5G Solutions for European Citizens

D4.7-D4.3B: LL performance evaluation and lessons learned v2

Document Summary Information

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V0.2	05/10/2022	30	Use Case Content Update	IRIS GLANBIA P&G ORBIS NTNU TNOR
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[1] According to 5G Solutions Quality Assurance Process:
1 month after the Task started: Deliverable outline and structure
3 months before Deliverable's Due Date: 50% should be complete
2 months before Deliverable's Due Date: 80% should be complete
1 months before Deliverable's Due Date: close to 100%. At this stage it sent for review by 2 peer reviewers
Submission month: All required changes by Peer Reviewers have been applied, and goes for final review by the Quality Manager, before submitted

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Glossary of terms and abbreviations used

Abbreviation / Term	Description
GW	Gateway
VM	Virtual Machine
WI-FI	Wireless Fidelity
TC	Test Case
UC	Use Case

1 Executive Summary

The following deliverable reports the findings and lessons learned of the LL1 UCs during the cycle 2 trials.

Specifically, the document focuses on:

- The qualitative analysis of the cycle 2 trials performed by LL1 use cases with respect to their architecture, deployment process and measured KPIs.
- Highlights in architecture from each use case, particularly from the KPI perspective to illustrate how current 5G capabilities can be leveraged for different applications in each use case.
- Next steps in order to evaluate and improve planning and developments for cycle 2 thus reflecting the latest improvement of the 5G infrastructure from the application perspective.
- Key decisions to keep evolving or stopping future cycle 3 trials.

2 Introduction

Following Cycle 2 completion, Cycle 3 will focus on the selection of the most mature Use Cases to be included in the final trials. Evaluation will be based on the possibility of each UC to provide:

- A detailed architecture and information flow diagram, including testbed components and software elements.
- Cross Domain Service Orchestrator (CDSO) and 5G facility orchestration requirements
- Visualization System (VS) requirements

The field trials implemented on Cycle 3 will be the evolution of Cycle 2 and will be considered the last iteration in order to achieve the target KPI of each case study.

Summarizing, this deliverable is the baseline for the 5G field trials for LL1, by creating, the test setup and architecture, purpose of the tests, challenge and mitigation measures, and also the next steps of the field trials for the factories of the future vertical.

2.1 Mapping Projects' Outputs

Purpose of this section is to map 5G Solutions Grand Agreement commitments, both within the formal Deliverable and Task description, against the project's respective outputs and work performed.

Table 1: Adherence to 5G-SOLUTIONS GA Deliverable & Tasks Descriptions

5G-SOLUTION Task	***Respective Document Charter***	***Justification***
Task 4.2 - Performance evaluation and lessons learned *The purpose of this task can be briefly described from the following three aspects. First of all, the performance of each use case will be evaluated, particularly from the KPI perspective to illustrate how current 5G capabilities can be leveraged for different applications in each use case. Secondly, according to the results received from each use case in every agile-based iteration, provide requirements and suggestions to further improve both functional and non-functional capabilities of 5G facilities. Following that, each use case will be further evaluated to reflect the latest improvement of the 5G infrastructure from the application perspective.* *This task will also provide and establish systematic feedback loops to WP1-WP3,*	*LL1 field trials Cycle 2 implementation and results.* *Chapter 3 provides qualitative analysis of Cycle 2 trials.* *Deliverable 4.7-4.3B contains qualitative analysis of the Cycle 2 tests and plans for Cycle 3 Trials.*	*Use Case 1.4 has run some experiments during Cycle 2 proving that 5G requirements are not strictly necessary for the use case, thus the use case will not run Cycle 3.* *Use Case 1.3 and Use Case 1.5 could not achieve Cycle 2.*

for continuous refinement. Results will be analysed both quantitively and quantifiably. Conclusions and recommendations will be drawn including recommendations for further trial validations. When possible, the impact of 5G deployment will be also analyzed so to potentially allow operators to evaluate their 5G network deployment scope, pattern and duration. Throughout the validation testing period, knowledge and findings will be documented in deliverable D4.3 together with evaluation reporting and impact assessment for the LL, and extracting lessons learned for internal dissemination among the consortium, capacity building and external dissemination as appropriate		
5G-SOLUTIONS Deliverable		
D4.3B LL1 performance evaluation and lessons learned (v2) reports per testing cycle, containing a critical evaluation and findings from the LL1, lessons learned, the degree the KPIs have been met and suggestions for improvements for Cycle 3.		

