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5G HEalth AquacultuRe and Transport validation trials

D6.1: Preliminary Trials plan

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Abstract	This deliverable describes the preliminary trials plan based on the planning process up to M20. It provides a roadmap for the components' readiness, the activities that are taking place during the preparation and the execution of the trials and the connection between those activities and the 5G platforms. It also provides an analysis of the activities in order to organise the concurrent use of the same resources of the employed testbed and resolve any possible conflicts.
Keywords	5G, trials, planning, verticals

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DEM: Demonstrator, pilot, prototype, plan designs

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

OTHER: Software, technical diagram, etc.

EXECUTIVE SUMMARY

The execution of multiple heterogeneous validation trials across different verticals is not a trivial task. Thus, the preparation of a detailed trials plan was considered necessary for the overall organization of the trials across the 5G facility sites and vertical domains. Organization includes detailed planning and coordination of deployment activities, ensuring timeliness and smooth delivery of vertical solutions, avoiding cases of conflicting activities across co-located verticals. Planning takes input from Tasks 4.1, 5.1 and 6.1, 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 preliminary trials plan is described, including the initial plan as this was drafted during the definition of the vertical use cases as well as information about the per-scenario / subcase planning, a roadmap for the remaining implementation work and the upcoming activities that are considered as the trials progress. The analysis of this information and the identification of specific overlaps and conflicts is an important part of this first plan. The outcome of this analysis aims to provide a basic time plan of the mid-trial activities, while identifying key period time frames that pose potential threats to the organization of the plan if not resolved in time. Additionally, it provides feedback to the vertical work packages as well as the platform owners with the necessary information to plan their activities and coordinate effectively to resolve any upcoming conflicts and fine tune their schedule towards the Final Trials Plan.

Key takeaways from the aggregation of this input include the utilisation of the available resources and the time scheduling of integration, deployment, testing and other activities. It is apparent that restrictions due to COVID-19 have caused significant delays especially to the facility visits for measurements, integration, etc. Subsequently, planning certain activities has been proven difficult, so the scheduling of specific dates is not always possible. Additionally, Phase 2 trials have been pushed back, so planning of specific configurations, such as specific slice requirements from the use cases, is still not defined, since focus has been given to the enhancement and integration of the developed solutions.

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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 AquaculturRe and Transport validation trials
8K	7680x4320 pixel resolution
AI	Artificial Intelligence
API	Application Programmer's Interface
AR	Augmented Reality
CE	EU certification mark for conformity ("Conformité Européenne")
CIoT	Cellular IoT
COTS	Common Off-The-Shelf
CPU	Central Processing Unit
D2C	Direct-to-Cloud
DL	Downlink
DOF	Degree of Freedom
E2E	End-to-End
EDT	Early Data Transmission (3GPP Release-15 feature)
eMBB	enhanced Mobile Broadband
eNodeB / eNB	Evolved Node B (4G)
EPC	Evolved Packet Core (4G)
EPS	Evolved Packet System (4G)
eSIM	embedded SIM
ETA	Estimated Time of Arrival
GDPR	General Data Protection Regulation
GP	General Practitioner
GSMA	GSM Association (industry group of mobile operators)
H.264	MPEG-4 AVC (video codec)
HD	High-Definition
HEVC	High Efficiency Video Coding (video codec also known as H.265)
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
LTE	Long-Term Evolution
LTE-A	LTE Advanced
LTE-M	LTE Machine Type communication
MANO	Management and Orchestration
MEC	Multi-access Edge Computing
mMTC	massive Machine Type Communications
NB-IoT	Narrow-Band IoT
NFV	Network Function Virtualisation
OTA	Over-The-Air
PCB	Printed Circuit Board

QoE	Quality-of-Experience
QoS	Quality-of-Service
RAM	Random Access Memory
RAN	Radio Access Network
RF	Radio Frequency
SDN	Software-Defined-Network
SIM	Subscriber Identity Module
TRL	Technology Readiness Level
UDP	User Datagram Protocol
UE	User Equipment
UI	User Interface
UL	Uplink
URLLC	Ultra-Reliable Low Latency Communications
USB	Universal Serial Bus
VNF	Virtual Network Function
VM	Virtual Machine
VPN	Virtual Private Network
VR	Virtual Reality
WG	Working Group
Wi-Fi	Wireless Fidelity
WP	Work Package

1 INTRODUCTION

The basis of the work in the 5G-HEART project is concentrated on the development of the trials for the use cases across the Health, Transport and Aquaculture verticals. 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 (Key Performance Indicator) measurements and results. Thus, the three phases are distributed across the three-year lifetime of the project, while due to the COVID-19 outbreak, a 6-month extension has prolonged this period adjusting the 3-phase planning accordingly. This is demonstrated in Figure 1.

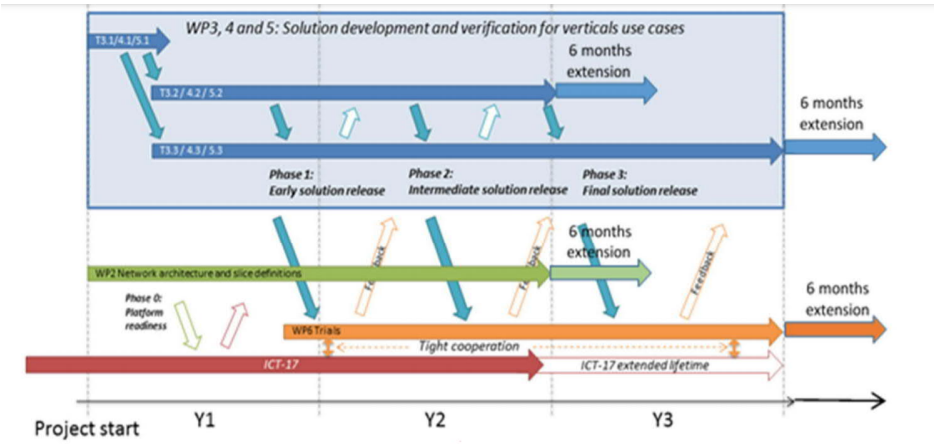

Figure 1: Updated timeline of vertical trials

In order to effectively guide the implementation and execution of the trials, it is crucially important to plan in parallel the activities that are taking place, discover emerging conflicts by potential trials occurring at the same time and trial site whilst using the same resources. Such activities include the following:

- Preparation, Development, Purchase, Deployment
  - Software
  - Hardware
- Integration activities / Workshops
- Network on-boarding
- Functionality testing
- KPI measurements
- Evaluation

The identification of the specific time periods and resources that are required by each trial activity, while also planning ahead for the in-time delivery of all necessary components, the confrontation of possible delays, escalations due to the COVID-19 situation and resource allocation conflicts can be guaranteed providing a clear horizon for the trials execution.

The general methodology that is followed for the implementation of the 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, while also running concurrent trials between different verticals. 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. Additional refinement of the use cases takes place to further connect each use case to specific service requirements that can be mapped to the 5G services and network capabilities. These concepts are analytically described in the relevant vertical deliverables (see D3.1, D4.1, D5.1) and in this deliverable we are going to present the whole picture of the work done for the vertical trials in the project.

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 seven 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 will be 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 later 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 will be 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. 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.

As the first step of the three-phased approach for trials and validations, these phase-1 trials aimed 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. This serves as (part of) the guidelines for preparing the phase-2 (more advanced, using 5G) trials.

2.2 Initial plan

In this section, the initial trial plans are displayed as presented in D3.1. These have been modified as the trials proceed and the updates are discussed in the following sections.

2.2.1 Phase 1 trials

In general, phase 1 trials represent early proof-of-concepts for the use case solutions and implementations. Leading up to milestone MS2, solutions must be developed and verified, and only very simple tests on performance in a 5G framework will be possible. The tests being planned for the different use cases in phase 1 are shown in Table 1.

Table 1 Phase 1 trials, platforms and locations

(sub) use case	**1st phase leading up to MS2 in M12 – May 2020**	**Platform and location**
H1A	• Use LTE at 5GTN, Oulu • Playback from 360 camera • Add DSLR video and heart beat sensor • Introduce the required measurement tools for QoE	5GTN, Oulu, FI

H1B	• Set up Philips Lumify/REACTS experiment on 5G-VINNI network as a first version of the Skype-like approach • Define and implement AR interfaces for local and remote users • Test the upgraded robotic framework via Ethernet locally at OUS • Define the approach for evaluation	5G-VINNI, Oslo, NO
H1C	• Implement baseline evaluation using 4G/LTE • Video streaming back to Ambulancezorg Groningen • Ultrasound solution based on Lumify/REACTS • Measure KPIs using simulations with medical students	5Groningen, Groningen, NL
H1D	• Define clinical KPIs • Implement baseline evaluation using 4G/LTE • Measure using simulations with medical students	5G-VINNI, Oslo, NO
H2A	• Define technical and clinical KPIs • HW platform design to facilitate the interface between the on-body and the in-body communication systems • Develop a computer simulation framework having an AI algorithm for polyp detection	5G-VINNI, Oslo, NO
H3A	• Develop vital-sign patch for post-surgery clinical case, using mMTC (NB-IoT/LTE-M) Release 13 and evaluate performance on commercial cellular networks in the Netherlands • Perform gap analysis of Release 13 technology relative to patch requirements and identify most promising Release 14-16 features to be tested in phase 2 and the 5G-HEART supported facilities to test them on	Commercial NB-IoT network, NL
H3B	• Lab demonstration • HW platform development • Algorithm validation	CEA lab, Grenoble, FR

2.2.2 Phase 2 trials

Phase 2 trials build on the experience gained in phase 1, however, clear targets have been set. Phase 2 contains a mix of advancing and extending the experiments, but clearly expects to address 5G feasibility of the use cases. The tests that are being planned for the different use cases in phase 2 are shown in Table 2.

