TELECOM INFRA PROJECT

Toward OpenRAN
CI/CD Automation

OpenRAN Project Group

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Glossary

CI/CD	continuous integration, continuous deployment
cNF	containerized network function, or cloud-native network function
E2E	end-to-end
EMS	element management system
FCAPS	fault, configuration, accounting, performance, security
NMS	network management system
RAN	radio access network
vCU	virtualized central unit
vDU	virtualized distributed unit
VM	virtual machines
vNF	virtualized network function

1 Introduction

Connectivity has created massive value to the global economy. According to the latest GSMA Mobility Report, the mobile industry contributed $4.1 trillion to global GDP in 2019. There are still great opportunities for it in emerging markets to connect the unconnected, and in advanced markets to provide universal broadband access and support new applications—such as AR/VR for consumers and new use cases for vertical industries. The COVID-19 pandemic makes the need for better connectivity even more evident.

Meeting fast-growing demand for connectivity and more bandwidth requires mobile network operators (MNOs) to invest heavily to expand coverage not previously offered, to upgrade to newer technology such as 5G, and to innovate new services for use cases that might not be well understood yet. Yet MNO revenue growth is staggering. This means they must do more with less while demonstrating flexibility and agility.

TIP OpenRAN's mission is to address these challenges by accelerating innovation in the radio access network (RAN) domain. Through horizontal and vertical disaggregation, OpenRAN enables significant TCO reduction, flexibility, and agility by:

- Increasing the **robustness** and **flexibility** of the RAN supply chain by enabling supplier diversification, by lowering the entry barrier for innovative players with specialized expertise
- Accelerating **innovation** in RAN technology, by choosing the best combinations of hardware and software that best fits different use scenarios
- Making it possible to apply modern software development technology to **automate build, test, deployment and delivery** of new features, helping improve operational efficiency as well as network performance and agility

OpenRAN operational efficiency was the main motivation for this project and thus is the focus of this whitepaper. Applying CI/CD in the network function integration, testing, delivery, and deployment process will also enable agility of feature and capability introduction.

Current operational models of single-vendor, integrated RAN solutions are monolithic and very hard to scale. Here it's not possible to use state-of-the-art advanced software technologies and DevOps methodologies.

DevOps is a collection of tools, processes, culture, and philosophy used to deliver value and positive effect on business as a whole. Further, achieving successful DevOps in an MNO environment requires a holistic approach. TIP has other initiatives to address processes and best practices (as well as culture and philosophy) for moving traditional MNO operations into a more DevOps-centric approach. The focus of this project was to provide the right tools to enable such transformation.

Wherever appropriate, existing cloud automation tools are adopted to execute auto-testing, vNF, and cNF orchestration; and to certify and manage network function artifacts, testing reports, and logs. For example, Robot Framework is used for test automation; Terraform is used for vNF instantiation and provisioning. Both are open source tools used in various projects.

However, it's anticipated that each MNO might have a preference when it comes to tools used in each network lifecycle management stage. Thus, the CI/CD platform architecture is designed such that with minimum customization being required for each MNO's tool choice, the platform architecture can be extended to integrate with other tools than those used in this project.

The platform is technology- and vendor-agnostic as well. During the project, a selected TIP partner's virtualized OpenRAN was deployed in a private cloud environment in the TIP Community Lab.

The CI/CD platform can be easily extended to support automated integration, testing, and deployment of other vendors' OpenRAN functions, be they virtualized or containerized, on to private (edge) cloud, central public cloud, or a hybrid cloud.

MNO partners who want to drive down operational costs and improve network performance through automation are invited to join the TIP OpenRAN initiative. Along with OpenRAN ecosystem technology partners and using all findings from the CI/CD project, they'll innovate toward a unified OpenRAN orchestration and automated lifecycle management solution.

TIP MNO partners are also encouraged to 1) deploy the current CI/CD platform in their TIP Community Labs, 2) explore its potential value, 3) get ready for large-scale OpenRAN commercial deployment, and 4) extend the current platform to support low-touch operations, performance optimization, and more.

