Vodafone Radio Networks
and Keysight Technologies
Open RAN Handbook

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# Vodafone Radio Networks and Keysight Technologies Open RAN Handbook

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# Document Control

## Revision History

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# 1 Introduction and Scope

In 2021, Vodafone unveiled its strategic vendors: Dell, NEC, Samsung Electronics, Wind River, Capgemini Engineering, and Keysight Technologies – to jointly deliver the first commercial deployment of Open Radio Access Network (Open RAN) in Europe. Since then, it has sparked other large-scale Open RAN launches and spearheaded the next wave of digital transformations across Europe.

Vodafone endeavoured to define a robust testing strategy for Open RAN systems and help to accelerate commercial deployments globally by operators at scale for telco and vertical industry use cases and applications.

Vodafone and Keysight would be thrilled to collaborate with many more vendors in order to help grow the OpenRAN eco-system.

# 2 Standards

## 2.1 Differences between: RAN, Open RAN, O-RAN, and OpenRAN

### 2.1.1 RAN

If you have used a cell phone, you have used a RAN.

A **RAN** (Radio Access Network) is what your cell phone[1] communicates with and connects to when you make a phone call.

In technical terms, your cell phone or User Equipment (UE) connects to the RAN portion of a Mobile or Cellular Network. A Mobile or Cellular Network is comprised of two domains: RAN and Core. The RAN connects to the Core through a fibre Backhaul.

A **Core** [Core Network] contains hardware and software, that runs Services (programs); these Services run on top of the Core Network and in turn connect to a Data Network (such as the Internet).

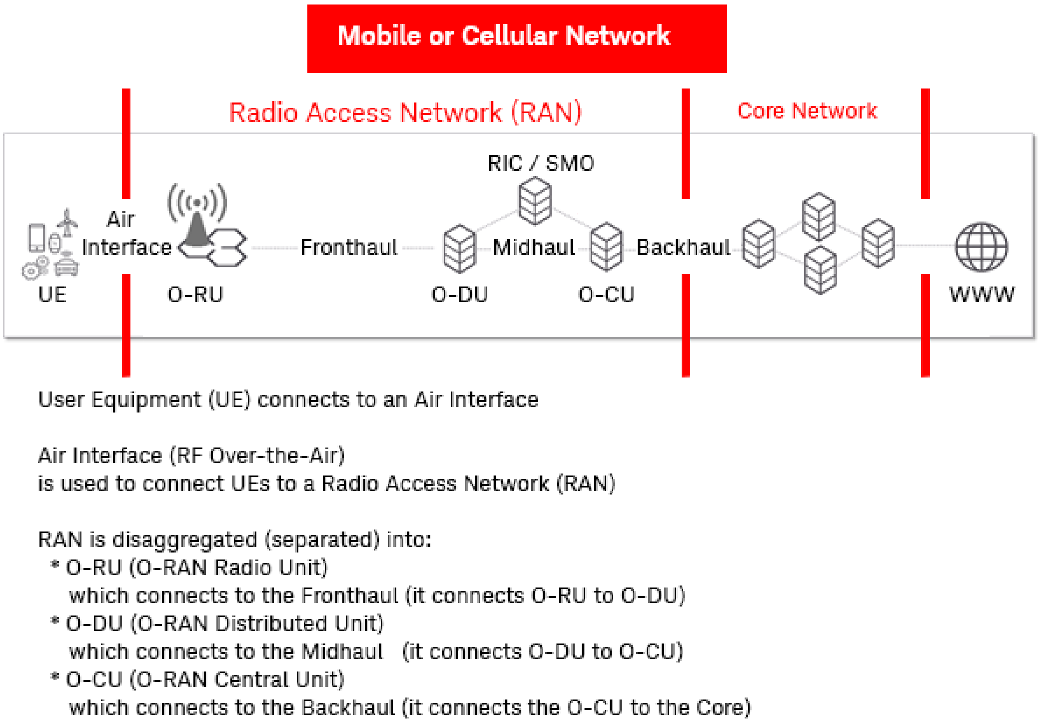


Figure 2-1. Open RAN High-Level Overview

[1] Cell phones may also be called mobile phones, cellular phones, or wireless devices.

### 2.1.2 Open RAN

Radio access networks (RANs) have been controlled by proprietary network equipment from the same vendor or group of vendors for the majority of cellular communications history. Single-vendor RANs may have provided certain benefits as the wireless communications industry matured, that time has long passed. Being locked into a proprietary RAN has placed mobile network operators (MNOs) at the mercy of network equipment makers, creating a bottleneck for innovation.

Open RAN enables mobile network operators to use equipment from multiple vendors and still ensure interoperability.

Open RAN disaggregated RAN functionality by using open interface specifications and community-developed standards between elements of the RAN; this means each piece of hardware and software can be separated and replaced by hardware or software from various vendors.

### 2.1.3 O-RAN ALLIANCE

Openness and intelligence are the names of the game at the O-RAN ALLIANCE.

In recent years, several global MNOs around the world are encouraging adoption of an open RAN for 5G, primarily through the O-RAN ALLIANCE.

The O-RAN ALLIANCE is acting as key force that brings together mobile network operators, network equipment manufacturers, chipset vendors, cloud providers including hyper scalers and application developers across the globe to develop open radio access network standards and recommendations.

The O-RAN ALLIANCE has defined a next-generation RAN architecture that divides what was previously a single-vendor, hardware-centric RAN into a fully programmable RAN consisting of dis-aggregated modular components most of which (apart from the Radio Units) are cloud native micro services designed for AI/ML (Artificial Intelligence/Machine Learning) assisted dynamic orchestration and zero touch automation. Building a more cost-effective, agile RAN necessitates transparency. Each of these components can be supplied by multiple vendors as the interactions between these components over open interfaces are precisely defined by interoperable standards developed by O-RAN ALLIANCE.

The figure below shows the 3 major innovation pillars of the O-RAN architecture.

1. Open Dis-aggregation
2. Open Cloudification
3. Open Intelligence

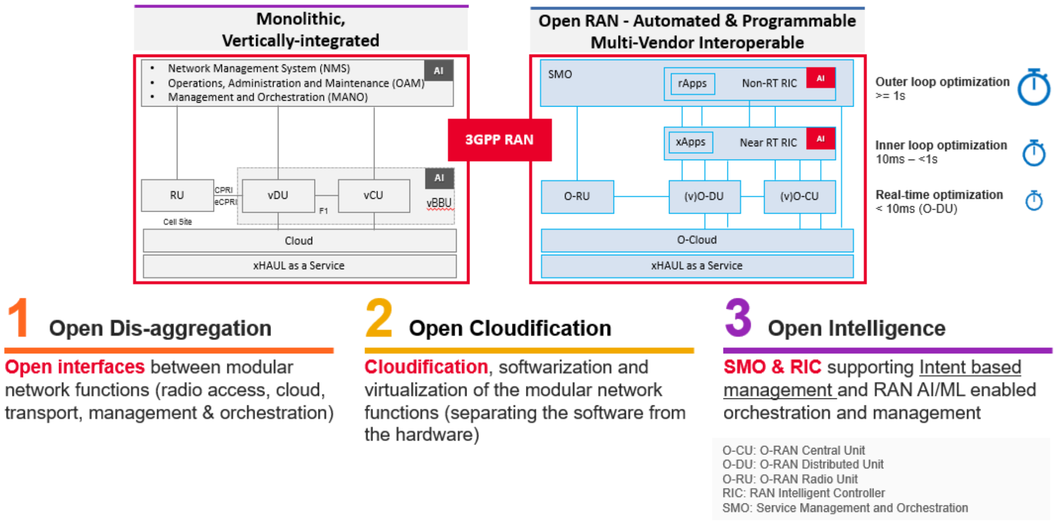


Figure 2-2. Open RAN Innovation Pillars

Open interfaces are required for small-scale providers to swiftly develop their own services. Open interfaces make multi-vendor installations possible, as well as a more competitive supplier ecosystem. While the move to open RAN offers numerous benefits for MNOs but it also imposes additional technical complexities and stringent testing requirements.

Figure 2-3 shows the Open RAN architecture and reference points.

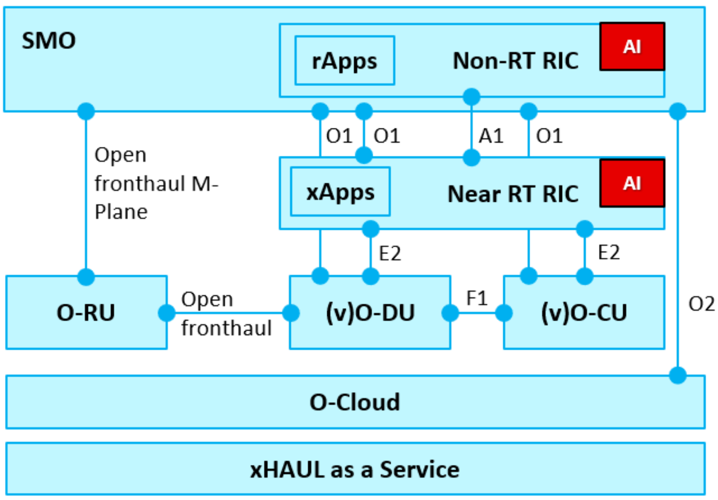


Figure 2-3. Open RAN Architecture and Reference Points

### 2.1.4 OpenRAN

OpenRAN[1] is a new approach to building the mobile networks that are needed to connect smartphones and other devices to the internet and other users. Traditional RAN solutions generally require telecommunications operators to work with single suppliers across an entire mobile site. This approach can be a barrier to entry for smaller suppliers that might not have the financial requirements or the resources to build and manage solutions across the entire RAN ecosystem (for example, radio antenna, baseband units, CU/DU servers, management, and orchestration software, etc.).

OpenRAN technology enables the creation of all software and hardware components of the RAN to be built to industry-wide specifications, ensuring interoperability between each component. This means telecommunications operations can choose the best solution providers for each component, safe in the knowledge that components will work together with the rest of the network (for example, able to exchange data and information).

This added flexibility will also allow Vodafone to become more software orientated as upgrade paths of each of the different components are decoupled (disaggregated). Introducing new software, features, and services becomes much simpler, faster, and more cost effective.

Ultimately, the aim of OpenRAN is to widen the pool of suppliers in the RAN ecosystem, while simultaneously lowering the barrier of entry for smaller companies and specialists. In time, a wider pool of suppliers will encourage greater competition, which will in turn lower the cost of delivering connectivity solutions and provide a catalyst for innovation.

Pioneered by Vodafone and its partners, OpenRAN will drive greater innovation through a diverse and open vendor ecosystem. It will lead to a more cost-effective, secure, energy efficient, and customer-focused network of the future.

[1] OpenRAN is a project group that is part of TIP [Telecom Infrastructure Project] (aka, TIP OpenRAN PG) with a main focus of developing fully programmable disaggregated RAN functionality that is built using open interface specifications between the various elements of the RAN.

# 3 Vodafone's Vision of an OpenRAN Testing Strategy

## 3.1 Test Labs Categories and Capabilities

OpenRAN testing can be performed in three different categories of test labs depending on the test objectives, capabilities of the lab's test setup, as well as the expertise and knowledge of standards, testing, and test tools (which includes test automation and reporting).

**Category 1 Test Labs:** Functional End-to-End (E2E) testing for LTE eNB and NR gNB can be performed in labs with basic lab setup and knowledge, especially if the test objective is for Open RAN technology exploration, assessment, and evaluation. For example, gaining experiences or learnings by testing to gain early exposure of Open RAN implementation maturity, benefits, and challenges; these might include smart manufacturing private network use cases and applications. Small cells and non-Massive MIMO radios may be more suitable for these labs, while Massive MIMO beam forming radios may be challenging to set up and test.

The O-RAN ALLIANCE Test and Integration Focus Group (TIFG) End-to-End (E2E) test specification test cases can be used by the Category 1 Test Labs as a starting point.

**Category 2 Test Labs:** In addition to Category 1 Test Labs, Category 2 Test Labs are designed to support 3GPP conformance, O-RAN conformance, and O-RAN interoperability testing. This testing can be performed in labs with a more elaborate lab setup and knowledge as compared to Category 1 Test Labs. Single Device Under Test (DUT) conformance testing, for example, an O-RAN Radio Unit (O-RU) requires more specialized knowledge to test and validate for compliance to 3GPP and O-RAN standards and specifications. Massive MIMO beam forming radios, O-RAN Distributed Units (O-DUs), and base stations can be tested in these labs which are more capable than Category 1 Test Labs focusing on the functional and conformance aspects. Category 2 Test Labs can complement Category 1 Test Labs with conformance and interoperability testing capabilities.

