Advanced testing of mobile applications and devices

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***Abstract*—This paper describes PerformNetworks, which is an enhanced test and research facility for cutting edge mobile communications managed by the MORSE group in the University of Malaga. This facility is an evolution, containing key improvements introduced on top of the work presented in NOMS 2012 [1]. The test environment has been extended to support new features available in LTE-Advanced networks, power consumption measurements and channel emulation in uplink. The PerformNetworks testbed is a reference research platform that has been used in multiple experiments.**

I. Introduction

According to Cisco [2], global mobile data traffic grew 74 percent in 2015, reaching 3.7 exabytes per month at the end of 2015, up from 2.1 exabyte per month at the end of 2014. In addition, mobile data traffic has grown 4,000-fold over the past 10 years and almost 400-million-fold over the past 15 years and the fourth-generation (4G) traffic exceeded third-generation (3G) traffic for the first time in 2015.

The fast pace of the standardization process adds more complexity to this picture. In current network deployments, while evolving towards 5G, 4G LTE coexists with 2G and 3G technologies. In conjunction with the set of new features added in each 3GPP release, the potential combinations of network configurations grow exponentially for operators.

Despite of that, mobile subscribers are increasingly focused on applications and keep demanding high levels of quality everywhere. Unfortunately, it is not unusual to find performance and connectivity problems that hugely impact on the user experience.

The University of Málaga participates in the Triangle European Project, integrated also by Keysight Technologies, RedZinc, University College London, AT4 Wireless and Quamotion. As part of the Triangle Project, we have recognized the need to provide adequate test means to increase the quality and reliability of mobile communications and applications in multiple domains.

One important additional trend in the mobile users communication patterns is the shift to generate a larger amount of data from the mobile devices themselves. Understanding these new use uplink centric use cases under realistic conditions is of great interest.

The energy dimension is also gaining importance with the appearance of new power demanding broadband services and with the upcoming optimizations for Internet of Things and Machine to Machine communications.

To enable the analysis and verification of mobile applications from a communication perspective, where possible, we have aimed to integrate any applicable standard test specification and recommendation. Of particular interest is the execution of test cases based on 3GPP technical recommendation TR 37901 for measurement of communication performance at the application level.

Enhancing the orchestration and automation has been a core part of the targeted improvements, involving communication and cooperation between multiple test components. Improved traceability and correlation between application and technology level information has also been considered.

One of the most challenging targets is to keep track with 4G LTE Advance and its evolution. To that end we have sought to establish a test environment able to exercise the maximum broadband speed in the state of the art. With the introduction of the new UE categories 15 and 16, the need to test at Gigabit/s rates has become a reality demanding state of the art test instrumentation. Providing access to the latest features introduced in the 3GPP standards is not a trivial task. Each release introduces new features and enhancements, such as complex carrier aggregation schemes involving 3 and more component carriers.

In this globalized context, we have also aimed to enable the analysis of the mobility between different technologies within a single operator network or involving multiple operator domains for roaming or emergency purposes.

To better understand the impact of mobile generated content it is required to add realistic radio impairments in the uplink. Unlike in our initial testbed configuration, we have also targeted the enhancement of the uplink with cannel emulation capabilities in order to realistically study the impact of the multipath propagation in uplink centric communications.

The energy consumption in mobile devices is highly linked with the instantaneous uplink transmission parameters, as well as with discontinuous reception schemes. To study these and other scenarios we have worked to add power analysis capabilities within the testbed.

II. Testbed overview

This section provides an overview of the testbed structure with emphasis in the orchestration plane. The system is composed of multiple elements interconnected through a control logic. The new prototype of the testbed comprises the following components: a mobile network emulator and a power

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analyzer from Keysight Technologies, mobile devices that can be instrumented with TestelDroid or other tools as the AT4 wireless Performance Test Tool, and additional application servers. The overall access and control of the test setup is initially managed through a Web portal, that allows defining campaigns of test cases, monitoring the test execution flow at runtime, storing and visualizing the measurement reports.

On one end, the mobile phone is connected to the UXM mobile network emulator from Keysight Technologies, interposing a SR5500 channel emulator only in the uplink path. In the downlink path the UXM itself features the MIMO channel emulation digitally for improved accuracy. The radio communication is not transmitted over the air but conducted through accurately calibrated cabling. For testing purposes most phones typically contain small antenna connectors than may be even hidden. Despite the use of cables, the UE observes a totally normal mobile network.