2.2 Deliverable Overview and Report Structure

Such deliverable has been defined in order to evaluate qualitatively the results of Cycle 2 trials, suggest lesson learned and recommendations to communicate findings with each of the use cases, to drive improvements during the implementation of each of the use cases. To this end, Section 3 of this deliverable will provide the description of the Cycle 2 trials performed during Cycle 2 for UC1.1, mainly since the other use case did not provided yet any information to include in the current deliverable. Moreover, UC1.4 will stop their activities for Cycle 3, thus just minimum information has been included.

3 LL1 Cycle 2 trials analysis of results, lessons learned & recommendations for Cycle 3 trials

3.1 UC1.1

The next points summarize qualitatively which has been the results of Cycle 2 trials for such a use case in comparison to the targeted KPI.

Moreover, a set of actions and recommendations are described in order to plan for future Cycle 3 trials.

3.1.1 Qualitative analysis of the results of Cycle 2 (KPIs vs reference KPIs)

The following table describes the results reported in the previous Deliverable D4.4 and adds the comparison with the targeted result and a brief description in case the KPI has not reached the target result expected.

Table 2: KPI Measurements Qualitative Analysis UC 1.1

Reference Test Case #	KPI	Trial Target (Reference KPI Baseline using other technology)	Trial Result	In case the KPI has not been achieved, a brief description about it.
TC1- UC1.1	Ping	<20ms	29ms	Partially achieved, using the Mobile 5G Phone less than 1 meter distance
	Downlink	Up to 1000 Mbps	269, 43 Mbps	The performance of the 5g is lower than expected due to the 5G AMARISOFT component of It is not a commercial device
	Uplink	Up to 1000 Mbps	23,21 Mbps	The performance of the 5g is lower than expected due to the 5G AMARISOFT component of It is not a commercial device
TC2 - UC 1.1	Transmission time (Image size: 854 Mb)	<20ms	37s	The size of the image is too big for the uplink speed that the 5G Node is being transferring.
	Downlink	Up to 1000 Mbps	269, 43 Mbps	The performance of the 5g is lower than expected due to the 5G AMARISOFT component of It is not a commercial device

	Uplink	Up to 1000 Mbps	23,21 Mbps	The performance of the 5g is lower than expected due to the 5G AMARISOFT component of It is not a commercial device

3.1.2 Cycle 2 detailed architecture and integration with the testbed, orchestrator and visualization system

Architecture is the same as the one described in D4.4

3.1.3 Lessons learned from Cycle 2 trials and recommendations

As has been commented in D4.4, such use cases have been divided into two sub use cases. The one linked to the Amarisoft node, can conclude that the trials of Cycle 2 have improved the result and the understanding about how to run trials, despite not reaching the target KPIs for the experiments.

On the other hand, the cycle has been used to extend the knowledge and understanding on the orchestration and creation of VNF. Despite those advancements, we do not see any benefit on the KPI Measurements done.

The experiments that have been done in IRIS simulating the industrial processes with the AMARISOFT node, demonstrate in comparison to Cycle 1 that the Node is configured for downlink rather than uplink, since the transmission speed is higher. Despite that, the node does not cover the expected transmission time needed for the industrial applications.

3.1.4 Planning for Cycle 3 trials

Cycle 3 will be dedicated mainly to improve the Use case based in the PGBS Facilities, which requires industrial commercial 5G Technology, mmWave. Such technology will be provided by a local Telecom operator, CITYMESH and will allow testing of such technology in order to test the limits of such technology indoors in an industrial environment. Such tests will take place during summer 2022 and will end up within a demonstration using similar cameras used at IRIS premises.

In reference to the AMARISOFT Node new configuration will be applied to the NODE in order to decrease the transmission time and lower it as much as possible to make the industrial application possible.

3.2 UC1.2

3.2.1 Qualitative analysis of the results of Cycle 2 (KPIs vs reference KPIs)

TCs 1 and 2 offered a good benchmark to evaluate the possible performance of the connectivity in the Glanbia plant. Since the results seen in cycle 1 were pretty poor, the biggest concern for cycle 2 was to arrange a setup that could allow us to run the tests required for the UC.

TCs 5 to 7 provided instead indications on the reactivity and usability of the application in a real production environment.

- TC01: Baseline tests over Wi-Fi using networking tools such as iperf for conditioning and coverage tests.