The CI/CD platform is developed with OpenRAN lifecycle management within its focus. However, its architecture is by no means only limited to OpenRAN. It's network domain-agnostic and can be easily extended to support other network domains—e.g., Open Core Network and IP transport network, IMS, and VoLTE—so long as such network functions and applications are virtualized or containerized.

Led by Telefónica, TIP's OpenRAN CI/CD project was established to innovate in OpenRAN lifecycle management automation. This document shares what has been learned from the project and is structured as follows:

- MNO pain points in today's network lifecycle management are discussed, along with new opportunities brought by OpenRAN architecture
- Telefónica's perspective is presented, followed by a description of the platform developed in the TIP OpenRAN CI/CD project, supported use cases, overall architecture, and a typical workflow for integration and testing
- The document concludes with a call for action

2 Challenges and Opportunities

Deploying, operating, and managing wireless communication networks is not an easy task. It can be very costly due to the distributed nature of the networks—especially RANs.

Traditionally, wireless networks consist of vendors' proprietary HW with tightly integrated SW. Deployment often involves several expensive and time-consuming site visits. This is true even for software upgrades, because often a hardware expansion is a prerequisite to a software upgrade.

To save deployment cost, software features are packaged into big releases and introduced once per year or over a long time frame. A network upgrade can typically take several months, resulting in a lengthy time to market for new capabilities and functions. Such a model doesn't support the flexibility and agility required by today's MNO business needs.

Introducing large software releases is a complex undertaking. So that nothing goes wrong during deployment, MNOs need to perform integration in a lab and or staging environment, thereby validating the new release is backward-compatible with the existing network and its configuration. Integration, verification, and deploymene with limited or no tool support and involves many manual touch points. All is prone to mistakes, thus degrading field network performance.

In contrast, cloud service providers have pioneered new models of software development, deployment, and data center operational management. Abundant tools now exist that automate the building, testing, and deployment of applications. Best practices such as continuous integration and continuous deployment (CI/CD) bridge the gap between DevOps and activities undertaken by operations teams.

With CI/CD, hyperscale cloud service providers can release software features whenever they're ready and needed. There is no need to wait for building a large release package. CI/CD leads to a shorter time to market, reduced cost of upgrades, and expansion offering better quality.

Appropriated from the IT realm, the CI/CD engineering concept is now recognized as essential for the telecom industry's ever-increasing software systems. It's a practice that requires developers to commit code into a shared central repository several times a day. Verified by an automated build with unit tests to flush out issues early on, code is automatically deployed for system testing. Thus CI/CD mostly falls on the vendor side of the divide in the telecom industry.

As TIP OpenRAN drives innovation for open, disaggregated RAN products and solutions, it's transforming traditional single-vendor, fully integrated RAN to multi-vendor, disaggregated OpenRAN build and deployment. Disaggregation of network HW and SW creates opportunities to apply the CI/CD paradigm to telecom. On the operator side in network lifecycle management (Figure 1), it bridges the vendor/operator divide as well as between operators' system integration and operations activities/teams.
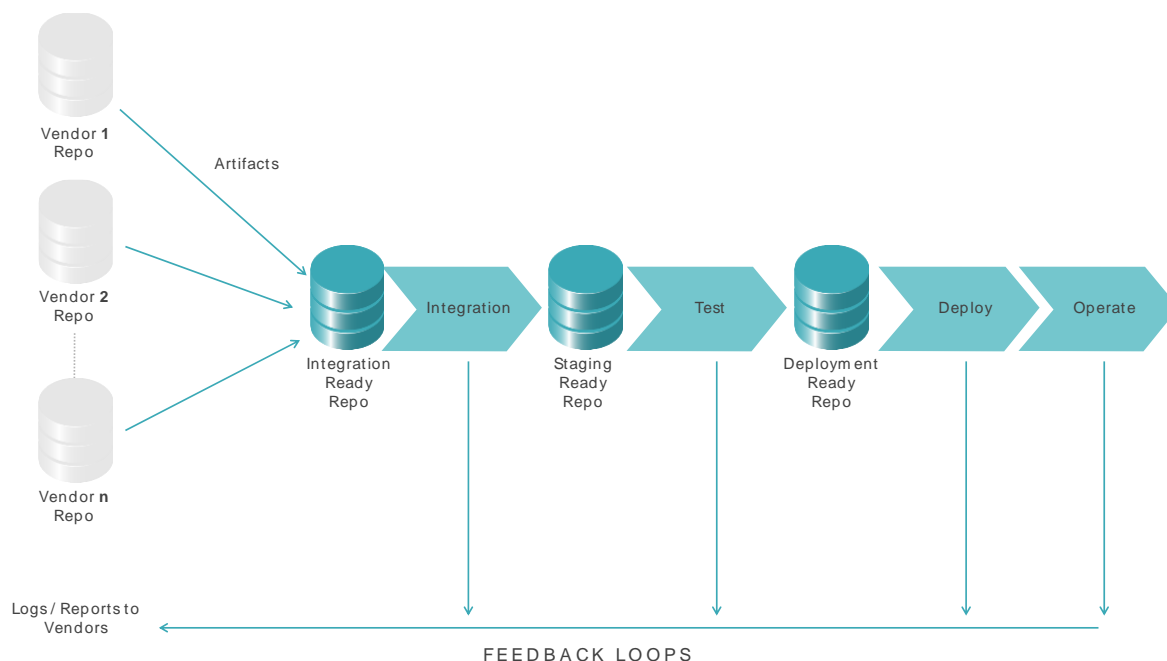
Figure 1. Workflow Processes of OpenRAN CI/CD Framework

