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Information technology – Underwater Acoustic Sensor Network (UWASN) – Part 4: Interoperability

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Information technology – Underwater Acoustic Sensor Network (UWASN) – Part 4: Interoperability

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Part 4: Interoperability

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This International Standard has been approved by vote of the member bodies, and the voting results may be obtained from the address given on the second title page.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

Water covers approximately 71 % of the surface of the Earth. Modern technologies introduce new methods to monitor the body of water, for example 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 locate underwater intruders, perform strategic surveillance, and so on.

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.

Additionally, the ISO/IEC 30140 series provides high-level functional models related to underwater sensor nodes and relationships among the nodes to construct architectural perspective of UWASNs. However, the ISO/IEC 30140 series is an application agnostic standard. Thus, the ISO/IEC 30140 series specifies neither any type of communication waveforms for use in UWASNs nor any underwater acoustic communication frequencies. Specifying communication waveforms and/or frequencies are the responsibility of architects, developers and implementers[1].

Acoustical data communication in sensor networks necessitates the introduction of acoustical signals that overlap biologically important frequency bands into the subject environment. These signals can conflict with regional, national, or international noise exposure regulations. Implementers of acoustical communication networks should consult the relevant regulatory agencies prior to designing and deployment of these systems to ensure compliance with regulations and avoid conflicts with the agencies.

The purpose of the ISO/IEC 30140 series is to provide general requirements, guidance and facilitation in order for the users of the ISO/IEC 30140 series to design and develop the target UWASNs for their applications and services.

The ISO/IEC 30140 series comprises four parts as shown below.

- Part 1 provides a general overview and requirements of the UWASN reference architecture.
- Part 2 provides reference architecture models for UWASN.
- Part 3 provides descriptions for the entities and interfaces of the UWASN reference architecture.
- Part 4 provides information on interoperability requirements among the entities within a UWASN and among various UWASNs.

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1 Architects, developers, and implementers need to be aware of the submarine emergency frequency band, near and below 12 kHz, and it is recommended to provide a provision for such submarine emergency band in their UWASN design and applications.

INFORMATION TECHNOLOGY – UNDERWATER ACOUSTIC SENSOR NETWORK (UWASN) –

Part 4: Interoperability

1 Scope

This part of ISO/IEC 30140 specifies interoperability between the selected physical entities of UWASN.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 29182-2, *Information technology – Sensor networks: Sensor Network Reference Architecture (SNRA) – Part 2: Vocabulary and terminology*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 29182-2 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

4 Abbreviated terms

ad-hoc UWA-SNode	ad-hoc underwater acoustic sensor node
CTI-AP	communication technology interoperability architecture point of view
CTI-SP	communication technology interoperability architecture from service point of view
UWA-APS	underwater application layer
UWA-BUN	underwater bundle layer
UWA-DL	underwater datalink layer
UWA-EUN	underwater acoustic extend united network
UWA-FN	underwater acoustic fundamental network
UWA-GW	underwater acoustic gateway
UWA-NWK	underwater network layer
UWA-PHY	underwater physical layer
UWA-SNode	underwater acoustic sensor node
UWASN	underwater acoustic sensor network
UWA-UN	underwater acoustic united network

5 Interoperability in UWASN

5.1 Overview

5.1.1 Interoperability definition

Interoperability refers to the ability of two or more components, applications, devices, systems, or networks to exchange information.

5.1.2 Achieving interoperability

Interoperability can be achieved using a gateway between networks for protocol translation, by having standard interfaces, or by defining common protocols between networks.

5.1.3 The need for interoperability

End-to-end connectivity is required to achieve interoperability. To maintain end-to-end communication, heterogeneous networks can interoperate with the help of a gateway.

UWASN interoperability allows underwater data to be transferred between heterogeneous networks effectively.

UWASN interoperability is typically related to the following.

- Software or hardware platforms, components, and systems enable device-to-device communication. Typically, these types of interoperability focus on communication protocols and infrastructure.
- Data formats should have well-defined syntax and encoding to transfer messages using communication protocols.
- For interoperability at the content level, the meaning of exchanged information has to be understood by both elements.

