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OPPORTUNITIES TO APPLY ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING TO THE VERIFICATION AND VALIDATION OF RADIO ACCESS NETWORKS.

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EXECUTIVE SUMMARY

In the verification and validation (V&V) of cellular telecommunications radio access networks (RAN) the role of the software quality assurance (SQA) engineer is to provide the essential RAN product metrics and key performance indicators (KPIs) that objectively and quantifiably define the RAN system-under-test's (SUT) quality with respect to various functional and non-functional test-types (e.g., performance, reliability, conformance, regulatory, security, scalability, and interoperability), and ultimately inform the RAN development project's stakeholders as to whether the RAN product meets the customer's requirements – all in a timely and easily comprehendible format.

The increasingly complex, modularised, open, and virtualised RAN architecture realised in each new industry standardised technology generation [1] [2] is not only creating significant business opportunities for RAN products to be developed by more original equipment manufacturers (OEMs), and thereby reduce the mobile network operator's (MNO) overall capital expenditure (CAPEX) but is also improving each cellular subscriber's quantifiable quality of service (QoS) and perceived quality of experience (QoE) over wider, more connected, and more subscriber dense areas of cellular telecommunications coverage.

However, these revolutions in RAN are creating new challenges for the SQA engineer who designs, implements, executes, and maintains the mostly automated tests assets essential for effective V&V during a RAN product's software development and software test lifecycles (SDLC, STLC).

These challenges are particularly acute in the case of the agile SDLC methodology combined with the steady flow of a tightly managed, automated and time-sensitive pipeline of continuous RAN software integration, deployment, and test (CI / CD / CT) due to its dependency upon the equally continuous management, version control, and availability for deployment and test of the SUT and its associated test assets; and the subsequent and timely analysis of potentially vast quantities of fragmented SUT and test asset logging necessary to ascertain test outcomes and defect root causes for each of the RAN test-types.

Furthermore, as RAN technology generations begin to adopt artificial intelligence (AI), and machine learning (ML) enhanced solutions (essential to meet the demanding radio resource and link management computational requirements of LTE-Advanced, 5G and 6G [3]) and self-management capabilities (essential to provide and maintain flexible, reliable, resilient, and optimised cellular telecommunications networks), the V&V of these enhanced solutions and capabilities will necessitate the SQA engineer to adopt and master a new test paradigm in which the RAN associated test assets themselves must also become enhanced with AI/ML and self-management capabilities to match the complexity of the RAN SUT.

AI/ML and self-management enabled test methods and tools are now commonly adopted V&V practises in many industries for the benefits of automating, scaling, expediting, and maintaining all aspects of their respective SDLCs and STLCs.

Opportunities to adopt AI/ML and self-management enabled test methods and tools must now be identified for RAN V&V so as to reap these same benefits and also make better use of the SQA engineer's finite resources to focus more on complex experience-based and expertise-based test activities, such as exploratory testing, test coverage risk-analysis and negative testing, that can contribute even greater value to increasing the RAN product quality and meeting the customer's requirements.

INTRODUCTION

The aim of this white paper is to justify the requirement and explore the opportunities for which RAN V&V can, or rather must, be enhanced by the AI/ML and self-management enabled test methods and tools necessary to measure the quality of the RAN SUT for an increasingly complex, modularised, open, and virtualised architecture across a broad range of essential functional and non-functional test-types.

PROBLEMS

The cellular telecommunications base station (that comprises the RAN product) is fast becoming a complex system-of-systems in which a once monolithic and bespoke single vendor product (the distributed RAN (D-RAN) model) is now a disaggregated and flexible collection of standardised RAN nodes comprising remote radio units / heads (RRU or RRH), distributed units (DUs) and centralised units (CUs) installed in an assortment of either dedicated performance-optimised hardware or virtualised on commercial off-the-shelf (COTS) servers (the centralised, open, and virtual RAN (C-RAN, ORAN and vRAN) models); interconnected by standardised interface protocols; supporting one or more technology generations; and each potentially developed by a different OEM; to readily integrate and work together as a coherent whole in mixed legacy and leading-edge cellular telecommunications network infrastructures.

