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5G HEalth AquacultuRe and Transport validation trials

D5.2: Initial Solution and Verification of Aquaculture Use Case Trials

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Abstract	In this deliverable, the solutions developed for the two pilots that are going to be used during the Aquaculture trials are described. The description includes the user application and the network architecture that are going to be deployed, as well as the testing and verification tools that are going to be used during the evaluation.
Keywords	5G, 5G-HEART, aquaculture, trials, validation

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[1] R: Document, report (excluding the periodic and final reports)

DEM: Demonstrator, pilot, prototype, plan designs

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

OTHER: Software, technical diagram, etc.

EXECUTIVE SUMMARY

This deliverable describes the initial setup of the Aquaculture trial solutions and the trial testing and verification methodologies that are used for the two pilots during Phase 1.

The work for the preparation of the Aquaculture trials is split in five different scenarios. These are described here:

- A1S1: Sensory Data Monitoring (Athens, Oslo)
- A1S2: Camera Data Monitoring (Athens, Oslo)
- A1S3: Automation and actuation functionalities (Athens)
- A1S4: Edge and Cloud-based computing (Oslo)
- A1S5: Cage to cage – on site communication (Oslo)

Two pilots (Greece, Norway) are prepared for this purpose, each one implementing a subset of the aforementioned scenarios. The Greek pilot aims to validate the application of 5G technologies on three different scenarios, A1S1, A1S2, and A1S3. As described in the trials planning, this is split into three phases where an incremental deployment and testing of the equipment and the underlying 5G infrastructure is going to take place to prepare the final trial setup in different stages. During Phase 1, initial deployment of the equipment has been done and is thoroughly tested collecting useful metrics. In particular, cameras and sensors have been installed, covering scenarios A1S1 and A1S2 for this first phase of implementation. During the next phase, A1S3 is also going to be deployed in a lab setup at first and gradually will be moved to the aquaculture site environment after some testing period. Additionally, more cameras and sensors are going to be deployed and tested with the 5G infrastructure, for stressing the network even more, while moving towards the integration with the network architecture.

The Norwegian pilot aims to validate the application of 5G technologies on scenarios A1S1, A1S2, A1S4, and A1S5. The network infrastructure and the user application have been developed separately, while the actual installations and on-boarding have been moved for the next phase. This is due to the COVID-19 situation that does not allow the aquaculture site to be operational during this period. On the other hand, the software and hardware components have been prepared and are ready for deployment. During the next phase, the actual installations will take place for scenarios A1S1 and A1S2, while scenario A1S4 will also be tested in the lab and gradually be moved to the aquaculture site.

This deliverable also describes the required 5G infrastructure to assist in the development of validation trials and provide suitable solutions for the described use cases. In the case of the Greek site, the network solution is based in an end-to-end architecture, since the data should be collected and transmitted reliably. The Non-standalone version of deployment will be adopted, using both LTE and 5G wireless systems. The Radio Access Network will collect the data from the equipment on site, through the baseband node. Radio Access Network connectivity in the site facility is LTE based. However, the appropriate software will be installed to operate the 3GPP wireless system including LTE (up to 3GPP Rel.14) and 5G (Rel. 15 and upwards). The Core Network (CN) will follow the RAN. A 5G EPC-in-a-box is proposed as a core network, which is a virtualized solution for CN, taking advantage of enabling multiple VNFs on a single server. For the case of the Norway site, the solution is also based in an end-to-end architecture, and its deployment will be done in two phases. Phase 1 for the implementation of the NSA (Non-standalone) and phase 2 where the SA solution will be deployed. The 5G-VINNI RAN ises 2.1 GHz (Band 1) for the 4G anchor, and both, 3.6 GHz (Band n78) and 26 GHz (Band n257) for the 5G NR.

Towards testing and verification, the two pilots use different tools to conduct the experiments. In the case of the Greek pilot, a KPI validation platform, as well as an Analytics engine are going to be used to collect metrics from the installed equipment and analyze the data to provide detailed results. Due to equipment delivery delays, initial collection of metrics is currently taking place and the analysis of these metrics will be conducted during the early stages of the next phase to provide initial results. In the case of the Norwegian pilot, the 5G-VINNI platform provides its own monitoring and testing infrastructure which will be used for collecting and analyzing initial metrics. This process will take place also at the early stages of Phase 2, as soon as the aquaculture site is available.

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ABBREVIATIONS

Acronym	Term
3GPP	3rd Generation Partnership Project
4G	4th Generation wireless systems
4K	3,980x2160 pixel resolution
5G	5th Generation wireless systems
5gNR	5G New Radio
5G-HEART	5G HEalth AquacultuRe and Transport validation trials
BBU	Baseband Unit
BW	Bandwidth
CA	Carrier Aggregation
CEE	Cloud Execution Environment
CIC	Cloud Infrastructure Controller
CN	Core Network
CoMP	Coordinated Multipoint
CPE	Customer Premises Equipment
CPRI	Common Public Radio Interface
CPU	Central Processing Unit
DL	Downlink
DO	Dissolved Oxygen
E2E	End-to-End
eCPRI	Evolved Common Public Radio Interface
eMMB	enhanced Mobile Broadband
eNodeB / eNB	Evolved Node B (4G)
FCR	Feed Conversion Ratio
FDD	Frequency Division Duplex
gNodeB / gNB	Gigabit Node B (5G)
GPU	Graphics Processing Unit
HD	High-Definition
HSS	Home Subscriber Server
HT	Hyper Thread
HW	Hardware
IBW	Instantaneous Bandwidth
IMU	Inertial Measurement Unit
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of Things
IP	Internet Protocol

ISO	International Organization for Standardization
KPI	Key Performance Indicator
KVaP	KPI Validation Platform
KVM	Kernel-based Virtual Machine
LCM	Life Cycle Management
LTE	Long-Term Evolution
MaaS	Monitoring-as-a-Service
MEC	Mobile Edge Computing
MIMO	Multiple-Input Multiple-Output
MME	Mobility Management Entity
mMTC	massive Machine Type Communications
MQTT	Message Queuing Telemetry Transport
NFV	Network Function Virtualisation
NR	New Radio
NS	Network Slice
NSA	Non-Stand-Alone
NSD	New Service Development
NTP	Network Time Protocol
OAI	Open Air Interface
ORP	Oxidation Reduction Potential
OWAMP	One-way Active Measurement Protocol
PC	Personal Computer
PCRF	Policy and Charging Rules Function
P-GW	Packet Data Network Gateway
PoE	Power-over-Ethernet
PV	Photovoltaic
QEMU	Quick Emulator
QoS	Quality of Service
RAN	Radio Access Network
RoIP	Radio over Internet Protocol
RTSP	Real Time Streaming Protocol
RU	Radio Unit
SA	Stand-Alone
S-GW	Serving Gateway
SSD	Solid-State Drive
SW	Software
TaaS	Testing-as-a-Service

TC	Test Case
TCP	Transmission Control Protocol
TDD	Time Division Duplex
TDS	Total Dissolved Solids
TLS	Transport Layer Security
TWAMP	Two-Way Active Measurement Protocol
UC	Use Case
UDP	User Datagram Protocol
UE	User Equipment
URLLC	Ultra-Reliable Low Latency Communications
USRP	Universal Software Radio Peripheral
vEPC	virtual Evolved Packet Core
VM	Virtual Machine
VNF	Virtual Network Function
VR	Virtual Reality
vSAPC	Virtual Service-Aware Policy Controller
vSGSN	Virtual Serving GPRS Support Node

1 INTRODUCTION

Two pilots are going to be deployed during the lifetime of the project, one in Greece and one in Norway, covering different requirements that exist in two completely different environments. The scenarios that are going to be executed are listed below:

- A1S1: Sensory Data Monitoring (Athens, Oslo)
- A1S2: Camera Data Monitoring (Athens, Oslo)
- A1S3: Automation and actuation functionalities (Athens)
- A1S4: Edge and Cloud-based computing (Oslo)
- A1S5: Cage to cage – on site communication (Oslo)

The two pilots have been developed, each with its selected scenarios, at different levels because of COVID-19 effects, but without major changes to the current planning. The design of the solutions has been provided covering both network and software/hardware related aspects, while the installations are continuously on-going.

In this deliverable, the initial setup of the Aquaculture trials for both the user application and the network architecture is described for all the scenarios, as planned during the first phase of the trials. Additionally, details about the testing and verification process are also provided, giving an overview of the KPIs that are going to be studied during the duration of the whole project and the tools that are going to be used.

2 A1S1 SENSORY DATA MONITORING

2.1 Description and motivation

Marine aquaculture in Europe has been evolved into a high-tech industry, with many modern aquaculture systems incorporating the collection of heterogeneous data from multiple sources into their daily routines. These procedures are primarily manual and labour intensive, relying on the efforts of the farm staff and regular site visits for monitoring and data collection. The workload on the operator is exacerbated when multiple parameters need to be monitored, such as water quality, fish behaviour and health, feeding, cage structural integrity, etc. Each parameter may require a series of different time-consuming procedures, thus making data collection time consuming. Therefore, in recent years automatic data collection systems have become extremely popular. Different sensors have been developed to collect data on a variety of parameters on a continuous basis, enhancing the facility operator's monitoring capabilities by decreasing the effort required for the collection of the data, while increasing the measurement rate and precision.

In addition to the requirement for the sensors to function and operate optimally, it is of vital importance that systems in place allow the efficient transmission, management and storage of the data. This will provide the operator with a series of services such as monitoring, operational management and decision-making support in a more efficient manner. The solutions consist of two different elements. Firstly, the hardware to be used on site collecting, accumulating and transmitting the sensor data. The acquisition of such amounts of heterogeneous data creates the need for its methodical storage and management, as well as its exploitation to provide all the aforementioned services. Thus, the solutions will also include the cloud platforms providing these functionalities, along with their server infrastructure and visualization technologies. Secondly, the network architecture that is going to be used in the two pilots is going to define the transmission capabilities and it is the main consideration of the trials with regard to its evaluation. The 5G platforms 5G-EVE[2] and 5G-VINNI[3] will provide this part and will be used to validate the contribution of 5G in the industry's requirements.

This scenario will provide a setup of the network, the user application and their integration, which are going to be tested to produce data regarding the network performance when performing functions such as collecting, transmitting and processing large amounts of sensory data collected on site.

2.2 Proposed setup

2.2.1 Network architecture

2.2.1.1 Greek pilot

For the Greek pilot, OTE will manage the network architecture that is going to be used during the trials, while ERICSSON will be providing the network equipment.

2.2.1.1.1 Network topology

The aquaculture Greek site is presented in Figure 1. The Skironis aquaculture site will be connected, via OTE premises at the City of Megara, to the OTE's testbed. There will be a connection to the Ericsson virtual Evolved Packet Core (vEPC) and finally, there will be a connection with the cloud applications. This topology is presented in more details in Figure 2, where the 5G New Radio access network (5gNR) is connected to a Network Time Protocol server (NTP) which is used in order to factor out the network latency. The NTP server is connected to the local cloud environment and, through the network-edge

[2] https://www.5g-eve.eu

[3] https://www.5g-vinni.eu

interface SGi, to the vEPC.

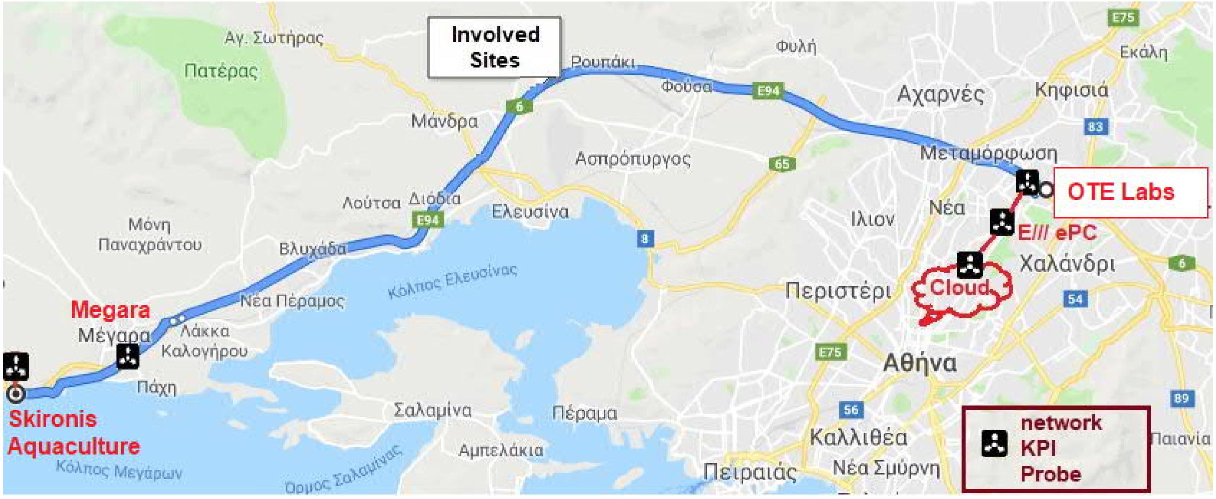


Figure 1: Aquaculture Greek site.

More specifically, the end-to-end network is separated in three parts (Figure 3):

1. The first part includes the devices or the User Equipment (UE). In order to be able to enjoy the 5G network benefits, the UEs should use 5G SIM cards. However, 4G SIM cards are also compatible.

2. The second part of the architecture is the Radio Access Network (RAN).

RAN consists of a hardware and a software part. The hardware elements are the baseband node (eNB for 4G network and gNB for 5G network) and radio unit(s) (RU), while all the appropriate components that are important in order to operate the 3GPP wireless system including LTE (up to 3GPP Rel-14) and 5G (3GPP Rel-15 and upwards) are the software part.

3. The Core Network (CN) is the last part of the architecture. The CN could be separated into the vEPC and the cloud infrastructure.

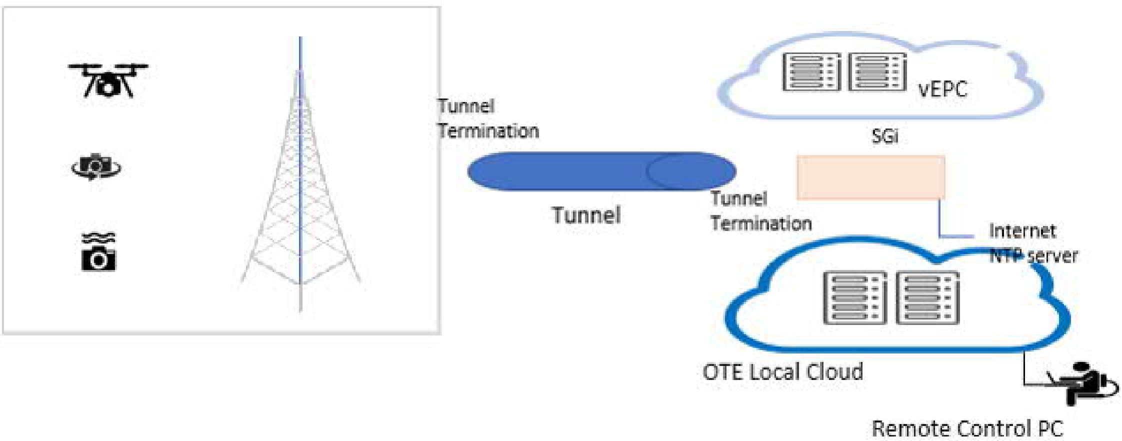


Figure 2: 5G network topology.