Table 2 Phase 2 trials, platforms and locations

(sub) use case	**2nd phase trials leading up to MS3 in M24 – May 2021**	**Platform and location**
H1A	• Using LTE and 5G • Move 360 camera to OUS in Oslo • Connect to 5G-VINNI platform • Interconnect 5GTN and 5G-VINNI • Playback from Oslo to Oulu • Introduce audio feedback channel	5GTN, Oulu, Fi 5G-VINNI, Oslo, NO Interworking
H1B	• Adapt and extend the Skype-like platform to offer more options for tele-ultrasound • Develop the AR-based platform • Test the upgraded reliable robotics framework over 5G network locally at OUS • Design an emergency protocol on top of UDP for the robotics framework • Evaluate effectiveness of the different approaches to deal with the identified scenarios, preferably AB testing, or benchmarking of current practices	5G-VINNI, Oslo, NO
H1C	• Implement 5G in a warehouse environment • Ultrasound with AR	5Groningen, Groningen, NL

	• Repeat simulations and measurements	
H1D	• Implement 5G connectivity • Repeat simulations and measurements	5G-VINNI, Oslo, NO
H2A	• Develop the interface to the proprietary in-body communication and on-body receiver system with a 4G/LTE and prepare a design document to bridge intra-body communication system with 5G • Demonstrate the communication system in computer and in human phantoms	5G-VINNI, Oslo, NO
H3A	• Evaluation of selected, advanced features from Release 14-16 with regards of their benefits to the patch clinical case(s) • Potentially broaden the application into more demanding clinical cases. • Define next steps for evaluation in 3rd phase	5G-VINNI, Oslo,NO
H3B	• Intermediate tests on CEA premises • Intermediate version of algorithms and demonstrator	CEA premises and Grenoble City, FR

2.2.3 Phase 3 trials

In phase 3, which is the final phase, the most advanced setups are being tested. This time, we expect to be able to clearly demonstrate both the feasibility of the solutions, the still remaining challenges, and quantified performance measures. The tests being planned in phase 3 for the different use cases are shown in Table 3.

Table 3 Phase 3 trials, platforms and locations

(sub) use case	**3rd phase trials leading up to MS4 in M36 – May 2022**	**Platform and location**
H1A	• Using LTE and 5G • Introduce mobility at both sides • Considering 5Groningen for server side with the ambulance context (see subcase H1C) • Mobile clients at 5GTN, Oulu, 5Groningen • Measure e2e metrics with quality assessment	5GTN, Oulu, FI 5G-VINNI, Oslo, NO (?) 5Groningen, Groningen, NL Interworking
H1B	• Improve the Skype-like and AR-based platforms based on the outcome of the evaluation experiments and perform further testing. • Improve the robotics framework based on the outcome of the experiments. • Design an emergency safe mode for the robot considering location of patient, technician and slave side devices.	5G-VINNI, Oslo, NO
H1C	• Extending phase 2 with 5G using mobility • Further evaluation of ultrasound approach	5Groningen, Groningen, NL
H1D	• Evaluate results from phase 2 and 3 • Extend or repeat testing as applicable to gain more data	5G-VINNI, Oslo, NO
H2A	• Demonstrate a 5G interface and uplink and downlink latency with AI simulations in MEG. • Demonstrate the concept in animal experiment • Prepare a prototype and documentation with an application to the Regional Ethics Committee to use AI for polyp detection • Describe the regulatory steps and approval procedures as a roadmap to get approval for first in human procedure	5G-VINNI, Oslo, NO
H3A	• Evaluation of selected, advanced features from Release 15-17. • Potentially broaden the application further into more demanding clinical cases. • Gap analysis as input to future 3GPP releases (i.e. requirements input to standardization).	5G-VINNI, Oslo, NO

H3B	• Final field trials in the city of Grenoble • More advanced demonstrations • Final localization algorithm validation	CEA premises and Grenoble City, FR

2.3 Component readiness roadmap

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

2.3.1 Use case H1: Remote interventional support

2.3.1.1 H1A

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
Network component (4G/5G)	4G and 5G infrastructure in 5GTN	VTT (5GTN)	4G fully functioning. COVID-19 delayed 5G operability	Full upgrade to 5G	
KPI measurement tools (Qosium)	Software tools to measure network KPIs	VTT (5GTN)	Done	Will be used similarly	
360 live video streaming setup	Video streaming setup used for medical healhcare education and remote analysis	VTT	Done	Enhanced version will be provided	

2.3.1.2 H1B

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
Network component (4G/5G)	4G and 5G infrastructure in 5G-VINNI	Telenor (5G-VINNI)			
KPI measurement tools					
Ultrasound machine (1^{st} & 2^{nd} proto)	Philips EPIQ machine SW 6.0 with Collaboration Live feature enabled for applicable Reacts accounts. Including webcam.	OUS/Philips (existing machine with upgrade provided by Philips).	-	X	X
Reacts client (1^{st} proto)	Laptop running Philips Reacts software.	OUS/Philips (OUS laptop with Philips downloadable software client).	-	X	X
Reacts accounts (1^{st} proto)	Access to Philips Reacts service for individuals involved in testing.	Philips.	-	X	X

Hololens 2 (2x), camera's and other stuff (2nd proto)	Hololens 2 to be used at both sides of the connection for AR/VR setup.	OUS	-	X	X
Updated WebRTC platform	Enables additional functionality above Collaboration Live, specifically relevant for support of Hololens2			X	X

2.3.1.3 H1C

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
Network component (4G/5G)	4G and 5G network infrastructure	TNO (5Groningen)	4G network	Upgraded to 5G NSA	To be upgraded to 5G SA
KPI measuring tools (iPerf, Speedtest app, ping and ROMES4)	Software tools to measure the throughput, latency and network coverage.	TNO (5Groningen)	Done	Done	
Video set	Used by paramedic to stream video to chief medical officer	RedZinc	Done	Enhanced version will be provided	
Ultrasound set	Philips Lumify/Reacts probe, tablet, software and Reacts accounts. Different camera setups.	Philips	Done	Need 5G enabled tablet or CPE for experiments on live 5G network.	
Updated WebRTC platform	Enables additional functionality above Reacts			Planned	

2.3.1.4 H1D

No information additional to what is included in D3.2 was available at this time due to COVID-19 related delays. Complete information of the trials plan will be included in D6.2.

2.3.2 Use case H2: Pill-camera

2.3.2.1 H2A

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
Network component (4G/5G)	4G and 5G network infrastructure	5G-VINNI	4G network	5G Upgrades Ongoing (HW FW)	

KPI measuring tools (iPerf, ping, Speedtest app)	Software tools to measure the throughput and latency	OUS / NTNU	4G network	5G	
Endoscope camera	Device that captures in-body images	OUS / NTNU	4G network	Ongoing preparations for 5G	
On-body wireless com device	Device that receives and broadcasts the images for inference	OUS / NTNU	4G network	Ongoing preparations for 5G	
Edge / Inference set	Device that processes the images and performs object detection before sending the to the cloud and sending instructions feed to the capsule	NTNU	4G network	Ongoing preparations for 5G	
Cloud	Server which either receives processed and inferred images or receives, processes, performs detection and provides feedback signal; or both	OUS	4G network	Ongoing preparations for 5G	
Software Polyp Detection	Deep learning model that detects polyps and other anomalies in the colon	OUS	First iteration ready but missing real time detection capabilities	Added real time detection, cut down inference time and adding remote network connectivity for different image formats	Working on precision improvement, detection on NBI mode and low data rate detection mode
Human Body Backscatter Com	A Pill-camera has been modified to cut down power consumption and to use HBBC for lower rates of data transmission	OUS	Customization of pill-camera plans and design	Modifications have been implemented on the capsule endoscope to reduce data rate to about 10 Mbps but on body recording system has been proven difficult to interact with in connection with the new data format. An FPGA solution has been designed to work around data transmission between the pill-camera and inference machine	Plan: adapt FPGA to receive serial data from pill-camera and send to the inference machine to translate to images before inference

FPGA Board	An FPGA board that received the raw data from human body backscatter	OUS	N/A	FPGA has been designed to translate HD video to low rate video or image (VGA) with the rate 10 Mbps. This will be streamed via PC LAN interface. In the first setup, we can connect this via LAN to a second PC and make the processing and demonstration where AI algorithm can be applied.	Connecting FPGA to capsule system and inference machine, tests with low data rate and signal loop

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

2.3.3.1 H3A

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
LTE-M or NB-IoT **module** featuring power class 6 (including evaluation kit)	Real form factor prototype of a vital-signs patch (does not allow experimentation with the 14 dBm power class) Use of evaluation kit of a module/silicon manufacturer to check antenna setting Goal: develop native 14 dBm support (i.e. an integrated PA capable of just 14 dBm and 3GPP compliant signalling) Alternative: 20/23 dBm PA clipped on 14 dBm with or without compliant signalling	Philips and/or Telenor from module manufacturer (e.g. Sequans from 5G-TOURS)	Various evaluation kits available, e.g GM01Q of Sequans.	GM02S of Sequans for at least power clipping Compliant signalling discussed	Native 14 dBm
Real form factor **antenna**, mounted in (near) real form factor patch and mounted on body phantom (e.g. pack of milk).	The vital-sign patch antenna has limited performance due to its small size, the inability for antenna diversity and its closeness to the human body. Both limited Tx power and the antenna situation will impact coverage.	Philips	Developed as part of real form factor Release 13 prototype patch.		
Some way to gather **coverage data** on a map		Telenor	Can use existing coverage maps for LTE-M		

2.3.3.2 H3B

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
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 SDR platform and COTS LPWA IoT platform particularly for city range measurements	Laboratory performance evaluation	Campus-wide trials	Large scale City wide trials
KPI measurement tools	GNSS measurement is performed on the same point of interest as radio ranging measurement to evaluate performance of low power radio localisation based on 5G NB-IoT and its possible evolutions	Ublox FP8 modules associated with active antennas are considered as reference			

2.4 Planned activities

2.4.1 Use case H1: Remote interventional support

2.4.1.1 H1A

Partners	Activity	Details	Date	Status
VTT, RedZinc, TNO, OUS	Testing the enhanced video streaming solutions between two locations 5GTN and 5G-VINNI		TBD depends on travel restrictions due to COVID-19, current estimation Spring 2021	Delayed

2.4.1.2 H1B

Partners	Activity	Details	Date	Status
Philips, OUS	Testing of remote ultrasound solution with EPIQ over 5G-network		May 2021	Running

2.4.1.3 H1C

Partners	Activity	Details	Date	Status
TNO, Philips, RedZinc	Testing of enhanced solutions for the dashboard, video set, ultrasound set and wireless network.		TBD (depends on progress made by the partners and the possibility of travel to the test facility).	TBD

2.4.1.4 H1D

No information additional to what is included in D3.2 was available at this time due to COVID-19 related delays. Complete information of the trials plan will be included in D6.2.

