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Abstract

The purpose of this document is to describe how the TRIANGLE testbed has been expanded to allow the connection of remote testbeds. As a direct result of this work, the TRIANGLE consortium is now using 3 different end-to-end testbeds, located at UMA, DEKRA and KEYSIGHT offices. All these testbeds are used on a regular basis by the experimenters.

Keywords

Remote testbeds, distributed testbeds, architecture.

Executive summary

The purpose of this document is to describe how the TRIANGLE testbed has been enhanced to allow the connection of remote testbeds, denoted as distributed testbeds. Distributed testbeds allow to increase the functionality of TRIANGLE, with reduced cost compared to deploying a whole new testbed by re-using components present in other testbeds. Explicitly, the TRIANGLE testbed has been expanded by adding two additional distributed testbeds, one located at DEKRA Spain premises and a second one located at Keysight Denmark offices. It should be noted that the addition of two distributed testbed to the TRIANGLE testbed has been of great help to coordinate the work of TRIANGLE experimenters. The original TRIANGLE testbed located at Málaga has been reserved for pure app developers, while the distributed testbeds are being used by IoT experimenters

The document is organized as follows. Section 1 discusses requirements for a successful interconnection between the main testbed and the distributed testbed and highlights the expected limitations. Section 2 describes the architecture used and the technology required to interconnect remote testbeds. Section 3 contains the performance of the testbeds and describes the impact on the TRIANGLE test cases and capabilities. Finally, Section 4 presents the conclusions.

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1 Introduction

The idea behind distributed testbeds is to interconnect existing testbeds and expand their functionality by re-using components present in other testbeds. This allows to significantly reduce the cost of deploying a whole new testbed. Consider for example the TRIANGLE testbed, where one key characteristic is the availability of a commercial LTE core network that enables end-to-end tests. A new end-to-end testbed can be deployed by simply interconnecting one remote eNodeB (LTE base station) to the TRIANGLE testbed.

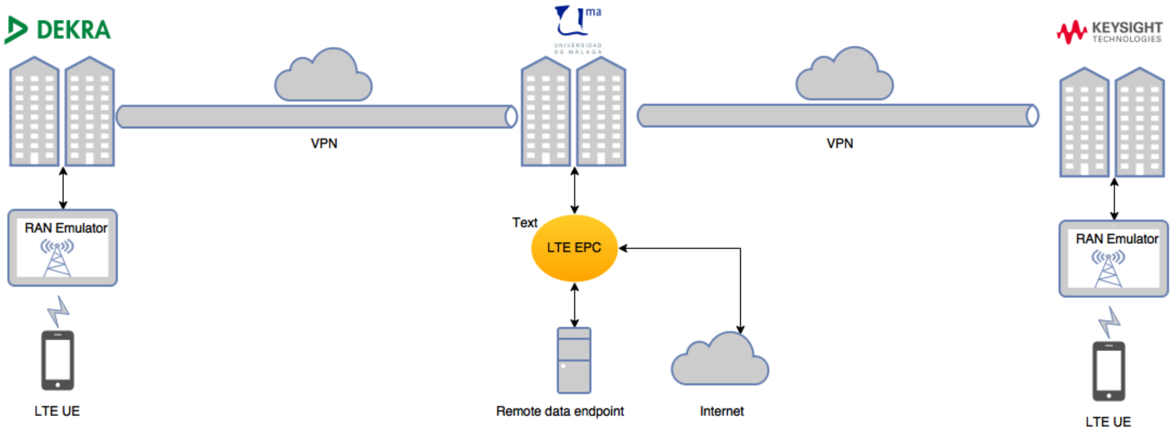

Figure 1 Illustration of the TRIANGLE Testbed (middle) and the distributed testbeds.

The TRIANGLE testbed has been expanded by adding two additional distributed testbeds (see Figure 1), one located at DEKRA premises and second one located at Keysight Denmark offices. It should be noted that the addition of two distributed testbeds to the TRIANGLE testbed has been of great help to coordinate the work of TRIANGLE experimenters. The TRIANGLE testbed located at Málaga has been reserved for pure app developers, while the distributed testbeds are being used by IoT experimenters. This allows to significantly offload the main testbed, increasing the amount of testbed time allocated for each experimenter.