The O-RAN ALLIANCE Working Groups (WGs) specify Conformance and Interoperability test specifications. At this current time of writing, O-RAN ALLIANCE WG2 (Non-Real Time RIC and A1 interface), WG3 (Near-Real Time RIC and E2 interface), WG4 (Open Fronthaul), WG5 (F1, X2, Xn), WG8 (Open Reference Stack), WG9 (xHaul transport), WG11 (Security) have published test specifications.

The conformance test specifications from 3GPP (base station conformance testing) and O-RAN WG4, interoperability test specifications from WG4 and WG5 can be used by the Category 2 Test Labs. O-RAN WG2, WG3, WG8, WG9 and WG11 test specifications are better suited for the Category 3 Test Labs.

**Category 3 Test Labs:** In addition to both Category 1 and Category 2 Test Labs, Category 3 Test Labs are designed to support deployment readiness testing capabilities; these additional tests must be performed in test labs with extensive lab setup and knowledge. Deployment readiness testing includes testing and optimizing for features, energy efficiency, performance, scalability, security, stability, robustness, and resiliency, under real-world operating conditions.

- **Massive MIMO beam forming and Multi-Users MIMO** radios, O-DUs, and base stations should be tested in Category 3 Test Labs for Key Performance Indicators (KPIs) such as spectral efficiency, capacity gains, power consumption, and energy efficiency among others.

- **Security resilience and failover** should be validated with extreme AI/ML enabled attacks, defence and failover validation, and threat detection in a complete Developer Security Operations (DevSecOps) approach.

- **Energy Plane - efficiency and savings** should be maximized for each of the software and hardware components and operations resulting in the most optimal usage of energy, while maintaining best in class user and service experiences, network performances, and minimizing impacts to User Equipment (UE), network complexities, and overheads.

- **Live-to-Lab testing** should be conducted as live network operating environments and lifecycle management are to be emulated in a lab environment; testing can be conducted in a realistic lab test environment.

- **Detailed troubleshooting with efficient root cause analysis** can be expected to be delivered by these labs as they are better equipped with troubleshooting tools and expertise in the technology in all domains – single interface across layers and multiple interfaces.

- **Network OAM** should be conducted to ensure that operational network scenarios including: FCAPS functionalities and Performance – fault – configuration capabilities are thoroughly validated; this requires extensive experience with network operations.

Category 3 test labs are designed to operate above and beyond Category 1 and 2 test labs capabilities.

The O-RAN ALLIANCE WG2, WG3, WG8, WG9 and WG11 test specifications can be used by the Category 3 Test Labs.

The deployment readiness test cases have been designed with many years of technology research and experiences testing, optimization and operating large scale commercial live networks across multiple generations of wireless technologies working with all parts of the wireless ecosystem. These deployment readiness test cases are currently not specified by O-RAN ALLIANCE.

**Vodafone operates Category 3 Test Labs** and partners with global Category 1 and Category 2 Test Labs; together, *Vodafone's Vision of an OpenRAN Testing Strategy* is comprehensive and covers: Category 1, Category 2, and Category 3 Test Labs.

## 3.2 Open RAN Deployment Blueprints

O-RAN ALLIANCE defined next generation RAN architecture and specifications supporting multi-vendors interoperability for all modular and programmable components offers to the ecosystem enormous opportunities for innovation.

However, the extreme flexibility which enables numerous possibilities for interoperability scenarios has created its own set of challenges for the vendors as it is not possible for the vendors to design, build, test and optimize components to support multi-vendors interoperability with deployment grade quality for all possible interoperability scenarios.

O-RAN ALLIANCE WG4 for example has defined an open fronthaul interoperability test profile template and has gathered a set of IOT profiles which have been implemented by the fronthaul node vendors. Testing and integration activities are typically needing these IOT profiles (including WG4 IOT profiles) to be provided by the vendors to assist with test cases design, selection, and test environment configuration.

Annex A1 and A2 detail the parameters which are required to be provided by the O-RU and O-DU vendors for conformance, interoperability and E2E testing focusing on the open fronthaul interface.

To accelerate the scaling of Open RAN adoption, Vodafone is collaborating with the Open RAN ecosystem to align and specify a set of Open RAN Deployment Blueprints which can be widely deployed by operators globally to support various deployment scenarios. These deployment blueprints will include specifications of IOT profiles which can be implemented, tested, and optimized by the vendors developing components in compliance to these blueprints. This set of deployment blueprints will drastically reduce the cost and complexity of test and integration efforts and maximize the return of investments for the vendors ecosystems as they are able to address a much wider market with the same products.

## 3.3 Vodafone’s OpenRAN Lab Partnership Strategy

In Vodafone’s OpenRAN test labs, as we partner with existing and upcoming vendors to define the success of this new technology, we wanted to assure we covered every aspect and defined a test process that is applicable to any and all projects that come to our door. To accomplish this, a step-by-step “Testing Strategy and Methodology” has been developed.

# 4 Testing Strategy and Methodology

Vodafone has developed a step-by-step "Manual Testing Methodology":
Step 1: **Identify** > Step 2: **Evaluate** > Step 3: **Execute** > Step 4: **Verify** > Step 5: **Share**

This methodology is one of many different methodologies that are equally crucial for effective deployment. It is operator, system integrator and vendor neutral, meaning other industry players can leverage it in combination with other methodologies in order to accelerate commercial deployments, driving demand and helping the Open RAN ecosystem to scale, leading to greater competition and innovation.

## 4.1 Manual Testing Methodology

### 4.1.1 Step 1: Identify

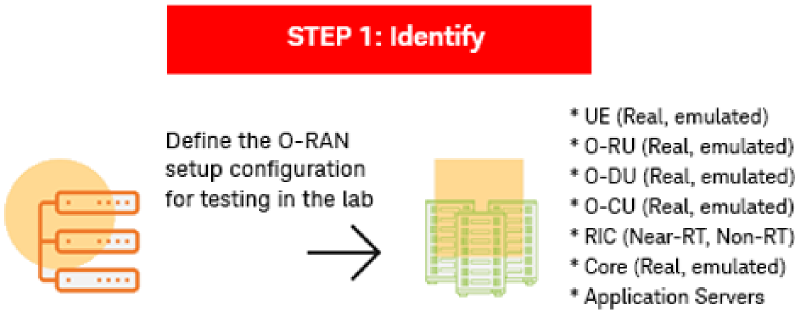


Figure 4-1. Manual Testing Methodology, Step 1: Identify

In this initial step, all of the details for the lab entry process are captured. For example, project baseline configuration, high level design (HLD), and hardware connection details from vendors.

We define the actual setup configuration for the O-RAN system under test. Because the O-RAN system is made up of numerous components, the DUT can be a single component or several components and some of them can be real or emulated versions.

There are several possible combinations involving real and emulated UEs and network functions. (Identifying the appropriate setup type will help us to define an accurate test plan[1] which is the second step in the process.)

[1] *Test Plans* can consist of any number of Test Steps. Each *Test Step* provides/encapsulates a specific functionality which may perform a simple or complex set of operations on a Device Under Test (DUT); these simple or complex set of operations are defined by each of the test cases.

### 4.1.2 Step 2: Evaluate

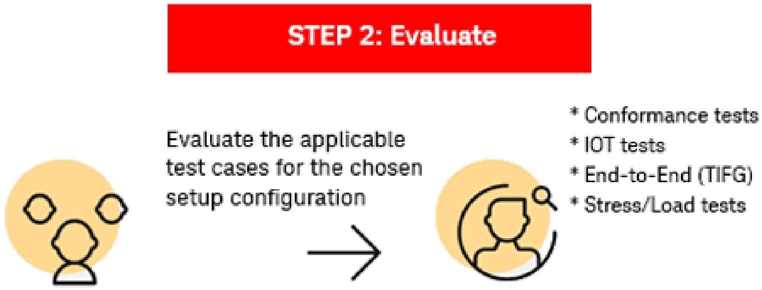


Figure 4-2. Manual Testing Methodology, Step 2: Evaluate

In this step, we define the test plan which is applicable to the selected setup configuration from Step 1: Identify.

Based on the setup configuration, we make decisions about which test cases[1] are applicable and supported by the configuration. This logical mapping between setup configuration and corresponding test plan helps us yield the actual number of test cases we can run in our lab from the master test plan.

### 4.1.3 Step 3: Execute

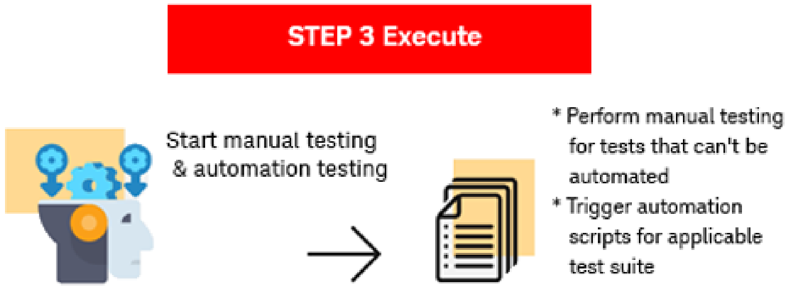


Figure 4-3. Manual Testing Methodology, Step 3: Execute

Once a test plan is ready, we execute the test cases. The initial plan is to run test cases manually and then spend the energy in automating them. Once test automation is in place, it will be easier to run a specific test plan in a limited time frame; we can then create automated test plans and run them using a test manager program as an overnight regression.

[1] *Test Cases* are a list of tests that can be run on each disaggregated (separated) portion of hardware or software, of an O-RAN Mobile Network Architecture; when run and passed, a test case should provide assurance that the disaggregated portion, of the O-RAN Mobile Network Architecture that was tested, conforms to O-RAN specifications as defined by the O-RAN ALLIANCE.

### 4.1.4 Step 4: Verify


Figure 4-4. Manual Testing Methodology, Step 4: Verify

Once the test cases are executed successfully, we verify the results against the standards defined in specifications (for example, 3GPP & O-RAN ALLIANCE specifications[1]).

There might be some failures too, hence we will be reporting them to respective stakeholders and making sure those are resolved within a specific timeframe; the failed test cases will be repeated. We will also make notes of new learnings that will happen during various testing cycles in order to make it less error-prone for future projects.

### 4.1.5 Step 5: Share

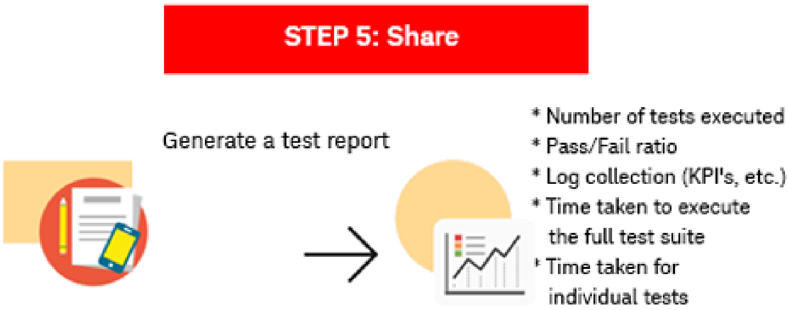


Figure 4-5. Manual Testing Methodology, Step 5: Share

Last, we generate a test report and capture all the details. The results are stored in a database for future references. The test report contains detailed information on executed test plans. This report can be shared widely within the organisation if needed.

[1] Specifications maintained by the 3rd Generation Partnership Project (3GPP), www.3gpp.org and the O-RAN ALLIANCE, www.o-ran.org.

## 4.2 Automated Testing Methodology with Test Automation Software

Open RAN technology features multiple moving parts, such as:

- Hardware: Different vendors, different models, different HW releases.
- Software: Different vendors, new features implemented, adoption of new standard versions,
- Real life traffic scenarios: Indoor, outdoor, hotspots, heterogeneous networks, special designs, rural, urban, suburban, traffic models, network environment, frequency bands, …

Automation is the way to efficiently test network functioning under large percentage of scenarios before going into network deployment.

### 4.2.1 Test automation invocation phases

Automation and test case invocation can be done at different phases in a project.

- **Pre-production phase**: Activities completed at the lab during validation of a new/modification/existing System Under Test (SUT) and test conditions. As example, moving parts referenced above.

