GRANT AGREEMENT No. 857034

Call: H2020-ICT-2018-2020
Topic: ICT-19-2019
Type of action: RIA

5G HEalth AquacultuRe and Transport validation trials

D6.2: Final Trials Plan

Revision: v 1.1

Work Package	WP6
Task	Task 6.1
Due date	M31 – 31 December 2021
Submission date	07 Jan 2022
Deliverable lead	WINGS ICT Solutions
Version	1.1
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Abstract	This deliverable describes the final trials plan based on the planning process up to M42. It provides a roadmap for the components' readiness, the activities that will take place during the final third period especially with regards to the execution of the trials and the connection between those activities and the 5G

	platforms. It also provides a short description of activities and a description of activities for Phase 2.
Keywords	5G, trials, planning, verticals

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Project co-funded by the European Commission in the H2020 Programme		
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Dissemination Level		
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* R: Document, report (excluding the periodic and final reports)

DEM: Demonstrator, pilot, prototype, plan designs

DEC: Websites, patents filing, press & media actions, videos, etc.

OTHER: Software, technical diagram, etc.

EXECUTIVE SUMMARY

This deliverable describes the final plans for the three verticals of Health Aquaculture and Transport of 5G-HEART. The timeline of the trials is structured in three phases:

- **Phase 1 (June 2019-May 2020)**: Components assembling – lab testing
  This phase is dedicated to the development of the main building components in terms of infrastructure, key-enablers, as well as methods to validate the Key Performance Indicator (KPI) metrics.
- **Phase 2 (June 2020 – November 2021)**: Advancing technical work
  In the second phase of the work is concentrated to advance the technical maturity of the 5G infrastructure, continue the testing of components in lab premises and extend the work to larger experimentation environments.
- **Phase 3 (December 2021 – November 2022)**: Further implementing in field trials
  The final phase of the project will combine all developments into integrated large-scale field trials and demonstrations

The preparation of a detailed final trials plan is necessary for the overall organization of the trials across the 5G facility sites and vertical domains. The organization of this deliverable includes a description of the trials that are planned to take place in Phase 3 (December 2021 – November 2022), description of the components that are going to be used during the final trials and an update of the testbeds and infrastructures that are going to be used.

This deliverable takes input from T3.2, T3.3, T4.2, T4.3, T5.2 and T5.3 so as to eventually deliver an overall schedule for the final trials. This plan will be delivered back to the aforementioned Tasks as input for final validation. Trial planning includes first stand-alone vertical/application trials, before proceeding with the concurrent trials of multiple vertical/applications on top of the same infrastructure.

In this deliverable, the final trials plan is described, where the definition of the vertical use cases as well as information on the per-scenario / subcase planning is provided. In addition, a roadmap for the remaining implementation work and upcoming activities that are considered as the trials progress are defined. The analysis of this information and the identification of specific overlaps and conflicts is an important part of the plan. The outcome of this analysis aims to provide a basic time plan of the final-trial activities, while identifying risks that are imposed by the COVID-19 pandemic. Additionally, it provides feedback to the vertical work packages as well as to the platform owners with the necessary information to plan their activities and coordinate effectively to resolve any upcoming trial scheduling conflicts.

The deliverable puts the grounds for the organization and timeline roadmap of the final trials for all scenarios of the three verticals. It presents the status of the infrastructure and the testbeds that are going to be used in the final trials. It also describes the final equipment, methods, technologies that are going to be used and implemented during the final trials. It is apparent that restrictions due to COVID-19 have caused significant delays especially to the facility visits for measurements, integration, etc. However, the partners have extended their effort towards contributing to the finalisation of the work needed to complete the tasks leading to the final trials. Additionally, work performed in Phase 2 trials is overviewed for the purpose of presenting the advancement of work performed from Phase 2 to Phase 3.

The preparation of 5G infrastructures SA or NSA is finalised for all the three verticals and some initial results already are taken from the field trials from some scenarios. This work will continue to lead to the testing of the performance, evaluation of the Key Performance Indices (KPIs) and assessment of the scenarios.

The upcoming deliverables D6.3 and D6.4 will provide measurement tools for the assessment of the KPIs and evaluation of the technical solutions of the different scenarios, respectively.

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ABBREVIATIONS

3GPP	3rd Generation Partnership Project
4G	4th Generation wireless systems
4K	3,980x2160 pixel resolution
5G	5th Generation wireless systems
5G NR	5G New Radio
5G PPP	5G Infrastructure Public Private Partnership
5G-HEART	5G HEalth AquacultuRe and Transport validation trials
8K	7680x4320 pixel resolution
AI	Artificial Intelligence
AR	Augmented Reality
BLE	Bluetooth Low Energy
CHD	Congenital Heart Disease
F-CNN	Fully Convolutional Neural Networks
COTS	Common Off-The-Shelf
CPM	Collective Perception Message
CPU	Central Processing Unit
DAG	Directed Acyclic Graph
DL	Downlink
DNL	Digital Navigation Link
DOF	Degree of Freedom
ECG	Electrocadiogram
eMBB	enhanced Mobile Broadband
eNodeB / eNB	Evolved Node B (4G)
EPC	Evolved Packet Core (4G)
FPGA	Field-Programmable Gate Array
GNSS	Global Navigation Satellite System
GP	General Practitioner
GPU	Graphics Processing Units
HAZMAT	Hazardous Material
HD	High-Definition
HR	Heart Rate
HTTP(S)	Hypertext Transfer Protocol (Secure)
HW	Hardware
I/O	Input/Output
ICT	Information and Communications technology
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet-of-Things
IP	Internet Protocol
IT	Information Technology
KPI	Key Performance Indicator
LoRA	Long Range
LOS	Line Of Site
LPWA	Low Power Wide Area
LTE	Long-Term Evolution
MEC	Multi-access Edge Computing
MF-PDoA	Multi-frequency phase difference of arrival
mMTC	Massive Machine Type Communications
MQTT	Message Queuing Telemetry Transport
NB-IoT	Narrow-Band IoT
NLOS	Non- Line of Sight
OAI	Open Air Interface

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OMR	Obstacle Misdetection Rate
PHP	Personal Home Page
PI	Performance Index
PoF	Phase of Flight
QoE	Quality-of-Experience
QoS	Quality-of-Service
RAM	Random Access Memory
RAN	Radio Access Network
RF	Radio Frequency
RMS	Root Mean Square
RSSI	Received Signal Strength Indicator
RTP	Real-Time Transport Protocol
RTSP	Real-Time Streaming Protocol
SNR	Signal to Noise Ratio
STUN	Session Traversal Utilities for NAT
TCP	Transmission Control Protocol
TDoA	Time Difference of Arrival
TURN	Traversal Using Relay NAT
UDP	User Datagram Protocol
UE	User Equipment
UL	Uplink
URLLC	Ultra-Reliable Low Latency Communications
USAR	Urban Search and Rescue
USB	Universal Serial Bus
USRP	Universal Software Radio Peripheral
Wi-Fi	Wireless Fidelity
WP	Work Package

1 INTRODUCTION

The main objective of this deliverable is to provide a timeline of the final trials for the scenarios of the the Health, Transport and Aquaculture verticals. The objective of T6.1 is to organise a detailed planning and coordination of the deployment activities regarding the preparation of the needed infrastructures and the deployment activities of the scenarios for the three verticals. T6.1 takes input from previous tasks of T3.1, T4.1 and T5.1 and D6.3 takes input from D3.3, D4.3 and D5.3, as seen in Figure 1. As discussed in previous deliverables, the trials' delivery has been split into three different phases and each one provides its own maturity level of implementation, along with the corresponding KPI measurements and results. The Phase 1 and Phase 2 trials are completed and plans for Phase 3 are presented in this deliverable.

The general methodology that is followed for the implementation of the Phase 3 trials is split into different layers as it will become clear from the following chapters. Specifically, an overview of the trial setup distributes the verticals across 5 different 5G platforms, namely 5G-VINNI, 5GENESIS, 5G-EVE, 5Groningen and 5GTN. A unique methodology has been defined for each vertical, which has been split into different use cases that cover the relation of each part of the vertical trials to specific parts of the industry. These concepts are analytically described in the relevant vertical deliverables (see D3.3 [3], D4.3 [4] and D5.3 [5]) and in this deliverable we are going to present the whole picture of the work to be done at the final trials in the project.

1.1 Deliverable Overview and Report Structure

In this section, a description of the deliverable's structure is provided, outlining the respective Chapters and their content, as follows:

- **Chapter 1:** Includes the executive summary and the introduction on the objectives of the T6.1 in relation to 5G-HEART project outputs and the main contents of this deliverable. Moreover, it presents a linkage to other deliverables as follows:
    - Inputs from other deliverables utilised in this report
    - Outputs from this report utilised by other deliverables
- **Chapter 2:** Provides a description of the work performed in Phase 2 and the planned work in Phase 3 for the healthcare vertical.
- **Chapter 3:** Provides a description of the work performed in Phase 2 and the planned work in Phase 3 for the transport vertical.
- **Chapter 4:** Provides a description of the work performed in Phase 2 and the planned work in Phase 3 for the aquaculture vertical.
- **Chapter 5:** Provides an overall planning for the verticals.
- **Chapter 6:** Overviews the evaluation planning and work done in other deliverables.
- **Chapter 7:** Concludes the deliverable.

1.2 Linkage to other project outputs

This section briefly shows how the work reported in this deliverable contributes to the general development pipeline of the project. Moreover, it presents a linkage to other deliverables as it is seen in Figure 1:

- Inputs from other deliverables utilised in this report
- Outputs from this report utilised by other deliverables

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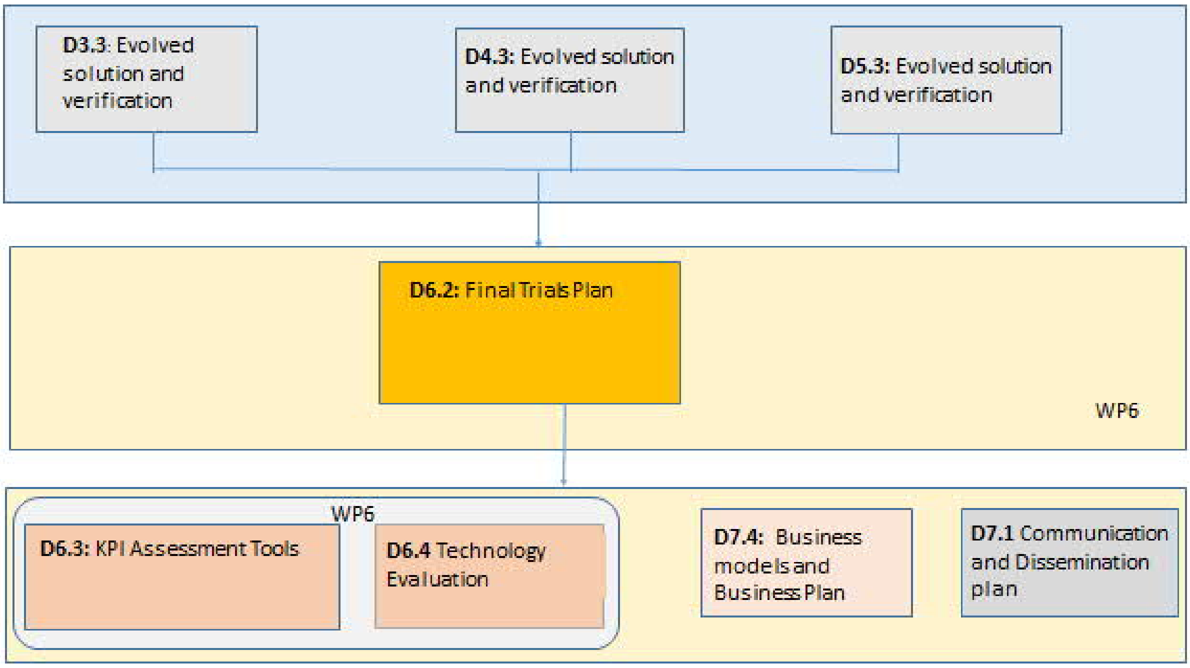

Figure 1. Linkage of D6.2 to other deliverables.

Table 1: Contributions of D6.2 from and to the rest of the project deliverables

5G-HEART deliverable	Deliverable Chapter(s)	Contribution and value of linkage
INPUTS from other deliverables <u>utilised in this report</u>		
D3.3: Evolved solution and verification	Chapter 2, Chapter 5	Phase 2 trials of healthcare
D4.3: Evolved solution and verification	Chapter 3, Chapter 5	Phase 2 trials of transport
D5.3 Evolved solution and verification	Chapter 4, Chapter 5	Phase 2 trials of aquaculture
OUTPUTS from this report <u>utilised by other deliverables</u>		
D6.3: KPI assessment tools	-	Planning of Phase 3 trials
D6.4: Technology evaluation	-	Planning of Phase 3 trials
D7.1: Communication and Dissemination plan	-	Contribution to dissemination
D7.4: Business models and Business Plan	-	Contribution to business modelling from each vertical

2 HEALTHCARE VERTICAL TRIAL PLANS

2.1 Description and methodology

5G-HEART healthcare use cases are clearly motivated by the clinical cases and improvements for the involved stakeholders. Three main use cases subdivided into eight subcases are pursued in 5G-HEART. Each subcase is treated independently from the other subcases, while common activities between subcases are organised, especially between the ones using the same platforms and resources. The tests are performed using test platforms in Norway (5G-VINNI), Finland (5GTN) and the Netherlands (5Groningen), while concurrent trials with the other verticals are planned for the final implementation stages. Some developing activities will also use commercial services in the Netherlands and special test facilities in France.

