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Internet of Things (IoT) – Underwater acoustic sensor network (UWASN) – Application profiles

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The text of this International Standard is based on the following documents:

FDIS	Report on voting
JTC1-SC41/150/FDIS	JTC1-SC41/161/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

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INTRODUCTION

Water covers approximately 70 % of the surface of the Earth. Modern technologies introduce new methods to monitor the body of water such as pollution monitoring and detection. Underwater data gathering techniques require exploring the water environment, which can be most effectively performed by underwater acoustic sensor networks (UWASNs). Applications developed for the UWASNs can record underwater climate, detect and control water pollution, monitor marine biology, discover natural resources, detect pipeline leakages, monitor and find underwater intruders, perform strategic surveillance, and so on.

In order to build and apply the UWASN technology, the most suitable methods for managing the network have been developed based on the already proposed ISO/IEC 30140 series. This document describes the application profiles outline and requirements appropriate to the UWASN under the constraints of underwater physical environment.

The ISO/IEC 30140 series provides general requirements, reference architecture (RA) including the entity models and high-level interface guidelines supporting interoperability among UWASNs in order to provide the essential UWASN construction information to help and guide architects, developers and implementers of UWASNs.

This document provides the guidelines for designing and developing the UWASN application. It also provides other information such as the components required for developing UWASN application, modelling techniques for UWASN application and UWASN application profiles example.

Various technical standards derived from the R&D results of the technical areas under the UWASN and underwater communication fields not covered by the ISO/IEC 30140 series are continuously proposed and developed.

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INTERNET OF THINGS (IoT) – UNDERWATER ACOUSTIC SENSOR NETWORK (UWASN) – APPLICATION PROFILES

1 Scope

This document provides the guidelines for designing and developing new applications in the underwater environment such as fish farming, environment monitoring, harbour security, etc. This document also:

- provides the components required for developing the application;
- provides instructions for modelling the application with examples;
- helps the user to understand the communication between the elements in the application for modelling the communication between elements;
- guides the user with the design process of underwater applications.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
application profile
set of documents which provides the effective guidance to develop a particular application

3.2
component
representation of an actor in a UWASN application profile

3.3
element
<of use case model> object used to connect the devices and networks in the underwater environment

EXAMPLE actors, use cases, relationships

3.4
element
<of sequence diagram model> essential part used to connect the devices and networks in the underwater environment

EXAMPLE class, execution place, lifeline

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3.5
element
<of class diagram model> class, object or method used for the communication between the devices and networks in the underwater environment

4 Abbreviated terms

RF	radio frequency
UUV	unmanned underwater vehicle
UWASN	underwater acoustic sensor network
UWA-GW	underwater acoustic gateway
UWA-SNode	underwater acoustic sensor node
UWA-CH	underwater acoustic cluster head
UWA-CH-id	underwater acoustic cluster head identity
UWA-SNode-id	underwater acoustic sensor node identity
UWA-DTN-GW	underwater DTN gateway
UWA-FN	underwater acoustic fundamental network

5 Overview of UWASN application profiles

5.1 Introduction to application profiles

In UWASN, the application profiles comprise of a group of components, approaches and guidelines for a specific application.

5.2 Benefits of application profiles

An application profile is a layout or outline for users. Application profiles can help users as suggested below:

– utilizing them to depict how applications are deployed, arranged and managed in submerged conditions;
– providing required components for building up new UWASN applications effectively;
– providing the basic information for planning;
– reducing the learning curve;
– standardizing the development work; and
– providing the general requirements and functional requirements for developing the application.

6 Design process of UWASN application profiles

6.1 General

The primary goal of the design process is to give guidance for developing underwater applications (See Annex A). The design process of UWASN application profiles provides the following information:

– purpose of UWASN application;
– overview of UWASN application;
– user requirements for the design process of UWASN application;
– general requirements for the design process of UWASN application;

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– functional requirements for the design process UWASN application;
– constrained requirements for the design process of UWASN application;
– consideration for the design process of UWASN application.

6.2 Criteria for the design process of UWASN application profiles

The criteria considered for the design process of the UWASN application profiles include but are not limited to the following:

– limitation in bandwidth;
– localization;
– limited battery power;
– deployment of devices;
– reliability;
– scalability;
– quality of service;
– distance of transmission;
– propagation delay;
– device configuration;
– device maintenance;
– self-management.

6.3 Design process steps for UWASN application profiles

Table 1 shows the steps for the design process of UWASN application profiles.

Table 1 – Steps for the design process of UWASN application profiles

Design process steps	Description
Step 1: User requirements analysis	The user requirements for a particular UWASN application are collected.
Step 2: General requirements analysis	The general requirements for particular UWASN application are collected.
Step 3: Functional requirements analysis	The functional requirements for a particular UWASN application are collected.
Step 4: Constrained requirements analysis	The constrained requirements for a particular UWASN application are collected.
Step 5: Design process	The design process of UWASN application profile needs the modelling techniques for designing the application such as case modelling, sequence diagram modelling and class diagram modelling.
Step 6: Implementation guideline process	The implementation process consists of installation, deployment, configuration, performing operation and testing.
Step 7: Specialized maintenance	The specialized maintenance for underwater applications is considered. For example, node reclamation (change battery/recharging), fouling cleaner, housing case, etc.

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7 Requirements for the design process of UWASN application profiles

7.1 General

Clause 7 discusses the various requirements such as user requirements, general requirements, functional requirements and constrained requirements for the design process of UWASN application profiles (See Annex A).

7.2 User requirements of UWASN application profiles

Table 2 shows the user requirements for UWASN application profiles.

Table 2 – User requirements of UWASN application profiles

User requirements	Description
Durability	Durability refers to the time period for which a product or system can meet its service and performance requirements.
System performance	System performance refers to the effectiveness of a system, which includes response time, throughput, latency, availability, etc.
Low cost	Low cost includes the total cost of the system, which includes the cost of procurement, installation, usage and disposal.
Efficiency	Efficiency of a system can be identified using various factors such as response time, number of tasks completed in a stipulated time, etc.
Adaptability	Adaptability refers to the extent to which a system adapts to the change in its working environment.
Reliability	Reliability refers to the hardware or software or other application related items; its performance is consistently monitored by the users. It can be considered while buying or using the product.
Usability	Usability can be defined as the ease of use with respect to the system. This includes measures such as learnability, efficiency, memorability, etc.
Availability	Availability refers to the percentage of time that the system is available and working according to the requirements.
Maintainability	Maintainability refers to the ability to make variations in the system quickly and cost effectively.
Security	Security refers to the ability of the system (1) to resist unauthorized usage and (2) to continue providing services to the legitimate users in case of attacks.
Portability	Portability can be defined as the ability of a system to run under different computing environments such as hardware, software, operating systems, etc.
Reusability	Reusability refers to the ability of a system to make reuse of existing components in new applications.

7.3 General requirements of UWASN application profiles

Table 3 shows the general requirements for UWASN application profiles.

Table 3 – General requirements for UWASN application profiles

General requirements	Description
Capability of discovery	The UWA-SNode shall use discovery capability mechanism to identify other nodes connected inside the UWASN system.
Connectivity support to different network	Integration shall be supported by different networks for avoiding complexity.
Routing techniques	The best routing algorithm is performed by the device known as router, used for passing the message from source to destination. This technique can also reduce the cost in UWASN.
Security	A standard security system shall be used to prevent attacks from illegal users.
Service quality	Service quality refers to a network capability to attain maximum bandwidth and deals with the various performance elements of network, which include latency, error rate, etc.
Scalability	If the number of devices increases, the UWASN system shall use the scalability support.
Dynamic adaptation	Due to the mobility of UUV and UWA-SNode, the UWASN shall use dynamic adaptation techniques.