Interoperability can be achieved by a standard development process that promotes open architectures and standardization of interfaces between UWASN service frameworks.

The ability to read and process information and exchange data between heterogeneous networks is mandatory for interoperability, as shown in Figure 1. Defining standardized interfaces for the UWASN is the most efficient way to make sensor networks interoperable.

Standardized interfaces should include the following:

1) standardized data format, type, name, definition and data processing rules;
2) standardized communication interfaces between UWASN service framework entities.

5.1.4 UWASN interoperability

UWASN is a system of spatially distributed underwater acoustic sensor nodes that interact acquire, process, and provide information about the underwater environment and optionally react to such information.

There are numerous different UWASN applications such as environmental monitoring, assisted navigation, disaster prevention, and tactical surveillance. Depending on the domain, significant differences exist in the service requirements, service types, processing functions, interfaces, operational attributes, and data formats. These differences influence the interoperability of UWASNs.

Due to these differences, a UWASN can be classified as either homogeneous or heterogeneous.

The differentiation of homogeneous and heterogeneous UWASNs can be viewed from underwater sensor type and communication protocol perspective. From the sensor type perspective, homogeneous sensor networks can be classified as having the same type or functionally identical UWA-SNodes. Heterogeneous UWASNs can be classified as having different types of UWA-SNodes or functionally different UWA-SNodes. From the communication protocol perspective, homogeneous UWASNs can be classified as having the same or interoperable protocols, whereas heterogeneous UWASNs can be classified as having different or not interoperable protocols. In this document, the communication protocol perspective is used to differentiate the types of UWASNs.

From the communication protocol perspective, homogeneous UWASNs are interoperable because they use the same communication protocol between the entities of their service domains. On the other hand, heterogeneous UWASNs cannot interoperate because they use different communication protocols.

Heterogeneity is a common feature of UWASN; however, this can cause various problems. UWASN applications can rely on different sub-networks in a heterogeneous UWASN.

Therefore, interoperability between heterogeneous UWASNs is a significant challenge in the UWASN reference architecture.

The flow of information from UWA-FN to users can be represented in a hierarchical architecture (Figure 1).

1) Interoperability 1: between the user and gateway (mandatory)
2) Interoperability 2: between gateway and underwater fundamental network (mandatory)
3) Interoperability 3: between underwater fundamental networks (optional)
4) Interoperability 4: between gateways (optional)