  Steps performed for the test:

  Open network cell info
  Verify that you are connected to the correct 5G node
  Record RSRP, RSSI, RSRQ, RSSNR values, repeat from at least three different positions form the node
  Open Hurricane Electric Network Tools
  Run Ping to a preselected IP address, repeat at least 3 times
  Run Traceroute to a preselected IP address, repeat at least 3 times

- TC02: Test wired connection between IIoT gateway and Kepware data collector.

  Steps performed for the test:

  Open Pinger
  Run Ping to a preselected IP address, repeat at least 3 times
  Open PingPlotter
  Run Ping to a preselected IP address, repeat at least 3 times

- TC05: Baseline tests over 5G using networking tools such as iperf for conditioning and coverage tests.

  Steps performed for the test:

  Open Network Cell Info
  Verify that you are connected to the correct 5G node
  Record RSRP, RSSI, RSRQ, RSSNR values, repeat from at least three different positions
  Open Hurricane Electric Network Tool
  Run Ping to a preselected IP address, repeat at least 3 times
  Run Traceroute to a preselected IP address, repeat at least 3 times
  Run Iperf 2 to Iperf 3 to a preselected server, repeat at least 3 times

- TC06: Test using IIoT gateway and generating traffic from the target sensor devices and handsets.

  Steps performed for the test:

  Open Network Cell Info
  Verify that you are connected to the correct 5G node
  Record RSRP, RSSI, RSRQ, RSSNR values, repeat from at least three different positions
  Open Hurricane Electric Network Tool
  Run Ping to a preselected IP address, repeat at least 3 times

Run Traceroute to a preselected IP address, repeat at least 3 times
Run Iperf 2 to Iperf 3 to a preselected server, repeat at least 3 times

TC07: Test 5G native, 5G gateway and 5G node.

Steps performed for the test:

Open the mobile application and navigate the home page
Record the latency

Table 3: KPI Measurments Qualitative Analysis UC 1.2

Reference Test Case #	KPI	Trial Target	Trial Result	Measurement Method
TC01- UC1.2	**Latency Avg**	**<20 ms**	**33 ms**	**Measure end-to-end Latency**
	Latency Std. Dev	**<5 ms**	**8 ms**	**Measure end-to-end Latency**
	RSRP	**>-102 dBm**	**-59 dBm**	**Measure spread signal**
	RSSI	**>-75 dBm**	**-113 dBm**	**Measure spread signal**
	RSRQ	**>-12 dBm**	**-6 dB**	**Measure spread signal**
	RSSNR		**30 dB**	**Measure spread signal**
	Packet Loss	**0**	**0 %**	**Measure from client**
TC02- UC1.2	**Latency Avg**	**< 1ms**	**0.234 ms**	**Measure end-to-end Latency**
	Latency Min	**<1ms**	**0.1 ms**	**Measure end-to-end Latency**
	Packet Loss	**0**	**0 %**	**Measure from client**

	Jitter	**<1ms**	**0 ms**	**Measure end-to-end Jitter**
TC05- UC1.2	**Packet Loss**	**0**	**0 %**	**Measure from client**
	Latency Avg		**33 ms**	**Measure end-to-end Latency**
	Latency Std. Dev		**8 ms**	**Measure end-to-end Latency**
	Throughput	**>100Mbps in download**	**iperf UDP Download: 145 Mbps Upload: 8.16 Mbps iperf TCP Download: 35.0 Mbps Upload: 6.81 Mbps**	**Measure Throughput per device**
	RSRP		**-59 dBm**	**Measure spread signal**
	RSSI		**-113 dBm**	**Measure spread signal**
	RSRQ		**-6 dB**	**Measure spread signal**
	RSSNR		**30 dB**	**Measure spread signal**
TC06- UC1.2	**Latency AVG**		**45 ms**	**Measure end-to-end Latency**
	Latency Std. Dev		**10 ms**	**Measure end-to-end Latency**
	RSRP	**>-102 dBm**		**Measure spread signal**
	RSSI	**>-75 dBm**		**Measure spread signal**
	RSRQ	**>-12 dBm**		**Measure spread signal**

	RSSNR			**Measure spread signal**
	Packet Loss	**0**	**0 %**	**Measure from client**
TC07- UC1.2	**API Latency**	**<100ms**	**69 ms**	**Measure API latency**
	Rendering Latency	**<500ms**	**886 ms**	**Measure rendering time**

The network KPIs are under control even though they don't meet the target (TC01 shows latency values above the target with the 5G node)

Application KPIs ensure a basic usability of the mobile application, but they don't allow exploiting AR or similar technologies.

