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Information technology – Underwater acoustic sensor network (UWASN) – Part 1: Overview and requirements

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INFORMATION TECHNOLOGY – UNDERWATER ACOUSTIC SENSOR NETWORK (UWASN) –

Part 1: Overview and requirements

FOREWORD

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International Standard ISO/IEC 30140-1 was prepared by subcommittee 41: Internet of Things and related technologies, of ISO/IEC joint technical committee 1: Information technology.

The list of all currently available parts of the ISO/IEC 30140 series, under the general title *Information technology – Underwater acoustic sensor network (UWASN)*, can be found on the IEC and ISO websites.

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

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, 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 may 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.

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 1: Overview and requirements

1 Scope

This part of ISO/IEC 30140 provides a general overview of underwater acoustic sensor networks (UWASN). It describes their main characteristics in terms of the effects of propagation variability and analyses the main differences with respect to terrestrial networks. It further identifies the specificities of UWASN and derives some specific and general requirements for these networks.

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 and the following 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
ad-hoc node
device in a wireless ad-hoc network

Note 1 to entry: A wireless ad-hoc network is defined in ISO/IEC 27033-6:2016[1], [2] 3.12, as a "decentralized wireless network which does not rely on a pre-existing infrastructure".

3.2
cross-layer
technology that permits communication between different layers by allowing one layer to access data of another layer to exchange information and enable interaction

3.3
management cross-layer
technology that provides a system-level management service to all or selected OSI layers in a wireless network system

[2] Numbers in square brackets refer to the Bibliography.

Note 1 to entry: Examples of management cross-layer are device management cross-layer, network management cross-layer, QoS management cross-layer, security management cross-layer, localization management cross-layer, power management cross-layer, etc.

3.4
underwater acoustic fundamental network
UWA-FN
wireless communication network that is built either exclusively using one or more cluster networks or exclusively using one or more ad-hoc networks for underwater environment using acoustic modems

Note 1 to entry: Fundamental network consists of only one network type, either cluster network or ad-hoc network.

Note 2 to entry: Wireless acoustic communication and data links are realized using an acoustic modem.

Note 3 to entry: A modem is defined in ISO/IEC 2382:2015[2], 2124386, as a “functional unit that modulates and demodulates signals”.

3.5
underwater acoustic united network
UWA-UN
wireless communication network that is made of two or more underwater acoustic fundamental networks (3.4) and relay nodes

Note 1 to entry: A relay node is, for example, an unmanned underwater vehicle, communication node, beacon, etc.

3.6
underwater acoustic extended united network
UWA-EUN
wireless communication network that is made of two or more underwater acoustic united networks (3.5)

3.7
underwater acoustic sensor node
UWA-SNode
sensor network element that includes at least one sensor and, optionally actuators with communication capabilities and data processing capabilities, which is built for underwater applications using acoustic modem as a communication unit internal to this element

Note 1 to entry: Wireless acoustic communication and data links are realized using an acoustic modem.

Note 2 to entry: A modem is defined in ISO/IEC 2382:2015, 2124386, as a “functional unit that modulates and demodulates signals”.

[SOURCE: ISO/IEC 29182-2:2013, 2.1.8 – modified: the original definition of sensor node is adapted to an underwater acoustics context.]

3.8
underwater acoustic cluster head
UWA-CH
unit that receives data from underwater acoustic sensor nodes (3.7) and transmits the data to one or more relay nodes or a nearby underwater acoustic gateway (3.9)

3.9
underwater acoustic gateway
UWA-GW
unit connecting different underwater networks or parts of one underwater network and performing any necessary protocol translation in underwater environment using acoustic modem

[SOURCE: ISO/IEC TR 29108:2013, 3.1.88.3 – modified: the original definition is adapted to an underwater acoustics context.]

