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colour inside

Internet of things (IoT) – Underwater acoustic sensor network (UWASN) – Network management system overview and requirements

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INTERNET OF THINGS (IoT) – UNDERWATER ACOUSTIC SENSOR NETWORK (UWASN) – NETWORK MANAGEMENT SYSTEM OVERVIEW AND REQUIREMENTS

FOREWORD

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FDIS	Report on voting
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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.

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

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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, most suitable methods for managing the network have been developed based on the ISO/IEC 30140 series. This document describes the network management 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 information such as requirements of an underwater network management system (U-NMS), functions supporting U-NMS and components required for U-NMS in UWASN.

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.

INTERNET OF THINGS (IoT) – UNDERWATER ACOUSTIC SENSOR NETWORK (UWASN) – NETWORK MANAGEMENT SYSTEM OVERVIEW AND REQUIREMENTS

1 Scope

This document provides the overview and requirements of a network management system in underwater acoustic sensor network (UWASN) environment. It specifies the following:

– functions which support underwater network management system;
– entities required for underwater network management system;
– data about the communication between elements in underwater network management system;
– guidelines to model the underwater network management system;
– general and functional requirements of underwater network management system.

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
agent
software program that manages the devices installed in underwater

3.2
u-MIB
collection of managed objects, which acts as the database for the management of each device in the underwater environment

3.3
manager
program installed in the management station, which is used for the management of devices in underwater networks

4 Abbreviated terms

UUV	unmanned underwater vehicle
UWASN	underwater acoustic sensor network
UWA-GW	underwater acoustic gateway
UWA-SNode	underwater acoustic sensor node
U-NMS	underwater network management system
UWA-CH	underwater acoustic cluster head
u-MIB	underwater management information base
OID	object identifier
FCAPS	fault-management, configuration, accounting, performance and security
FCAPSC	fault, configuration, accounting, performance, security and constrained management
MO	managed object
UUV	unmanned underwater vehicle
AUV	autonomous underwater vehicle

5 U-NMS overview

5.1 General

The UWASN operates in a constrained environment as compared to terrestrial network's operating environment. Hence, the UWASN needs an efficient network management system to handle and compensate for phenomenological difficulties encountered in the underwater environments. This system can be termed an "underwater network management system" or "U-NMS".

Figure 1 shows the diagrammatic representation of a U-NMS module residing within the UWA-Application Layer.

