SEVENTH FRAMEWORK PROGRAMME - THEME ICT
INFORMATION AND COMMUNICATION TECHNOLOGIES

# Underwater Acoustic Networks

## WP7 Deliverable 7.2
## Final plan for the use and dissemination of the foreground

PROJECT ACRONYM: UAN

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PROJECT TITLE: UNDERWATER ACOUSTIC NETWORK

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| Dissemination Level: | | |
|---|---|---|
| PU | Public | |
| PP | Restricted to other participants (including the Commission Services) | X |
| RE | Restricted to a group specified by the consortium (including the Commission Services) | |
| CO | Confidential, only for member of the consortium (including the Commission Services) | |

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# 1. INTRODUCTION

## 1.1. PURPOSE AND CONTENT

The goal of this deliverable is to highlight the use of the project outcomes, it was tried to deal with the UAN exploitation to a greater or lesser degree. This means that it was tried to consider not only the UAN network as a whole but also some of its peculiar capabilities.

In the same time were suggested ideas on alternative use of the outcomes, alternative respect what considered at the beginning of the project, these suggestions could give both the possibility to start new collaborations and to give evidence to the improvements that could be subject of study for the years to come.

Since the exploitation of the results depends by the experimentation results, in the last paragraph are also included considerations on the experimentation and the improvement to be pursued.

## 1.2. Reference documents

| Reference ID | Document/action title |
|---|---|
| Ref 1. | UAN Project – Description of Work |
| Ref 2. | UAN deliverable 2.1: Operational and threat scenario |
| Ref 3. | UAN deliverable 5.2: Lab Test Evaluation |
| Ref 4. | NIAG 110 - Maritime Force Protection Effects in the Above Water Environment |
| Ref 5. | Water Side Security 2010 conference: Archimede, an Integrated Network-Centric Solution Supporting Situational Awareness and Protection |
| Ref 6. | Security Research Conference'11 Poster Session participation: UAN network in a Harbour Protection context |

# 2.

## 2.1. Acronyms

| | |
|---|---|
| AUV | Autonomous Underwater Vehicle |
| BB | Building Block |
| C2 | Command and Control |
| CIP | Critical Infrastructure Protection |
| COP | Common Operational Picture |
| CS | Control Station |
| E/O | Electro-Optics |
| GS | Ground Station |
| GS | Ground Station |
| GW | Gateway |
| HCI | Human Computer Interface |
| NCW | Net Centric Warfare |
| OMG | Object Management Group |
| P2P | Point To Point |
| RHIB | Rigid-hulled inflatable boat |
| RMP | Recognized Maritime Picture |
| ROV | Remotely operated underwater vehicle |
| RWO | Real World Objects |
| UAN | Underwater Acoustic Network |

| | |
|---|---|
| UAN | Underwater Acoustic Network |
| UAV | Unmanned Air Vehicle |
| USV | Unmanned Surface Vehicle |

# 3. Rationale

The UAN project includes different key functionalities that can be considered as the potential outcome of the project, this means that the exploitation of the results can involve both the UAN proposal as a whole both the key functionalities included in the project.

The goal of this approach is to highlight the possibilities of a commercial exploitation of the research activity results, we try to deal with the UAN exploitation to a greater or lesser degree.

The field test held in Trondheim at the end of May gave the possibility to evaluate the system functionalities and their strength and weak points; as a consequence, this experimentation and the inferred lessons learned gave the fundamental inputs to develop the exploitation ideas.

The field test verification gave to the consortium what we define as a "conceptual validation" of the approach; this means that, with the experimentation, has been verified the capabilities of UAN to perform an underwater networking having embedded a capability to define the best interconnection among the nodes of the network by the use of mobile nodes and by the assessment of the sound propagation conditions.

Besides this networking concept, we have verified the capability of the network to deliver the information able to describe the underwater evolving situation considered of interest in relation with the assumed operational situations.

Two are the operational context assumed of commercial interest:

- The harbor surveillance

- The environmental control around the oil platform

In both the situations  the UAN system is only a component of the surveillance to be integrated with the information extracted by the above water sensors, it will be the information  fusion of the two components to resolve the ambiguities due to the boundaries condition in between the above and below water environments. These ambiguities will be resolved in the Command and Control which gathers all the information coming from the two environments.