1.1 List of Requirements

The requirements of the TRIANGLE testbed should be transparent from how an instance of the TRIANGLE testbed has been deployed (local or distributed). However, the fact of splitting the testbed into two locations surely has impact (due to physical reasons) on the testbed capabilities. Then, setting additional requirements for the distributed testbed deployment will help to mitigate from design stage some undesirable effects on the TRIANGLE testbed capabilities.

The following table provides a list of the extra requirements to be fulfilled by a distributed testbed deployed across two different locations.

Table 1 –TRIANGLE Distributed Testbed Extra Requirements

Category	**Requirement**
Operational	The type of testbed deployment (local or distributed) must be transparent to the end user of the testbed who uses the TRIANGLE portal (certification profile) as user interface.
Operational	The type of testbed deployment (local or distributed) must be transparent to the end user of the testbed who uses the Test Automation Platform portal (experiment profile) as user interface.

Operational	The link between both sides of the distributed testbed shall not be firewalled and the entire range of TCP and UDP ports shall be open
Operational	The health of the link between both sides of the distributed testbed shall be observable by the owner of the testbed.
Functional	The measurement capabilities, level of automation and test cases availability of the distributed testbed shall be the same that of a local testbed [1] which is provisioned with the same test equipment.
Functional	If there is an error in the link between both sides of the distributed testbed (e.g., link cut-off, or performance degradation) during the execution of a test session, the testbed user interface shall clearly report to the end user the error cause.
Performance	The capacity (Mbit/s) of the link between both sides of the distributed testbed shall be higher than the maximum expected capacity of the DUT LTE-Uu interface
Performance	The delay of the link between both sides of the distributed testbed shall not contribute to exceed the delay requirements of the AUT.
Performance	The delay of the link between both sides of the distributed testbed shall be balanced (downlink and uplink).
Performance	The delay variation of the link between both sides of the distributed testbed shall be below zero milliseconds.
Performance	The delay variation of the link between both sides of the distributed testbed shall be balanced (downlink and uplink).
Performance	The link between both sides of the distributed testbed shall not drop any IP packet as long as the imposed traffic load from the endpoint is lower than the declared link capacity.

1.2 TRIANGLE Distributed Testbed Capabilities

The TRIANGLE testbed is a complex system, where a very high level of automation is required. Therefore, it is expected that not all the TRIANGLE capabilities will be enabled in the distributed testbeds. One major limitation is that the portal is only available in the main testbed. This is not seen as a major issue because certain TRIANGLE experimenters do not require access to the portal, e.g., IoT developers or researchers. In addition, certain components cannot be shared among the different testbeds, e.g., a power analyser is required to measure the power consumption, which in turn requires a physical connection to the device under test. It is also clear that some of the requirements specified above are not feasible mostly due to the distance between the distributed and the central testbed. The following table compares the capabilities of the original TRIANGLE testbed with its distributed testbeds.

Table 2 – List of TRIANGLE Capabilities [UMA]

Testbed Capabilities	**UMA**	**DEKRA**	**KEYD**
Portal	Supported	Not supported	Not supported
N6705B Power Analyzer	Supported	Not supported	Supported
LTE Devices	Available	Available	Available
IoT Devices	Not available	Available	Available
Quamotion Webdriver	Supported	Supported	Supported

DEKRA Performance Tool	Supported	Supported	Supported
TestelDroid	Supported	Supported	Supported
Web Reporting Tool	Supported	Not supported	Not supported
Commercial EPC (Polaris)	Supported	Supported	Supported
Test Automation Platform (TAP)	Supported	Supported	Supported
ETL Module	Supported	Supported	Supported
Emulated Impairments	Supported	Not supported	Not supported
Database	Supported	Supported	Supported
Booking System	Supported	Not supported	Not supported

2 TRIANGLE Testbed Architecture

Before the addition of distributed testbeds, the TRIANGLE testbed architecture was rather simple. On the one hand, a network (denoted as Network A), provides service to all the instruments of the testbed, such as the portal, the power analyzer, the UXM (eNodeB), the user interface, the RF switches, the orcomposutor, etc. On the other hand, all core network elements (i.e., the EPC) are part of a separate network (denoted as Network B). The UXM is also connected to this network via an additional network interface, which is required for the S1 interface. Finally, the devices connected to the testbed via LTE are part of a third network (Network C). Note that Network C is provided by the EPC component.