This combination of increasing RAN complexity and flexibility is creating new challenges for the SQA engineer, such as those in the following examples:

- Early in the SDLC the deployment of each individual RAN node's suite of software libraries, their configuration (for themselves and for interoperability with other network nodes), and their subsequent maintenance may require significant manual effort until a fully automated deployment and management process is available for all RAN nodes. **Furthermore, any alteration to a RAN node's suite of software libraries or deprecation of a RAN node configurable parameter may 'break' inflexible implementations of automated deployment and management procedures in which RAN node contents and configurable properties are 'hard-coded'.**

- The increasing number of automated test assets necessary to provide sufficient RAN V&V test coverage will likewise require an increase in their version control management and overall maintenance effort, especially because the number of deployed RAN product versions increases exponentially with each supported combination of different RAN node versions. **Furthermore, any change to a RAN node configurable parameter may 'break' inflexible implementations of automated test assets in which RAN node configurable properties are 'hard-coded'.**

- The collation of the logging available from each RAN node, and their cohesive synthesis into a chronological sequence of meaningful information that sufficiently describes the RAN product behaviour will make ascertaining test outcomes and defect root causes considerably more challenging if logging formats per RAN node are OEM specific and test scenarios contain large numbers of cellular subscribers whose numerous interactions with the base station are recorded over significantly long periods of time. **Furthermore, any change to the logging format of a single RAN node may 'break' inflexible implementations of automated test asset outcome decisions and logging analysis tools in which RAN node logging syntax is 'hard-coded'.**

SOLUTIONS

To address these and other potential challenges for SQA, AI/ML and self-management enabled test methods and tools could be trained upon, applied to, and benefit a typical RAN SUT STLC as follows:

IN THE TEST PLANNING AND TEST DESIGN PHASES

- generating test designs (e.g., scenarios, specifications, procedures, and checklists) from a given test basis.
- analysing test assets to identify duplicate, superfluous, or deprecated test coverage for removal (i.e., 'self-optimising').
- selecting from the available test assets to suit the chosen test objective. For example, to choose the appropriate test assets for either a specific test-type, a specific test phase, a specific feature or interface, to examine a potential risk, or to assess the regression impact caused by an erroneous implementation (i.e., 'self-adapting').

IN THE TEST IMPLEMENTATION, DEPLOYMENT AND TEST EXECUTION PHASES

- enhancing the test asset integrated development environment (IDE) with test code reviews and improvement recommendations; and even implementing test code for a given test basis.
- maintaining and repairing (i.e., 'self-healing') the CI / CD / CT pipeline to ensure the continuous availability of the SUT and the associated test assets; redeploying upon detecting an erroneous SUT software library (e.g., either corrupted, deprecated or omitted); and selecting an alternative and equivalent test facility hosting the SUT and the associated test assets upon detecting a CD or CT blockage (i.e., 'self-organising').
- optimally configuring the SUT according to the test objective (i.e., 'self-configuring').
- adapting the test execution flow in real-time to manage unexpected or unforeseen variations in the SUT behaviour (i.e., 'self-adapting').
- monitoring the SUT and test asset availability 'health' in real-time and restoring both to a known state in the event of terminal SUT or test asset behaviour, such as a fatal exception.
- analysing the available test assets, their execution, test outcome histories and any logged data and generating additional test scenarios, specifications, procedures, checklists and code or scaling or adapting existing test assets according to test coverage gaps identified with the test basis and potential risks identified from the historical test executions, outcomes and data (i.e., 'self-learning').

IN THE TEST COMPLETION AND TEST MAINTENANCE PHASES

- determining the test outcome when it contains multiple and complex test assertions.
- collating and analysing each RAN node logging and the associated test asset logging to ascertain test outcomes and defect root causes for each of the RAN test-types.
- generating test asset data (e.g., metrics, defect reports, execution reports, coverage maps and gaps, analytics, and risks) in a comprehendible and succinct format to inform the project's stakeholders as to whether the product meets the customer's requirements.

CONCLUSION

Applying AI/ML and self-management enabled test methods and tools to a typical RAN SUT STLC could provide the following benefits:

FOR THE SQA ENGINEER:

To contribute significantly to managing, automating, improving, and maintaining many aspects of the RAN SUT CI / CD / CT pipeline and STLC, and thereby release the SQA engineer to make more efficient use of their finite resources and focus more on complex experience-based and expertise-based test activities, such as exploratory testing, risk-analysis and negative testing, that will add further significant value to the measurement of the RAN product quality.

FOR THE BUSINESS:

To expedite the creation and sale of increasingly complex and flexible RAN products with the confidence that their behaviour with respect to a wide range of functional and non-functional criteria (including performance, reliability, conformance, regulatory, security, scalability, and interoperability) and derived from comprehensive test asset data, will be predictable, to the expected standards, and will meet the customer's requirements – all without incurring significant additional SDLC V&V costs.

REFERENCES

[1] The 3rd Generation Partnership Project (3GPP): https://www.3gpp.org/

[2] The O-RAN Alliance: https://www.o-ran.org/

[3] The AI-RAN Alliance: https://ai-ran.org/