  We can distinguish the following in non-mutually exclusive ways:

  - Lab Benchmark and Validation: Engineers defining test campaign on a Test Manager and executing (scheduling or queuing) some specific testing to validate, benchmark, or troubleshoot a given setup.
  - Continuous Testing: Automatic trigger test execution and reporting under given conditions or periodic testing executions of predefined test campaigns.
- **Live production phase**: Activities completed at the lab and potentially some on the real network to ensure validation of a new network change before moving into large deployment.

### 4.2.2 Test automation architecture

Test automation architecture needs to be ready for the different testing invocation methods, in order to take maximum advantage of test infrastructure in different phases of the life cycle.

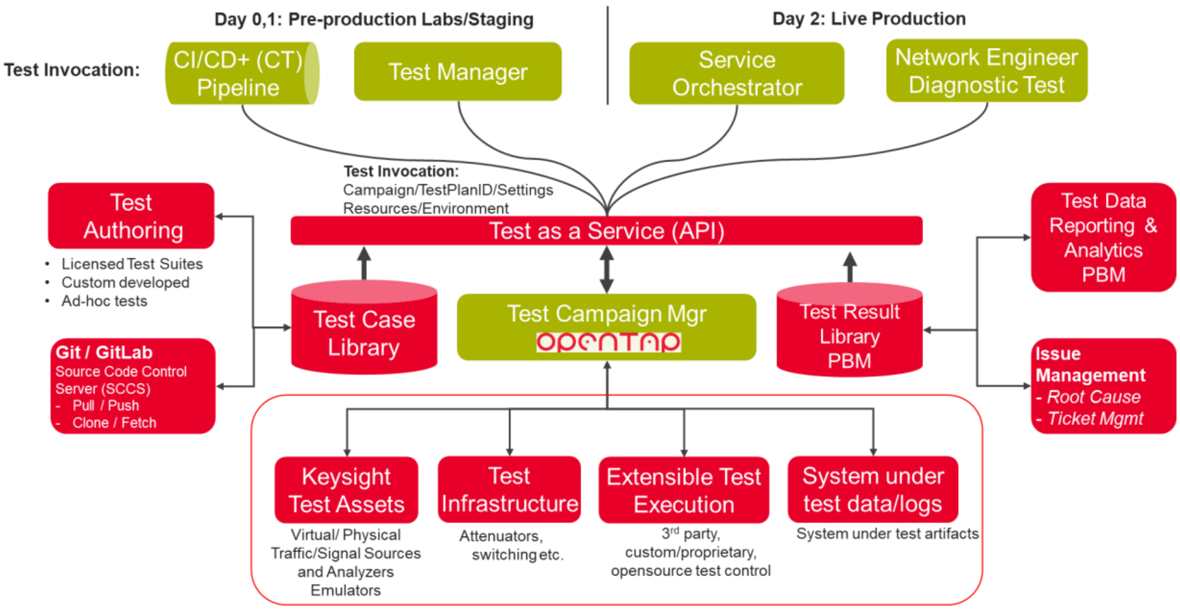


Figure 4-6. Test Automation High Level Architecture

**Test Manager**: Enables Engineers to define and launch test campaigns execution (scheduled or queued). Access to logs for troubleshooting and formal report generation. Different use cases can be identified:

- Compliance testing mode: Minimum parametrization changes on the test cases. Important ease of use and efficient workflow, including formal report generation.
- Development testing mode: Flexibility to adapt standard test cases with different parametrization to explore system under test (SUT) limits.

**Test Campaign Manager**: Enables orchestration of test invocation request from different sources.

**Test Case Library:** Library of built test scripts; Based on standards or ad-hoc requirements. Test case/solution versioning tracking it is recommended.

**Test Results Library (PBM)**: Database of test executions with granularity on date, test setup, … This database it can be used for analytics, reporting, AI/ML, …

**Keysight Test Assets/Test Infrastructure**: Test Equipment available.

**System Under Test**: In same cases it is required to automate the system under test. Potentially it might be non-API driven element.

**Test Data Reporting & Analytics (PBM)**: It is highly recommended for troubleshooting complex scenarios.

### 4.2.3 3GPP RF and O-RAN WG4 conformance automation

Test packages for O-RU conformance:

- Automated O-RAN WG4 Fronthaul Conformance test (CUSM-Plane) to support Test Configuration 1 specified in section 6.1
- Automated 3GPP RF Conformance test (Chapters 6 & 7) to support Test Configuration 1 specified in section 6.1

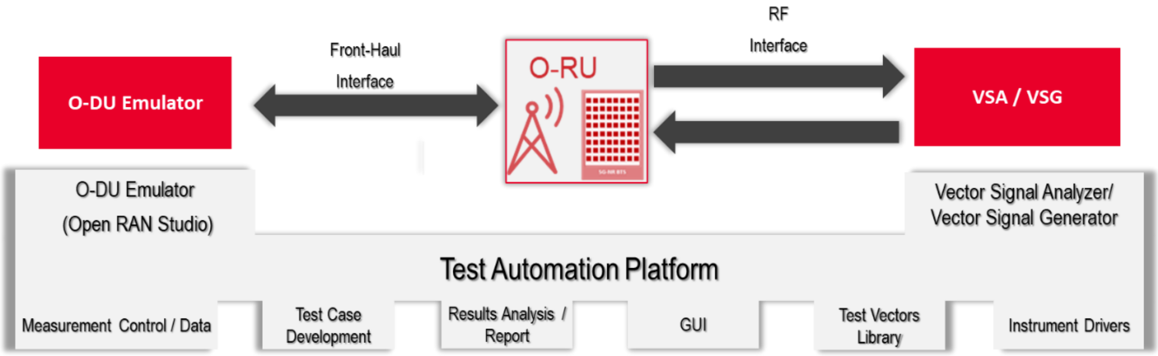


Figure 4-7. 3GPP RF and O-RAN WG4 Conformance Automation (Simplified)

Testing in the Uplink high level concept:

- Automation builds waveform, loads it into the VSG which will propagate on the RF interface.
- O-RU (DUT) receives the waveform in the RF interface and propagates it into the Fronthaul.
- Automation collects O-DU Emulator capture on the Fronthaul, completes test script procedures, and a test case verdict is produced and stored together with execution logs.

Testing in the Downlink high level concept:

- Automation builds, encapsulates waveform and O-DU Emulator sends it on the Font-Haul.
- O-RU (DUT) receives signal on the Fronthaul interface and propagates it to the RF interface.
- Automation collects RF waveform from VSA, completes test script procedures and a test case verdict is produced and stored together with execution logs.

### 4.2.4 O-RAN Fronthaul Interoperability testing

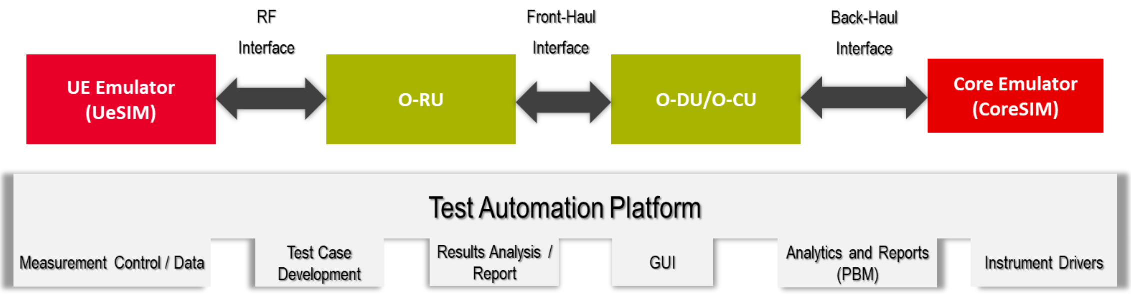


Figure 4-8. E2E TIFG Test automation using Test UEs/Emulated UEs (Simplified)

Testing Fronthaul Interoperability high level concept:

- Automation triggers pre-defined test scenarios and information exchanged between O-RU and O-DU/O-CU would be collected through Keysight Fronthaul Analyzer, and verdict will be produced and stored together with execution logs.

### 4.2.5 O-RAN TIFG Test automation using Test UEs/Emulated UEs (UeSIM/RuSIM)

Test packages for O-RAN TIFG E2E testing:

- Automated O-RAN TIFG E2E test specification test cases with Test UEs to support Test Configuration 3 specified in section 6.3
- Automated O-RAN TIFG E2E test specification test cases with Emulated UEs (UeSIM) to support Test Configuration 3 specified in section 6.3
- Automated O-RAN TIFG E2E test specification test cases with Emulated UEs (RuSIM) to support Test Configuration 2 specified in section 6.2
- Additional packages for Analytics, Benchmarking and Advanced Reporting

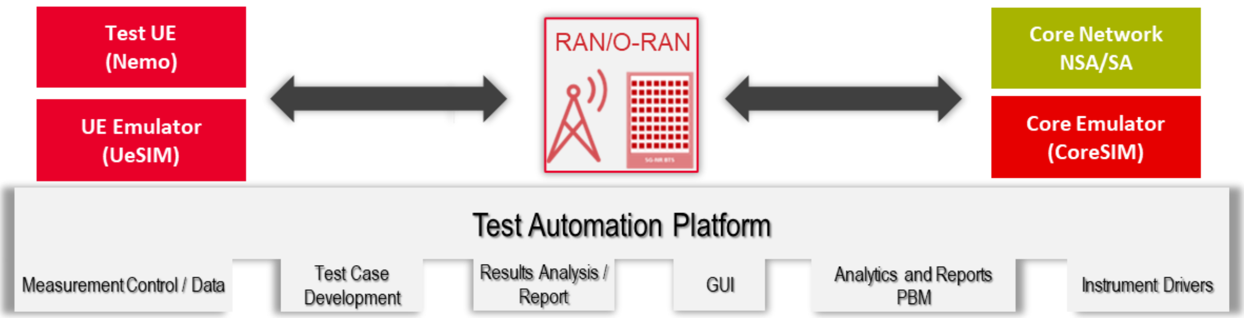


Figure 4-9. E2E TIFG Test automation using Test UEs/Emulated UEs (Simplified)

Testing E2E Test Automation high level concept:

- Automation triggers pre-defined traffic profile in 1-N devices, collects KPIs and verdict is produced and stored together with execution logs.
- PBM (Performance Benchmarking Solution) can produce results analytics and advanced reporting.

### 4.2.6 Functional/Load and Stress testing automation using emulated UEs (UeSIM and RuSIM)

Test packages for Load/Stress testing:

- UeSIM/RuSIM Module
- UeSIM/RuSIM Test Case Module
- UeSIM/RuSIM SCAS Test Case Module

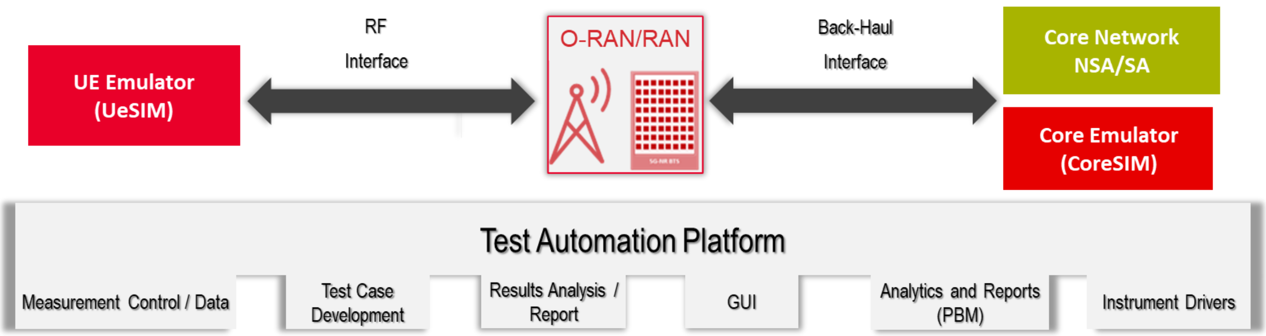


Figure 4-10. Load/Stress Testing Automation (Simplified)

Testing Load/Stress Test Automation high level concept:

- Automation with multiple pre-defined/ad-hoc test scripts to test load/stress testing together with analytics and reporting with PBM.
- Example: O-RAN TIFG E2E Test Specification Chapter 7 (Security), Chapter 8 (Load and Stress Test)

### 4.2.7 Test automation efficiency benchmarking and improvements

While the benefits of test automation are well understood to reduce the time required to run repetitive tests in a consistent and repeatable manner (as they are much faster than manual tests) at no additional cost, it is of key interest to the industry to measure the efficiency of test automation and work on continuous improvements.