While OpenRAN creates opportunities to apply CI/CD to improve operational efficiency and agility, automation becomes a prerequisite for large scale deployment success. Through disaggregation, OpenRAN lets MNOs mix and match the best of breed RAN products—where RU, vDU, and vCU can all come from different suppliers. But such complexity, coupled with the amount of work in system integration and interoperability testing, can only be addressed using automation tools.

Our scope starts when a vendor's software, hereafter called artifact, is delivered to operators for integration with other functions to form a targeted network solution. It's then tested in a lab and/or staging environment. If successfully validated, the artifacts are deployed to production according to the operator's network evolution strategy.

A key in addressing the vendor/operator divide is the feedback loop at each CI/CD process stage; it provides visibility and helps resolve issues as early as possible in the cycle. The gap between an operator's integration and operations team is closed by automating process workflows.

Unlike the IT industry, the telecom CI/CD project doesn't start with code, but rather with artifacts provided by vendors (software developers). Herein we'll still refer to this tool and process as CI/CD because it enables network solutions to be integrated, tested, and deployed much more frequently than before—monthly, weekly, or even on-demand rather than annually.

TIP OpenRAN's CI/CD platform is a first-use case. It focused on how to best use the software-based architecture to provide flexibility and agility. And it examined RAN lifecycle

management automation to achieve better efficiency—from integration, testing, and deployment to operations and optimization.

3 Telefónica's Needs and Perspectives

As a major global operator, Telefónica is shifting away from running decades-old business models and equipment. It recognizes that traditional approach complexity isn't sustainable if it's to realize rapid innovation and service introduction—not to mention the need to quickly respond to local requirements per county or region wherever it operates.

Telefónica works with many internal operations teams, in addition to a number of external suppliers. In prior years its vendors, supporting developers, and operations staff used the waterfall methodology. Switching to a network software approach means being flexible to learn new skills to stand behind operational change—even if this means working with open source communities, small-to-big vendors, third-party network application developers, and a wide selection of system integrators.

From its recent OpenRAN trials, Telefónica's operations team learned how important it is to properly synchronize local and field changes—along with the correct configuration of target infrastructure and its desired topology, images, and configuration states. If not done correctly, these can easily result in inefficient operational workflows. With the assurance of a smooth, automated workflow, Telefónica expects the TIP CI/CD platform will bridge the gaps between system integration and network operations teams.

All must work in a coordinated manner to make this shift—from separately developing, installing, configuring, monitoring, and repairing proprietary networking hardware—to developing automated network services at scale. And they must perform all of this while meeting customer quality of service (QoS) expectation.