Resuming what above exposed the following key functionalities  may constitute subject matter for the exploitation, the functionalities are ranked by the complexity level starting from the highest value:

- Underwater detection and classification of the threat
- Anti – intrusion underwater function
- Reference control network for the control of cooperative vehicle
- Environmental measures
- Robust below water P2P connection

Related to these functionalities, besides  the operational contexts above mentioned, we can consider too:

- the seafloor situational awareness, where a cooperating vehicle can move inside a well defined area ( a port for example)  to monitor the seabed having its position geo-referenced by the UAN network
- Water quality monitoring
- the information transfer from a sensor placed in a strategic point, difficult to be connected to the command and control , to the centralized above water command and control where all information are fused and finalized to obey to the system requirements.

# 4. ARCHITECTURAL CONSIDERATION

It is important to define the reference architecture since the architecture together with its components gives the suggestions to generate two degree levels of the exploitation (greater or lesser)

All the operational contexts foresee a kind of architecture which can be represented by the following general scheme (Fig 1) :

The capability to exploit this architecture in a specific contexts depends on:

- the payload that can be installed in the components of the architecture and
- the complexity of this payload in terms of power consumption, weight and data troughput.

Above water area context

Ground station

Command & Control

Intelligence

E/O systems

Radar systems

Effectors

Underwater UAN operative context

Vertical array

UAN network

FixedNode

FixedNode

FixedNode

Mobile Node

Mobile Node

Cooperating AUV

High value sensor

**Figure  Reference Architecture**

# 5. Component

In the following the possible use of the components is considered, in the meantime an evaluation feasibility was attached.  This operating way will give ideas on the possibility to exploit the results at different level and, also, will  give  ideas to the subject matter expert on the activity to be performed in order to achieve a more effective capabilities in the UAN network:

## *Mobile Node Component*

It is an organic component of the UAN network, in the project the role is covered by the Folaga a light weigth AUV having a reduced payload  capability. The key functionality of the Folaga inside UAN network  is the network connectivity maintenance, to realize this it requires a dedicated payload to process the network routing protocol and to host  the network transponder. For this reasons only a light equipment dedicated to the application can be installed, we assume two kind of  sensors are foreseen:

- a DIFAR, directional frequency and ranging  sonobuoys
- a sensor for environmental measure

The related information could be transmitted to the ground station by the use of the UAN networt itself

## *Fixed node Component*

It is an organic component of the UAN network. This component is the most suitable to be connected to a specific sensoriality at least for the weight constraints. Seafloor hydrophones can be easily connected to the network node

## *Cooperating AUV Component*

This is a component external to UAN network, th AUV  uses the network to increase its capabilities to control the path and to  obtain reference values to augment  its navigation capability.  The AUV is chosen to realize a scan of the sea bed, the execution of a periodic monitoring of the sea bottom will allow to detect threat like mine or, with the help of the historical comparision also the IED could be detected. No data transmission is foreseen, due to the large amount of data to transmitted ,all the data retrieved by the  AUV will be delivered at the end of the scanning activity.

Autonomous Underwater Vehicles (AUVs) have in recent years convincingly demonstrated their capabilities in real applications. Civilian applications include detailed seabed mapping, environmental monitoring and research and inspection work for offshore industry. Short time frame military applications include Mine CounterMeasures (MCM) and Rapid Environmental Assessment (REA). In a longer time frame, AUVs will play an important part in the general robotization of modern warfare. Modern AUV designs must handle submerged autonomous operation for long periods of time. The state of the art solution embedded in the AUVs is a Doppler Velocity Log (DVL) aided Inertial Navigation System (INS) that can integrate various forms of position measurement updates. In autonomous operations, position updates are only available in limited periods of time or space, thus the core velocity aided inertial navigation system must exhibit high accuracy. However, position uncertainty of a DVL aided inertial navigation system will eventually drift off, compromising either mission operation or requirements for accurate positioning of payload data.  To meet the requirements for a range of military and civilian AUV applications the UAN network can be considered to update the AUV positions.

In  the following is included a list of possible AUV the can be considered in relation to the operative requirements:

Hugin: Marked by Kongsberg Marittime, the  Hugin AUV is specific for geophisic explorations in depth water (three versions 1000,2000,3000), heavy and expensive (1.2M:2M€)

Figure  Hugin AUV

Remus: Realized by the Woods Hole Oceanographic Institute for environmental applications is marked by the Hydroid.It is udsed in shallow water, small dimensions easily oprated. It is mostly used for milatiry purpose, mine detection.