Under the common concept of "Remote interventional support", four different subcases are explored. *Educational surgery* is about using a video platform providing a near real-time feed from an operational facility towards a classroom for educational purposes. *Remote ultrasound examination* is about enabling an expert to guide a remote General Practitioner (GP) or paramedic in performing ultrasound examinations and ultrasound guided intervention. This subcase is now explored with two different setups, one using AR/VR as a tool for remote ultrasound guidance and diagnosis, and one pursuing the use of assisted robotics in which the expert remotely controls the ultrasound probe. 5G can connect a healthcare professional responding to medical emergencies providing *Paramedic support* by a medical expert located at a hospital or medical facility. In the case of a *Critical health event*, using wearable video can provide higher situational awareness for a mass causality supervisor and scene commanders. The second main use case is the *Pill-camera*, in which we will test real-time transmission with feedback control of a wireless colon capsule to improve screening diagnosis of, e.g., colon cancer. The third main use case, "Vital-sign patches with advanced geolocation", intends to develop a disposable *Vital-sign patch prototype* for monitoring ambulatory patients, anytime and anywhere, and to develop a *Localizable tag* technology needed to be able to position tags within a few metres.

As the first step of the three-phased approach for trials and validations, the phase-I trials was able to gather clinical requirements to be able to enable meaningful innovation in healthcare and validate the performance of the existing or initial solutions using mature state-of-the-art wireless communication technologies (4G/LTE, Wi-Fi, etc.). This serves as a baseline for the future trials using 5G. Trials have involved and been observed by project partners and other stakeholders in the healthcare sector. Completed trials have provided insights about advantages and disadvantages of existing/initial solutions, as well as aspects to be improved. During phase 2 trials intermediate setups have been developed and many of the subcases have been connected to the 5G test platforms. Further clinical tests have been performed as well relevant network KPI assessments. Now moving into the Phase 3 of the trials, the final solutions will be developed, tested and evaluated.

2.2 The work produced in Phase 2

In this section a short description of the work performed at the trials in Phase 2. It is outlined for reasons to easily depict the updates planned for Phase 2. The solutions include infrastructure developments, tests performed in the field and also if KPIs were measured.

Note, that the contents of Table 2 are verbatim copies of the executive summary of D3.3. They are repeated here for reader convenience.

Table 2: Outline of the work performed in Phase 2

(Sub) Use case	Outline the work performed in trials	Platform and location
H1A	Multiple single lens cameras were added to the video streaming platform, complementing the 360° camera introduced in phase-1. This	5GTN, Oulu, FI

	way application latency could be reduced, and video quality could be improved. Different test cases to evaluate the impact of network and protocol on delay have been conducted on the 5GTN NSA network. The first test case involved measuring network delay for the 360º camera feed (13 Mb/s) running over RTMP. This showed that 5G can help reduce the delay by as much as 70% compared to LTE especially in the uplink, which can be considered as a significant improvement, particularly in live, remote, education/consultancy sessions, where near real-time communication is required. The subsequent batch of test cases involved measuring network delay for a single lens camera feed comparing two different low latency protocol candidates, namely RTMP and RTSP/RTP (both running over TCP). The differences between both candidates were found to be very small. The final test involved measuring network delay for both of these protocol candidates under an increasing network load of other traffic. The network delays were measured to be 12 ms in the UL and 6 ms in the DL. End-to-end latency from camera capture to player display well under 200ms. Beyond a load of 40 Mb/s the network started to experience congestion and both RTMP and RTSP/RTP showed a sharp increase in network delay, with little difference between the protocols themselves. This increase in delay is the result of TCP retransmissions, partly caused by the non-prioritized scheduling in the small cell. Although, RTSP/RTP could alternatively be carried over UDP this was not attempted, considering that NATs and firewalls could become a problem. In addition to the delay measurements, Oulu University hospital, with assistance from VTT, have teamed up with RedZinc to conduct trials with the RedZinc wearable video solution, but those ongoing trials will be reported in D3.4.	
H1B CHD	A live demonstration of a remote ultrasound examination session was casted from Oslo, while operating over the 5G-VINNI network. This demo was part of the first 5G-HEART project review meeting in June 2021 and was based on the commercially available EPIQ / Collaboration Live solution by Philips. However, post-demo analysis of the logs uncovered that the audio, video, and ultrasound streams were routed via the Internet instead of staying within the core network. This issue needs further investigation, as keeping traffic local to dedicated slices is essential for reliable and trustworthy deployment of critical care solutions. OUS has started to conduct two sets of clinical trials using Philips' EPIQ / Collaboration Live. Although the research is still ongoing, some preliminary results are available indicating the feasibility of: (1) inexperienced students conducting crude examinations of the heart through remote guidance (N=11), and (2) relatively inexperienced doctors, supported by a remote paediatric cardiologist, reaching a correct treatment plan for a neonate with suspected Congenital Heart Disease, (CHD), as to whether admit the patient to a paediatric heart centre (N=3). Philips is developing prototype solutions beyond EPIQ / Collaboration Live. Specifically, a first iteration of an AR-based interface has been created, where the ultrasound is shown as a virtual window in the workspace of the local paediatrician. Next to that, the workspace is captured by two Azure Kinect cameras. Performance limits of WebRTC data channels (50 Mb/s) and the limited processing power on AR headsets are among the challenges to address, also considering that a first estimate of the total bandwidth requirements could be as high	5G-VINNI, Oslo, NO and 5G networks in the Netherlands (5Groningen and 5G-Hub in Eindhoven)

	as 650 Mb/s. Also, real-time streaming of Digital Navigation Link, (DNL), ultrasound data over a reliable WebRTC data channel poses some challenges for the next phase.	
H1B Robot	A clinical study is in preparation to assess the effectiveness and efficiency of the remotely controlled ultrasound robot in capturing cardiac ultrasound images. More specifically, the capture of the parasternal long axis, parasternal short axis, and apical four chamber views will be addressed. The time to capture and the quality of the image captured during a remote exam, performed on a healthy volunteer, will be compared to those of a "golden standard" exam performed by an expert operating the ultrasound probe directly on the volunteer. Specific attention will also be given to accurately measuring chamber dimensions and flow rate. A safety risk analysis has been performed in order to obtain approval for the clinical study. Also, a couple of preliminary tests have been performed with the technical setup. These suggest that it is indeed possible to capture ultrasound images of sufficient quality, in order to perform measurements, and to do so within an acceptable timeframe. During those tests it became apparent that the robot may get locked while changing view positions. To remedy that problem, a new 3D-printed probe holder has been developed to adjust the angle at which the probe is held by the robot arm.	5G-VINNI, Oslo, NO
H1C	Trials were conducted at a warehouse in the province of Groningen, the Netherlands, on September 29th and 30th, 2021. These trials, following-up on the March 2020 phase-1 trials involved TNO, RedZinc and Ambulancezorg Groningen, evaluating the RedZinc wearable video solution that was integrated on the medical manager's dashboard with a Corpuls® patient monitoring device. The trials comprised evaluating 5G network performance, as well as usability by healthcare professionals i.e., paramedics and the medical manager. The network performance tests addressed the feasibility of delivering video via the 5G SA network installed in the warehouse. These tests involved measuring throughput (UL/DL) and round-trip time between a 5G SA smartphone and ping / iperf3 servers on the edge, on the same locations as where the usability tests were performed. An average latency of 10 ms and an average throughput of 80 Mb/s on the uplink and 290 Mb/s on the downlink were measured. Furthermore, stopwatch measurements of the RedZinc video solution (with server on the Internet in Frankfurt) showed an average 350 ms end-to-end latency. The usability tests were conducted pretty much in the same way as during the phase-1 trials and involved enacting three different clinical cases with the help of a volunteer (actor) trained in medical simulations. Compared to the phase-1 trials, the RedZinc video headset features an improved ergonomic design with higher resolution (2 megapixel) and wider viewing angle (158 degrees) and also the accompanying BlueEye mobile app has undergone several improvements. These video quality improvements paid off, but for some use cases (e.g., viewing a wound or an Electrocardiogram, (ECG) printout in detail) picture snapshots were preferred over video. Furthermore, several additional improvements to the RedZinc wearable video solution were proposed e.g., camera position in middle of forehead, longer cable to phone, switchable noise cancellation, and mounting a microphone on the headset.	5Groningen, Groningen, NL
H1D	The RedZinc BlueEye solution was trialled in June 2021 during a training event of the Oslo Ambulance Service. The focus of these	5G-VINNI, Oslo, NO

	qualitative trials was put on user experience, leveraging Telenor's commercial 4G network in Oslo. Note that quantitative trials to evaluate the performance over 5G are anticipated for phase-3, leveraging either a commercial 5G deployment or the 5G-VINNI facility. Two scenarios, one with a focus on Hazardous Materials, (HAZMAT) and one on USAR (Urban Search and Rescue), have been played out. Several runs of the experiments were conducted with several groups, each group comprising two people on the scene and a remote incident commander. Several practical issues with the BlueEye solution were identified and have since been rectified or are being rectified, leading to an improved design of device and service. Overall, the concept was very well received by the ambulance service, quoting better situational awareness, better cooperation with fire brigade and police, and improved confidence as key advantages, and good picture quality (even from within a positive pressure suit) and sufficient battery life as technical highlights.	
H2A	OUS has continued the development and technical evaluation of their colon cancer screening solution. The envisaged solution comprises a swallowable capsule that travels through the intestines to record video images and transfer them to a body-worn modem via energy-efficient, backscatter communications, which in turn forwards the images via 5G to the Edge to enable real-time, AI-based analysis for polyp detection. A feedback channel is anticipated to control the resolution and lighting settings of the capsule to optimize capture for suspected anomalies in real-time, while minimizing energy expenditure. The backscattering transceiver on the capsule side comprises a single switching gate that consumes very little energy (10 pJ/bit), prolonging battery life and minimizing cost. It has been developed for data rates up to 16 Mb/s and shown to work for up to 10 Mb/s. For the AI-based analysis, a CNN-based, encoder-decoder network is used to predict a 2D Gaussian shape. This network (ResNet34, trained on the ImageNet dataset) is based on the U-Net family, which is specifically developed for medical image segmentation, and capable to deal with a limited amount of available training data, while operating in real time. The benefits of 2D Gaussian masks over binary ones have been demonstrated. A sensitivity of 82% and a precision of 90% has been achieved, while processing up to 100 frames-per-second on an NVIDIA RTX 3090 GPU. Different in-system latencies have been evaluated as well.	5G-VINNI, Oslo, NO
H3A	Extensive experiments using an automated test framework have demonstrated that a vital-signs patch for monitoring post-surgery patients is feasible from an energy consumption perspective. Complementing the phase-1 experiments, this is still found to be valid in case of relatively poor coverage (~ -130 dBm) for LTE-M, while using Cloud-native data ingest protocols (HTTPS / OAuth 2.0). The straightforward optimization of extending OAuth token lifetime sufficed to reach this result. Furthermore, an investigation of a broader class of potential vital-sign patch propositions has revealed that their communication requirements – in terms of number of uploads and amount of payload per upload – are in the same ballpark as for the post-surgery case. Nevertheless, a more in-depth study has been conducted – and still continues – to further optimize energy usage. However, insufficient coverage has been identified as a potential threat to a broad uptake of vital-signs patches. The combination of LTE-M's CE Mode B not being supported by operators and the small antenna worn close to the	Commercial network, NL