1) Perform the "Manual Testing Methodology" with Keysight solutions and make a note of the time taken for each test case to run manually. Also, take note of the time taken for any one-time configurations needed on the system. As we will need to change setup configurations for different projects, each one-time configuration will need to be done before testing commences.

2) As we establish the confidence in manual testing, start automating the test cases in parallel.

3) Run the automation campaigns (test plans) using test manager and generate the test report. The test report will contain total run time for the campaign as well as time taken for individual tests. This will give us a brief comparison of how much time is saved using test automation. Using test automation, we can run certain test campaigns in multiple iterations to gauge the performance of networks and components involved in testing.

4) This will eventually help in benchmarking a process as we can compare test reports of similar test campaigns, with similar iterations, executed for different OpenRAN systems.

# 5 Test Specifications and Focus Areas

## 5.1 Conformance, Interoperability, and End-to-End (E2E) Testing

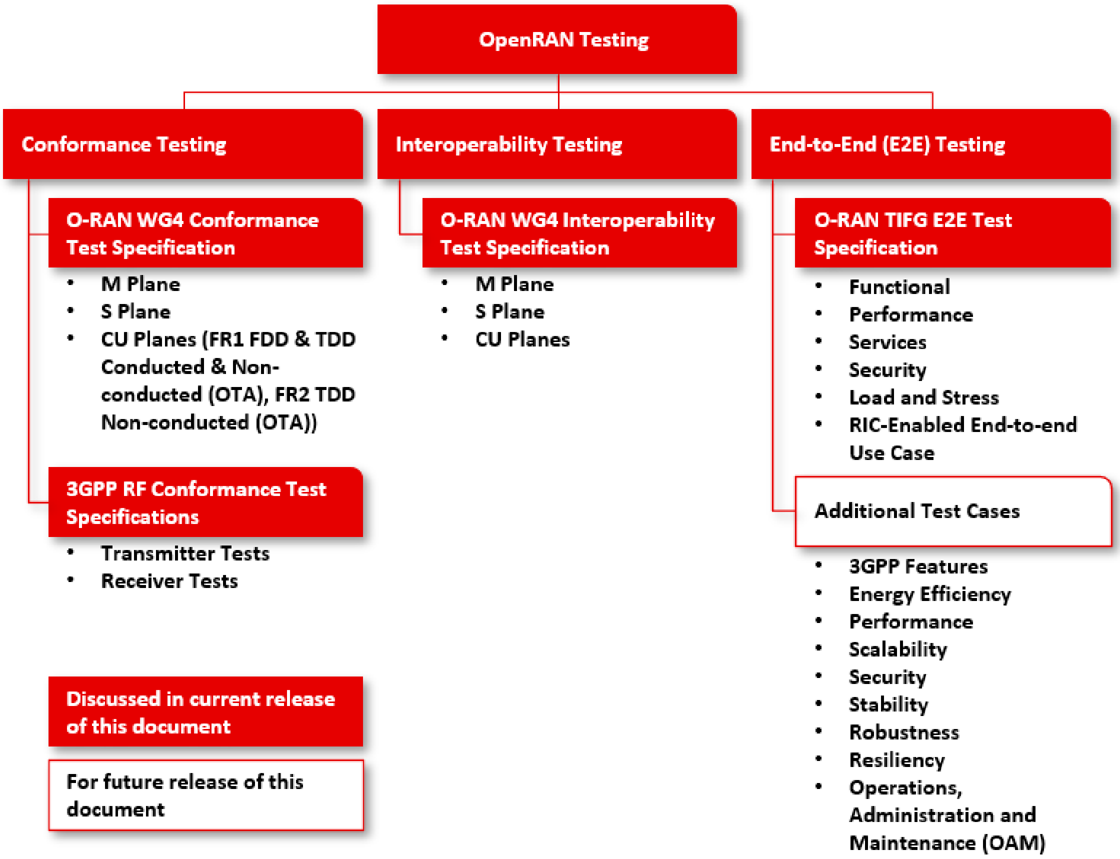


Figure 5-1. Conformance, Interoperability, and End-to-End (E2E) Testing

Figure 5-1 shows the test specifications and focus areas in this release of the document.

**Conformance testing** focuses on the most detailed test and verification for a single DUT (such as an O-RU or O-DU) and its functions and interfaces implementation compliance to normative 3GPP and O-RAN technical specifications using conformance test specifications and test cases.

**Interoperability testing** focuses on the interoperability between two DUTs (such as an O-RU and O-DU) and its functions and interfaces implementation compliance to normative O-RAN technical specifications using interoperability test specifications and test cases.

**End-to-End (E2E) testing** focuses on the E2E RAN testing with the multi-vendors O-RAN system tested as a 3GPP compliant RAN. All the O-RAN network functions are DUTs. 3GPP and O-RAN test specifications are used for End-to-End (E2E) testing.

For all Conformance, Interoperability, and E2E testing, the DUTs are required to be tested in operational state with all surrounding network functions either emulated (mostly in stateful manners) or as reference network functions which may be deployed ensuring that all tests performed are fully repeatable and produce consistent, accurate, and reliable test results.

Test results and outcomes should be determined using information gathered from test tools as much as possible to avoid / minimize the dependency on using DUTs vendors specific logs for testing and verification in order to ensure vendors neutral test outcomes and the test results are not influenced by the logging process which may impact DUTs performance during tests which is undesirable.

Table 5-1. Test Specifications and Number of Test Cases

| Test Specification (latest version number) | DUTs (IUTs) | Number of Test Cases |
|---|---|---|
| O-RAN WG4 Conformance Test (version 7.0) | O-RU (fronthaul) | Control and User: 219<br>Synchronization: 2<br>Management: 36 |
| | O-DU/O-CU (fronthaul) | Control and User: 8<br>Synchronization: 4<br>Management: 36 |
| | FHM | Conformance test cases specified are not in scope for this version of the document |
| 3GPP RF Conformance Test (Conducted)<br><br>3GPP TS 38.141-1 V16.13.0 (2022-09) | RU (Uu) | Transmitter: 12<br>Receiver: 8 |
| 3GPP RF Conformance Test (Radiated)<br><br>3GPP TS 38.141-2 V16.13.0 (2022-09) | RU (Uu) | Transmitter: 9<br>Receiver: 5 |
| O-RAN WG4 Interoperability Test (version 9.0) | O-RU & O-DU (fronthaul) | Control and User: 7<br>Synchronization: 6<br>Management: 2 |
| O-RAN TIFG E2E Test (version 4.0)<br><br>3GPP Security Assurance Specification (SCAS) for the next generation Node B (gNodeB) TS 33.511 V16.8.0 (2022-09) | eNB, gNB | Functional: 13<br>Performance: 13<br>Services: 23<br>Security: 25<br>Load and Stress: 8<br>RIC enabled E2E Use case: 1 |

# 6 Test Configurations (Identify and Evaluate)

In this chapter, details are provided on helping to select the required test plans[1] and in each of these test plans, the test cases[2] which are applicable to a selected test configuration.

## 6.1 Test Configuration 1

### 6.1.1 Step 1: Identify

Device Under Test (DUT) = O-RU
Interface Under Test (IUT) = O-RAN Fronthaul (OFH) and 3GPP Uu

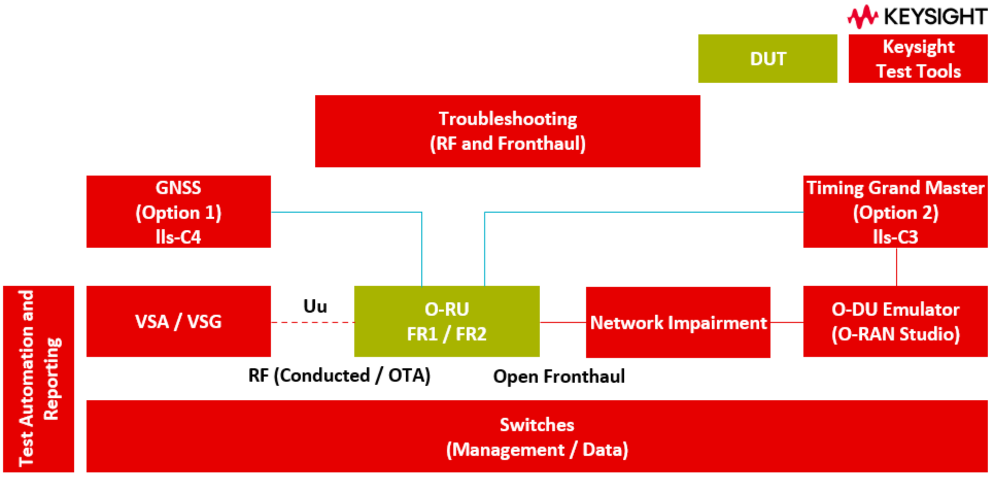


Figure 6-1. Test Configuration 1, Step 1: Identify

Possible testing for Test Configuration 1:

- 3GPP RF Conformance (Chapter 6 and 7)
- O-RAN WG4 Fronthaul Conformance

[1] *Test Plans* can consist of any number of Test Steps. Each *Test Step* provides/encapsulates a specific functionality which may perform a simple or complex set of operations on a Device Under Test (DUT); these simple or complex set of operations are defined by each of the test cases.

[2] *Test Cases* are a list of tests that can be run on each disaggregated (separated) portion of hardware or software, of an O-RAN Mobile Network Architecture; when run and passed, a test case should provide assurance that the disaggregated portion, of the O-RAN Mobile Network Architecture that was tested, conforms to O-RAN specifications as defined by the O-RAN ALLIANCE.

### 6.1.2 Step 2: Evaluate

Similar to "6.1.1 Step 1: Identify", there are several possible combinations involving a real UE, an emulated UE, and network functions. Identifying the appropriate setup type helps define an accurate test plan.

Device Under Test (DUT) = O-RU
Interface Under Test (IUT) = O-RAN Fronthaul (OFH) and 3GPP Uu

#### 6.1.2.1 Selection of test plans

Table 6-1. Selection of test plans for DUT = O-RU

| Interface Under Test (IUT) | Test Plans | Comments |
|---|---|---|
| O-RAN Fronthaul (OFH) | O-RAN WG4 Conformance Test Specification | |
| 3GPP Uu | 3GPP NR Base Station conformance test:<br>Conducted<br>(3GPP TS 38.141-1)<br>Radiated<br>(3GPP TS 38.141-2) | To select the required 3GPP test specification, the mode of connection to the O-RU, on the RF interface, must first be determined as either: Conducted or Radiated (OTA)[1]. |
| General | Additional test plans to be listed (for example, possible additions of power consumption measurements and others.) | |

#### 6.1.2.2 Selection of test cases

O-RAN WG4 Conformance test specification documents the testing methodology, test setup, and test cases for open fronthaul conformance testing of control, user, synchronization, and management planes (CUSM-Planes) for the O-RU and O-DU.

O-RAN WG4 Conformance test cases are classified as Mandatory, Conditional Mandatory (dependent on the capabilities of the DUTs) which are required to be passed, while the Optional test cases will have to be determined if these will need to be executed and passed.

[1] *Radiated can also be referred to as Over-the-Air (OTA).*

The O-RAN O-RU test profile includes the following listed information required to determine a set of test cases for the specific O-RU (DUT). It is recommended to manage, and version control all O-RAN O-RU test profiles in a central (cloud) location accessible to all test beds.

- O-RAN WG4 open fronthaul test profile as this will include key information such as Radio access technology: LTE/NR, FDD/TDD, IQ compression, Beamforming Methods (if beam forming feature is supported by the DUT), S-Plane topology configuration.
- DUT information – to be determined depending on Vodafone's test report requirements. The "O-RAN Certification and Badging Processes and Procedures" document defines a set of test report templates which can serve as a good reference as the templates include information such as O-RU vendor, model number, versions for hardware, software and firmware among other information which are required for test reporting purpose.
- List of test cases with the test specification releases and version numbers.

#### 6.1.2.3 Test setup

The actual O-RU test setup is to be determined with the following listed parameters:

- Connectivity to the O-RU on the RF interface
  - Open Radio Unit (O-RU) is Category A or B
  - Conducted or Radiated (OTA)
  - Massive MIMO or non-Massive MIMO support
- Connectivity to the O-RU on the fronthaul interface
  - Number of ports and connectivity rates (10GE/25GE/others)
- Timing and Synchronization topology LLS-C1, LLS-C2, LLS-C3

#### 6.1.2.4 Test tools

The following test tools are required to test the O-RU.

