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Core Network and Interoperability Testing (INT); Methodologies for E2E Testing & Validation of Vertical Applications over 5G & Beyond networks

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Core Network and Interoperability Testing (INT).

Modal verbs terminology

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Executive summary

The purpose of the present document is to provide recommendations on methodologies for end-to-end testing and validation of vertical applications over 5G and beyond networks. The present document includes recommendations covering the most aspects of a B5G-app validation framework by providing recommendation on B5G capabilities and enablers, on the testing and validation environment, on involved processes, on the relevant KPI mechanisms and, finally, on the design of vertical applications under test. Such recommendations can be equally applicable to a wide range of industry verticals, application cases and beyond 5G scenarios.

The main value of such end-to-end testing and validation activity is the fact that the vertical application provider can experiment with the 5G and beyond network in order to make business decisions previously to going into commercialization. In this context it is assumed that the subject under test is the application and that the 5G and beyond network setup (as well as the configurations considered in such experimentation) have already been tested and qualified both from functionality and performance perspective.

To that end, the present document provides a survey and review of the existing methodologies for testing and validating vertical applications, leveraging on the experiences gain through several innovation projects. This exercise permits the identification of existing gaps in such methodologies, proposing solutions to cover them. The present document describes Processes, Mechanisms and Strategies involved in the testing and validation of innovative vertical applications enabled by 5G and Beyond networks. The work does not consider any assumption on the specific business or nature of the vertical domain, with the intention to identify common methodologies applicable to as wide a range of vertical domains as possible.

Introduction

Most vertical industries are transforming their processes and innovating their business model, and for that purpose they are actively exploring and adopting a wide range of new technologies. In particular, the adoption of 5G for overcoming limitations and challenges of connectivity and flexibility of other technologies is regarded instrumental for their success. The new 5G landscape of architectures, evolving features and superior performance levels enables possibilities for vertical industries in its digital transformation, and therefore 5G has become a subject of priority focus all along their innovation life-cycle for new applications and solutions, from business opportunity identification to new application's design, solution integration and technical and business validation.

Actually, from early stages of 5G standardization to its regulation, and first commercial deployments, a number of vertical industries have engaged not only on proactive surveillance of 5G technology but also in tight collaborations with Communication Service Providers (CSPs), Telecommunications Equipment Vendors, Academic and Research Institutions and start-ups. That has been a major factor in the steering and shaping of new innovation ecosystems around 5G all around the world, being a remarkable example the one boosted in Europe by the 5G Infrastructure Public Private Partnership (5G PPP) which is a joint initiative between the European Commission and European ICT industry. Virtually all initiatives and projects have been promoted by the 5G PPP. On the one hand, 5G PPP has analysed transformation opportunities of major players of vertical industry sectors, with special attention to end-to-end application requirements and, in turn, their expectations on connectivity and flexibility of the underlying 5G network. On the other hand, 5G PPP has studied and validated the feasibility of 5G architectures and solutions for fulfilling those expectations.

This type of prior-to-commercialization critical validation activities, and that of their implicit challenges motivated, in 2018, the substantiation of large European infrastructures (namely 5G EVE, 5G-VINNI and 5GENESIS projects) for effectively and efficiently host and run the increasing number of 5G-ready application validation activities in the 5G PPP ecosystem. Furthermore, in 2019, the experience and learnings in validation activities translated into the creation of a special 5G PPP workgroup devoted to the applied science of Testing, Measurement and Validation (TMV). The workgroup has been collecting and analysing rich and varied information, from a broad set of projects, on their challenges, approaches, methodologies and tools producing guidelines and recommendations for piloting, adoption, design and execution of validation activities.

Such experience can serve as a good basis for sharing and applying beyond the 5G PPP ecosystem. And given the pace of evolution of 5G towards B5G networks, combined with the intense innovation in vertical applications, a further and careful look into the upcoming challenges for validating applications over B5G networks, seems to be well justified too. So, the ambition of the present document is to leverage the first-hand experience and learnings in 5G PPP, and to assess and provide a basic set of recommendations for crafting effective capabilities, processes and mechanisms for validating vertical applications over 5G and beyond networks.

Despite the reference work being based on initiatives triggered at European level, the outcomes of the present document intend to be globally applicable, without limitation to specific geographic conditions or circumstances. The focus of analysis also sees to that the expectations from the relevant stakeholders involved in the innovation and validation cycle of innovative vertical applications relying on 5G and beyond networks are specified, analysed and supported by the proposed recommendations.

1 Scope

The purpose of the present document is to provide recommendations on methodologies for end-to-end testing and validation of vertical applications over 5G and beyond networks. Such recommendations can be equally applicable to a wide range of industry verticals, application cases and beyond 5G scenarios.