The approach for distributed testbeds is also conceptually simple. Ideally, each component of the distributed testbed shall be connected to the respective network, e.g., Network A, Network B, and Network C. In practice, however, we will focus in connecting the remote eNodeBs to the corresponding network via Virtual Private Networks (VPNs)., leaving aside any additional instruments that might be present in the distributed testbed. The reasoning for this approach is that the distributed testbeds are being used for IoT experimenters. Therefore, the portal is not required; instead, a local machine running TAP to control all the elements of the distributed testbed should suffice.

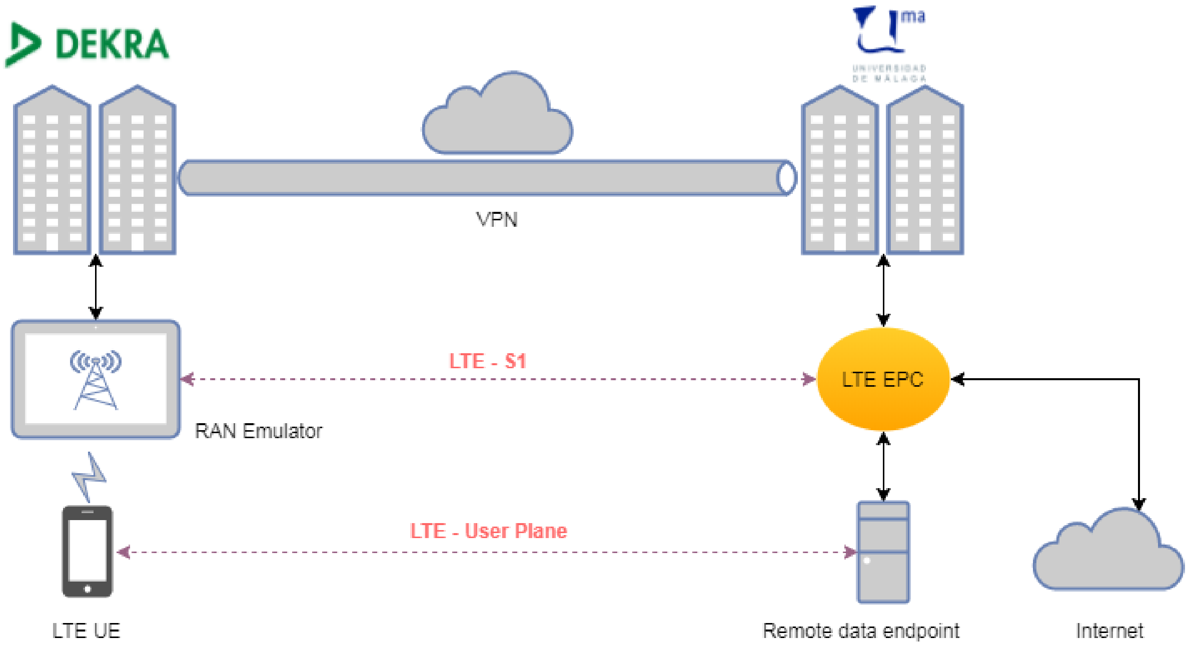

Figure 2. LTE Logical View of the TRIANGLE Distributed Testbed

To connect a given testbed to the TRIANGLE testbed, we use a VPN, which is an end-to-end IP Sec based tunnel. The VPN establishes an encrypted link between the distributed testbed and the original TRIANGLE testbed, as seen in Figure 1. This diagram also depicts the high-level architecture of the distributed testbed showing the location of the LTE interfaces. As shown in the figure, LTE UE and LTE eNodeB are located at for example at DEKRA office; while the LTE EPC including MME, Serving Gateway, PDN Gateway is located at UMA office. The remote data endpoint (for Data Performance tests) and the Internet access are also located in UMA office.

The following sections present the architecture from the network point of view. In addition, a configuration example of the VPN is available in Annex 1: DEKRA-UMA VPN Configuration.

2.1.1 TRIANGLE Physical View

On top of the layout shown in the previous section, the TRIANGLE test bed specific interfaces are required for deploying the distributed testbed. For example, the Portal and the Testbed Management entities [2], which will run on a single Desktop PC. The design of the testbed has been driven by the network connectivity requirements between all the elements of the testbed, which are listed in Table 3.