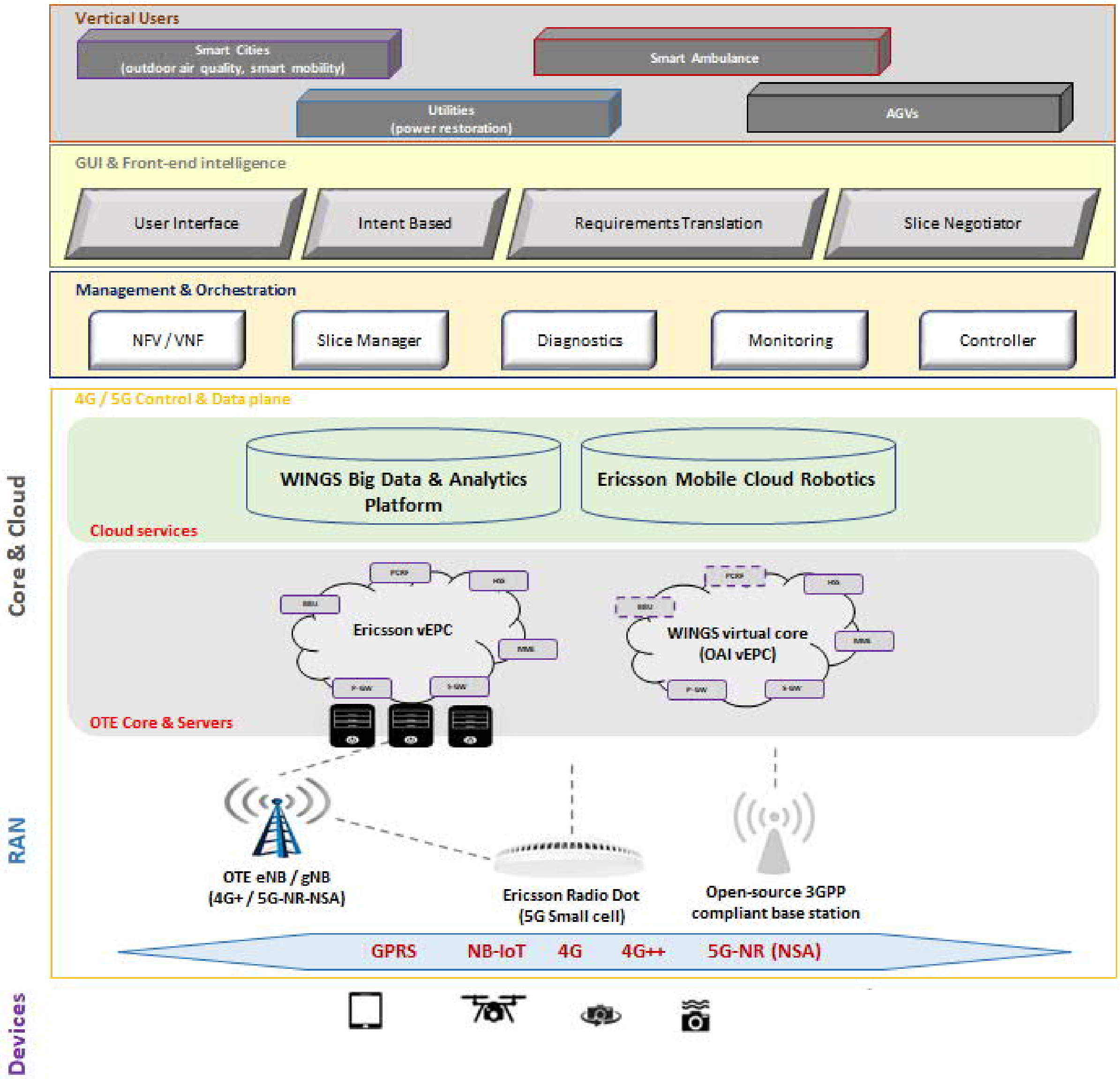


Figure 3: 5G network architecture in OTE's premises.

Focusing on the vEPC, the Non-standalone architecture is implemented. Therefore, there are both CN legacy (4G EPC) and new 5G Core Network included in the 5G system (5G CN).

Since the network is implemented in a lab environment, there are not many subscribers on the testbed. Thus, for cost-effective reasons, a virtualized solution for CN will be used. Each of the functions presented in Figure 3, Packet Data Network Gateway (P-GW), Home Subscriber Server (HSS), Serving Gateway (S-GW), Policy and Charging Rules Function (PCRF), baseband unit (BBU), and Mobility Management Entity (MME), is deployed as a Virtual Network Function (VNF). Additionally, a further evolution of the VNF single server deployment is the ability to enable multiple VNFs on a single server. In this case, all functions are deployed in one box.

Additionally, there is also a 5G testbed based on Open Air Interface platform. Open Air Interface (OAI) is an open-source hardware and software wireless technology platform (simulation and emulation).

In the OAI based testbed, the vEPC is emulated by OAI, which is installed in a high-level PC. This PC is connected with a Universal Software Radio Peripheral (USRP) through a high-speed link. USRP is a software-defined radio and it is used as data transmitter/receiver.

The typical system requirements of OAI used to emulate vEPC are:

- 1-3 machines running Ubuntu 16.04, Kernel > 4.10.x
- 64-bits OS, 8-16GB RAM
- 2-4 cores Intel Gen. 3/4/5/6 i5,i7 or 2/3/4 Xeon
- 1-2 Ethernet ports (1Gb S1, 1Gb SGI)

Regarding the cloud part of the network topology, there is an OTE cloud infrastructure available, presented in Figure 4.

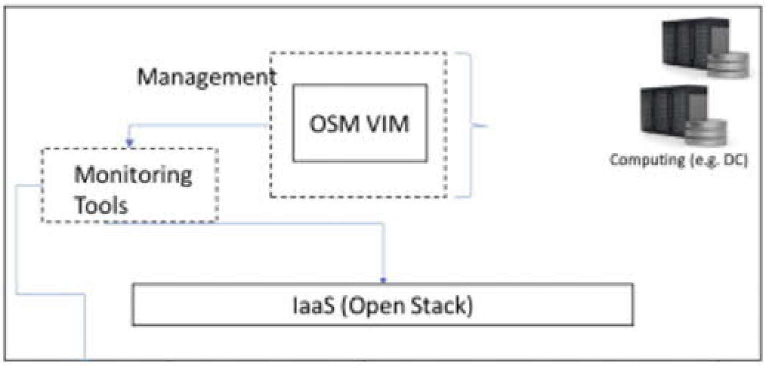


Figure 4: Cloud-based infrastructure.

The network concept that was preferred was the Network Function Virtualization (NFV), since it offers high-performance and scalability, while at the same time it is running on standard server platforms. The NFV infrastructure is using the Open Stack cloud operating system. Furthermore, a Kernel-based Virtual Machine/Quick Emulator (KVM/QEMU) is used to host the supporting systems (ldap, vpn, dns, routing, etc).

The cloud network infrastructure is depicted in Figure 5. The openstack cloud consists of three servers (controller, compute1 and compute2). There are also several other devices as part of the development environment, as well as auxiliary nodes for remote access and authentications services (vpn, ldap). A virtual Openstack router is responsible for the communication between the openstack created instances (e.g., Kubernetes) and the development environment. The decision to keep the development tools and support systems separate was taken in order to have flexibility in rebuilding OpenStack or making major changes without affecting the development environment or access to the systems. The supporting systems, namely vpn and ldap, are hosted on the KVM/QEMU host and provide vpn (which is used for remote access), routing, dns, authentication and directory services.

All servers are connected thought the same switch, which is connected to a PE-router.

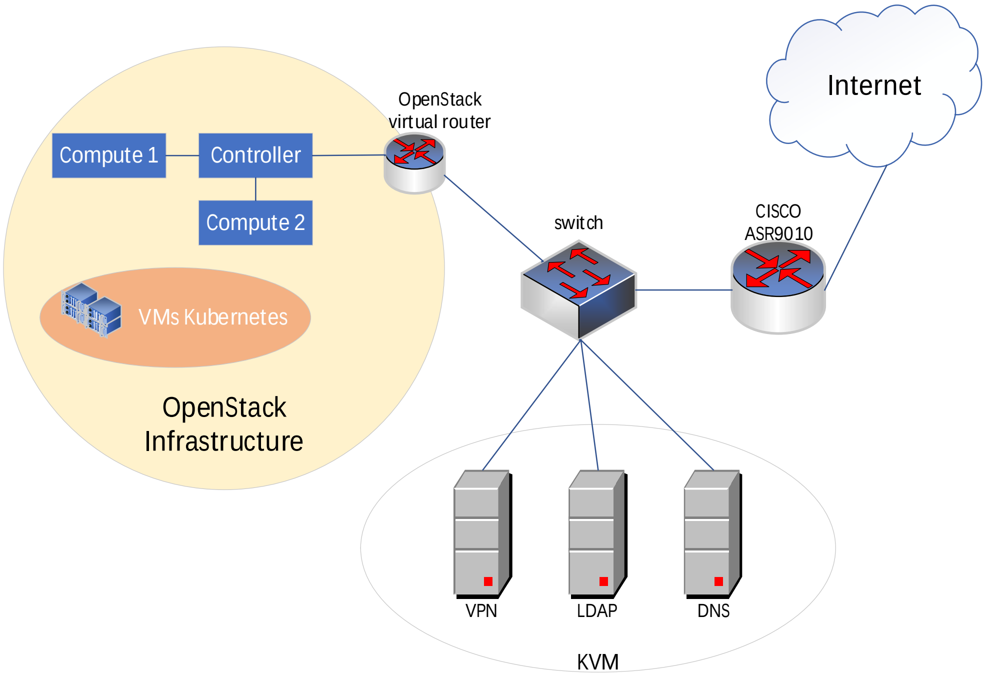


Figure 5: Cloud topology.

The components of the testbed are:

Systems hardware description

- 1x Dell PowerEdge R630 – KVM/qemu
- CPU: 2xIntel(R) Xeon(R) CPU E5-2699 v4 @ 2.20GHz
- NUMA node(s): 2
- Network: 4xIntel Corporation Ethernet Controller X710 for 10GbE SFP+
- MemTotal: 264100124 kB
- 3xDell PowerEdge R740 – controller/neutron and 2 compute nodes
- CPU: 2xIntel(R) Xeon(R) Gold 6152 CPU @ 2.10GHz
- NUMA node(s): 2
- Network: 4xIntel Corporation Ethernet Controller X710 for 10GbE SFP+
- MemTotal: 263748204 kB

Network Hardware Description

- 1xswitch DELL NETWORKING N4032F (shared with other systems)
- 1xCisco ASR-9010 (shared)

2.2.1.1.2 Radio Solution

The Ericsson Radio Access Network is constituted of two parts: a hardware (HW) and a software (SW) base. The HW comprises the baseband node and one or more radio units depending on the coverage area. The software includes the components needed to operate the 3GPP wireless system, including LTE (up to 3GPP Rel.14) and 5G (Rel. 15 and upwards). The baseband unit is common across different radio configurations. It provides the baseband processing resources for the encoding and decoding of the uplink and downlink radio signals, the radio control processing, the radio network synchronisation, the IP and the O&M interface for the Ericsson Radio System.

The Ericsson RAN architecture builds on the Cloud RAN concept**,** which incorporates important aspects of both the network architecture and RAN functionality – today and on the road to 5G.

One of the key aspects in the Cloud RAN concept is Coordination, which is provided by using advanced network coordination functionality. Carrier Aggregation (CA) and Coordinated Multipoint (CoMP) features are able to maximise network performance and minimise interference. Low latency transport network as well as phase and time synchronisation are necessary components to support the time critical L1 and L2 RAN functionality.

The Ericsson Radio Network will target the following key points:

- NSA (Non-Stand-Alone) architecture, option 3x, will be used for the trial (Figure 6)

- Needed band B42F (NR 3.6 TDD, 100MHz BW) will be provided by Cosmote. B78B will be used for the deployment of 5G coverage in the target, which is 3500-3600 MHz.

- LTE 2600 FDD, Band B7 (10MHz), for anchor band will be used.

The 4G/5G radio network scope targets an NSA (Non-Stand-Alone) architecture according to option 3x as specified in 3GPP R15.

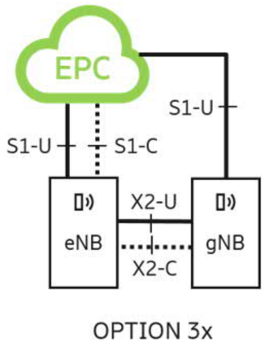


Figure 6: Non-Stand-Alone Dual Connectivity Architecture

<u>EN-DC Option 3x</u>

The NSA architecture will be implemented by deploying an overlay 4G/5G RAN based on the following principles:

- Deploy FDD LTE carrier on 2600 MHz in a frequency region currently not used in the live network. The LTE carrier will be used as an anchor band with 10 MHz of BW and MIMO (2x2) capability.
- Deploy TDD NR on B78B (3500-3600) MHz as a capacity layer with a total of 100 MHz bandwidth

2.2.1.1.3 Product Selection

Baseband 6630

The Baseband 6630 (Figure 7) will be used for providing 4G and 5G functionality, mainly for macro sites deployment. Baseband 6630 supports both Common Public Radio Interface (CPRI) and evolved CPRI (eCPRI) capabilities, which means that can be used either for connecting to passive radio units or Active Integrated Radio (AIR) solutions based on the new eCPRI transport technology.

Figure 7: Baseband 6630

Baseband 6318

Baseband 6318 (Figure 8) is a zero footprint, integrated outdoor baseband unit that can be used as an alternative option to Baseband 6630 in sites where there is limited space for equipment installation. Therefore, it is recommended to be used for outdoor 4G/5G sites.

Figure 8: Baseband 6318

Baseband 6318 is HW prepared to support NR with max throughput up to 5Gbps in DL and 1Gbps in UL, as well as 3 sectors with 100MHz carrier and 16/8 layers in mid-band implementation. An illustration for one sector 4G/5G Street level implementation by using the zero-footprint baseband 6318 is presented in Figure 9.

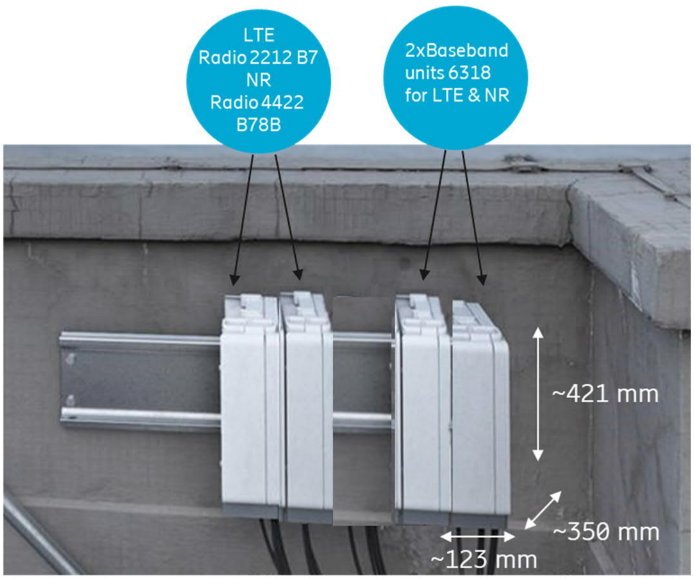


Figure 9: Illustration for one sector 4G/5G Street level implementation by using the zero-footprint baseband 6318 together with passive radio units for LTE anchor 2212 B7 and NR Radio 4422 B78B

Antenna Integrated Radio, AIR 6488

AIR 6488 is a 64TR TDD Active Antenna System (AAS) connected to an array of dual polarized antenna elements. AIR 6488 is particularly efficient for deployment in high capacity, high-rise, dense urban environments. The AIR unit has beamforming and MU-MIMO technology, capable to fully utilize radio resources in both azimuth and elevation. The main benefits compared to conventional macro solutions are:

- Enhanced coverage - High gain adaptive beamforming.
- Enhanced capacity - High order spatial multiplexing and multi-user MIMO.
- Advanced RAN features - Vertical and horizontal beamforming.
- Improved network performance - Low inter-cell interference.

The AIR 6488 unit will be used to deploy NR coverage in the selected outdoor macro sites. The NR carrier will have an Instantaneous Bandwidth (IBW) of 100 MHz and will be operated in the frequency of B78B (3500-3600) MHz.

