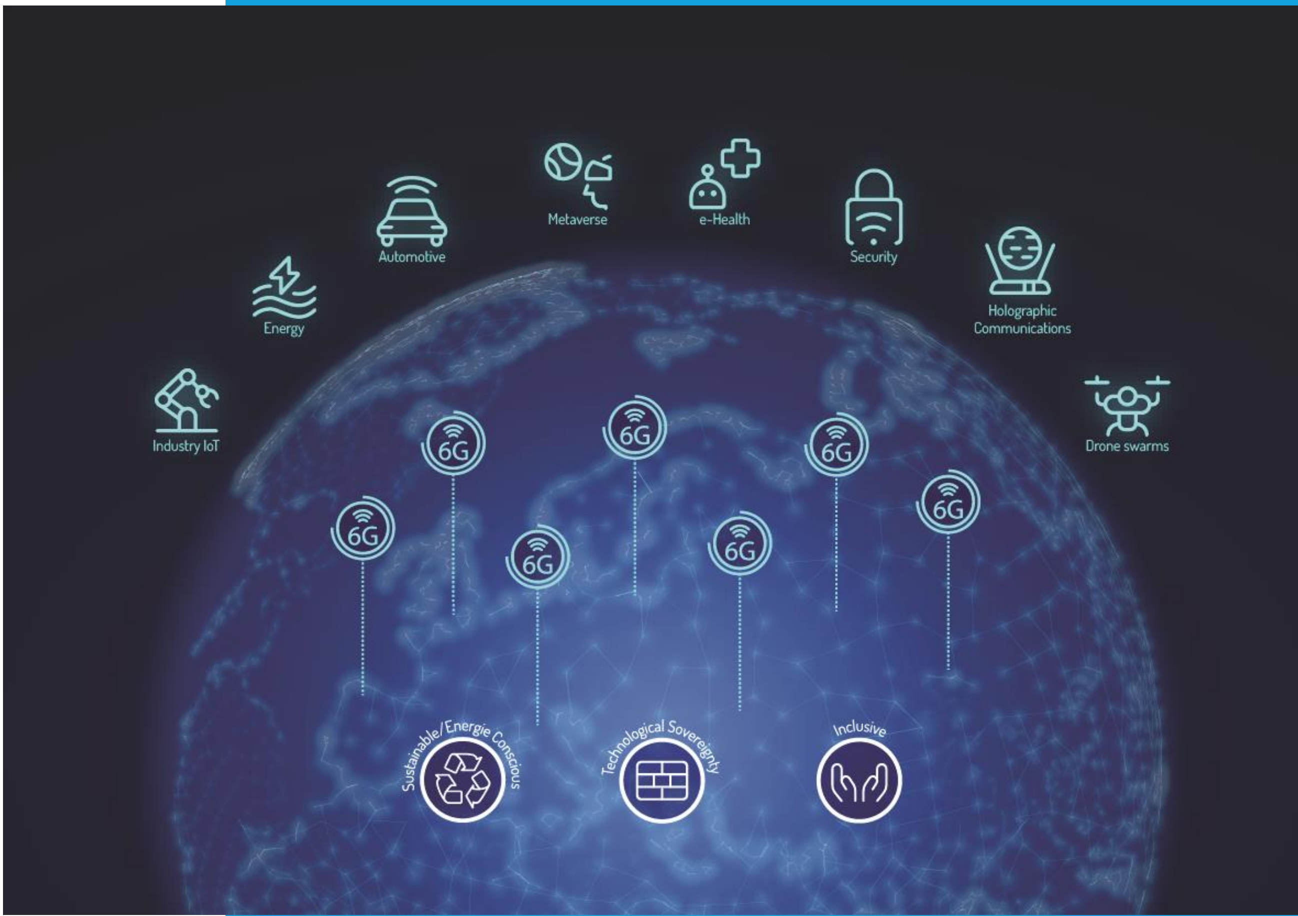

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