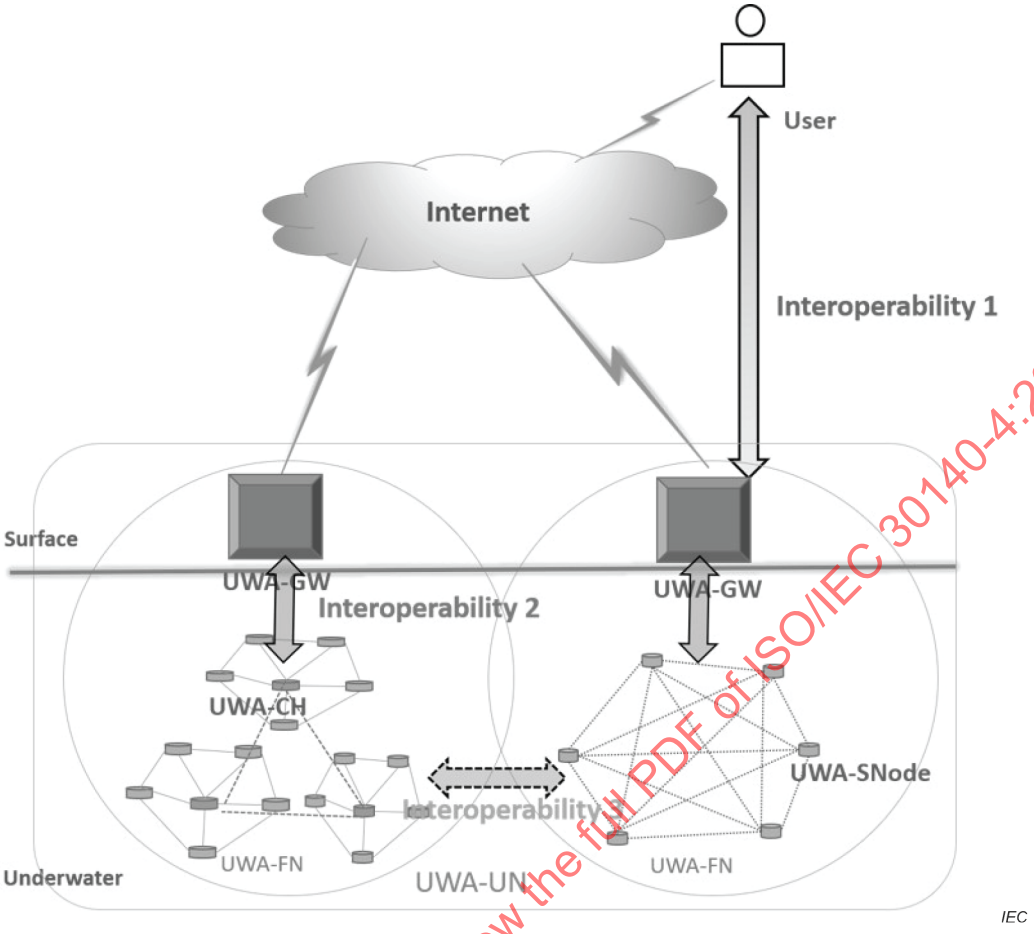

Figure 1 – Interoperability in UWASN

There are various communication protocols or interfaces for each entity. Interoperability implies an internetworking capability between entities in the UWASN framework. Figure 2 is a graphical representation of an interoperable UWASN framework. Here, the arrows represent interfaces that enable seamless interoperability between entities.

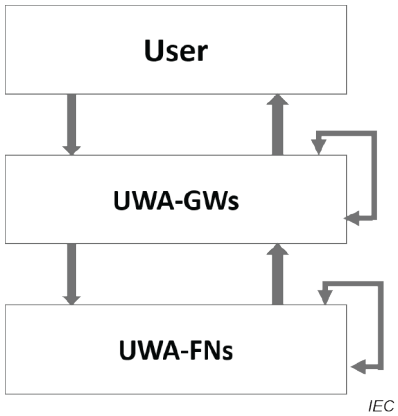

Figure 2 – Graphical representation of interoperable UWASN

Interoperability should also allow information to be exchanged seamlessly within the hierarchical structure of the sensor networks to support a complex system of systems. Therefore, various cases for the interoperability of sensor networks should be considered. Figure 3 illustrates the complexity of interoperability within this system of systems.

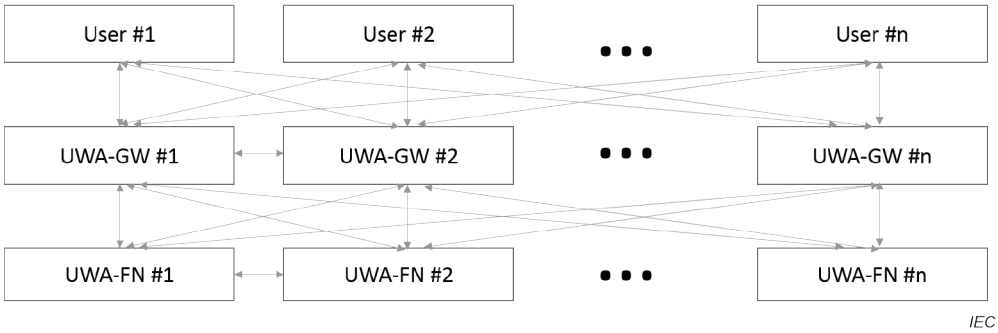

Figure 3 – Interoperability of UWASN

Various entities of the UWASN framework can use different communication technologies, protocols, and data formats. Therefore, data flow between various entities should be interoperable.

5.2 Interoperability between the user and the UWA-GW

UWA-GW is an intermediate entity that interconnects appropriate users and UWA-FNs. The data collected from the UWA-FNs and management messages, such as underwater data and device management messages, are exchanged via this interface.