In the version having an operating depth of 100 m has a value ranging from 100K and 250K $.

Figure  Remus AUV

Gavia: Marke by the  Hamfynd,  Gavia is small and easy to handle operating in shallow water, it is similar to Remus usable for the environmental monitoring and for the port surveillance and the mine counter. The first to be realized in a modular way has a value starting from 60K€.

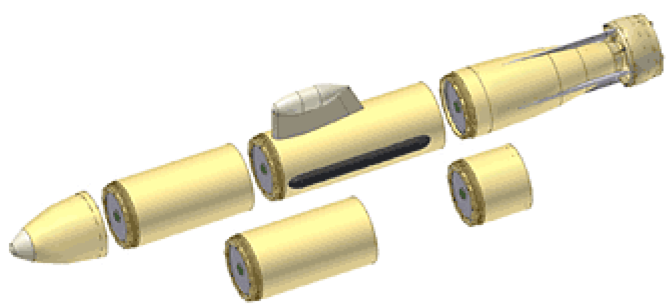

Figure  Gavia AUV

## *High value sensor Component*

The reason of the inclusion of this not organic sensor is to cover this  operational need:

Inside a surveillance system in its most complete realization, that is a distributed system which include many underwater and above water sensors to be connected to the command and control,  one of the key aspect is the sensors allocation optimization in order to achieve the high degree of surveillance capability.

It could happen   that the best underwater point associate to the high value sensor or source of information, if this best point is difficult to be connected by cable ( being this point both fixed or mobile) with the Command and Control centre an higher level of transmission data rate can be reached by the use of the high capacity connection supported by the UAN Network.

# 6. The harbor surveillance context

The arbour protection context represents the reference situation that was considered at the beginning of the project. The reason why the UAN project was considered it was to get the availability of new technologies able to face the competitor solutions in a domain of great interest.

A Selex-si stategic planning concerning the port protection activity was considered for the years to come., form 2011 to 2016.

This planning considers a research activity for the first 2 years, this research activity was considered mainly to optimize the underwater component of the harbour protection system which represents the most challenging part.

As a matter of fact, among the threats foreseen in this operational context, the underwater ones are those that represent a higher risk due to their camouflage capacity and the weakness of the sonar protection systems when used in shallow water environments, mainly, due to the strong reverberation

The UAN concept, in case the nodes were endowed with suitable sensors, could give the capability to set a security perimeter supported by a set of autonomous mobile-nodes for patrol and interception missions. The option for acoustic wireless communications (instead of wired systems) makes the network re-establishment faster in case of node failure due to an equipment breakdown or sabotage and makes easier the installation of the protection system in a location where a potential attack is anticipated. A network of such type requires reliable underwater acoustic communications to guarantee the network integrity and high data rate communications for the transmission of sensors raw data (e.g. acoustic or optic images) in case there is a threat detected.

The Payload, the fast deployment, the power consumption and the robust communications; these are the key aspects to be enhanced in order to include the UAN concept in the strategic planning mentioned before. The mentioned research activity, mentioned at the beginning of this paragraph, is foreseen to realize more convenient or optimized solutions that cover the UAN network functionalities.

The last paragraph gives an idea of this aspect.

In this context Selex-si has conceived Archimede, an *Integrated Network-Centric Harbour Protection System",* the system is dedicated to protect the Italian Military Harbour with the goal to enlarge the proposal to the foreign countries, it is due to these market analysis that the table was completed.

The Finmeccanica (FNM) ARCHIMEDE system provides automatic or semi-automatic, protection of the harbour area against air, surface and subsurface threats. FNM demonstrated at fist the system at the Harbour Protection Trial 2007 (HPT-07), in Taranto (Italy) as required by the NATO Naval Armament Group (NNAG). For that trial the local harbour Vessel Traffic Service (VTS) system was also linked to illustrate the ability of ARCHIMEDE to integrate with existing local systems.

The figure below describes a specific context where the system was tested, for  the UAN system exploitation activity   the interesting part is that one related to the Underwater environment where are included sensors such as acoustic  barriers, sonar, during this experimentation relevant difficulties were faced to integrate  the underwater sensors. This was the key reason way the participation to the UAN project took place.