2.4.2 Use case H2: Pill-camera

2.4.2.1 H2A

Partners	Activity	Details	Date	Status
OUS, Telenor, NTNU	Testing of enhanced solutions for the dashboard, capsule set, on-body set, edge computer, cloud and wireless network.		TBD (depends on progress made by the partners and the possibility of travel to the test facility).	TBD
OUS, Telenor, NTNU	FPGA design, assembly and testing in connection with on body recording system		Ongoing, tentatively Dec 2020	Running
OUS, Telenor, NTNU	FPGA fusion with AI inference and testing		Second half of January 2021	Running
OUS, Telenor, NTNU	Network for testing remote inference and control signal loop		CPE provided by Telenor cannot be reached, trying to find a workaround, also. 5G option not available. Ready when CPE workaround.	Running
OUS, Telenor, NTNU	Inference time reduction is being implemented, hardware components including new GPUs with a new tensor architecture are being ordered but supply is limited		Hardware supply is out of stock until January 2021	TBD
OUS, Telenor, NTNU	KPIs on the clinical side have been designed to involve colonoscopists to validate the pill-camera's findings and evaluate and confirm the utility of the solution.		Late January / Early Feb 2021	Running

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

2.4.3.1 H3A

Partners	Activity	Details	Date	Status
Philips, Telenor	Exploring indoor coverage and planning			Running

2.4.3.2 H3B

Partners	Activity	Details	Date	Status
CEA	Testing and measuring localisation performance of 5G NB-IoT and its evolutions in difference environment		See below	
CEA	Phase 1: evaluation in laboratory environment to validate platform concept	v1	Q1 2020	Done

CEA	Phase 2: Campus wide performance measurements	Ongoing – Encouraging preliminary results	Completion of this phase planned Q1 2021	Running
CEA	Phase 3: City wide performance measurements		Starting Q4 2021	TBD

2.5 Slice mapping

As information about the requirements of the use cases in terms of slice options from the utilized 5G platforms is currently not available, the mapping of the scenarios to the different slices will be described in *D6.2: Final Trials plan.* For information regarding the slicing availability from the 5G platforms' side, consult the upcoming deliverable *D2.3: 5G-HEART Network Architecture and Slice Definition.*

3 TRANSPORT VERTICAL TRIAL PLANS

3.1 Description and methodology

As the first step of the 5G-HEART's three-phased approach for trials and validations, the described Phase 1 trials aim to validate the baseline performance (i.e., of fourth generation (4G)/long-term evolution (LTE) technologies) and initial 5G solutions developed for the transport vertical sector. Based on the observations made during these trials, insights have been 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 2) 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 trials have been conducted per scenario, 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, provided by the new member who recently joined the consortium (i.e., Technical University Chemnitz (TUC)). 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 that will be held at the TUC premises as soon as the COVID-19 restrictions are lifted.

Based on the results, observations and insights acquired during Phase 1 trials, a 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. As the trials have been progressing up to this point, five core scenarios have been considered to guide the process, followed by the rest of the scenarios that are going to complement the validation activities based on the setups utilised for the core ones.

3.2 Initial plan

In this section, the initial trial plans are displayed as presented in D4.1. These have been modified as the trials proceed and the updates are discussed in the following sections.

3.2.1 Phase 1 trials

In general, Phase 1 trials represent early testing of the preliminary use case solutions and implementations with simple tests addressing 5G performance. The tests being planned for the different use cases in Phase 1 are shown in Table 4.

Table 4: Planned Phase 1 trials, platforms and locations.

Trial scenario	Phase 1 leading up to MS2 in M12 – May 2020	Trial platform
T1S1&T1S2	The see-through and situational awareness functionalities are used to inform the passengers of the platoon members of what is happening ahead of the platoon leader, thus resulting in a better driving experience.	Surrey, UK
T1S3	The trial system will be demonstrated using a traffic progression model in traffic controllers together with connectivity to a vehicle OBU via 5G.	Surrey, UK
T2S1&T2S2	The interaction between the individual modules within the architecture will be tested based on current SotA (4G/LTE). This will provide the baseline for the next phases.	Groningen, Netherlands
T2S3	The most appropriate driving mode is initially selected for a homogeneous trip. The best driving mode should be maintained along the whole trip trajectory.	Surrey, UK
T2S4	Collection and distribution of driver's physiological parameters related to fatigue such as sleep metrics, recovery status and physical activity is performed. Slow moving (<50 km/h) sensor devices with short-range data transfer and a 5G NR link through a dedicated GW device are utilised. Unicast transmission is used from user to application service and back.	Oulu, Finland
T3S1	Testing of each of the architectural modules of the remote driving application. More specifically, by the term architectural modules the distinct functionalities of TeSo application are meant.	Surrey, UK
T4S1	Configuration and testing of the architecture for collecting the vehicle data. Focus will be on basic connectivity and performance of the 5G uplink.	Surrey, UK
T4S2	Configuration and testing of the architecture for collecting the vehicle data. Focus will be on basic connectivity and performance of the 5G downlink.	Surrey, UK
T4S3	Installation and configuration of the available equipment and preparation to gather and process information from the sensors installed on the vehicles and/or from the RSUs.	Surrey, UK
T4S4	Vehicle moves through the campus and depending on trigger coordinates, gets text advertisement pop-ups, audio prompts and HD audio/video adverts.	Surrey, UK
T4S5	Individual trials with E2E slices associated with various use case scenarios of the transport vertical.	Surrey, UK
T4S6	Prepare the test setup with the baseline maps and HD mapping application in a distributed or centralised deployment across cloud servers and/or RSUs. Both vehicles and RSUs will be prepared and testing will be conducted focusing on the 5G connectivity for the overall scenario.	Surrey, UK
T4S7	Vehicle moves through the campus and uploads environmental data continuously from on board sensors.	Surrey, UK

3.2.2 Phase 2 trials

Phase 2 trials build on the experience gained in Phase 1 with clear targets set for addressing the 5G feasibility of the overall use cases. The tests being planned for the different use cases in Phase 2 are shown in Table 5.

Table 5: Planned Phase 2 trials, platforms and locations.

Trial scenario	2nd Phase trials leading up to MS3 in M24 – May 2021	Trial platform
T1S1&T1S2	An initial 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 small scale. The transmitted video of the front scene serves as a prior visual notification to allow the drivers of the platoon members to expect the manoeuvres of the leading vehicle and get ready to take over the control of the vehicle.	Surrey, UK
T1S3	A trial of optimizing channel assignment within the coverage area of one single RSU will be conducted with a focus on intersections / junctions.	Surrey, UK
T2S1&T2S2	The individually tested modules will be integrated with 5G capable equipment, e.g. a 5G capable UE. After which the connectivity and functionality of the individual modules will be tested.	Groningen, Netherlands
T2S3	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. Compared to the previous, this phase includes a set of mechanisms to change the driving mode during the trip at the proper time and location.	Surrey, UK
T2S4	Generation of information/feedback/warning messages based on post-processed and analysed sensor data is tested. Unicast transmission is used from user to application server and broadcast from application server to all users in the area.	Oulu, Finland
T3S1	After having tested the functionality of each distinct module in the first trialling phase, the demonstration of the integrated modules will follow. This phase targets to execute step-by-step the use case/service flow described in the previous section and thus, accomplish successfully a tele-operation of a vehicle.	Surrey, UK
T4S1	Implementation and testing of the vehicle service application for the processing of the collected data. Focus will be on the E2E performance of the service.	Surrey, UK
T4S2	Implementation and testing of the vehicle software update application. Focus will be on the delivery of software update packages to the vehicles.	Surrey, UK
T4S3	Implementation, creation and storage of the dynamic heatmaps based on the decided discretisation in the spatial and time domains. Implementation of the decision making entity that exploits the produced heatmaps, vehicle profile and user preferences to select the optimal route.	Surrey, UK
T4S4	Vehicle moves past a billboard which identifies it and displays a relevant advertisement based on the vehicle destination or other parameters.	Surrey, UK
T4S5	Concurrent trials with multiple E2E slices associated with co-located use case scenarios of the transport vertical.	Surrey, UK

T4S6	Utilisation of one or more in-vehicle sensors to create an HD map from scratch using one or both vehicles.	Surrey, UK
T4S7	Vehicle moves through the campus at higher speed to test the system reliability and real time applications.	Surrey, UK

3.2.3 Phase 3 trials

In phase 3, which is the final phase, the most advanced setups will be tested. This involves demonstrating the feasibility of the solutions, quantifying all performance measures and identifying any remaining challenges. The tests being planned in Phase 3 for the different use cases are shown in Table 6.

Table 6: Planned Phase 3 trials, platforms and locations.

