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Abstract

The FIRE project TRIANGLE is building a framework to help app developers and device manufacturers in the evolving 5G sector to test and benchmark new mobile applications, devices, and services utilizing existing and extended FIRE testbeds. Connected apps will be a dominant software component in the 5G telco domain. Ensuring a correct and efficient behaviour of the applications and devices becomes a critical factor for the mobile communications market to meet the expectations of final users. While radio related certification of mobile devices has a strong standards based ecosystem there is still a lack of consensus on the benchmarking or testing methods at the apps level. The project will identify reference deployment scenarios, will define new KPIs and QoE metrics, will develop new testing methodologies and tools, and will design a complete evaluation scheme for apps and devices. At the same time the methodology to be used in the design and development of the TRIANGLE test framework will ensure that the testbed end user is not overwhelmed by

the complexity of the overall testbed by providing an intuitive high level configuration layer for the experiments and a flexible framework architecture to incorporate new 5G networking topologies as they become available.

Keywords: LTE, 5G, Mobile Applications, Mobile Devices, Benchmarking.

18.1 Introduction

The focus of TRIANGLE project [1] is the development of a test framework that facilitates the evaluation of the QoE of new mobile applications and devices designed to operate in the future 5G mobile broadband networks. The framework will include testbeds which will comprise test equipment and test software, formal test specifications and test methodology and will exploit existing FIRE facilities adding new capabilities when necessary.

The project will identify reference deployment scenarios, will define new KPIs (Key Performance Indicators) and QoE metrics, will develop new testing methodologies and tools, and will design a complete evaluation scheme. The project will focus on the development of a framework to ensure users QoE in the new challenging situations, especially those due to heterogeneous networks and considering the important role software will have in the new 5G ecosystem.

The framework as value added will also provide the means to allow certification and quality mark for the applications compliant to the requirements and test specifications developed within the project. To ensure sustainability after the project the framework will be developed according to formal languages and methods and handover to key alliances. The formalization of the test scheme so that it can be used for certification will also be extensible to other FIRE test solutions. The outcome of the project will allow vendor differentiation, especially for start-ups and SMEs, in the current globalized and competitive markets and further visibility of FIRE facilities.

Moreover, it is expected that the proliferation of personal devices such as smartphones, tables, wearables and sensors will play a key role in health, safety, social and professional applications, areas in which testing is essential to guarantee performance and security issues under critical conditions such as mobility. In this respect TRIANGLE project will also focus on the testing of mobile devices.

The framework, methods and tools developed during the project will focus on providing the mechanisms to incorporate new wireless technologies and topologies envisaged in 5G and contribute to the new ecosystem.

The objectives of the project can be summarized as follows:

- Objective 1. Provision of a testing framework setting the pathway to test new applications and devices for the purposes of pre-normative benchmarking and ease the access of start-ups to a qualified testing environment.
- Objective 2. Development of networking infrastructures and measurement techniques and tools to pave the way for 5G scenarios.
- Objective 3. Foster collaboration between the FIRE community, certification bodies, testing houses, the research community and SMEs to maintain a strong competitive position of FIRE platforms in the industry and to improve the opportunities offered by FIRE to European technology organizations to build better devices and applications.

The project will be executed in a time frame where 4G mobile technologies mature and 5G is still in the requirements definition phase or early trials. Although there is an initial timeline and plan for IMT-2020 and technical discussion related to IMT2020 submission in RAN WGs will start from March 2016, a firm detailed architectural plan for 5G is not yet available. However 5G aspirations are well defined and the European industry is expected to significantly invest as we move towards 2020. Many new products and applications will be developed in the 4G world targeting the evolution towards 5G. For the success of a product it is very important to verify that it meets the standards and it functions close to the expectations of the final users before they become openly released both in the existing 4G scenario and in the targeted 5G uses cases. Being in a pre-normative, pre-standards phase for 5G, the approach within TRIANGLE is to work on the end-to-end testing setting the pathway towards the testing of fifth generation applications and their certification. Benchmarking against TRIANGLE test cases (TTC) will be provided to third parties (e.g., SMEs, app developers, devices vendors and network operators). An informal triangle mark will be provided based on the KPIs measured. Elements needed for a proper standalone certification scheme will be identified as well as the possible integration into existing mobile certification schemes such as GCF.