By applying such standard end to end testing and validation methodologies, the vertical application provider would be able to experiment with the 5G and beyond network in a systematic and consistent manner and make informed business decisions upon about further development and commercialization of the features of its application under that rely on 5G technologies and beyond. In this context it is assumed that the subject under test is the application and that the 5G and beyond network set up and configurations considered in such experimentation have already been tested and qualified both from functionality and performance perspective.

Therefore, general (application-independent) testing and characterization of 5G network setups is not in the scope of analysis of the present document. Actually, special emphasis on making clear distinction between network testing and application validation concerns and distinct challenges is secured along the analysis since the processes, mechanisms, tools and strategies typically used for network testing can prove inadequate or misleading for vertical application validation purposes.

The present document provides a survey and review of the existing methodologies for testing and validating vertical applications, to identify existing gaps in such methodologies and propose solutions to cover them. The proposed methodology describes Capabilities, Processes and Mechanisms involved in the testing and validation of innovative vertical applications enabled by 5G and Beyond networks.

No assumptions are made on the specific business or nature of the vertical domain, with the intention to identify common methodologies applicable to as wide a range of vertical domains as possible. The analysis of specific methodologies for applicability limited to specific vertical domains is beyond the scope of the present document.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

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[i.16] Supplement 71 to ITU-T Q-series of Recommendations: "Testing methodologies of Internet related performance measurements including e2e bit rate within the fixed and mobile operator's networks".

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3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

5G PPP Facility: each one of the testing sites which form an ICT-17 5G validation platform. Thus, each platform has several facilities in different geographical locations

5G Platform: ICT-17 platforms funded by EU Commission: 5GEVE, 5GVINNI and 5Genesis

5GS observation points: observation points located on interfaces within the 5G System, including the 5G Radio, Edge, Transport and 5G Packet Core

APP E2E observation points: observation points located on the hardware and software application or services that the vertical controls or owns

B5G Network: beyond 5G Networks are networks built with technology that is specified by future releases of 3GPP after release 17, and are planned to be introduced starting 2025

Communication Service Provider (CSP): company that offers communication services, typically, Network Operators offering Public Mobile services communications

experiment: running of a specific process that includes End user devices, 5G Network components and Vertical application to discover KPI values that are not know in advance

experiment blueprint: set of composed actions including end user devices, network components, vertical application, test cases, measurements, and KPIs that can be introduced in a 5G Facility to characterize the behaviour of the system under specific configuration

Management and Orchestration (MANO): framework developed by a working group of the same name within the European Telecommunications Standards Institute (ETSI) Industry Specification Group for NFV (ETSI ISG NFV)

NOTE: It is the ETSI-defined framework for the management and orchestration of all resources in a virtualized data centre including computer, networking, storage, and Virtual Machine (VM) and Container resources.

(Network) Monitoring: monitoring is a computer network's systematic effort to detect slow or failing network components, such as overloaded or crashed/frozen servers, failing routers, failed switches or other problematic devices

NOTE: In the event of a network failure or similar outage, the network monitoring system alerts the network administrator. Network monitoring is a subset of network management.

performance: in the context of Networking, analysis and review of collective network statistics, to define the quality of services offered by the system considering end to end interactions between end user devices and vertical applications

subject under test: artefact that is being evaluated for testing purposes

NOTE: Typically, in the context of 5G Platforms, the subject under test matches with Vertical Applications.

test: process of validating either a functional or non-functional behavior of a system (e.g. device, software component, etc.)

NOTE: In the context of the present document, a Test consist in running a specific process that includes End user devices, 5G Network components and Vertical Application to obtain KPI values and verify that obtained values fit in predefined thresholds.

T&M methodologies: methods, rules and processes required to test and measure results of these tests

Test, Measurement, and KPIs Validation (TMV) Working Group: one of the working groups in 5G PPP whose objective is to bring together the projects within the 5G PPP that have common interest in the development of Test and Measurement methods, test cases, procedures and KPI validation

Test as a Service (TaaS): automation and interfacing layer that allows to connect all the Test & Measurement tools needed for validating and verifying a system, from the individual components up to the E2E service

NOTE: It speeds up repeating tests and validating proper behaviour of a system after introducing changes.

testing: process of evaluating a system or its component(s) with the intent to find whether it satisfies the specified requirements

validation cycle: collaborative process between Vertical industries and Communication Service Providers sharing objectives, timelines, outcomes and learnings to guarantee proper integration between Vertical applications and Communications networks

vertical application: software program that performs specific data processing related to specific domain. Examples of vertical are Factory of the Future (FoF), Unmanned Aerial Systems (UAS), Vehicle to Infrastructure Communications (V2X) and Edge Applications (EDGEAPP)

vertical KPI model: relationship between service KPIs as defined by the vertical and network KPIs enforced by the provider

NOTE: It refers to a model which represents the influence of network service KPIs on the Vertical-level KPIs. It can be presented in a tabular structure (mapping) or in a more complex form.