Trial scenario	3rd phase H2/2021-H1/2022 (M36)	Trial platform
T1S1&T1S2	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
T1S3	Large-scale trials will be conducted in areas spanning the coverage area of various RSUs. This requires collaboration between various RSUs to efficiently deal with border effects (e.g., avoid co-channel interference along borders and perform handover at the right time and location).	Surrey, UK
T2S1&T2S2	The integrated system will be tested, evaluated and demonstrated.	Groningen, Netherlands
T2S3	The best driving mode is dynamically determined and selected 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).	Surrey, UK
T2S4	Data exchange and data fusion between wearable devices and other automated driving support systems (on-board or online), including live biosignals like heart rate, is trialled and demonstrated.	Oulu, Finland
T3S1	A comparison between 5G network capabilities and its 4G network counterpart will be conducted. 5G network provides enhanced capabilities and goes beyond the barriers of legacy networks.	Surrey, UK
T4S1	Scalability testing for the network and service architecture.	Surrey, UK
T4S2	Scalability testing for the network and service architecture.	Surrey, UK
T4S3	Testing according to the outcome of the available routes, taking into consideration the profiling information of the vehicle and possible restrictions associated with it.	Surrey, UK
T4S4	Vehicle moves through the campus at higher speed to test the system responsiveness and in wider area to test the 5G handover. In addition, vehicle moves through the campus and plays back different types of adverts to test content independence with both in-vehicle and outdoor ‘billboard ‘ads.	Surrey, UK
T4S5	Concurrently trials multiple E2E slices associated with different vertical applications (i.e., transport and healthcare) across different sites.	Surrey, UK

T4S6	Dynamic update of the HD map across all three elements (i.e. cloud mapping application, RSUs and both vehicles).	Surrey, UK
T4S7	Vehicle moves through the campus at signal shadow regions to test the system reliability. Various functionalities will be trialled in the test setup, including the integration of data/information from different sensors in centralised server application, map visualisation of weather information and distribution of local weather map back to vehicles.	Surrey, UK

3.3 Component readiness roadmap

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

3.3.1 Use case T1: Platooning

3.3.1.1 T1S1&T1S2

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
Hardware components					
HD front camera (platoon leader)	Front camera to capture the scene in front of the platoon leader	TUC	Available	Available	Available
On-board screen (platoon members)	To display the platoon leader's front scene inside platoon members	TUC	Available	Available	Available
Software components					
Video transmitter	Application to transmit the video to platoon members (platoon leader)	UOS/TUC	Not started	Under development	Available
Video receiver	Application to receive the front scene video and forward to the on-board screen (platoon members)	UOS/TUC	Not started	Under development	Available

3.3.1.2 T1S3

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
Software components					

System-level simulator	Simulator that supports a high number of platoons to assess the proposed functionality (i.e., optimised channel assignment) at scale. **This is a word-around as the initial target of trialling the scenario is not feasible due to the limited number of vehicles available for trials (i.e., 2)**	UOS	Started (initial steps)	Finalise the simulator **(best effort)**	The simulated scenario will evolve into a hardware-in-the-lop (HIL) setup, where one of the simulated platoons will be substituted by an actual platoon formed by the CARAI research experimentation vehicles. **The feasibility of such mixed setup is still to be studied. If it is deemed unfeasible, the scenario will be ruled out due to the unavailabiltiy of enough vehicles.**
Radio environmental map (REM)	An REM optimises the assignment of radio channels to the various platoons based on the vehicle geo-location information, platoon movement and spatiotemporal availability of radio channels.	UOS/EPI	Not started	To be developed once the platoon simulator is built (**best effort**)	Available (**best effort**)
Not feasible to trial due to the unavailability of enough vehicles. The hardware-in-the-loop (HIL) work-around has been deemed feasible. Currently trying to integrate this as extra functionality into one of our core use case scenarios (e.g., T2S2&T2S2). If this is not possible, T1S3 will be dropped due to the unavailability of vehicles.					

3.3.1.3 T1S1&T1S2 + T1S3

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
Platooning agents	Software agents to implement the basic platooning operation between the two CARAI vehicles.	UOS/TUC	Not started.	To be started in Q1/Q2 2021.	Available

3.3.2 Use case T2: Autonomous/Assisted driving

3.3.2.1 T2S1&T2S2

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
Network component (4G/5G)	4G and 5G network infrastructure	TNO (5Groningen)	4G network	To be upgraded to 5G	
KPI measuring tools (iPerf, ping, ETSI CPM-based app)	Software tools to measure the throughput and latency	TNO (5Groningen)	Done		
IP-based security camera	Camera used for object detection (e.g. vehicle or road user tracking)	TNO (5Groningen)	Done		
On-board unit	OBU functioning as UE configured for both LTE-Uu and LTE-V2X	TNO (5Groningen)	Done	To be upgraded to 5G version	
Back-office cloud server	Server running a MQTT broker and hosting the object detections	TNO (5Groningen)	Done		
Traffic Light controller	A traffic light controller operating the intersection in Helmond (within the 5Groningen's coverage)	Dynniq	Connectivity to the Traffic Light controller has been delayed to Phase 2 due to connection issue.	In Phase 2, the connectivity to the Traffic Light controller will be added.	

3.3.2.2 T2S3

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
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 (deployed at the Edge of 5GENESIS)	To be extended/strengthened	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	First prototype available	To be refined	Available
Estimator and connectivity and QoS levels	It allows to negotiate the connectivity and QoS levels provided by the network	UOS	Not started	Under investigation (in incorporate a static form of QoS level estimation).	Available (dynamic estimation based on the latest 3GPP progress).

3.3.2.3 T2S4

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
Polar M600 sports watch	Hardware component. Used as the wearable sensor device for Phase 1 trials.	VTT	Available	Not used	Not used
Polar H10 heart rate sensor	Hardware component. Used as the wearable sensor device for Phase 2 and 3 trials.	VTT	Not used	Available	Available
Sensor data streamer	Software component in the UE. Used to stream the sensor data received from the wearable sensor device (via BLE) to the 5G network.	VTT	Available	Not used	Not used
Polar sensor logger	Software component in the UE. Used to stream the sensor data received from the wearable sensor device (via BLE or WiFi) to the 5G network.	Polar	Not used	Available	Available
Sleep history API	Software component in the backend server. Used to provide analysed historical data related to sleep quality and recovery.	Polar	Available	Available	Available
5G user equipment	Network components. Different models used for the trials and measurements: OnePlus 7 Pro 5G smartphone, Samsung Galaxy S10 5G smartphone, Nokia FastMile 5G CPE, Huawei 5G CPE Pro.	VTT (provided by 5GTN)	Available	Available	Available

5G network	Network components. Indoor and outdoor coverage using 5G-NR Rel-15 NSA at 3.5 GHz with 60 MHz bandwidth. Lightweight and carrier grade options for EPC and 5GC services.	VTT (provided by 5GTN)	Available	To be updated to 5G SA and partial Rel-16 compatibility	Further Rel-16 updates as per platform roadmap

3.3.3 Use case T3: Support for remote driving

3.3.3.1 T3S1

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
Software components					
Camera module [Vehicle side application]	It captures the video stream(s) and transmits them through the network to the ROC, to be processed by the ROC Streaming module.	NTUA/ TUC develop	Development of the basic functionality.	Extension to support more than one video streams.	
Sensor and Instrumentation module [Vehicle side application]	It captures the sensor and instrumentation data, such as GPS data corresponding to the position of the vehicle and transmits it through the network to the ROC, to be processed by the ROC Sensor and Instrumentation module.	NTUA/TUC develop	Development of the basic functionality.	Extension to support additional types of sensory data (e.g., steering angle, gear position,etc.; the exact list of sensory data to be included will be determined in Phase 2 according to the capabilities of the vehicles).	
Control module [Vehicle side application]	This module is related to the interface with the human-operator. Its purpose is to receive the remote-control commands from the respective ROC module and transfer them to the vehicles' actuators in order to realize the requested	NTUA /TUC develop	Development was delayed due to COVID-19 restrictions	Development of the basic functionality.	Finalization depending on the trial's needs.

	actions and control the vehicle.				
Streaming module [Remote control centre application]	This part of the architecture resides at the cloud or MEC and is in charge of receiving the video stream(s) through the network and display them appropriately to the human operator.	NTUA develop	Development of the basic functionality.	Extension to support the concurrent display of multiple video streams.	
Sensor and Instrumentation module [Remote control centre application]	This part of the architecture resides at the cloud or MEC and is in charge of receiving the sensor and instrumentation data, such as GPS data corresponding to the position of the vehicle and display it appropriately to the human operator.	NTUA develop	Development of the basic functionality.	Extension to support display of additional sensory data (e.g., steering angle, gear position,etc.; the exact list remains to be determined according to the capabilities of the vehicles).	
Remote control module [Remote control centre application]	This module is in charge of providing an interface to the human-operator in order to control the vehicle. It is responsible for transmitting the actual remote-control commands to the vehicle side control module.	NTUA develop		Development of the basic functionality.	Finalization depending on the trial's needs. Create a unified application incorporating all ROC functionality.
Hardware components					
Research vehicle	Vehicles that have been gradually extended to allow a variety of research options related to autonomous driving.	TUC order			
OBU	Provides an interface with the vehicle's sensors\instruments and actuators.	TUC order			