18.2 Motivation

The primary motivation of the TRIANGLE project is to promote the testing and benchmarking of mobile applications and devices in Europe as the industry moves towards 5G. This project will provide a pathway towards the

verification of application level perceived performance in order to support qualified mobile developments in Europe, using FIRE testbeds as testing framework.

As shown in Figure 18.1 three distinct areas for testing and benchmarking are considered in the project: (i) applications and (ii) devices and (iii) mobile network operators. Applications are often provided by Small and Medium Enterprises (SMEs). Testing the performance of mobile application in the 5G uses cases defined by entities such as the Next Generation Mobile Network Alliance (NGMN) becomes critical due to the highly demanding requirements of these, which range from broadband access to low latency or higher user mobility. SMEs often find it difficult to gain access to testing processes under realistic network conditions; moreover it can be much harder for them to understand the requirements of standard bodies or even to know which testing scheme would be more appropriate for their products. In addition, the costs of testing (requiring specialised infrastructure) are high for small companies and start-ups, especially if the market share is small.

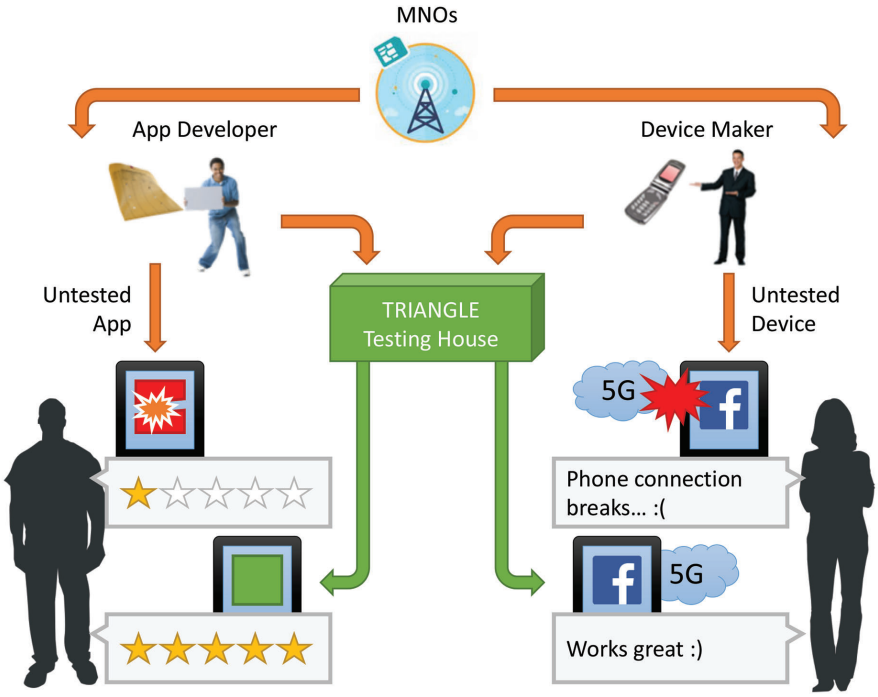

Figure 18.1 Problem statement.

The testing framework envisaged in this project can help to overcome these barriers. TRIANGLE project will provide not only a testing framework but also testing assessment through the provision of reference scenarios and Key Performance Indicators (KPIs) for a set of use cases covering areas defined for 5G by NGMN [2] and other standardization bodies [3–5].