Table 3 – Remote testbed Connectivity Requirements

Purpose	**A**	**B**
DEKRA Performance Tool (orchestration)	Control PC	LTE UE
DEKRA Performance Tool (orchestration)	Control PC	Remote endpoint (@ UMA EPC)
Keysight Test Automation Platform (orchestration)	Control PC	RAN Emulator
LTE Use Plane	LTE UE	Remote endpoint and Internet (@UMA EPC)
LTE Control Plane	RAN Emulator	MME (@UMA EPC)

In order to meet the requirements above the following networking elements have been used:

- IP over ADB (Android Device Bridge): The Control PC is connected to the LTE UE by a test interface in order to provide the Web Driver based UE Automation feature. Therefore, ADB with USB wire is already used when the LTE UE is an Android device. ADB provides a feature to replace USB by Wi-Fi as physical interface. Part of this feature enables a network mapping on top of the ADB connection. We have used this feature to provide IP connectivity between the Control PC and the LTE UE (Android) by setting up an IP network on top of the ADB interface.
- SSH Tunnel: The Control PC needs IP connectivity with the remote endpoint (located at UMA network) in order to orchestrate the Data Performance tests. However, the Control PC is only physically connected to the RAN Emulator through a network interface also for orchestration purposes. Then, we have proposed to use a SSH tunnel on top of the VPN between DEKA and UMA to transport the control plane of the DEKRA Performance Tool.

The diagram in Figure 3 depicts the distributed testbed networking layout showing the IP addressed used for the elaboration of this deliverable.

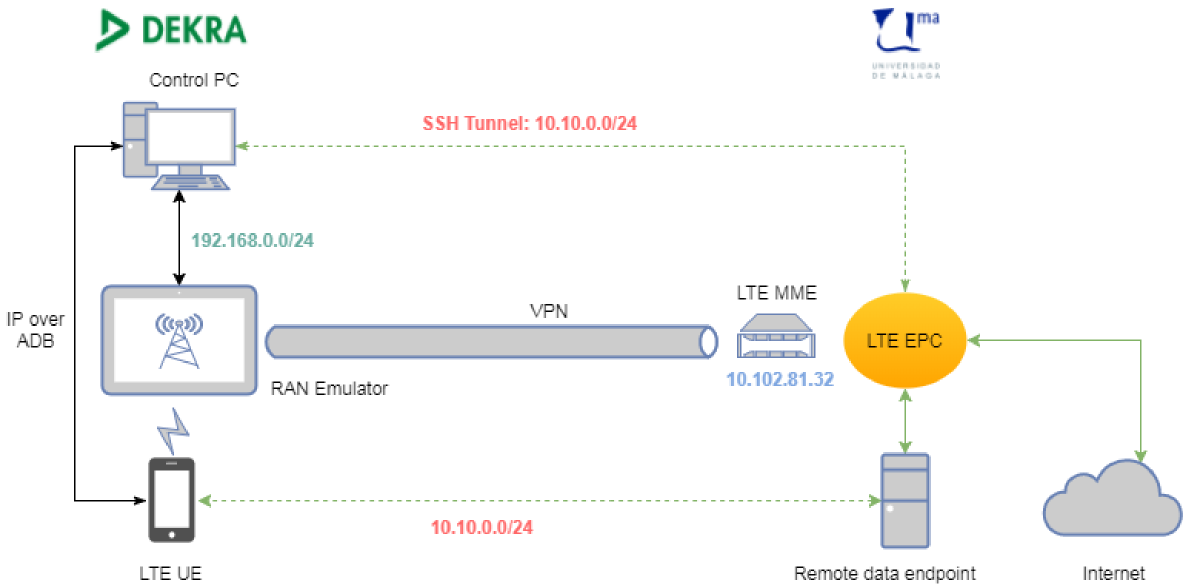

Figure 3. Physical View of the TRIANGLE Distributed Testbed

3 Distributed Testbeds Performance

3.1 Reference Testbed

The original and main testbed in TRIANGLE is the one located at UMA facilities. The performance of this testbed is used as a reference for the analysis done in this section. End-to-end tests were carried out to determine its performance, configuring the involved elements with agreed initial conditions to be likewise utilized by the distributed testbeds. Table 4 summarizes the parameters selected for the radio link parameters, i.e., the connection between the UE and the eNodeB. Note that the performance will strongly depend on these parameters and the capabilities of the UE.