Radio 4422

The Radio 4422 is a passive radio unit with 4x40 [w] capability. The Radio 4422 will be used in order to deploy NR coverage in the selected outdoor sites. The NR carrier will have an IBW of 100 MHz and will be operated in the frequency of B78B (3500-3600) MHz.. An example of using Radio 4422 with Baseband 6318 is presented in Figure 10.

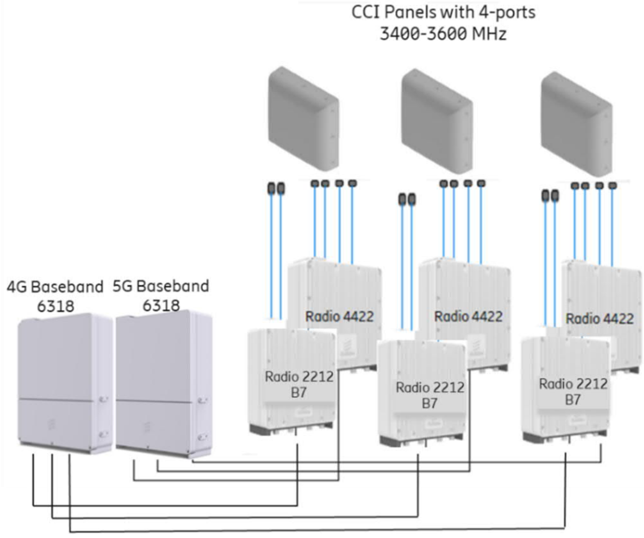


Figure 10: Three sector site with NR coverage using Baseband 6318 and Radio 4422

2.2.1.1.4 Core Solution

The solution for the core part of the Greek trial site leverages the ICT-17 5G--EVE, (5G European Validation platform for Extensive trials) platform.

In the 5G -EVE site facility, a 5G virtual EPC is installed. A 5G EPC-in-a-box fulfils the requirements for cost-effective test systems with few subscribers and minimal footprint. It is a further evolution of the Virtual Network Function (VNF) single server deployment enabling multiple VNFs on a single server. The deployment contains vEPG, vSGSN-MME and virtual Service-Aware Policy Controller (vSAPC).

EPC-in-a-box, as depicted in Figure 11, is designed to run on top of Ericsson OpenStack IaaS, i.e., Cloud Execution Environment (CEE) and can use either HDS 8000 CRU or Dell 630 as HW. It is also tuned to be as efficient as possible when all VNFs are running at the same time.

EPC-in-a-box deployment is built on Ericson CEE, which includes the following necessary functions:

- Virtualized CIC (Cloud Infrastructure Controller).
- Support for running the vCIC in a non-redundant single-vCIC mode.
- Hyper-Threading.
- Pinning of the VM vCPUs to specific Hyper Threads (HTs), ePC, slicing.

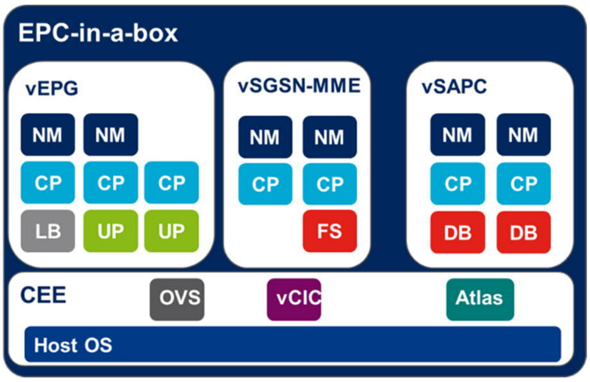


Figure 11: EPC-in-a-box

2.2.1.2 Norwegian pilot

The reference architecture of the 5G-VINNI [1] facilities is shown in Figure 12 below. Network slices will be provided ‘as-a-service’ over the network and infrastructure.

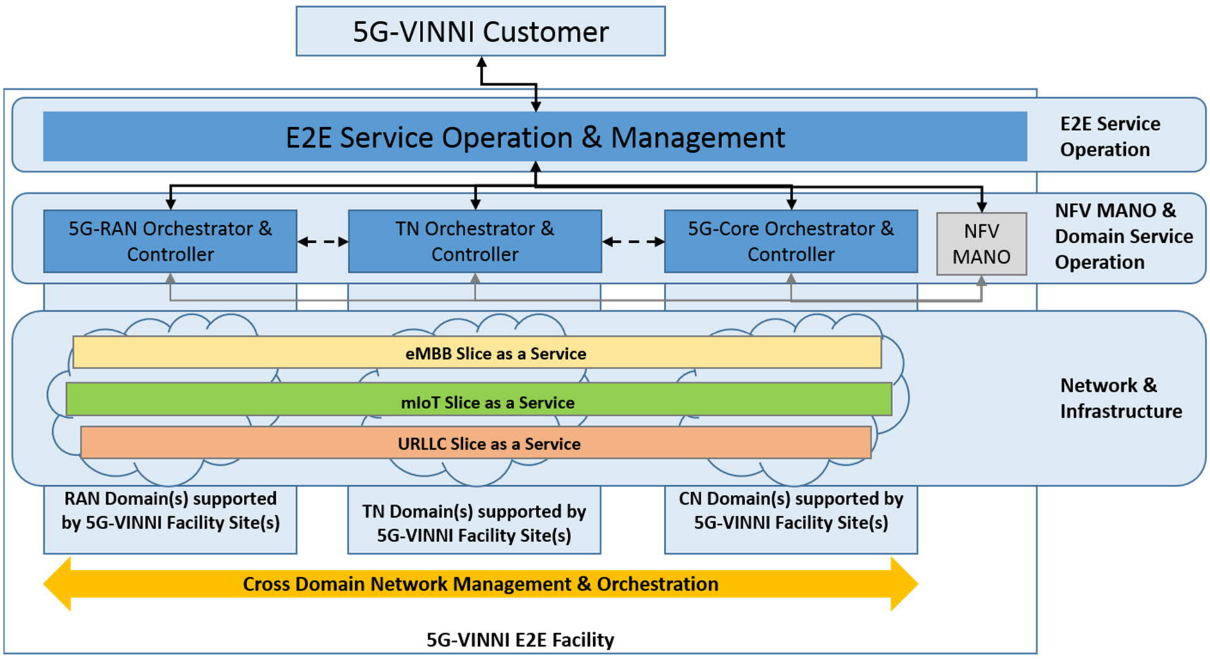


Figure 12: Reference architecture with slice/VNF implementation (5G-VINNI D2.1)

The architecture is composed by three main network-domains, namely the RAN, the Transport and the CORE, each one with the respective controllers. Resources are split in these domains in order to provision different network slices. NFV-MANO is focused on virtualisation-specific tasks (i.e., management at the virtualized resource level), while network-domain controllers focus on non-virtualisation-related operations (i.e., management at the application level).

The E2E service operations and management is in charge of coordinating the different domain controllers and the network services provisioned by the NFVO, in order to have a harmonic service across RAN, transport and Core.

The Fish farm use cases in Norway will be implemented and tested using the Norwegian 5G-VINNI facility, which will be explained in detail in the next three sub-sections.

2.2.1.2.1 Core Solution and Slice Design of the 5G-VINNI Norway Facility

The A1 use case in the Norwegian site will be implemented and tested using the Norwegian 5G-VINNI facility. The 5G-VINNI facility is deployed in two different phases, and further changes can be considered in two additional small sub-phases.

The Phase 1 (NSA) of the 5G-VINNI Norway facility will only support Non-Stand-Alone NSA architecture. For NSA Slices selection DECOR functionality is implemented (Full description in [2] 5G-VINNI D2.1). The first slice available was the eMMB, followed by the URLLC and finally the mMTC is about to be finalized at the time of writing this document. Finally, additional NSA slices can be considered in future, representing the small sub-phases mentioned above.

Figure 13 below, shows the NSA slice implementation in phase 1, using VNFs that are provided in 5G-VINNI.

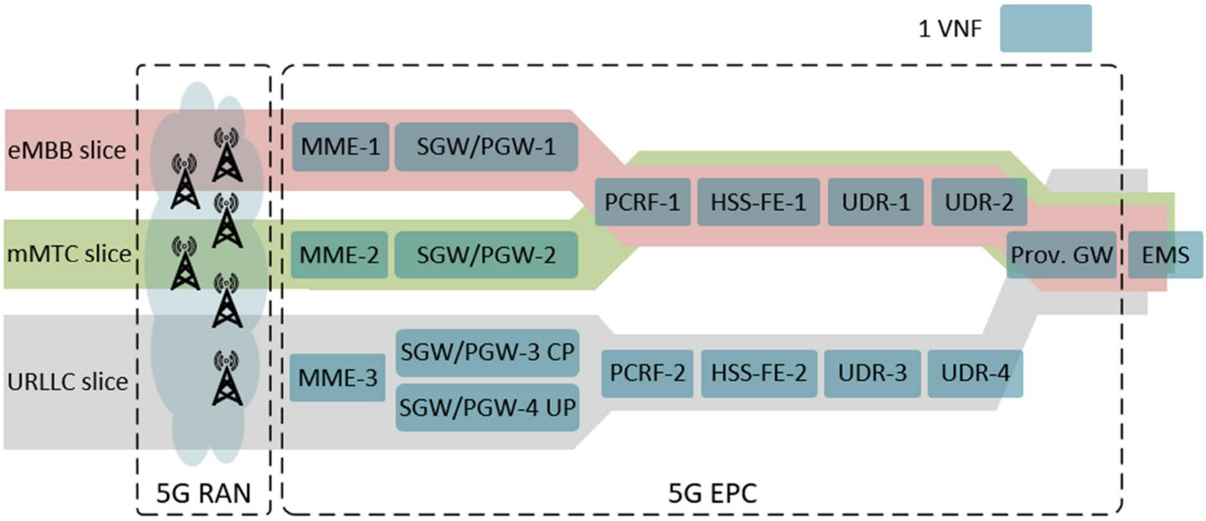


Figure 13: Slice/VNF implementation Norway (5G-VINNI D2.1)

The phase 2 (SA) of the 5G-VINNI Norway facility will support also the Stand-Alone SA architecture, and in addition EDGE is implemented for some use cases and is open to be extended and used when the use case demands it. Figure 14 below, shows the full scope of the 5G-VINNI Norway facility including SA, NSA and Edge.

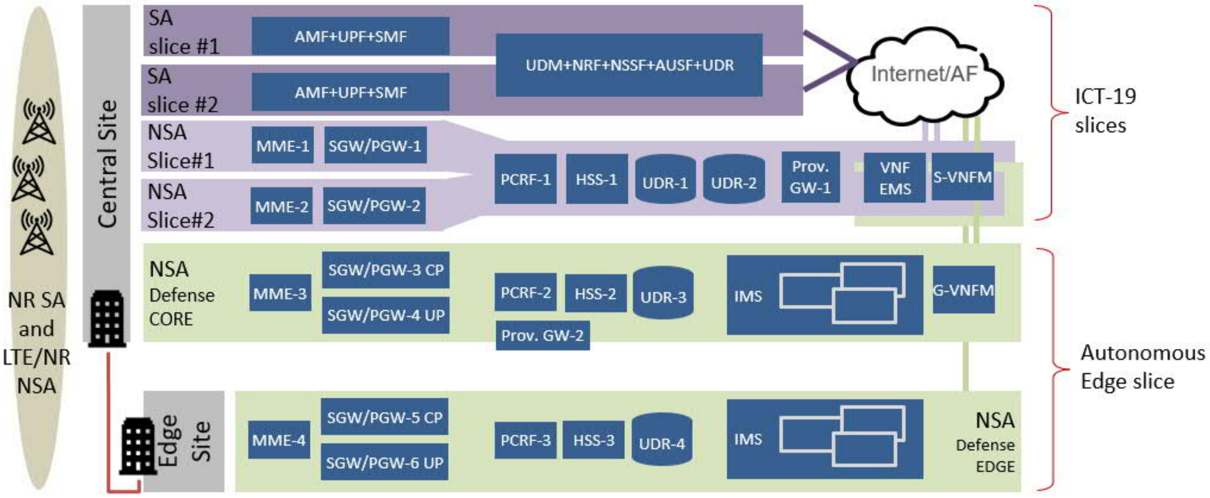


Figure 14: SA, Edge and NSA Slice/VNF implementation Norway.

The aquaculture field experiment will utilize an edge computing server, at the application end.

2.2.1.2.2 RAN Solution, coverage and radio parameters for the 5G-VINNI RAN

All aquaculture trials in Norway are going to be performed at a selected fish farm on the Norwegian coast. An outdoor 5G gNB will be installed at the premises, which will cover the relevant area, as shown in the map and panorama overview in Figures 15 and 16. The main sector (B), is indicated, as well as the beamwidth of the 5G active antenna.

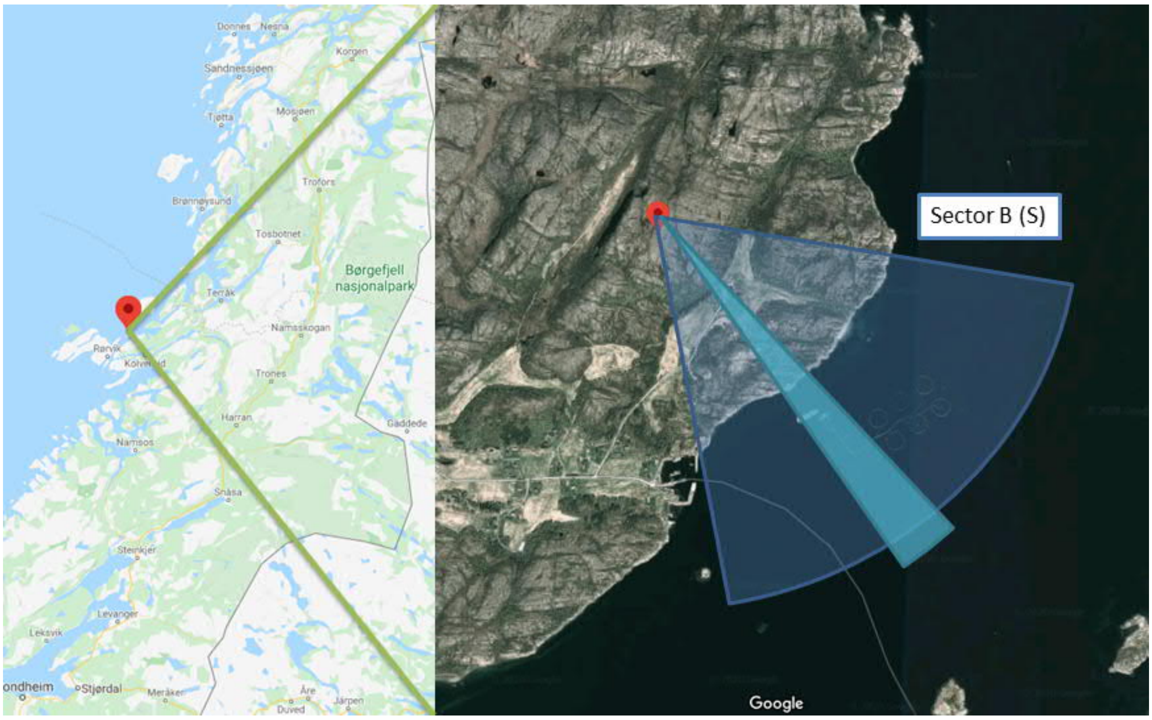


Figure 15: Map of fishfarming area and 5G-VINNI site.

Figure 16: Panorama overview of the Norwegian fishfarm.

The 5G-VINNI RAN is currently NSA, using 2.1 GHz (Band 1) for the 4G anchor. The 'Gjerdinga' site will be using both 3.6 GHz (Band n78) and 26 GHz (Band n257) for the 5G NR. Therefore, each sector is covered by three separate antennas. The main radio parameters of the 5G-VINNI gNB are listed in Table 1.