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	body causes a loss of a few dB in comparison to a regular LTE-phone. To make matters worse, indoor coverage enhancements such as DAS and small cells for hospitals and VoWiFi for homes often do not address LTE-M or NB-IoT. Furthermore, an ecosystem approach will be needed to have any roaming plan purchased by the patch manufacturer interoperate with any in-hospital cellular deployment. A new study was started to address this coverage issue by investigating to what extent NB-IoT with a very lean – non-Cloud native – data upload protocol could be part of the solution. Preliminary results reveal that a ~12 dB gain over LTE-M seems feasible, while still remaining in the right ballpark for energy consumption. A third study to investigate the potential benefits of lower transmit power (power class 6) on battery dimensions has been discontinued as outlooks were poor.	
H3B	The phase-1 experiments on the CEA campus have been extended during phase-2 with in-building trials, addressing both LOS and NLOS propagation. Besides, the initial multi-channel phase-of-flight simulations from phase-1 have been extended. Multi-frequency phase difference of arrival (MF-PDoA) has been studied to extend the work to synchronized base stations, and to remove the constraints of two-way ranging. The results from simulations and field trials are consistent but yet complementary. In comparison to legacy ToF, in LOS scenarios the ranging accuracy (RMS) is reduced from 180 to 4 m and for NLOS scenarios from 190 to 42 m. The latter results are in the same order of magnitude as the multipath outdoor measurements on campus from phase-1 which showed an improvement from 250 to 30 m. The proposed concept Phase of Flight (PoF) is sufficiently flexible to be advantageously adapted to 5G-NB-IoT evolutions, as long as frequency hopping mechanisms is considered.	CEA Lab, Grenoble, FR
H3C	A setup has been realized to safeguard the health and safety of workers in the aquaculture industry, considering that they are exposed to many occupational hazards such as sprains, strains, fractures, cuts, amputations, musculoskeletal injuries, hypo-/hyperthermia, back/neck/shoulder pain, sunburn, keratitis, cataract, pterygium, blindness, tendonitis, tenosynovitis, bursitis, and carpal tunnel syndrome, as well as psychological risks. WINGS proposes a combination of remote health monitoring of the workers, and remote support for the caregivers or supervisors of the aquaculture area, to adequately address these hazards and risks. For the remote health monitoring, a setup is being realized with the Withings ScanWatch measuring vital signs (ECG, SpO2, etc.) and other health-related information, and uploading them via a 5G compatible phone into WINGS' STARLIT Cloud platform for analytics and visualization. As for the analytics part, a deep convolutional neural network is developed to analyse the ECG signal, while predictive algorithms for SpO2 have also been developed. Notifications/alerts, based on this analysis, are raised in case health issues/emergencies are identified, or future issues are forecast. For the remote support, Vuzix' smart glasses with live streaming via a Messenger Application have been tested. Considering that this subcase was only recently added to the 5G-HEART healthcare vertical, the clinical and technical validation of the concept is planned for the next phase of the project.	5G-EVE, Athens, GR

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2.3 The work planned to be done in Phase 3

Phase 3, (December 2021-November 2022), is the final phase of the project, in which case the final set-ups and trials are going to be demonstrated, in addition measurement of network KPIs and production Performance Indices (PIs) are going to be taken and assessment of the trials will be performed.

Table 3: Description of the work to be performed in Phase 3

(Sub) Use case	Description of the planned work for Phase 3	Platform and location
H1A	• Live demonstrations using 5GTN and 5G-VINNI with the proposed live streaming setup during Spring 2022. • 5G SA measurements as a continuum to NSA. • Dynamic video adaptation techniques to improve capability against uplink fluctuations. • Real-time heartbeat sensor data migration on top of the video as an overlay. • Testing the proposed setup also in mobile vehicular scenarios. • Assistance in the field trials with RedZinc and Oulu University Hospital, evaluation of the RedZinc equipment with 5GTN.	5GTN, Oulu, FI 5G-VINNI, Oslo, NO
H1B CHD	• Exploration of WebRTC streaming over 5G, including edge deployment and optimal ways for reliable, real-time streaming of ultrasound data. • Clinical evaluation of EPIQ / Collaboration live for remote ultrasound examination of adult cardiac and for CHD. • Exploration of 3D and DNL streaming over WebRTC. Subject to resolving issues with existing WebRTC platforms. • Evaluation of some of the above on Stand Alone (SA) with KPI measurements.	5G-VINNI, Oslo, NO and/or 5G networks in the Netherlands (5Groningen and 5G-Hub in Eindhoven)
H1B Robot	• Exploration of long-distance robotic teleoperation using the upgraded robotic system that includes a new 3D printed part and video solution with three fixed cameras and ultrasound video. • Evaluation of system transparency in terms of slave robot manipulation and force feedback through the 5G network. • Evaluation of the system's telepresence using a video solution by having clinical study over healthy volunteers • Clinical evaluation of different control modes of the robotic system • Providing safety documentation and risk assessments that are compliant with the Norwegian Medicines Agency	5G-VINNI, Oslo, NO
H1C	• Further evaluation of ultrasound • Extending Phase 2 with mobility and slicing in a joint-trial with T2S1	5Groningen, Groningen, NL
H1D	• To conduct a controlled experiment, involving several scenarios, in which the effectiveness and efficiency of the legacy method is compared to those of the newly proposed method. The application-level KPIs to be assessed in the comparison are time to completion and procedure error minimization. • To conduct the network (quantitative) tests	5G-VINNI, Oslo, NO

H2A	• Solve challenges of related to the formatting of the video data from the camera module, which is not adapted to the backscatter communication system. • Develop an Field Programming Graphics Array, (FPGA) based system to display the streamed video, or to make changes in the backscatter reader to support the new data format. • Integrate a simple receiver in the capsule, to program the capsule on-air, to change the data rate or format on request. • Investigate the abovementioned latency issue with HTTP/TCP and will try to reduce it by testing different User Datagram Protocol (UDP) based protocols, or, if possible, by enabling slicing technology in the 5G-VINNI core network, in order to provide priority to the video stream. • Develop a faster and more accurate AI model that takes the temporal information between the frames into consideration, in order to make output decisions and generate feedback signals to the client PC / PillCam more reliably.	5G-VINNI, Oslo, NO
H3A	• Wrap up upload protocol study by assessing benefits of session resumption (subject to proper support by relevant modem vendors). • Complete study on the potential of NB-IoT to solve the coverage concerns (subject to proper support by relevant modem vendors). • Smalls study on feasibility of firmware-over-the-air updates.	Commercial network, NL, possibly also 5G-VINNI, Oslo, NO
H3B	• Final field trials in the city of Grenoble • More advanced demonstrations • Final localization algorithm validation	CEA Lab, Grenoble, FR
H3C	• Field trials in the Skironis aquaculture area demonstrating the use case scenario • Measuring KPIs • Involvement of medical expert	5G-EVE, Athens, GR

2.4 Component readiness roadmap

In the following sections, the network infrastructure and components that are going to be used in Phase 3 are described.

2.4.1 Use case H1: Remote interventional support

2.4.1.1 H1A

Component	High-level description of Functionality	Source	Status
Network component (4G/5G)	4G and 5G infrastructure in 5GTN (NSA & SA)	VTT (5GTN)	Ready
KPI measurement tools (Qosium)	Software tools Qosium and iPerf3 to measure network KPIs	VTT (5GTN)	Ready, connected
360 live video streaming setup	Video streaming setup used for medical healthcare education and remote analysis	VTT	On track

2.4.1.2 H1B CHD

Component	High-level description of Functionality	Source	Status
Network component (4G/5G)	4G and 5G infrastructure in 5G-VINNI	Telenor (5G-VINNI)	Connected
KPI measurement tools	Hawkeye, iPerf3	Telenor (5G-VINNI)	On track
Huawei 5G CPE Pro 2 (2x for 1st proto, 4x for 2nd proto)	5G modem with Ethernet connection	Telenor (5G-VINNI)	Available
Ultrasound machine (1st proto)	Philips EPIQ (7G, hardware revision B.0) ultrasound machine with version 6.0 software for EPIQ with Collaboration Live enabled for applicable Reacts accounts.	OUS/Philips (existing machine with upgrade provided by Philips).	Available
Reacts client (1st proto)	Laptop running Philips Reacts software (e.g., version 3.15.2.3630).	OUS/Philips (OUS laptop with Philips downloadable software client).	Available
Reacts accounts (1st proto)	Access to Philips Reacts service in Canada for individuals involved in testing.	Philips.	Available
USB camera (1st proto)	Regular webcam.	OUS	Available
Azure Kinect DK (3x) (2nd proto)		Philips	Note (applies to all below) deployment of 2nd prototype at OUS not decided yet due to COVID-19 travel restrictions (using fallbacks in Groningen and Eindhoven in the Netherlands)
Hololens 2 (2x) (2nd proto)	Hololens 2 to be used at both sides of the connection for AR/VR setup. For the remote expert HTC Vive or screen-based are alternatives. Running	Philips	(see above)

	applications developed by Philips.		
Lumify Ultrasound probe (USB) (2nd proto)	All three types are used: S4-1 broadband phased array, C5-2 broadband curved array and L12-4 broadband linear array.	Philips	(see above)
Laptops/PCs, minimal Intel Core i7 but Core i9 / RTX 2080 for rendering (2nd proto)	Running 3D, DNL applications on local paediatrician's side and remote expert application on the remote expert's side.	Philips	(see above)
Signalling server deployed on the 5G Edge (2nd proto)	Enables additional functionality above Collaboration Live, specifically relevant for support of Hololens2. For example, Live Switch.	Philips	(see above)

2.4.1.3 H1B Robot

Component	High-level description of Functionality	Source	Status
Network component (4G/5G)	4G and 5G infrastructure in 5G-VINNI	Telenor (5G-VINNI)	Not connected
KPI measurement tools	Hawkeye, iPerf3	Telenor (5G-VINNI)	On track
UR5 from Universal Robots with point 5.10.5 of the standard EN ISO 10218-1:2006,	The 6 Degrees of Freedom, (DOFs), robotic arm manipulator serves as slave robot in teleoperation framework. The Ultrasound probe is attached to the manipulator with a custom design 3D printed holder.	Oslo University Hospital	Available
UR5 Control box	The internal controller box that accepts both joint velocity setpoints and joint trajectory setpoints. The controller box has 16 digital inputs, 16 digital outputs, 2 analogue inputs and 2 analogue outputs. It can communicate with an external controller using a	Oslo University Hospital	Available

	direct Ethernet connection and a proprietary communication protocol		
USB Haptic Device	6 DOFs haptic devices serve as the master console in the teleoperation framework	Oslo University Hospital	Available
GE Ultrasound machine	GE Vivid E 9 or E 95 Ultrasound Machine	Oslo University Hospital	Available
GE Ultrasound Probe	M5Sc GE Ultrasound Probe	Oslo University Hospital	Available
USB camera (3x)	Regular webcam	Oslo University Hospital	Available
PC with a quad core Intel i7-960 3.2 GHz processor, 3 Gb of RAM, and is running Linux 2.6.38 and Xenomai 2.6.0.	This PC serves as the main controller in the slave site and the Robotic system controller connected to the PC through Ethernet. LabVIEW interface and main controller is running in this machine. The machine is equipped with a DAQ to connect the 6DOF force/torque sensor.	Oslo University Hospital	Available
a laptop with Xeon E-2176M (6 Core, 12 threads, 12MB Cache, 2.70GHz up to 4.40GHz Turbo, 45W, vPro) processor, 32 Gb of RAM. The PC is running Linux 4.9.38 and Xenomai 3.0.5.	The laptop serves as the main controller in the master site and the Haptic device connected to this machine with a USB connection.	Oslo University Hospital	Available
Gamma SI-65-5 from ATI Industrial Automation. The sensor is a 6 DOF force/torque sensor with a dynamic range of 200 N with a resolution of 0.025 N in the forward force axis, 65 N with a resolution of 0.0125N in the sideways force axes, and 5 Nm with a resolution of 0.75 · 10-3 Nm in the torque axes.	This sensor is using to measure the interaction force/torque of the ultrasound probe with the patient body to provide force feedback signal for the main controller and the haptic device.	Oslo University Hospital	Available

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21 inch Screen (3x in master site, 1x in the slave site)	To Display the video conferencing between the master and the slave sites	Oslo University Hospital	Available

2.4.1.4 H1C

Component	High-level description of Functionality	Source	Status
Network component (4G/5G)	4G and 5G network infrastructure	TNO (5Groningen)	Done
KPI measuring tools (iPerf, Speedtest app, ping and ROMES4)	Software tools to measure the throughput, latency and network coverage.	TNO (5Groningen)	Done
Video set	Used by paramedic to stream video to chief medical officer	RedZinc	Done
Ultrasound set	Philips Lumify/Reacts probe, tablet, software and Reacts accounts. Different camera setups.	Philips	Planned

2.4.1.5 H1D

Component	High-level description of Functionality	Source	Status
Network component (4G/5G)	4G and 5G network infrastructure	Telenor (5G-VINNI and/or commercial network)	Connected to commercial network
KPI measurement tools	Hawkeye, iPerf3	Telenor	Ready
Video set	Used by paramedic/rescue worker to stream video to scene commander	RedZinc	Done

2.4.2 Use case H2: Pill-camera

2.4.2.1 H2A

Component	High-level description of Functionality	Source	Status

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Network component (4G/5G)	4G and 5G network infrastructure	5G-VINNI	Connecting
5G modems	Huawei CPE Pro 2	Telenor	Ready
KPI measurement tools	Software tools to measure the throughput and latency Hawkeye, iPerf3	OUS / NTNU / Telenor	Ready
Endoscope camera	Device that captures in-body images	OUS / NTNU	Test and developments
On-body wireless com device	Device that receives and broadcasts the images for inference	OUS / NTNU	Under development
Cloud	Server which either receives processed and inferred images or receives, processes, performs detection and provides feedback signal; or both	OUS	Planning
Software Polyp Detection	Deep learning model that detects polyps and other anomalies in the colon	OUS	Test and development
FPGA Board	FPGA PYNQ-Z1 boards	OUS	Developing