Table 4 – Reference Testbed RF Configuration

Parameter	**Value**
TM	4
Bandwidth (MHz)	20
Resource blocks	All
CQI	15
Dl MCS	27 (64 QAM)
Ul MCS	23 (16QAM)

The theoretical peak data rate of this configuration is 230 Mbits/s in the downlink and 50 Mbits/s in the uplink.

3.1.1 LTE User Plane Tests

The following table shows the results of the end-to-end user data performance tests in the TRIANGLE reference testbed:

Table 5 – Reference testbed end-to-end Performance tests – Summary

KPI Name	**Value**
UL Average TCP Throughput (Mbit/s)	48.606
DL Average TCP Throughput (Mbit/s)	235.41
UL Average TCP Throughput (Mbit/s) (10 streams)	46.653
DL Average TCP Throughput (Mbit/s) (10 streams)	235.75
UL Average UDP Throughput (Mbit/s)	49.904
DL Average UDP Throughput (Mbit/s)	228.76
UL Average One Way Delay (ms) (at 5 Mbit/s)	14.93
DL Average One Way Delay (ms) (at 5 Mbit/s)	13.34
UL Average One Way Jitter (ms) (at 5 Mbit/s)	1.50
DL Average One Way Jitter (ms) (at 5 Mbit/s)	1.66

UL Average One Way Packet Loss (%)(at 5 Mbit/s)	0
DL Average One Way Packet Loss (%) (at 5 Mbit/s)	0

3.2 DEKRA Distributed Testbed (Málaga)

3.2.1 Validation Tests

To verify that the TRIANGLE testbed is fully operational in the distributed architecture deployed in Málaga between DEKRA and UMA, we have performed a set of validation tests. These tests have been designed to verify the performance of TRIANGLE elements which may have been potentially affected by the distributed architecture. For example, testing the Web Driver UE automation module has not been necessary because this module runs locally to the LTE UE.

Table 6 summarizes the list of tests performed. Running the tests in the order as presented in the list is recommended.

Table 6 – Distributed testbed validation tests

Test Purpose	**Tool Used**
Verify IP connectivity between RAN Emulator (@DEKRA) and MME (@UMA) through the VPN	Ping
Verify the ability of the VPN to set up the LTE S1 interface tunnel by checking that the involved SCTP port (36412) and GTP (2152) are open.	S1EmulationTester[1]
Verify that Data Performance tests [3] can be executed and that the KPIs are properly reported.	DEKRA Performance Tool
Verify that Reference Application tests [D22] (for example, YouTube™) can be executed and that the KPIs are properly reported.	DEKRA Performance Tool
Verify that the VPN is stable and does not show any performance degradation over long periods of time (24 hours or higher)	DEKRA Performance Tool

3.2.2 VPN Link Performance Tests

The goal of these tests was to measure the performance of the VPN between DEKRA and UMA. Table 7 summarizes the results of the tests.

Table 7 – DEKRA Distributed testbed VPN Performance tests – Summary

KPI Name	**Value**
DEKRA->UMA Average TCP Throughput (Mbit/s)	139.871
DEKRA<-UMA Average TCP Throughput (Mbit/s)	231.003

[1] This is a tool developed by the University of Málaga

DEKRA->UMA Average One Way Delay (ms)	13
DEKRA<-UMA Average One Way Delay (ms)	15
DEKRA->UMA Average One Way Jitter (ms)	0.1
DEKRA<-UMA Average One Way Jitter (ms)	0.5
DEKRA->UMA Average One Way Packet Loss (%) (at 5 Mbit/s)	0
DEKRA<-UMA Average One Way Packet Loss (%)(at 5 Mbit/s)	0

The TCP throughput results presented above establish the upper limit of the achievable throughput in actual TRIANGLE testing sessions. The UDP tests were conducted at an imposed load of 5 Mbit/s. The delay values establish the lower limit of the end-to-end latency in actual TRIANGLE testing sessions.

