5G-HEART Newsletter

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5G HEART
5G Health, Aquaculture and Transport Validation Trials

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INSIDE THIS ISSUE

"The aquaculture use cases in 5G-HEART challenge the performance and availability of telecom, which only 5G can meet."

1. Aquaculture use cases

Aquaculture is one of three industry verticals in the 5G-HEART project. The use case for the aquaculture vertical will comprise of two pilot sites, showcasing the applicability of the solution developed in different locations. The first site in Greece (GR) will utilize the 5G-EVE node and the second pilot in Norway (NO) will use the Norwegian node of 5G-VINNI to access the network.

Figure 1. *Country locations of the aquaculture vertical pilot sites - Greece (dark blue) and Norway (yellow).*

The scenarios to be developed for the two pilot sites:

- A1S1: Sensory Data Monitoring (GR, NO)
- A1S2: Camera Data Monitoring (GR, NO)
- A1S3: Automation and actuation functionalities (GR)
- A1S4: Edge and Cloud-based computing (NO)
- A1S5: Wireless communication on site (NO)

2. Understanding the needs of the aquaculture sector

The EU's *Blue Growth Strategy* identifies aquaculture as a sector which could boost economic growth across Europe and is ideally placed to meet targets set out in the EU *Green Deal* and *Farm to Fork* Strategies. However, aquaculture has not met its potential within the EU and although it is valued at over €5 billion the EU remains a net importer of seafood products. The European Commission is focusing on the development and application of new and emerging technologies to aid the sustainable development of European aquaculture through the introduction of 'smart farming'.

The industry-driven multi-stakeholder platform EATiP (the European Aquaculture Technology and Innovation Platform) in its position paper *EATiP Position Paper & Recommendations 2019* [1] highlighted the need for high-precision farming to give better control, higher efficiency and high animal welfare standards. Sharing farm data and integrating Big Data, the Internet of Things, Artificial Intelligence and Deep Learning into husbandry practices will contribute to standardisation and the possibility to benchmark the best production conditions. This will lead to better growth predictability and feeding regimes, more precise welfare and health monitoring, autonomous operations and improved safety conditions for aquaculture workers.

Monitoring of the fish stocks, environment and the farm infrastructure are key areas for maintaining optimal production and minimizing environmental impacts of aquaculture. Significant advances have been made in recent years through the development of technologies for autonomous data acquisition and communication in the areas of monitoring fish behavior and feeding within the net pens on marine farms, monitoring water quality parameters to determine environmental impacts and the integrity of the farm structures to minimize the potential of fish escaping. These technologies need to be supported by an appropriate communication and data processing infrastructure, capable of supporting offshore systems. Current systems often rely on legacy 3G or 4G coverage which is often unstable or lacks sufficient bandwidth for the expected level of data transportation, offer poor video quality and are unable to support remote autonomous operations. In addition, many systems require the data to be physically downloaded on site.

5G connectivity offers the opportunity to connect a wide range of sensors directly with applications, enable real-time video monitoring with negligible latency and supports remote monitoring, thus providing a ubiquitous communication infrastructure solution for aquaculture.

5G-HEART investigates aquaculture use cases based on the real needs of the sector.

3. Network infrastructure and measurements

With network virtualization and slicing mechanisms that are introduced by 5G, logical networks that accommodate different network traffic requirements can be created to fulfil diversified connectivity needs and provide scalability. Moreover, one of the key 5G enablers are the bandwidth and data rate improvements, in comparison to earlier mobile network generations, which may not be required by vertical applications. Specifically, for IoT applications the higher bandwidth rates lead to increased energy consumption, which in turn minimize battery life of the associated devices. Hence, for such applications lower bandwidth or data rate may suffice. Thus, to satisfy the diversity of application and network Quality-of-Service (QoS) requirements, slicing services are defined with enhanced Mobile Broadband (eMBB), Ultra-Reliable Low Latency Communications (URLLC) and massive Machine Type Communications (mMTC) as the standardized options. Hence, a vertical application that requires reliability for critical traffic or improvements in energy efficiency for battery-powered devices would select a URLLC slice, with a cost on performance.

Aquaculture infrastructure (Greece)

For the aquaculture use case a combination of eMBB, URLLC and mMTC slicing services is required, that also allows to achieve a diverse set of key performance indicators (KPIs) for the involved scenarios with diverse requirements. Power efficiency, for example, is a key requirement in the aquaculture use case due to the need for extended battery life of sensors, while video monitoring and autonomous operation of drones require a high level of reliability. The trials are validating the scalability of the 5G network, in order to accommodate different network traffic requirements and meet reliability as well as power efficiency requirements associated with the specific use case.