The gateway should be capable of exchanging information with any user. Using a generic sensor network application interface is one way to ensure interoperability between the gateway and the user, as shown in Figure 4.

There are numerous approaches to ensure interoperability between the user and the gateway using the generic interface defined in ISO/IEC 29182-5.

A standardized interface specification and data format between the gateway and the user, shown as interoperability 1 in Figure 1, is defined in ISO/IEC 30140-3.

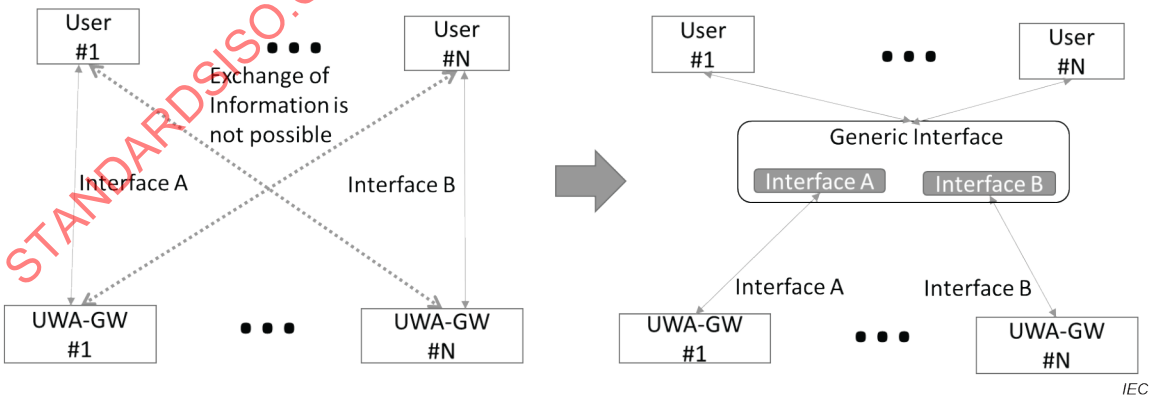

Figure 4 – Generic standardized interface for interoperability in UWASNs

5.3 Interoperability between the UWA-GW and the UWA-FN

The interface between UWA-FNs and UWA-GWs facilitates the transfer of data. UWA-GWs should be capable of extracting certain information from fundamental networks. UWA-GWs

should also be capable of communicating with any heterogeneous underwater fundamental network to ensure interoperability.

Using multiple interfaces in the gateway is one way to achieve interoperability between UWA-FNs and gateways.