Like other operators, Telefónica aims to empower its operations teams with open CI/CD applications and interfaces, such that automation practices can grow organically while being vendor-agnostic within supply chains. Adoption of CI/CD tools and their open interfaces will shape how fast Telefónica can react to customer demands, while continually enhancing network capabilities and resiliency.

As Telefónica organically enhances its automation toolsets, it's natural that end results will lead to new expectations such as:

- Enhanced vendor interaction with respect to continuous release management and feature introductions
- HW and SW components that can be scaled in virtualized or containerized compute environments following the traffic pattern
- Quick fixes that are quickly certified and implemented
- Rapid response methods to deal with disasters, failures, and policy changes

Security is a typical afterthought. Traditional practices have strictly segregated production and test networks. Some have posed a challenge to Telefónica's ability to 1) adopt CI/CD for integrating virtual network functions (vNFs), 2) provide exact-replica test networks in lab environments, and 3) offer service levels representing prime technology benefits.

Telefónica believes any CI/CD automation platform must be able to validate its security rules and policies. Connectivity should have the ability to shift artifacts from developers in test infrastructures onto the production network path. Therefore, prior to subsequent production a CI/CD platform must provide for testing as well as incremental graduation of releases and artifact updates toward field trials.

As configuration updates and frequent vendor software releases consistently progress from the CI environment to the integration lab—then on to staging and finally to production environments—such a platform needs to provide strict, secure options. And it must do so with secure automation that adheres to Day 0/Day 1/Day 2 principles.

Figure 2 summarizes Telefonica's request for the system and functions to be supported by CI/CD. In some cases, open source or third-party tools are integrated with the platform to enable functionality.
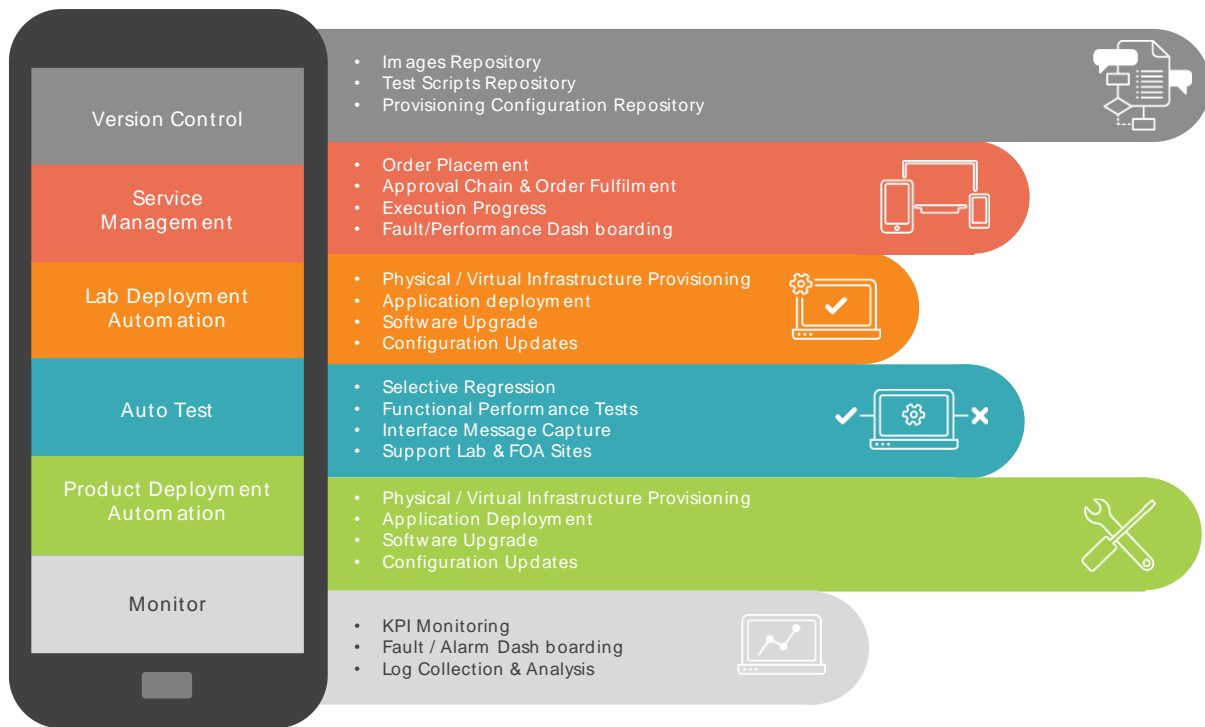
Figure 2. Full end to end system requirements