For the purpose of demonstrating the aquaculture use case, two pilot sites are deployed in different locations, Greece and Norway. The Greek pilot is deployed in Megara, near Athens. The Greek 5G EVE node located in Athens will be utilised to enable 5G connectivity for this site. The second pilot site in Norway will use the Norwegian 5G VINNI node to access the network.

The high-level architecture of the Greek node is presented in Figure 2. The node is based on Non-Standalone (NSA) architecture. The NSA architecture is designed to take advantage of existing 4G network equipment while offering 5G services simultaneously. Currently, the Greek site consists of a URLLC slice. However, it is able to run a service using a different Access Point Name(APN). The APN differentiation slicing mechanism will provide an eMBB or mMTC type of application.

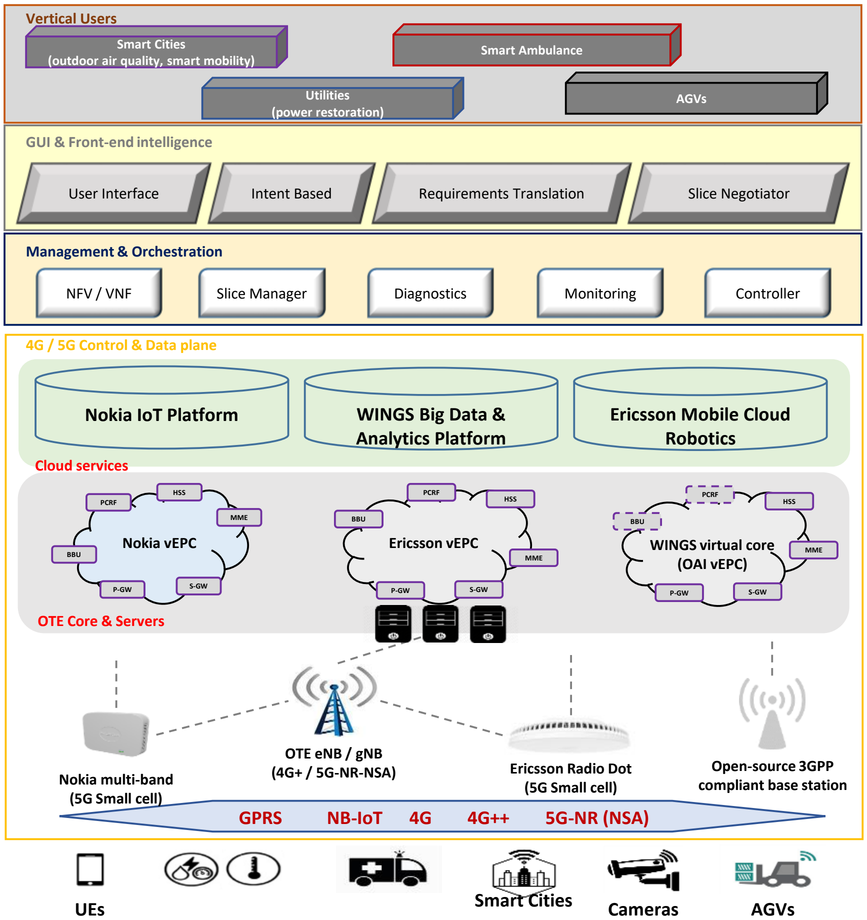

Figure 2*. High-level architecture of the aquaculture use case for Greece.*

The Radio Access Network (RAN) is the only part of the network located on the Greek aquaculture site. The base station is the RAN component to which equipment is connected. A variety of different equipment is used for the collection, processing and transmission of data. The RAN is connected to the Hellenic Telecommunications Organisation (OTE) premises where the Ericsson Virtual Evolved Packet Core (vEPC) is located, via a 10Gbps link. vEPC includes the following elements which are responsible for user authorisation and service accessibility:

- Mobility Management Entity – MME: responsible for user authentication. Additionally, it generates temporary identities to user equipment (UE) and verifies whether the UE is authorised to camp on the service provider's Public Land Mobile Network.
- Serving/Packet Data Network Gateway – S/PGW (Software functionality of proposed EPG): S-GW is responsible for packets routing to and from the base station, while P-GW filters user traffic in order to ensure the QoS.
- Service-Aware Policy Controller – SAPC: responsible for the policy control and charging rules and supports the optimised utilisation of network resources.

Finally, the vEPC is connected to the Cloud and the application infrastructure which is located at the premises of WINGS ICT Solutions.

ACTA Ltd., KPI probes will monitor the network traffic at the farm gateway and at four other locations, namely at the OTE premises at the City of Megara, the Psalidi OTE LABs in the OTE-Academy location, the Ericsson EPC and the WINGS Cloud platform, as shown in Figure 3. This will provide segmentation of the network monitored, in addition to end-to-end monitoring, of the quality in the segments.