Table 6-2. Test Tools for DUT = O-RU

| Testing Tool | Keysight Test Solution | Connection to DUT (O-RU) | Requirements |
|---|---|---|---|
| O-DU Emulator | Open RAN Studio | Open fronthaul (ethernet) towards the O-RU | **Required**: for all O-RU O-RAN WG4 conformance CUSM-Planes test cases |
| Network Impairment Emulator | Network Emulator 2/3 | Open fronthaul (ethernet) inline between the Open RAN Studio and O-RU | **Required**: for test cases which require selective packet discards, delay, and jitter such as for delay management testing. |
| Signal Analyzer (Keysight VSA) | VXT | RF towards the O-RU | **Required**: for all O-RU O-RAN WG4 conformance CUSM-Plane test cases needing RF analysis |
| | MTRX | RF towards the O-RU | **Required**: for all O-RU O-RAN WG4 conformance CUSM-Plane test cases needing RF signal generation including Beam forming tests support |
| Signal Generator (Keysight VSG) | VXT | RF towards the O-RU | **Required**: for all O-RU O-RAN WG4 conformance CUSM-Plane test cases needing RF signal generation |
| | MTRX | RF towards the O-RU | **Required**: for all O-RU O-RAN WG4 conformance CUSM-Plane test cases needing RF signal generation including Beam forming tests support |

Table 6-2. Test Tools for DUT = O-RU

| Testing Tool | Keysight Test Solution | Connection to DUT (O-RU) | Requirements |
|---|---|---|---|
| Air monitor | WaveJudge | Passive monitoring of the RF interface | **Optional**: Troubleshooting interoperability issues on the RF interface |
| Fronthaul analytics | Open RAN Studio Fronthaul Analytics | Full stack fronthaul analytics | **Optional**: Troubleshooting interoperability issues on the fronthaul interface |
| Timing and Sync Tester | Time Sync Analyzer | Open fronthaul (ethernet) towards the O-RU | **Required**: for O-RAN WG4 conformance S-Plane test cases |
| OTA chamber<br><br>Shielded room | Functional: MPAC (Multi-Probe Anechoic Chamber)<br><br>RF Performance: CATR (Compact Antenna Test Range) | RF towards the O-RU | **Required**: for O-RU OTA connectivity particularly in FR2 |
| Test Automation and Reporting | Test Management Center | Not applicable | **Required**: manages and orchestrates test cases scheduling and execution. Performs test results verdicts and reporting. |

## 6.2 Test Configuration 2

### 6.2.1 Step 1: Identify

Device Under Test (DUT) = O-DU/O-CU
Interface Under Test (IUT) = O-RAN fronthaul (OFH)
NR Deployment Architecture = Non standalone (NSA) Option 3x or Standalone (SA) Option 2.

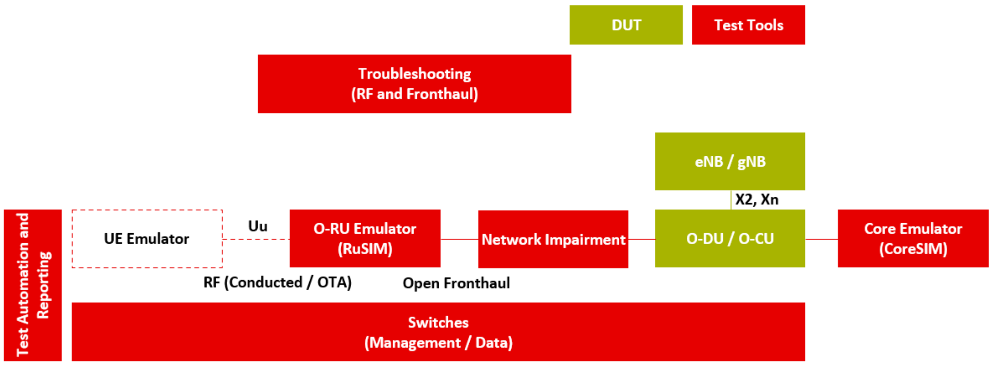


Figure 6-2. Test Configuration 2, Step 1: Identify

Possible testing for Test Configuration 2:

- O-RAN WG4 fronthaul conformance testing
- O-RAN WG4 fronthaul interoperability testing (IOT) with O-RUs emulated

  Note that different diagram is needed for Interoperability testing between (non-emulated) O-RU / O-DU and O-DU / O-CU.
- Load testing with O-RUs emulated
- End-to-End (E2E) testing with O-RUs emulated

### 6.2.2 Step 2: Evaluate

Similar to "6.2.1 Step 1: Identify", there are several possible combinations involving a test UEs, emulated UEs, and network functions. Identifying the appropriate setup type helps define an accurate test plan.

Device Under Test (DUT) = O-DU/O-CU
Interface Under Test (IUT) = O-RAN fronthaul (OFH)
NR Deployment Architecture = Non standalone (NSA) Option 3x or Standalone (SA) Option 2

#### 6.2.2.1 Selection of test plans

Table 6-3. Selection of test plans for DUT = O-DU/O-CU

| Interface Under Test (IUT) | Test Plans | Comments |
|---|---|---|
| O-RAN Fronthaul (OFH) | O-RAN WG4 Conformance Test<br><br>O-RAN WG4 fronthaul interoperability test (IOT) | |
| General | O-RAN TIFG E2E test specification<br><br>Additional E2E testing<br><br>Load testing<br><br>Additional test plans to be listed (for example, possible additions of power consumption measurements and others) | |

#### 6.2.2.2 Selection of test cases

**O-RAN WG4 Conformance test specification** documents the testing methodology, test setup and test cases for open fronthaul conformance testing of control, user, synchronization, and management CUSM-Planes for the O-RU and O-DU.

Test cases are classified as Mandatory, Conditional Mandatory (dependent on the capabilities of the DUTs) which are required to be passed, while the Optional test cases will have to be determined if these will need to be executed and passed.

The O-RAN O-DU test profile includes the following listed information which is required to determine the set of test cases that are applicable for the specific O-DU (DUT). It is recommended to manage, and version control all O-RAN O-DU test profiles in a central (cloud) location accessible to all test beds.

- O-RAN WG4 open fronthaul interoperability test (IOT) profile will include key information such as radio access technology: LTE/NR, FDD/TDD, IQ compression, Beamforming Methods (if the beam forming feature is supported by the DUT), and S-Plane topology configuration.
- Additional parameters which are required for test case selection include RAN topology – number of cells, and configuration for each of the cells.
- DUT information – to be determined depends on Vodafone's test report requirements. The "O-RAN Certification and Badging Processes and Procedures" document defines a set of test report templates which can serve as a good reference since the templates include information such as O-DU vendor, model number, versions for hardware, software, and firmware among other information required for test reporting purposes.
- List of test cases with the test specification releases and version numbers.

**O-RAN WG4 fronthaul interoperability test specification** documents the testing methodology, test setup, and test cases for open fronthaul interoperability testing of control, user, synchronization, and management planes (CUSM-Plane) for the O-RU and O-DU.

Test cases are classified as Mandatory, Conditional Mandatory (depending on the capabilities of the DUTs) which are required to be passed.

The O-RAN fronthaul interoperability test (IOT) profile includes the following listed information which are required to determine the set of test cases that are applicable for the specific pair of O-RU and O-DU (DUTs). It is recommended to manage, and version control all O-RAN IOT test profiles in a central (cloud) location accessible to all test beds.

- O-RAN WG4 open fronthaul interoperability test (IOT) profile will include key information such as radio access technology: LTE/NR, FDD/TDD, M-Plane architecture model, and S-Plane topology configuration.
- DUT information – to be determined depends on Vodafone's test report requirements. The "O-RAN Certification and Badging Processes and Procedures" document defines a set of test report templates which can serve as a good reference since the templates include information such as O-RU and O-DU vendor, model number, versions for hardware, software, and firmware among other information which are required for test reporting purposes.
- List of test cases with the test specification releases and version numbers.

#### 6.2.2.3 Test setup

The actual O-DU test setup is to be determined with the following listed parameters:

- Connectivity to the O-DU/O-CU on the fronthaul interface
    - Number of ports and connectivity rates (10GE/25GE/others)
- Timing and Synchronization topology LLS-C1, LLS-C2, LLS-C3

#### 6.2.2.4 Test tools

The following test tools are required to test the O-DU/O-CU.

Table 6-4. Test tools for DUT = O-DU/O-CU

| Testing Tool | Keysight Test Solution | Connection to DUT (O-RU) | Requirements |
|---|---|---|---|
| O-RUs Emulator and embedded multi-UEs emulation capabilities | RuSIM | Open fronthaul (ethernet) towards the O-DU | **Required**: for O-DU O-RAN WG4 conformance CUM-Planes test cases, O-RAN WG4 IOT test cases, O-RAN TIFG E2E test cases |
| Core emulator OR Reference core network and application servers | CoreSIM | S1 (LTE/NR NSA) or N1/N2/N3 (NR SA) towards the O-CU | **Required**: for O-DU O-RAN WG4 conformance CUM-Planes test cases, O-RAN WG4 IOT test cases, O-RAN TIFG E2E test cases |
| Network Impairment Emulator | Network Emulator 2/3 | Open fronthaul (ethernet) inline between the RuSIM and O-DU | **Required**: for test cases which require selective packet discards, delay, and jitter such as for delay management testing. |
| Fronthaul analytics | Open RAN Studio Fronthaul Analytics | Full stack fronthaul analytics | **Optional**: Troubleshooting interoperability issues on the fronthaul interface |
| Timing and Sync Tester | Time Sync Analyzer | Open fronthaul (ethernet) | **Required**: for O-RAN WG4 conformance S-Plane test cases |

Table 6-4. Test tools for DUT = O-DU/O-CU

| Testing Tool | Keysight Test Solution | Connection to DUT (O-RU) | Requirements |
|---|---|---|---|
| Test Automation and Reporting | Test Management Center | Not applicable | **Required**: manages and orchestrates test cases scheduling and execution. Performs test results verdicts and reporting. |

## 6.3 Test Configuration 3

### 6.3.1 Step 1: Identify

Device under Test (DUT) = LTE eNB, NR gNB (with either O-RU/O-DU or O-DU/O-CU)
NR Deployment Architecture = Non-standalone (NSA) Option 3x or Standalone (SA) Option 2

Interface under Test (IUT) = O-RAN fronthaul (OFH) and others

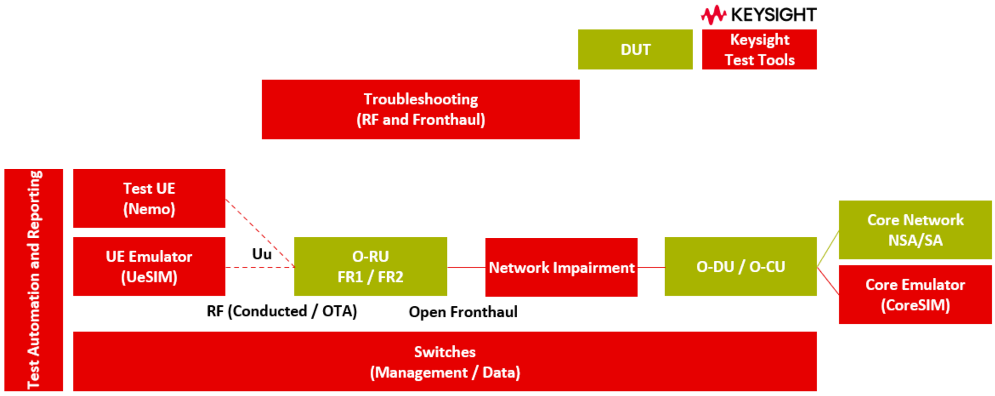


Figure 6-3. Test Configuration 3, Step 1: Identify

Possible testing for Test Configuration 3:

- O-RAN WG4 fronthaul interoperability testing (IOT)
- Load testing
- End-to-end (E2E) testing
-

### 6.3.2 Step 2: Evaluate

Similar to “6.3.1 Step 1: Identify”, there are several possible combinations involving real and emulated UEs and network functions. Identifying the appropriate setup type will help us to define an accurate test plan.

Device Under Test (DUT) = LTE eNB or NR gNB (with either O-RU/O-DU or O-DU/O-CU)
NR Deployment Architecture = Non-Standalone (NSA) Option 3x or Standalone (SA) Option 2.