Intel NUC mini PC 1st option: Intel Barebone NUC NUC8i3BEH 8109U, Corsair Desktop RAM Vengeance LPX 16GB Kit 3200MHz DDR4, Samsung SSD 860 EVO 500GB 2nd option: Intel Barebone NUC NUC8i7BEH 8559U, Corsair Desktop RAM Vengeance LPX 32GB Kit 2400MHz DDR4, WD SSD Blue 3D 1TB	Serves as an intermediate point (i.e., ROC gateway) for the communication between the vehicle and the ROC.	NTUA order			
Network components					
5G core		UOS platform			
KPI measuring tools					
ping		NTUA develop		Testing of QoS including the E2E delay and throughput	Testing of the QoE
iperf + keysight Nemo for throughput		NTUA develop			
Qosium for E2E delay		NTUA develop			
Software component ROC-GW	This software node will be located at the vehicle and will be responsible for the communication between the remote operator and the vehicle's sensor/actuators, publishing/subscribing and receiving/transmitting the suitable data types to OBU and ROC, respectively.	NTUA	Support for 4 video streams and gps position	Support for 4 video streams, gps position, vehicle state (velocity), automation state (on/off, throttle/brake percentage, steering wheel angle) and remote control commands (desired throttle/brake percentage, steering wheel angle)	Finetuning and exploring alternative design options based on the results of the trials (e.g., UDP vs. TCP, exploiting timestamps, etc.)
Software component ROC	The interface with the remote human operator. Responsible for displaying all received information regarding the vehicle's state and its	NTUA	Standalone display of video streaming and the trace of the vehicle on a map based	A unified GUI application, displaying/visualizing all sensory/instrumental data and video	Exploring alternative ways of input and extending the visualized information

	environment and for receiving and sending to the vehicle the operator's control commands.		on the received gps data.	streams and incorporating the required control components for remote driving input.	(e.g., video timestamps)
Software component OBU	This component acts as an interface between the vehicle's internal data bus and the ROC-GW unit	TUC			
Hardware component NUC	Mini PC that will be mounted on the vehicle and might be the host of ROC-GW	NTUA	Purchased	Setup and configured with the latest version of required software (ROC-GW implementation and dependencies)	

3.3.4 Use case T4: Vehicle data services

3.3.4.1 T4S1

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
Road side unit + application	Hardware and software components. Used to collect vehicle status information in the field.	TBD	Not available	TBD	TBD
Vehicle Repair Centre server + application	Hardware and software components. Used to analyse the collected vehicle status information and to inform the driver on service needs.	TBD	Not available	TBD	TBD
Measurement client + server	MQTT client and broker configured to be used in the Phase 1 trials. Utilised to create test traffic for the baseline measurements.	VTT	Available	To be integrated into T2S4 trial setup	To be integrated into T2S4 trial setup
5G user equipment	Network components. Samsung Galaxy S10 5G smartphone, Huawei 5G CPE Pro.	VTT (provided by 5GTN)	Available	Available	Available
5G network	Network components. Indoor and outdoor coverage using 5G-NR Rel-15 NSA at 3.5 GHz with 60 MHz bandwidth. Lightweight and carrier	VTT (provided by 5GTN)	Available	To be updated to 5G SA and partial Rel-16 compatibility	Further Rel-16 updates as per platform roadmap

	grade options for EPC and 5GC services.				

3.3.4.2 T4S2

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
Road side unit + application	Hardware and software components. Used to deliver OTA updates to vehicles.	TBD	Not available	TBD	TBD
Car Manufacturer Software Repository server + application	Hardware and software components. Used to provide ECU software updates to vehicles when needed.	TBD	Not available	TBD	TBD
Measurement server	File server containing test files for downloading dummy update packages. Utilised to create test traffic for the baseline measurements.	VTT	Available	To be integrated into T2S4 trial setup	To be integrated into T2S4 trial setup
4G user equipment	Network component. Samsung Galaxy S9 smartphone.	VTT (provided by 5GTN)	Available	Available	Available
4G network	Network components. Indoor and outdoor coverage using 4G LTE at 2.6 GHz with 15 MHz bandwidth. Emulated EPC services.	VTT (provided by 5GTN)	Available	Available	Available
4G eMBMS	Network component. Enensys Expway eMBMS server.	VTT (provided by 5GTN)	Available	To be integrated into T2S4 trial setup	To be integrated into T2S4 trial setup
5G user equipment	Network component. Huawei 5G CPE Pro.	VTT (provided by 5GTN)	Available	Available	Available

5G network	Network components. Indoor and outdoor coverage using 5G-NR Rel-15 NSA at 3.5 GHz with 60 MHz bandwidth. Lightweight and carrier grade options for EPC and 5GC services.	VTT (provided by 5GTN)	Available	To be updated to 5G SA and partial Rel-16 compatibility	Further Rel-16 updates as per platform roadmap

3.3.4.3 T4S3

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
Software components					
Analytics for calculating AQI	Analytics for calculating the Air Quality Index (AQI) based on sensor measurements (NO2, O3, CO, SO2, PM2.5, PM10)	WINGS develop	Development of the full functionality	available	available
AQI Heatmap creation	Analytics for creating the spatial heatmap from the AQI measurements, that the routing of the user/vehicle will be based on	WINGS develop	Development of the basic functionality	available	available
Route caluculation	determination of the areas with high AQI index/restricted areas and navigate the user based on the result and the emissions of the vehicle	WINGS develop	Development of the basic functionality that navigates the vehicle to avoid areas with poor AQI	Extension to take into account user preferences in a weighted optimization - available	available
Mobile application	The end-user application through which the user will have access to the service	WINGS/Epitomical develop	planned	planned	development of the full application
Hardware components					
Air quality sensors	sensors measuring the appropriate air quality entities (NO2, O3, CO, SO2, PM2.5, PM10)	no sensors available - simulation used. Possibility for using a testing sensors just for a proof of G12)	simulation	simulation	simulation

3.3.4.4 T4S4

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
H/W: OBU	Automotive embedded board	Epitomical	Available	Available	Available
H/W: RF Frontend	To access 4G/5G network	UoS	Available	Available	Available
S/W: Client App	Download and display advertisements	Epitomical	Developed	Developed	Developed
S/W: Server App	Streaming of multimedia to client	Epitomical	Developed	Developed	Developed

3.3.4.5 T4S5

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
Slicing-as-a-service functionality	It will be exploited to support various use cases of the transport vertical	UOS	Available (CN slicing)	Available (CN slicing being extened and automated)	Available (to be extended with a form of RAN slicing).

3.3.4.6 T4S6

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
H/W: OBU	Automotive embedded board	Epitomical	Available	Available	Available
H/W: RF Frontend	To access 4G/5G network	UoS	Available	Available	Available
S/W: Client App	Aceess local camera and stream to server	Epitomical	Developed (Initial version)	To Be Upgraded	To Be Upgraded
S/W: Server App	Analytics and Storage of video	Epitomical	Developed (Initial version)	To Be Upgraded	To Be Upgraded

3.3.4.7 T4S7

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
H/W: OBU	Automotive embedded board	Epitomical	Available	Available	Available
H/W: RF Frontend	To access 4G/5G network	UoS	Available	Available	Available
S/W: Client App	Collect sensor data and transmit to server	Epitomical	Developed	Developed	Developed

S/W: Server App	Collect and store sensor data	Epitomical	Developed	Developed	Developed

3.3.1 Network components

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

3.3.1.1 5GENESIS

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

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
Hardware components					
5xUSRP-2954R	Software defined radio (SDR) for baseline 4G experimental	UOS	Acquired	Available	Available
2x USRP N320	SDR for baseline 5G experimental	UOS	Acquired	Available	Available
2x Dell XPS 15 7590	High-end laptop to run OpenAirInterface (OAI)	UOS	Acquired	Available	Available
A set of Google Pixel smartphones	Commercial off-the-shelf smartphones to be used in conjunction with the 4G/5G OAI+USRP setups	UOS	Acquired	Available	Available
External antennas	External antennas to be used in conjunction with the USRPs placed inisde vehicles	UOS	N/A	Acquired	Available
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)	Installed, configured and optimised. Some initial results were generated based on the 4G experimental setup	4G C-V2X sidelink feature and 5G NR	4G C-V2X sidelink feature and 5G NR. NR-based sidelink (3GPP R16) subject to availability of OAI code.
Network components					
4G eNBs/5G gNBs	Mixture of commercial and experimental (i.e., OAI+USRP) eNBs/gNBs.	UOS (5GENESIS)	Available	Available	Available
4G/5G 5GIC core	In-house 4G/5G core network	UOS (5GENESIS)	Available	Available	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	UOS (5GENESIS)	Available	Available	Available

	access/networking systems, computing and storage distributed units.				
Performance Monitoring (PM)	Devoted to the active measurements of performance indicators.	UOS (5GENESIS)	Available	Available	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	Available	Available
InfluxDB	Measurement data storage.	UOS (5GENESIS)	Available	Available	Available
Grafana	Visualization	UOS (5GENESIS)	Available	Available	Available
OAI built-in tools	These will be used to debug and monitor the performance of the OAI communication links.	UOS (5GENESIS)			

3.3.1.2 5GTN

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

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
Kaitotek Qosium	KPI measurement tool. Passive measurements for quality of service (QoS)/quality of experience (QoE) parameters.	VTT (provided by 5GTN)	Available	Available	Available
Keysight Nemo Handy	KPI measurement tool. Throughput measurements during field trials and general connectivity debugging.	VTT (provided by 5GTN)	Available	Available	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	Available	Available
iPerf	KPI measurement tool. Test traffic generation.	VTT (provided by 5GTN)	Available	Available	Available
Mobiilimittari	KPI measurement tool. Throughput and round-trip delay measurements with QoS mapping.	VTT (provided by 5GTN)	Available	Available	Available
Cellmapper	Network monitoring tool. Cellular tower and coverage mapping.	VTT (provided by 5GTN)	Available	Available	Available
InfluxDB	KPI measurement and network monitoring tool. Data collection and storage.	VTT (provided by 5GTN)	Available	Available	Available
Grafana	KPI measurement and network monitoring tool. Data visualisation.	VTT (provided by 5GTN)	Available	Available	Available

3.4 Planned activities

3.4.1 Use case T1: Platooning

3.4.1.1 T1S1&T1S2

Partners	Activity	Details	Date	Status
TUC	Transport at TUC premises for integration and initial tests.		Was planned for 29-30.9.2020 (to be re-scheduled due to COVID-19)	Delayed
UOS	Trial showcase event at UOS campus		TBD (end of Phases 2&3)	TBD
UOS, TUC	UOS-TUC workshop to integrate the OAI+USRP setup and developed software agents to transmit the video stream from the plartoon leader to the platoon members.	Subject to the readiness of the OAI+USRP setup and finalisation of the required software agents	To be organised Q1/2021.	Running
UOS, TUC	Start building the basic platooning operation.	To be organised once the integration work is finalised	To be started in Q1/Q2 2021.	TBD