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General requirements	Description
Deployment	Easy deployment techniques shall be used for the deployment of UWA-SNodes in the underwater environment.
Battery life time management	In UWASN, the battery life time management shall be used to increase the battery life time of underwater devices.
Localization	Localization techniques shall be used to find the location of UWA-SNodes, UUVs, etc.
Time synchronization	Time synchronization shall be used to synchronize the time of all sensor nodes used in UWASN.
Network management	Network management shall be used to manage the whole applications such as fish farming, environment monitoring, etc.
Wired/wireless communication	Wired or wireless communication shall be established based on the requirements.
Privacy	Any information cannot be provided for all. So, this function shall be used for maintaining privacy.
Packet loss reducing	Various techniques shall be used to minimize the packet loss in UWASN.

7.4 Functional requirements of UWASN application profiles

Table 4 shows the functional requirements for UWASN application profiles.

Table 4 – Functional requirements for UWASN application profiles

Functional requirements	Description
Data processing	Data processing is used for performing the operations such as classifying, retrieving, transforming, etc.
Device management	Device management is used for the management of components such as UWA-SNode, UWA-GW, etc.
Data acquisition	The data acquisition function is used for measuring the physical characteristics of water such as temperature, dissolved oxygen, pH value, etc.
Validation process	The validation process is used for application quality management, such as whether the application meets its requirements or services.
Integration	This is used to integrate different components to perform the required functions.
Data communication	Communication module and efficient protocols are required for long-range and short-range communication.
Data storage	The amount and type of data stored in UWA-SNode, UWA-CH, etc.
Identification	The UWA-SNode needs a unique identifiable address.
Self-localization	The UWA-SNode, UWA-CH and UUV needs the ability to identify their location.
Data security	In UWASN the functions like key distribution, data integrity and authentication are used to increase the security level.
Key distribution	The shared key mechanism can be used between the nodes such as UUV, UWA-SNode, UWA-CH, etc. to increase the reliability of communication.
Integrity	The integrity mechanism is used to increase the confidentiality while sending and receiving data.
Authentication	The authentication mechanism is used to ensure whether the messages are generated from the authenticated user or not.
Network recovery	The network recovery functions are used to reconnect the network when the connection is broken.
Device recovery	The devices such as UWA-SNodes, UUVs, etc. consist of all the information related to environment. If some failures occur in the device, the device recovery function shall be used.
Battery capacity	To identify the maximum amount of power availability in underwater devices such as UWA-SNodes, UUVs, etc. the battery capacity function is needed.

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The functional requirements are used to indicate the function performed by each component in the UWASN system.

– The UWA-Application Layer: This layer is used to exchange information in the application process. The main functionality of this application is to exchange data.
– The UWA-Bundle Layer: This layer is used to carry the group of information between the layers such as application and network layer. The store and forward concepts are used for transmitting the packets.
– The UWA-Network Layer: The main functionality of this layer is routing. The operations performed by this layer are packet generation, underwater device communication, address management, etc.
– The UWA-Data link Layer: The main functionality of this layer is controlling the UWA-Physical Layer. This layer has the responsibility to check and correct the errors that occur in the UWA-Physical Layer or devices.
– The UWA-Physical Layer: This layer is used to establish and maintain the connection between the physical devices in underwater environments.

7.5 Constrained requirements of UWASN application profiles

7.5.1 General

Table 5 shows the constrained requirements for UWASN application profiles.

Table 5 – Constrained requirements for UWASN application profiles

Constrained requirements	Physical entities															
	Underwater														Surface	
	UWA-CH	UWA-GW	UUVs	UWA-SNode	Acoustic communication	Relay node	Battery	Housing case	Fouling cleaner	UWA-DTN-GW	Ad-hoc network	Moving gateway	Communication module	Acoustic modem	Access network	Backbone network
Deployment																
Network scale																
Wired/wireless communication																
Service quality																
Discovery ability																
Localization																
Time synchronization																
Network management																
Privacy																
Routing																

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Constrained requirements	Physical entities														
	Underwater													Surface	
	UWA-CH	UWA-GW	UUVs	UWA-SNode	Acoustic communication	Relay node	Battery	Housing case	Fouling cleaner	UWA-DTN-GW	Ad-hoc network	Moving gateway	Communication module	Acoustic modem	Access network	Backbone network
Battery life management																
Routing management																
Device management																
Data communication																
Maintenance																
Connectivity																

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7.5.2 Connectivity

The connectivity of UWASN application should be described. Details of UWASN interoperability between different physical entities can be found in ISO/IEC 30140-4.

7.5.3 UWA-GW

– Role of moving UWA-GW: The moving UWA-GW shall be used to collect different data from different UWA-FN and transfer the data to a base station. This can connect different networks from underwater network to terrestrial network by moving from one place to another. For example, a ship can act as the moving UWA-GW.

– Role of fixed UWA-GW: The fixed UWA-GW shall be used to connect the terrestrial network with the underwater network. This can collect the data from a single UWA-FN.

7.5.4 UWA-DTN-GW

The UWA-DTN-GW shall be used to support the interoperability of local networks by considering long delays and by interpreting between regional systems.

7.5.5 Housing case

Waterproof housing shall be used in applications such as fish farming, environmental monitoring, harbour security, etc. to protect the devices from corrosion and failure caused by water.

7.5.6 Fouling cleaner

Fouling cleaner shall be used in applications such as fish farming, environmental monitoring, harbour security, etc. to clean mussels, weeds, and barnacles from the UWA-SNode periodically.

7.5.7 Node deployment

Node deployment shall be used for the placement of devices such as UUVs, UWA-CH, UWA-SNode, etc.

7.5.8 Battery

Batteries are required for the management of power in underwater devices such as UUVs, UWA-CH, UWA-SNode, etc.

8 Modelling techniques for designing UWASN application profiles

8.1 General

Modelling is an approach used for designing the application. Modelling is the main phase of the application development, which should be performed before the development of application. In UWASN, modelling is specialized because of constrained environmental conditions. The modelling technique applied to develop the UWASN applications is the Unified Modelling Language (UML). The UML based modelling techniques can be used for modelling the UWASN applications such as environmental monitoring, fish farming, etc.

8.2 Use case model

8.2.1 General

The main purposes of the use case model are to view interactions between the elements in a UWASN system and to show the objectives achieved by those interactions.

8.2.2 Elements of use case diagram

– Actors: In UWASN, the actors are the things that interact with the system, such as devices, users, and other entities within the system. Examples of actors in UWASN are listed below (see also Figure 1):

- base station;
- network manager;
- UUV;
- UWA-GW.

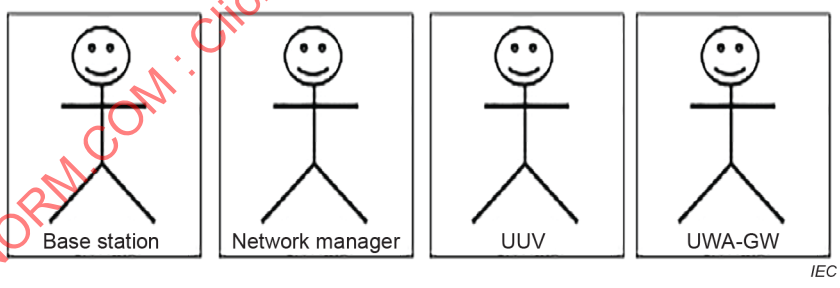

Figure 1 – Actor representation examples

– Use cases: In UWASN, the use cases are the actions performed by the actors inside the system. Examples of use cases in UWASN are listed below (see also Figure 2):

- monitoring;
- maintenance;
- sensing information;
- validating information.