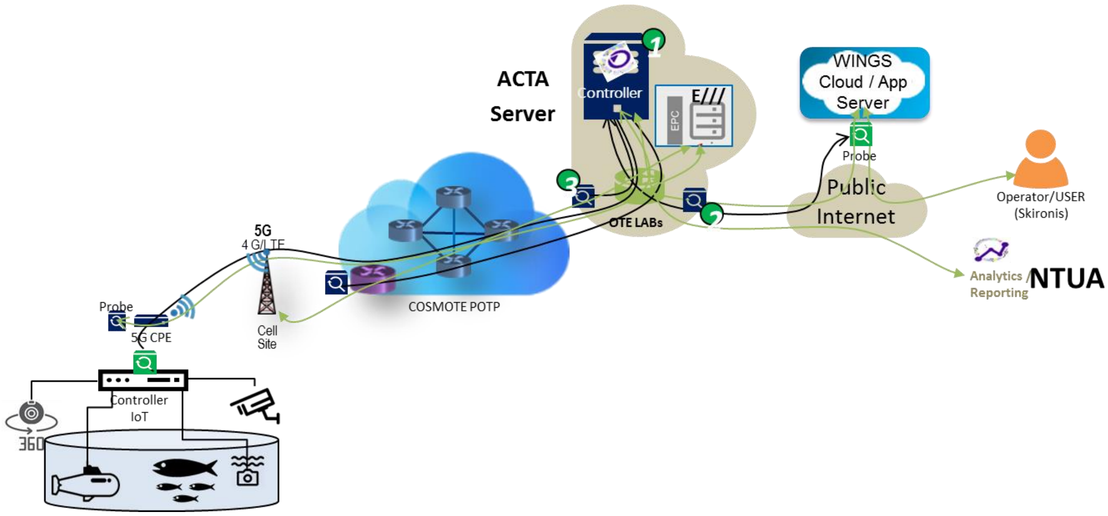

***Figure 3**. ACTA's installed components.*

In the context of 5G-HEART, different probe alternatives, both hardware (shown by blue) and software (green) are currently, or planned to be, installed on the 5G-HEART network expansion:

- Hardware probe VIAVI-MT-S5800 (with 10 Gbps Optical Interface) also capable of traffic generation
- Smart SFPs (placed in the main Control Plane Switch and Data Plane L2/L3 Switch)
- MicroPC with L4 (and L3) Testing S/W (open source and proprietary)
- Hardware NSC/ONX portable probe by VIAVI
- Software TWAMP implementation (reflectors and clients) running at UEs and some of the above probes

Network KPIs of particular importance will be throughput (esp. uplink) and latency, for video transmission.

To achieve E2E measurement of KPI values, the various probes will have to communicate with a central controller software, for configuration, management and data-measurement acquisition and storage purposes.

The ACTA KMVaP (KPI Measurement and Validation Platform) shown in Figure 4 below, is the central management system for the multitude of probes that are installed in the network and are responsible for collecting data from measurements of network KPIs.