3.4.1.2 T1S3

Partners	Activity	Details	Date	Status
UOS	The feasibility of the hardware-in-the-loop (HIL) work-around still to be confirmed. If it is deemed feasible, some activities may be scheduled in Phases 2&3. Otherwise, the scenario will be ruled out due to the unavailabiltiy of enough vehicles.			Done
UOS	**Not feasible to trial due to the unavailability of enough vehicles. The hardware-in-the-loop (HIL) work-around has been deemed feasible. Currently trying to integrate this as extra functionality into one of our core use case scenarios (e.g., T2S2&T2S2). If this is not possible, T1S3 will be dropped due to the unavailability of vehicles.**			

3.4.2 Use case T2: Autonomous/Assisted driving

3.4.2.1 T2S1&T2S2

Partners	Activity	Details	Date	Status
TNO, Dynnic	Upgrading the current 4G network infrastructure to 5G.		The activity has been delayed to the travel restriction. The upgrade was planned for July 2020.	TBD
TNO, Dynnic	Connecting the Traffic Light controller which controls the intersection at the Neervoortse Dreef in Helmond to the 5Groningen network.		TBD (depends on the possibility to travel)	TBD

TNO, Dynnic	The architecture of the ETSI CPM based application will be upgraded to include Edge Computing.		TBD	TBD

3.4.2.2 T2S3

Partners	Activity	Details	Date	Details
TUC	Transport at TUC premises for integration and initial tests.		Was planned for 29-30.9.2020 (to be re-scheduled due to COVID-19)	Delayed
TUC	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.		TBD (end of Phase 2/3)	TBD
UOS, TUC	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)	Done
UOS, TUC	TUC-UOS workshop to be organised to discuss the next steps and make a plan for the collection of the first trial trial results.	Need to include a form of QoS level estimation.	Q1 2021	Running

3.4.2.3 T2S4

Partners	Activity	Details	Date	Status
VTT	Finalisation of pending Phase 1 measurements.	Measured KPIs: throughput, latency, reliability	September-October 2020	Done
VTT, Polar	Business development and Phase 2 planning workshop.		September 2020	Done
	Starting of Phase 2 deployment and testing.	Inclusion of the warning message triggering framework at the network edge	November 2020 - January 2021	Running

3.4.3 Use case T3: Support for remote driving

3.4.3.1 T3S1

Partners	Activity	Details	Date	Status
NTUA, TUC	Extend the already implemented modules to accommodate multiple video streams and additional types of sensory data		end of Phase 2	TBD

NTUA, TUC	Implement the modules comprising the control functionality and downlink communication from the remote-control centre to the vehicle		before 29/9	Done
NTUA	Create a unified application incorporating all ROC functionality		end of Phase2	TBD
NTUA, UoS, TUC	Integration to research vehicles: NUC – OBU & NUC-USRP, initial E2E measurements		Planned workshop: 29/9	Delayed
NTUA	Testing: ping, iperf + keysight Nemo for throughput, Qosium for E2E delay		end of Phase 2	TBD
NTUA, TUC	Integration	Integration of ROC-GW software component with autonomous vehicle; ROC-GW module developed over a nuc device and connected via ethernet with the autonomous vehicle on-board unit.	December 2020 - January 2021	Running
NTUA, UOS	Integration	Integration of ROC-GW software component the 5G radio front-end; The software will be installed in the laptop controlling the 5G USRP board, followed by functionality testing; The same laptop will be employed for controlling a 4G radio front-end, employed for comparison purposes.	December 2020 - January 2021	Running
NTUA, TUC	Deployment	Integration testing regarding the functionality of the ROC-GW and on-board unit, e.g., connectivity, as well as integration testing regarding the control of vehicle's functionalities; Two types of integration testing, one considering the ROC application at TUC premises and one considering the ROC application at NTUA premises; Deployment and testing of the software regarding the packet tracing or probe mechanism employed for accurate end-to-end latency measurements.	January 2021	Running
NTUA, UOS	Deployment	Integration testing regarding the functionality and interoperability of the ROC-GW software component with the 5G radio front-end; Computational performance of the integrated hardware.	January 2021	Running
NTUA, TUC	Measurements	Initial measurement trials will take place mainly regarding the associated delay components associated with the overall latency	January-February 2021	Running

		from the vehicle to the ROC and back to the vehicle (closed-loop control latency); Partial effort will be dedicated to the measurement of achieved throughput as well.		
NTUA, TUC	Integration	Integration of ROC-GW software component with autonomous vehicle; ROC-GW module developed over a NUC device and connected via Ethernet with the autonomous vehicle on-board unit.	December 2020 - January 2021	Running

3.4.4 Use case T4: Vehicle data services

3.4.4.1 T4S1

Partners	Activity	Details	Date	Status
VTT	Finalisation of pending Phase 1 measurements.	Measured KPIs: throughput, latency	November 2020	Done
VTT, UOS, EPI, WINGS	Phase 2 planning telcos (as part of WP4 plenary telcos).		September-November 2020	Done
VTT	Integration to T2S4 trial setup.	Focus on the optimisation of 5G uplink performance for different service deployment options in T2S4	March 2021	TBD

3.4.4.2 T4S2

Partners	Activity	Details	Date	Status
VTT	Finalisation of pending Phase 1 measurements.	Measured KPIs: Throughput, Latency	November 2020	Done
VTT, UOS, EPI, WINGS	Phase 2 planning telcos (as part of WP4 telcos).		September - November 2020	Done
VTT	Integration to T2S4 trial setup		March 2021	TBD

3.4.4.3 T4S3

Partners	Activity	Details	Date	Status
WINGS	Simulate service requests to measure initial E2E latencies		done during Phase 1	Done
WINGS	modification of the service to be able to accommodate (simulation of) multiple simultaneous requests to process		within Phase 2	Running
WINGS	possibility for acquiring AQ-sensor info using testing sensor which will simulate the whole pipeline		within Phase 2	Running

3.4.4.4 T4S4

Partners	Activity	Details	Date	Status
UoS	Integration of server to UoS datacenter		October 2020	Done
UoS	Integration to UoS 5G network		October 2020	Done
UoS	Performance Testing		October 2020	Done
UoS	Performance optimization over 5G network		May 2021	TBD
UoS	Mobility testing over 5G network		May 2021	TBD

3.4.4.5 T4S5

Partners	Activity	Details	Date	Status
UOS (organising partner)	Trial showcase event at UOS campus		TBD (end of Phases 2&3)	TBD
UOS	A set of baseline eMBB slicing experiments were conducted in collaboration with the Surrey's team of the 5GENESIS project.	The experiments performed two sets of test cases to assess the achievable end-to-end throughput and RTT delay on the 5GENESIS trial facility.	Documented in D4.2 v2.0 (30.11.2020)	Done
USO, NTUA	Applying the 5GENESIS slicing as-a-service functionality to T3S1 (i.e., tele-operated support).	This is subject to the finalisation of closing the chain of T3S1 with 5G radio access.	Q2 2021	TBD

3.4.4.6 T4S6

Partners	Activity	Details	Date	Status
UoS	Finalization of design		November 2020	Done
UoS	Performance optimization over 5G network		May 2021	TBD
UoS	Mobility testing over 5G network		May 2021	TBD

3.4.4.7 T4S7

Partners	Activity	Details	Date	Status
UoS	Integration of server to UoS datacenter		October 2020	Done
UoS	Integration to UoS 5G network		October 2020	Done
UoS	Performance Testing		October 2020	Done
UoS	Performance optimization over 5G network		May 2021	TBD
UoS	Mobility testing over 5G network		May 2021	TBD

3.5 Slice mapping

As information about the requirements of the use cases in terms of slice options from the utilized 5G platforms is currently not available, the mapping of the scenarios to the different slices will be described in *D6.2: Final Trials plan.* For information regarding the slicing availability from the 5G platforms' side, consult the upcoming deliverable *D2.3: 5G-HEART Network Architecture and Slice Definition.*

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 utilizes 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 ROV 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 begins the implementation of 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 provides initial network measurements that will be used as a baseline for later analyzing and comparing data from 5G measurements. Phase 2 includes 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 are taking place enhancing 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 finalization of the trials and of the evaluation KPI measurements.

For the Norwegian pilot, the methodology followed is different. During Phase 1, installations of the necessary equipment and its functionality testing using the 4G network is taking place in parallel with the preparation and testing of the 5G network. During Phase 2, evaluation KPI measurements are taking place 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 is being completed, while the evaluation and trials of the setup is being finalized.

4.2 Initial plan

In this section, the initial trial plans are displayed as presented in D5.1. These have been modified as the trials proceed and the updates are discussed in the following sections.

4.2.1 Phase 1 trials

Phase 1 includes the initial setup of the site and communication installations, as well as the integration of the overall solution with the network. The specific actions that are going to take place are briefly described in Table 7.

Table 7: Phase 1 actions

1) Aquaculture solution development
The development of the first version of the aquaculture solutions end-to-end is designed and implemented during this period.
2) Site installations
For the Greek site, a basic sensor setup will be deployed along with the integration of security camera footage to the solution and lab testing of the underwater drone. For the Norwegian site, sensors and underwater cameras will be installed.
3) Network setup/configuration

For the Greek site, a Proof-of-Concept 4G+/NB-IoT network will be deployed on site, providing connectivity to WINGS' cloud platform solution. For the Norwegian site, a first 5G network setup will be deployed.
4) Communication installations
For the Greek site, communication equipment for supporting the 4G+/NB-IoT network setup will be installed. For the Norwegian site communication equipment for supporting the 5G network setup will be installed.
5) Network integration and verification
Integration and on-boarding of the solutions to the platforms and verification

Table 8: Phase 1 roadmap

Greek pilot / Norwegian pilot	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
Aquaculture solution development												
Site installations												
Network Setup/ Configuration												
Communication installations												
Network integration and verification												

4.2.2 Phase 2 trials

Phase 2 includes the enhanced setup of the site and communication installations, as well as the integration of the overall solution with the network. During this phase, feedback from the previous phase is evaluated and utilised to generate an enhanced version of the solution. The specific actions that are going to take place are briefly described in Table 9.