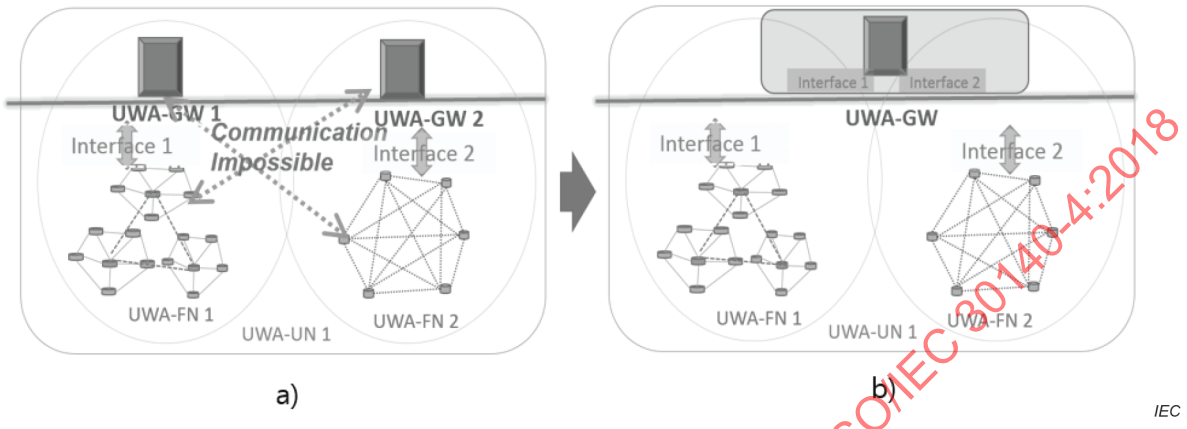

Figure 5 – Multiple interfaces on a UWA-GW to provide interoperability in UWASN

In Figure 5 a), UWA-UN1 has two fundamental networks. UWA-FN1 is a cluster based network and UWA-FN 2 is an ad-hoc based network. Each fundamental network communicates with its corresponding gateway. Each fundamental network has its own interface for communication with the gateway. In Figure 5 a), UWA-FN 1 communicates with UWA-GW 1 using interface 1. Similarly, UWA-FN 2 communicates with UWA-GW 2 using interface 2. Herein, UWA-FN 1 cannot communicate with UWA-GW 2 directly. Similarly, UWA-FN 2 cannot communicate with UWA-GW 1 directly. Therefore, interoperability between the UWA-GW and the UWA-FN is required. In Figure 5 b), the UWA-GW should have two interfaces to facilitate communication between two fundamental networks using a single gateway.

5.4 Interoperability between UWA-FNs

In the UWASN, interoperability between two fundamental networks is optional. In some cases, two fundamental networks communicate with each other to exchange sensor node network topology information, control information, and sensor. To ensure interoperability between UWA-FNs, protocols and data formats should be standardized. In UWA-UN, the fundamental network can communicate with another fundamental network through the gateway. Similarly, the UWA-UN network can communicate with another UWA-UN network through the corresponding gateways. Hence, interoperability between gateways is required.

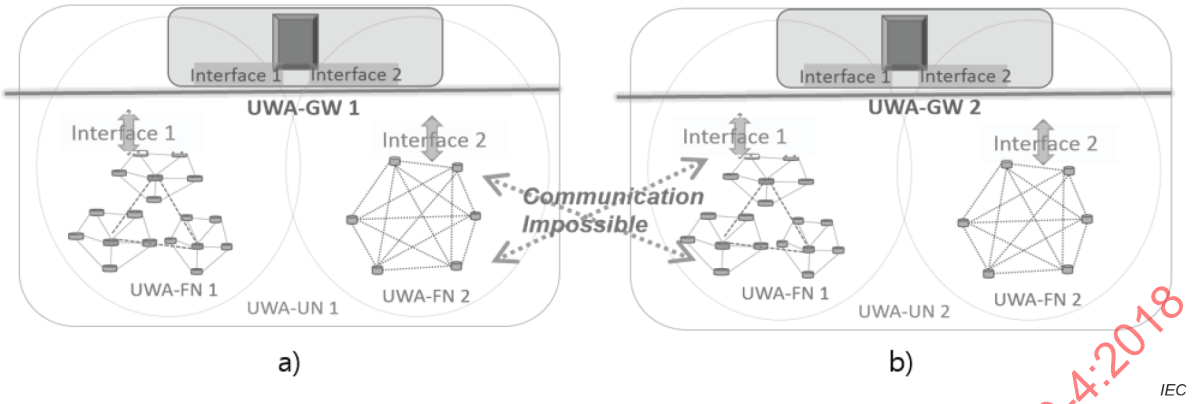

Figure 6 – Interoperability between fundamental networks

In Figure 6, in UWA-UN 1, the ad-hoc sensor node can communicate with the cluster header of the UWA-UN 2 network. Note that direct communication is not possible. Herein, we require a common gateway for communication between two UWA-UN networks.

5.5 Interoperability between UWA-GWs

Interoperability between fundamental networks and between underwater gateways is interrelated. In Figure 7, interoperability between two gateways UWA-GW1 and UWA-GW2 is required.