18.3 Approach: Simplicity Operations for Testbed End Users

During the last years the estimated mobile traffic growth has been used as motivation for many wireless testbeds. Indeed this estimation is bigger year after year but has not reflected on the number of users of FIRE wireless testbeds. The main reason for this situation is the design of the FIRE testbeds themselves, which are network centric. Current testbeds are too focused on network configuration and have very complex and sophisticated configuration mechanisms, while the experimenters are not familiarized with the complex setup of the network resources and most of the time end up just using the default configuration. From experience obtained the federation of PerformNetworks testbed, it can said that most efforts were centered on providing access to all the low level parameters which have impact on the transport performance of the user traffic, however final users of the testbed do not know how to set up these parameters to generate a consistent experimentation scenarios, resulting in them.

The main idea that underpins the methodology to be used during the design and development of the TRIANGLE test framework is to ensure that the end user is not overwhelmed by the complexity of the overall testing testbed as a result of being exposed to its full set of details. In order to fully understand the testbed details the researcher will need multi-disciplinary knowledge (protocols, radio propagation, software, etc.). This is achieved by ensuring proper abstraction of underlying networking technologies by offering (see Figure 18.2): a) a high level configuration layer (personality) which calls on detailed scenarios definition, b) a flexible framework architecture to incorporate new 5G networking topologies when they become available The project will design a set of scenarios in the higher layer, scenarios that can be reproduced and whose final output is a Behaviour Indicator or Quality Mark, which defines how good the product (application or device) behaves when used in a realistic network, including energy consumption and model-based runtime checking of the apps and devices. Those scenarios can be modified by means of a scenario editor, which provides an API and a GUI to setup very

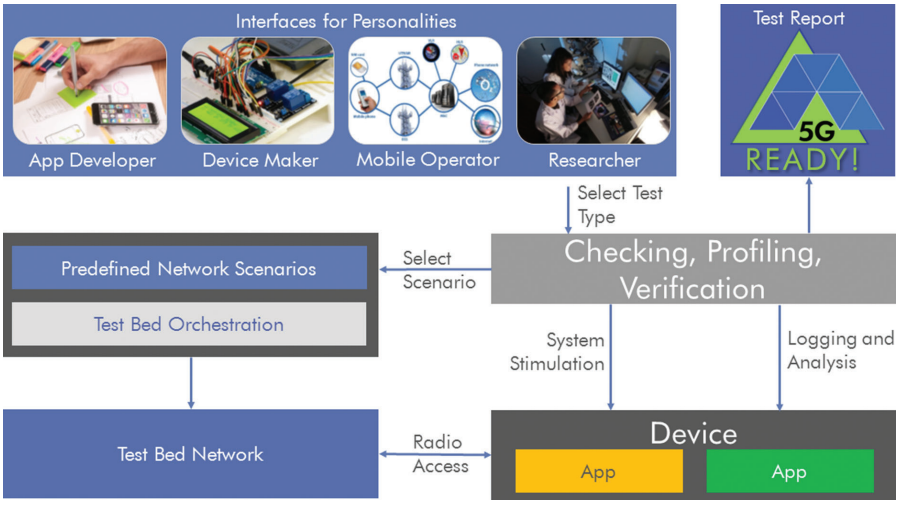

Figure 18.2 Triangle high level testing framework.

complex scenarios. This scenario editor can load pre-defined scenarios and can generate scenarios based on 5G use cases covering KPIs of interest for each one of them.

The project will provide a framework with different layers of abstraction using when possible commercial configuration interfaces as well as experi mentation standards, including those provided by Fed4FIRE [6]. Where needed, advanced users can be exposed to deeper configuration details and flexibility.

18.4 Technical Test Framework Approach and Methodology

18.4.1 TRIANGLE Components

TRIANGLE project will develop a testing framework based on existing testing know-how, and existing platforms: (i) the UXM Wireless Test Set from Keysight (ii) the UMA PerformNetworks testbed and tools, (iii) the AT4 Performance tool, (iv) the UCL app testbed, (v) the test automation tool from Quamotion and (vi) the RedZinc's virtual path slice solution VELOX. These existing platforms will be extended with new 5G requirements and functionalities.