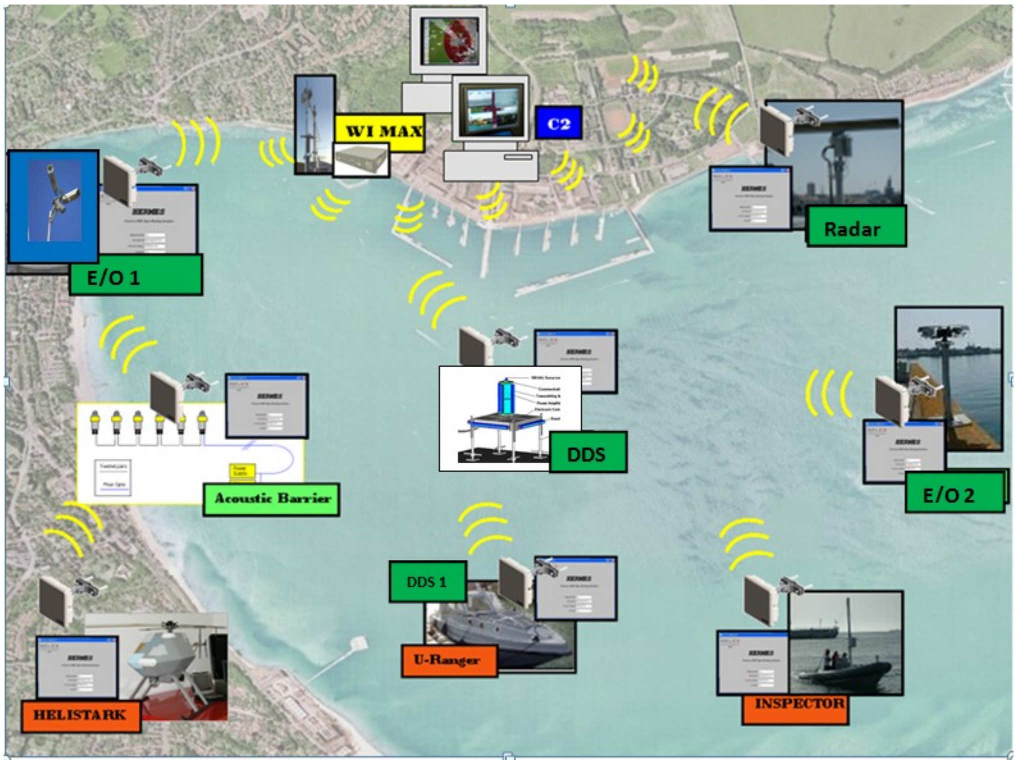


Figure  Example of a specific Harbour protection system

In the following will be given, at first, a more detailed description of the architectural configuration of the mentioned example as it was conceived by Selex_si , secondarily will be described  the philosophy of the approach in order to give evidence on the UAN network inclusion in such a context.

ARCHIMEDE integrates different types of sensors (radar, infra-red (IR), TV, sonar) and various classes of vehicle (surface, underwater, air unmanned aerial vehicles) which then cooperate in a multi-environmental scenario (above water, under water, sea surface, ground and air). The system design focuses on the following functionalities: fuse the data, classify, identify.  It then presents combined data from all sensors and automatically generates warnings on the Command & Control (C2) interactive console.

The C2 module receives all sensor data (e.g. tracks, video etc) using wireless/radio data links. It then fuses the track data to produce one “system track” for each Real World Object present in the scenario. This data then provides the Common Operation Picture (COP). On this tactical picture, ARCHIMEDE detects dangerous behaviours, trigger alarms and proposes responses. Most importantly, a single operator can supervise the evolution of the whole scenario.  He also has the ability to manually amend the classification and identification processes, re-direct the selected sensor towards a required direction, and, if required, take defensive actions. The two monitors incorporated in the C2 console enable the operator to observe EO video in one display while the COP is presented on the second. The system thus interconnects the various sub-systems using a middleware that is able to meet the critical real-time performance criteria essential for this demanding application. The coherent integration of sensors, decision-makers and effectors enables ARCHIMEDE to better use all available information towards the goal of "right information, right place, right time - but without information overload".

The philosophy of the approach is described in the reference architecture represented in the figure below, this architecture is suitable to understand how the UAN system was conceived to be included.