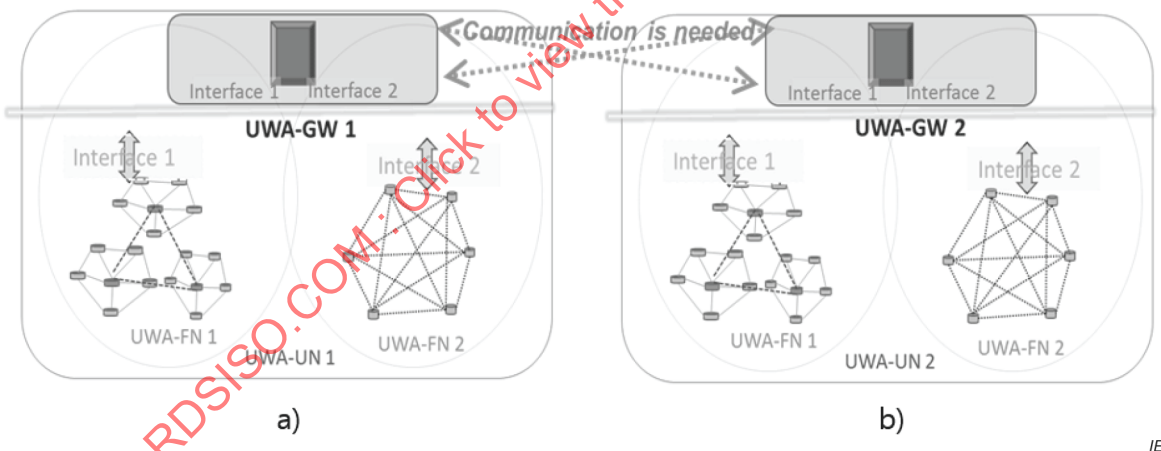

Figure 7 – Interoperability between UWA-GWs

6 UWASN communication technology interoperability architecture point of view

The UWASN communication technology interoperability architecture point of view (UWASN CTI-AP), shown in Figure 8, shows the domains, the entities within the domains, and the interfaces between entities from an underwater communication technology perspective.

The three domains are as follows.

1) Application domain.
2) Network domain.
3) UWASN domain:

- surface domain;
- controlling domain;
- sensing domain.

The entities and domains are specified in ISO/IEC 30140-2.