Table 9: Phase 2 actions

1) Aquaculture enhanced solution development
The development of the 2nd version of the aquaculture solutions end-to-end is designed and implemented during this period.
2) Site installations
For the Greek site, a full sensor setup will be deployed along with the installation of a basic setup of underwater cameras, a 360 camera for infrastructure monitoring and a basic setup of the drone on site. For the Norwegian site, the MEC node will be installed.
3) Network setup/configuration:
For the Greek site, a full sensor setup will be deployed along with the installation of a basic setup of underwater cameras, a 360 camera for infrastructure monitoring and a basic setup of the drone on site. For the Norwegian site, the MEC node will be installed.
4) Communication installations:
For the Greek site, communication equipment for supporting the 5G network setup will be installed. For the Norwegian site communication equipment for supporting the 5G network setup will be installed. For both sites, communication equipment for supporting the 5G network setup will be configured according to feedback obtained from the previous phases.
5) Network integration and verification:
Integration and on-boarding of the enhanced solutions to the platforms and verification.

Table 10: Phase 2 roadmap

Greek / Norwegian	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18
Aquaculture enhanced solution development												
Site installations												
Communication installations												
Network Setup/ Configuration												
Network integration and verification												

4.2.3 Phase 3 trials

Phase 3 includes the final setup of the site and communication installations, as well as the integration of the overall solution with the network. During this phase, feedback from the previous phases is evaluated and utilised to generate the final version of the solution. The specific actions that are going to take place are briefly described in Table 11.

Table 11: Phase 3 actions

1) Aquaculture enhanced solution development
The development of the final version of the aquaculture solutions end-to-end is designed and implemented during this period.
2) Site installations
For the Greek site, a massive sensor setup will be deployed along with the installation of a full setup of underwater cameras and the full setup of the drone on site. For the Norwegian site, the cage to cage communication devices will be installed.
3) Network setup/configuration
For both sites, the final 5G network solution will be deployed on site.
4) Communication installations
For both sites, communication equipment for supporting the 5G network setup will be configured according to feedback obtained from the previous phases.
5) Network integration and verification
Integration and on-boarding of the final solutions to the platforms and verification.

Table 12: Phase 3 roadmap

Greek / Norwegian	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24
Aquaculture final solution development												
Site installations												
Communication installations												
Network Setup/ Configuration												
Network integration and verification												

4.3 Component readiness roadmap

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

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

4.3.1.1 A1S1: Sensory data monitoring

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
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	Initial version providing environmental monitoring (among other) functionalities	Platform upgrades	Platform upgrades
WINGS Smart NB-IoT Gateway	A device to collect, process and transmit sensory data from deployed sensors	Developed by WINGS	Initial version	Upgrade	To be tested and extended if needed
Aquaread AP5000 Multiparameter probe	A multiparameter probe measuring 13 different environmental parameters	Purchased by WINGS	Purchased		
OxyGuard Standard Oxygen Probe (x Units)	An oxygen sensor to measure dissolved oxygen and temperature	Purchased by WINGS	Purchased	Multiple units to be purchased and deployed	Multiple units to be purchased and deployed
WINGS Smart 4G/5G Gateway	A device to collect, process and transmit sensory data from deployed sensors	Developed by WINGS	Initial 4G version	Upgrade to 5G. Testing	To be tested on site and extended if needed
SEALAB Cage Cabinet with IMU- 8 units	Connection Point for Subsea-units.	SEALAB produce	Planning	Installed	
Salinity sensor (15m) - 8 units	Measures the salinity level in the cages.	SEALAB order	Planning	Installed	
Oxygen sensor (15m) - 8 units	Measures the oxygen level in the cages.	SEALAB order	Planning	Installed	
Weather station - 1 unit	Measures weather data related to wind, rain, air temperature and air pressure	SEALAB order	Planning	Will be installed	
IMU Box - 1 unit	Measures inclination of feed barge.	SEALAB order	Planning	Will be installed	

Touch Screen - 1 unit	Used in the control room to control the monitor layouts, and select which camera is active.	SEALAB order	Planning	Installed	
Unifi Switch	Connection point for network	SEALAB order	Planning	Installed	
TV 65” - 3 units	For monitoring all cameras in Barge Control Room	SEALAB order	Planning	Installed	
Joystick - 1 unit	Unit for controlling cameras	SEALAB order	Planning	Installed	
NUC	Next Unit of Computing	SEALAB order	Planning	Installed	
Fiber cable 125 m - 7 units	Fiber cables from cage to cage, making a cirlce with Redundancy	SEALAB order	Planning	Installed	
Fiber cable 250 m - 2 units	Fiber cables from Barge to the first two cages	SEALAB order	Planning	Installed	
VAC 15 m - 8 units	VAC cables to the SEALAB Cage Cabinets	SEALAB order	Planning	Installed	
BlueThink GO	Remote monitoring (livetream, sensor data...)	SEALAB produce	Planning	Will be activated	

4.3.1.2 A1S2: Camera data monitoring

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
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	Initial version providing fish behaviour and disease monitoring functionalities	Platform upgrades	Platform upgrades
Underwater camera (x units)	An underwater camera for fish monitoring	Purchased by WINGS	Purchased and tested	To be updated by another model. Testing and deployment	Deployment of multiple units
Dahua IPC-EBW81230 360 camera	A 360 camera for infrastructure monitoring	Purchased by ICOM	Purchased	Testing	To be deployed

WINGS Smart 4G/5G Gateway	A device to collect, process and transmit sensory data from deployed sensors	Developed by WINGS	Initial 4G version	Upgrade to 5G. Testing	To be tested on site and extended if needed
SEALAB Cam (subsea) - 8 units	Underwater surveillance	SEALAB produce	Planning	Installed	
SEALAB Winch - 8 units	Control the position of the underwater camera and light.	SEALAB produce	Planning	Installed	
SEALAB LED-Light (subsea) - 8 units	Ensure high quality video recordings at any time and at any depth	SEALAB produce	Planning	Installed	
HikVision Surface Cam - 9 units	Surveillance above sea level.	SEALAB order	Planning	Installed	

4.3.1.3 A1S3: Automation and actuation functionalities

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
BlueROV2 underwater drone	An underwater drone for monitoring the underwater infrastructure	Purchased by WINGS	Purchased	Testing in lab	Testing on site and deployment
WINGS Smart 4G/5G Gateway	A device to collect, process and transmit sensory data from deployed sensors	Developed by WINGS	Initial 4G version	Upgrade to 5G. Testing	To be tested on site and extended if needed

4.3.1.4 A1S4: Edge and cloud-based computing

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
Pellet detection AI	AI software providing decision support during feeding. (Real time data will be presented to the operator on a video overlay)	SEALAB develop	Planning and testing	Will be activated	
MEC-Node (Mobile Edge Computing) - 1 unit	The main on-site processing unit, will host virtual machines for AI applications and video distribution.	Nokia	Planning	Installation will take place	

4.3.1.5 A1S5: Cage to cage – on site communication

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
5G Node/gateway - 8 units	Small unit mounted on/in SEALAB Cage Cabinet. 5G communication.	Telenor	Planning		Will be installed
SEALAB Fiber Cabinet - 8 units	Connection point between the Cage Cabinet and the fiber cable.	SEALAB produce	Planning		Will be installed

4.3.2 Network components

Component	High-level description of Functionality	Source	Phase 1	Phase 2	Phase 3
5G Basestation	The ERICSSON base station to be installed in Megara close to the aquaculture site	ERICSSON install	Planning	Installation	Testing / Trials
Core ePC	ERICSSON core ePC (part of the 5G-EVE infrastructure is installed) will be upgraded and re-configured as independent (from the commercial) network in OTE Labs	ERICSSON install, configure	Planning	Installation, re-configuration and upgrade	testing/trials
KPI measurement tools (VIAVI)	The MT5800 VIAVI KPI monitoring probes will be installed in the OTE Labs in either Psalidi or in the Megara location.	ACTA configure	Planning, conclude in probe selection	Installation, initial testing	Installation, testing/trials
5G Antenna - 2 units	Installed on the feed barge, connected to the 5G Gateway	Telenor order	Planning	Will be installed	
Edge rack with 5G Gateway and MEC node - 1 unit	Transfering data to the cloud.	Telenor order	Planning	Will be installed	
5G Basestation		Telenor order	Planning	Will be installed	

4.4 Planned activities

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

4.4.1.1 A1S1: Sensory data monitoring

Partners	Activity	Details	Date	Status
WINGS	[Greek] AQUAWINGS Platform configuration and deployment		September 2019	Done
WINGS	[Greek] NB-IoT gateway preparation		April 2020	Done
WINGS, SKIRONIS	[Greek] Initial sensor installations	Re-deployment required because of power and connectivity issues	February 2021	Delayed
ACTA, WINGS	[Greek] Finalisation of pending Phase 1 measurements.	Probes have been installed, connected to the Core network at OTE Labs. Measurements started in January 2021. Expansion of installations and measurements are planned from February 2021.	February 2021	Delayed
WINGS, OTE, ERICSSON	[Greek] Integration between 5G gateway and the 5G-EVE platform		February 2021	Running
NTUA, ACTA, WINGS, OTE,	[Greek] Setup of the KPI measurement data collection and analysis platform	Initial indicative network KPI data collection provided. Actual 5G-HEART network KPI data will be provided after February.	February 2021	Running
WINGS, SKIRONIS	[Greek] Multiple sensor deployments		September 2021	TBD
SEALAB, Sinkaberg Hansen	[Norwegian] Installation of SEALAB hardware on Barge		26.08.2020	Done
SEALAB, Sinkaberg Hansen	[Norwegian] Installation of Infrastructure (Fiber Cables and Electricity)		09.11.2020	Done
SEALAB, Sinkaberg Hansen	[Norwegian] Deployment of SEALAB Hardware at location (Gjerdinga)		03.12.2020	Done