3.2.2 Cycle 2 detailed architecture and integration with the testbed, orchestrator and visualization system

All interfaces and integrations are unchanged from cycle 1. The deployment on Glanbia servers required a setup inside Glanbia's firewall.

3.2.3 Lessons learned from Cycle 2 trials and recommendations

We used the experience from cycle 1 to overcome the main obstacles the 5G node performance throwed on our project with discrete success. We managed to run all the tests we forecast despite the results not always good.

3.2.4 Planning for Cycle 3 trials

Cycle 3 will replicate the same tests on the Amarisoft 5G node. Glanbia pushed further with Three (5G public mobile operator) to expand the coverage of the public 5G network on the plant and run the tests without the Amarisoft node to compare the eventual performance with a real 5G network.

3.3 UC1.3/UC1.5

Since the required infrastructure was not available during Cycle 2, the following results show the KPIs with the improved architecture mentioned in D4.2B.

3.3.3 Qualitative analysis of the results of Cycle 2 (KPIs vs reference KPIs)

Table 4: KPI Measurements Qualitative Analysis UC 1.3/UC1.5

Reference Test Case #	KPI	Trial Target	Trial Result	In case the KPI has not been achieved, a brief description about it.
TC1- UC1.3	UL Throughput	> 500 Mbps	90 Mbps	Likely to be improved with local 5G node

TC2- UC1.3	DL Throughput	Order of Mbps	380 Mbps	
TC5- UC1.3	Latency – 5G	< 10 ms	17.5 ms	Likely to be improved with local 5G node

3.3.4 Lessons learned from Cycle 2 trials and recommendations

We see improvements in the test results compared to Cycle 1 due to utilizing the MNO's network. The results are likely to improve even more when an SA core becomes available during Cycle 3.

3.3.5 Planning for Cycle 3 trials

Work on getting 5G-VINNI ready is still ongoing. We are expecting it to be in operation in time for Cycle 3 trials.

3.4 UC1.4

The next points summarize qualitatively which has been the results of Cycle 2 trials for such a use case in comparison to the targeted KPI.

Moreover, a set of actions and decisions are described in order to face Cycle 3 trials.

3.4.3 Qualitative analysis of the results of Cycle 2 (KPIs vs reference KPIs)

The following table describes the results reported in the previous Deliverable D4.4 and adds the comparison with the targeted result and a brief description in case the KPI has not reached the target result expected.

Table 5: KPI Measurements Qualitative Analysis UC 1.4

Reference Test Case #	KPI	Trial Target (Reference KPI Baseline using WIFI)	Trial Result	In case the KPI has not been achieved, a brief description about it.
TC1- UC1.4	Transfer time	14 ms	53 ms	The trial has not reached the KPI in comparison to the WIFI Baseline. The reasons why are diverse, but mainly due to the low performance of the hardware used.
	Bandwidth	64 Mbps	12 Mbps	The trial has not reached the KPI in comparison to the WIFI Baseline. The reasons why are diverse, but mainly due to the low performance of the hardware used.

3.4.4 Cycle 2 detailed architecture and integration with the testbed, orchestrator and visualization system

There is no further explanation on the architecture.

3.4.5 Lessons learned from Cycle 2 trials and recommendations

Such trials have demonstrated that the WIFI covers the requirements of the use case, thus at this stage 5G technology is not strictly necessary.

3.4.6 Planning for Cycle 3 trials

Due to the previous information and results, it's been decided to stop activities of such use case for Cycle 3.

4 Conclusions and Next Actions

To achieve Cycle 2 trials, each of the Use Case owners has faced many difficulties in order to implement and upgrade each of the test beds in comparison to Cycle 1.

In cycle 2 deployment processes were defined and tested in the most mature use cases UC1.1 – UC1.2 –

UC1.4. The main points to overcome during Cycle 3 LL1 trials are:

- *New 5G Technologies are needed in order to improve the KPI Requirements from UC1.1*
- *New trials will be implemented under UC 1.2 in order to allow service virtualization and CDSO connectivity.*
- *UC1.3 and UC1.5 will make their best to implement trials once the 5G VINI Infrastructure is ready.*
- *UC 1-4 has decided to stop their trial activities since the use case requirements are not strictly necessary engaged to used 5G Technology.*

During the next months, the use case owners will face key moments to take decisions in order to demonstrate an improvement of 5G in comparison of Cycle 1 and 2 or to stop activities since the potential improvements will not bring any big step forward on the KPI Measurements.