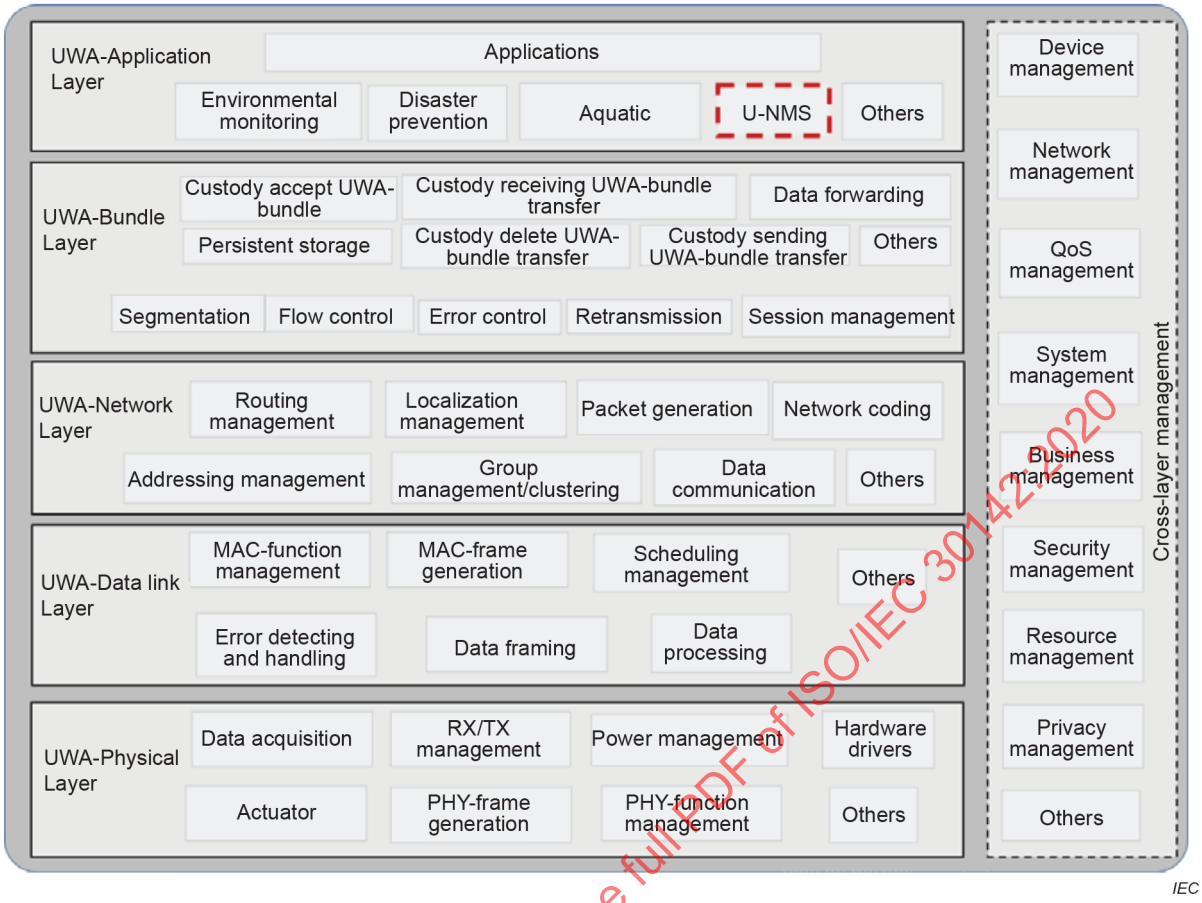

Figure 1 – Stack of layers in a U-NMS

5.2 Problem statements

As the conditions of the underwater environment differ significantly from terrestrial networks, it becomes mandatory to have an appropriate network management system designed uniquely for the underwater environments.

The specific challenges or issues for the UWASNs to operate with the help of U-NMS are given below.

– Low data rate: In UWASN, the total amount of data collected during the monitoring process by each sensor is less, when compared to terrestrial networks. This is because of the limitation in memory, battery power, etc. in underwater devices.

– Transmission range: In UWASN, the nodes can cover only less distance when considering the network coverage and battery power planning. On the other hand, signals are usually transmitted in low frequencies under water, in order to avoid being absorbed by water. This in turn allows longer transmission ranges, but at the same time increases the chances for interference and collision.

– Battery charge level: As battery backup is limited for all devices in the underwater environment, energy efficiency turns out to be a major challenge when considering the cost of battery recharging.

– Attenuation: In UWASN, the transmission loss can occur based on an absorption in the underwater environments.

– Deployment depth: In UWASN, the node deployment and the node management encounter difficulties due to the depth of sea.

– Size of the antenna: In UWASN, the size of the antenna is designed as small for short range communication and bigger for long range communication. So, it faces difficulties during deployment in underwater communication.

– Data delivery rate: In UWASN, the total packets delivered to the receiver can be influenced by various factors such as time, traffic, etc.

– Delay of data transmission: In UWASN, as the underwater environment is heavily congested with acoustic signals, this situation can cause delays during data transmission.

– Bit errors: In UWASN, the increased bit errors at receivers are caused by various factors such as noise, attenuation, interference, etc.

5.3 Description of the U-NMS

The U-NMS is a program or collection of programs that allows the administrators to independently manage and control every component in an underwater network system.