The link was considered stable as it did not have any packet losses at 5 Mbit/s rate and the jitter was very low (close to none). Therefore, it is expected that the VPN between DEKRA and UMA will not impact the performance of the tested applications which use TCP as transport protocol, in both categories app under test and device under test.

3.2.3 LTE User Plane Tests

The goal of these tests was to measure the performance of the end-to-end path between the LTE UE (@DEKRA) and the data endpoint (@UMA).

For these tests the LTE UE configuration has been the following one:

Table 8 – LTE UE Configuration

Parameter	**Value**
TM	4
Bandwidth (MHz)	20
Resource blocks	All
CQI	15
DL MCS	27 (64 QAM)
UL MCS	23 (16 QAM)

Table 6 summarizes the results of the tests

Table 9 – DEKRA Distributed testbed end-to-end Performance tests – Summary

KPI Name	**Value**
DEKRA->UMA Average TCP Throughput (Mbit/s)	48.63
DEKRA<-UMA Average TCP Throughput (Mbit/s)	34.53
DEKRA->UMA Average TCP Throughput (Mbit/s) (10 streams)	48.53
DEKRA<-UMA Average TCP Throughput (Mbit/s) (10 streams)	53.00
DEKRA->UMA Average UDP Throughput (Mbit/s)	49.81

DEKRA<-UMA Average UDP Throughput (Mbit/s)	203.70
DEKRA->UMA Average One Way Delay (ms) (at 5 Mbit/s)	24.69
DEKRA<-UMA Average One Way Delay (ms) (at 5 Mbit/s)	23.72
DEKRA->UMA Average One Way Jitter (ms) (at 5 Mbit/s)	1.56
DEKRA<-UMA Average One Way Jitter (ms) (at 5 Mbit/s)	1.36
DEKRA->UMA Average One Way Packet Loss (%)(at 5 Mbit/s)	0
DEKRA<-UMA Average One Way Packet Loss (%) (at 5 Mbit/s)	0

As part of the validation, we also executed performance tests (as baseline) with a data endpoint running on the RAN emulator, i.e., using the internal EPC provided by the UXM. In this setup, the UMA EPC is not used.

Table 10 – Local testbed end to end Performance tests – Summary

KPI Name	**Value**
RAN->UE Average TCP Throughput (Mbit/s)	242.251
RAN->UE Average TCP Throughput (Mbit/s) (10 streams)	243.694
RAN->UE Average UDP Throughput (Mbit/s)	247.903
RAN->UE Average One Way Delay (ms) (at 5 Mbit/s)	10.90
RAN->UE Average One Way Jitter (ms) (at 5 Mbit/s)	1.37
RAN->UE Average One Way Packet Loss (%)(at 5 Mbit/s)	0.00

These tests demonstrate that the link used to connect DEKRA (UE) may have some limitations in some test scenarios. The TCP performance of the link is poor (34 Mbit/s versus 242 Mbit/s). The reason may be the latency introduced by the link (10.90 ms vs 23.72 ms). This latency is likely introduced by the underlying VPN operation (IP sec tunnel).

3.3 Keysight Distributed Testbed (Aalborg)

3.3.1 Validation Tests

The procedure is already described in Section 3.2.1.

3.3.2 VPN Performance Tests

The goal of these tests was to measure the performance of the VPN between KEYSIGHT and UMA. Table 7 summarizes the results of the tests.

Table 11 – KEYD Distributed testbed VPN Performance tests – Summary

KPI Name	**Value**
KEYSIGHT->UMA Average TCP Throughput (Mbit/s)	6.55

KEYSIGHT <-UMA Average TCP Throughput (Mbit/s)	6.26
KEYSIGHT ->UMA Average One Way Delay (ms)	40
KEYSIGHT <-UMA Average One Way Delay (ms)	40.5
KEYSIGHT ->UMA Average One Way Jitter (ms)	0.357
KEYSIGHT <-UMA Average One Way Jitter (ms)	0.06
KEYSIGHT ->UMA Average One Way Packet Loss (%)	0.012
KEYSIGHT <-UMA Average One Way Packet Loss (%)	0.024

From these results it is already clear that the testbed in Aalborg must be used with caution. The performance of the VPN link is questionable. This is to be expected due to the considerable distance between UMA and KEYSIGHT (around 3500 km).