2.4.3 Use case H3: Vital-sign patches with advanced geo-localization

2.4.3.1 H3A

Component	High-level description of Functionality	Source	Status
Test framework or energy and coverage testing of LTE-M / NB-IoT	Comprising LTE-M/NB-IoT modem (e.g., Nordic nRF91, Sequans GM02) evaluation board, SIM, Otii current meter, Adaura 2-channel USB RF attenuator, JRE1724 RF-shielded box and a PC running proprietary software.	Philips	Available

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Vital-signs patch with external power supply / button on a stick	For in-field testing, different versions for LTE-M and NB-IoT for comparative testing.		Under development

2.4.3.2 H3B

Component	High-level description of Functionality	Source	Status
NB-IoT and low power wide area and its future evolutions for localization	CEA is proposing and evaluating localization as a function geared towards H3 scenarios where the localization function is as accurate as possible with as little energy overhead introduced by the function	Proprietary network platform (including radio base station) and COTS LPWA modules particularly for city range measurements	Done
KPI measurement tools	Ground truth Global Navigation Satellite System (GNSS) measurement is performed on the same point of interest as radio ranging measurement to evaluate performance of low power radio location based on COST module and its possible 5B NB-IOT evolutions	Quectel L76 GNSS modules associated on COST LPWAN boards are considered as reference	In progress

2.4.3.3 H3C

Component	High-level description of Functionality	Source	Status
Network Component (4G/5G)	4G and 5G network infrastructure	OTE (5G-EVE or commercial network)	Initial experiments through commercial network will be carried out. Investigations on full experimental network.
Devices – Smartwatch	Connected devices to the STARLIT platform. Smart watch worn by the aquaculture worker.	Withings Scanwatch	Integrated and tested
Devices – Smart glasses	Connected devices to the STARLIT platform. Video set worn by the	Vuzix	Connected and tested

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	aquaculture supervisor/carer.		
Cloud Platform (Intelligence)	STARLIT cloud-based platform for data analysis including AI/ML algorithms for the early detection of health related and respiratory issues	WINGS	Almost ready - refinements on UI
KPI measurement tools	Software tools for measurements of latency (round trip time), Throughput (UL/DL), Service reliability, Service availability	Ping and IPerf	To be integrated

2.5 Planned activities

2.5.1 Use case H1: Remote interventional support

2.5.1.1 H1A

Partners	Activity	Details	Date	Status
VTT, RedZinc, Telenor, OUS	Testing the enhanced video streaming solutions between two locations 5GTN and 5G-VINNI		Spring 2022	Delayed
VTT, RedZinc, Telenor	Planning, designing and testing the BlueEye in 5GTN and 5G-VINNI with SA/NSA modes		Ongoing, test plan to be finalised Q1/2022	Running

2.5.1.2 H1B CHD

Partners	Activity	Details	Date	Status
Philips, OUS	Testing of remote ultrasound solution with EPIQ over 5G-network	Demonstrated at review meeting as planned (June 2nd). Point-to-point streaming not possible, anticipating on-edge Session Traversal Utilities for NAT (STUN)/ Traversal Using Relay NAT (TURN) server deployment for next experiments (see below).	May-2021	Done
Philips, TNO (and others)	Exploration of WebRTC streaming over 5G, including edge deployment and optimal ways	Within 5G-HEART first experiments have been conducted at the TNO facilities in Hoogezand (a.k.a. Groningen) on November 3rd and 4th leading to useful insights for further exploration. Philips complements this	Jun-2022	Running

	for reliable, real-time streaming of ultrasound data.	with the 5G-Hub (Vodafone, Ericsson) facility at its own campus as well is with testing at the 5G-TOURS facility in Rennes, France. Current experiments involve streaming of DNL ultrasound. Experiments with 3D (much higher bitrates required) are in preparation.		
OUS, Philips	Clinical evaluation of EPIQ / Collaboration live for remote ultrasound examination of adult cardiac and for CHD.	OUS has conducted first experiments: (1) showing feasibility of inexperienced medicine students making crude images of the heart through remote guidance, and (2) a team of inexperience doctor and remote expert (i.e., paediatric cardiologist) arriving at the same conclusions about the need for admission of a neonate expected with CHD, compared with physical expert examination. Experiments to continue with larger sample sizes, to be followed by report out. Experiments under (1) expected to complete by early 2022, while those under (2) by end of project.	Nov-2022	Running
Telenor, OUS, Philips	Evaluation of some of the above on SA with KPI measurements.		Jun-2022	Delayed

2.5.1.3 H1B Robot

Partners	Activity	Details	Date	Status
OUS	Test the performance of the robotic teleoperation framework over wired connection	Test the preformance of the teleoperation framework to capture Ultrasound |images with three video solutions to choose the best video solution for the system over the wired connection	October 2020	Done
Telenor, OUS	Connecting to 5G network	Test and verify the proposed setup for connecting to 5G-VINNI or the commercial network	Q1/2022	Delayed
OUS	Clinical test over healthy volunteers over wired connection	These trials will focus on determining the time required for the US examination to capture ultrasound images of the	June 2022	Running

		parasternal long axis, parasternal short axis, and apical four chamber viewpoints of the heart using the robotic teleoperation system and comparing the results to a gold standard examination. Although preliminary testing on one healthy volunteer was effective, clinical testing on more than twenty healthy participants requires approval from the Norwegian Medicines Agency.		
Telenor, OUS	Test performance over 5G	The trials will focus on the latency in manipulating the slave robot and the force feedback performance over the 5G network. The transparency of the robotic system in terms of manipulation, video solution, and force feedback over the 5G network will be studied through the use of the robotic system for an ultrasound examination on one healthy volunteer.	November 2022	Not started

2.5.1.4 H1C

Partners	Activity	Details	Date	Status
TNO, Philips, RedZinc	Philips and TNO plan to have a separate trial test the delivery of ultrasound video streaming via the same 5G SA network.	These trials will focus on the technical evaluation of one or more system setups on the 5G SA network, rather than on clinical and usability aspects.	Spring 2022	Delayed
TNO, Philips, RedZinc	In the Phase 3 trials, an integration of the healthcare (WP3, H1C subcase) and transport (WP4, T2S1 subcase) aspects of the ambulance services will be carried out.	For this purpose, we will use another outdoor 5G SA network located in Helmond (The Netherlands). Two network slices, using the same network infrastructure, may be configured for the delivery of healthcare- and transport- related traffic data, respectively. The ultimate	Summer-autumn 2022	Planned

		objective is to test how well 5G may support traffic of multiple verticals (in this case healthcare and transport).		

2.5.1.5 H1D

Partners	Activity	Details	Date	Status
RedZinc, OUS	Controlled experiment to compare legacy methods with a newly prosed method	This trial focus on how the wearable video method differs from today's practice, addressing application level KPIs like time to completion and procedure error minimization	Q1/2022	Planned
Telenor, RedZinc	Network KPI assessment	To conduct network KPI measurements relevant to the application. Especially focusing on user throughput and video quality	Q1/2022	Delayed

2.5.2 Use case H2: Pill-camera

2.5.2.1 H2A

Partners	Activity	Details	Date	Status
OUS, Telenor, NTNU	Latency investigations	End to end and end to core network latency to be determined. Latency is a critical KPI for the use case, and it is important to understand the whole latency budget using HTTP/TCP. Different UDP based protocols will be implemented and tested.	Q1/2022	Planned
OUS, NTNU	Speed and accuracy of the AI model	The trials will focus on taking temporal information between the frames into consideration in order to make output decisions and generate feedback signals to the client PC / PillCam more reliably	Q1/2022	Ongoing

2.5.3 Use case H3: Vital-sign patches with advanced geo-localization

2.5.3.1 H3A

Partners	Activity	Details	Date	Status

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Philips, Telenor	Exploring indoor coverage and planning	Proper contact person at OUS identified, intend to initiate discussions. Indoor experiments to be determined, as COVID-19 travel restrictions continue to make this very hard. Considering that public Narrow Band-IoT (NB-IoT)/LTE-M networks suffice, this can also be addressed elsewhere (see below).	Nov-2022	Delayed
	Wrap up upload protocol study by assessing benefits of session resumption.	In-depth literature study and extensive experiments have been conducted and are reported upon in D3.3. To wrap-up this study some more experiments on session resumption are still desirable. The extent to which this can be realized is subject to proper support by relevant modem vendors.	Nov-2022	Running
	Complete study on the potential of NB-IoT to solve the coverage concerns.	Promising first results using the test framework are reported in D3.3 and the work is continuing further confirming these first insights. This work will be complemented with field testing using the "vital-signs patch with external power supply / button on a stick" (see above). The extent to which this can be realized is subject to proper support by relevant modem vendors.	Nov-2022	Running
	Smalls study on feasibility of firmware-over-the-air updates.	Measurements of energy usage for single download of application / modem firmware over lifetime of device.	Nov-2022	Running

2.5.3.2 H3B

Partners	Activity	Details	Date	Status
CEA	Field Trial preparation : Network Infrastructure architecture design for ground truth data collection	Network services (broker, Message Queuing Telemetry Transport , (MQTT), database, queue, etc.) have been selected, tested and deployed on-premises (CEA servers).	Q3 2021	Done
CEA	Field Trial preparation: device setup for crowd-sourcing.	COST multi-LPWAN (including NB-IoT, LTE-M, Long Range Wide Area Network (LoRaWAN) modules have been designed	Q4 2021	Done

		(including hardware and software).		
CEA	Field Trial preparation: Base Station deployment in Grenoble city Area.	6 Base station to be deployed in Grenoble Area to increase city coverage with multi-base station. 4 are already deployed.	Q1 2022	In progress
CEA	Algorithm optimization.	Radio metrics collected (Time difference of Arrival), (TDOA), Received Signal Strength Indicator, (RSSI), Signal to Noise Ratio, (SNR), using crowdsourcing, technology limits and “a priori” map information to be used.	Q2 2022	In progress
CEA	Evaluation of geo-location algorithm.	Demonstration using 5GVinni after a feasibility phase.	Q3 2022	Not started

2.5.3.3 H3C

Partners	Activity	Details	Date	Status
Wings, ACTA, OTE	KPIs measurements	Latency, throughput, reliability, availability, etc.	June – October 2022	In progress
WINGS, Skironis, medical expert	Pilot deployment	Setting up piloting activities with the involvement of aquaculture workers and remote healthcare expert.	May - June 2022	In progress

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3 TRANSPORT VERTICAL TRIAL PLANS

3.1 Description and methodology

As the final step of the 5G-HEART's three-phased approach for trials and validations, the described phase 3 trials plan aim to validate the baseline performance (i.e., of fourth generation (4G)/long-term evolution (LTE) technologies) and the 5G solutions developed for the transport vertical sector. Based on the observations made during these trials, insights will be gained into the limits of the existing solutions and the improvements that are brought by the developed solutions. These will augment and guide the subsequent more advanced (i.e., Phase 3) trials using optimised 5G networks.

A set of four representative use cases have been considered for the transport vertical sector, each of which is further divided into one or more scenarios:

- T1 – "*Platooning*" that considers vehicles forming a tightly coordinated "train" with significantly reduced inter-vehicle distance, thus increasing road capacity and efficiency.
- T2 – "*Autonomous/assisted driving*" that involves semi-automated or fully-automated driving to achieve safer travelling, collision avoidance, and improved traffic efficiency.
- T3 – "*Support for remote driving*" that enables a remote human operator or cloud-based application to operate a remote vehicle.
- T4 – "*Vehicle data services*" that focuses on interconnecting various third-party data sources to connected and automated vehicles via the available 5G infrastructure.

The Phase 1 and 2 trials have been conducted on a per scenario basis, coordinated by the scenario leaders, and using the 5GENESIS (Surrey, UK), 5Groningen (Groningen, the Netherland) and 5GTN (Oulu, Finland) trial facilities. Different levels of progress have been achieved on the various use case scenarios depending on the availability of vehicles for trials, for which research experimentation vehicles are going to be used. To ensure the by-design integrability of these components, extensive discussions and remote collaboration have been established with the team responsible for maintaining these vehicles, while the actual integration will be performed during a set of on-site workshops subject to the recent COVID-19 restrictions.

Based on the results, observations and insights acquired during phase 1 - 2 trials, planning of the next steps has been provided for each of the use case scenarios. Certain synergies have also been identified between transport scenarios (e.g., *T2S3: Quality of service (QoS) for advanced driving* and *T3S1: Tele-operated support (TeSo)*) and with other verticals (e.g., *T2S4: Human tachograph* with healthcare use cases), and these will be exploited in future combined trials.

3.2 The work produced in Phase 2

In this section, a short description of the work performed at the trials in Phase 2 is provided. It also outlines the updates planned for Phase 3. The solutions include infrastructure developments, tests performed in the field and the measured KPIs.

