Test Tool Evolution From 4G to 5G

Rebaca

ENSURING QUALITY ON SCHEDULE

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Introduction

Mobile networks have undergone an extremely fast paced upgrade from the proof of concept networks that sprung up in the late 90s to the fast-paced, large data delivery networks of the new millennium. The evolution from 2G to 4G has happened in not more than 10 odd years. We're now getting ready for the next evolution from 4G to 5G and this is set to happen in the next few years.

There are a lot of differences in the latest evolution to its predecessors. The key aspects that are aiding the evolution can be classified into the following.

- **Virtualization:** Network Functions Virtualization is probably the biggest catalyst for the evolution to the 5G era.A lot depends on the ability of the 5G network to adopt this paradigm. Virtualization has a very important role to play in both the access and core network.
- **New Radio:** In the true 5G world New Radio technologies will complement the virtualization paradigm in order to deliver on the promise of higher bandwidth in the last mile.
- **Mobile Edge Computing:** The ability to make decisions close to the edge of the network is a key driver for low latency use cases that would otherwise be impossible to achieve.
- **Network Slices:** The ability to serve subscribers based on the broadly defined categories of eMBB (Enhanced Mobile Broadband), URLLC (Ultra Reliable Low Latency Communications) and mMTC (Massive Machine Type Communication) by slicing the network accordingly.

When all these key aspects are put together, a true 5G network is created. But this network has to co-exist with its legacy 3G, 4G (and in some cases 2G) components in order to continue providing seamless services to the subscriber base. This evolution needs to be supported by a set of tools that need to be equally lean and agile in terms of investment and ease of use. The automation capability of the tools is imperative in order to support the service capability of the network. More specifically, the Test Tool to be used for Automated Integration, Troubleshooting or Proof of Concept needs to adequately and economically support these needs

The Test Tool and Virtualization

Virtualization brings in a set of requirements that need to be adopted in order to make themigration from legacy software components to their virtualizable clones.
Of utmost importance is the need to remove dependencies from the kernel while still catering to performance requirements in a cost-effective manner. The ques-

tion is about how the test tool needs to evolve in order to be part of the cloud. Let us take the example of the ETSI MANO architecture to visualize a Telecom Cloud:

Telecom Centric Openstack Architecture and Applications

- DDoS Protection
- Deep Packet Inspection
- Virtual EPC (Evolved Packet Core)
- Virtual IMS (IP Multimedia Subsystem)
- Virtual Firewalls
- Virtual Routing & Switching
- Application Acceleration
- Application Delivery Controllers/ Load Balancers
- Virtual Radio Access Network
- Virtual CPE (Customer Premises Equipment)

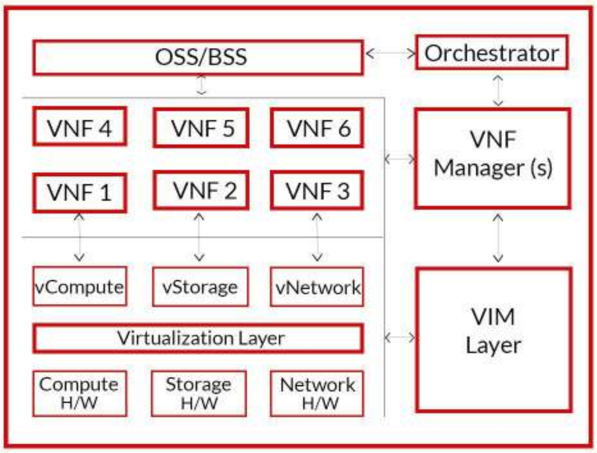

Fig 1: ETSI MANO Architecture

In order to support cloud native requirements, the Test Tool like other applications in the Telco Cloud, needs to support the following requirements:

- **Auto Provisioning:** The Test Tool needs to have the capability of provisioning itself usually with the help of a Cloud Orchestrator and VNF Manager. This requires that the Test Tool needs to have a package that is deployable and configurable without human intervention.
- **Auto Scaling:** The Test Tool needs to be able to scale horizontally according to performance needs identified during execution of one or more of its instances. The scaling capability requires a closed loop feedback with the cloud Orchestratorso that it is able to direct the VNF manager to scale up or scale down.
- **Auto Redundancy:** The ability to shift workloads to separate instances in case of failure is another basic cloud native requirement and requires communication between the various instances of the Test Tool.
- **Micro-Service Capability:** The capability of the Test Tool to be deployed in a cloud container environment is of utmost importance from the point of view of optimal use of cloud resources.