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4 TIP OpenRAN CI/CD Platform

4.1 Use Cases

Led by Telefónica to fully unleash OpenRAN potential, TIP OpenRAN partners developed a platform to prove the automated CI/CD concept. The process began with pulling artifacts from OpenRAN vendor repositories through integration, testing, deployment, and operation.

Built-in platform flexibility uses microservice chaining and workflow pipeline design to address disparate use cases in E2E processes. Figure 3 outlines the main use case categories supported by CI/CD.

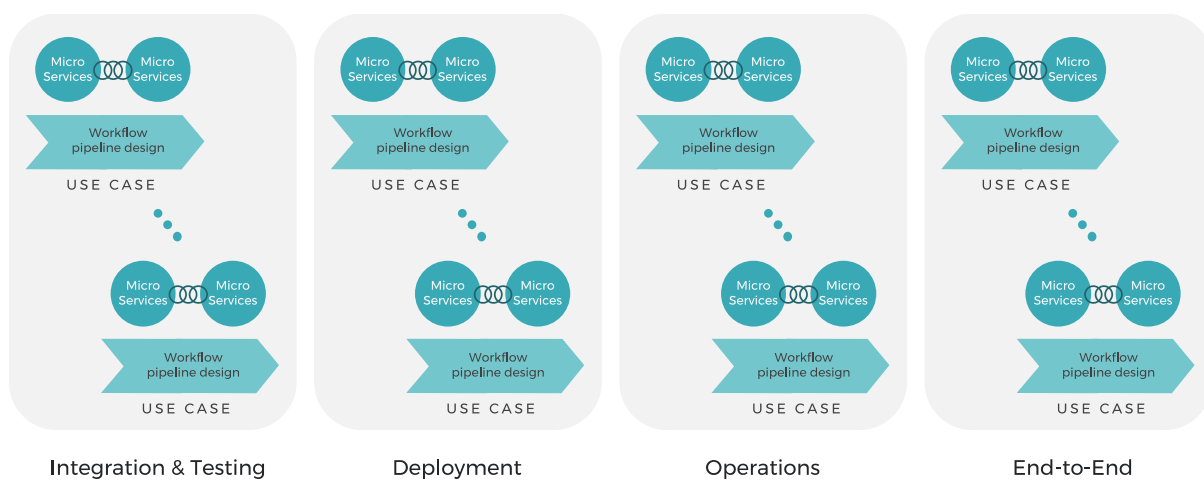| Integration & Testing | Deployment | Operations | End-to-End |

Figure 3. Use case categories

Some use cases supported by the current TIP OpenRAN CI/CD platform implementation are:

- Integration and testing use cases

  - ✓ Maintain image and test scripts version control

  - ✓ Test suites creation for different lineups

  - ✓ Maintain multiple lineups to orchestrate vCU, vDU

  - ✓ Test logs and reports collection

  - ✓ Logs and reports posting (to vendors)