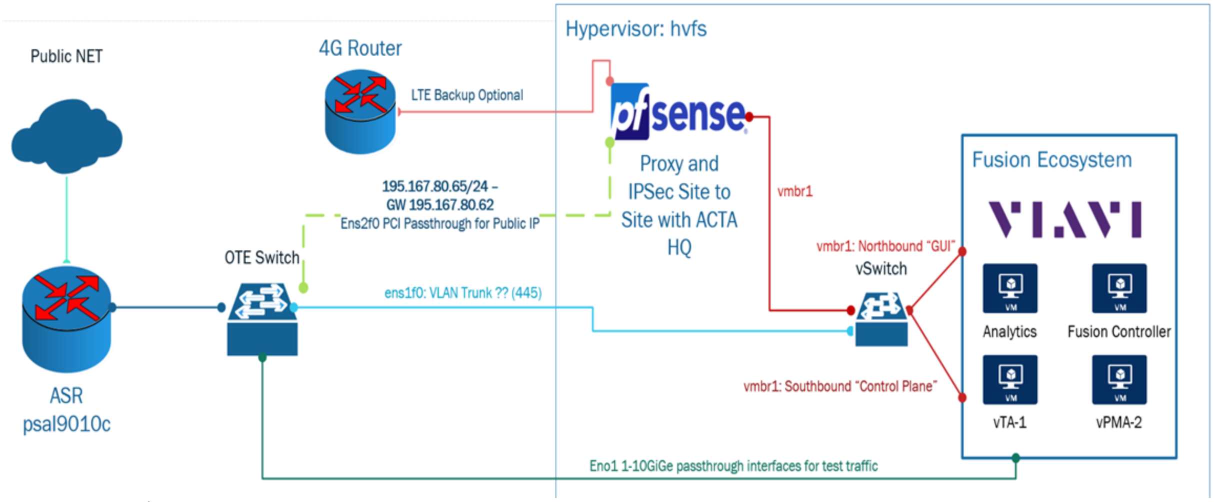

***Figure 4**. ACTA's KMVaP ecosystem for KPI measurement and validation.*

ACTA's KMVaP is installed in OTE-group R&D Laboratories and interconnected with Psalidi OTE's LAB infrastructure and through this, to the 5G-EVE and 5G-HEART infrastructures.

Analytics Engine

An Analytics Engine has been developed by the National Technical University of Athens (NTUA) to support a set of analysis processes over the collected network and compute resources' usage data within the Greek pilot site. The Analytics Engine aims to support the execution of different types of analysis and the extraction of insights with regards to 5G KPIs. It is an extension of the software developed in the 5GTANGO project and released as part of the SONATA NFV Orchestrator. The main supported functionalities include the execution of analysis over time series data, the easy registration of analysis scripts based on open APIs and the visualisation and tracking of the analysis results.

Monitoring data is collected in a time series database maintained by a Prometheus monitoring engine, upon their availability in a Kafka Publish/Subscribe broker. Data is provided by different probes that are installed in the Greek pilot site. Open APIs are made available for executing an analysis, as well as for registering new analysis scripts in the Analytics Engine. Analysis scripts can be easily onboarded and used by the end-users. Two indicative screenshots are shown below (Figures 5 and 6), illustrating the interface for the specification of an analysis process to be executed along with indicative analysis results based on time series decomposition.