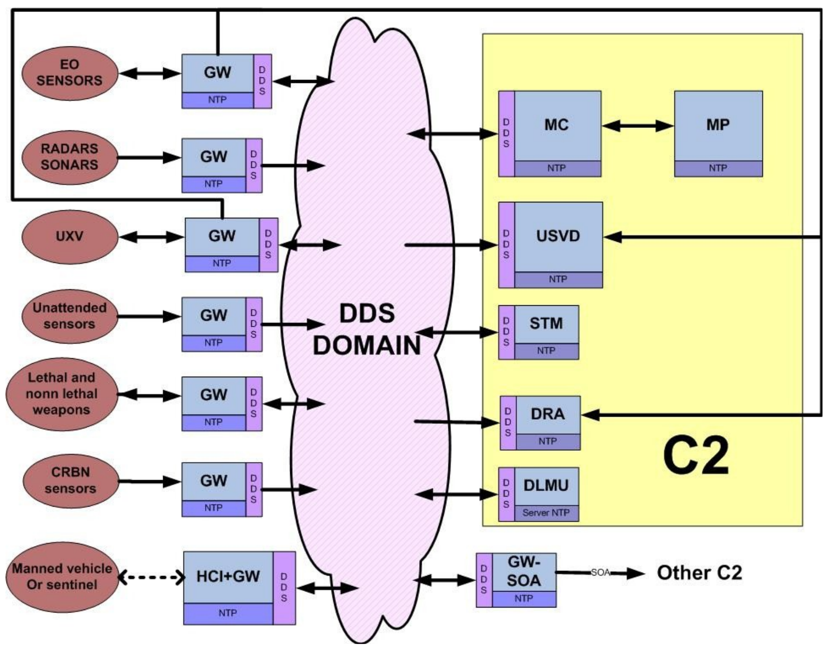


Figure UAN Network in the Archimede reference Architecture

In such a structure the UAN related system was presented as included in the " other C2", as it is referenced in the figure. It is the gateway SOA ( a middleware gateway) to allow the inclusion of the UAN context and this solution is considered the most relevant one to expand the capability of the "Archimede" system taking in to account the outcomes of the UAN projects. Due to its mentioned flexible middleware, the HP system shows a wide set of growth capabilities: one of the most important is the implementation of underwater sensors (mid/high frequency SONARs, divers detection SONARs, SONAR arrays, etc.) and other remotely-operated/autonomous underwater vehicles; another growth capability to be soon explored is the study and implementation of vehicles/sensors swarms. The assumption of a Net-Centric approach maximize the possibility of UAN exploitation in harbour protection context, the level of exploitation will depend on the project outcomes, the related considerations are presented in the last paragraph. In this kind of applications the customer it is assumed to be the Navy, the related operational situation of interest and the related solution to be analyzed in order exploit the results are listed below:

1. Realize an alarm system inside a naval base

This operational context is the most suited with the Archimede system application , the followings are consideration on functionalities that could receive improvement by the UAN project ( again in the conclusion are included the consideration that could give value to the project and to the exploitation possibility).

- Realize an underwater connection a specific high value sensor in some specific situation unsing the high capacity transmission achieved in the testing od the UAN network
- Two kind of alarm handling could be could be considered depending on the structure ol the fixed node position. It could be deployed an acoustic barrier where the net controls a restricted access point to the high value part of the harbour .A sparse passive array could be deployed, this array is connected to UAN the network while the active sources are placed in a free way inside the harbor ( a bistatic approach is used able to reduce the power consumption the sparse array belonging to the UAN network)
- In both the situation the self configuration of the network and for messaging addressing in the network could be a key solution.

2. Realize a sea bottom surveillance inside a naval base

This context responds to the need of a continuous monitoring of the port inner water sea bottom. The considered theath is represented by the IED. This kind of object being unconventional cannot be recognized from their shape but, more conveniently, by the periodic comparison between subsequent assessments of the seafloor status.

Considering the reference architecture above introduced in this application a cooperative AUV is considered. In this situation the UAN network could be considered to overcome difficulties in the navigation handling and in the geo referencing of the information.