Table 1: 5G-VINNI gNB at OUS technical parameters

Parameter	Value
Carrier frequency and bandwidth	LTE anchor (Band 1): • DL: 2132.6 MHz (EARFCN: 226) • UL: 1942.6 MHz (EARFCN: 18226) • BW: 5 MHz 5G NR, C-band (Band n78): • DL/UL: 3655 MHz (NR-ARFCN: 643667) • BW: 80 MHz 5G NR, mm-wave (Band n257) • DL/UL: 26900 MHz (NR-ARFCN: 2060832) • BW: 800 MHz
5G NR antenna	C-band: 64T64R active beamforming antenna mm-wave: 384T384R (4T4R effective) active antenna
LTE antenna	4T4R RRU and passive antenna
LTE beamwidth (3dB) and gain	65° horizontal; 6.3° vertical Gain: 17.7 dBi

2.2.1.2.3 Interfacing with the application endpoints – 5G UEs and devices

In phase 1, the control centre located at the fish farm barge is connected to the 5G-VINNI infrastructure using a single CPE (Customer premises equipment) device, or 5G router. These are fixed UEs designed for FWA applications, which are bulkier and need main power. The CPE used in 5G-HEART will be from Huawei 5G CPE Pro 2[4].

Physically connecting to the 5G network will be as shown in Figure 17.

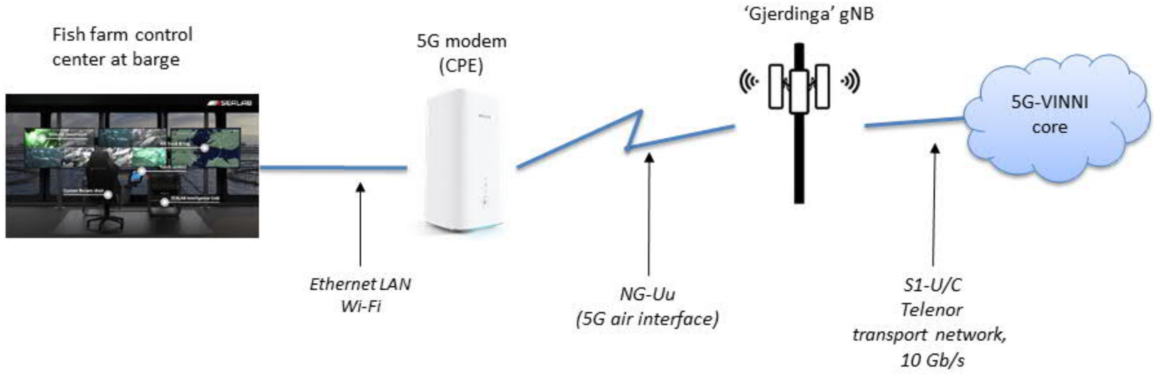


Figure 17: Principal connection of application equipment to the 5G-VINNI network

The CPE will communicate with the application setup via cabled Ethernet.

2.2.2 User application architecture

2.2.2.1 Greek pilot

The user architecture for the Greek pilot is presented in Figure 18. WINGS' AQUAWINGS platform is going to be used for the trials, including the cloud platform providing the high-level functionalities to the user, as well as the hardware components that are needed for the collection and transmission of the data.

[4] https://consumer.huawei.com/en/routers/5g-cpe-pro-2/

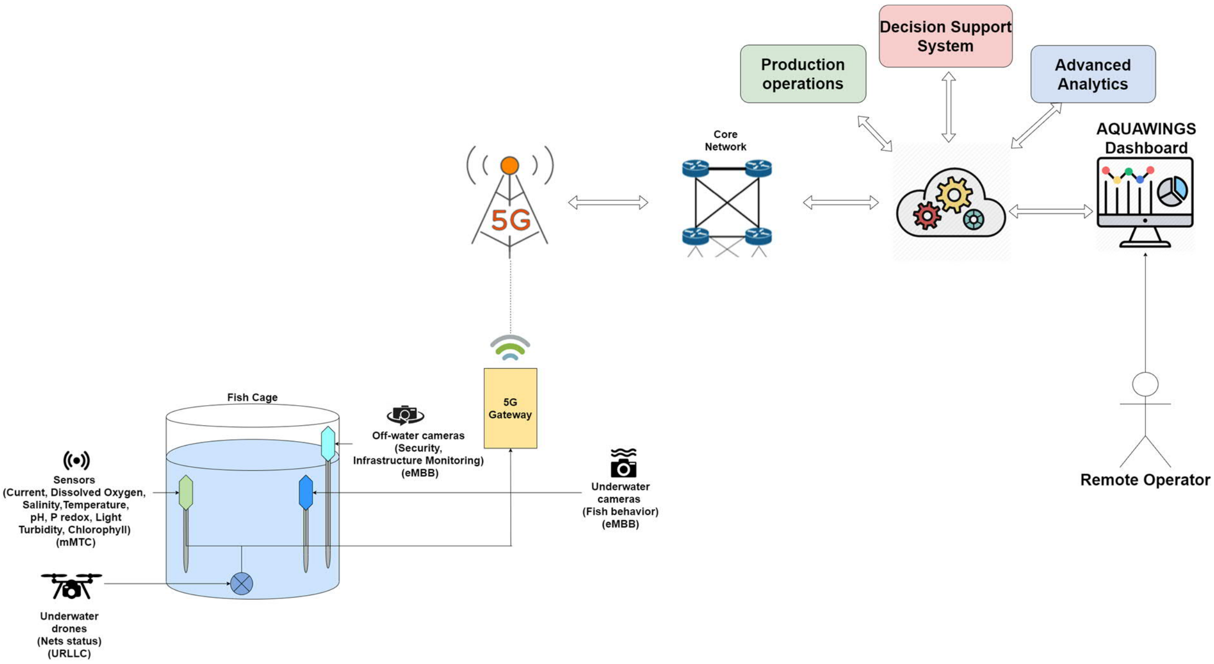


Figure 18: Greek pilot - User architecture

In this scenario, the focus is on the application details regarding water quality monitoring utilizing sensors that measure water parameters. As shown in the figure above, the user application architecture consists of two parts. The aquaculture site equipment responsible for the collection, processing and transmission of the data, and the cloud platform responsible for the storage and visualization of the collected data, as well as the enhancement of monitoring and management capabilities via analytics and decision-making mechanisms and algorithms. These components are described in detail in sections 2.2.3.1 and 2.2.4.1.

The data flow of the architecture that generates the network traffic can be described as follows. Data is collected from heterogeneous sources, sensors measuring temperature, dissolved oxygen, salinity, conductivity, ORP, pH, turbidity, chlorophyll-a, ammonia, nitrate, and is aggregated into gateways which will preprocess and transmit the data through the network to the cloud platform, while producing early alerts for threshold violations or parameters' increasing/decreasing trends. At the cloud, data is stored, analyzed and distributed to all applications that need to consume it. As a result, a series of decision-making support functionalities are enabled, producing suggestions, warnings, and alerts to the operators, enhancing their ability to manage the aquaculture system.

2.2.2.2 Norwegian Pilot

The user architecture for scenario A1S1 for the Norwegian pilot is shown in Figure 19. This scenario focus is on the application details regarding data collection and transfers from different in-water sensors to determine water quality and conditions for optimized fish welfare and feeding as well as above water sensors to determine parameters such as wind, temperature, tides and rainfall regarding the safety of the personnel and planning of operations.

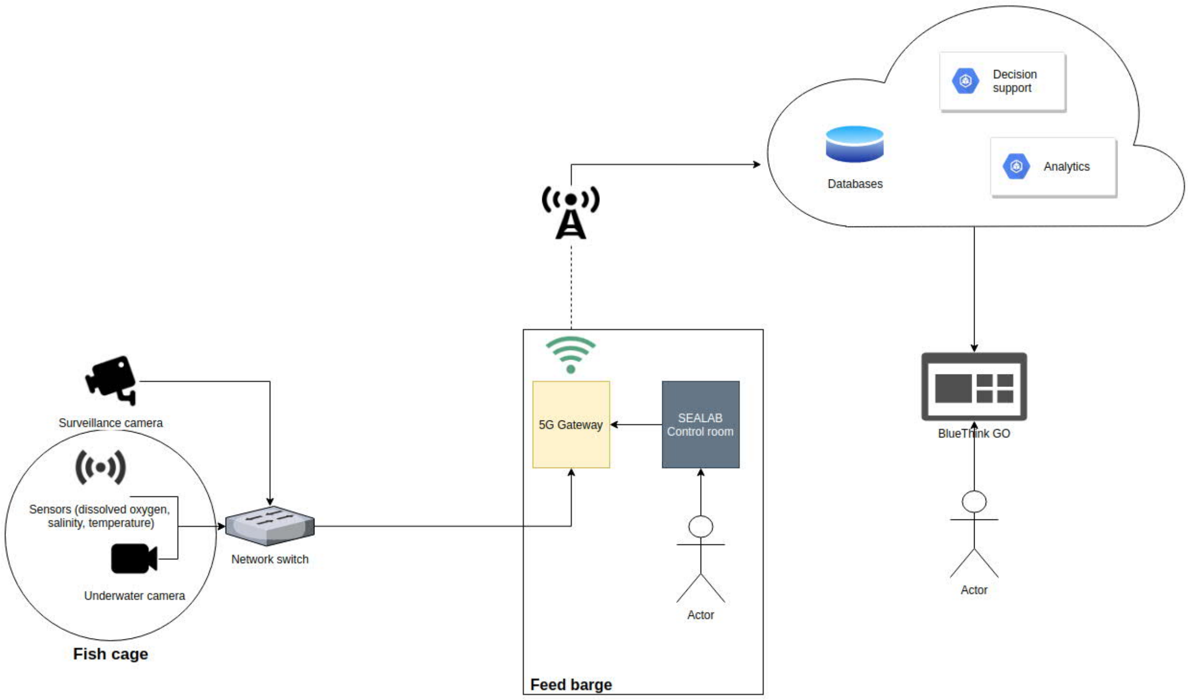


Figure 19: Norwegian Pilot – User architecture scenario A1S1

The data flow of the architecture can be described as follows. Data is collected by underwater- and surface sensors. The data is transported to the 5G Gateway on the feed barge by a fiber network. The gateway transfers the data to the cloud where it is stored, analyzed, and distributed to all applications that need to consume it. The fish farmers get access to the data through the control room on the feed barge and through the web application BlueThink GO.

2.2.3 Hardware components

2.2.3.1 Greek pilot

The hardware components used in the Greek pilot are the following:

OxyGuard Standard Oxygen Probe

An inexpensive probe for temperature and DO monitoring to be deployed at each cage. The probe consists of a galvanic cell and compliments the main optical DO probe of the Aquaread AP5000, providing additional information from more locations on site. Its purpose is to improve the monitoring of oxygen throughout the fish feeding phase in order to optimise feeding time and reduce costs. It is connected to the WINGS smart 4G/5G gateway for data transmission.

Aquaread AP5000 Multiparameter probe

A multiparameter probe for water quality monitoring is placed at a central point in the aquaculture site at a depth of 4-7 meters. It measures a total of 12 main parameters including Dissolved Oxygen (DO), pH, temperature, electrical conductivity, total dissolved solids (TDS), turbidity, salinity, Chlorophyll-a, Nitrates (NO3) and ammonium (NH4). The probe is connected to the Aqauread BlackBox data converter.

Aquaread BlackBox

The BlackBox data converter allows for the Aquaread AP5000 probe to be interfaced directly to the WINGS smart control and data transmitting device. It uses a MODBUS (RS485) digital interface and is able to output data from all optical and ISE sensor types connected to the AP5000 multi-parameter probe.

WINGS Smart NB-IoT/4G/5G gateway

The device used for transmitting data over the network. The BlackBox for the AP5000 sensor and Oxyguard are directly connected to this device for data logging and transmitting measurements. Widely used communication protocols RS485 and RS232 are supported to read from different sensors. The device can also support transmission over NB-IoT and 4G/5G.

2.2.3.2 Norwegian pilot

Salinity sensor

Conductivity/salinity sensor from Aqualabo. It will be used to measure the salinity level [‰] in each cage, at a depth of 5 meters. The sensors will be connected to the cage cabinet. The communications protocol is Modbus RTU over RS485.

Oxygen sensor

OXYnor Optical Sensor. It will be used to measure the oxygen level [%] [mg/L] and sea temperature in each cage, at a depth of 5 meters. The sensors will be connected to the cage cabinet. The communications protocol is RS485.

Weather station

Weather Transmitter from VAISALA. Will be used to measure weather data related to wind, rain, air temperature and air pressure. The weather station will be installed at the roof of the feed barge. The communications protocol is RS485.

Cage cabinet with IMU

SEALAB cage cabinet will be mounted on the side of each cage. Inside each cage cabinet there is an IMU (Bosch BNO055 9-axis IMU), used to log the G-forces acting on the cage. This is the connection point for all SEALAB hardware; distributing electricity and network to the subsea units, winch and topside surveillance camera. Both the salinity and oxygen sensor will be connected to the cage cabinet. Serial communication: 115200 baud, 8N1.

Raspberry Pi 3B+

A Raspberry Pi 3B+ is used in the cage cabinet as a sensor interface. This is responsible for reading sensor data from their respective serial communication lines, tagging the metrics with metadata such as the origin cage, sensor type, and time of measurement, before publishing the sensor data on the on-site MQTT broker.

SEALAB Fiber Cabinet

A fiber cabinet will be installed on each cage, approximately 3 meters from the Cage Cabinet. This is the connection point between the Cage Cabinet fiber cable and the fiber cable coming from the barge. The fiber network is installed in a ring topology for redundancy in case a cable is broken. Three fiber connectors will be left open for potential third party suppliers.

CORNING Fiber Cables

Two fiber cables (250m) will be installed between the feed barge and two of the cages. Between the cages seven fiber cables (125m) will be installed.

2.2.4 Software components

2.2.4.1 Greek pilot

Embedded Intelligence

The software running on WINGS Smart sensor gateway includes additional functionalities other than reading and transmitting data from the connected sensors. Specifically, it introduces the early identification of increasing/decreasing trends as well as the threshold violation of certain parameters. Such observations are instantly reported to the operator in the form of warnings/alerts.

Data Management System

The AQUAWINGS Data Management System includes a variety of features that are used for the evaluation of the conditions of the aquaculture site. These conditions are considered using the monitoring system that the platform provides and more specifically the multiple sources of data that are integrated. In order to manage such heterogeneous data (like operational inputs, satellite images and sensor data), a complex data management system has been developed, offering data ingestion and data consumption functionalities to external components. A visualization dashboard is also available to provide an overview of the status and conditions that take place at the site.

Specifically, the system consists of the following components:

- Database: The basic storage system that implements the Data Model and stores all available data.
- Data broker: The data bus that integrates all data transfers inside the system to efficiently provide it to all applications that need to subscribe and consume incoming data at real-time.
- Data acquisition: The system that integrates all subcomponents that take up to receive data from heterogeneous data sources. For the purpose of integrating with the sensor data sources a UDP server is set up to receive all available data.
- Data consumption: The components that are attached on the data bus (broker) to forward incoming streams to external applications

This is the core system that enables the functionality of all other components. This is why a specific architecture along with the corresponding interface has been explicitly defined. This is displayed in Figure 20.