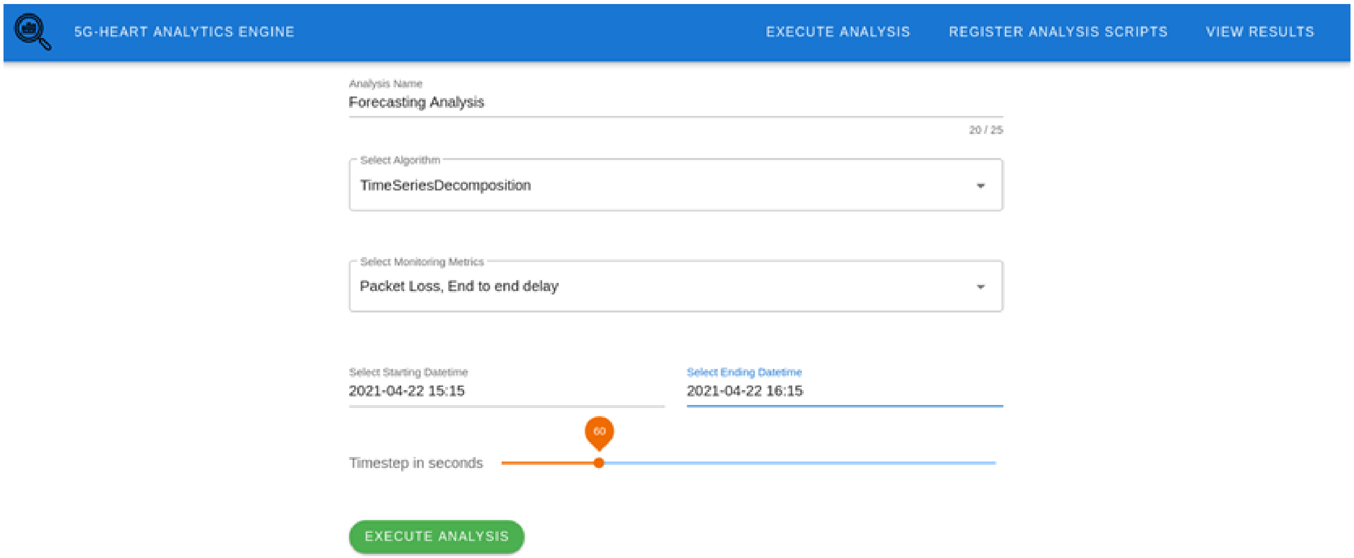

Figure 5. *Analysis process specification in the Analytics Engine.*

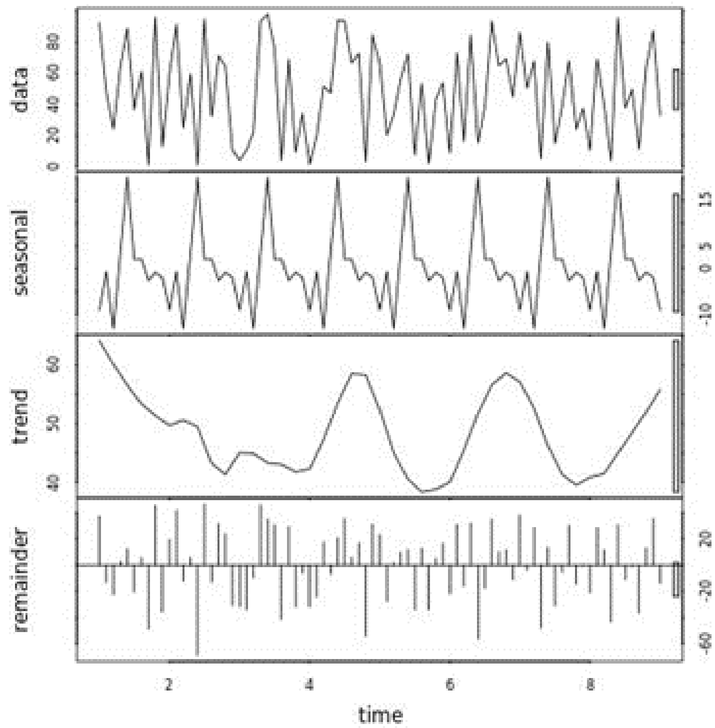

Figure 6. *Time series decomposition analysis result.*

Aquaculture infrastructure (Norway)

For the Norwegian case, the 5G Network infrastructure is composed of two main components: the Radio and the Core part. The Norwegian facility will leverage New Radio (NG-RAN) from Huawei. The radio components used in 5G-VINNI are based on antenna integrated radios for mid-band (3600 MHz) and high-band (24.5-27.25 GHz). The CORE is composed by both: Stand-Alone (SA) and Non-Stand-Alone (NSA Core). For NSA, Ericsson VNF Virtual Machines (VMs) run on a Nokia cloud platform. For slice selection, the DECOR (Dedicated Core Network) functionality will be used. It is composed by MME (Mobility Management Entity), SPGW (Serving Packet Data Network Gateway), PCRF (Policy and Charging Rules Function), HSS (Home Subscriber Server) and UDR (User Defined Route). On the other hand, the SA Core uses the 5G Core from Ericsson, delivered and executed as a set of containers and designed to run on a Kubernetes container orchestration platform. A Container-as-a-Service (CaaS) layer will be deployed as a set of VMs on top of the Nokia cloud infrastructure (NCIR) and will facilitate two SA network slices with a combination of independent NFs per slice (AMF, SMF, UPF) and shared NFs (UDM, UDR, AUSF, NRF, NSSF). Figure 7 presents de details of the 5G-VINNI Norwegian facility to be used for the aquaculture use case in Norway.