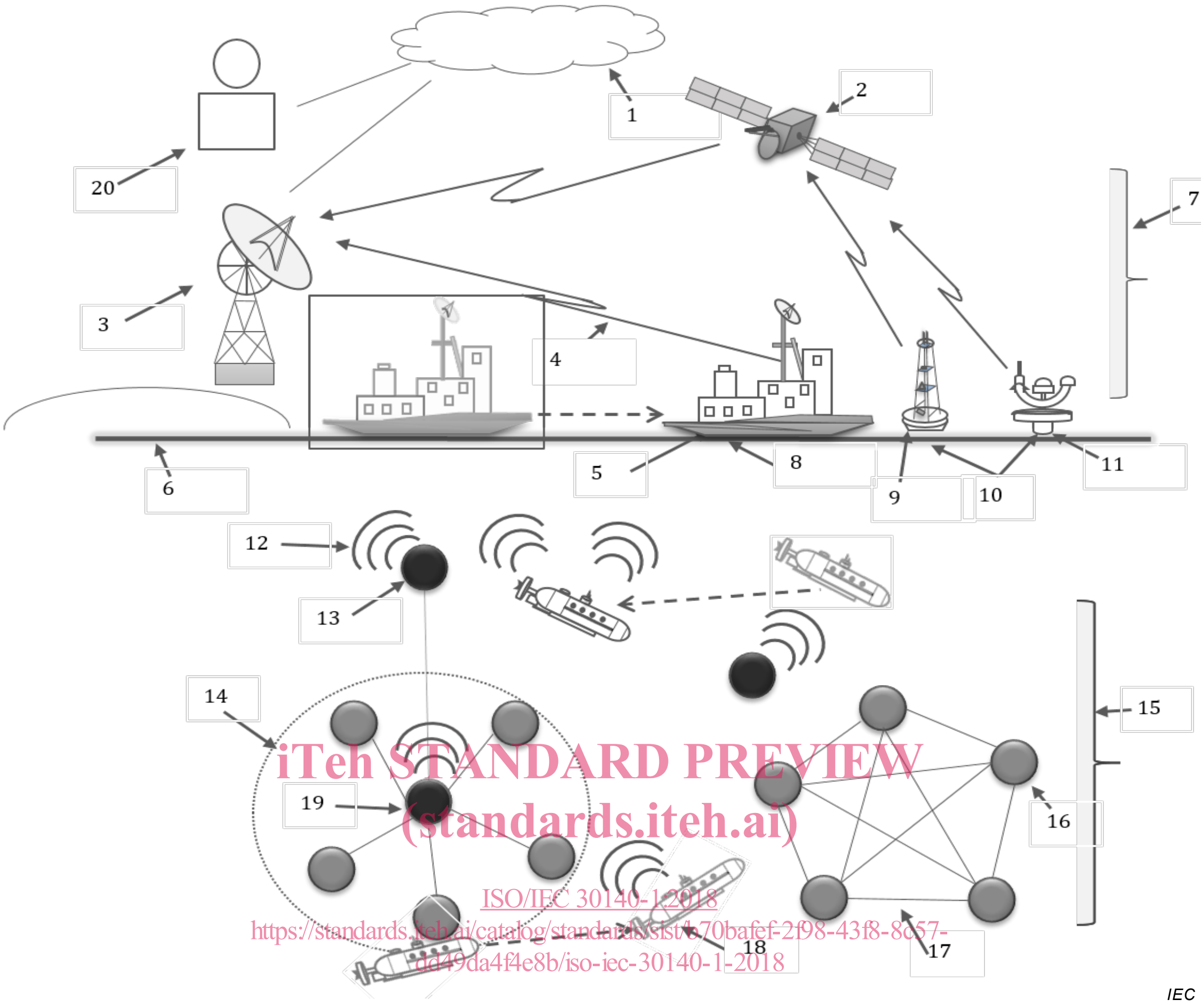
4 Abbreviated terms

2D	two dimensional
3D	three dimensional
BER	bit error rate
DG	distance group
DTN	delay and disruption tolerant network
EM	electromagnetic wave
EMI	electromagnetic interference
GPS	global positioning system
kbps	kilobits per second
LED	light emitting diode
μPa	Micropascal
Mbps	megabits per second
MCCP	minimum cost clustering protocol
QoS	quality of service
RF	radio frequency
RSS	received signal strength
UUV	unmanned underwater vehicle
UWASN	underwater acoustic sensor network
UWA-CH	underwater acoustic cluster head
UWA-DTN	underwater delay tolerant network
UWA-DTN-GW	underwater DTN gateway
UWA-EUN	underwater acoustic extend united network
UWA-FN	underwater acoustic fundamental network
UWA-GW	underwater acoustic gateway
UWA-SNode	underwater acoustic sensor node
UWA-UN	underwater acoustic united network