On the other end, the battery pins of the mobile device are connected to a DC power analyzer. This allows us both to control the input voltage to the phone and to measure the instantaneous power borrowed from the instrument.

A. Orchestration of the testbed

For the orchestration and automation of the different components used in our testbed, we provide two different technologies, one of them is based on OMF [10], and the other one is based on TAP [11].

OMF is a collection of services, protocols, libraries and scripting languages that help with experiments that span multiple resources, such as UEs, network equipment and measurement probes. OEDL (OMF Experiment Description Language) is the scripting language used to write an experiment, including the resources that take part in it. Resources controllers wrap the actual resources with an interface that understands the protocol used by OMF. OMF already provides several resource controllers, including one that manages a computer and allows executing arbitrary programs. This is useful for controlling any component that has a command line interface, without having to write a custom resource controller. However, this resource controller only works with Linux machines. We had to perform some small changes in the resource controller so that it worked with the Windows machines that some of our tools required.

The measurements taken during and experiment are collected and sent to a centralized database, using the OML measurement framework [4]. This facilitates the analysis and correlation of the measurements taken from heterogeneous sources. Tools can implement OML support directly, or rely in scripts that can parse and send measurements stored in the popular CSV format.

As part of Triangle project the Test Automation Platform (TAP), from Keysight, is being deployed as coordinator responsible for configuring and running the tests. This new coordinator is needed to synchronize the executions time sensitive operations such as handovers and other network behaviours.

TAP is a Microsoft .NET-based application that can be used stand-alone or in combination with higher-level test executive software environments, for example, we can use OMF to control TAP. Each testbed component is controlled through a TAP driver, which serves as bridge between the TAP engine and the actual component interface.

B. LTE-A test network emulator

We have integrated the UXM Wireless Test Set from Keysight, as an enhanced replacement to the previous network emulation platform introduced [5]. The UXM is a flagship mobile network emulator that provides state of the art test features. It can operate either in a single box or in a scalable array configuration to create complex emulated networks. A single box can generate up to 4 LTE cells, as well as supporting other technologies as GSM, WCDMA and TDSCMA. LTE cells can be aggregated in the downlink up to 5 component carriers and 2 in the uplink. This enables the use of up to 100 MHz of aggregated bandwidth.

Additionally, dense antenna configurations are supported, including channel emulation schemes with up to 8 transmitting antennas per cell and 4 receiving antennas in the mobile device. The use of a higher number of antennas increases the spectrum efficiency, enabling Gbps transfers with 3 cells when using 256QAM modulations. It is worth mentioning that at the 2016 Mobile World Congress, Keysight and Qualcomm jointly demonstrated Gbps connectivity with the UXM Wireless Test Set and a QC Snapdragon X16 LTE modem [6].

The UXM provides a powerful logging environment, that enables cross layer analysis of application traffic down to physical layer transmissions. Its integration with the widely known Wireshark protocol analyser improves significantly the learning curve. The source of communication problems can be traced down to the radio frequency level, as the UXM can operate as a signal analyzer. For that purpose, it integrates the X-Series measurement application with tight synchronization with the selected network configuration parameters.

Moreover, its cohesive programming model and remote control command interfaces enable the use of powerful automation tools.

Some additional key features for the research on network management include CAT0(M2M), flexible Inter Cell Interference Coordination (eICIC) schemes, WLAN offloading, IMS/End to End VoLTE communications between multiple devices, and battery drain performance with flexible network and sleep mode settings. More detail on the potential of this instrument for its use in research and education environments have been provided in [7].

C. Power consumption analyzer

To carry out the analysis on battery life characterization, a key factor in mobile devices, we have specific equipment: an N6715B with an N6781A-ATO unit. Power rating is 20 W. As a measurement tool, it is capable of measuring values down to nA and V at a rate of 5.12 s/sample for one parameter. It is possible to store measurement data for up to 99,999 hours using the data logger function. Data can be exported to a file, which can be analyzed and graphed later. A histogram function for current measurements is also available.

D. Uplink channel emulation

One important additional trend in the mobile users communication patterns is the shift to generate a larger amount of data from the mobile devices themselves. Not having been considered in traditional test methodologies oriented to verify downlink communications, understanding these new uplink centric use cases under realistic conditions is of great interest.