Table 4: Outline of the work performed in Phase 2

Trial scenario	3rd phase December 2021 – November 2022	Trial platform
T1S1&T1S2	• One-to-one Sidelink (Unicast) experiment (in-lab) • One-to-many (Multicast) experiment (in-lab) • On-boarding HW/SW to cars completed.	Surrey, UK
T2S1	• Performed KPI measurements on the 5G SA network • Implemented Edge Computing • Implemented intelligent Traffic Light Controller and a back-office server platform	5Groningen, Groningen, NL

T2S2	• Implemented the fusion of CPM messages • Studied the impact of LTE-V2X connectivity on the fusion of the generated CPM messages • Evaluated Obstacle Misdetection Rate (OMR) after CPM fusion	CEA, France
T2S3	• Hardware setup finished • Edge application deployed • map with virtual obstacles generated trajectory planning • KPI measurement over 4G completed • The best driving modes are initially selected for a given heterogeneous trip. The trip trajectory includes different segments where different driving modes should be used, this phase also includes a set of mechanisms to change the driving mode during the trip at the proper time and location.	TUC, Germany
T2S4	• The extended Phase 2 trial implementation included an edge cloud environment and updated 5G Non-Standalone (NSA) network architecture. • The user application architecture was updated with new sensor devices and streaming software for the wearable's sensor data. Edge cloud implementation of the sensor data collection and warning message triggering framework was also added to the architecture. • The performance verification of the 5G NSA network configuration and updated user application components was done with laboratory and field measurements. o The lowest average UL latencies were approximately 7 ms. o The lowest average DL latencies were approximately 4 ms. o In the DL direction, 11-13 ms latency for the warning messages was achieved with 99.99 % reliability.	5GTN, Oulu, Finland
T3S1	• Fine-tuned the software components based on the insights gained during the integration into the vehicle and the first validation trials. • Finalized the measurement methodology for the final trials. • Realized reference measurements to determine the best-case performance of the employed network setup. Ping to measure the RTT and iPerf3 to measure the Transmission Control Protocol (TCP) throughput at both UL and DL between the devices (i.e., laptops) hosting the ROC-GW node (mounted on the vehicle) and the ROC GUI app ("remote" location). • Realized actual validation trials performing several simple manoeuvres at a controlled open space at TUC premises with a line-of-sight setup.	NTUA, TUC, Greece/Germany

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T4S1	• Performance verification of the updated 5G NSA network configuration (implemented in T2S4) was done with mobile users. o Depending on the application payload size, the achieved UL latency was approximately 5-7 ms. o The theoretical maximum amount of simultaneously supported user was estimated to be 36-380.	5GTN, Oulu, Finland
T4S2	• The Phase 2 trials were done to determine the baseline performance of the 4G Evolved Multimedia Broadcast Multicast Service (eMBMS) -based multicasting in a file download scenario. • The achieved baseline performance was compared to performance of the 5G NSA DL. o Based on a theoretical estimation, the spectral efficiency of the eMBMS-based multicasting exceeds that of 5G NSA unicasting when the number of simultaneous users requiring the same OTA update data exceeds 6.	5GTN, Oulu, Finland
T4S3	• Simulate service requests to measure initial E2E latencies • Development of frontend component and integration of all modules • Physical Sensor on-site testing and integration with the service (on-going)	WINGS Infrastructure, Greece
T4S4	• Integration to 5G • Server is redeployed in UoS datacentre • Measurements taken over 5G • Vehicle moves past a billboard which identifies it and displays a relevant advertisement based on the vehicle destination or other parameters.	EPI/Surrey, UK
T4S5	• Rel. B 5GENESIS software suite trialled • SW deployment and correct operation verified after running multiple validation scripts • Can now apply CN slicing (APN-based) on selected use case scenarios (in isolation). • Collaboration with ICOM on "slice isolation" (discussions ongoing)	Surrey, UK
T4S6	• Initial implementation using research rover • Integration to 5G • Server is redeployed in UoS datacentre • Measurements taken over 5G • Utilisation of one or more in-vehicle sensors to create an HD map from scratch using one or both vehicles.	EPI/Surrey, UK
T4S7	• Integration to 5G • Server is redeployed in UoS datacentre • Measurements taken over 5G	EPI/Surrey, UK

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	• Vehicle moves through the campus at higher speed to test the system reliability and real time applications.	

3.3 The work planned to be done in Phase 3

Phase 3, (December 2021-November 2022), is the final phase of the project, during which the final set-ups and trials are going to be demonstrated, in addition measurement of network KPIs and production performance indices (PIs) are going to be taken and assessment of the trials will be performed.

Table 5: Planned Phase 3 trials, platforms and locations.

Trial scenario	3rd phase December 2021 – November 2022	Trial platform
T1S1&T1S2	• Test and evaluation of setup inside vehicles (sync. Via GPS) • Test see-through functionality over V2V for different operating conditions (e.g., moving speed, inter-vehicle distance and network load). • Work on two use cases: i) Off network scenario (e.g., both vehicles are out of coverage), ii) Relay network scenario, one node is connected to an eNB/gNB. • Evolve to a mixed setup i.e. Once the 4G/5G C-V2V support becomes available on 5GENESIS, use both USRPs and commercial 4G/5G modems & compare achieved performance. • A more detailed assessment of the effectiveness of see-through and situational awareness in ensuring a smooth switch between platooning and individual driving modes will be trialled at large scale.	Surrey, UK
T2S1	• Extend the Phase 2 measurements by further evaluating the Traffic Light status information application with regards to the Green Wave Priority request mechanism. • Further evaluate the potential benefits of Slicing for the ETSI CPM-based application with regards to latency and availability. • Joint trial with healthcare use case H1C	5Groningen, Groningen, NL
T2S2	• Implementing 5G NR in the simulation framework (CPM based) • Generation of 5G-based performance measurements	CEA, France
T2S3	• Deployment and trials with 5G NSA • Inclusion of ETSI messages • Visualization enhancement • Dynamic selection of best driving mode during the trip. The trip trajectory is heterogeneous i.e., includes different segments where different driving modes should be used. For each segment, the most appropriate driving mode should be determined depending on the time-varying operating conditions (e.g., network load, road traffic and traffic diversions).	TUC/Surrey, UK
T2S4	• Based on the available test network development roadmap, 5G Standalone (SA) and RAN slicing support becomes	5GTN, Oulu, Finland

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	available in the 5GTN test facility in the beginning of Phase 3. o The updated test network functionality will be utilised in the final trials and their effect to the overall 5G, and service performance will be trialled and validated. • A hardware-based UE emulator, which enables generation of multiple artificial UEs and traffic for different network slices, becomes available in the 5GTN test facility also in the beginning of Phase 3. o The UE emulator will be utilised for evaluating the scalability of the trialled service in 5G networks. • In parallel with the validation trials and measurements, the implementation of the final demonstration for the use case scenario will be finalised. o The demonstration implementation will include additional 5G performance monitoring as well as data analysis and visualisation components, which can be used to show the progress of the trial scenario to the demonstration viewers in real time.	
T3S1	• Achieve precise clock synchronization between the devices hosting the ROC-GW node and the ROC GUI application • Evaluate the actual performance of the developed remote driving application when in use following the devised methodology • Update the network setup from the currently used 4G LTE to the 5G protocol stack • Interconnection to 5GENESIS facility	ICOM/Surrey, UK
T4S1	• The performance of the 5G SA UL will be measured and validated using the vehicle prognostics traffic profile. • The scalability of the service will be evaluated using the hardware-based UE emulator to generate additional UEs and transmit test traffic in the utilised 5G NR cell.	5GTN, Oulu, Finland
T4S2	• The performance achieved in 5G SA DL will be validated against the use case scenario specific KPIs and analysed against the performance achievable with the eMBMS-based multicasting. • The scalability of the trialled service in 5G networks will be evaluated using the hardware-based UE emulator to generate additional UEs and receive test traffic in the utilised 5G NR cell.	5GTN, Oulu, Finland
T4S3	• Test validity of solution based on real data (sensor installed in Athens) (simulation) • Interconnection to 5GENESIS facility	WINGS Infrastructure
T4S4	• Performance testing over 4G/5G networks • Load testing over 4G/5G networks • KPIs to be measured in better network conditions • Mobility Testing with vehicle moving at various speeds	EPI/Surrey, UK

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T4S5	• Apply CN slicing on selected use case scenarios (in isolation). • Collaboration with ICOM on "slice isolation"	Surrey/ICOM, UK
T4S6	• Performance Optimization • Further enhancements to map data • Usage of 3D LIDARs for more accuracy • Tuning of sensor data uploaded • Exploration of sensor fusion using cameras • Dynamic update of the HD map across all three elements (i.e. cloud mapping application, RSUs and both vehicles).	EPI/Surrey, UK
T4S7	• Performance testing over 4G/5G networks • Load testing over 4G/5G networks • KPIs to be measured under better network conditions • Mobility Testing with vehicle moving at various speeds	EPI/Surrey, UK

3.4 Component readiness roadmap

In the following sections, the components' roadmap for all subcases are displayed.

3.4.1 Use case T1: Platooning

3.4.1.1 T1S1&T1S2

Component	High-level description of Functionality	Source	Status
Hardware components			
HD front camera (platoon leader)	Front camera to capture the scene in front of the platoon leader	TUC	Available
On-board screen (platoon members)	To display the platoon leader's front scene inside platoon members	TUC	Available
Software components			
Video transmitter	Application to transmit the video to platoon members (platoon leader)	UOS/TUC	Under development
Video receiver	Application to receive the front scene video and forward to the on-board screen (platoon members)	UOS/TUC	Under development

3.4.1.2 T1S1&T1S2

Component	High-level description of Functionality	Source	Status
Platooning agents	Software agents to implement the basic platooning operation between the two CARAI vehicles.	UOS/TUC	Under development

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3.4.2 Use case T2: Autonomous/Assisted driving

3.4.2.1 T2S1&T2S2

Component	High-level description of Functionality	Source	Status
Network component (4G/5G)	5G SA network infrastructure	TNO (5Groningen)	Available
KPI measuring tools (iPerf, ping, ETSI CPM-based app)	Software tools to measure the throughput and latency	TNO (5Groningen)	Available
IP-based security camera	Camera used for object detection (e.g. vehicle or road user tracking)	TNO (5Groningen)	Available
On-board unit	OBU functioning as UE configured for both LTE-Uu and LTE-V2X	TNO (5Groningen)	Available
Back-office cloud server	Server running a MQTT broker and hosting the object detections	TNO (5Groningen)	Available
Traffic light controller	A traffic light controller operating the intersection in Helmond (within the 5Groningen's coverage)	Dynniq	Available

3.4.2.2 T2S3

Component	High-level description of Functionality	Source	Status
Trajectory planning application	It determines for a given manoeuvre (i.e., position, destination, heading and velocity), an optimal and collision-free trajectory on a given map subject to the existence of some obstacles.	TUC	Available
Client-server API	This serves for the communication between the Edge and vehicle. It is implemented based on ZeroMQ “Radio-Dish” sockets with user datagram protocol (UDP) protocol.	TUC	Available
Estimator and connectivity and QoS levels	It allows to negotiate the connectivity and QoS levels provided by the network	UOS	Planned

3.4.2.3 T2S4

Component	High-level description of Functionality	Source	Status
Polar H10 heart rate sensor	Measures the driver biosignals including Heart Rate (HR), ECG, and Accelerometer (ACC), and broadcasts them continuously over a Bluetooth Low Energy (BLE) link.	VTT	Available

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Polar Mobile SDK	Enables to read live data (streamed through BLE) directly from Polar sensors, including ECG data, ACC data and HR broadcast.	Polar	Available
Polar Sensor Logger	Android application that implements decoding of the H10 BLE signalling using the Polar SDK and visualization of the biosignal measurements. Includes also an MQTT publisher for the measurement and trial purposes, i.e., it publishes the sensor data from a smartphone to the MQTT brokers at the network edge cloud in the 5GTN-VTT test facility and Polar's remote research server.	Polar	Available
Polar Open Test API	Provides a direct information sharing link between the Polar ecosystem and research server as well as between the Polar research server and 5G network edge cloud environment for historical data.	Polar	Available
MQTT broker and clients	Broker running in the edge cloud for initial reception and forwarding of the published biosignal data packets. Clients publishing the biosignal data packets to the network and subscribing to the published biosignal data packets in the network.	VTT	Available
Polar remote research server	Provides estimation of fatigue levels for the day based on user's sleep history (recent sleep amount and timing in relation to circadian rhythm) is calculated on the research server. Fatigue level prediction also takes into account daytime napping (not currently available in history data, but through manual notation).	Polar	Available
5G user equipment	Network components. Different device models (UEs and CPEs) used for the trials and measurements.	VTT (provided by 5GTN)	Available
5G network	Network components. Indoor and outdoor cells using 5G-NR in NSA or SA mode at 3.5 GHz with 60 MHz bandwidth. Lightweight and carrier grade options for EPC and 5GC services. Support for MEC/edge cloud processing.	VTT (provided by 5GTN)	Available