Operations performed by the U-NMS are the following:

– configuring underwater networks;

– monitoring the performance of components;

– identifying and controlling traffic;

– dealing with problems like device failure, attacks, etc.

5.4 Purpose and advantages of the U-NMS

The main purposes of the U-NMS are to

– monitor the network systems and functions of UWASNs, and

– ensure that the generated data can be transmitted and received at the destination efficiently through the network.

The advantages of using the U-NMS include, but are not limited to, the following.

– Cost reduction: In a constrained environment, it is difficult to manage the devices physically at all times. For example, power, memory, deployment, fouling cleaning, etc. require efficient management mechanisms. Also, the cost is very high for direct management. If a proper management system is employed, then the operational cost, installation cost, etc. can be reduced.

– Easy network monitoring: Each device and the network can be used for monitoring the connection between the devices and network in the underwater environments.

– Error handling: In the underwater environment, the errors can occur in both the devices and network sides and this can be easily handled using the U-NMS.

– Automatic software updates: In the U-NMS, the automatic updating of software over the underwater network is essential.

– Network configuration flexibility: The U-NMS provides easy configuration support among the hardware, software, devices, network, etc. In this way, flexible connections can be made between devices and network.

– Service improvement: The U-NMS can provide the high-quality services such as data collection, processing, predicting, communicating, etc.

– Data control over network: The U-NMS can control the status of devices such as memory, power, network range, etc. Also, the U-NMS can control each underwater management device by collecting and processing dynamic data.

– Security solutions: The U-NMS consists of a security module which can protect the underwater devices from authorization and authentication related issues. Also, the U-NMS can manage the security level of the system based on the security rules.

– Log data analysis: In the U-NMS, log data is the set of underwater activity observation data captured by underwater devices, underwater networks, operating system, etc. Log data can be used to analyse user behaviour, security risks, audit, etc.

6 Functions of the U-NMS

6.1 Overview

In UWASN, the network management system utilizes different methods and tools to assist a human operator in order to manage underwater devices, networks or systems. The functions of U-NMS are modelled using Fault, Configuration, Accounting, Performance, Security and Constrained management (FCAPSC).

FCAPSC functions of U-NMS are described in Figure 2.