4.4.1.2 A1S2: Camera data monitoring

Partners	Activity	Details	Date	Status
WINGS	[Greek] AQUAWINGS Platform configuration and deployment		September 2019	Done
WINGS	[Greek] 4G gateway preparation		April 2020	Done
WINGS, SKIRONIS	[Greek] Initial camera installations	Re-deployment required because of power and connectivity issues	February 2021	Delayed
WINGS, SKIRONIS	[Greek] Multiple camera deployments		September 2021	TBD

ACTA, WINGS	[Greek] Finalisation of pending Phase 1 measurements.	Probes have been installed, connected to the Core network at OTE Labs. Measurements started in January 2021. Expansion of installations and measurements are planned from February 2021.	February 2021	Delayed
WINGS, OTE, ERICSSON	[Greek] Integration between 5G gateway and the 5G-EVE platform		February 2021	Running
NTUA, **ACTA**, WINGS, OTE,	[Greek] Setup of the KPI measurement data collection and analysis platform	Initial indicative network KPI data collection provided. Actual 5G-HEART network KPI data will be provided after February.	February 2021	Running
SEALAB, Sinkaberg Hansen	[Norwegian] Installation of SEALAB hardware on Barge		26.08.2020	Done
SEALAB, Sinkaberg Hansen	[Norwegian] Installation of Infrastructure (Fiber Cables and Electricity)		09.11.2020	Done
SEALAB, Sinkaberg Hansen	[Norwegian] Deployment of SEALAB Hardware at location (Gjerdinga)		03.12.2020	Done

4.4.1.3 A1S3: Automation and actuation functionalities

Partners	Activity	Details	Date	Status
WINGS, SKIRONIS	[Greek] Underwater drone deployment		September 2021	TBD
WINGS, OTE, ERICSSON	[Greek] Drone 5G operation test on lab		Spring 2021	TBD

4.4.1.4 A1S4: Edge and cloud-based computing

Partners	Activity	Details	Date	Status
SEALAB	[Norwegian] Running SEALAB Artificial Intelligence (pellet detection)		Approximately Q1 2021	TBD

4.4.1.5 A1S5: Cage to cage – on site communication

Partners	Activity	Details	Date	Status
Telenor, SEALAB	[Norwegian] Installing 5G Nodes on one or two cages		Approximately Q4 2021	TBD
Telenor, SEALAB	[Norwegian] Wireless communication for one or two cages		Approximately Q4 2021	TBD
Telenor, SEALAB	[Norwegian] Installing 5G Nodes on every cage		Approximately Q4 2021	TBD

4.4.2 Network on-boarding

The network on-boarding activities taking place for the Aquaculture vertical include the activities evolving around the two utilised platforms, 5G-EVE and 5G-VINNI and involve multiple scenarios. These are shown in the table below.

Partners	Activity	Details	Date	Status
WINGS, OTE, ERICSSON	[Greek] Integration between 5G gateway and the 5G-EVE platform		February 2021	Running
ERICSSON, WINGS, OTE	[Greek] 5G base station requirements definition and installation		Spring 2021	Running
OTE, WINGS, ACTA, ERICSSON	[Greek] Aquaculture site connection to the 5G-EVE platform		May 2021	Running
Telenor, SEALAB	[Norwegian] Installing Edge rack with 5G gateway and MEC node on barge at location (Gjerdinga)		Approximately January 2021	TBD
Telenor, SEALAB	[Norwegian] 5G-VINNI platform integration and testing		Approximately January 2020	Done

4.5 Slice mapping

As information about the requirements of the use cases in terms of slice options from the utilized 5G platforms is currently not available, the mapping of the scenarios to the different slices will be described in *D6.2: Final Trials plan*. For information regarding the slicing availability from the 5G platforms' side, consult the upcoming deliverable *D2.3: 5G-HEART Network Architecture and Slice Definition*.

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, Healthcare, Transport and Aquaculture, taking into consideration the activities that take place for all scenarios and subcases using the available 5G platforms as well as the solution and network components developed to compare and map to the corresponding resources and time frames.

As a starting point for all verticals, an initial plan has been created to guide the implementation and execution of the tests during the first stages. As the trials progress, the initial plan is being refined, providing an updated component implementation roadmap along with the activities planned for the rest of the trials period. In order to efficiently execute multiple trials during the same 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 13: 5G-VINNI activities

Scenario/ Subcase	Activity	Date
H1A	Interconnectivity testing (5GTN and 5G-VINNI)	March - May 2021
H1B	Functionality testing	September 2021 – August 2022
H2A	Functionality testing	Depending on other activities
H3A	Coverage testing	Currently planning
A1S1, A1S2	Installations on site	January 2021

As it can be seen from Table 13 no overlaps are detected up to this point. Basic connectivity and functionality testing will take place during 2021, while certain activities are dependent on travel ability or progress on other activities.

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.

Table 14: 5GENESIS activities

Scenario/ Subcase	Activity	Date
T1S1&T1S2	Vehicle integration	January – March 2021
T2S3	Planning	January – March 2021
T3S1	Vehicle integration Network integration Deployment Integration, functionality and connectivity testing Measurements	December 2020 - January 2021
T4S4, T4S6, T4S7	Performance optimization Mobility testing	May 2021
T4S5	Slicing testing	April – June 2021

From Table 14, we identify certain overlaps between scenarios that should be considered for the planning of the corresponding activities. One of the time periods of interest is Q1 of 2021 (January – March) which is crucial for Phase 2 implementations across all verticals, where (remote) vehicle integration is planned for both T1S1&T1S2 and T3S1. Additionally, network capabilities testing, such as mobility, performance and slicing is planned for Q2 of 2021 (April – June) for scenarios T4S4-7. These time periods will complete the preparation for the final Phase 2 trials, which are planned to wrap-up by August 2021.

The aforementioned observations are especially important considering the pandemic situation in UK where there is currently a full lockdown and experimentation is restricted. Thus, the periods mentioned above are prone to significant delays.

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. However, since this subcase's planning is ongoing at the time of this deliverable, all information is going to be included in D6.2.

Table 15: 5G-EVE activities

Scenario/ Subcase	Activity	Date
A1S1, A1S2	Network integration	February 2021
A1S3	Connectivity and functionality testing (lab)	March - May 2021
A1S1, A1S2, A1S3	Installations on site	March – May 2021
A1S1, A1S2, A1S3	Connectivity testing (site)	June – August 2021

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 2021 as well, setting up the ground for the final trials of Phase 2.

5.2.4 5GTN – Oulu, Finland

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

Table 16: 5GTN activities

Scenario/ Subcase	Activity	Date
H1A	Interconnectivity testing (5GTN and 5G-VINNI)	March - May 2021
T2S4	Deployment and testing	November 2020 - January 2021

The related activities planned regarding work on the facilities of the platform are shown in Table 16. No overlaps are observed up to this point, while ongoing deployment and testing activities take place during Q1 and Q2 of 2021 in preparation for the end of Phase 2 in the summer.

5.2.5 5Groningen – Groningen, The Netherlands

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

Table 17: 5Groningen activities

Scenario/ Subcase	Activity	Date
H1C	Functionality and connectivity testing	Depending on other activities
T2S1&T2S2	Network integration	Depending on other activities

As shown in Table 17, 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

Concurrent trials are part of Phase 3 of the project. Up to this point individual scenarios and subcases are being prepared and tested individually. With the finalization of Phase 2, the Final Trials Plan will take form and within it the analysis of the possible concurrent scenarios that are going to be trialed. This will be properly documented in D6.2.

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 D3-5.2 [3][4][5]. The finalized plan including the evaluation of the selected KPIs across all three verticals and their in-between comparison and analysis will be included in D6.2.

7 CONCLUSION

This deliverable was able to collect the initial input regarding all planning activities of the vertical use cases, in both a scenario/subcase-specific level and a cross-vertical level. Information about the components used for the solutions and for the connection to the 5G network defines the progress of the solutions and sets a tentative roadmap for the future. The activities that were/are planned regarding development, testing, deployment, KPI measurements etc. have been thoroughly documented providing a basic time plan for the mid-end period of the project. An analysis of the aggregated input was able to generate the following results/observations:

- Phase 1 has been completed without major delays
- Phase 2 has faced significant delays, especially because of the restrictions to access the facilities due to COVID-19
- A time plan per scenario/subcase has been provided regarding previous and upcoming activities
- Mapping of activities to platforms and facilities has provided the timeframes where planning should be more focused to handle possible conflicts
- The unavailability of information about the usage of the slices offered by the 5G platforms has been identified setting this activity as a major priority for the upcoming period
- Individual scenario/subcase evaluation is considered in the vertical work packages, the overall evaluation of the trials is yet to be defined

This deliverable has been designed to provide the skeleton of the Trials Plan that will be followed for the Final Trials Plan as well. The complete documentation of the solutions' roadmap, on-boarding activities and the planning to resolve any conflicts will be prepared for the Final Trials Plan in D6.2. At the time of writing this deliverable specific parts of the plan are still under investigation (e.g. slice mapping, evaluation) and will be formed based on the experience gained from the early-mid stages of the trials.

REFERENCES

[1] 5G-EVE Project [Online], https://www.5g-eve.eu/

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[4] 5G-HEART, "Initial Solution and Verification of Transport Use Case Trials", [Online]. Available: https://5gheart.org/dissemination/deliverables/

[5] 5G-HEART, "Initial Solution and Verification of Aquaculture Use Case Trials", [Online]. Available: https://5gheart.org/dissemination/deliverables/