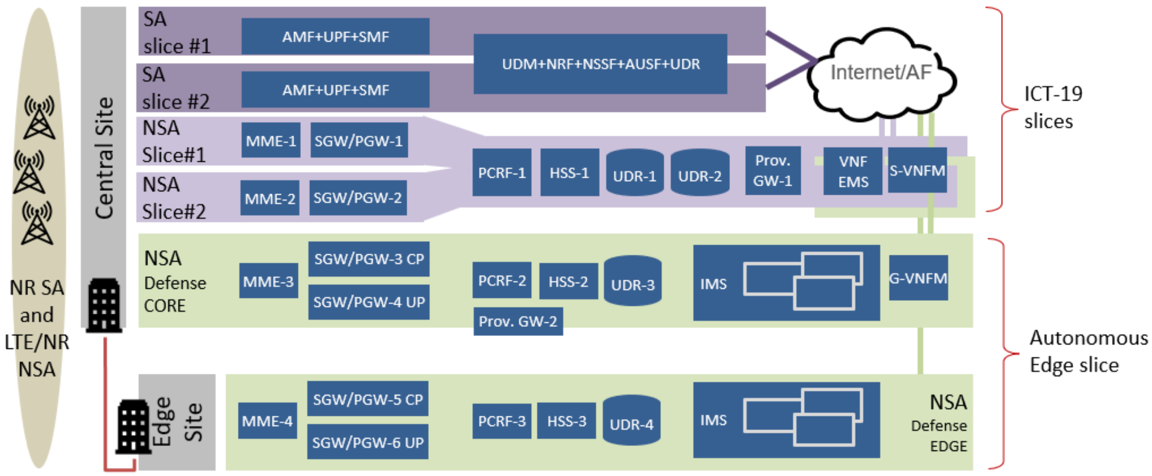

Figure 7. *SA, Edge and NSA Slice/VNF implementation Norway.*

Based on the previous concepts, the Norwegian facility is composed of 5 different slices (3 NSA and 2 SA) as presented in Figure 8 below. For NSA, the slices available are eMMB, followed by the URLLC and finally the mMTC. As with the NSA, the SA configuration allows the possibility to provide four slice types, eMBB, URLLC, mMTC, and customized slice. The fish farm use case will be implemented in the NSA eMBB. The implementation of this use case is presented in Figure 8. The yellow box contains the network equipment and is composed of the 5G-CPE in charge of connecting the fish farm to the 5G antenna and network. The second one is a backup VPN-box solution used for management purposes and as a backup path. Finally, the Edge cloud which consists of a small datacentre, will be able to process locally some of the information obtained from the cameras and sensors. It will implement artificial intelligence routines from SeaLab for the more efficient detection of issues at the farm, and for a better selection of videos to be transmitted.

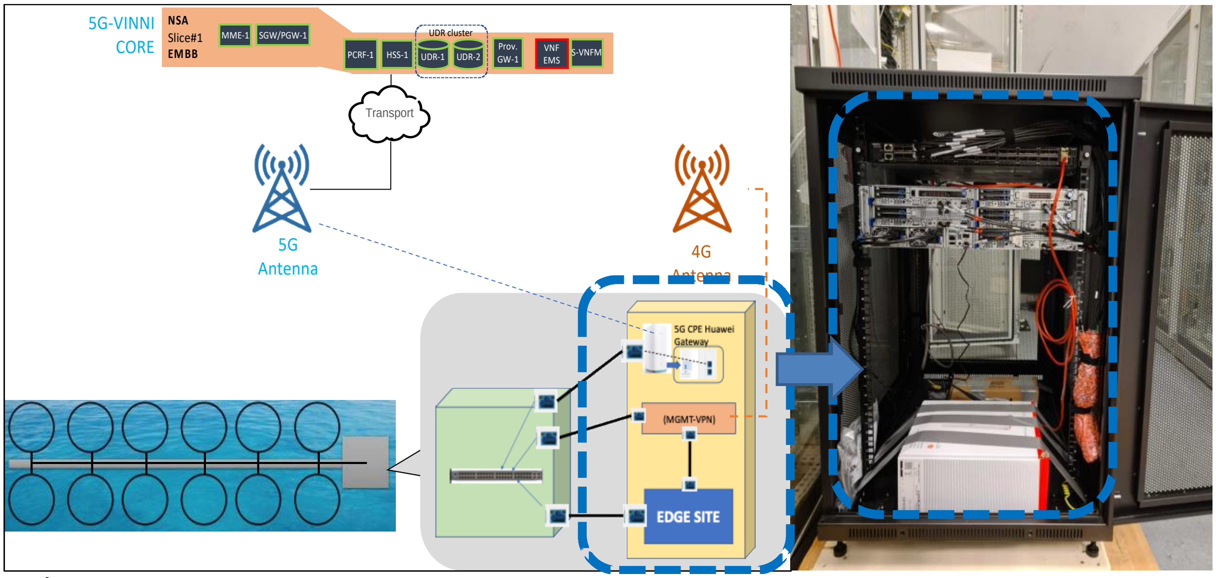

Figure 8. *Network Infrastructure at the Aquaculture use case using the eMBB NSA Slice.*

The service provided to the aquaculture use case will be pre-tested by using measurements that consist of monitoring applications at the User Equipment (UE) that will send data to specific vTAPs (virtual Terminal Access Points) allocated in the same cloud platform where the 5G Core functions are installed. The traffic generated between the UE-APP and the vTAP will allow the collection of end-to-end performance measurements that are in principle focused on Delay and Throughput. Finally this system described for the pre-test will also be used and implemented periodically, in order to have measurements of the QoS delivered and the respective trigger of actions, should performance degradation be detected. An illustration of the testing platform mentioned above is presented in Figure 9.