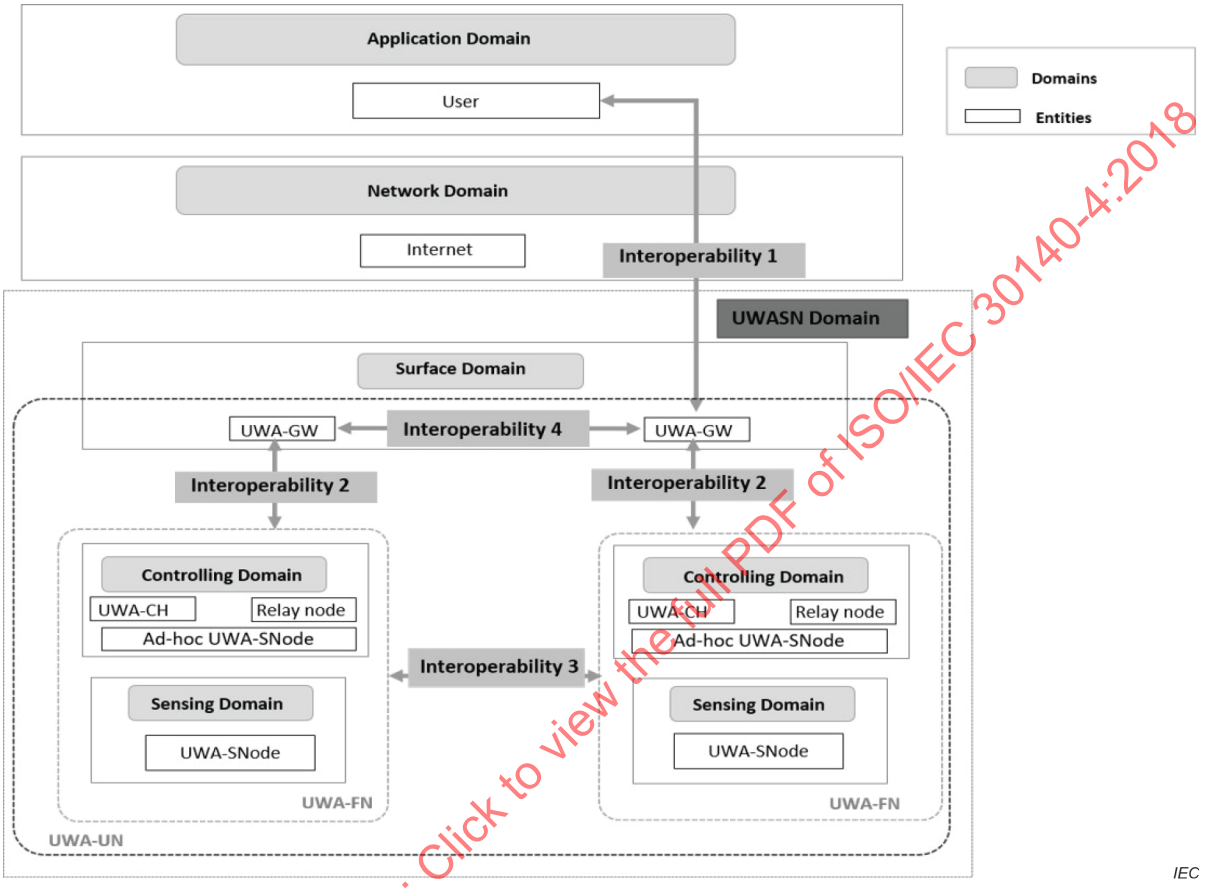

Figure 8 – UWASN communication technology interoperability architecture point of view

With the help of interfaces, entities are connected within each domain or between domains. A relevant interconnection alternative can be represented by the number of interfaces that connect the entities.

Table 1 provides a description and associated comment for each entity found in the communication interoperability architecture point of view shown in Figure 8.

Table 2 provides all the interfaces and interoperability found in Figure 8, including entity1 and entity2 connected by the interface and the interoperability line.

7 UWASN communication technology interoperability architecture from service point of view

7.1 General

The UWASN communication technology interoperability architecture from a service point of view (UWASN CTI-SP), shown in Figure 9, displays the entities, services, and interfaces from underwater communications technology perspective.