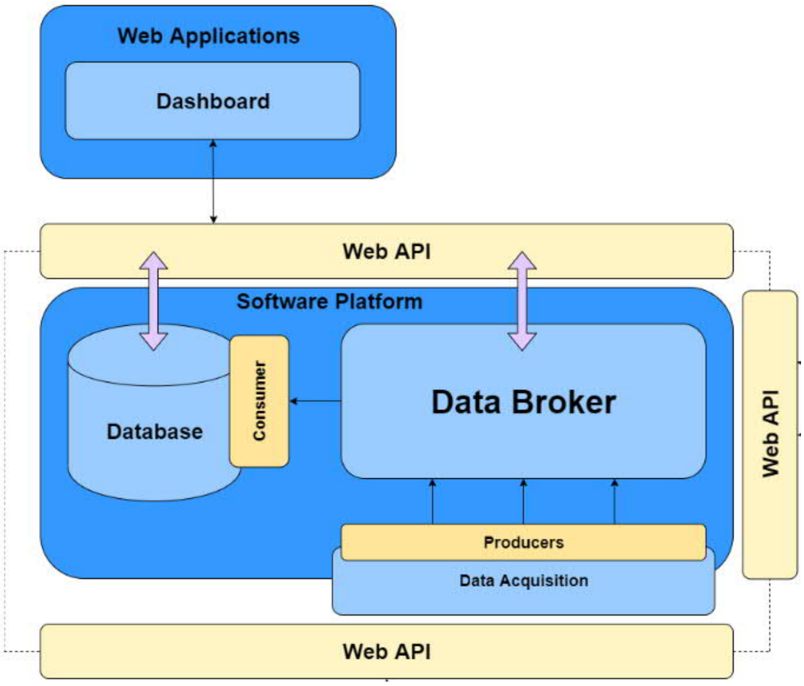


Figure 20: Data management and visualization

Water Quality Analytics

The Water Quality algorithms of the AQUAWINGS platform analyze the measured parameters' time series to recognize outlier values that may indicate irregularities in the system and calculate the probability of external events that may have caused this deviation. Corresponding messages are generated recording these results as automatic observations. Additionally, trend lines and predictions for the parameters are generated, producing predicted time series, while raising alerts for threshold violations and warnings for values getting close to the specified thresholds.

Decision Support System

The Decision Support System of the AQUAWINGS platform is based on a set of business requirements that have been considered to drive the business logic of the system and assist the operator to make decisions regarding different aspects of the operation. These algorithms exploit the available collected data to answer specific questions for the user or provide an overview of the status to facilitate decision making.

In specific, the following aspects are considered for the main functionality of the algorithms:

- Optimal Feeding: Provides the suggested amount of feed that is needed for each stock and validates automatically if and how the feeding process can be executed.
- Production planning: Provides suggestions about the time frames of the harvest and seeding procedures and validates the circumstances for efficient planning.
- Optimal grading: Provides feedback to the operator about efficient grading scheduling, taking into consideration stock distribution inside cages, preventing large variations.
- Breeding: Provides to the operator a way to monitor fish breeding and try out efficient breeding, filtering fish over a series of criteria and matching healthy males to females.
- Disease prevention and mitigation: Evaluates specific observations as well as the recorded environmental data to suggest actions/protocols that can prevent or mitigate specific diseases.
- Infrastructure, stock integrity and security: Provides task planning for possible damages observed, as well as prevention measures such as maintenance actions.
- Environmental footprint: Provides long-term suggestions concerning environmental sustainability as well as environmental threshold violation monitoring and predictions.

- Stock welfare: Calculates a series of indices related to Water Quality, Behaviour, Condition, Infrastructure, Husbandry, Feeding, Environment by evaluating all available data, offering a quantified overview of the status at the site.
- Reporting: Provides a set of reports to display information about environment regulatory thresholds, production status, health conditions, traceability and ISO standards to enhance the operator's decision support.

Dashboard

All the aforementioned features become available to the operator over a user-friendly Dashboard, specifically designed to enhance monitoring water quality parameters as well as management and decision making. The provided functionalities are described below:

- Production monitoring: Production parameters such as stock density, FCR, stock size and more information are all visualized at the homepage of the site as well as in each specific structure's dedicated information page.
- Environmental monitoring: Environmental parameters can be monitored at all times via the dashboard. Important values are always displayed on the dashboard, while the user can always access each individual sensor and check the evolution of their parameters' time series in dedicated charts. Additionally, the water quality analytics that are executed on the background are visualized and indicate trends for specific parameters, as well as identified outlier values or threshold violations that were observed.
- User data input: Operational data such as manual observations or husbandry operations can be regularly reported through a series of input forms.
- Decision making support: The Dashboard provides a rich interface to interact with the Data Management System, but also with the Decision Support System to utilize it and support a variety of different features that are offered regarding optimal feeding, production planning, disease mitigation, environmental footprint, etc.
- Task management: The management of the maintenance, operational and husbandry tasks is one of the features that is also offered by the dashboard.
- Configuration: A settings page allows the operator to declare their preferences in terms of parameters, protocols and other options. Additionally, the configuration of the site can be modified here, editing the structures, the species residing on site and other characteristics of the farm.

2.2.4.2 Norwegian pilot

SEALABs software components for sensor data monitoring include sensor interface components responsible for reading and publishing data from external sensors, on-site network health monitoring services, and outage alert systems. Every on-site software component runs in a separate docker container for ease of deployment and device swapping.

All the software components communicate over TLS-encrypted MQTT. Sensor data and other metrics are published to an Eclipse Mosquitto MQTT broker on the feeding barge. From there, relevant data is relayed to SEALABs cloud infrastructure, using the Mosquitto MQTT broker bridge.

BlueThink GO - Remote monitoring

Figure 21: BlueThink GO - web based service

BlueThink GO (Figure 21), the mobile control room, lets you monitor your fish farm from anywhere, anytime.

A personal web page will be activated for the fish farming site. User authentication ensures that the information on the page remains private. The following information and functionalities are available through BlueThink GO:

- Livestream
- Timelapses
- Weather data
    - Temperature
    - Wind
    - Air pressure
    - Rainfall
    - Sunset/sunrise
- Sea conditions
    - Salinity level
    - Oxygen level
    - Sea temperature
    - Sea level
    - Wave height
- Security
    - G-force acting on the cages
    - Inclination of feed barge
    - AIS
- IT Infrastructure
    - Data Usage
    - Power VAC
    - Network
- Historical data for all sensor data

2.3 Testing and verification

2.3.1 Test and verification and the Norway Facility

Each partner that is responsible for some of the network domains in 5G-VINNI Norwegian facility has proprietary testing tools to check the performance of the part they provide. For instance, for the physical servers and virtualized environment Nokia uses proprietary NFVI testing and monitoring tools, and the same applies for Ericsson for the respective performance of the VNFs that belong to the CORE. A full description on the monitoring and testing tools that each of the 5G-VINNI partners provide can be found in the 5G-VINNI Deliverable 2.4 [2].

In addition, for the E2E Service test and verification 5G-VINNI has partners such as Keysight and EANT, which offer commercial monitoring and testing tools that have been tailored to the 5G-VINNI Norway facility.

Since those services involve additional expenses, especially due to licence costs, the use of such test and monitoring tools is achieved in two different ways:

First, the tools are used internally by Telenor during the deployment of each VNFs or new slice component, or during the installation and implementation of a new radio site.

Second, 5G-VINNI users such as 5G-HEART can order those testing and monitoring services to be used at any time and interval that is needed by the user, depending on their specific requirements. The details on the available on-demand test facilities offered by 5G-VINNI can be found in the following public web portal:

https://www.5g-vinni.eu/2020/04/21/videos-and-presentations-of-5g-vinni-training-webinars-on-testing/

Customers can order experiments in the form of test cases (TCs). Each TC can be executed multiple times to collect sufficient data in different environments (or network conditions).

A brief overview of the testing and monitoring services provided by 5G-VINNI is provided below.

2.3.1.1 Testing and Monitoring services

5G-VINNI offers two types of services for testing and validation, Testing-as-a-Service (TaaS) and Monitoring-as-a-Service (MaaS):

- TaaS: is a set of testing tools and an automation framework that allow the customers to either execute standard/default TCs to *actively* verify the NS (or network slice), or create and execute customized TCs that can be successfully integrated into the LCM of the NSD.
- MaaS: is developed for observation and maintenance of the network slicing services. It contains two types of services:
    - Network Monitoring that produces the traditional overview of the traffic traversing through the network, with special attention to the visibility of special critical points. For network monitoring, the customers define the visibility scope, and provide the tools for analysis if needed. 5G-VINNI will provide a set of monitoring tools, as illustrated in Figure 22:
        - Network tap that can sniff (North-South and East-West) traffic with simple filtering and re-routing (to a specified destination). It can be deployed in specific points of the network and described in NSDs
        - Packet broker that can perform a preliminary sorting of the selected traffic flows. It allows for more advanced traffic filtering, aggregation, and re-routing (e.g., to an analysis tool or a traffic recording server).
    - Telemetry that focuses on providing the health and performance of the individual NS (or network slice) or application components. It can collect metrics exposed by

individual service components (e.g., VNFs) that are either actively pushed or passive collected.

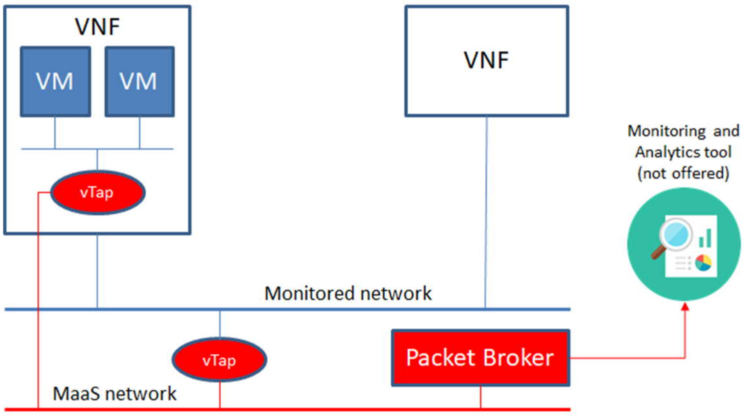


Figure 22: Monitoring tools that will be offered in 5G-VINNI

TaaS supports several testing tools that can be deployed, configured and even automated through offered web services, e.g., traffic generators that emulate real traffic and protocols. In 5G-VINNI, the testing services offered by TaaS include:

- Onboard specific drivers for automating vertical applications and Use Cases (UC).
- Create and execute test scripts to automate the tests or experiments.
- Create and execute test campaigns, i.e., a batch of test scripts that can be executed on multiple target infrastructures.
- Visualize logs and results through the TaaS visualization system.

MaaS is resource-consuming (computation and networking), and therefore is not always suggested unless necessary.

2.3.1.2 Integration process

In a sense, the TCs are a special class of services available to customers, and in general they include the following steps:

- TC design: produces a detailed design plan/scheme for the experiment, by considering the following aspects:
  - what is the objective of the experiment, e.g., the target SUT or the target KPIs,
  - which KPIs are interesting,
  - where are these KPIs measured, i.e., the measurement points (UEs, VNFs, or network ingress/egress interfaces),
  - how are these KPIs measured, i.e., via 5G-VINNI testing and monitoring platform (e.g., 5G-VINNI provides TaaS and MaaS that offer network-side KPIs),
  - what tools are needed to measure these KPIs, 5G-VINNI testing and monitoring tools vs. 3rd party monitoring tools, etc.,
  - how possible is it to automate the experiment orchestration process?
- TC preparation and validation: in most cases, the TC needs KPIs from the 5G-VINNI facility, at least for the network-side data. Then a TC descriptor should be prepared. 5G-VINNI provides TaaS to customers. In TaaS, all experiments or TCs are defined by test scripts that are to be written by customers (UC owners). These scripts contain information on:
  - the testing and monitoring tools involved,
  - the workflows to execute the experiments, and
  - the KPIs to be measured and collected,

    - (probably) the policies of how the KPIs are collected and stored (e.g., sampling period, etc.). The scripts need to be validated, e.g., syntax checking, etc.
- TC deployment: includes two parts:
    1) Onboard the drivers specific for automating the TCs
    2) Deploy the testing and/or monitoring tools demanded by each TC (instantiation and configuration) prior to the activation of the TC. The deployment could be manual or automated, depending on how the tools are supported by TaaS or MaaS. It is also expected that the deployed TC is validated to ensure that
        - The required KPIs are measured and collected.
        - The required KPIs can be properly retrieved by the KPI visualization system.
- TC ordering: customers (UC owners) can order TC services via 5G-SOLUTIONS CDSO that passes the ordering request to 5G-VINNI TaaS.
- TC activation: once the orders are validated by 5G-VINNI TaaS, the TC services are activated to run the corresponding experiments and collect the KPIs of interest.
- TC data collection: the measurement data (KPIs) are stored in 5G-VINNI TaaS and can be retrieved by 5G-SOLUTIONS KPI visualization system for visualization and/or further processing and analysis.

Note that pre-activation tests can be run by the Norway facility via TaaS to validate the slicing service before activating it while there is no application traffic. These tests require minimal configurations and are enclosed as part of the service deployment of CFS (as built-in or default tests). The objective is to ensure proper instantiation of VNFs, NSs and network slices, and proper measurement and extraction of the required KPIs.

The UC-specific TCs include UC applications, which onload application traffic to the activated network slice.

2.3.1.3 Example KPIs from 5G-VINNI

The 5G-VINNI facility provides network KPIs by default that measure the capabilities of the 5G network provisioned by the facility infrastructure. As shown in Table 2, these KPIs are divided into:

- E2E network performance that validates the E2E network service performance by using handsets and CPEs from end to end.
- NFVI network performance that verifies the connectivity capability of the infrastructure.
- NFVI compute resource performance that verifies if the NFV HW profile is capable of supporting the NFV architecture.

Table 2: Example KPIs collected by 5G-VINNI

Category	KPI	Description
E2E Network performance	UL Max throughput (Mbps)	mmWave, 27.3-27.5GHz, 4T4R, 1 stream
	DL Max throughput (Mbps)	mmWave, 27.3-27.5GHz, 4T4R, 40 streams
	UL latency (ms)	3.6GHz, low foot-print traffic profile with 100Kbit/s bandwidth.
	DL latency (Ms)	
	UL jitter (ms)	mmWave, 27.3-27.5 GHz, 4T4R, low foot-print traffic
	DL jitter (ms)	

		profile with 100Kbit/s bandwidth.
	UL frame loss (%)	3.6GHz, low foot-print traffic profile with 100Kbit/s bandwidth.
	DL frame loss (%)	
NFVI network performance	Max throughput with 0 frame loss	Two compute nodes, DPDK was configured in the test environment.
	Latency between VMs	
NFVI compute resource performance	CPU benchmarking score	Yardstick CPU/Memory/storage tests
	Memory read latency	
	Memory r/w bandwidth	
	Storage r/w IOPS	
	Storage r/w latency	
	Storage r/w bandwidth	

2.3.2 Testing and verification in the Greek facility

2.3.2.1 Methodology

The Two-Way Active Measurement Protocol (TWAMP) will be used by ACTA for the measurement of Latency, Jitter and Packet Loss (Figure 23). TWAMP uses the methodology and architecture of the One-way Active Measurement Protocol (OWAMP). The OWAMP, specified in RFC4656, provides a common protocol for measuring one-way metrics between network devices. OWAMP can be used bi-directionally to measure one-way metrics in both directions between two network elements. However, it does not accommodate round-trip or two-way measurements. TWAMP is an open protocol for measurement of two-way or round-trip metrics in addition to the one-way metrics of OWAMP and allows continuous measurements (24h basis) with traffic covering fully all the use case trial periods. In this case, TWAMP is going to be used for measurements over ethernet.

TWAMP employs time stamps applied at the echo destination (reflector) to enable greater accuracy. TWAMP consists of two inter-related protocols: TWAMP-Control and TWAMP-Test. TWAMP-Control is used to initiate, start, and stop test sessions, and TWAMP-Test is used to exchange test packets between two TWAMP entities.

The TWAMP-Control and TWAMP-Test protocols accomplish their testing tasks as outlined below:

- The Control-Client initiates a TCP connection on TWAMP's well-known port, and the Server responds with its Greeting message, indicating the security/integrity mode it is willing to support.
- The Control-Client responds with the chosen mode of communication and information supporting integrity protection and encryption, if the mode requires them. The Server responds to accept the mode and give its start time. This completes the control-connection setup.
- The Control-Client requests a test session with a unique TWAMP-Control message. The Server responds with its acceptance and supporting information. More than one test session may be requested with additional messages.
- The Control-Client initiates all requested testing with a Start-Sessions message, and the Server acknowledges.
- The Session-Sender and the Session-Reflector exchange test packets according to the TWAMP-Test protocol for each active session.