An essential component in the testbed is an instrument capable of emulating multiple cellular networks in a controlled manner. To that end, TRIANGLE envisions the usage of the UXM Wireless Test Platform device

by Keysight Technologies, which supports multiple radio access technologies (multi-RAT), including GSM/GPRS, UMTS and LTE-Advanced networks (i.e., 2G, 3G and 4G). The UXM features include intra-RAT and inter-RAT handovers, protocol debugging, IP end-to-end delay and throughput measurements, and performing RF conformance tests. Finally, it should be noted that the UXM also features an advanced fading engine with the main channels models defined by 3GPP.

The UCL App lab is a high level platform for distributing applications to a large-scale testbed for pre commercial testing and validation services. App Lab provides an app store offering in-the-wild user rapid field testing. App Lab collects valuable data for evaluation fast iteration of releases for app improvement cycles and includes audio and video capability as part of the government sponsored Innovate UK Digital Testbed. App Lab will allow the TRIANGLE partner organizations to have their own private mobile applications deployments for the pilot projects. As in standard app marketplaces (like Google Play or Apple Store), App Lab will allow developers to deliver mobile applications to pilot users (or a specific subset) after following an approval and publishing process. App Lab is comprised of client applications for Android and iOS mobile devices and a JEE server portal for application upload, management and distribution. The platform has a Web Management Console that carries out management tasks of the store: upload of new applications or updates (applications developed by the company, public applications or purchased applications), case definitions for testing, approval and publication of applications which will be adapted for the TRIANGLE pilot cases.

PerformNetworks (formerly PerformLTE) is a FIRE+ experimental platform, designed to offer a realistic experimentation environment covering LTE, LTE-A and future networks. The testbed is based on commercial off-the-shelf solutions (both in the radio and core network), software defined radio equipment and conformance testing equipment. The testbed offers a wide range of possibilities covering pilots, interoperability, performance evaluation, QoS, QoE and more. PerformNetworks is operated by the MORSE research group at the Universidad de Mlaga. The University of Mlaga also provides TestelDroid [10], a software tool that enables passive monitoring of radio parameters and data traffic in Android-based devices. Logging is implemented as an Android service that can be running in the background logging all the information while the application under test is being executed. This functionality enables monitoring of the traffic information generated by any

application, which extends the testing to a very wide range of use cases. The parameters to be logged (network, neighbor cells, GPS, traffic) can be flexibly configured using the SCPI interface.

The AT4 Performance tool is composed of two components, Controller and Agents (data endpoints), and uses proprietary mechanisms to synchronize the Agents and provides accurate one-way measurements. This tool includes a built-in traffic generator with the capability of generating constant rates, ramps, loops and statistical traffic patterns which is something of utmost importance for setting up the desired environment in terms of varying traffic loads (e.g., for measuring LTE-U impact on Wi-Fi networks). Additionally, this tool has the ability to automate some mobile Apps on Android devices and measuring relevant QoE KPI such as YouTube buffering occurrences.

Quamotion Automate Mobile App Testing enables test automation, manual testing and exploratory testing of mobile apps. While RedZinc's virtual path slice solution enables that applications can demand to the network the prioritization of their traffic.

18.4.2 TRIANGLE's Components Orchestration

In order to orchestrate the components of the testbed and design repeatable test cases a control and management framework is also needed.

The the high level architecture of the TRIANGLE testbed, including this orchestration framework, is provided in Figure 18.3. On top of this architecture TRIANGLE will provide an online access Portal for people interested in running an experiment on the test bed, whether it is an app developer, a device maker, a telecom operator or in general a telecom engineer. The testbed Portal will be the main entry point for users wishing to have their applications tested/certified by TRIANGLE. It will provide an easy interface allowing users to request a testing campaign for an application, describe the scenarios which are part of the campaign and their parameters, check the execution of the tests, and obtain a report on the results.

Internally, the testbed Portal must be aware of the availability of resources in the testbed and must be capable of initiating the execution of testing campaigns. In order to reduce development time, TRIANGLE plans to use Labwiki as a the basis of the Portal. Labwiki is an existing web-based interface for OMF [8, 9] based testbeds, capable of running experiments and graphing its results.