3.4.3 Use case T3: Support for remote driving

3.4.3.1 T3S1

Component	High-level description of Functionality	Source	Status
ROC-GW	The ROC-GW node resides at the vehicle and was constructed using the DRAIVE Link framework. The implemented node	NTUA, TUC	Available

	acts both as a subscriber and a publisher, having seven input pins and three output pins. According to the configured subscriptions, the input pins receive the respective data types published in the mesh network by the On-Board Unit (OBU). To forward these objects to the ROC over the 5G network, ZeroMQ, a high-performance asynchronous messaging library, is employed.		
ROC GUI	The ROC GUI application is the interface with the human operator. It has been implemented using the Qt5 framework and following a multithreaded design. The main (or GUI) thread is responsible for the construction of the main window with all the included widgets (described in Section 9.2.2) and for obtaining the user input and sending the remote-control commands to the ROC-GW. The signals and slots mechanism of Qt is used for displaying the vehicle's data sent from ROC-GW.	NTUA	Available
OBU	The On-Board Unit provides an interface with the vehicle's sensors\cameras and actuators. It publishes the captured operational and ambient data to a mesh network in order to enable their use by other components integrated to the vehicle (i.e., ROC-GW). At the other direction, the control commands, which are transmitted over 5G from the ROC to the vehicle, are received by ROC-GW and forwarded to the OBU, where their conversion into control commands for the vehicle's actuators takes place.	TUC	Available
Measurement Setup	The end-to-end chain of the remote driving application can be divided into three main parts: vehicle integration, network application, and human cognitive process. The overall end-to-end (or even round-trip if so desired) delay can then be estimated by adding the corresponding upstream and downstream components with the constant representing the vehicle integration and the estimate/bound regarding the human reaction time found in the literature. This will enable us to evaluate the actual performance of the developed remote driving application when in use.	NTUA, TUC	Planned

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4G Network	At the vehicle's side, the USRP device is connected to a personal computer which hosts a full-stack software radio User Equipment (UE) implementation of the srsRAN open-source platform. In a similar manner, at the ROC's side, the USRP device is connected to a personal computer that hosts the srsENB and srsEPC, implementing the software radio eNB and Core Network (CN), respectively, via the use of the srsRAN platform.	TUC	Available
5G Network	Update the network setup from the currently used 4G LTE to the 5G protocol stack using the same srsRAN open-source suite.	TUC	Planned

3.4.4 Use case T4: Vehicle data services

3.4.4.1 T4S1

Component	High-level description of Functionality	Source	Status
MQTT broker and client	MQTT broker and client configured to emulate the vehicle prognostics application functionality, i.e., collection of vehicle status information. Utilised to create use case scenario specific test traffic for the KPI measurements.	VTT	Available. Integrated to the T2S4 trial setup.
5G user equipment	Network components. Different device models (UEs and CPEs) used for the trials and measurements.	VTT (provided by 5GTN)	Available
5G network	Network components. Indoor and outdoor cells using 5G-NR in NSA or SA mode at 3.5 GHz with 60 MHz bandwidth. Lightweight and carrier grade options for EPC and 5GC services. Support for MEC/edge cloud processing.	VTT (provided by 5GTN)	Available

3.4.4.2 T4S2

Component	High-level description of Functionality	Source	Status
Measurement file server	File server containing test files for downloading dummy update packages. Utilised to create test traffic for the KPI measurements.	VTT	Available. Integrated to the T2S4 trial setup.

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4G user equipment	Network component. Different UE models used for the trials and measurements.	VTT (provided by 5GTN)	Available
4G network	Network components. Indoor and outdoor coverage using 4G LTE at 2.6 GHz with 15 MHz bandwidth. Lightweight and carrier grade options for EPC	VTT (provided by 5GTN)	Available
4G eMBMS	Network component. Enensys eMBMS solution.	VTT (provided by 5GTN)	Available
5G user equipment	Network components. Different device models (UEs and CPEs) used for the trials and measurements.	VTT (provided by 5GTN)	Available
5G network	Network components. Indoor and outdoor cells using 5G-NR in NSA or SA mode at 3.5 GHz with 60 MHz bandwidth. Lightweight and carrier grade options for EPC and 5GC services. Support for MEC/edge cloud processing.	VTT (provided by 5GTN)	Available

3.4.4.3 T4S3

Component	High-level description of Functionality	Source	Status
Software components			
Analytics for AQI	Storage and processing of the entities provided by the AQ sensors to infer AQI	WINGS	Available
Analytics for optimal routing based on air quality index and traffic information	Routing realization using AQI provided by the previous component	WINGS	Available
Dashboard	Web dashboard provided for the Use Experience to visualize the resulting route	WINGS	Available
Hardware components			
Sensors providing AQI	7 sensors installed in the south region of Athens that provide measurements of NO2, O3, CO, SO2, PM2.5, PM10)	WINGS	Available

3.4.4.4 T4S4

Component	High-level description of Functionality	Source	Status
H/W: OBU	This consists of an ARM based automotive board running Android.	Epitomical	Available
H/W: RF Frontend	This is the RF HW to access the 4G network. Huawei LF 7880 CPE is used, which offers both WiFi and Ethernet interfaces.	UoS	Available
S/W: Client App	Download and display advertisements. This is a Java application to playback HLS streamed from the server.	Epitomical	Available
S/W: Server App	Streaming of multimedia to client. This is a Personal Home Page (PHP) application to serve HLS file segments.	Epitomical	Available

3.4.4.5 T4S5

Component	High-level description of Functionality	Source	Status
Slicing-as-a-service functionality	It will be exploited to support various use cases of the transport vertical	UOS	Available (CN slicing)

3.4.4.6 T4S6

Component	High-level description of Functionality	Source	Status
H/W: OBU	This consists of an Intel-based board running Ubuntu Linux. This has a 2D LiDAR capable of gathering scans along with other sensors like IMU.	Epitomical	Available
H/W: RF Frontend	This is the RF HW to access the 4G network. Huawei LF 7880 CPE is used, which offers both WiFi and Ethernet interfaces.	UoS	Available
S/W: Client App	Linux based C++ application based on Robot Operating System (ROS), which transmits sensor data to the cloud server.	Epitomical	Available - To Be Upgraded
S/W: Server App	Analytics and Storage of sensor data. The cloud application uses the received sensor data to generate map of the location.	Epitomical	Available - To Be Upgraded

3.4.4.7 T4S7

Component	High-level description of Functionality	Source	Status
H/W: OBU	This consists of an ARM based automotive board running Android.	Epitomical	Available
H/W: RF Frontend	This is the RF HW to access the 4G network. Huawei LF 7880 CPE is used, which offers both WiFi and Ethernet interfaces.	UoS	Available
S/W: Client App	Used to collect sensor data and transmit to server. This is a Java application to broadcast PM2.5 and PM4.0 readings over MQTT to the backend server.	Epitomical	Available

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S/W: Server App	Used to collect and store sensor data. The MQTT server acts as a data bus providing publish/subscribe methods	Epitomical	Available

3.4.5 Network components

The components that are common across multiple scenarios that utilize specific platforms with the corresponding equipment are displayed in this section.

3.4.5.1 5GENESIS

Covering scenarios T1S1&S2, T1S3, T2S3, T3S1, T4S3, T4S4, T4S5, T4S6 and T4S7:

Component	High-level description of Functionality	Source	Status
Hardware components			
5xUSRP-2954R	Software defined radio (SDR) for baseline 4G experimental	UOS	Acquired
2x USRP N320	SDR for baseline 5G experimental	UOS	Acquired
2x Dell XPS 15 7590	High-end laptop to run OpenAirInterface (OAI)	UOS	Acquired
A set of Google Pixel smartphones	Commercial off-the-shelf smartphones to be used in conjunction with the 4G/5G OAI+ Universal Software Radio Peripheral (USRP) setups	UOS	Acquired
External antennas	External antennas to be used in conjunction with the USRPs placed inside vehicles	UOS	Acquired
Software components			
OpenAirInterface (OAI)	Open-source 3GPP-compliant SW implementation of the 4G protocol stack (5G in progress) to be used in conjunction with SDRs.	UOS (based on open-source OAI)	Available
Network components			
4G eNBs/5G gNBs	Mixture of commercial and experimental (i.e., OAI+USRP) eNBs/gNBs.	UOS (5GENESIS)	Available
4G/5G 5GIC core	In-house developed 4G (Rel.15)/5G (Rel.16 SA) core network	UOS (5GENESIS)	Available
KPI measuring tools			
Infrastructure Monitoring (IM)	Focuses on the collection of data that synthesize the status of the architectural components, e.g., end-user devices, radio access/networking systems, computing and storage distributed units.	UOS (5GENESIS)	Available
Performance Monitoring (PM)	Devoted to the active measurements of performance indicators.	UOS (5GENESIS)	Available
Storage and machine learning (ML) Analytics	Enables efficient management of large sets of heterogeneous data and drives the discovery of hidden values and correlation among them.	UOS (5GENESIS)	Available

InfluxDB	Measurement data storage.	UOS (5GENESIS)	Available
Grafana	Visualization	UOS (5GENESIS)	Available
OAI built-in tools	These will be used to debug and monitor the performance of the OAI communication links.	UOS (5GENESIS)	Available

3.4.5.1 5GTN

The 5GTN platform covers scenarios T2S4, T4S1, T4S2:

Component	High-level description of Functionality	Source	Status
Kaitotek Qosium	KPI measurement tool. Passive measurements for quality of service (QoS)/quality of experience (QoE) parameters.	VTT (provided by 5GTN)	Available
Keysight Nemo Handy	KPI measurement tool. Throughput measurements during field trials and general connectivity debugging.	VTT (provided by 5GTN)	Available
Nokia BTS Site Manager	KPI measurement and network monitoring/management tool. Configuration and collection of performance counters directly from eNBs and gNBs.	VTT (provided by 5GTN)	Available
iPerf	KPI measurement tool. Test traffic generation.	VTT (provided by 5GTN)	Available
Mobiilimittari	KPI measurement tool. Throughput and round-trip delay measurements with QoS mapping.	VTT (provided by 5GTN)	Available
Cellmapper	Network monitoring tool. Cellular tower and coverage mapping.	VTT (provided by 5GTN)	Available
InfluxDB	KPI measurement and network monitoring tool. Data collection and storage.	VTT (provided by 5GTN)	Available
Grafana	KPI measurement and network monitoring tool. Data visualisation.	VTT (provided by 5GTN)	Available

3.5 Planned activities

3.5.1 Use case T1: Platooning

3.5.1.1 T1S1&T1S2

Partners	Activity	Details	Date	Status
UOS/TUC	5G-based trials	Extend the Phase 2 setup to 5G .	Jan. – June 2022	In progress
UOS	5G Performance measurements	-	July – Oct 2022	Planned
UOS	Trial showcase event at UOS campus	-	Oct – Nov 2022	Planned
UOS, TUC	UOS-TUC workshop to integrate the OAI+USRP setup and developed software agents to	Subject to the readiness of the OAI+USRP setup and finalisation of the required software agents	Jan – June 2020	Planned

	transmit the video stream from the platoon leader to the platoon members.			
UOS, TUC	Building the basic platooning operation.	To be organised once the integration work is finalised	Jan – June 2020	Planned

3.5.2 Use case T2: Autonomous/Assisted driving

3.5.2.1 T2S1&T2S2

Partners	Activity	Details	Date	Status
TNO, Dynniq	Extend the Phase 2 measurements to 5G.	Further evaluating the Traffic Light status information application with regards to the Green Wave Priority request mechanism.	Jan. – June 2022	In progress
TNO, Philips, RedZinc, Dynniq	Combined trials - In the Phase 3 trials, an integration of the healthcare (WP3, H1C subcase) and transport (WP4, T2S1 subcase) aspects of the ambulance services will be carried out.	For this purpose, we will use another outdoor 5G SA network located in Helmond (The Netherlands). Two network slices, using the same network infrastructure, may be configured for the delivery of healthcare- and transport- related traffic data, respectively. The ultimate objective is to test how well 5G may support traffic of multiple verticals (in this case healthcare and transport).	July – Nov. 2022	Planned

3.5.2.2 T2S3

Partners	Activity	Details	Date	Status
TUC	5G-based trials	With the upcoming release 21.10 of srsRAN[†] in November 2021, 5G Non-Standalone (NSA) is expected to be available	Jan. – June 2022	In progress

[†] https://docs.srsran.com/en/latest/general/source/2_release_roadmap.html

		for gNB. Together with the already existing support for the 5G NSA UE we will be able leverage that functionality for additional trials in Q1/2022. For the final demonstration it is expected that full 5G SA support will be available with the release 22.04. of srsRAN in Q2/2022.		
TUC	Combined trials.	A combined instance with T3S1 will be trialed at the end of Phases 2/3 after the remote driving functionality (i.e., T3S1) becomes available.	Sept. 2022	Planned
UOS, TUC	Remote access to 5GENESIS facility	Remote access to TUC granted to deploy at the Edge of 5GENESIS the preliminary trajectory planning application and the first API prototype of the communication between the Edge and vehicle.	November 2020 (finalised)	Available
UOS, TUC	Updates to planning trajectory application	Extensions to include a more advanced trajectory planning application relying on sensor data from the vehicles and thus increasing the bandwidth demand as well as employing a predictive QoS mechanisms based on the latest 3GPP progress. For the final project trials, it is envisaged to combine the Edge-assisted automated manoeuvre functionality with the T3S1 use case scenario (i.e., tele-operated support) to switch between different	Jan. – June 2022	In progress

		modes of teleoperation (e.g., from manoeuvring to trajectory provision) depending on the operating conditions.		