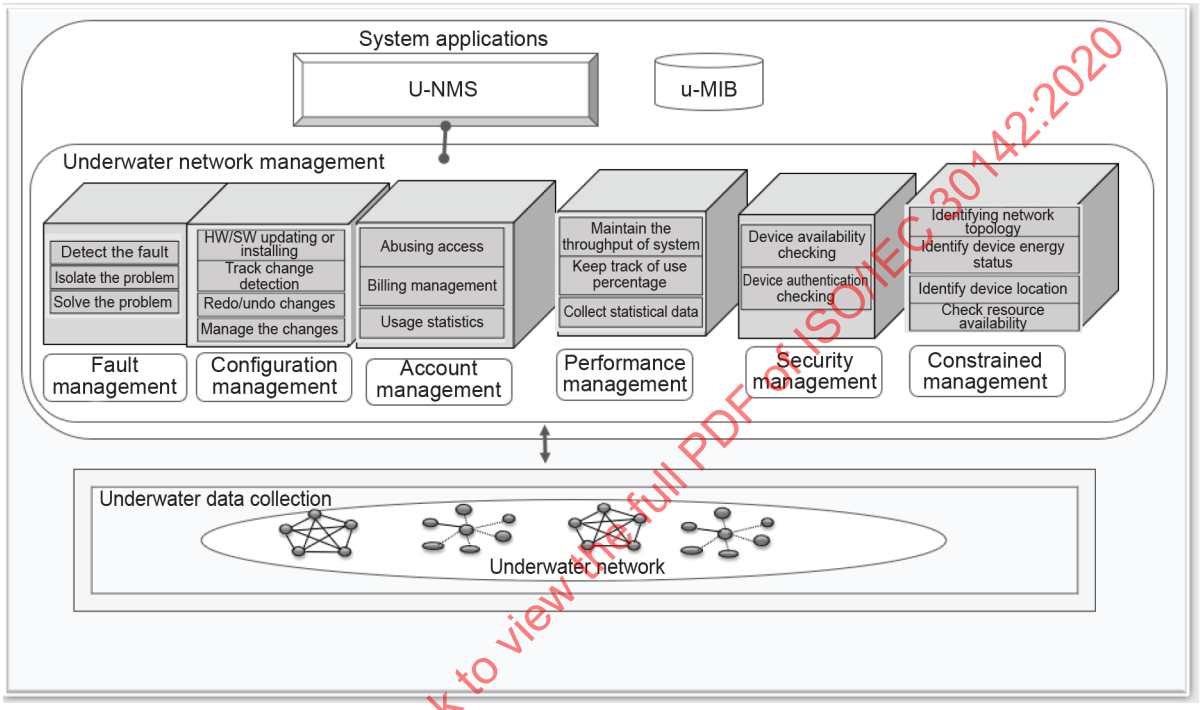

Figure 2 – Functions of the U-NMS

6.2 U-NMS fault management

The main goal of fault management in U-NMS is to notify the faults and abnormal operations in the UWASN. U-NMS fault management functionality includes examining and maintaining the error logs, responding to notifications, finding the faults, performing the diagnostic tests and correcting the faults.

Network problems are detected, isolated and corrected at the fault management level in the U-NMS. As a fault may occur in various components of the system, it is important to identify the relationship between these components. The network always stays operational with the help of the fault management mechanism. The fault management shows how to design and install the services of faults in the U-NMS.

The U-NMS fault management steps are as follows.

– Detect the fault: In U-NMS, the fault detection is indicated by notification messages. The u-MIB has the information related to types of fault that will correlate and find the reasons for the occurrence of faults such as device faults, battery faults, etc.

– Isolate the problem: The source of fault occurring in the U-NMS such as device, battery, network, etc. can be identified.

– Solve the problem: The faults identified are resolved, repaired or corrected depending on the severity of faults.