- Deployment use cases

  - ✓ Instantiate the vCU and vDU

  - ✓ Perform VM provisioning on OpenStack for vCU, vDU

✓ Push the Day 0 configuration to vCU and vDU

✓ Push the Day 1 configurations to vCU/vDU/RRU

● Operation use cases

✓ Operation logs and reports collection

● E2E use cases

✓ Support RRU firmware upgrade

✓ Support vCU and vDU software upgrade

4.2 Overall Architecture

The CI/CD platform is based on containerized, Kubernetes-managed microservices. The modular, open software architecture offers an environment for ecosystem partners to contribute and enhance it.
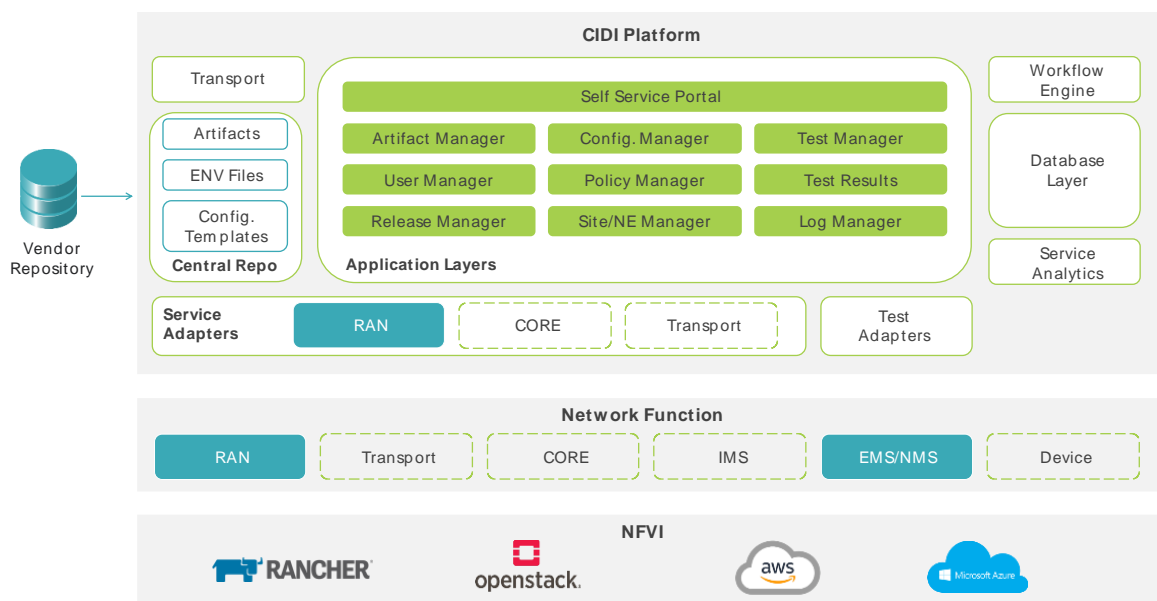
NB: Functions in orange dash boxes are not implemented in current CI/DI platform

Figure 4. CI/DI Platform Architecture Diagram

The platform comprises the following components (Figure 4):

● Self Service Portal – A single UI provides access to features or services based on specific user roles.

- Artifact Manager – Integrates with vendor repositories, continuously polls for artifact updates (i.e., software deliverables), pulls them to the CI/CD platform, then certifies and uploads them to the central repository.
- Release Manager – Provides the capability to create, manage, and promote releases (i.e., a set of distinct artifacts that can be deployed together). For a given release, a Release Manager user can select the lineup/environment, map the test suite, and promote it. Release Promote instantiates the vNFs, configures them, executes test cases, and publishes test results.
- User Manager – Enables management of CI/CD platform users. They can request portal access through a registration form.
- Test Manager – Provides the ability to create, manage, and execute test suites (each being a collection of test cases). The Test Manager can run tests on demand or in a scheduled manner.
- Policy Manager – Manages and enforces policies (rules pertaining to any given task) for the platform to act upon. In the current release, it creates and manages the auto-deploy policy for OpenRAN vNF deployments.
- Users create auto-deploy policy with vNF type, vendor, instance, and test suites. Each policy can automatically fetch artifacts of the selected vNF type and vendor, upload them, instantiate the vNFs on the selected instance, execute the selected test suite on the selected lineup, and publish test results.
- Log Manager – Provides the ability to collect, analyze, and publish logs to a centralized log management system. The CI/CD platform currently collects and publishes application (vNFs) and Kubernetes logs from all nodes. Any subsystem/external systems can push the logs to the central log manager.
- Workflow Engine – Enables seamless deployments and tests with no manual intervention. It stitches tasks across components for continuous integration, deployment, and validation.
- Service Adapter Layer – Consists of multi-vendor, multi-system adapters. It augments integration with network systems (e.g., RAN, core, transport, IMS), devices (e.g., routers, switches), EMS/NMS systems, and other external systems.
- Test Adapter Layer – Comprises adapters for third-party test platforms such as TM500, UE simulators, TerraVM.
- API Gateway – Single-point of entry to interact with the various CI/CD microservices; handles request routing, composition, and protocol translation.