3.5.2.3 T2S4

Partners	Activity	Details	Date	Status
VTT	Initial tests with the 5G SA network configuration.	Phase 2 trials repeated in the updated test facility.	Dec. 2021 – Feb. 2022	In progress
VTT, Polar	Implementation of the use case scenario demonstration.	Trial setup extended with additional monitoring and visualisation components.	Jan. – May 2022	Planned
VTT	Scalability testing for the trialed service.	Trials with multiple emulated users.	Feb. – May 2022	Planned
VTT, Polar	Final performance measurements.	Execution of the final trials and validation of 5G performance.	May – Nov. 2022	Planned

3.5.3 Use case T3: Support for remote driving

3.5.3.1 T3S1

Partners	Activity	Details	Date	Status
NTUA, TUC	Extension to 5G	Extend the already implemented modules to 5G to accommodate multiple video streams and additional types of sensory data	Feb. – May 2022	In progress
NTUA	Create a unified application incorporating all ROC functionality	-	Feb. – May 2022	In progress
NTUA	Accurate Sync.	Achieve precise clock synchronization between the devices hosting the ROC-GW node (inside the vehicle) and the ROC GUI application (“remote” location), which is necessary for realizing accurate one-way latency measurements.	Jan – Mar 2022	In progress

NTUA, UoS, TUC	Integration	Integration to research vehicles: NUC – OBU & NUC-USRP, initial E2E measurements	May 2022	Planned
NTUA	5G-based trials & Performance Testing/measurements	ping, iperf + keysight Nemo for throughput, Qosium for E2E delay	July-Sept 2022	Planned

3.5.4 Use case T4: Vehicle data services

3.5.4.1 T4S1

Partners	Activity	Details	Date	Status
VTT	Scalability testing for the trialed service.	Trials with multiple emulated users.	Feb. – May 2022	Planned
VTT	Final performance measurements.	Execution of the final trials and validation of 5G performance.	May – Nov. 2022	Planned

3.5.4.2 T4S2

Partners	Activity	Details	Date	Status
VTT	Scalability testing for the trialed service.	Trials with multiple emulated users.	Feb. – May 2022	Planned
VTT	Final performance measurements.	Execution of the final trials and validation of 5G performance.	May – Nov.2022	Planned
VTT	Comparison of the achieved 5G unicast and 4G multicast performance.	Detailed analysis of the results achieved in the Phase 1-3 trials.	Aug. – Nov.2022	Planned

3.5.4.3 T4S3

Partners	Activity	Details	Date	Status
WINGS	Integration of all components to deliver an E2E system	-	Dec.2021 – May 2022	In progress
WINGS	Test validity of solution based on real data (sensor installed in Athens)	-	Feb. – June 2022	Planned

3.5.4.4 T4S5

Partners	Activity	Details	Date	Status
UOS / NTUA	Applying the 5GENESIS slicing as-a-service	This is subject to the finalisation of closing	Feb – July 2022	Planned

	functionality to T3S1 (i.e., tele-operated support).	the chain of T3S1 with 5G radio access.		
UOS / NTUA	Collaboration with ICOM on "slice isolation	-	Jan – July 2022	Planned

3.5.4.5 T4S4 / T4S6 / T4S7

Partners	Activity	Details	Date	Status
EPI/UoS	Performance Testing over 5G SA network	-	Feb – July 2022	Planned
EPI	Performance optimization over 5G network	-	July – Sept. 2022	Planned
EPI	Mobility testing over 5G network	-	July – Sept. 2022	Planned

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4 AQUACULTURE VERTICAL TRIAL PLANS

4.1 Description and methodology

In the Aquaculture vertical, one use case is defined, A1: Remote monitoring of water and fish quality, which utilizes two different pilots for the execution of the trials. One is based in Athens (Greece) and exploits the infrastructure of the 5G-EVE [1] platform and the second utilises the 5G-VINNI [2] platform in Oslo, Norway. For both pilots, a series of different tests are executed regarding water quality and fish behaviour monitoring, edge computing functionalities, cage-to-cage communication and drove operation, for validating the value of 5G in Aquaculture through various scenarios.

For each of the pilots, a different approach is considered covering the needs for the preparation of the overall setup across the three implementation phases. The Greek pilot implemented Phase 1 by testing an initial NB-IoT/4G setup end-to-end for testing the functionality of the developed solution and the corresponding transmission equipment. Additionally, Phase 1 provided initial network measurements that will be used as a baseline for later analysing and comparing data from 5G measurements. Phase 2 included the on-boarding of the solution to the 5G-EVE platform by executing tests in a lab environment and collecting measurements using the 5G network. Furthermore, during Phase 2, additional installations were performed to enhance the setup to be used for Phase 3. During Phase 3, the final setup is prepared, including the final equipment installations, the setup of the 5G network on site as well as the completion of the trials and of the evaluation KPI measurements.

The Norwegian pilot will follow a different methodology. During Phase 1, installations of the necessary equipment and testing of the functionality using the 4G network took place in parallel with the preparation and testing of the 5G network. During Phase 2, evaluation KPI measurements were taken for the initial installations while the preparation of additional scenarios is also going to proceed. Finally, during Phase 3, the inclusion of the tested scenarios will be completed, while the evaluation and trials of the setup will be finalised.

4.2 The work produced in Phase 2

This section describes the work performed at the trials in Phase 2. It is outlined for reasons to easily depict the updates planned for Phase 3. The solutions include infrastructure developments, tests performed in the field and also if KPIs were measured.

Table 6: Outline the work performed in Phase 2

Scenario	Outline the work performed in phase 2 trials	Platform and location
A1S1	Athens: the gateway with sensors was installed in fish cages for monitoring the water quality, salidity and temperature. Data were monitored in sea. The communication between Skironis aquaculture area and 5G-EVE testbed in OTE premises was executed with the routing work. New license was installed in the EPC core of Ericsson's equipment. The 5G NRs were loaded with new software. OSLO: The control room on the feeding barge was installed, fiber cables were installed between all cages and sensors where installed in alle 8 cages. Telenor works on setting up the base station and 5G-network. As the production on the site ended and all fish was harvested all equipment on the feeding barge and cages was uninstalled.	5G-EVE, Athens, Greece

A1S2	Athens: A new stereo-scope camera was installed in the gateway for monitoring the fish cage and fish health. The camera assisted for providing live view of fish in the cage. A surveillance camera was installed for monitoring the outer area of the fish cage. For the monitoring of the aquaculture facility, the testing of the application and server functionality in lab environment was completed. The 360° camera and ICOM's server were installed, set up and connected via Ethernet. Initial testing to verify their functioning was performed. OSLO: Subsea and surface cameras was installed in all 8 cages. Telenor works on setting up the base station and 5G-network. As the production on the site ended and all fish was harvested all equipment on the feeding barge and cages was uninstalled.	5G-EVE, Athens, Greece
A1S3	An underwater drone was procured for monitoring the status of the net of the fish cage and also the underwater area. Initial tests in the sea presented some problems with water leakage in the drone. Development of an analytics engine to support analysis of real-time monitoring streams produced by network and computational equipment in the Greek pilot. The analytics engine has been integrated to the end-to-end 5G monitoring solution developed in the Greek pilot, in collaboration with all the involved partners (ACTA, OTE, WINGS, ERICSSON).	5G-EVE, Athens, Greece Hosted in computational infrastructure at NTUA.
A1S4	Oslo: As the fish on Gjerdinga was harvested the edge rack was moved to another fish farm called Krigsholmen. This was done to start testing the network setup and pellet detection running on the edge rack. These tests will only be done over 4G. Telenor continues on setting up the 5G-network at Gjerdinga.	5G-VINNI, Oslo
A1S5	Will be done in phase 3.	5G-VINNI, Oslo5G

4.3 The work planned to be done in Phase 3

Phase 3, (December 2021-November 2022), is the final phase of the project, in which case the final set-ups and trials are going to be demonstrated, in addition measurement of network KPIs and production performance indices (PIs) are going to be taken and assessment of the trials will be performed.

Table 7: Description of the work that will take place in Phase 3

Scenario	**Description of work**	**Platform and location**
A1S1	Athens: At Phase 2 tests will be performed end-to-end with the sensors installed in the gateway. Diagrams for the various quantities such as water temperature, salinity will be provided. Data will be transferred to the 5G-EVE testbed for further processing.	5G-EVE, Athens, Greece

	Oslo: Complete 5G-network at Gjerdinga. Reinstall all equipment on feeding barge and cages. Testing the scenario. Network KPI measurements. Application KPIs measurements.	5G-VINNI, Oslo
A1S2	Athens: Live videos will be taken with the stereo-scope camera for fish monitoring. It will be used also for monitoring fish health. Data will be transferred to the 5G-EVE testbed. Prediction of biomass and fish weight will be considered and examined with actual data from the farmer Testing will be performed to ensure connectivity is available and the different quality streams obtained by ICOM's server connected to the 360^o camera as well as the control commands from the camera client (operator) are transmitted to the network. Testing will be performed to collect data rate and latency measurements. Data rate tests will measure the data rate between ICOM's server and the camera client running the application for both the low and high quality streams while latency tests will evaluate the delays incurred in the transmission of the camera streams and the control commands. Oslo: Complete 5G-network at Gjerdinga. Reinstall all equipment on feeding barge and cages. Testing the scenario. Network KPI measurements. Application KPIs measurements.	5G-EVE, Athens, Greece 5G-VINNI, Oslo
A1S3	Athens: Tests will be performed with the drone in the sea water. Based on the results of the performance tests, a set of analysis scripts are going to be executed by the analytics engine to extract insights related to KPIs and identify correlations among the collected metrics.	5G-EVE, Athens, Greece Hosted in computational infrastructure at NTUA.
A1S4	Oslo: Finish test with pellet detection on edge rack over 4G on Krigsholmen. Then move the edge rack back to Gjerdinga and do the same test with 5G.	5G-VINNI, Oslo
A1S5	Oslo: Testing the scenario of wireless communication for one or several cages.	5G-VINNI, Oslo

4.4 Component readiness roadmap

In the following sections, the components' roadmap for all subcases are displayed.

4.4.1 Use case A1: Remote monitoring of water and fish quality

4.4.1.1 A1S1 Athens: Sensory data monitoring

Component	High-level description of Functionality	Source	Status
AQUAWINGS Cloud Platform	A user Dashboard used to monitor and manage the aquaculture system. The user is able to access information about the aquaculture site's status, monitoring the current situation, from a water	Developed by WINGS	Running

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	quality and production perspective as well as a behavioural and infrastructure one. Additionally, maintenance, production and husbandry activities are organized and coordinated through the Dashboard. The core of the system is developed, maintained and deployed around the data storage and distribution components as a software platform system hosting all capabilities and services offered to the operator. These include the data broker aggregating all incoming data and publishing it to any applications listening to it and the database where all data is managed and stored. Advanced Analytics functionalities The Decision Support System		
WINGS Smart 4G/5G Gateway	4G/5G interfaces, edge computing capabilities, RS-232, edge computing capabilities	Developed by WINGS	Running
Aquaread AP5000 Multi-parameter probe	A multi-parameter probe measuring 13 different environmental parameters. It measures temperature, PH, turbidity, Nitrate and Ammonium, Oxygen	Purchased	Integrated in the gateway
vCPE	Virtual probe for network KPIs monitoring, (L3: delay, jitter, loss)	ACTA	To be integrated and tested
MTS 5800	Traffic Generator, KPI monitoring – L4: throughput, RTT	ACTA	Ready
Outdoor CPE	E2E KPIs monitoring	ACTA	Planned

4.4.1.2 A1S1 OSLO: Sensory data monitoring

Component	High-level description of Functionality	Source	Status
Oxygen sensor	Measures oxygen levels and temperature in the sea.	SEALAB	Ready
Salinity sensor	Measures salinity levels in the sea.	SEALAB	Ready
Weather station	Measures temperature, air pressure, wind speed, wind direction, rain fall on the site	SEALAB	Ready

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Cage cabinet with IMU	Measures G-forces on the cage. This is the connection point for al SEALAB hardware.	SEALAB	Ready
Raspberry Pi 3B+	Responsible for reading sensor data	SEALAB	Ready
Fiber cables	Transfers data between cages and the barge	SEALAB	Ready
BlueThink GO	Web page that displays sensor and weather data	SEALAB	Ready
5G-network and base station	Network for communication	Telenor	Partly ready