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

5G PPP	5G Infrastructure Public Private Partnership
5G-RAN	5G-Radio Access Network
5GS	5G System
AFI	Autonomic Management and Control Intelligence for Self-Managed Fixed & Mobile Integrated Networks
AI	Artificial Intelligence
AIM	Automated Intelligent Management
AMC	Autonomic Management and Control
AMF	Access and Mobility Management Function
AN	Access Network
API	Application Programming Interface
APP	Application
B5G	Beyond 5G
BBF	Broadband Forum
CC	Component Carriers
CI/CD	Continuous Integration/Continuous Deployment

CP	Cyclic Prefix
CPU	Central Processing Unit
CSC	Communication Service Customer
CSP	Communication Service Provider
CSV	Comma Separated Value
DL	Downlink
DMRS	Demodulation Reference Signal
DTR	Draft Technical Report
E2E	End-to-End
EEM	Experiment Execution Manager
ELCM	Experiment LifeCycle Manager
eMBB	enhanced Mobile Broadband
EU	European Union
FDD	Frequency Division Duplex
F-MBTS	Federated Model-Based-Translation Service
GANA	Generic Autonomic Networking Architecture
GPU	Graphics Processing Unit
GSMA	Groupe Speciale Mobile Association
GST	Generic Slice Template
GUI	Graphical User Interface
HTML	Hypertext Markup Language
IBN	Intent-based Networking
ICT	Information and Communication Technology
ID	Identifier
IG	Introductory Guide
IMT	International Mobile Telecommunications
IoT	Internet of Things
IP	Internet Protocol
IPTV	Internet Protocol television
IT	Information Technology
JSON	JavaScript Object Notation
KP	Key Performance
KPI	Key Performance Indicator
LPWA	Low Power Wide Area
MANO	Management and Orchestration
MBTS	Model-Based-Translation Service
MEC	Multi-access Edge Computing
MIMO	Multiple-input multiple-output
MIoT	Massive Internet of Things
ML	Machine Learning
mMTC	massive Machine Type Communications
MNO	Mobile Network Operator
MU	Multi-User
NEF	Network Exposure Function
NetOp	Network Operation
NFV	Network Function Virtualization
NFVI	NFV Infrasrtucture
NGI	Next Generation Internet
NGMN	Next Generation Mobile Networks
NGRAN	Next Geenration Radio Access Network
NG-RAN	Next Geenration-Radio Access Network
NS	Network Slice
NSA	Non-standalone
NSD	Network Service Descriptor
NSI	Network Slice Instance
NSMF	Network Slice Management Function
NSSF	Network Slice Selection Function
NST	Network Slice Template
OAI	Open Air Interface
OAM	Operation And Maintenance
OFDM	Orthogonal Frequency Division Multiplexing
OLA	Operational Level Agreement

ONAP	Open Network Automation Platform
ONIX	Overlay Network system of information servers for Information eXchange
OPEX	Operational Expenditure
OPNFV	Open Platform for Network Function. Virtualization
OSM	Open Source MANO
PDF	Portable Document Format
PDSCH	Physical Downlink Shared Channel
PHP	Hypertext Preprocessor
PLMN	Public Land Mobile Network
PNG	Portable Network Graphics
PoC	Proof of Concept
QAM	Quadrature Amplitude Modulation
QoE	Quality of Experience
QoS	Quality of Service
QPSK	Quadrature Phase-Shift Keying
R&D	Research and Development
RAN	Radio Access Network
RAV	Real-Time Analytics and Validation
RCA	Root Cause Analysis
RCS	Rich Communication Services
REST	REpresentational State Transfer
RRC	Radio Resource Control
RRM	Radio Resource Management
RT	Real Time
RTC	Run-Time Configuration
RTT	Round Trip Time
SA	Standalone
SBA	Service-Based Architecture
SDK	Software Development Kit
SDN	Software Defined Networks
SDO	Standardization Development Organization
SLA	Service Level Agreement
SLO	Service Level Objectives
SLS	Service Level Specification
SME	Small and Medium Enterprise
SMF	Session Management Function
SQL	Structured Query Language
STQ	Speech and multimedia Transmission Quality
SU	Single User
SUT	Subject Under Test
T&M	Test and Measurement
TaaS	Test as a Service
TAP	Testing Automation Platform
TDD	Time Division Duplex
TIM	Telecom Italia
TMV	Testing, Measurement and Validation
TV	Television
UE	User Equipment
UI	User Interface
UL	Uplink
UPF	User Plane Function
URL	Uniform Resource Locator
URLLC	Ultra-Reliable Low Latency Communications
UTRAN	UMTS Terrestrial Radio Access Network
V2X	Vehicle to Infrastructure Communications
VF	Virtual Function
VIM	Virtual Infrastructure Manager
VM	Virtual Machine
VNF	Virtual Network Functions
VNFD	VNF Descriptor
VoLTE	Voice over LTE
VPN	Virtual Private Network