The platform is integrated with open source and third-party tools to provide complete E2E automation (Figure 5), where:

- Robot Framework supports test automation and execution.
- TerraForm supports infrastructure as code for provisioning OpenRAN software functions (e.g., vDU, vCU).

- Ansible playbooks support managed OpenRAN function configurations.
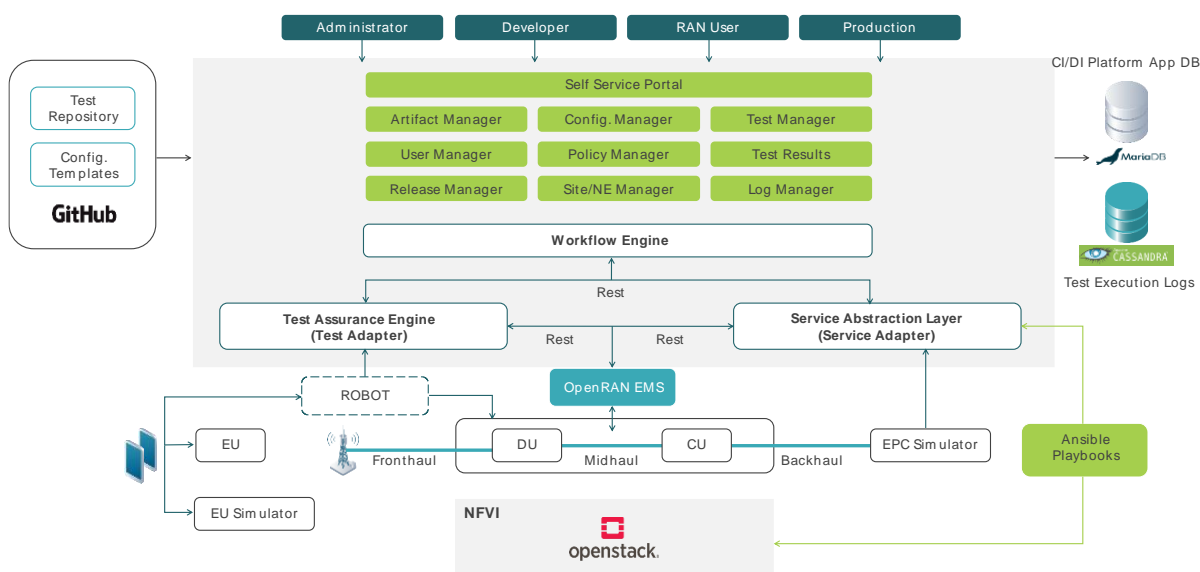- MariaDB and Casandra perform application data management and data logs.

Figure 5. Implementation in first release of the CI/DI Platform

4.3 Workflow Example

A simplified workflow example explains how the CI/CD platform seamlessly performs continuous integration, deployment, and testing. Figure 6 illustrates steps in an integration and testing use case:

1. Pull artifacts from vendor's repository

2. Upload artifacts after certification

3. VNF Orchestrator fetches vNF image for instantiation

4. VNF Orchestrator instantiates image in on-demand manner or at scheduled time

5. Config Manager applies Day-0/Day-1 configuration

6. Test Case Manager triggers test cases wrapped in test suite and pushes test results to DB

7. Test results published to end users

Note: Not all details are mentioned in this example, e.g., how policy will be applied for auto deployment.