If one is able to drill down to the implementation of each one of these activities in the cloud we could describe each of them. Below is a case study depicting the capability of a Test Tool to integrate with an existing cloud native environment and provide for auto provisioning.An important requirement for Auto-Provisioning is that the time taken for installation and provisioning the system should be at a minimum. The ability to Auto-Provision itself accurately within seconds is the main characteristic of a highly performant cloud native VNF solution.

Once provisioned, the VNF provides interfaces for Auto-Scaling in a cloud environment. When it comes to a Test Tool, the ability to provide feedback to the Orchestrator in order to scale horizontally, becomes a crucial requirement for the execution of automated performance benchmark test cases. The Orchestrator provides APIs for the OSS to use and inform the VNFManager about the need to scale up or down instances among other functions. Below is a diagram depicting the decisions made by the Orchestrator and the role of the Test Tool in making these decisions

Test Tool Providing Feedback in MANO Architectecture for Closed Loop Auto Scaling and Healing

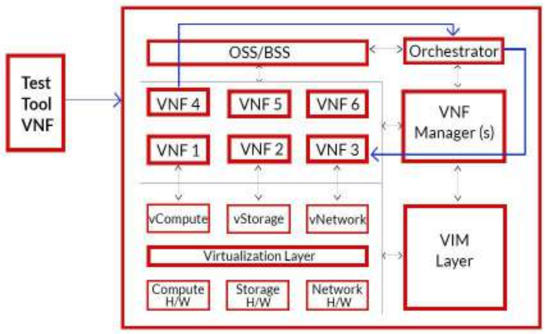

Fig 2: Closed Loop Feedback

Auto-Redundancy is an important function for applications that are serving live customers, like that of a Telecom Network. When it comes to the Test Tool to support this capability, it has to detect a faulty Test Tool instance and give the Orchestrator the capability to decommission the instance. Toprovide this function, the Test Tool needs to be capable of interacting with the Orchestrator in order to send vital statistics that are deemed to be anomalous. The Orchestrator then reserves the right to inform the VNF Manager to commission a new instance if required and/or decommission the unhealthy instance. As prescribed by the ETSI MANO architecture, below is a table that depicts the different responsibilities of the VNF Management layer:

Operation	Description
VNF Instance Management	Validation of VNF Instance based on state Analyisis
Virtualized Resource Management	Scaling VNF up or down in containerized environment
VNF Fault and Recovery	Healing and Migration to support SLA
VNF Performance Management	Validation of Performance Management

Fig 3: NFV Management Layer

The last most important attribute of the Cloud Native Architecture is the ability of the VNF application to be capable of micro-services that can reside in a Container in the Telco Cloud. The Containerization of the cloud components exacts special restrictions in the Architecture of the application. A typical performance improvement in a VNF application is if one can move a particular code function to Kernel Space so as to reduce the latency in buffer copies between User and Kernel space. The repercussions of this approach in today's world of Containerization can be disastrous. The portability of the resultant codebase is greatly reduced due to this attempt at increasing the performance of the application. From a Test Tool implementation point of view, there are many that have moved important Data Traffic functions to the Kernel Space. The result has been a re-engineering effort with new user space acceleration technologies such as DPDK, OVS, Virtio etc

Test Tool Performance Requirements 4G to 5G

The performance requirements for 5G are slightly different from 4G when seen from a core network perspective. The requirement to support eMBB, uRLLC, and mMTC is a new set of requirements in addition to the traditional requirements for 4G such as attach/detach and mobility use cases. The new requirements need to factor in a new set of KPI and continue to provide support for the older set of KPI. Each of the KPI below can be measured against a network slice as per the guidelines specified by 3GPP. Below is a table depicting the different performance KPIs that are relevant in order to guarantee the advertised 5G user experience and their applicability to the different network slices.

KPI	eMBB	mMTC	uRLLC	Target 5G Value
Peak Data Rate	Y			DL: 20 Gbps UL: 10 Gbps
Peak Spectral Efficiency	Y			DU: 30 bps/Hz UL: 15 bps/ Hz
User Experienced Data Rate	Y			DL: 100 Mbps UL: 50 Mbps
Area Traffic Capacity	Y			10 Mbps/m^2
User Plane Latency	Y		Y	uRLLC: 1ms eMBB :4ms
Control Plane Latency	Y		Y	20 ms
Connection Density		Y		1,000,000 devices/km^2
Energy Efficiency	Y	Y	Y	Qualitative Watt per second per node
Reliability			Y	1x10 ^-5 Sucess Probability for Tx 32B in 1ms

Mobility	Y			Qualitative Handover success ratio
Mobility Interruption Time	Y		Y	0ms
Bandwidth	Y	Y	Y	Atleast 100 Mhz upto 1 Ghz for higher frequency bands.