- When appropriate, the Control-Client sends a message to stop all test sessions.

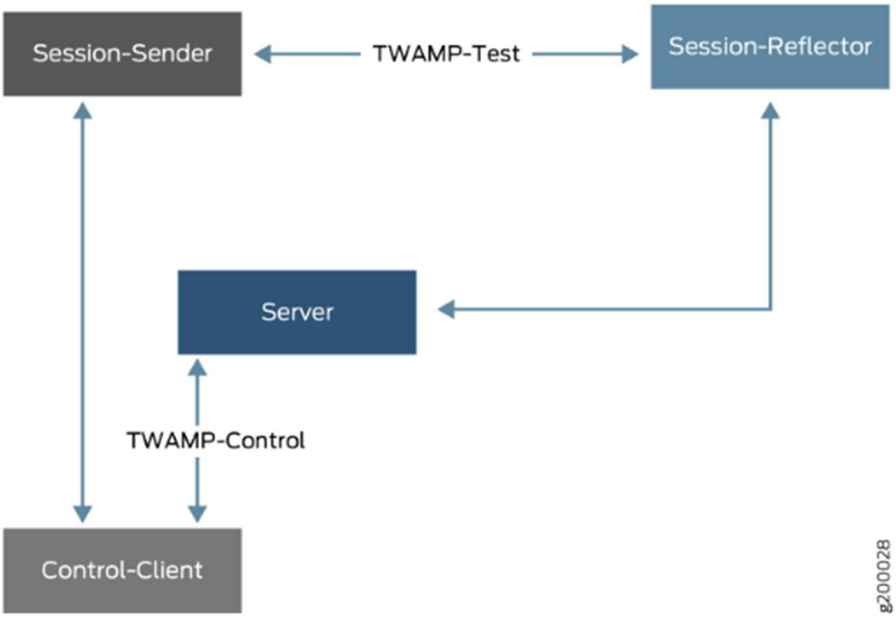


Figure 23: The four elements of TWAMP

For the evaluation of the Throughout KPI, ACTA will apply the evaluation procedures described in 3GPP TS 28.552 [3] standard, that is related to the management and orchestration of 5G performance measurements and to the 3GPP TS 28.554 [4] standard that specifies the end-to-end Key Performance Indicators (KPIs) for the 5G network and network slicing. The selection of one or the other protocol is based on the granularity of the throughout measurements. In case, that we would validate the throughput in a per UE basis, then the 3GPP TS 28.552 standard will be adopted. In cases that the accumulated throughout of a network slice will be evaluated, the 3GPP TS 28.554 will be used.

2.3.2.2 List of Key Performance Indicators

NTUA and ACTA have identified a set of network KPIs to be evaluated in the A1S1 use cases that are also applicable to the A1S2 and A1S3 use cases. These KPIs comprise metrics related to the service provided to the end users as well as to the operation of the network. The definition of each KPI are presented below.

Table 3: KPI definitions

UC A1S1 KPIs	Definition
UL Max throughput (Mbps)	Throughput is the amount of information transmitted per unit of time. Throughput is usually measured in bits per second (bit/s or bps). User experienced data rate (bps) is a minimum achievable data rate for a user in real network environment. Peak data rate (bps) is a maximum achievable data rate per user.
DL Max throughput (Mbps)	
UL latency (ms)	Latency is the time it takes to transfer a first/initial packet in a data burst from one point to another.
DL latency (Ms)	
UL jitter (ms)	Jitter is the deviation from true periodicity of a periodic signal. Jitter can be quantified in the same terms as all time-varying signals, e.g., root mean square (RMS), or peak-to-peak displacement. Also, like
DL jitter (ms)	

	other time-varying signals, jitter can be expressed in terms of spectral density.
UL frame loss (%)	Frame loss is the percentage of the number of service frames not delivered in relation to the total number of service frames sent, during a specific time period
DL frame loss (%)	
UL Packet loss (%)	Packet loss occurs when one or more packets of data travelling across a computer network fail to reach their destination. Packet loss is either caused by errors in data transmission, typically across wireless networks, or network congestion. Packet loss is measured as a percentage of packets lost with respect to packets sent
DL Packet loss (%)	

2.3.2.3 Measurement and Testing Tools

ACTA's implementation is based on the use of Accedian's network probes (Figure 24) that are managed via the in-house developed KPI Validation Platform (KVaP). The KPI metrics involve Performance from the Network Links, Nodes, Services, Physical & ServicePorts, Signal levels etc. The measurements are being performed with sub-millisecond accuracy and transmitted in a Cloud Server for further processing.

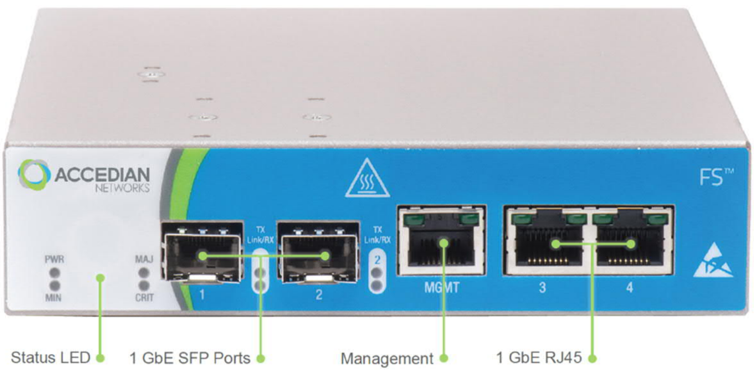


Figure 24: The Accedian FS network performance probe

The system includes both the ability to monitor the traffic passing through the network (user traffic), and extracting important KPIs such as bandwidth utilisation and transfer speeds per service, as well as active testing (test traffic) which provides packet loss, delay and jitter information for selected network paths.

The first probe will be connected via Ethernet in Through configuration between the WINGS router and Ericsson's BBU. The second probe will be connected between Ericssons BBU and the Packet Core network in OTE labs and the third will be connected between the Packet Core at OTE labs and WINGS Application Server (see Figure 25). This configuration will be used in A1S1, A1S2 and A1S3 scenarios.

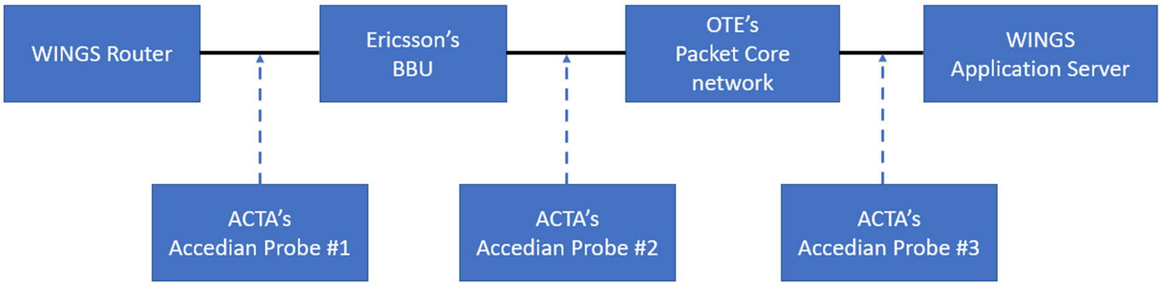


Figure 25: Probe topology in the network

Once the probes are connected the TWAMP protocol is initialized. Each measurement is conducted between two probes, one playing the role of the session sender and the other playing the role of the reflector and vice versa (see Figure 23). The session sender sends tests packages via ethernet to the reflector and the key metrics shown in Table 3 are recorder by the probes.

An Analytics Engine is currently under development, aiming to support a set of analysis services over the time series data collected from the network monitoring infrastructure provided by ACTA in the Greek pilot. The set of collected data refers to various Quality of Service (QoS) metrics and is made available in the ACTA database. A set of APIs are currently under design for consuming such data from the Analytics Engine. Through these APIs, it will be possible to fetch data related to specific monitoring parameters, time period and frequency. It should be noted that in addition to network monitoring data, further data related to the usage of computational resources may be also consumed, given their availability in time series format.

Focus is given on the openness of the tool towards data scientists, facilitating the ease of integration and usage of analysis processes. The data scientist is able to develop and onboard analysis scripts for supporting specific types of analyses. Such scripts can be developed in R or Python. These scripts are then made available to the end users of the Analytics Engine for performing analyses over the collected time series data. The supported analysis processes at the current phase include algorithms for time series decomposition (identification of seasonalities and trends and support of forecasting), (multiple) linear regression (identification of correlation among dependent and independent variables) and correlograms (check statistically significant correlations among numerous variables).

2.3.2.4 Initial results

During this period, ACTA is working on the preparation of several test measurements scenarios in cooperation with OTE. Preliminary tests are being prepared in the 4G network of OTE using the aforementioned Accedian probes. These tests will allow further optimization of ACTA's KVaP platform and assist in the adaptation of 5G network requirements.

2.4 Next step plans

During the next phase, at the Greek site, additional sensor installations are going to follow, stressing the network with multiple concurrent data streams. Additionally, lab testing using the 5G-EVE infrastructure is going to take place, validating the integration with the platform. For the Norwegian site, installation of the sensors is going to be carried out, along with their overall integration with the software platform and the network.

3 A1S2 CAMERA DATA MONITORING

3.1 Description and motivation

Fish behaviour, disease and feeding as well as infrastructure monitoring are very important aspects of modern aquaculture. Efficient identification and management of the various incidents that may come up during production is crucial for the welfare of the fish as well as for the maintenance of the infrastructure. The availability of camera streams transmitting the current status of the site aims to face current practices that include frequent visits on site and thus, additional effort for the operator.

In this scenario, the aquaculture solutions developed will take up to support video streaming directly to the operator. Furthermore, any issues regarding disease or behavioral irregularities can be identified using Computer Vision and Artificial Intelligence algorithms, while the feeding procedure is optimized by specifying suitable times to start and stop feeding according to behaviour observations as well as to feed waste observations at real-time. These features will become available over a specifically defined user interface.

In order to support the concurrent operation of multiple camera streams for monitoring all available fish cages as well as the infrastructure for maintenance and security purposes, the optimization of the network infrastructure is necessary. As described in detail later, the utilization of multiple cameras will validate the applicability of 5G through the concurrent monitoring of all cages through a software platform, as well as the 360-degrees video coverage of the whole infrastructure, providing a variety of different loads that will stress the network.

3.2 Proposed setup

3.2.1 Network architecture

The network architecture that will be used was described in details in sections 2.2.1.1 and 2.2.1.2.

3.2.2 User application architecture

3.2.2.1 Greek pilot

The user architecture for the Greek pilot is described in Figure 18. WINGS' AQUAWINGS platform is going to be used for the trials, including the cloud platform providing the high-level functionalities to the user, as well as the hardware components that are needed for the collection and transmission of the data.

In this scenario, focus is given in the application details regarding fish monitoring which exploits underwater cameras observing the site's aquaculture pens underwater. As shown in Figure 18, the user application architecture consists of two parts. The aquaculture site equipment responsible for the collection, processing and transmission of the data, and the cloud platform responsible for the storage and visualization of the collected data as well as the enhancement of monitoring and management capabilities via analytics and decision-making algorithms. These components are described in detail in the next sections.

The data flow of the architecture that generates the network traffic can be described as follows. Data is collected from multiple sources, multiple cameras for every pen and is aggregated into gateways that take up to preprocess and transmit the data through the network to the cloud platform, while producing early alerts for behaviour, disease or feeding warnings. At the cloud, data is stored, analyzed and distributed to all applications that need to consume it. As a result, a series of decision-making support functionalities are enabled, producing suggestions, warnings, alerts to the operators, enhancing their ability to manage the aquaculture system.

3.2.2.2 Norwegian pilot

The user architecture for scenario A1S2 for the Norwegian pilot is shown in Figure 26. This scenario focus is on the transfer and storage of image/video data. Access to real time image and video data (HD and 4K resolution) from the site is crucial for all aspects related to remote operations of the fish farm. Also storing image/video data for documentation and further processing is required.

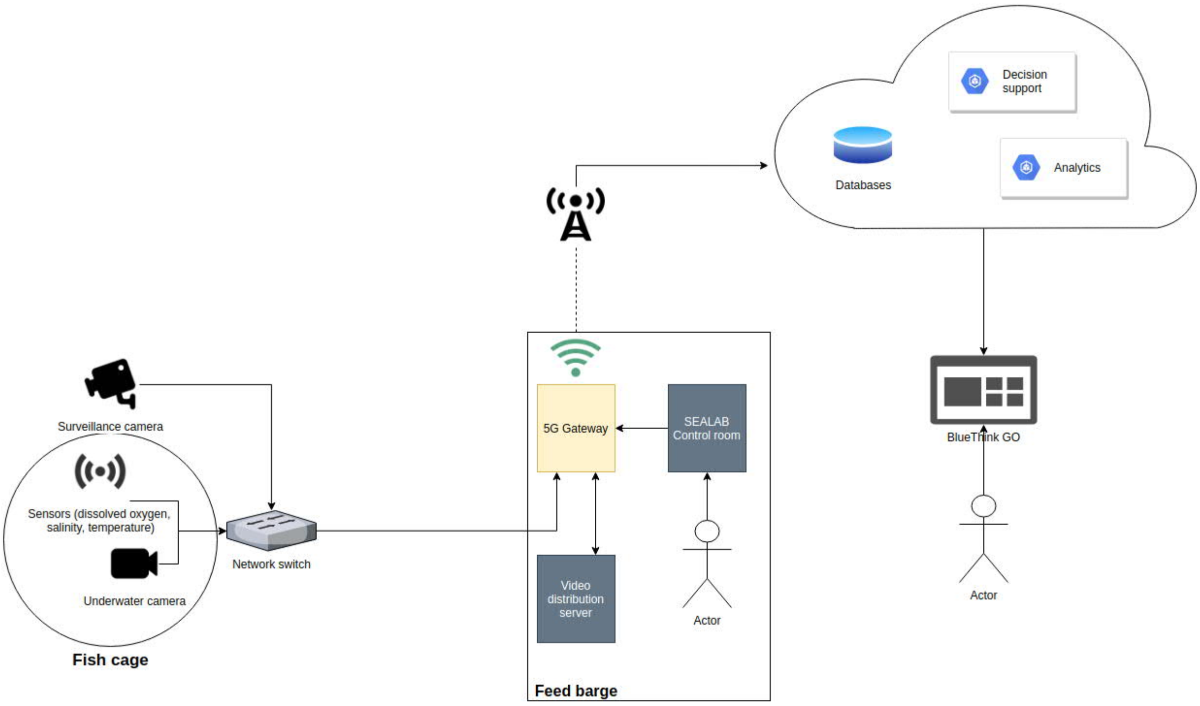


Figure 26: Norwegian pilot – User architecture scenario A1S2

The data flow of the architecture can be described as follows. Image data is collected by underwater- and surface cameras. The image data is transported to the video distribution server on the feed barge by a fiber network. The video distribution server is a machine for video distribution, serving as a centralized location where every video stream may be fetched from. Initially, this will likely be a dedicated desktop computer for which the hardware specifications have not been determined at the time of writing. Additionally, video material will be pushed to the cloud through the 5G gateway, where it is stored, and distributed to all applications that need to consume it. The fish farmers get access to the video through the control room on the feed barge and through the web application BlueThink GO.

3.2.3 Hardware components

3.2.3.1 Greek pilot

BARLUS UW-S5-4CSX10

The underwater IP camera installed to monitor fish underwater from a top-down view at each cage. The camera is made of 316 anti-corrosive steel with an IP68 rating for permanent submersion and is connected to the smart 4G/5G gateway for video footage streaming. The camera uses RTSP protocol and can output 3 streams at different resolutions supporting h.264 encoding. The stream is to be delivered automatically during feeding phases.

WINGS Smart 4G/5G camera gateway

The device used for transmitting video footage over the network. It can support transmission over 4G/5G. It is connected directly to the camera and is placed near the rail of the sea cage.