Figure 18.4 provides a detailed description of the internal composition of the testbed. The architecture proposed is in-line with current tools promoted

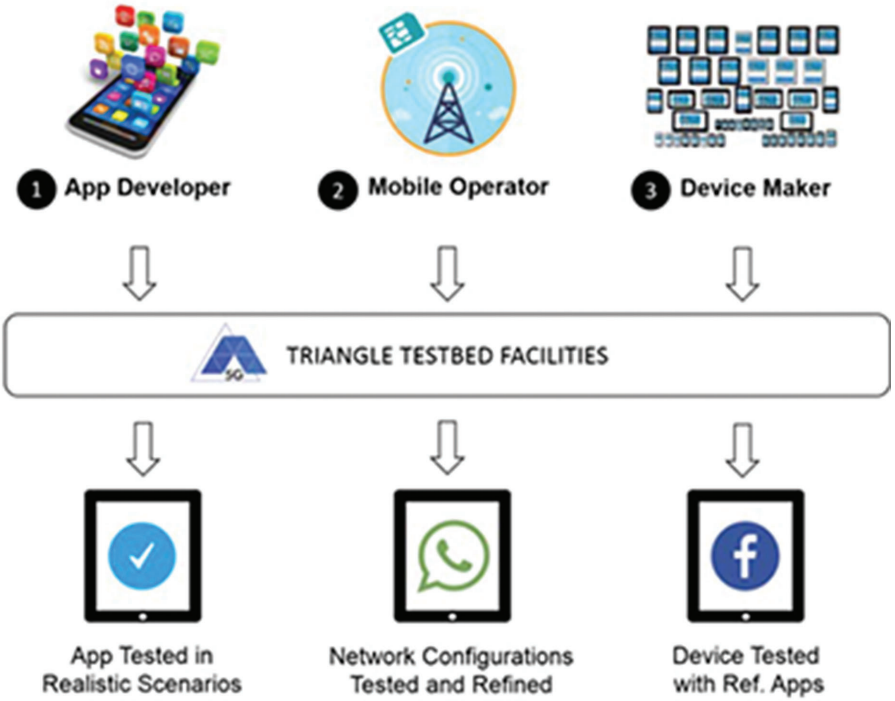

Figure 18.3 High level approach.

by Fed4Fire project and the FIRE community: OMF (Orbit Management Framework), OML (Orbit Measurement Libray), OEDL (OMF Experiment Description Language) and LabWiki [7].

OMF is the framework that manages experiment execution in Perform-Networks and other Fed4FIRE testbeds. It allows the definition of repeatable and automatable experiments thanks to the OEDL definition language. OEDL is a domain-specific language defined for the description of an experiment execution. OEDL provides a set of experiment-oriented commands and statements which can used to define the tests, the measurements and the graphical results. These OEDL scripts are interpreted by the Experiment Controller (EC), which orchestrates the resources present in the testbed during the execution of experiments. Each resource in the testbed is managed by a Resource Controller (RC). Thus, in the testbed, there are RCs for managing smartphones, network equipment, Quamotion tools, application servers, etc. Communication between the experiment controller and resource controllers is