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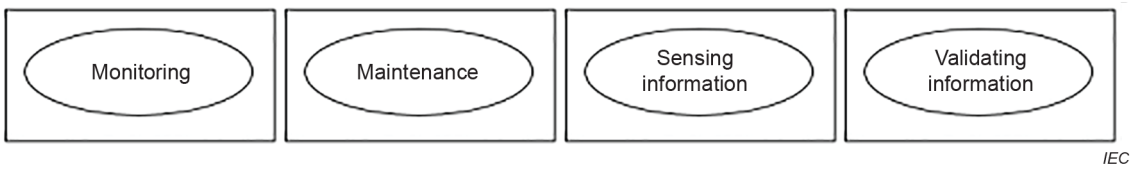


Figure 2 – Use case representation examples

– System boundary: This is the boundary line used for the separation of actors and use cases. The system boundary for UWASN is represented using the symbol in Figure 3.

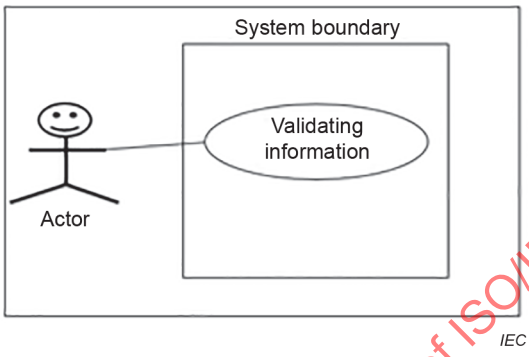


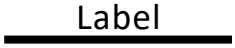
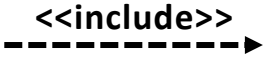
Figure 3 – System boundary representation example

8.2.3 Relationships

– Generalization: For representing the link between actors.
– Association: For representing the link between actor and use cases.
– Include: For breaking use cases into sub use cases.
– Extend: For showing the detailed execution of base use cases.

Relationship and symbols of use case diagram are shown in Table 6.

Table 6 – Relationship and symbols of use case diagram

Relationship	Symbol
Generalization	
Association	
Include	
Extend	

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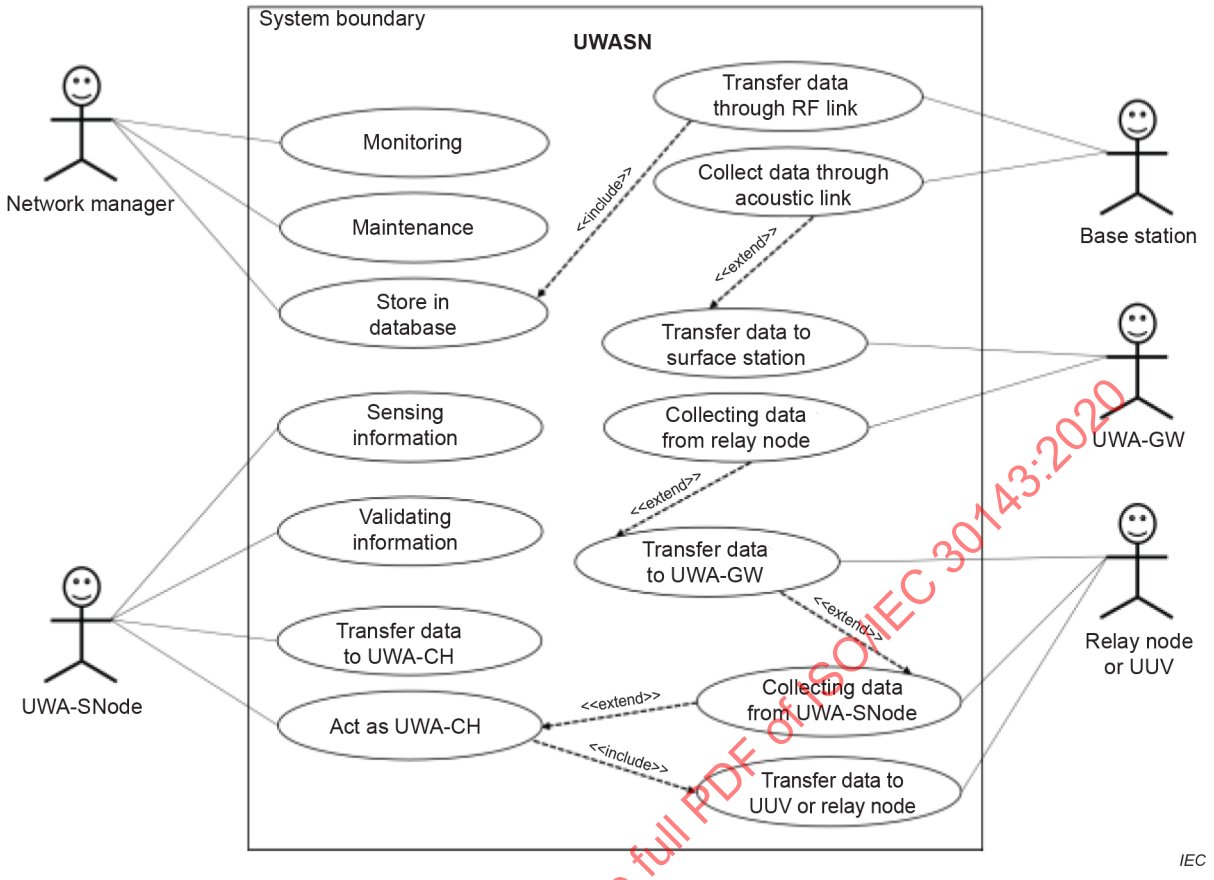

Figure 4 – Use case model for UWASN application profiles

Figure 4 shows the actors, use cases, system boundary and relationships of UWASN application profiles. The components like surface station, UWA-SNode, UWA-GW, network manager and UUV are represented as actors. The actions performed by each of the actors are represented as use cases. For example, the actions like sensing information, validating, transferring data to UWA-CH are performed by UWA-SNodes. The relationships like association, includes and extends are used for building the connection between actors and use cases, and also between the use cases.

8.3 Sequence diagram model

8.3.1 General

In UWASN, the sequence diagram model is used by the application developers to model the communication between the elements. It shows how the interaction works between the elements in UWASN and also how the objects interact with other objects.

8.3.2 Elements of sequence diagram

1) Class: In sequence diagram, class describes the role of objects inside UWASN. The object is represented using the symbol given in Figure 5.

Figure 5 – Object symbol in a sequence diagram

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2) Execution place (Execution box): In sequence diagram, the execution place shows that the object is busy with another process. The execution box is represented with the symbol given in Figure 6.

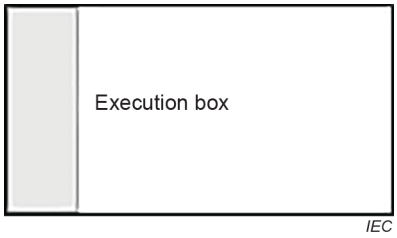

Figure 6 – Execution box symbol in a sequence diagram

3) Lifelines: In sequence diagram, the lifelines are represented using vertical lines with dashes (see Figure 7) which are used to indicate the presence of an object in the system.

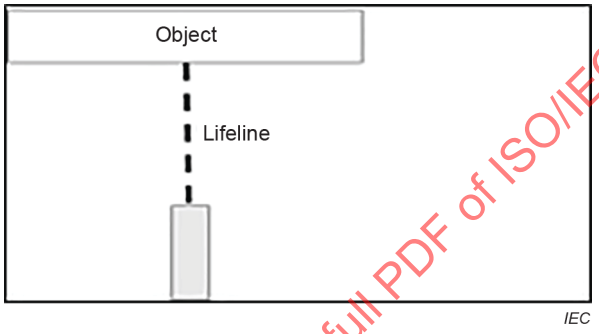

Figure 7 – Lifeline representation in a sequence diagram

4) Messages: In sequence diagram, the messages are used for the interaction between the objects. The messages are represented using the arrow symbols shown in Figure 8.