Interface Under Test (IUT) = O-RAN Fronthaul (OFH) and others

#### 6.3.2.1 Selection of test plans

Table 6-5 Selection of test plans for DUTs = O-RU and O-DU

| Interface Under Test (IUT) | Test Plans | Comments |
|---|---|---|
| O-RAN Fronthaul (OFH) and others | - O-RAN WG4 fronthaul interoperability test (IOT) | |
| General | - O-RAN TIFG E2E test specification<br>- Additional E2E testing<br>- Load testing<br>- Additional test plans to be listed (for example, possible additions of power consumption measurements and others) | |

#### 6.3.2.2 Selection of test cases

**O-RAN WG4 fronthaul interoperability test specification** documents the testing methodology, test setup and test cases for open fronthaul interoperability testing of control, user, synchronization, and management planes (CUSM-Plane) for the O-RU and O-DU.

Test cases are classified as Mandatory, Conditional Mandatory (dependent on the capabilities of the DUTs) which are required to be passed.

The O-RAN fronthaul interoperability test (IOT) profile includes the following listed information which are required to determine the set of test cases which are applicable for the specific pair of O-RU and O-DU (DUTs).

It is recommended to manage, and version control all O-RAN IOT test profiles in a central (cloud) location accessible to all test beds.

- O-RAN WG4 open fronthaul interoperability test (IOT) profile as this will include key information such as radio access technology: LTE/NR, FDD/TDD, M-Plane architecture model, S-Plane topology configuration.
- DUT information – to be determined depending on Vodafone's test report requirements. The "O-RAN Certification and Badging Processes and Procedures" document defines a set of test report templates which can serve as a good reference as the templates include information such as O-RU and O-DU vendor, model number, versions for hardware, software, and firmware among other information which are required for test reporting purpose.
- List of test cases with the test specification releases and version numbers.

**O-RAN TIFG End to End (E2E) test specification** documents the testing methodology, test setup and test cases for LTE eNB and NR gNB for NSA (Option 3x) and SA (Option 2) deployment scenarios.

Test cases are classified as Mandatory which are required to be passed while the Optional test cases will have to be determined if these will need to be executed and passed.

The O-RAN E2E test (IOT) profile includes the following listed information which are required to determine the set of test cases which are applicable for the LTE eNB, NR gNB for NSA and SA (DUTs). It is recommended to manage, and version control all O-RAN E2E test profiles in a central (cloud) location accessible to all test beds.

- Parameters which are required for test cases selection include Radio access technology: LTE, NR NSA, NR SA, RAN topology – number and configuration of the cells, O-RUs, O-DUs, O-CUs.
- DUT information – to be determined depending on Vodafone's test report requirements. The "O-RAN Certification and Badging Processes and Procedures" document defines a set of test report templates which can serve as a good reference as the templates include information such as LTE eNB, NR gNB vendor, model number, versions for hardware, software and firmware among other information which are required for test reporting purpose.
- List of test cases with the test specification releases and version numbers.

#### 6.3.2.3 Test setup

**O-RAN WG4 fronthaul interoperability test specification** - the actual test setup is to be determined with the following listed parameters:

- Connectivity to the O-RU on the RF interface
  - Conducted or Radiated (OTA)
  - Massive MIMO or non-Massive MIMO support
- Connectivity to the O-DU on the fronthaul interface
  - Number of ports and connectivity rates (10GE/25GE/others)
- Timing and Synchronization topology LLS-C1, LLS-C2, LLS-C3

**O-RAN TIFG End to End (E2E) test specification** - the actual E2E test setup is to be determined with the following listed parameters

- Connectivity to the LTE eNB or NR gNB for NSA and SA on the RF interface
  - Conducted or Radiated (OTA)
  - Massive MIMO or non-Massive MIMO support
- Connectivity to the LTE eNB, NR gNB for NSA and SA on the Core interface
  - LTE eNB – needing 4G Core either reference or emulated
  - NR gNB for NSA – needing EN-DC Core either reference or emulated
  - NR gNB for SA – needing SA NG core either reference or emulated

- Connectivity to the NR gNB for NSA on the X2 interface
    - Needing LTE eNB either reference or emulated
- Timing and Synchronization topology lls-C1, lls-C2, lls-C

#### 6.3.2.4 Test tools

The following test tools are required to test the O-RU and O-DU.

Table 6-6 Test tools for DUTs = O-RU and O-DU

| Testing Tool | Keysight Test Solution | Connection to DUT (O-RU & O-DU) | Requirements |
|---|---|---|---|
| Multi-UEs Emulator (LTE, NR NSA, NR SA) | UeSIM | RF towards the O-RU | **Required**: for O-RAN WG4 IOT test cases, O-RAN TIFG E2E test cases |
| Test UEs (LTE, NR NSA, NR SA) | Nemo/PBM | RF towards the O-RU | **Required**: for O-RAN WG4 IOT test cases, O-RAN TIFG E2E test cases |
| Core emulator OR Reference core network (LTE, NR NSA, NR SA) | CoreSIM | S1 (LTE/NR NSA) or N1/N2/N3 (NR SA) towards the O-CU | **Required**: for O-RAN WG4 IOT test cases, O-RAN TIFG E2E test cases |
| Application (traffic) server | CoreSIM | Not applicable | **Required**: for O-RAN WG4 IOT test cases, O-RAN TIFG E2E test cases needing data transfers and services testing |
| Network Impairment Emulator | Network Emulator 2/3 | Open fronthaul (ethernet) inline between the O-RU and O-DU | **Required**: for test cases which require selective packet discards, delay, and jitter such as for delay management testing. |
| Fronthaul analytics<br><br>Packet capture tool | Open RAN Studio Fronthaul Analytics | Full stack fronthaul analytics (passive monitoring) | **Optional**: Troubleshooting interoperability issues on the fronthaul interface |
| Air monitor | WaveJudge | Full stack RF interface analytics (passive monitoring) | **Optional**: Troubleshooting interoperability issues on the RF interface |

Table 6-6 Test tools for DUTs = O-RU and O-DU

| Testing Tool | Keysight Test Solution | Connection to DUT (O-RU & O-DU) | Requirements |
|---|---|---|---|
| Timing and Sync Tester | Time Sync Analyzer | Open fronthaul (ethernet) | **Required**: for O-RAN WG4 conformance S-Plane test cases |
| Test Automation and Reporting | Test Management Center | Not applicable | **Required**: manages and orchestrates test cases scheduling and execution. Performs test results verdicts and reporting. |
| OTA chamber or Shield room | Functional: MPAC (Multi-Probe Anechoic Chamber)<br><br>RF Performance: CATR (Compact Antenna Test Range) | RF towards the O-RU | **Required**: OTA connectivity between the UE emulator and/or Test UEs to the O-RU typically recommended for FR2 |
| Massive MIMO MU-MIMO conducted test connector | Beam MIMO Detect (BMD) | RF towards the O-RU | **Required**: conducted connectivity between the UE emulator to the O-RU typically recommended for FR1 for Massive MIMO and MU-MIMO full stack testing. |
| Security attack module – DoS/DDoS attack<br><br>Packet generation tool / DoS emulator | O-RAN Security Test Suite (DoS/DDoS attack module) | O-DU's open fronthaul interface<br><br>O-DU's open fronthaul interface<br><br>[for future release of this document] Near-RT RIC's A1 interface | **Required**: O-RAN TIFG E2E Test Specification<br><br>7.2.1 S-Plane PTP DoS Attack (Network layer)<br><br>7.2.2 C-Plane eCPRI DoS Attack (Network layer)<br><br>[for future release of this document] 7.2.3 Near-RT RIC A1 Interface DoS Attack (Network layer) |
| Security attack module – Fuzzing attack<br><br>Fuzzing tool | O-RAN Security Test Suite (Fuzzing attack module) | O-DU's open fronthaul interface<br><br>O-DU's open fronthaul interface | **Required**: O-RAN TIFG E2E Test Specification<br><br>7.2.4 S-Plane PTP Unexpected Input (Network layer) |

Table 6-6 Test tools for DUTs = O-RU and O-DU

| Testing Tool | Keysight Test Solution | Connection to DUT (O-RU & O-DU) | Requirements |
|---|---|---|---|
| | | [for future release of this document] Near-RT RIC's A1 interface | 7.2.5 C-Plane eCPRI Unexpected Input (Network layer)<br><br>[for future release of this document] 7.2.6 Near-RT RIC A1 Interface Unexpected Input (Network layer) |
| Security attack module – Vulnerability scan<br><br>Vulnerability scanning tool | O-RAN Security Test Suite (Vulnerability scan and audit module) | [for future release of this document] Near-RT RIC's A1 interface | **Required**: O-RAN TIFG E2E Test Specification<br><br>[for future release of this document] 7.2.7 Blind exploitation of well-known vulnerabilities over Near-RT RIC A1 interface (Network layer) |
| Security attack module – Cloud attack<br><br>NFV benchmarking and resource exhaustion tool | O-RAN Security Test Suite (Cloud attack module) | O-Cloud | **Required**: O-RAN TIFG E2E Test Specification<br><br>7.3 O-Cloud resource exhaustion type of security test (Virtualization layer), 7.3.1 O-Cloud side-channel DoS attack |

# 7 Vodafone's Current OpenRAN labs testing capabilities

**Vodafone OpenRAN test labs are currently equipped with state-of-the-art testing solutions enabling its comprehensive Category 3 Open RAN lab testing capabilities**.

These test labs currently support functional and performance testing and validation of multi-vendor O-RAN fronthaul solutions including

- O-RAN open fronthaul Conformance testing for O-RUs and O-DUs
- 3GPP Conformance testing for gNBs and eNBs
- O-RAN open fronthaul Interoperability testing for O-RUs and O-DUs
- End to End testing for gNBs and eNBs using both test UEs and emulated UEs (applicable in general for all multi-vendors network functions and interfaces)

Additional Open RAN functional and performance testing capabilities which the test labs can currently offer include

- Open fronthaul testing of the O-DUs
- F1 midhaul testing of the O-CUs
- F1, X2, Xn interoperability testing between gNB-CU/gNB-DU, eNB/en-gNB and gNBs
- E2 testing of the O-RAN Near Real-Time RIC (xApps) and AI/ML enabled optimization
- A1 interoperability testing of the Near Real-Time RIC (xApps) and Non-Real-Time RIC (rApps)

**Vodafone's OpenRAN test and integration strategy requires automation for all test cases**.

Test automation and reporting capabilities are progressively added to the test labs starting with End-to-End testing for gNBs and eNBs using real test UEs and in the near-term adding test automation suites to support

<u>Automation test suite currently supported</u>

- End to End testing for gNBs and eNBs using real UEs

<u>Automation test suites planned to support as future roadmap</u>

- O-RAN open fronthaul Conformance testing for O-RUs
- 3GPP Conformance testing for gNBs and eNBs
- O-RAN open fronthaul Interoperability testing for O-RUs and O-DUs
- O-RAN open fronthaul testing of the O-DUs
- End to End testing for gNBs and eNBs using emulated UEs

Vodafone plans to continue to evolve its OpenRAN test labs capabilities to support additional test scenarios such as Massive MIMO beam forming / Multi-users MIMO, Security, Energy Efficiency and Savings among others which are listed in Chapter 8.

# 8 Vodafone's Plan to Extend Open RAN Testing Confidence

The current focus of this handbook details a testing strategy and methodology that enables manual testing as well as robust automated testing and validation of multi-vendor O-RAN fronthaul solutions; the implementations leverage a common set of industry standards and test specifications for conformance, interoperability, and E2E testing for functional, performance, and security perspectives.

Vodafone and Keysight plans to extend this handbook to include additional topics such as **advanced deployment readiness tests** once they have been specified in industry standards and test specifications (they are largely not specified in the current versions). These deployment readiness tests are essential to ensure that O-RAN compliant network functions can be deployed by operators at scale for telco and vertical industry use cases and applications with confidence.