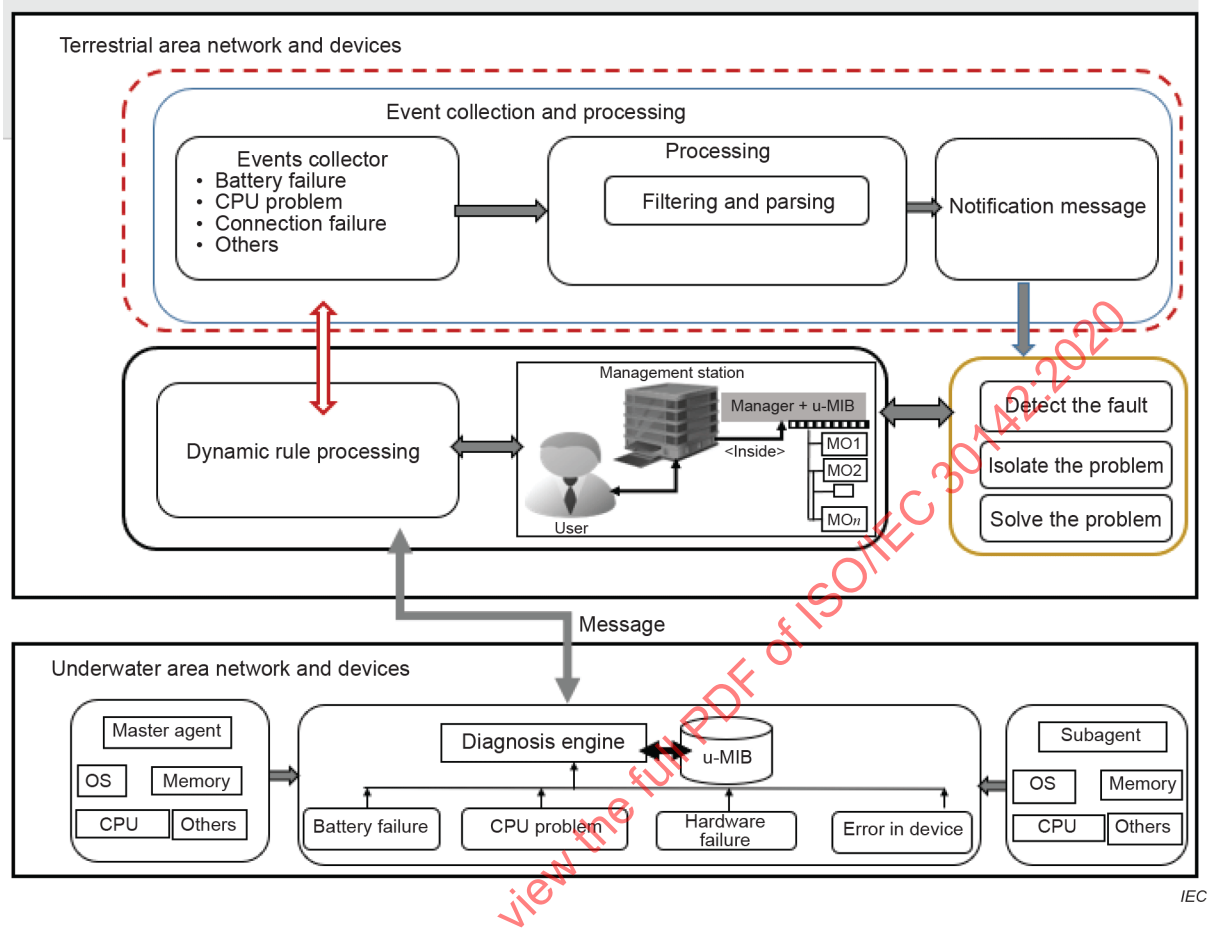

Figure 3 – Fault management in the U-NMS

Figure 3 shows how the fault management mechanism works in the U-NMS. The faults that occur in the underwater network and devices are, for example, battery failure, error in devices, connection failure. This fault information is collected by the diagnosis engine inside the master agent and subagent. The notifications sent by the diagnosis engine are processed by the dynamic data processing rules module, which consists of three sub-modules such as Events collector, Processing and Send notification. The events collector module collects all the notifications sent by the diagnosis engine. The filters are used to validate the data received from different devices based on the dynamic data processing rules. After receiving the notification, the U-NMS will process the functions such as redo/undo changes, hardware/software updating, manage the changes, etc.

6.3 U-NMS configuration management

The main purpose of configuration management in the U-NMS is to monitor the configuration between the underwater networks and the system. Therefore, the issues that occur in different components such as hardware and software components of UWASN can be found and managed using a configuration management function in the U-NMS.

The parameters used for the configuration management in the U-NMS are as follows:

– reconfiguration;

– change detection;

– hardware/software update.

The functions of U-NMS configuration management are as follows.

– Installation/update: The installation module is used to install or update the software or hardware parts inside the devices.
– Track change detection: This module is used to track the type of changes that appear in the devices and network.
– Redo/undo changes: This module supports the forward and reverse operation while doing the configuration or reconfiguration.
– Manage the changes: This module can manage the changes done during reconfiguration, e.g. device location, device ID, etc.
– Configuration auditing: This module is used to check whether the changes are made correctly or not.