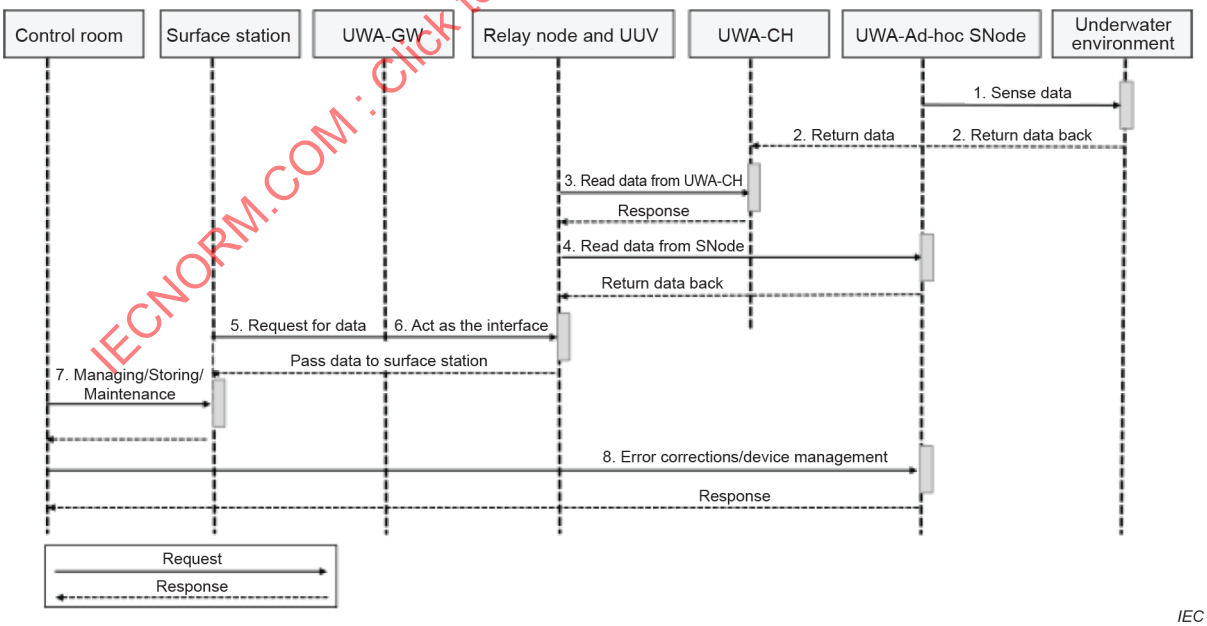

Figure 8 – Sequence diagram modelling for UWASN application profiles

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Figure 8 shows the sequence flow of messages between each object in the UWASN system. The above sequence diagram consists of objects and message flows between the objects. In the diagram, control room, surface station, UWA-GW and UUV, etc. are represented as objects. Request for data, response, error correction, etc. are represented as the "message flows" between the objects.

8.4 Class diagram model

8.4.1 General

In UWASN, the class diagram is used by the application developer to show the whole structure of the UWASN system. It describes the attributes and the operations of each class in the system and the relationship between them. The class diagram visually indicates the needs of the application.

8.4.2 Elements of class diagram

1) Class name: This is the upper section of class diagram (see Figure 9), which represents the name of the class.
2) Attributes: This is the middle section of class diagram (see Figure 9). The attributes are considered as the properties of class.
3) Methods: This is the lower section of class diagram (see Figure 9), which describes the operation or actions of the class.

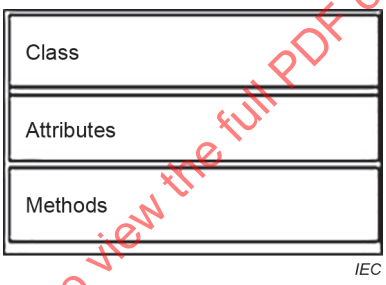

Figure 9 – Representation of different sections in class diagram

4) Relationships: The relationships are separated into four categories:
   - association;
   - generalization;
   - realization;
   - dependency.

Figure 10 illustrates class diagram modelling for UWASN application profiles.

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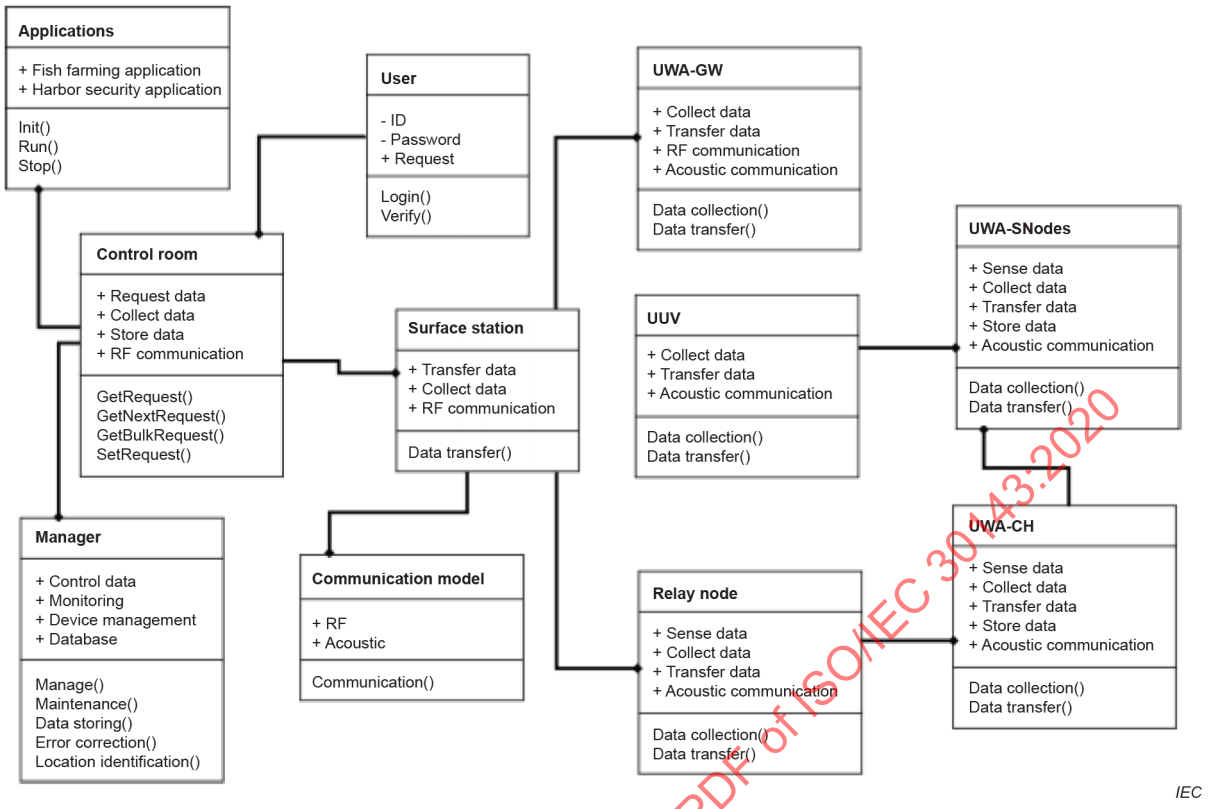

Figure 10 – Class diagram modelling for UWASN application profiles

9 Guidelines for the implementation of UWASN application profiles

9.1 Layered design approach for developing UWASN application profiles

The layered design technique, illustrated in Figure 11, is a combination of layers from the UWA-Physical Layer to the UWA-Business Layer. This technique is used to control the connection between each layer.