360^0 camera

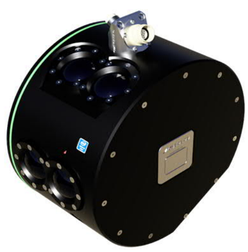
A 360^0 on-surface camera for infrastructure monitoring with VR/360^0 video delivery will be used. A 12MP panoramic fisheye camera (Dahua IPC-EBW81230) will be installed. The camera can output multiple streams at different resolutions supporting H.264 and H.265 encoding. It is also ONVIF compliant for interoperability of IP-based physical security products, Power-over-Ethernet (PoE) compatible (thus does not require power cable or adapter for charging) and resistant to weather conditions (following the IP67 and IK10 protection standards). The 360^0 on-surface camera will be installed on the raft to provide facility surveillance of the site around where the cages are placed connected via Ethernet to the 5G/Edge gateway.

Autonomous Photovoltaic (PV) System

An autonomous PV panel (Luxor LX 100Wp of 72 cells) is to be powering everything that is deployed on each cage, such as the cameras, the OxyGuard probe and WINGSsmart 4G/5G gateway. Robust closed-cap lead batteries of 35Ah of total capacity are used to offer up to 3 days of autonomy. Power consumption of the load has been measured and is estimated to be around 119 Wh per day for a total of 3 hours of daily video streaming. All electrical components (batteries, charge controller etc.) are to be placed in a IP65 rated waterproof and anti-corrosive enclosure made of polyester to ensure their safety near the harsh sea environment.

3.2.3.2 Norwegian pilot

SEALAB Underwater PT-Cam



360 degree pan & 140 degree digital tilt, HD/4K Machine Vision Camera. Stereo Camera forward, upward and downwards for biomass measurement and artificial intelligence. One unit will be installed in each cage and connected to the cage cabinet on the surface.

SEALAB Underwater Light

360 degree light with maximum capacity of 40 000 LUMEN. An underwater light will be installed in each cage in order to obtain high quality video recordings at any time and at any depth. It is mounted 70 cm above the underwater camera. The light can be dimmed (0-100%) from the control room.

SEALAB Winch

A winch is mounted behind the SEALAB Cage Cabinet on each cage. It is used to control the position of the underwater camera and light. Can be controlled manually using the buttons on the winch or from the control room.

Surveillance camera

HikVision DS-2DE4225IW-DE is used for surveillance above sea level. Infrared night mode gives you clear images during nighttime and dark hours in the winter. 25 x Zoom allows you to zoom in and inspect for example mooring. These are installed on the roof of the feed barge and on each cage, giving the opportunity to see the whole fish farm from almost every angle up close.

Navi controller (HID)

GrayHill 3J1115-G2-C3AW navi controller communicating over J1939. It is placed in the control room on the feed barge and used to control the hardware on the cages and the surveillance camera on the top of the feed barge.

Touchscreen (HID)

A touch screen (Elo E045337) is used in the control room to control the monitor layouts, and select which camera is active. The navi controller will control the camera currently selected on the touchscreen.

Video distribution server

A machine for video distribution, serving as a centralized location where every video stream may be fetched from. Initially, this will likely be a dedicated desktop computer for which the hardware specifications have not been determined at the time of writing.

3.2.4 Software components

3.2.4.1 Greek pilot

Embedded software

The software components used for controlling the ROV as well as handling the video stream received from the on-boarded camera.

Media server

The server that takes up the control of incoming streams and coordinate it to the corresponding outputs.

Dashboard

The user Dashboard (part of the AQUAWINGS platform) provides an interface to operate the drone at real-time, while also displaying the camera output of the drone.

Analytics

The AQUAWINGS platform provides a series of Analytics functionalities. These include:

- Behaviour Analysis: Behavioral patterns are identified to notify the operator for the status of the stock, producing results related to hyper-energetic/lethargic behaviour and fish schooling patterns that may be identified.
- Disease diagnosis: Computer vision algorithms are used to provide results about the condition of the fish. Disease marks are identified and reported to the operator, so the early observation of spreading diseases can result in their quick mitigation or even prevention.
- Intelligent Feeding: Feed waste is identified at real-time, highly optimizing the feeding procedure with the production of corresponding suggestions/warnings, while also offering corresponding autonomous operations (feeding).

360^0 camera

Software related to the functionality of the 360^0 on-surface camera, e.g., for video streams optimisation and dispatching (encoding, splitting, etc) will be installed depending on the provided infrastructure.

3.2.4.2 Norwegian pilot

A HID controller enables users to control the winches as well as the on-board motors in the underwater and above-water cameras, allowing an operator to reposition and reorient both the underwater and above-water surveillance cameras.

The video distribution server will be running Wowza Streaming Engine. The on-board computer in each underwater camera will push the videos from each camera to the Wowza Streaming Engine, making them available on URLs following the format *rtsp://<server IP>:<port>/<cage number>/<camera*

ID>, where *camera ID* describes which of the cameras within the given underwater camera module to use.

3.3 Testing and verification

Refer to scenario A1S1 for the analysis of the methodology, key performance indicators, testing tools and initial results of the testing and verification of this scenario.

3.4 Next step plans

During the next phase, for the Greek site additional camera installations are going to follow, stressing the network with multiple concurrent streams. The support of multiple streams will also be investigated from the side of the cloud platform, considering the coverage of functional requirements. Additionally, lab testing using the 5G-EVE infrastructure is going to take place, validating the integration with the platform. For the Norwegian site, installation of the cameras is going to be carried out, along with their overall integration with the software platform and the network.

4 A1S3 AUTOMATION AND ACTUATION FUNCTIONALITIES

4.1 Description and motivation

Current aquaculture techniques rely on the manual activities executed during daily/weekly maintenance and management of the site. Maintenance tasks such as fixing the mooring systems or identifying damages at an early stage require the presence of divers that inspect and maintain the infrastructure. Additionally, the operator's daily presence is required for husbandry operations such as feeding, grading, or stocking. However, modern trends give value to the applicability of remote techniques that allow the operator to execute frequent operations without visiting the farm. Automatic feeder machines are widely available, while autonomous agents such as underwater drones that allow monitoring of the whole underwater infrastructure with actuation capabilities such as anchor or nets maintenance are also considered for such operations.

The aquaculture solution that will enable such operations, provides an interface for the operator to activate the available actuators on site such as feeding or oxygenation machines, as well as to remotely operate systems like an underwater drone to monitor the underwater infrastructure. Additionally, autonomous operations will also be investigated, to provide even more autonomy to the overall system. These functionalities can display strong real-time requirements that can be translated in low-latency requirements as well as high throughput for video streaming related features. Thus, in this scenario, the 5G infrastructure will be tested against such high requirements using the proposed setup.

4.2 Proposed setup

4.2.1 Network architecture

The network architecture that will be used was described in details in section 2.2.1.1.

4.2.2 User application architecture

The user architecture for the Greek pilot is described in Figure 18. WINGS' AQUAWINGS platform is going to be used for the trials, including the cloud platform providing the high-level functionalities to the user, as well as the hardware components that are needed for the collection and transmission of the data.

In this scenario, focus is given in the application details regarding fish and infrastructure monitoring which exploits underwater drones observing the site's aquaculture underwater infrastructure. As shown in Figure 18, the user application architecture consists of two parts. The aquaculture site equipment responsible for the collection, processing and transmission of the data, and the cloud platform responsible for the storage and visualization of the collected data as well as the enhancement of monitoring and management capabilities via analytics and decision-making algorithms. These components are described in detail in the next sections.

The data flow of the architecture that generates the network traffic can be described as follows. Data is collected from the available drones and is aggregated into gateways that take up to preprocess and transmit the data through the network to the cloud platform, while producing early alerts for infrastructure damages or warnings. At the cloud, data is stored, analyzed and distributed to all applications that need to consume it. As a result, a series of decision-making support functionalities are enabled, producing suggestions, warnings, alerts to the operators, enhancing their ability to manage the aquaculture system.

4.2.3 Hardware components

Underwater ROV

An underwater high-performance ROV with a 6-thruster vectored configuration, open-source electronics and software. It is also expandable with additional hardware such as its gripper and a sonar that allow remote actuation functionalities. Provides live HD video streaming and lighting.

WINGS Smart 4G/5G control gateway

The device used to transmit video footage over the network and receive operation instructions for the drone. It can support transmission over 4G/5G.

4.2.4 Software components

Embedded software

The software components used for controlling the ROV as well as handling the video stream received from the on-boarded camera.

Media server

The server that takes up the control of incoming streams and coordinate it to the corresponding outputs.

Dashboard

The user Dashboard (part of the AQUAWINGS platform) provides an interface to operate the drone at real-time, while also displaying the camera output of the drone.

4.3 Testing and verification

Refer to scenario A1S1 for the analysis of the methodology, key performance indicators, testing tools and initial results of the testing and verification of this scenario.

4.4 Next step plans

During the next phase of the trials, the Underwater ROV will be tested using the 5G-EVE infrastructure validating the coverage of high throughput, low-latency and other KPIs considered for this scenario. The integration of the drone's operation with the cloud platform will also be performed during the next phase.

5 A1S4 EDGE AND CLOUD-BASED COMPUTING

5.1 Description and motivation

The norwegian aquaculture industry is the second largest industry in Norway, only beaten by the oil industry. With 420 million salmon swimming in the sea at any time the need for better and constant surveillance is bigger than ever.

The aquaculture industry is not located in urban areas and salmon farming is rated the second most dangerous job in Norway.

Salmon aquaculture is centred around the breeding of salmon, which poses many challenges during the production cycle. The first need is to follow the salmon and the feeding process, which is mainly done with cameras and operated by a feeder who sits behind the monitors and controls the feeding process. This process is monotonous and exhausting and is a factor for differentiation on the results.

The farming industry still has many processes that can be automated both for decision support and fully automated decisions made based on the input. Monitoring the production generates massive amounts of datastreams to be processed, analysed and processed by the farmer. The lack of good network solutions can be a bottleneck for the production facility if the data that is transmitted from the site demand higher bandwidth than what is available. Therefore, both edge- and cloud-based processing is needed to get the right data, at the right time, for the right purpose. Every cage represents a unique stream of raw data and will be processed before entering the barge or the cloud.

5.2 Proposed setup

5.2.1 Network architecture

5.2.1.1 Norwegian pilot

In the 5G-VINNI Norway Facility, several Edge designs have been implemented and planned in the architecture. For a full scope and description of those concepts, 5G- VINNI deliverables 1.4 and 2.1 [2] can be consulted.

In the context of this document, it can be mentioned in general that Edge Cloud brings computing and storage closer to the customer. Within 5G-VINNI, the incorporation of Edge platforms demands a deeper assessment on the cost and needs balance. Edge infrastructure brings additional costs that must be considered.

Operator internal drivers are typically related to expanding the network clouds towards the edge to enable distribution of network functions and content for efficient delivery and production of services, including core, RAN and content. Enterprise use case drivers are related to utilizing the mobile network and infrastructure to solve customer needs, e.g., by replacing legacy systems, introducing systems for process automation, and enabling new services. Consumer use case drivers are related to reducing latency and more efficient delivery of consumer services.

For the use cases related to 5G-HEART it is worth to mention two types of edge as described in Figure 27. The device and the access edge.

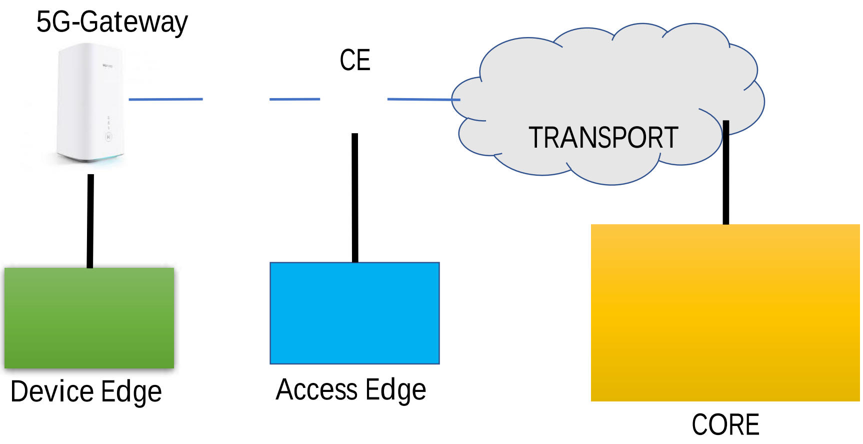


Figure 27: Overall view on Edge Design and types.

The access edge is the one that hosts network functions for serving enterprise use cases. It is located at or close to customer premises. There will be varied implementations adopted for the specific use cases, ranging from small deployments with basic infrastructure such as for low latency applications to larger deployments hosting the complete mobile core network to ensure autonomy and private networks. Enterprise applications might also be hosted in Enterprise Edge Cloud (Figure 28). This type of edge is the one that in principle is considered in the scope of Figure 13 presented in Section 2.2.1.2.1 (Core Solution and Slice Design of the 5G-VINNI Norway Facility).

The Device Edge hosts only enterprise applications and no network functions. It is located at customer premises (behind the 5G-Gateway). It is used for tasks such as data analytics and hosting or enterprise applications. In the case of the fish farm, this type of edge is the one that will be implemented at an initial stage. At the moment of writing this document this edge is under construction and the purpose of it is to allocate artificial intelligence algorithms that will process some of the image from the cameras mentioned in previous sections. The objectives with this type of edge are two: First, to have direct information on potential sickness or special circumstances at the fish farm directly at the platform. Second, to avoid to send redundant and unnecessary information via the 5G channel.

The technical details on the implementation of this edge can be found in 5G-VINNI deliverables 1.4 and 2.1 [2], and a brief overview of the infrastructure to be used in such edge is presented below.

Figure 28: Infrastructure used on the Device edge in the Norway fish farm use case.

The employed hardware is the following:

- 1x 3U Chassis

- 5 x Servers (24c, single CPU, 192GB RAM)
- 1x Z9100 leaf switch (32x100Gb ports)
- 2x GPU NVIDA capability for the servers
- Openstack Rocky release
- All servers can work as compute nodes
- High availability Openstack with 3 controllers
- CEPH storage solution with SSD disks

5.2.2 User application architecture

The user architecture for scenario A1S4 for the Norwegian pilot is shown in Figure 29. This scenario focus is on edge and cloud-based computing. Due to the evolution of high speed, high resolution cameras and real time image/data processing algorithms users need a data network infrastructure that supports the payloads of such functionalities. The benefits of such functionalities when enabled by edge and cloud-based computing are of great interest for the user.