3. Realize a surveillance system to protect an anchored vessel

This operational context is quite similar to that one of the oil platform protection, the possibility to obtain this kind of local coverage could be based on two architectural solution:

- Using simple detection sensors with low power consumption connected to the UAN network, by which the information is delivered to C2 via the UAN ground station
- Using the swarm approach. In this situation more small AUV ( such as Folagas) equipped with DIFAR sensors or similar move inside the UAN network and deliver the information through it. The SINTEF technology for the self configuration of the network and for messaging addressing in the network could be a challenging solution.

# 7. THE OIL PLATFORM SURVEILLANCE CONTEXT

In this context the customer  is assumed to be the  oil company, the related operational situation of interest could be:

1. Realize an alarm system around the platform

This operational context is similar to that one considered for the harbour protection. The differences to be considered  is the sea bottom depth , the noise level around the high value point to be protected.

2. Realize a water quality monitoring system around the platform

In this application the UAN operating condition could be considered , it is still to be selected a sensor usable for the water quality  measure.  As a reference challenging applicable system it was considered the Biota Guard AS, Biota Guards award winning environmental monitoring technology is now successfully deployed at 500m in the west coast of Norway. Biota Guard was the first to demonstrate real time monitoring operation including instrumented whole organisms (biosensors) at depths of 500m

# 8. Conclusions and recommendations

All the suggestions on the use of the foreground discussed in the previous paragraphs require some specific capabilities to the UAN system, these capabilities are embedded in the UAN concept of operations their effective exploitation requires a refinement of the adopted solutions.

In this paragraph are resumed, for convenience, the results obtained int the Trondheim sea trial including the refinements that could be achieved in order to exploit the assessed results.

During Trondheim experiment, the overall system is used by Selex operator in order to

- Receive information about underwater node position and status
- Move Folaga on a specific position
- Move Folaga in order to investigate a simulated threat
- Activate high rate channel in order to receive a pre-charged image from one node
- Integrate in the same console information from acoustic channel, camera IP and from surface protection simulation

From Selex point of view, main objectives were obtained and the experiment was successful: all the planned tests were performed. By the way, to go further a “conceptual validation” and to to propose the overall system as a product, there are some additional points must be investigated:

- **Ground Station concept**

The concept of Ground Station should be applied in the next experiment. Ground Station has different functionalities from C2. It is able to:

- Collect all the information from the network (in the experiment, this point is guaranteed by Base Station with Moos Database and High Rate image storing and by Network Control Interface)
- Receive surveillance or investigation task from C2 (in the experiment, this point is guaranteed by Base Station with Moos Database and High Rate image storing and by Network Control Interface)
- Receive payload information and share to C2 (for example as done for High Rate image)
- Receive environmental data from the sensor in the network and analyse network performance
- Adapt the network to the changing environment condition
- Make available a local interface in order to configure and monitor the network

- Payload

In the underwater network, some nodes should be equipped by sensor (for example looking forward sonar). Payload information must be provider to C2. This step is fundamental for a final conceptual validation.

- “Real time” monitoring

In Norway, it was hard for a C2 operator to understand what is happening to Folaga. Folaga position and status were updated at a very low rate (Folaga is “jumping” on the human computer interface). It’s difficult to understand if a command is received because the delayed is too high. If messages to or from C2 are lost, C2 C2 must be informed. In same case, operator saw that Folaga is moving in the IP camera before acknowledge was received. This causes a lack in the surveillance capabilities of the system.

- “Surface information”

Surface data can be used to increase robustness of underwater information. For example, a surface wireless network can be used to know Folaga position before and after the immersion.

- Electro-optical

One lesson learned in the experiment is the importance of electro-optical (EO) system. The IP camera has been used to monitor the area but even to show logistic and operational activities as a conceptual validation. Surface protection EO can be used to support the unmanned deployment.

- In-service time

It should be investigated how extend system in-service time reducing time need for maintenance activities (for example load and upload unmanned vehicle or charge batteries).

Overall concept has been validated during the final test. Interested topics related to Command and control can be:

- Use unmanned vehicle with sensor payload to investigate on a possible threat or for surveillance task without the risk to lose system connectivity. It’s interesting to understand how a mission task, proposed to the underwater network by C2, can be accepted and performed or refused. The concept to evaluate is the “designation risk” (how can be balanced the importance to fulfill a mission and the risk to lose connectivity?).
- Assigned a mission to the underwater network unmanned node can change their position and depth in order to permit to a vehicle with payload to reach the designated point.