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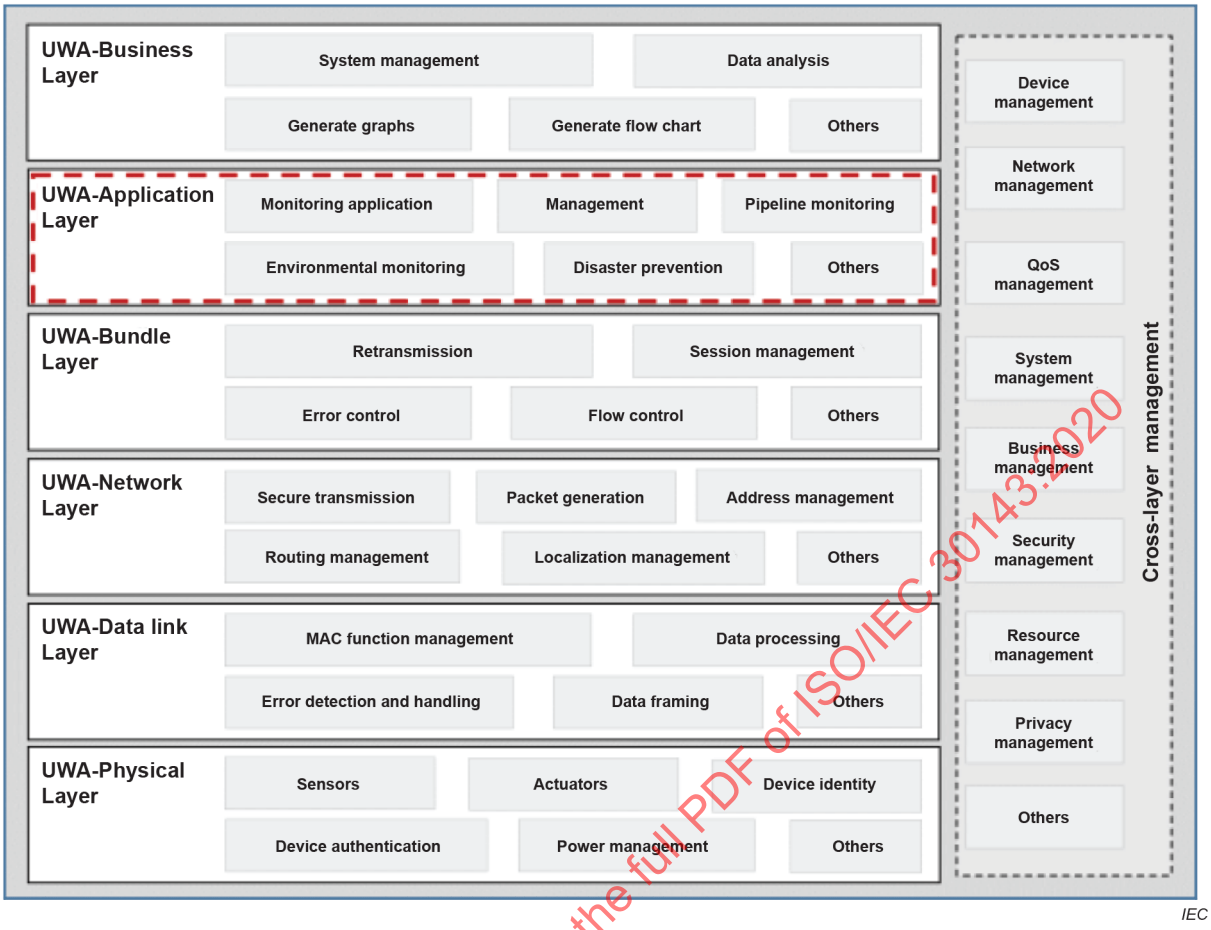

Figure 11 – Layer design approach

9.2 Specific architecture for implementing UWASN application profiles

The UWASN specific architecture helps the user to plan, design, deploy and implement new applications. For designing the architecture of UWASN application, the user follows the application structure as shown in Figure 12.

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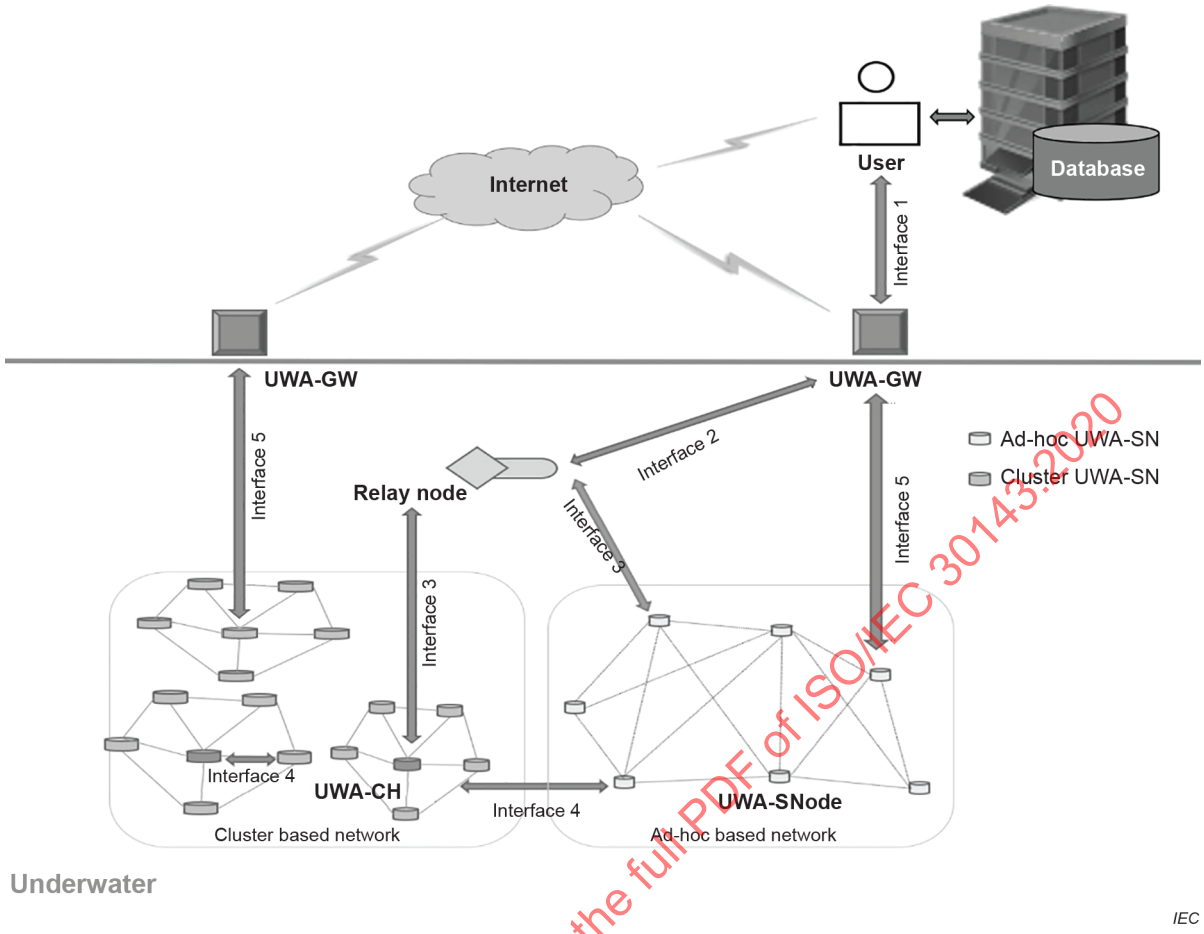

Figure 12 – UWASN specific architectural model

– General description of architecture: A reference architecture with high-level description of UWASN application is required. Configuration of UWASN reference architecture with systems reference architecture, communication reference architecture, and information reference architectures are presented in ISO/IEC 30140-2.