3.3.3 LTE User Plane Tests

In addition to the questionable performance of the link, we also need to take into account that the LTE device used for these test is not capable of achieving the results shown in the previous sections. The theorical values achievable by this device are 65 Mbits/s in the downlink and 20 Mbits/s in the uplink.

Table 12 – LTE UE Configuration

Parameter	**Value**
TM	1
Bandwidth (MHz)	20
Resource blocks	All
CQI	15
DL MCS	27 (64 QAM)
UL MCS	23 (16 QAM)

Error! Reference source not found. summarizes the results of the tests

Table 13 – Keysight Distributed testbed end-to-end Performance tests – Summary

KPI Name	**Value**
KEYSIGHT->UMA Average TCP Throughput (Mbit/s)	7.48
KEYSIGHT <-UMA Average TCP Throughput (Mbit/s)	4.09
KEYSIGHT ->UMA Average TCP Throughput (Mbit/s) (10 streams)	7.02
KEYSIGHT <-UMA Average TCP Throughput (Mbit/s) (10 streams)	4.1
KEYSIGHT ->UMA Average UDP Throughput (Mbit/s)	13.4
KEYSIGHT <-UMA Average UDP Throughput (Mbit/s)	55.9
KEYSIGHT ->UMA Average One Way Delay (ms) (at 5 Mbit/s)	48
KEYSIGHT <-UMA Average One Way Delay (ms) (at 5 Mbit/s)	49
KEYSIGHT ->UMA Average One Way Jitter (ms) (at 5 Mbit/s)	0.901

KEYSIGHT <-UMA Average One Way Jitter (ms) (at 5 Mbit/s)	2.28
KEYSIGHT ->UMA Average One Way Packet Loss (%) (at 5 Mbit/s)	5
KEYSIGHT <-UMA Average One Way Packet Loss (%) (at 5 Mbit/s)	0.02

As anticipated, the TCP link is severely affected by the distance and delay introduced by the VPN tunnel. It might surprise the LTE TCP connection is actually faster than the performance of the VPN tests. This is due to the huge fluctuation of the results observed during all these tests execution.

3.4 Performance Comparison between testbeds

The purpose of this section is to provide an overview of the performance of the distributed testbeds. Concerning the testbed located at KEYSIGHT (Aalborg), it is obvious the large distance (more than 3500 km) greatly impacts the final performance. On the other hand, DEKRA's testbed is performing well for most of the investigated KPIs; the only weak point are the TCP connections in the downlink.It should be noted the performance of the device itself will also influence the results. This is the underlaying cause for in some cases observing better results in DEKRA's testbed than in UMA's testbed.

KPI Name	**UMA**	**DEKRA**	**KEYD**
UL Average TCP Throughput (Mbit/s)	48.606	48.63	7.48
DL Average TCP Throughput (Mbit/s)	235.41	34.53	4.09
UL Average TCP Throughput (Mbit/s) (10 streams)	46.653	48.53	7.02
DL Average TCP Throughput (Mbit/s) (10 streams)	235.75	53.00	4.1
UL Average UDP Throughput (Mbit/s)	49.904	49.81	13.4
DL Average UDP Throughput (Mbit/s)	228.76	203.70	55.9
UL Average One Way Delay (ms) (at 5 Mbit/s)	14.93	24.69	48
DL Average One Way Delay (ms) (at 5 Mbit/s)	13.34	23.72	49
UL Average One Way Jitter (ms) (at 5 Mbit/s)	1.50	1.56	0.901
DL Average One Way Jitter (ms) (at 5 Mbit/s)	1.66	1.36	2.28
UL Average One Way Packet Loss (%) (at 5 Mbit/s)	0	0	5
DL Average One Way Packet Loss (%) (at 5 Mbit/s)	0	0	0.02

3.5 Feasibility and Impact on TRIANGLE Test Cases

3.5.1 DEKRA Distributed Testbed

The VPN between DEKRA and UMA could be a bottleneck in the TRIANGLE domain High Speed Internet access. The performance results obtained during the validation of the distributed testbed, and presented in Section 3.2.1 proved that there is an upper limit around 150 Mbit/s. The reason behind this limit is set by the DEKRA's (or UMA's) Internet service provider. This could be fixed by upgrading this link to higher capacity.