Fig 4: 5G Quality of Experinece

Below is an in-depth view of the various KPI that one can measure using the ABotTest Tool. Each of the below parameters map to the higher level KPIs that are mentioned in Figure 4

ABot Performance Parameters	ABot Test Tool and VNF Life Cycle Parameters	ABot Performance Features
Maximum Number of Control Plane Sessions	Teardown	Control Plane Sessions
Session Performance (TPS)	Topology Creation	Session Performance (TPS)
Message Processing Time	Control Plane State Sync	Message Processing Time
Data Plane Throughput DL/UL	VNF Onboarding/ Instantiation	Data Plane Throughput DL/UL
	Time	
		Test Case Teardown
		VNF Onboarding and Instantiation
		Topology Creation

Fig 5: ABot Test KPIs

ABot Metrices (Graphical Feedback)
DUT Power Consumption
DUT CPU Utilization
DUT Memory Utilization
Session Setup and Teardown Rates
Session Failures
Packet Loss DL/UL
Packets per Second per Bearer
Latency Distribution Min/Max/Avg
PDN Connections
Bearer Release Time
Bearer Creation Failure Ratio
Service Request Failure Ratio
EPS Attach Success Rate
Tracking Area Update Success Rate
Dedicated Bearer Creation Success Rate
Control Plane Traffic Throughput

Fig 6: ABot Test Metrices

Each of the above KPI can be measured per Network Slice as per the requirements of the 5G paradigm.

Test Tool Architecture and Artificial Intelligence

The ability of the Test Tool to collect all this data and analyze it to generate meaningful analytics plays an important role. The Test Tool has to produce logs and capture KPIs relevant to a Use Case that depict accurate application pathsand its performance that helps to detect anomalous behavior of the system. Thisis valuable for building a system that has strict functional and performance benchmark requirements.Due to the vast variance of the 5G Use Cases, machine learning has to be applied. Contemporary rule based approach to analyze such a large data set is impossible.If we take the example of the ETSI MANO architecture, the machine learning entity could be located close to the orchestration entity of the network or could be part of the orchestration entity itself. By collating information ranging from different functional components of the Test Tool, such as execution logs, KPI measurement characteristics, there lies the possibility of training an expert system in order for it to make decisions in a real production environment. The AI that is built using this platform must follow the guidelines as detailed below:

1. **Human agency and oversight:** AI systems should enable equitable societies by supporting human agency and fundamental rights, and not decrease, limit or misguide human autonomy.

2. **Robustness and safety:** Trustworthy AI requires algorithms to be secure, reliable and robust enough to deal with errors or inconsistencies during all life cycle phases of AI systems.

3. **Privacy and data governance:** Citizens should have full control over their own data, while data concerning them will not be used to harm or discriminate against them.

4. **Transparency:** The traceability of AI systems should be ensured.

5. **Diversity, non-discrimination and fairness:** AI systems should consider the whole range of human abilities, skills and requirements, and ensure accessibility.

6. **Societal and environmental well-being:** AI systems should be used to enhance positive social change and enhance sustainability and ecological responsibility.

7. **Accountability:** Mechanisms should be put in place to ensure responsibility and accountability for AI systems and their outcomes.

Keeping the above in mind, ABot the Test Tool from Rebaca Technologies has developed a novel method by which the Test Tool remembers the different test cases that are executed on the Test Bench over a period of time. It then applies Machine Learning algorithms on the mined information to visualise the network from a Functional as well as a System Test perspective. Potential loop holes can be analyzed with the help of this capability.

Conclusion

To summarize - the different advancements made while we make the move from 4G to 5G, enhancements in the Core and Radio, coupled with virtualization techniques are changing the architecture of the Telecom Network. Protocols are being enhanced to carry larger payloads with lesser amount of signalling information. There are considerable enhancements in Radio capabilityto delivered Gbps level user plane traffic. All these changes demand a Test Tool to evolve to the new requirements and network paradigm.

With the advancements in Machine Learning coupled with the protocol information mining capability of next generation cloud native Test Tools like ABot, the promise of a more capable Telecom Network looms in the horizon.