- **O-RAN conformance and interoperability for additional Open interfaces and network functions** such as:
  - **F1** (gNB-CU | gNB-DU)
  - **X2** (eNB | en-gNB)
  - **Xn** (gNB | gNB)
  - **E2** (Near Real-Time RIC | E2 nodes)
  - **Near Real-Time RIC APIs** (Near Real-Time RIC | xApps)
  - **A1** (Near Real-Time RIC | Non-Real-Time RIC)
  - **R1** (Non-Real-Time RIC | rApps)
  - **O1** (O-RAN managed entities | SMO)
  - **O2** (O-Cloud | SMO)
  - **O-RAN Accelerator Abstraction Layer (AAL) API** (hosted O-RAN workloads | hardware accelerators)

- **O-RAN RAN Intelligent Controller (RIC) AI/ML enabled optimization use cases centric training, testing, and validation** for each of the subsystems, interoperability between a pair of subsystems, and from the E2E perspective. RIC-enabled use cases of interest may include Traffic Steering, QoS and QoE Optimization, RAN Slicing, Massive MIMO Optimization, Shared O-RU, RAN Energy Savings, RAN Analytics Exposure API, and O-Cloud Resource Optimization, etc.

- **O-RAN Massive MIMO beam forming and Multi-Users MIMO** radios, O-DUs, and base station testing with performance KPIs such as spectral efficiency, capacity gains, power consumption, and energy efficiency, etc.

- **O-RAN Security resilience and failover validation** as operators have adopted a zero-trust approach on security. Operators expect multi-vendor O-RAN systems to be robustly tested and validated for commercial grade security implementation from the functional, performance, and Developer Security Operations (DevSecOps) perspective; this includes each of the O-RAN components, interfaces, and systems be designed and optimized for deployment scenarios of choice. This may include testing with extreme AI/ML enabled attacks, defence and failover validation, and threat detection in a complete DevSecOps approach.

- **O-RAN Energy Plane - efficiency and savings** characterization, testing, and benchmarking for each of the software and hardware components and operations resulting in the most optimal usage of energy, while maintaining best in class user and service experiences, network performances, and minimizing impacts to User Equipment (UE), network complexities, and overheads.

- **Live-to-Lab** testing as live network operating environments and lifecycle management are to be emulated in a lab environment; testing can be conducted in a realistic lab test environment for both the radio and network perspectives therefore accelerating live-to-live deployments with "field" tested and optimized O-RAN solutions.

- **Service Management and Orchestration (SMO) enabled Network OAM** should be conducted to ensure that operational network scenarios including: FCAPS functionalities, Performance – fault – configuration capabilities are thoroughly validated; this requires extensive experience with network operations.

- **DevOps Automation Continuous Integration, Continuous Deployment / Development and Continuous Testing (CI/CD/CT) model** evolving from current test automation models which will accelerate Open RAN technology speed and cost of evolution drastically with seamless transitions from lab to field to operations and vice versa.

# 9 Concluding Remarks

Open RAN presents enormous opportunities for the telecom industry to innovate the next generation connectivity fabric for consumer and enterprise use cases with its open architecture supporting multi-vendors interoperability. At the same time, it has created challenges from the testing and system integration standpoint which must be solved to accelerate Open RAN technology adoption.

In Vodafone's OpenRAN test labs, as we partner with the global ecosystem of operators and vendors to define the success of this new technology, we wanted to assure we covered every aspect and defined a test process that is applicable to all projects that come to our door.

To accomplish this, Vodafone has developed this O-RAN handbook as we have shared our vision and detailed a robust testing strategy and methodology for Open RAN systems as our goal is to help accelerate commercial deployments globally by operators at scale for telco and vertical industry use cases and applications.

**Test automation** is one of the key pillars of the test and integration strategy shared in this handbook as it is a fundamental building block required to apply the CI/CD/CT pipeline approach to Open RAN solutions which is an essential enabler to accelerate commercial deployments at scale.

An effective test automation strategy and successful implementation offer tremendous benefits in terms of scaling testing expertise, increased test coverage, accuracy, reliability, repeatability, and consistency of test results. It enables significant savings in terms of time, resources, and improvements on return of investments as expert resources are invested into enhancing test automation implementation rather than spent on recurring cycles of manual test executions.

The test configuration, test results analysis and determination of the test outcome, test reporting stages of the manual test cycle which are particularly laborious and time consuming can be drastically optimized using test automation techniques enabling time savings when implemented for a set of test specifications developed by O-RAN ALLIANCE made available in the public domain.

In the short term, Vodafone plans to automate test cases relating to the specifications listed below with the ambition of achieving the time savings indicated as follows.

- O-RAN O-RU fronthaul conformance[1] - up to 60% and above
- O-RAN TIFG End-to-End system test using emulated UEs[2] - up to 60% and above
- O-RAN TIFG End-to-End system test using test UEs[3] - up to 50% and above

The amount of time, resources and investments savings will obviously vary depending on the complexities of the test scenarios and test cases.

O-RAN ALLIANCE test specifications are designed for validating O-RAN network functions' compliance to O-RAN normative specifications and interoperability between these network functions, with the majority of these test cases focused on functional testing.

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[1] O-RAN WG4 Conformance test specification "Mandatory" and "Conditional Mandatory" test cases are considered.

[2] O-RAN TIFG E2E test specification test cases which are applicable for Emulated UEs are considered.

[3] Only a subset of test cases specified in the O-RAN TIFG E2E test specification applicable for Test UEs are considered.

While the O-RAN test specifications are used to provide a good starting point for test and integration activities, O-RAN products and systems are designed for commercial grade applications – additional test cases will be required to test, validate, and optimize them for commercial deployments.

Deployment readiness test cases standardised in 3GPP have been designed with many years of technology research and experiences testing, optimization and operating large scale commercial live networks across multiple generations of wireless technologies working with all parts of the wireless ecosystem. These deployment readiness test cases are currently not specified by O-RAN ALLIANCE and the industry would benefit from them doing so.

Vodafone's goal is to adopt a holistic approach for test and integration of Open RAN products and systems as our plan is to support a complete set of automated test suites to include all relevant O-RAN ALLIANCE and 3GPP test specifications and additional test cases supporting 3GPP releases-features, deployment readiness testing and optimization for the targeted use cases and deployment scenarios. Deployment readiness testing should include energy efficiency, performance, scalability, security, stability, robustness, and resiliency, under real-world operating conditions.

The future is bright for Open RAN technology as the potential benefits certainly are alluring. We are just at the beginning of this Open RAN journey, and we look forward to co-creating and making Open RAN a global success.

# Annex / Appendix A

This information request captures the information required to illustrate compliance with the full suite of relevant ORAN ALLIANCE specifications.

## A1. Information for the O-RU vendor to provide

| Questions | O-RAN Radio Unit Vendor Response | Does the O-RAN WG4 IOT Profile Provide Guidance | M-Plane Yang |
|---|---|---|---|
| **O-RAN WG4 IOT Profile** | | | |
| Share O-RU vendor recommended IOT profiles | | | |
| **Ethernet interface** | | | |
| Number of Ethernet ports | | Yes, multiple choice | |
| Speed – 10/25/50 Gbps? | | | |
| SFP type | | | |
| **S-Plane** | | | |
| ITU-T G8275.1 (only profile mandated in IOT profile) | This is mandatory for O-RU to support 8275.1 | Yes | |
| **M-Plane** | | | |
| IPv4 or IPv6 | | Yes | |
| Version | | | |
| **Radio and radio setup** | | | |
| Number of RF ports supported | | | |
| Tx / Rx on same port? | | | |
| Band | | | |

| Questions | O-RAN Radio Unit Vendor Response | Does the O-RAN WG4 IOT Profile Provide Guidance | M-Plane Yang |
|---|---|---|---|
| RF frequency | | | Determine from: *max-supported-frequency-dl, min-supported-frequency-dl max-supported-frequency-ul, min-supported-frequency-ul* |
| RF carrier bandwidth | | Yes, multiple choice | Determine from: *max-carrier-bandwidth-dl, min-carrier-bandwidth-dl, max-carrier-bandwidth-ul, min-carrier-bandwidth-ul* |
| RF subcarrier spacing | | Yes | |
| RF input power | | | |
| RF output power | | | Determine from: *max-gain* |
| RF inline attenuator | | | |
| TDD/FDD | | Yes | Determine from: *duplex-scheme* |
| TDD config | | Yes, multiple choice | |
| Phase compensation yes/no | | | |
| **Transport configuration** | | | |
| M-Plane via VLAN? VLAN-ID | | | |
| CU-Plane via VLAN? VLAN-ID | | | |
| MTU size | | | |

| Questions | O-RAN Radio Unit Vendor Response | Does the O-RAN WG4 IOT Profile Provide Guidance | M-Plane Yang |
|---|---|---|---|
| **RU category support** | | | |
| CAT-A / CAT-B | | Yes | Determine from: *ru-supported-category* |
| **Carrier config for the test** | | | |
| Carrier type - LTE/NR | Only NR support with automation | | Determine from: *supported-technology-ul, supported-technology-dl* |
| Numerology | | Yes | Determine from: *supported-frame-structures* |
| PRACH format, Sub-carrier spacing | | Yes, multiple choice | Determine from: *supported-prach-preamble-formats* |
| PRACH frequency offset | | | |
| IQ power scaling | | | |
| **Compression method support** | | | |
| Configurable via M-plane? | | | |
| Static compression support (ORAN spec makes dynamic mandatory) | | | Determine from: *o-ran-uplane-conf -> compression-method-supported* |
| Compression method supported (list) | | | |
| DL I/Q Bitwidth | | | |
| UL I/Q Bitwidth | | | |
| **O-RAN Beamforming** | | | |

| Questions | O-RAN Radio Unit Vendor Response | Does the O-RAN WG4 IOT Profile Provide Guidance | M-Plane Yang |
|---|---|---|---|
| Is beamforming supported? | | | Determine from:<br>*section-type => 5,6 for Channel Information based*<br>*supported-section-extensions => 1 for dynamic weight based*<br>*supported-section-extensions => 11 for flexible weight based*<br>*o-ran-beamforming being present* |
| Beamforming configurable via M-Plane? | | | |
| Beamforming methods support (list) | | Yes | Determine from:<br>*section-type => 5,6 for Channel Information based*<br>*supported-section-extensions => 1 for dynamic weight based*<br>*supported-section-extensions => 11 for flexible weight based*<br><br>*o-ran-beamforming*<br>*-> per-band-config*<br>*-> capabilities-groups*<br>*-> beamforming-trough-attributes-supported*<br>*-> beamforming-trough-ue-channel-info-supported* |
| **eAxC-ids** | | | |
| DL eAxCid | 0x0001 (used by default) | | |
| UL eAxCid | 0x0001 (used by default) | | |
| PRACH eAxCid | 0x0004 (used by default) | | |
| **End point definitions** | | | |

| Questions | O-RAN Radio Unit Vendor Response | Does the O-RAN WG4 IOT Profile Provide Guidance | M-Plane Yang |
|---|---|---|---|
| Are there any specific M-Plane configs for end point definitions? | | | |
| | | | |
| | | | |
| **O-RU timing window configuration** | | | Assume T12_max = 1 µs |
| **Downlink timing** | | | |
| T1a_cp_dl_max | | Yes | Determine from: *o-ran-delay-management->t2a-max-up - T12_max* |
| T1a_cp_dl_min | | Yes | Determine from: *o-ran-delay-management->t2a-min-up + T12_max* |
| T1a_up_dl_max | | Yes | Determine from: *o-ran-delay-management->t2a-max-cp-dl - T12_max* |
| T1a_up_dl_min | | Yes | Determine from: *o-ran-delay-management->t2a-min-cp-dl + T12_max* |
| **Uplink timing** | | | |
| T1a_cp_ul_max | | Yes | Determine from: *o-ran-delay-management->t2a-max-cp-ul - T12_max* |
| T1a_cp_ul_min | | Yes | Determine from: *o-ran-delay-management->t2a-min-cp-ul + T12_max* |