– Physical entities: A brief description of physical entities of UWASN application shall be given. Details of UWASN domain physical entities, network domain physical entities, and application domain physical entities are given in ISO/IEC 30140-3.

– Functional entities: The functional entities of UWASN application should be described. Details of UWASN functional entities of different layers including cross-layer entities can be found in ISO/IEC 30140-3.

– Interfaces: The interfaces of UWASN application should be described. Details of UWASN interfaces between different physical entities and between different functional entities can be found in ISO/IEC 30140-3.

9.3 Framework for implementing UWASN application profiles

9.3.1 User interface

The user interfaces are used to import all the needed objects and variables for the application by the user. Through the user interface, the underwater view for a particular application can be monitored. The UWA-SNode settings, UWA-SNodes location settings, start, stop and data storage can be done through this interface.

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9.3.2 System calculation unit

The system calculation unit consists of three modules: UWA-Nodes operation, UWA-GWs operation and communication module. The UWA-Nodes defines the functions of underwater nodes such as UWA-CH, UWA-SNode, UUV, etc. UWA-GW defines the functions of underwater gateway and the communication module shows the RF link and acoustic link between the devices in UWASN.

9.3.3 Surface devices

The function of this module is to access data from UWA-SNodes, UUVs, etc. via acoustic communication and transmit those data from UWA-GWs to a base station with the help of RF communication.

9.3.4 Sensor node

The along with protocols for communication between UWA-SNodes and gateway. It performs the operations such as sensing, data collection, data transmission, etc. The sensor unit consists of the following fields.

– UWA-SNode-id: The UWA-SNode-id is the unique value used by the sensor node.

– UWA-CH-id: When UWA-FN is formed, then UWA-CH's value is considered as UWA-CH-id.

– Battery level: sensor unit performs the functions of nodes such as UWA-CH, UUVs, UWA-SNodes, etc. The sensor unit uses an algorithm showing the initial level of battery.

– Energy level: The remaining energy is calculated here.

– Message-id: This is the sequence number for each message.

Figure 13 shows the framework of UWASN application profiles. The UWASN application has specific functions to perform different operations. The application is run to make the configuration between the devices such as UWA-SNode, UWA-GW, UWA-CH, etc. The process like node settings, node movement, node communication, etc. is done through user interface. The system calculation unit will make the underwater devices work according to user requests through the user interfaces.

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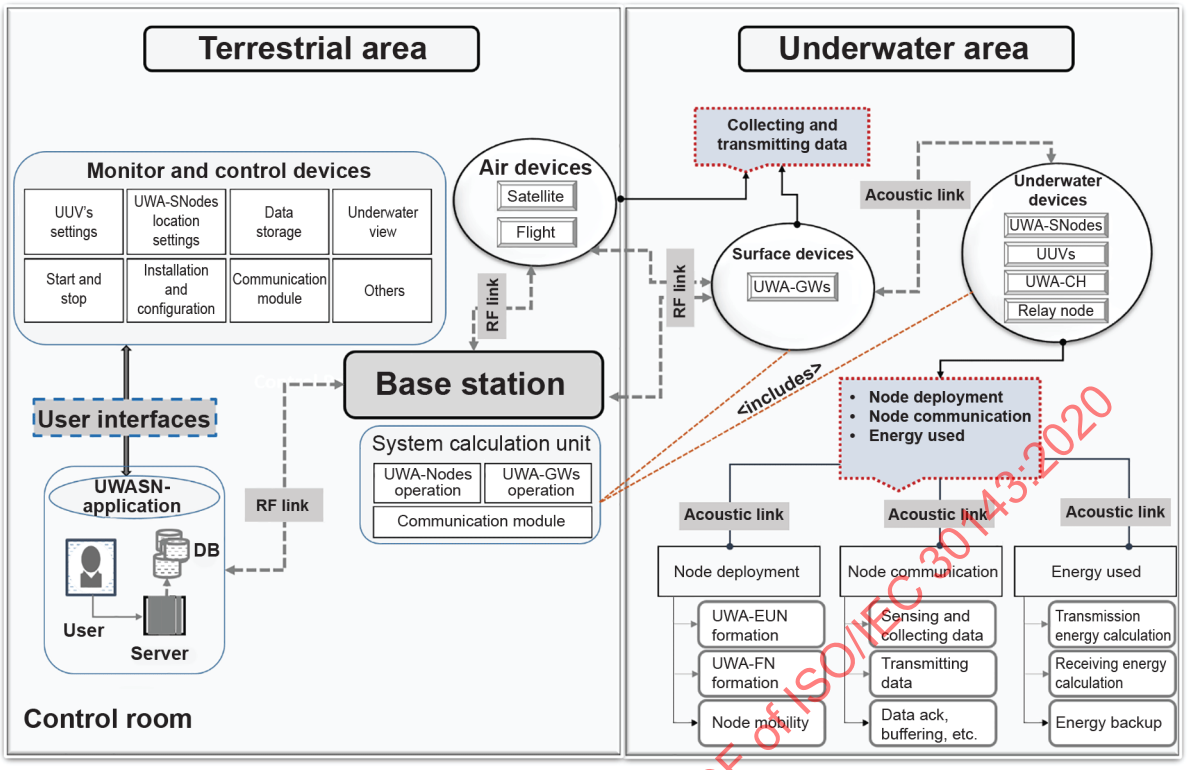

Figure 13 – Framework of UWASN application profiles

Table 7 shows the components for implementing UWASN application profiles.

Table 7 – Components for implementing UWASN application profiles

Components	Function
Server	Server is the central repository which can provide access to the various resources in underwater communication.
Control room	In control room, all the events are controlled and managed.
User	The user can select the operation to monitor and control the devices.
UWA-GW	The UWA-GW is used to collect the data from sensing devices and transfer those data to the control room.
Sensing device	The sensing device is used to collect the information such as temperature, pressure, salinity, etc. For example, UWA-SNodes, UWA-CHs, UUVs, etc.

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9.4 Functional operations for implementing UWASN application profiles

Figure 14 shows the functional operation for implementing UWASN application profiles.