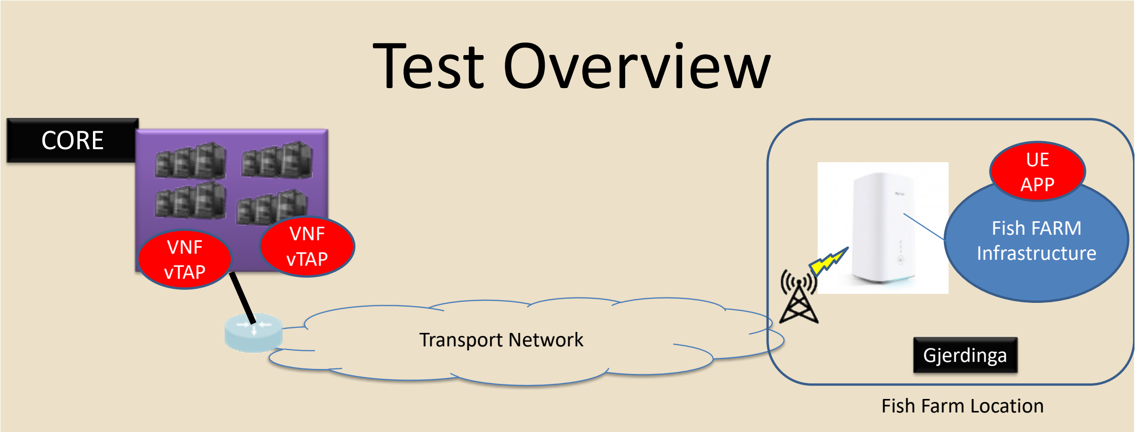

Figure 9. *Test Platform of the Norwegian aquaculture use case.*

4. Aquaculture use case in Greece

The use case in Greece is located at Megara in the suburbs of Athens. The fish farm, Aquaculture Skironis, has an area of 50 km^2 and is licensed for an annual production of 1,500 tonnes of seabass and seabream in sea cages.

The main objective of the use case, is a more efficient production combined with a reduction in the overall environmental footprint. The 5G-Heart project gives us the opportunity to test a series of technologies that demand a high bandwidth network for their operation but can offer critical contributions not only in decision making and daily operations of production, but also in the safety of the personnel and the infrastructure.

Planned equipment installation for the trials includes:

- Underwater cameras for feeding control and fish behavior monitoring in the cages, also providing a biomass estimation feature;
- Sensors for measuring real-time environmental parameters;
- On-site cameras for security;
- On-site 360^0 camera for infrastructure monitoring;
- Underwater drones for infrastructure monitoring.

It is intended to thoroughly test the fish biomass estimation feature of the underwater cameras and compare the results with manual fish sampling and weighting. Biomass estimation is a key factor for calculating daily feeding rates. As 50% of the overall production costs are due to fish feed, an accurate biomass estimation combined with live monitoring for excess/insufficient feeding will contribute to achieving a more optimized feeding level. That will have a positive impact on the production efficiency and will reduce the overall environmental footprint. Finally, the multi sensors will automatically gather and provide information on environmental parameters including oxygen, temperature, salinity, currents etc.

Figure 10. *Sea bass at the Skironis fish farm.*

Monitoring of the aquaculture site with on-site and underwater cameras is of great importance for both security surveillance of the infrastructure and fish welfare, e.g., to prevent escapes from fish cages. The real-time video transmission for the fish farm requires 1) high bandwidth due to the demanding high definition video (4K, 8K or even 360°) and 2) low latency due to the real-time streaming aspect. For this reason, the eMBB slice type was chosen, as it incorporates network and video streaming resources over the shared and multi-tenant 5G infrastructure. This delivers high bandwidth and low latency compared to the previous mobile network generations.

The developed monitoring solution will utilise a VR/360° surveillance camera, to provide full infrastructure visibility and early detection of structural failures. The camera allows the dynamic update of the focus angle, called a field of view (FOV), as well as the visualization of multiple streams at different resolutions. However, the eMBB slice does not allow the high-quality video stream to be received with the lowest possible delay when changing the selected FOV. To overcome this issue, a URLLC slice will be incorporated for content transmission at a lower latency. Nevertheless, the trade-off is that URLLC slices allow limited bandwidth, which corresponds to a lower quality of video. Therefore, to utilise the advantages of both eMBB and URLLC slices, a combined scenario will be followed. In this scenario, lower quality video is visualised when changing the FOV to minimise delay. When the FOV is stabilized, the quality of the video is optimised by changing the high-resolution stream.

The transmission of 360° camera footage for the surveillance of the entire infrastructure and the transmission of multiple concurrent camera streams for monitoring the fish cages will be combined. This will stress the 5G network and validate its efficiency when applied to the aquaculture use case.

***Figure 11**. The Skironis sea bass/sea bream farm in Greece.*

5. Aquaculture use case in Norway

The Norwegian use case is located at a fish farm in Rørvik, on the west-coast of Norway. The farm consists of eight cages where Atlantic Salmon are produced.

Figure 12. *Panorama overview of the Norwegian fish farm.*

Aquaculture has become a high-tech industry, and new technology to optimize production, improve sustainability and lower environmental impacts are constantly developed. For the 5G-HEART project each cage will be equipped with HD-underwater cameras with underwater lights to monitor the fish live and to use Artificial Intelligence (AI) like pellet detection to control feeding of the fish. There will also be topside cameras and environmental sensors installed on each cage.