While the OpenRAN CI/CD platform currently runs in a TIP Community Lab (where integration, deployment, and testing are done), nothing prohibits it from being integrated with a staging network—or even a subsequent production network.
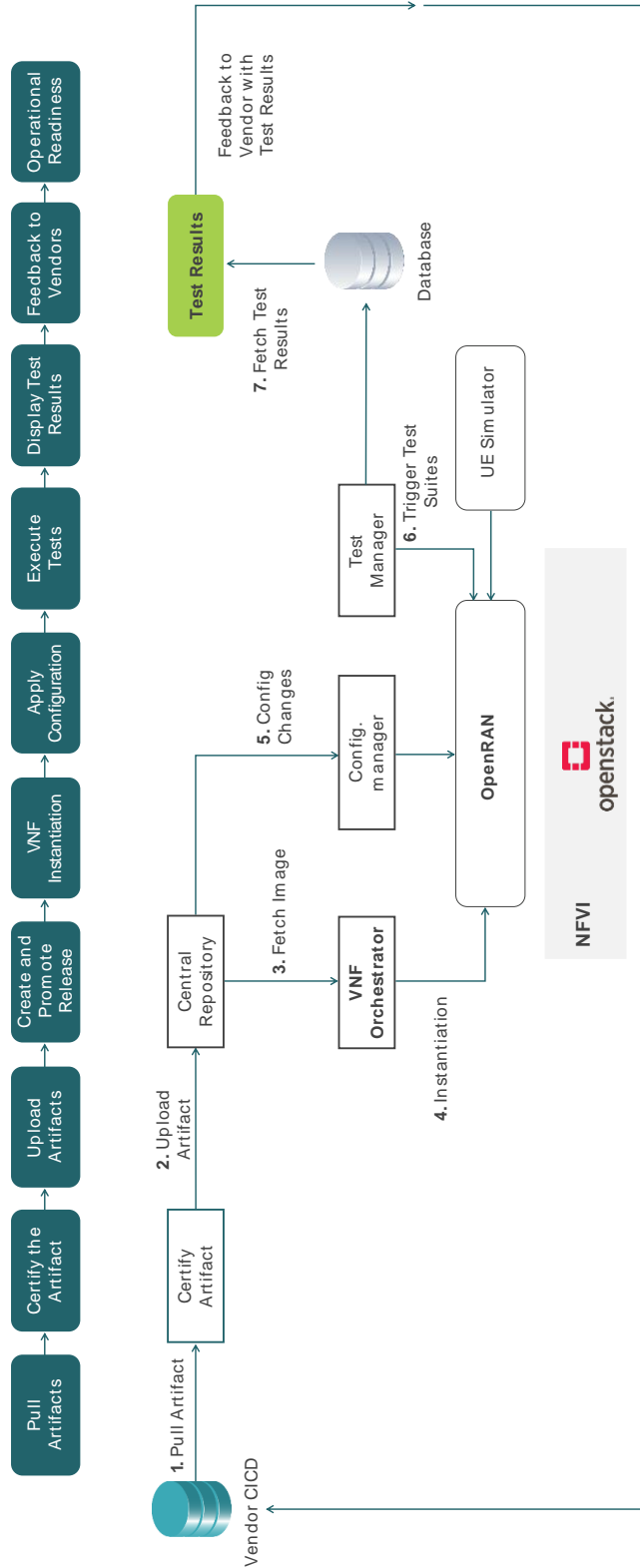

Figure 6. An example OpenRAN CI/DI workflow

5 Summary and Call for Action

We have presented challenges MNOs face when building wider and deeper connectivity to 1) connect the unconnected and 2) provide more bandwidth in existing locations to meet growing demand. By driving innovation, the TIP OpenRAN initiative addresses these challenges to accelerate commercial deployment of open, disaggregated, and standard-based RANs, leading to:

- Sustained MNO's supply chain with motivation to innovate
- Software-based architecture with flexibility and agility for ongoing network evolution
- Enabled by automation, the opportunity to apply modern IT technology for operational efficiency

As part of TIP OpenRAN Project Group, the OpenRAN CI/CD project developed a CI/CD platform, verified its feasibility, and demonstrated the value of automation.

Given the project findings, MNOs are invited to join TIP OpenRAN, then:

- Deploy the CI/CD platform in their TIP Community Lab
- Get first-hand experience with OpenRAN CI/CD automation
- Understand its potential impact on their organization, people, and culture
- Get ready for large-scale OpenRAN deployment

MNOs are welcome to join us in advancing unified, OpenRAN lifecycle management automation beyond CI/CD to also include low-touch operation and RAN optimization.