To better understand the impact of mobile generated content it is required to add realistic radio impairments in the uplink. Unlike in our initial testbed configuration, we have also targeted the enhancement of the uplink with channel emulation capabilities.

When comparing different network configurations, not considering RF impairments may cause some results to be unrealistically optimistic. As an example, using a low modulation and coding scheme index (IMCS) may reduce the maximum theoretical throughput under ideal conditions. However, in a realistic environment a excessively high IMCS may cause the connection to drop.

Transport and application level protocols may be also sensitive to communication delays. In an ideal environment, the jitter will be very small and the delays predictable under reasonable network loads. Some approaches in the literature relay in the use of artificially added delays with a given statistical patterns, but even that may not accurately resemble the actual nature of the mobile protocols and channels. Fading emulation may be quite varying in the short term causing bustiness, in fact it is only statistically predictable in the long term. As an example, despite the heavy interest in reducing test time (and cost) the 3GPP test specifications recommend using up to a few minutes as minimum test time for some conditions. Having a realistic fading emulation will help us identify complex scenarios where TCP or other protocols could react dynamically in unexpected ways.

A side effect of the presence of uplink multipath fading is the impact of power control on the UE uplink transmission. As the fading will make the channel gain to vary, the eNodeB will send transmit power commands to the UE to keep the power constant at the base station receiver. Thus the UE will effectively increase or decrease its transmission power accordingly. As power consumption is highly correlated with the UL transmission power, fading scenarios will be of great interest for some use cases such as VoLTE.

E. Performance test tool

5G test scenarios will require high resolution for reporting target QoS KPIs. The Triangle testing framework will provide up to layer 7 SDU packet resolution in the computation of data performance KPI thanks to the integration of the AT4 Performance Tool [8].

F. TestelDroid

TestelDroid is another solution for measurement and monitoring in Android devices integrated in the testbed. It has been developed by the MORSE group in the University of Málaga and is widely available in the Google Play Store for Android applications. It provides both passive and active traffic generation and monitoring, as well as correlation with location, battery and network information. For further reference, it was originally introduced in detail in [9].

To enhance its integration in the testbed, a number of extensions have been recently added to TestelDroid. The extensions include support for Standard Commands for Programmable Instruments (SCPI), cOntrol and Management Framework (OMF) and OMF Measurement Library (OML). SCPI is the most widespread interface for measurement equipment control in many areas. OMF and OML extensions enable powerful orchestration framework languages that reduce the time required to define experiments.

III. Experimental results

The testbed gathers information and generates statistics and measurements at many different levels. Some of then are highlighted in this section.

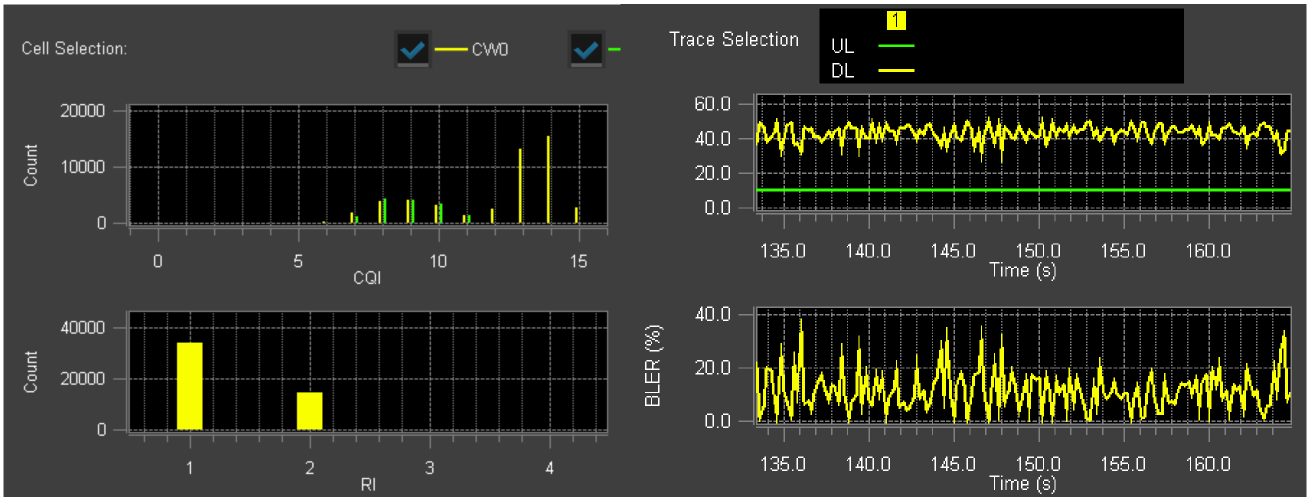
Figure 1a represents the LTE Channel State Information (CSI) reported by the UE under multipath fading conditions. It includes both Rank Indications (RI) and Channel Quality Index (CQI) reports. When configured accordingly, the UE reports periodically (or on asynchronously upon demand) the quality and rank of the radio channel based on its current physical layer estimations. The purpose of these reports are to guide the network in the selection of the optimum modulation and coding scheme, typically targeting a 10 percent of error transmissions in the initial downlink transmissions. Although multiple antennas were used in a MIMO transmission mode during the associated test, the UE also recommends using a single layer scheme because of the present impairments. It can be observed that the quality histogram does not contain a single value but presents a Gaussian distribution instead. This is also caused by the variations in the instantaneous conditions. Figure 1b represents the evolution of the instantaneous IP throughput and Block Error rate (BLER).