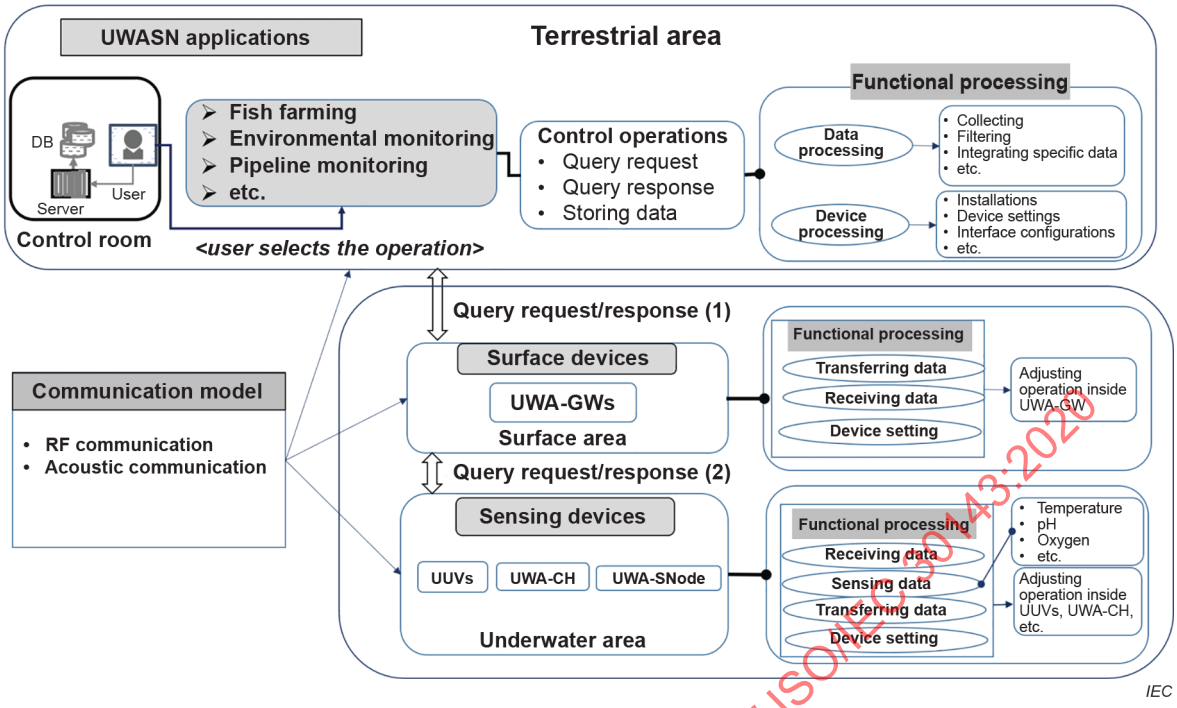

Figure 14 – Operation design approach

Table 8 shows the operation process for implementing UWASN application profiles.

Table 8 – Operation process of UWASN application profiles

Operation process	Functions
Query request/response	This operation process refers to the request sent by the user and the response collected through UWA-GWs.
Data processing	Data processing defined as the collection of operations such as data collection, filtering, integrating specific data, etc.
Device processing	Device processing refers to the operation performed for each device in underwater such as installations, device settings, interface configuration, etc.
Sensing, collecting and sending	The sensing devices are used for sensing, collecting and sending data to the UWA-GW.
Transferring/receiving data	The UWA-GWs are used for receiving and transferring the data to control room.
Communication model	RF communication is used in the terrestrial area and acoustic communication is used in the underwater environment.

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10 Specialized maintenance for UWASN application profiles

Table 9 shows the key factors used for monitoring the condition of devices and networks in UWASN application.

Table 9 – Key factors for monitoring UWASN application profiles

Components	Functions
Device monitoring	The device monitoring can monitor the device functions such as device status monitoring, battery status monitoring, self-handling, etc.
Network monitoring	The network monitoring can monitor the network functions such as network status, error handling, connectivity, etc.

In UWASN application, device maintenance is the next step after the monitoring process.

Table 10 shows the components used for the maintenance of UWASN application profiles.

Table 10 – Components used for the maintenance of UWASN application profiles

Components	Description
Housing case	In UWASN, waterproof housing case shall be used for protecting UWA-SNodes from corrosion and failure.
Fouling cleaner	Fouling cleaner shall be used to clean the marine wildlife, for example algae, weeds, zebra mussels, and barnacles, attached to underwater devices.
Battery replacement	The battery replacement techniques shall be used for the reuse of nodes in underwater. The technology such as node pickup and replacement are used in UWASN.
Battery recharging	The battery is limited for UWA-SNodes in underwater. In this case the battery recharging technology should be needed for the reuse of UWA-SNodes.
Others	All the hardware parts inside the system such as devices, networks, control room, UWA-GWs, UUVs, etc. should be maintained in UWASN.

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Annex A
(informative)

Application profile example

A.1 Fish farming

A.1.1 General

Clause A.1 explains fish farming (aqua farming) using UWASN, which is otherwise known as "water cultivation". The act of water cultivation is well used for the consumption of end users. To monitor the characteristics of water, the technology used is UWASN. The growth of aquaculture, along with the terrestrial farming, is also fast. Thus, it is necessary to monitor the growth of fish in underwater. The main properties monitored during fish farming are physical characteristics of water, level of water, chemical contents in water, electrical conductivity of water, etc.

The UWASN (the node) which is deployed under the water can also monitor the biological activities of the fish like count of the fish. Active and non-active fish are monitored using bio-sensors. Hence, the node can send the frequent set of data to the monitoring system (notification is frequently sent to the monitoring system via network).

A.1.2 Guidelines for designing UWASN fish farming application

A.1.2.1 General

The main purpose of this application is to monitor and protect fish from abnormal temperature, dissolved oxygen, pH level, etc. So, the UWASN is used here for the proper management of fish farming.

A.1.2.2 Overview

In this application, the sensor nodes are deployed underwater to collect the information such as pH, temperature, dissolved oxygen and pass that to the UUVs. From the UUVs, the information is transferred to UWA-DTN-GW using acoustic links. The UWA-DTN-GW transfers the information to a base station using RF link.

A.1.2.3 Considerations for designing UWASN fish farming application

The considerations for the design process of UWASN fish farming applications are as follows:

– limitation in bandwidth;
– localization;
– limited battery power;
– deployment of devices;
– reliability;
– scalability;
– quality of service;
– distance of transmission;
– propagation delay;
– device configuration;
– device maintenance.

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A.1.2.4 Steps for designing UWASN fish farming application

Table A.1 shows the steps for designing UWASN fish farming application.

Table A.1 – Steps for designing UWASN fish farming application

Steps	Description
Step 1: Fish farming user requirements analysis	The user requirements for UWASN fish farming application are collected.
Step 2: Fish farming general requirement analysis	The general requirements for UWASN fish farming application are collected.
Step 3: Fish farming function requirements analysis	The functional requirements for UWASN fish farming application are collected.
Step 4: Fish farming constrained requirements analysis	The constrained requirements for UWASN fish farming application are collected.
Step 5: Design process for fish farming application	The design processes of UWASN fish farming application need the modelling techniques, such as case modelling, sequence diagram modelling and class diagram modelling.
Step 6: Guidelines for the implementation process of fish farming application	The implementation process consists of installation, deployment, configuration, performing operation and testing.
Step 7: Specialized maintenance for fish farming application	The specialized maintenance for underwater applications is considered. For example, node reclamation (change battery/recharging), fouling cleaner, waterproof housing case, etc.

A.1.3 Requirements for the design process of UWASN fish farming application

A.1.3.1 User requirements of UWASN fish farming application

Table A.2 shows the user requirements of UWASN fish farming application.

Table A.2 – User requirements for the design process of UWASN fish farming application

User requirements	Description
Durability	Durability refers to the time period for which a product or system can meet its service and performance requirements.
System performance	This refers to the effectiveness of a system which includes response time, throughput, latency, availability, etc.
Low cost	This includes the total cost of the system, which includes the cost of procurement, installation, usage and disposal.
Efficiency	Efficiency of a system can be identified using various factors such as response time, number of tasks completed in a stipulated time, etc.
Adaptability	Adaptability refers to the extent to which a system adapts to the change in its working environment.
Reliability	This refers to the degree to which a system can perform its functions as required.
Usability	Usability can be defined as the ease of use with respect to the system. This includes measures such as learnability, efficiency, memorability, etc.
Availability	This refers to the percentage of time that the system is available and working according to the requirements.
Maintainability	Maintainability refers to the ability to make variations in the system quickly and cost effectively.
Security	This refers to the ability of the system (1) to resist unauthorized usage and (2) to continue providing services to the legitimate users in case of attacks.

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User requirements	Description
Portability	Portability can be defined as the ability of a system to run under different computing environments such as hardware, software, operating systems, etc.
Reusability	This refers to the ability of a system to make use of existing components in new applications.

A.1.3.2 General requirements of UWASN fish farming application

Table A.3 shows the general requirements of UWASN fish farming application.