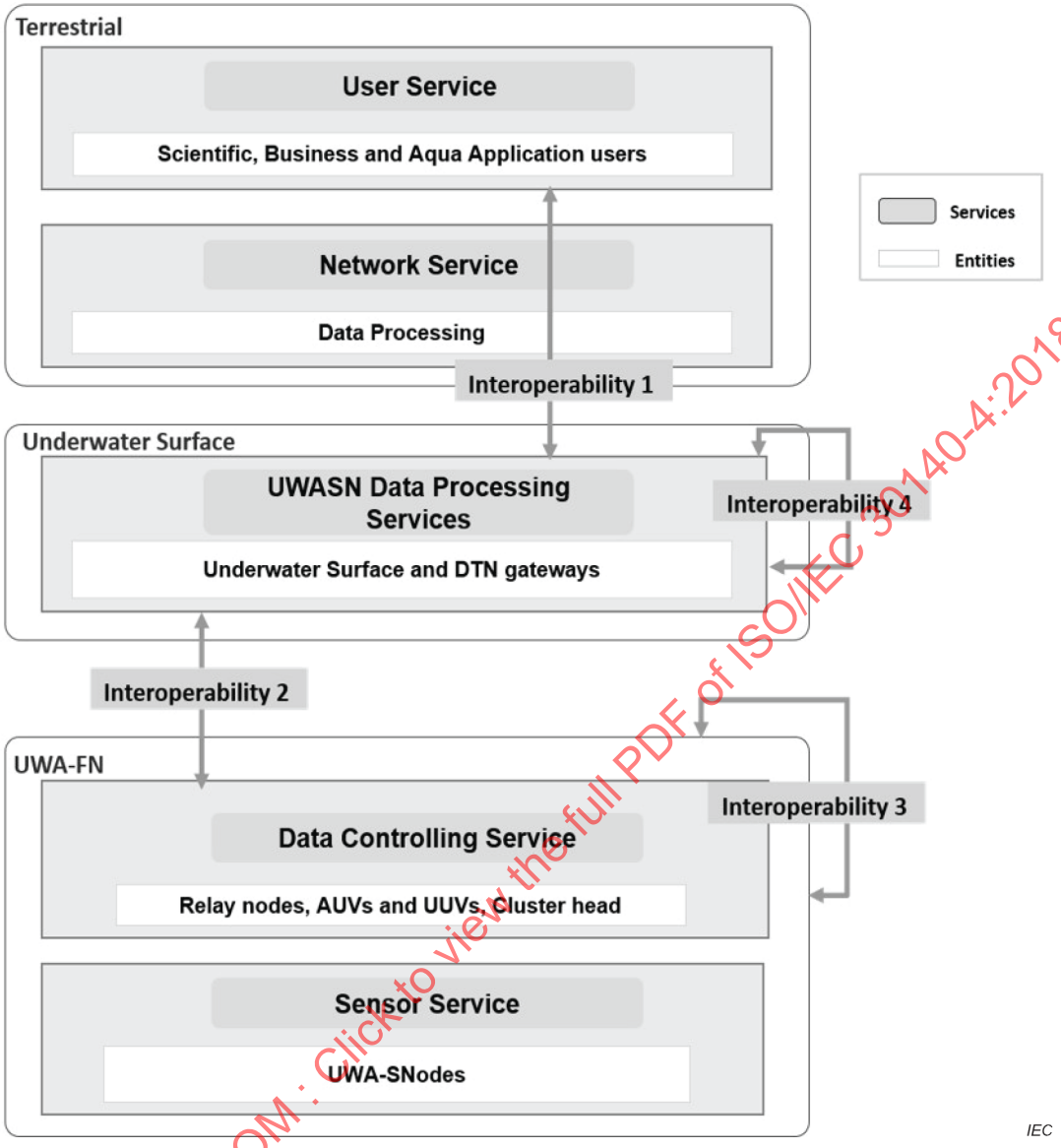

Figure 9 – UWASN communication technology interoperability architecture from a service point of view

Table 2 provides a description and an associated comment for each interface and interoperability found in the communication interoperability service point of view shown in Figure 9.

Table 1 – UWASN CTI-AP entities

Entity	Description	Comments
User	The user can visualize underwater sensor data.	Scientific, business and military applications use underwater data for environmental monitoring, disaster prevention, and detecting submarines.
Internet	Connection between the user and the surface gateway.	Using wired or wireless communication for data transmission.
UWA-GW	Connection between underwater acoustic sensor network and the Internet.	The surface gateway receives underwater related data from sensor nodes and transmits the data to a monitoring centre through wireless communication.
UWA-CH	In a cluster based network, one of the sensor nodes can act as a cluster head.	The cluster head receives information from cluster nodes and transmits the information to relay nodes.
Relay Node	Relay nodes can be UUVs.	Relay nodes transfer data from sensor nodes to the surface gateway.
UWA-SNode	Sensor nodes can be sensors, UUVs or acoustic tags.	Sensor nodes collect data and deliver the data to relay nodes or the gateway.

Table 2 – UWASN CTI-AP interoperability

Interoperability	Entity1	Entity2	Comments
Interoperability 1	User	UWA-GW	UWA-GW is an intermediate entity that interconnects appropriate users and UWA-FNs.
Interoperability 2	UWA-GW	UWA-FN	UWA-GW should be capable of extracting certain information from fundamental networks.
Interoperability 3	UWA-FN	UWA-FN	In UWA-FNs, sensor nodes exchange network topology information, control information, and sensor data.
Interoperability 4	UWA-GW	UWA-GW	UWA-UN network can communicate with another UWA-UN network through corresponding gateways.

7.2 Example: Interoperability between heterogeneous networks

Interoperability between terrestrial and underwater environments is beneficial to the following sectors.

1) Ocean sampling networks: Underwater sensor nodes test the ocean environment (e.g. pH, turbidity, temperature, oxygen levels, and salinity).
2) Environmental monitoring: The underwater environment can be affected by chemical, biological, and radioactive pollutants. UWASN can observe some of these pollution levels.
3) Undersea exploration: Submerged sensor systems can help to identify submerged oilfields.
4) Disaster prevention: A sensor network can monitor natural disasters such as earthquakes.
5) Assisted navigation: Underwater nodes can recognize various problems in the sea base, such as dangerous rocks or shoals.
6) Distributed tactical surveillance: Autonomous underwater vehicles and static nodes mutually examine regions for monitoring, and exploring.