4.4.1.3 A1S2 Athens: Camera data monitoring

Component	High-level description of Functionality	Source	Status
AQUAWINGS Cloud Platform	An Aquaculture monitoring and management platform utilised for the functional operations and environmental monitoring needs of the use case	Developed by WINGS	Ready
Underwater camera (x units)	Imenco under-water camera	Purchased by WINGS	Ready
WINGS Smart 4G/5G Gateway	A gateway that is equipped with sensors and transmits data to the 5G NR. The data then are transported to the 5G-EVE platform at the OTEresearch premises	Developed by WINGS	Ready
ICOM's 360° on surface camera	Camera for the monitoring of the aquaculture facility	Purchased by ICOM	Ready
ICOM's server	It deploys the server functionality required for capturing and processing the streams from the on surface camera.	Purchased by ICOM	Ready

4.4.1.4 A1S2 OSLO: Camera data monitoring

Component	High-level description of Functionality	Source	Status
Subsea camera	Video monitoring in the cages	SEALAB	Ready
Surface camera	Video monitoring of cage surface	SEALAB	Ready

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Winch	Navigation subsea camera	SEALAB	Ready
Quintus	Providing light under water when needed	SEALAB	Ready
Tablet	Controlling the equipment from the control room	SEALAB	Ready
Joystick	Positioning of camera from control room	SEALAB	Ready

4.4.1.5 A1S3 ATHENS: Automation and actuation functionalities

Component	High-level description of Functionality	Source	Status
BlueROV2 underwater drone	An underwater drone for monitoring the underwater infrastructure	Purchased by WINGS	To be tested in the sea-water
WINGS Smart 4G/5G Gateway	A device to collect, process and transmit sensory data from deployed sensors	Developed by WINGS	Running

4.4.1.6 A1S4 OSLO: Edge and cloud-based computing

Component	High-level description of Functionality	Source	Status
Pellet detection AI	AI application for detecting pellets under water	SEALAB	Ready
MEC-Node (Mobile Edge Computing) - 1 unit	Will run edge application (pellet detection) and connect system to the 4G/5G	Telenor/Nokia	Ready

4.4.1.7 A1S5 OSLO: Cage to cage – on site communication

Component	High-level description of Functionality	Source	Status
5G Node/gateway - 8 units	For wireless communication on each cage	Telenor	Not ready

4.5 Planned activities

4.5.1 Use case A1: Remote monitoring of water and fish quality

4.5.1.1 A1S1 Athens: Sensory data monitoring

Partners	Activity	Details	Date	Status

WINGS Skironis	AQUAWINGS Platform operation in Skironis fish farm	The AQUAWINGS platform is installed in the Skironis fish farm	Q1/Q2 2022	Ongoing
ACTA, WINGS, NTUA	E2E measurements on KPIs	ACTA with the measurement equipment will perform end to end KPI measurements	Q1/Q2 2022	Ongoing
ERICSSON	5G-EVE platform	The whole system from the 5G NR to the NSA EPC is functioning and ready to perform measurements	Q1/Q2 2022	Ongoing

4.5.1.2 A1S1 OSLO: Sensory data monitoring

Partners	Activity	Details	Date	Status
SEALAB	Reinstall equipment on feeding barge and cages	Will be done as soon as fish arrive at Gjerdinga	Q1/Q2 2022	Pending
Telenor	Finish 5G-network configuration and setup on Gjerdinga		Q1 2022	Ongoing
Telenor	Network KPI measurements		Q2 2022	Pending
SEALAB/Telenor	Application KPIs measurements		Q2 2022	Pending

4.5.1.3 A1S2 Athens: Camera data monitoring

Partners	Activity	Details	Date	Status
WINGS, SKIRONIS	Camera is integrated in the gateway platform and monitors fish	The camera in installed in a fish cage. Different installations in the water are tested in order to determine the best means for the camera	Q1/Q2 2022	Running
WINGS, SKIRONIS	Measurement of performance indices (PIs) of the application	The system is ready to measure application PIs	Q1/Q2 2022	Running
Ericsson	Completed the E2E network functionality.	The network is operating E2E and is ready for the measurements	Q1/Q2 2022	Running

4.5.1.4 A1S2 OSLO: Camera data monitoring

Partners	Activity	Details	Date	Status
SEALAB	Reinstall cameras at all cages	Will be done as soon as fish arrive at Gjerdinga	Q1/Q2 2022	Pending
Telenor	Finish 5G-network configuration and setup on Gjerdinga		Q1 2022	Ongoing
Telenor	Network KPI measurements		Q2 2022	Pending

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SEALAB/Telenor	Application KPIs measurements		Q2 2022	Pending

4.5.1.5 A1S3 Athens: Automation and actuation functionalities

Partners	Activity	Details	Date	Status
WINGS, SKIRONIS	Underwater drone to be installed in the sea water	The drone has been tested in the lab. It has been carefully configured for avoiding water leakages.	Q1/Q2/Q3 2022	To be tested

4.5.1.6 A1S4 OSLO: Edge and cloud-based computing

Partners	Activity	Details	Date	Status
SEALAB	Running SEALAB Artificial Intelligence (pellet detection) on Krigsholmen using 4G		Q1 2022	Ongoing
SEALAB	Running SEALAB Artificial Intelligence (pellet detection) on Gjerdinga using 5G		Q2 2022	Pending

4.5.1.7 A1S5 OSLO: Cage to cage – on site communication

Partners	Activity	Details	Date	Status
Telenor, SEALAB	Installing 5G Nodes on one or two cages		Q2/Q3 2022	Pending
Telenor, SEALAB	Wireless communication for one or two cages		Q2/Q3 2022	Pending
Telenor, SEALAB	Installing 5G Nodes on every cage		Q2/Q3 2022	Pending

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5 OVERALL PLANNING OF THE VERTICALS

5.1 Methodology

In the previous sections, focus was given in the collection of the scenarios/subcases individual information regarding the trials progress and planning ahead. In this section, we will concentrate on the overall organization and conflict resolution of the trials for the three verticals in 5G-HEART, i.e., Healthcare, Transport and Aquaculture. We will take into consideration the activities that take place for all scenarios and subcases using the available 5G platforms as well as the solutions and network components developed. This way, we are able to compare and map to the corresponding resources and time frames between the different trial scenarios/sub use cases.

As a starting point for all verticals, an initial plan has been created to guide the implementation and execution of the first Phase 3 tests. As the final trials progress, the initial plan is being refined, providing an updated component implementation roadmap along with the activities planned for the rest of the Phase 3 trialing period. In order to efficiently execute multiple trials during the same time period, it is important to demonstrate how the available resources are distributed to the running scenarios and at which time periods. Based on this analysis, possible overlaps and timing conflicts will be easy to spot and resolve beforehand.

5.2 Platforms and facilities activity mapping

In this section, the activities running for each validation platform (5G-VINNI, 5GENESIS, 5G-EVE, 5GTN, 5Groningen) are summarized and laid down on a common timescale. These are based on the overall planned activities of all the scenarios/subcases as described in the previous sections. We focus on creating a timeline of all the activities on the utilized 5G platforms, identifying possible overlaps between different scenarios and partners and coming up with the timeframes that the platform owners should pay special care to, to organize and distribute the available timeslots and resources.

5.2.1 5G-VINNI – Oslo, Norway

5G-VINNI includes scenarios/subcases from both the Healthcare and the Aquaculture verticals.

Table 8: 5G-VINNI activities

Scenario/ Subcase	Activity	Date
H1A	Interconnect with 5GTN and testing wearable video from RedZinc	Depends on 5G-VINNI platform stability
H1B	Testing two cases of remote ultrasound using NSA, focusing on latency and throughput	May 2021 – Nov 2022
H2A	Testing pill cam video transmission and round-trip latency	Sept 2021 – Nov 2022
H3A	Testing coverage of NB-IoT and/or LTE-M	Sept 2021 – Nov 2022
A1S1, A1S2, A1S4, A1S5	Testing coverage and latency in outdoor marine environments connecting to application edge and remote underwater cameras	March 22 – Nov 22

5.2.2 5GENESIS – Surrey, UK

5GENESIS is the main validation platform that will be utilised for the Transport vertical trials. It is located in Surrey and apart from the 5G network, it will also host the vehicles that are going to be used for the execution of the various tests of the running scenarios.

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Table 9: 5GENESIS activities

Scenario/ Subcase	Activity	Date
T1S1&T1S2	Vehicle integration	May 2021 – Nov 2022
T2S3	Planning	May 2021 – Nov 2022
T3S1	Vehicle integration Network integration Deployment Integration, functionality and connectivity testing Measurements	May 2021 – Nov 2022
T4S4, T4S6, T4S7	Performance optimization Mobility testing	May 2021 – Nov 2022
T4S5	Slicing testing	May 2021 – Nov 2022

5.2.3 5G-EVE – Athens, Greece

5G-EVE is one of the two 5G platforms that are going to be used for the validation of the Aquaculture vertical. While the test cases focus on the Aquaculture vertical, a new subcase has been introduced in the Health vertical, so activities and test cases are going to be executed concurrently.

Table 10: 5G-EVE activities

Scenario/ Subcase	Activity	Date
A1S1, A1S2	Network KPI measurements	Q1/Q2 2022
A1S3	Connectivity and functionality testing (lab)	Q1/Q2 2022
A1S1, A1S2, A1S3	Installations on site	Q1/Q2 2022
A1S1, A1S2, A1S3	Connectivity testing (site)	Q1/Q2 2022

All aquaculture scenarios are combined in this case, so all activities are able to run in parallel without any conflicts. We should mention here though, that the periods of interest where the integration work and the installations on site are to take place concentrate in Q1 and Q2 of 2022 as well, setting up the ground for the final trials of Phase 3.

5.2.4 5GTN – Oulu, Finland

The 5GTN platform in Oulu is responsible for both Healthcare and Transport vertical use cases.

Table 11: 5GTN activities

Scenario/ Subcase	Activity	Date
H1A	Testing the enhanced video streaming solutions between two locations 5GTN and 5G-VINNI. Planning, designing and testing the BlueEye in 5GTN and 5G-VINNI with SA/NSA modes	Spring 2022
T2S4, T4S1, T4S2	Scalability testing for the trialled service and final performance measurements.	February – November 2022

The related activities planned regarding work on the facilities of the platform are shown in Table 11. There is potential overlap in the Phase 3 trialling schedules of the Healthcare and Transport verticals as

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the progress of H1A also depends on the travel restrictions and availability of resources at the 5G-VINNI test facility. However, the trialling schedule of T2S4, T4S1 and T4S2 has been planned to be flexible in order to accommodate to the needs of H1A and lower the risk related to overlapping schedules towards the end of the project.

5.2.5 5Groningen – Groningen, The Netherlands

The 5Groningen platform takes up to host use cases for the Healthcare and Transport verticals.

Table 12: 5Groningen activities

Scenario/ Subcase	Activity	Date
H1C	Functionality and connectivity testing	Q1/Q2 2022
T2S1&T2S2	Network integration	Q1/Q2 2022

As shown in Table 12, activities regarding functionality, integration and connectivity testing are taking place at the platform's facilities, while the specific dates of the activities are dependent on the travel availability of the corresponding partners as well as other ongoing activities.

5.3 Concurrent trials analysis

Up to this point individual scenarios and subcases are being prepared and tested individually. Concurrent trials of are under discussion as the implementation and testing of the vertical use cases progresses towards the final trials and demonstrations during Phase 3 of the project. The details of the concurrent trial configurations as well as the trial results will be reported in deliverables D3.4, D4.4, D5.4 and D6.4.

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6 EVALUATION PLANNING

The complete methodology and explanation of the evaluation procedure for each individual subcase / scenario up to this point has been analytically documented in deliverables D3.3 [3], D4.3 [4] and D5.3 [5], respectively. The evaluation of the selected KPIs across all three verticals and their in-between comparison and analysis will be included in D6.3 and D6.4, respectively.

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7 CONCLUSION

This deliverable presented a summary of all the planning activities of the vertical 5G-HEART vertical use cases/scenarios/subcases. Information about the infrastructure and the components used for the trialling of the solutions are described with a timeline for the E2E testing and assessment of each scenario. The performed activities in Phase 2 and roadmap towards the final trials in Phase 3 are presented. More specifically, the deliverable provides the following results/observations:

- Work progressed during Phase 2 has faced significant delays, especially because of the restrictions to access the facilities due to COVID-19.
- A high-level work analysis performed in Phase 2 per scenario/subcase has been provided with regards to the work update from each test facility site.
- Timeline for the work to be performed in Phase 3 is provided with an update on the status and availability of the infrastructure and components that are going to be used for the final trials.

This deliverable has been designed to provide the timeline of the Final Trials Plan at Phase 3. At the time of writing this deliverable specific parts and technical details of the plan are still under investigation and will be finalised based on the experience gained from the preparation of the final trials.

Planned work for the KPIs measurement and assessment of the performance of each scenario will be presented in deliverables D6.3 and D6.4, respectively.

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