5 UWASN overview and applications

5.1 Overview

Figure 1 shows the basic topology of UWASN. In a cluster-based network, the data sensed by underwater acoustic sensor nodes (UWA-SNodes) are transmitted via acoustic communication to an underwater acoustic gateway (UWA-GW) using an underwater acoustic cluster head (UWA-CH), unmanned underwater vehicle (UUV), or relay nodes. Users receive the transmitted data through various externally connected networks (e.g. radio frequency (RF) or satellite communication). During these processes, underwater communication is implemented by acoustic communication. In general, UWA-GWs are either moving nodes or fixed nodes. Topologies and communication configuration models could be adaptively modified according to the application domain’s needs at any given time.



Key

1 Internet
2 Satellite
3 Base station
4 RF link
5 Moving gateway
6 Surface
7 RF
8 UWA-GW
9 Buoy
10 Fixed gateways
11 UWA-DTN-GW
12 Acoustic link
13 Relay node
14 Cluster
15 Underwater
16 UWA-SNode
17 Ad-hoc network
18 UUV
19 UWA-CH
20 User

Figure 1 – Overview of a UWASN

RF communication systems are used in terrestrial sensor networks. The reasons for this are their high efficiency and low cost. Underwater RF communication is very difficult due to limited wave propagation characteristics that arise from the high attenuation due to the conductivity of water. Underwater communications can also be achieved by optical links employing lasers or LED light sources. Optical waves are still affected by attenuation, but can typically operate over longer ranges than RF.

Diode laser beams and low cost light sources such as LEDs can also be utilized. A light source for an underwater communications system is practicable using LEDs with an optical wavelength between 400 nm and 550 nm.[3]

Presently, underwater acoustic communication is the primary method for establishing wireless communication among UWA-SNodes, UUVs and UWA-GWs. This is because sound travels much further in water than RF radio signals. A UWASN consists of different types of

UWA-SNodes and UUVs positioned so as to perform collective underwater monitoring. UWA-SNodes and UUVs are organized autonomously into a network that should adapt to changing ocean environments over time.[4]

UWA-SNodes are applicable to pollution monitoring, oceanographic information gathering, strategic observation, assisted navigation, offshore examination, and disaster prevention. Several UUVs with equipped sensors explore underwater resources and gather precise location information. To make this possible, reliable underwater communication between UWA-SNodes and UUVs is required.

UWA-SNodes and UUVs should have self-configuration capabilities that allow them to network themselves. They should manage the operations by sharing location information, configurations, and movements, in order to send monitored data to an on-shore location.

5.2 Application domain of UWASN

A UWASN can realize unexplored underwater applications, increasing the capacity for detecting and forecasting changes in time-varying oceanic environments. Table 1 shows the UWASN market segments and their current and future potential applications.

Annex A provides a description of the selected application of UWASN.

Table 1 – UWASN market segments and their current and future applications list

Market segment	Description
Scientific applications	Early warning system for detection of disasters and tsunami, and providing warnings Studying the effects of oceanic earthquakes (seaquakes) Climate recording Pollution control Oil/gas fields exploration Detecting climate change Improving weather forecasting Studying marine biology Ocean circulation studies
Business applications	Discovery of natural resources Temperature monitoring in runtime Chemical and biological changes Detection of pipeline leakages Seismic monitoring allowing reservoir management approaches
Civilian applications	Assisted navigation Identifying hazards in the seabed Identifying submerged wrecks Identify the mooring positions Underwater hazard avoidance Defining seabed pipeline routes Identifying underwater oilfields Defining paths for the layering of underwater cables
Aqua applications	Aquaculture and farming Remote control-monitoring of costly devices