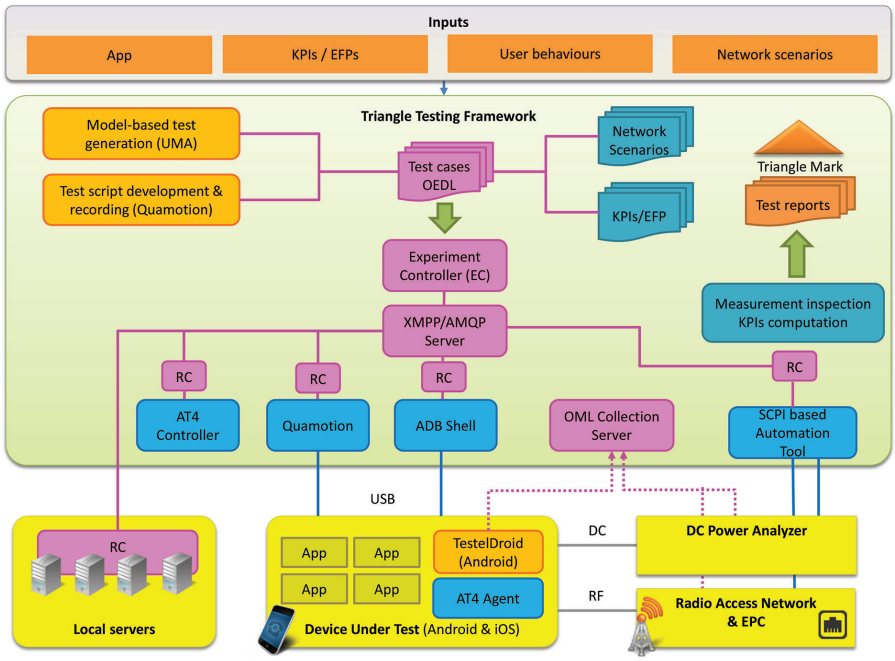

Figure 18.4 Testing framework architecture.

performed over the Advanced Message Queuing Protocol (AMQP). Measurement data obtained during experiment execution will be collected via OML in a central server. OML provides a programming library for easy application instrumentation, a collection point and a server which stores measurements in an experiment database. The instruments (eNodeB emulator and DC Power Analyser) are managed through the test automation platform provided by Keysight to manage SCPI (Standard Commands for Programmable Instruments) based instruments. The eNodeB emulator, is a generic platform used not only in conformance RF and signalling testing but also for design verification. In addition to LTE signalling and RF connection features, it also integrates channel emulation and digital generation of impairments such as AWGN, which is a critical feature for achieving high accuracy when setting Signal to Noise Ratio conditions. Standard multipath fading profiles defined by 3GPP are supported to emulate reference propagation conditions. The eNodeB emulator provides up to 3GPP release 10 and release 12 features, thus increasing the range of test possibilities with interesting network configurations. The DC Power Analyser is key to characterize power consumption in mobile devices.

Measurements collected by the tools and equipment available at the tesbed are sent to an OML collection server.

18.5 Testing Workflow Based on FIRE Technology

The application testing flow starts with the definition of the test cases. The test cases can be defined in several ways, supported by tools executed locally by the developer. The developer may write a script that contains the interactions that should be performed on the device (user behaviours), such as pressing buttons or entering text in text fields. Instead of writing the script by hand, this script may be generated by recording the interactions of the developer with a real device, which can then be replayed on the devices Both of these solutions will be provided by Quamotion. In addition, UMA will provide a model-based solution for app test case generation following the test specification methodology defined by AT4. The developer may provide a model of the possible user interactions with the app, which will then be used to automatically generate test cases. TRIANGLE users also have to indicate performance measurements (Key Performance Indicators (KPIs and Extra-Functional Properties) of interest from a list provided by the testbed. Finally the users of the testbed will select the network scenarios which are relevant for them: office, driving, pedestrian, Internet cafe, etc.

Once all the information is available the test cases can be completely defined and executed in the testbed. In order to coordinate the execution of the tools integrating the testbed each one will have associated a Resource Controller (RC). These RCs will allow the tools and the instruments to be controlled as part of the test, and receive commands from the experiment controller to execute a particular action. During the tests, the OML collection server will collect all the measurement results from all layers and measurement points present on the testbed. The results are passed to the Measurement inspection and KPI calculation, which will produce the final test report that leads to the "Triangle Mark".

18.6 Conclusion

TRIANGLE is the first FIRE project that provides a market oriented set of tools to perform a vendor-independent exhaustive analysis of a number of KPIs to qualify applications and devices in the pathway to 5G networks. TRIANGLE will provide a number of advances beyond the state of the art

which includes to enable the testing with 5G networking features, to provide solutions for testing apps in the smartphone market, to provide apps oriented qualification of devices as a complement of radio access certification and to provide a sustainable business model involving stakeholders in certification and testing industry (including SMEs), research institutes (including FIRE) and apps developers.

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