Table A.3 – General requirements for the design process of UWASN fish farming application

Requirement	Description
Deployment	The underwater sensor node should be deployed underwater at different depth levels such as the surface, bottom and middle to sense the properties for fish farming.
Network scale	According to the difficulties faced in different environments such as sea, pond, tank, or lake, the approximate range and number of nodes needed should be decided.
Wired/wireless communication	Wired or wireless communication should be established based on fish farming requirements.
Service quality	The services provided between the systems need to be of good quality, so that the ability to pass the information between them is fast.
Discovery ability	The nodes inside this system should have the capability to find other nodes inside the system.
Localization	Localization techniques are optional in fish farming.
Time synchronization	Time synchronization is optional in fish farming.
Network management	The management of whole sensor networks in this system is considered.
Privacy	Some information can't be provided for all users. So, this application is programmed for maintaining data privacy.
Routing	To reduce the cost of the application, some routing algorithms are used in this UWASN application.
Battery life time management	Battery life time management should be maintained in fish farming.

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A.1.3.3 Functional requirements of UWASN fish farming application

Table A.4 shows the functional requirements of UWASN fish farming application.

Table A.4 – Functional requirements for the design process of UWASN fish farming application

Functional requirements	Description
Data processing	Data processing shall be used in fish farming application for performing the operations such as classifying, retrieving, transforming, etc.
Device management	Device management shall be used in fish farming application for the management of components such as UWA-SNode, UWA-GW, etc.
Data acquisition	The data acquisition shall be used in fish farming application for measuring the physical characteristics of water such as temperature, dissolved oxygen, pH value, etc.
Validation process	The validation process shall be used in fish farming application for application quality management, such as whether the application meets its requirements or services.
Integration	Integration shall be used in fish farming application to integrate different components to perform the required functions.
Data communication	Communication module shall be used in fish farming application for long-range communication and short-range communication. Efficient protocols are required for achieving the same.
Data storage	Data storage shall be used in fish farming application to identify the amount and type of data stored in UWA-SNode, UWA-CH, etc.
Identification	The UWA-SNode shall use a unique number for the identification purpose in fish farming application.
Self-localization	To identify the location of UWA-SNodes, UUVs, etc. in fish farming application, the self-localization mechanism shall be used.
Data security	Data security is optional in fish farming application.
Key distribution	The shared key mechanism can be used between the nodes such as UUV, UWA-SNode, UWA-CH, etc. to increase the reliability of data.
Integrity	The integrity mechanism is used to increase the confidentiality while sending and receiving data.
Authentication	The authentication mechanism is used to ensure whether the message is generated from the valid user or not.
Network recovery	The network recovery function is used to reconnect the network when the connection is broken.
Device recovery	The device such as UWA-SNode, UUV, etc. consists of all the information related to environment. If some failure occurs in the device, the device recovery function can be used.

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A.1.3.4 Constrained requirements of UWASN fish farming application

Table A.5 shows the constrained requirements for the design process of UWASN fish farming application.

Table A.5 – Constrained requirements for the design process of UWASN fish farming application

Constrained requirements	Physical entities															
	Underwater														Surface	
	UWA-CH	UWA-GW	UUVs	UWA-SN	Acoustic communication	Relay node	Battery	UWA-DTN-GW	Ad-hoc network	Moving gateway	Hosing case	Fouling cleaner	Communication module	Acoustic modem	Access network	Backbone network
Deployment			•			•		•		•						
Network scale									•				•		•	•
Wired/wireless communication	•				•				•				•		•	•
Service quality					•	•	•									
Discovery ability	•	•	•													
Localization		•														
Time synchronization	•	•	•					•								
Network management		•	•			•		•					•			•
Privacy	•	•				•		•								
Routing	•	•	•													
Battery life management				•		•										
Routing management		•	•													
Device management	•	•	•													
Data communication		•	•	•												
Maintenance											•	•				
Connectivity	•	•	•	•	•	•										

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A.1.4 Modelling techniques for designing UWASN fish farming application

A.1.4.1 General

In fish farming application, the modelling techniques are used for designing the application based on the methods such as use case and sequence modelling.

A.1.4.2 Use case model

The main aim of use case model is to view the interaction within the UWASN system and to show the goal achieved. Figure A.1 shows the use case modelling for fish farming application.

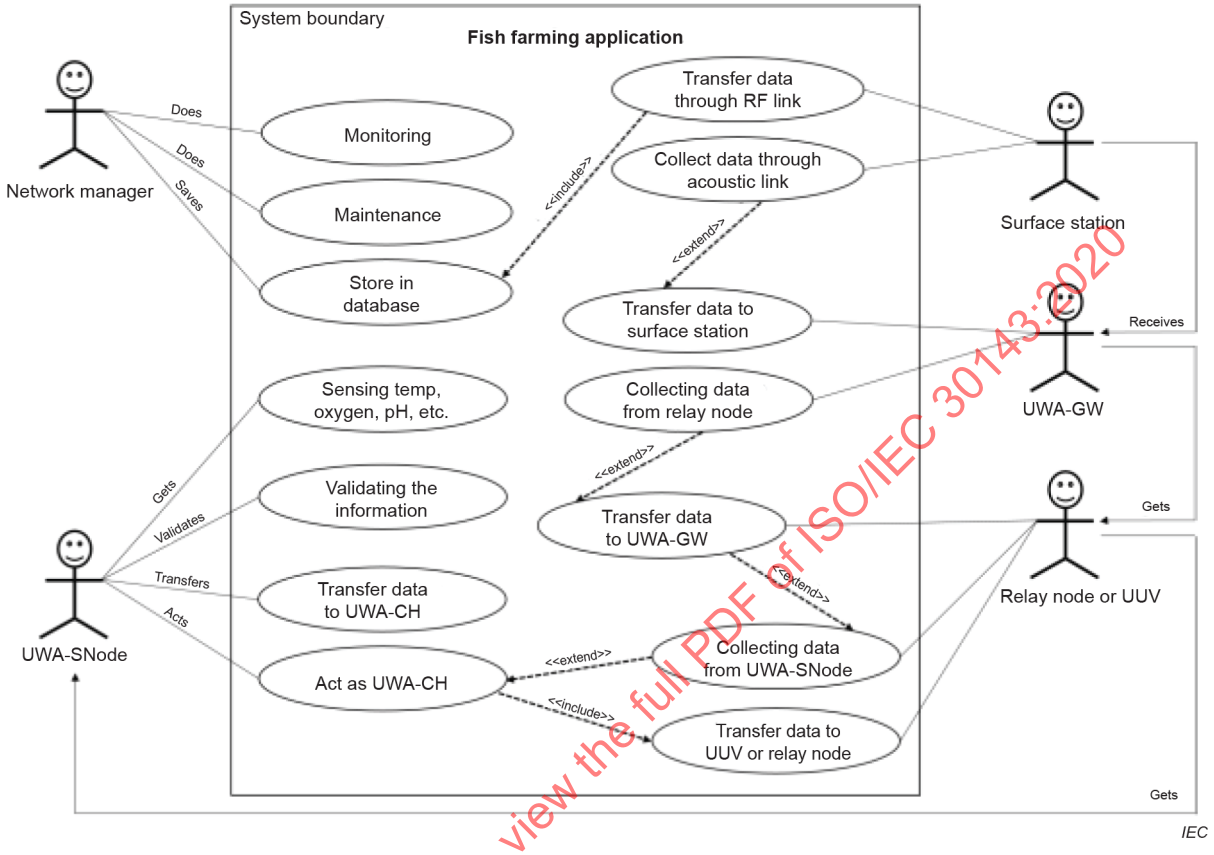

Figure A.1 – Use case model for fish farming application

A.1.4.3 Sequence diagram model

In fish farming application, the sequence diagram modelling is used to model the communication between the elements. Figure A.2 shows the sequence diagram modelling for fish farming application.

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