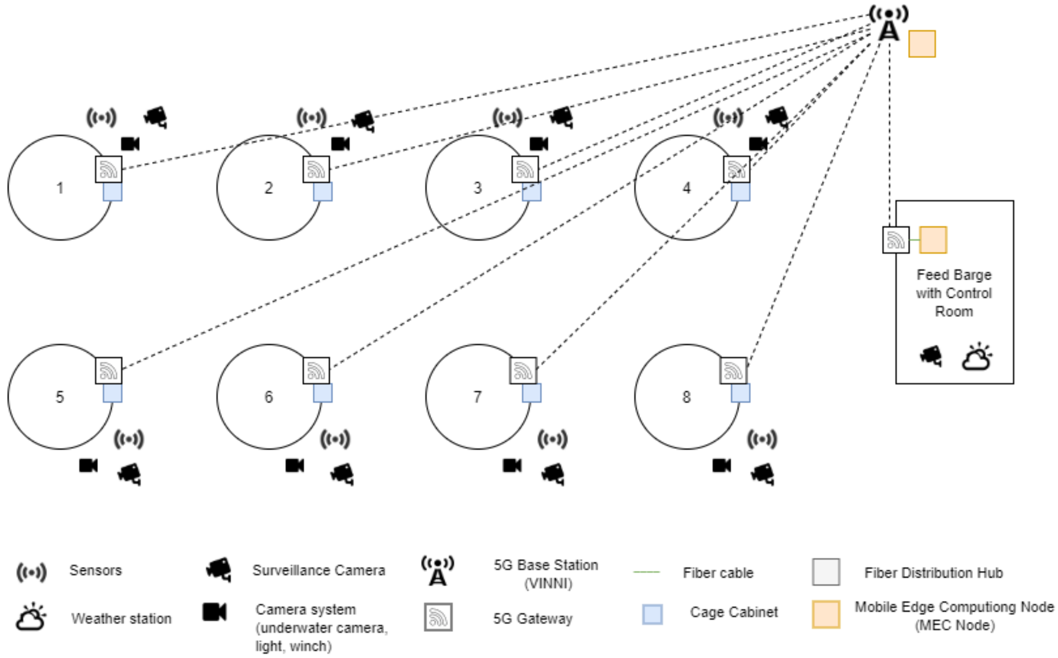

Figure 13. *Illustration of the Norwegian pilot site with the planned installed equipment in the final phase.*

The tests conducted at the pilot site will include experiments on various features:

- **Remote monitoring of physical conditions at site:** Data collection and transfer from different in-water sensors to determine water quality and conditions for optimised fish welfare and feeding as well as above water sensors to determine wind, temperature, tides, temperatures for the safety of personnel and planning of operations. The connection density of devices supported by the network will be tested.
- **Live stream - transfer and storage of image/video data:** Access to real time image and video data from the site is crucial for all aspects related to remote operations of the fish farm. Storing image/video data for documentation and further processing is also required. Further to navigate and position underwater cameras and controlling of lights for optimal footage latency as well as bandwidth and throughput will be examined in this test.
- **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 which 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 and the tests will focus on bandwidth, throughput and latency.
- **Wireless communication on site:** The capacity of the 4G-network is too low to support the amount of data needed to be transferred from a fish farm. Today, cable networks are being used to transfer data however these cables are susceptible to damage and breakage. By using the 5G-network to operate the cameras, farmers can trust the system to be more stable, which is critical for several daily operations.

6. Summary

With modern data collection systems becoming popular in marine aquaculture for enabling the monitoring, operational management and automated decision making support of fish farms, the use of 5G network infrastructures can be of utmost importance to cover the needs of such services and efficiently transmit, process and manage the massive amounts of data/video streams that these may involve. The aquaculture use case is split into two pilots, one in Greece supported by the 5G-EVE node in Athens and one in Norway using 5G-VINNI in Oslo. The two pilots have been developed to cover various requirements in two completely different environments and aquaculture settings i.e. a Mediterranean seabass/sea bream farm and a NE Atlantic salmon farm.

Multiple data streams from sensors and monitoring stations are used to stress the network with different loads of varying network requirements such as low latency for autonomous remote operations or high throughput for real-time high definition video transmission. The trials will demonstrate the applicability of 5G innovations such as slicing mechanisms for the aquaculture use case and validate their efficiency by defining and measuring appropriate KPIs.

References

1. European Aquaculture Technology and Innovation Platform. (2019). EATiP Position Paper & Recommendations. http://eatip.eu/wp-content/uploads/2019/10/eatip-position-paper.pdf