# A2. Information for the O-DU vendor to provide

**CUS Profile:**

| Category | Item | Related O-RAN specification and section |
|---|---|---|
| General | Radio access technology | |

| Category | Item | Related O-RAN specification and section |
|---|---|---|
| | TDD configuration | |
| | Nominal sub-carrier spacing | |
| | SSB sub-carrier spacing | |
| | Nominal FFT size | |
| | Total channel bandwidth | |
| | Number of spatial/antenna streams | |
| | Fronthaul Ethernet link | |
| | PRACH preamble format | - |
| | RU category | ORAN-WG4.CUS Specification Section 2.1 |
| | LAA | |
| Delay management | Network delay determination | ORAN-WG4.CUS Specification Section 2.3.3 |
| | RU adaptation of delay profile information (based on lls-CU delay profile and transport delay) | ORAN-WG4.CUS specification section 2.3.3.2 |
| | O-DU timing advance type | ORAN-WG4.CUS specification section 2.3.4-2.3.5, Annex B |
| | T1a_max_up | ORAN-WG4.CUS specification section 2.3, Annex B |
| | T1a_min_up | ORAN-WG4.CUS specification section 2.3, Annex B |
| | T2a_max_up | ORAN-WG4.CUS specification section 2.3, Annex B |
| | T2a_min_up | ORAN-WG4.CUS specification section 2.3, Annex B |
| | Tcp_adv_dl | ORAN-WG4.CUS specification section 2.3.2, Annex B |
| | Ta3_max_up | ORAN-WG4.CUS specification section 2.3, Annex B |
| | Ta3_min_up | ORAN-WG4.CUS specification section 2.3, Annex B |
| | Ta4_max_up | ORAN-WG4.CUS specification section 2.3, Annex B |
| | Ta4_min_up | ORAN-WG4.CUS specification section 2.3, Annex B |

| Category | Item | Related O-RAN specification and section |
| --- | --- | --- |
| | max (Ta4_max - Ta4_min) | Vendor's extension for Vendor's E2E operation |
| | T1a_max_cp_ul | ORAN-WG4.CUS specification section 2.3.2-2.3.3, Annex B |
| | T1a_min_cp_ul | ORAN-WG4.CUS specification section 2.3.2-2.3.3, Annex B |
| | T2a_max_cp_ul | ORAN-WG4.CUS specification section 2.3.2-2.3.3, Annex B |
| | T2a_min_cp_ul | ORAN-WG4.CUS specification section 2.3.2-2.3.3, Annex B |
| | T12_max | ORAN-WG4.CUS specification section 2.3, Annex B |
| | T12_min | ORAN-WG4.CUS specification section 2.3, Annex B |
| | max (T12_max - T12_min) | Vendor's specific extension |
| | T34_max | ORAN-WG4.CUS specification section 2.3, Annex B |
| | T34_min | ORAN-WG4.CUS specification section 2.3, Annex B |
| | max (T34_max - T34_min) | Vendor's specific extension |
| | Non-delay managed U-plane traffic | ORAN-WG4.CUS specification section 2.3.6 |
| C/U-Plane transport | Transport encapsulation | ORAN-WG4.CUS specification section 3.1.1-3.1.2 |
| | Jumbo frames | ORAN-WG4.CUS specification section 3.1.2 |
| | Transport header | ORAN-WG4.CUS specification section 3.1.3 |
| | eCPRI concatenation | ORAN-WG4.CUS specification section 3.1.3.1 |
| | eAxC ID CU_Port_ID bitwidth | ORAN-WG4.CUS specification section 3.1.3.1.6 |
| | eAxC ID BandSector_ID bitwidth | ORAN-WG4.CUS specification section 3.1.3.1.6 |
| | eAxC ID CC_ID bitwidth | ORAN-WG4.CUS specification section 3.1.3.1.6 |
| | eAxC ID RU_Port_ID bitwidth | ORAN-WG4.CUS specification section 3.1.3.1.6 |
| | Fragmentation | ORAN-WG4.CUS specification section 3.5 |
| | Transport prioritization across CUSM-Plane | ORAN-WG4.CUS specification section 3.3 |
| | Transport prioritization within U-Plane | ORAN-WG4.CUS specification section 3.3 |
| | Separation of UC-Plane and M-Plane traffic | ORAN-WG4.CUS specification section 3.4 |

| Category | Item | Related O-RAN specification and section |
|---|---|---|
| | Transport-based UC-Plane endpoint identifier to differentiate O-RUs | ORAN-WG4.CUS specification section 3.4 |
| Digital Power Scaling | UL gain_correction | ORAN-WG4.CUS specification section 6.1.3.2 |
| | Reference_Level (for DL) | ORAN-WG4.CUS specification section 6.1.3.3 |
| Beamforming | RU beamforming type | ORAN-WG4.CUS specification section 2.1 |
| | Beamforming control method | ORAN-WG4.CUS specification section 5.4, Annex J |
| IQ compression | U-Plane data compression method | ORAN-WG4.CUS specification section 6, Annex A |
| | U-Plane data IQ bitwidth | ORAN-WG4.CUS specification section 6, Annex D |
| | FS adjustment: FS_Offset | ORAN-WG4.CUS specification section 6.1.3 |
| | IQ data frame format not including udCompHdr field | ORAN-WG4.CUS specification section 6.3.3.13 |
| C-Plane | Section Type 0 | ORAN-WG4.CUS specification section 5.4.2 |
| | Section Type 1 | ORAN-WG4.CUS specification section 5.4.2 |
| | Section Type 3 | ORAN-WG4.CUS specification section 5.4.2 |
| | Section Type 5 | ORAN-WG4.CUS specification section 5.4.2 |
| | Section Type 6 | ORAN-WG4.CUS specification section 5.4.2 |
| | Section Type 7 | ORAN-WG4.CUS specification section 5.4.2 |
| | "symInc" flag | ORAN-WG4.CUS specification section 5.4.5.3 |
| | C-Plane for PRACH formats with preamble repetition | ORAN-WG4.CUS specification section 5.3.2 |
| | Section extension 1 (beamforming weights) | ORAN-WG4.CUS specification section 5.4.7 |
| | Section extension 2 (beamforming attributes) | ORAN-WG4.CUS specification section 5.4.7 |
| | Section extension 3 (DL Precoding configuration parameters and indications) | ORAN-WG4.CUS specification section 5.4.7 |
| | Section extension 4 (modulation compr. params) | ORAN-WG4.CUS specification section 5.4.7 |
| | Section extension 5 (modulation compression additional scaling parameters) | ORAN-WG4.CUS specification section 5.4.7 |
| | Section extension 6 (Non-contiguous PRB allocation) | ORAN-WG4.CUS specification section 5.4.7 |

| Category | Item | Related O-RAN specification and section |
|---|---|---|
| | Section extension 7 (Multiple-eAxC designation) | ORAN-WG4.CUS specification section 5.4.7 |
| | Section extension 8 (regularization factor) | ORAN-WG4.CUS specification section 5.4.7 |
| | Section extension 9 (Dynamic Spectrum Sharing parameters) | ORAN-WG4.CUS specification section 5.4.7 |
| | Section extension 10 (Multiple ports grouping) | ORAN-WG4.CUS specification section 5.4.7 |
| | Section extension 11 (Flexible BF weights) | ORAN-WG4.CUS specification section 5.4.7 |
| | Section extension 12 (Non-Contiguous PRB Allocation with Frequency Ranges) | ORAN-WG4.CUS specification section 5.4.7 |
| | Section extension 13 (PRB Allocation with Frequency Hopping) | ORAN-WG4.CUS specification section 5.4.7 |
| | Section extension 14 (Nulling-layer Info. for ueId-based beamforming) | ORAN-WG4.CUS specification section 5.4.7 |
| | Section extension 15 (Mixed-numerology Info. for ueId-based beamforming) | ORAN-WG4.CUS specification section 5.4.7 |
| | Section extension 16 (Section description for antenna mapping in UE channel information-based UL beamforming) | ORAN-WG4.CUS specification section 5.4.7 |
| | Section extension 17 (Section description for indication of user port group) | ORAN-WG4.CUS specification section 5.4.7 |
| | Coupling Method of C-Plane and U-Plane | ORAN-WG4.CUS specification section 5.4.1.2 |
| | IQ data transfer without C-Plane (configuration over M-Plane) | ORAN-WG4.CUS specification section 6.2.2 |
| S-plane | PTP Full Timing Support G.8275.1 | ORAN-WG4.CUS specification section 3.2.3, 9 |
| | PTP Partial Timing Support G.8275.2 | ORAN-WG4.CUS specification section 3.2.3, 9 |
| | GNSS based sync | ORAN-WG4.CUS specification section 3.2.3, 9 |
| | SyncE | ORAN-WG4.CUS specification section 9, Annex H |
| | Topology configuration | ORAN-WG4.CUS specification section 9.2.2 |
| Other information specific to interoperating with O-RU emulator | ORAN Spec version supported | |
| | IQ Compression Method and Bit Width | |
| | RU Port IDs (eAXC ID) | |
| | MAC Address | |

| Category | Item | Related O-RAN specification and section |
|---|---|---|
| | C-Plane VLAN ID | |
| | U-Plane VLAN ID | |
| | MTU Size | |

**M-Plane Profile:**

| Category | Item | Related O-RAN Specification and section O-RAN-WG4.MP |
|---|---|---|
| High Level Description | Architectural models | 2.1.2 M-Plane architecture model |
| | IP version | 2.1.3 Transport Network |
| | Hash algorithm for data integrity | 2.4 Security |
| | Ciphering algorithm | 2.4 Security |
| | host key algorithms | 2.4 Security<br>5.3 Download |
| | key exchange methods | 2.4 Security |
| 'Start up'' installation | O-RU identification by DHCP option | 3.1.1 O-RU identification in DHCP |
| | VLAN Discovery | 3.1.2 Management Plane VLAN Discovery Aspects |
| | IP address assignment | 3.1.3 O-RU Management Plane IP Address Assignment |
| | O-RU controller discovery | 3.1.4 O-RU Controller Discovery |
| | DHCP format of O-RU controller discovery | 3.1.4 O-RU Controller Discovery |
| | NETCONF Call Home | 3.2 NETCONF Call Home to O-RU Controllers |
| | SSH Connection Establishment | 3.3 SSH Connection Establishment |
| | TCP port for SSH establishment (for test purpose) | 3.3.1 NETCONF Security |
| | NETCONF Authentication | 3.3.2 NETCONF Authentication |
| | User Account Provisioning | 3.3.3 User Account Provisioning |
| | sudo | 3.4 NETCONF Access Control |
| | nms | 3.4 NETCONF Access Control |
| | fm-pm | 3.4 NETCONF Access Control |
| | swm | 3.4 NETCONF Access Control |
| | NETCONF capability | 3.5 NETCONF capability discovery |

| Category | Item | Related O-RAN Specification and section O-RAN-WG4.MP |
|---|---|---|
| | Watchdog timer | 3.6 Monitoring NETCONF connectivity |
| O-RU to O-DU Interface Management | VLAN tagging for C/U/M-Plane | 3.1.2 Management Plane VLAN Discovery Aspects<br>4.3 C/U-Plane VLAN Configuration |
| | C/U-Plane IP Address Assignment | 4.4 O-RU C/U-Plane IP Address Assignment |
| | Definition of processing elements | 4.5 Definition of processing elements |
| | C/U-Plane Transport Connectivity | 4.6 Verifying C/U-Plane Transport Connectivity |
| | O-RU Monitoring of C/U-Plane Connectivity | 4.10 O-RU Monitoring of C/U-Plane Connectivity |
| Configuration Management | Baseline configuration | 6.1 Baseline configuration |
| Fault Management | subscribe notification | 8.2 Manage Alarms Request |
| Synchronization Aspects | Sync Capability Object | 10.2 Sync Capability Object |
| Details of O-RU Operations | Activation, deactivation, and sleep | 12.3.2 Activation, deactivation, and sleep |

**Supplementary requirement for O-RAN operation - not documented in the M-Plane profiles published in O-RAN**

| | | |
|---|---|---|
| **SISO/RRM Configuration specific functionalities** | PRACH Static configuration | 12.6.1 Static configuration for PRACH processing |
| | Configurable FS offset | C.2 Option YANG Features: Table 15, No #18 |
| | eAxC specific gain correction | C.2 Option YANG Features: Table 15, No #19 |
| | Tx gain reference level control | C.2 Option YANG Features: Table 15, No #20 |
| | Static configuration of PRACH pattern | C.2 Option YANG Features: Table 15, No #21 |
| **Alarms** | Supported Alarms & Fault IDs | Annex A Alarm definition |

| | | |
|---|---|---|
| **Counters** | Counters for Transceiver | B.1 Transceiver Statistics |
| | Counters for FH Reception Window | B.2 Rx Window Statistics |
| | Counters for power and temperature | B.4 Energy, Power, and Environmental Statistics |
| **Supported ORAN Mandatory YANG modules** | | |
| **Additional Functionalities** | ORAN optional Yang modules to be supported | C.1 Optional Namespace |
| | ORAN Yang optional features to be supported | C.2 Optional YANG Features |
| | ORAN EXPOSED Optional Capabilities | C.3 Optional Capabilities Exposed Using O-RAN YANG Models<br>C.4 Optional Capabilities Exposed Using Common YANG Models |
| **Detailed M-Plane requirements** | Requested additional vendor's proprietary operability functions to be supported | No O-RAN references |