Another potential impact, also derived from the VPN link, is the stability of the link in terms of delay, jitter and packet loss. Poor values of those KPIs would have a dramatic impact on the performance of the 5G applications, which are implemented on top of the LTE UE TCP stack. However, based on the performance results obtained (section 3.2.3) the link between DEKRA and UMA has very low jitter values and no packet loss at all. Then, we assume that the distributed architecture does not have an impact on the TRIANGLE testbed capabilities.

We have observed that the VPN link introduces 15 ms of latency, which is to be added to the end-to-end latency budget of a local architecture of the test bed. We do not foresee that this lower limit of the latency implies any degradation on the user experience [3] KPIs such as response time or video freezing events. However, it could be relevant in the High Speed Internet Access domain, which may require very high throughout. This is not a concerning issue as it can be resolved by just tuning the TCP stack of the data endpoints.

Based on the considerations above, Table 14 summarizes an impact assessment on each individual TRIANGLE KPI class.

Table 14 – Impact on TRIANGLE KPIs

KPI	**Impact**	***KPI***	**Impact**
App Access Time (s)	High	*App Current Consumption*	Low
App Accessibility (%)	Low	*Current Consumption (A)*	Low
App Availability (%)	Low	*OTA DL U-plane throughput*	Medium
Content Load Time (s)	High	*OTA DL C-plane throughput*	Medium
Response Time (s)	Medium	*OTA UL U-plane throughput*	Medium
Feature Availability (%)	Low	*OTA UL C-plane throughput*	Medium
Content Stall (%)	Medium	*PDCP-SAP goodput UL/DL*	Medium
Content Search Time (s)	High	*Number of bearers*	Low
Content DL Throughput (Mbit/s)	High	*Number of transport connections*	Low
Content UL Throughput (Mbit/s)	High	*Burst inter-generation time at transport level*	Low
Content Resolution	Low	*Frame Loss Rate (%)*	Medium
Broadcast Content Resolution	Low	*Recovery after fail (%)*	Low

3.5.2 KEYD Distributed Testbed

Clearly, the performance of the Keysight Denmark distributed testbed will no fulfil the requirements of most 5G applications. However, the testbed still has great potential as a testbed for the Internet of Things market. These devices are characterized by extremely low data rates and by being delay tolerant.

4 Conclusions

The main outcome of the work described is the addition of two distributed testbeds to the TRIANGLE testbed, one located at DEKRA facilities in Málaga and the other at Keysight Denmark. These testbeds present an ideal test set, where one is relatively close (<100km) to the main testbed at UMA; and the second one is more than 3500 km away.

The results show that the distance plays a very important factor in the achievable performance. DEKRA testbed results show no significant impact on the TRIANGLE testcases; being the additional delay the only factor to be considered. On the other hand, the Keysight Denmark distributed testbed must be used with extreme care. Due to the significant delays, packet drops and limited performance of the testbed, only IoT related experiments can be run.

5 References

[1] D3.3 Report on Testing and Reporting Software Tools.

[2] D3.2 Report on the Implementation of Testing Framework Release 2 and Specification of Testing Framework Release 3.

[3] D2.2 Final Report on the Formalization of the Certification Process, Requirements and Use Cases.

1 Annex 1: DEKRA-UMA VPN Configuration

The following table summarizes the configuration parameters used by the VPN between DEKRA and UMA networks.

Table 15 – DEKRA-UMA VPN Configuration

Parameter	**Value**
Key Mode	IKE with Preshared Key
Local Group Setup	
Security Gateway Type	IP Only
IP address	150.214.47.150
Security Group Type	Subnet
IP address	10.102.81.0
Subnet Mask	255.255.255.0
Remote Group Setup	
Security Gateway Type	IP Only
Security Group Type	IP
IP address	10.10.0.128
IPSec Setup	
Phase 1 DH Group	Group 2 – 1024 bit
Phase 1 Encryption	3DES
Phase 1 Authentication	SHA1
Phase 1 SA Lifetime	86400
Perfect Forward Secrecy	True
Phase 2 DH Group	Group 2 – 1024 bit
Phase 2 Encryption	AES-128

Phase 2 Authentication	SHA1
Phase 2 SA Lifetime	28800
Advanced	
Keep-Alive	True
Dead Peer Detection Interval	10 s