In addition to this measurements, the integration with the versatile AT4 wireless Performance Test Tool, enables the derivation of quality of experience metric as shown in Figure 1c. In this Figure we can see the evolution of the resolution of the video and the playback time during a YouTube session.

Finally Figure 1d represents the evolution of the power consumption averaged over multiple radio network conditions.

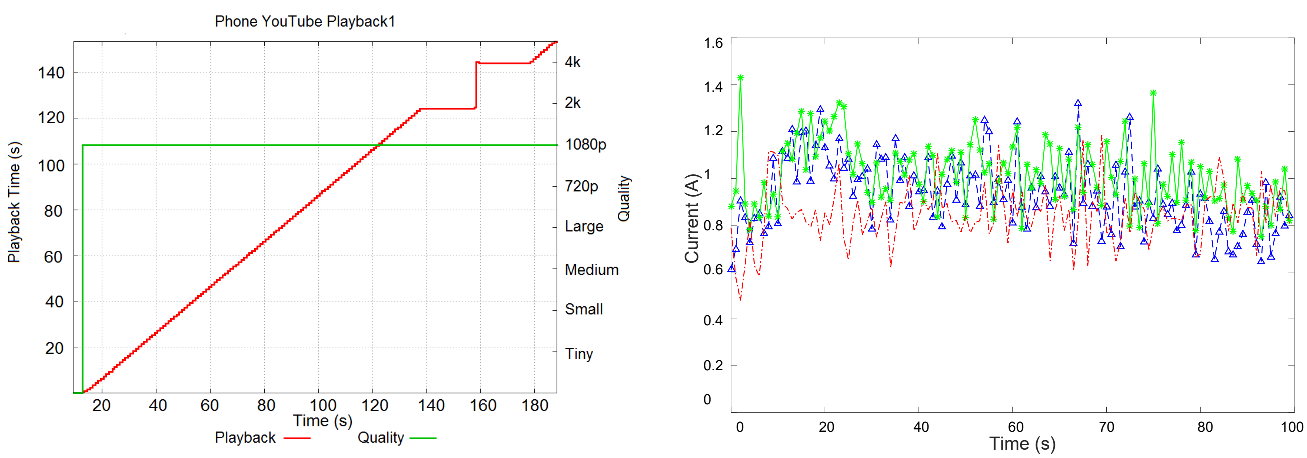
IV. Conclusions

We have introduced PerformNetworks, which is a reference testbed for research and experimentation with applications and communications in mobile devices and networks. It has evolved over the time with numerous enhancements described also through this presentation and it is currently being integrated in the Triangle project focused on 5G experimentation.



(a) LTE Channel Information System

(b) IP Throughput and Block Error Rate (BLER)



(c) Playback time and video quality versus time

(d) Power consumption

Fig. 1. Experimental measurements provided by the testbed

In the future, it will continue integrating new features in different working areas through the collaboration with multiple partners. Additional networking scenarios are being considered as the interconnection to external Evolved Packet Core (EPC) or the integration of mall cells and Wi-Fi access points. Additionally, automation of mobile applications will be enabled by integrating Quamotion solutions [12].

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