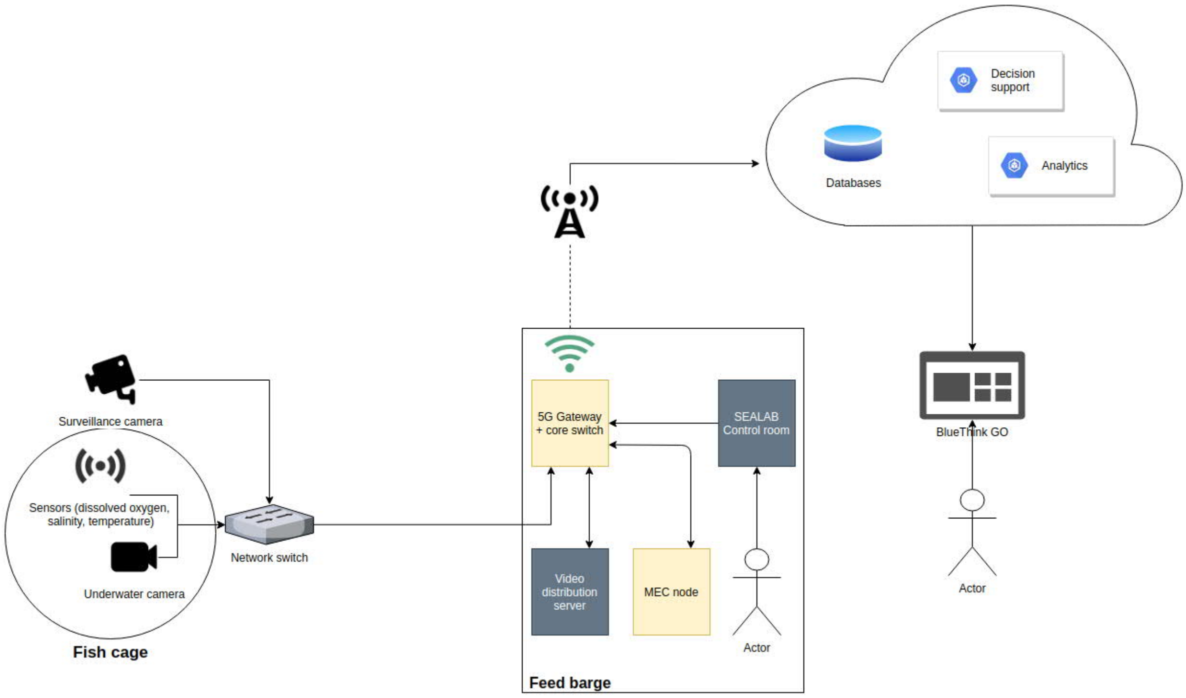


Figure 29: Norwegian pilot – user architecture scenario S1A4

The data flow of the architecture can be described as follows. Image data is collected by underwater- and surface cameras. The image data is transported to the video distribution server on the feed barge by a fiber network. In this scenario a Mobile Edge Computing (MEC) node is installed. This node's primary purpose will be to run the pellet detection AI. Meanwhile, the video distribution will also be moved to the MEC node, as this server is estimated to have sufficient computational power to run both the pellet detection and video distribution.

Real time pellet detection results will be presented to the operator on a video overlay, providing decision support during feeding. Video material will be pushed to the cloud through the 5G gateway, where it is stored, and distributed to remote applications that need to consume it.

5.2.3 Hardware components

5.2.3.1 Norwegian pilot

In addition to the hardware components used in A1S1 and A1S2, a MEC node will be installed on the barge. SEALAB is working with Nokia on setting up this server, which will be used as the main on-site processing unit and will host virtual machines for AI applications and video distribution.

MEC Node specifications

- Around 196 hyperthreaded vCPUs
- 650-700GB RAM
- 2.7-3TB SSD storage (CEPH)
- 2x25GB network ports in each server. One may be used for infra and the other one for tenant traffic
- 2 GPUs
- OVS-DPDK with 2 Cores allocated per server (4vCPUs) for VM networking

5.2.4 Software components

5.2.4.1 Norwegian pilot

Artificial Intelligence

Initially, SEALAB will use the MEC node to run a pellet detection AI. This uses a simple blob detector to find round objects in a picture. A snippet of that object is then passed to the AI that determines whether the snippet is of a pellet or not. This processing is performed entirely on the CPU, as the GPU communication overhead takes longer than the resulting increase in processing speed. As the content of each blob can be classified independently, our solution to increase throughput is to automatically scale the number of parallel AIs based on the hardware of the system it is running on or a predefined number. This means a high core count setup will be better for this application, as more blobs can be processed in parallel. Real time data will be presented to the operator on a video overlay, providing decision support during feeding.

Video distribution

The software behaviour of this solution is described in *section 3.2.4.2*.

5.3 Testing and verification

Please refer to scenario A1S1 for the analysis of the testing and verification details for this scenario.

5.4 Next step plans

The MEC node is going to be installed alongside the rest of the equipment to allow the proceeding execution of the trials for this scenario.

6 A1S5 CAGE TO CAGE – ON SITE COMMUNICATION

6.1 Description and motivation

Various service and maintenance operations at the aquaculture site such as boats for transport and delousing, handling mortalities, net inspections, etc. are greatly facilitated and improved by having access to sensor and video data from the cage, as well as data from management systems, while conducting their operations. Additionally, the operation and navigation of underwater cameras in real-time require the network to support low latency. By moving the 5G connection point from the centralized feed barge of the site to connection points at each cage, this test will also identify the benefits of 5G technologies in comparison with cabled networks (e.g. fiber optics, ethernet) and wireless networks such as 4G, and Radio over Internet Protocol (RoIP) that are most frequently used today. Bandwidth, latency and coverage will be measured in this test. In Figure 30, the pilot site with the planned installed equipment is presented.

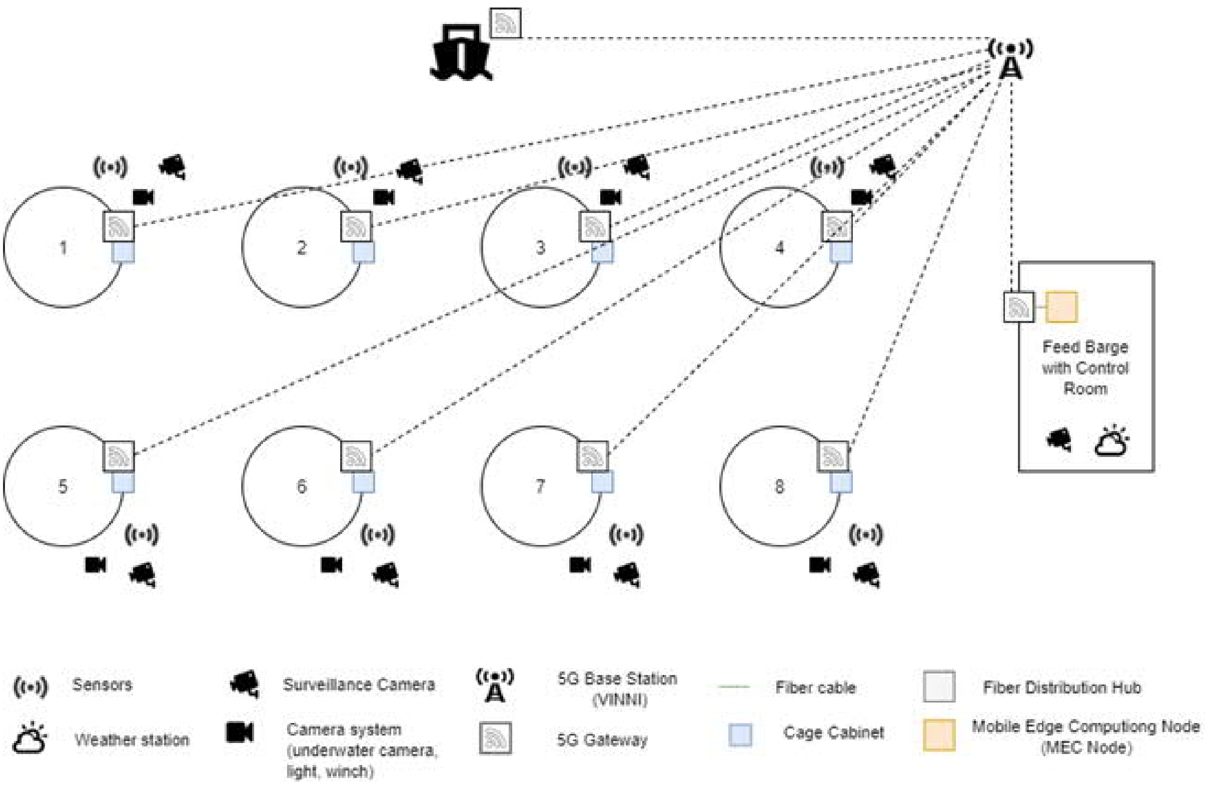


Figure 30: Illustration of the pilot site with the planned installed equipment in phase 3

6.2 Proposed setup

6.2.1 Network architecture

The network architecture that will be used was described in details in section 2.2.1.2.

6.2.2 User application architecture

6.2.2.1 Norwegian pilot

The user architecture for scenario A1S5 for the Norwegian pilot is shown in Figure 31. This scenario focus is on cage to cage – on site communication. This 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 utilized to generate the final version of the solution. In this phase, the fiber optic network is replaced with a wireless 5G communication set up, which must meet the demands for data traffic and stability.

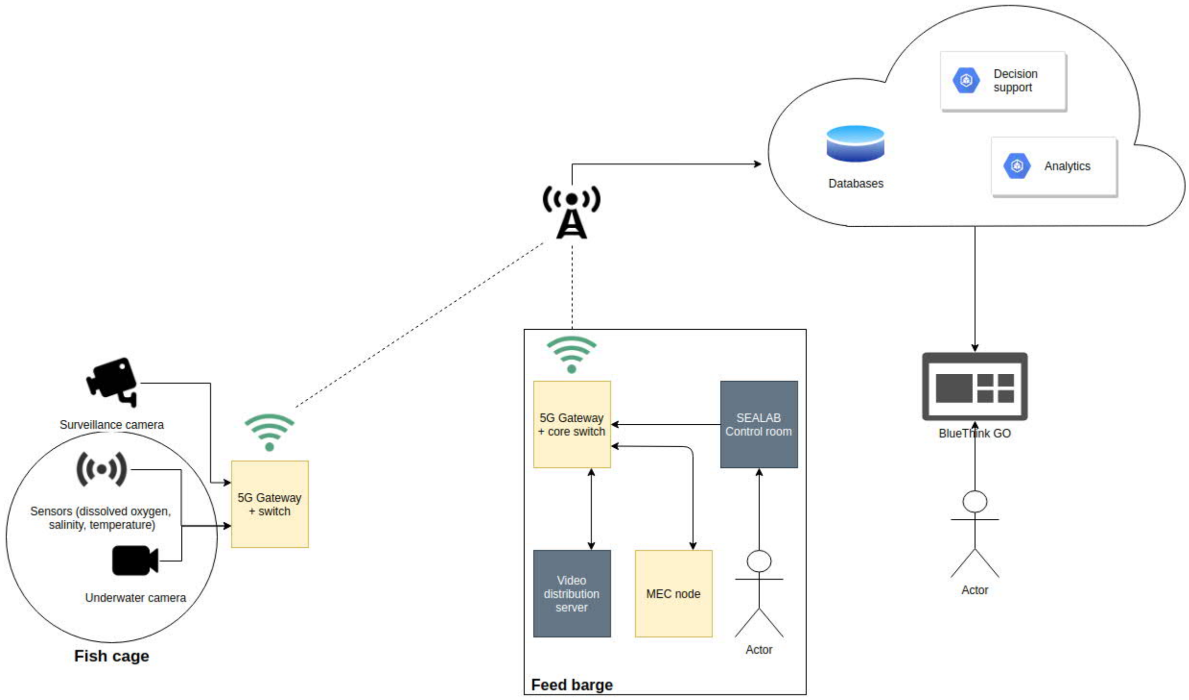


Figure 31: Norwegian pilot – user architecture scenario A1S5

6.2.3 Hardware components

In addition to the hardware components used in A1S1, A1S2 and A1S4 a 5G Gateway (exactly which one will be specified by Telenor) and a network switch will be installed on each cage (and service vessel) for this phase. The fiber network between the cages and barge will be removed.

6.2.4 Software components

6.2.4.1 Norwegian pilot

Communication of metrics, control signals, etc. within a farm when every cage has a separate gateway can be achieved in two different ways:

1. Keeping the MQTT broker on the barge like in the previous cases, but allowing external traffic on port 8883 to reach the MQTT broker. This will require a port forwarding in the 5G gateway.
2. Moving the on-site MQTT broker from the feed barge to a cloud-hosted virtual machine to ensure every software component can reach the MQTT broker.

For the video case, a server running Wowza Streaming Engine on the barge is to be used in the same manner as described in A1S2. The key difference is that video ingress will have to go through the 5G gateway on the feed barge, meaning that devices in the cages have to be able to access the public IP of the barge gateway and a public port (preferably 1935) has to be forwarded to port 1935 on the video distribution server for video ingress. SEALAB can adapt to other choices of public port if necessary.

At the time of this project, SEALABs system has no need to communicate between cages. All communication is between a cage and the barge. However, in this project it is desired to test communication between a 5G-connected service vessel and a cage with cameras and sensors. Because of how the underlying system is designed, this communication must go through the hubs for sensor data and video respectively. Most likely, both of these will be hosted on the barge. Streaming video from a 5G-connected cage to a 5G-connected vessel will then result in the traffic following this pattern: cage -> 5G network -> barge -> 5G network -> service vessel. The cage-to-vessel communication is presented in Figure 32.

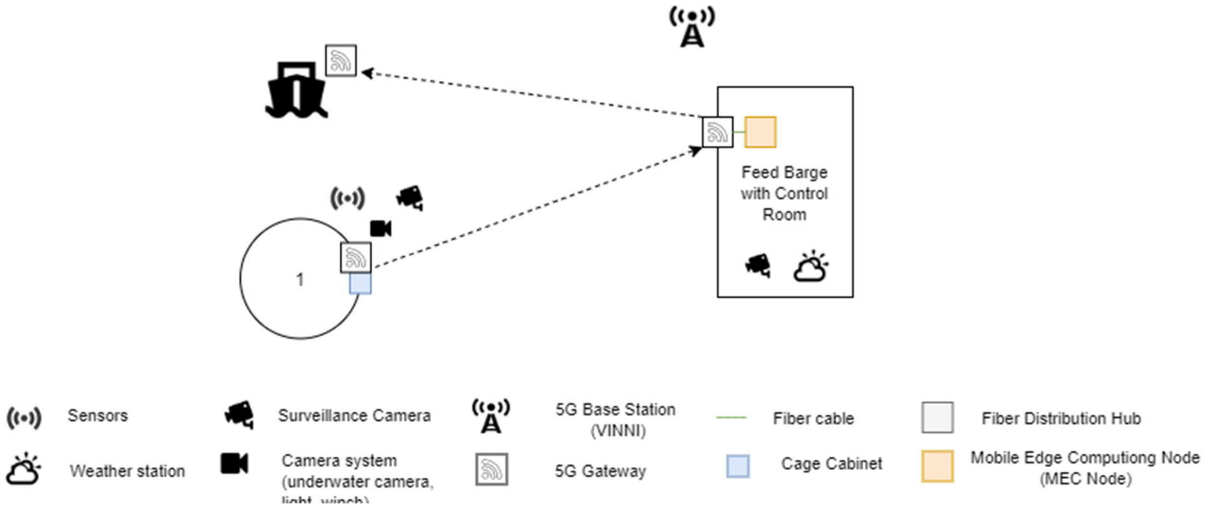


Figure 32: Cage to vessel communication

6.3 Testing and verification

Please refer to scenario A1S1 for the analysis of the testing and verification details for this scenario.

6.4 Next step plans

The cage to cage communication equipment is going to be installed alongside the rest of the equipment to allow the proceeding execution of the trials for this scenario. The design for these installations is going to be studied during Phase 2, while the actual installations and testing are going to take place during Phase 3.

7 CONCLUSION

Concluding the work that has been done during the first phase of the Aquaculture trials, the user application and network architecture for each of the scenarios has been defined, the equipment that is going to be installed including sensors, cameras gateways and computing resources has been specified, while the design of the overall solution has been provided covering network and software aspects for all scenarios.

In specific, the work has been split in two pilots, one in Athens using 5G-EVE and one in Oslo using 5G-VINNI. The current status for the Greek pilot includes the deployment of initial equipment (sensor, camera) on site as well as the deployment of the initial solution for the software platform that is going to be used. During this work, integration aspects have been investigated regarding the available 4G/NB-IoT network as well as the integration between the different solution components. An end-to-end solution for the first phase has been provided as the end result of this work for scenarios A1S1 and A1S2 as planned, while lab tests planned for scenario A1S3 activities have been pushed to Phase 2 due to delivery of the necessary equipment. For the Norwegian pilot, the full setup of the solution has been described from both the user application and network angles for scenarios A1S1, A1S2 and is ready for deployment. Initial installations and testing have been delayed due to the aquaculture site's unavailability as one of the COVID-19 effects in the work of the trials.

During the next phase, both sites are planned to be deployed covering scenarios A1S1, A1S2, A1S3 (initial testing at the lab) and A1S4, while A1S5 is planned for Phase 3.

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