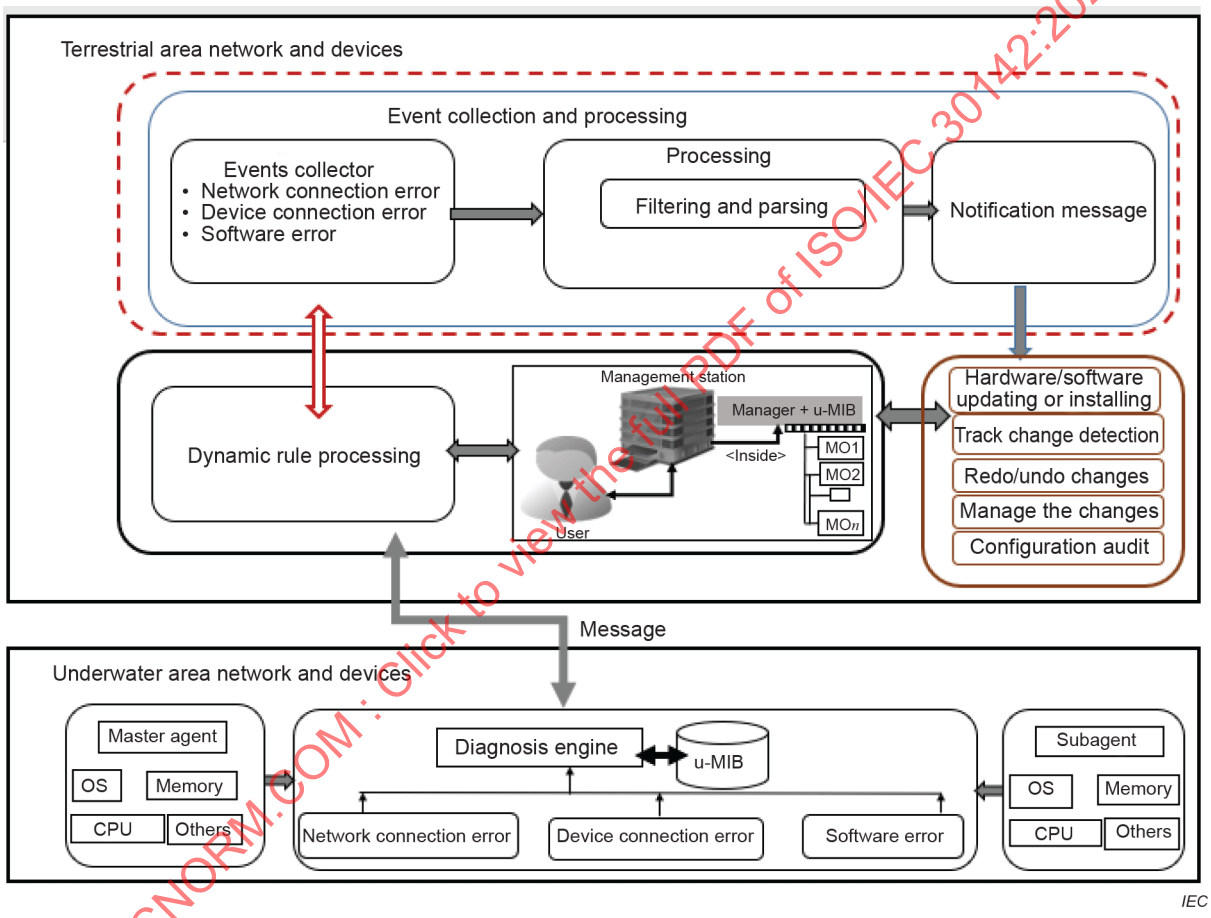

Figure 4 – Configuration management in the U-NMS

Figure 4 shows how the configuration management mechanism works in the U-NMS. The failures that occur in the underwater network and devices are, for example, error in devices, connection failure, etc. This fault information is collected by the diagnosis engine inside the master agent and subagent. The notifications sent by the diagnosis engine are processed using the dynamic data processing rules module which consists of three sub-modules: Events collector, Processing and Send notification. The events collector collects all notifications sent by the diagnosis engine. The filters are used to validate the data received from different devices based on the dynamic data processing rules. After receiving the notification, the U-NMS will process the functions such as redo/undo changes, hardware/software updating, manage the changes, etc.

6.4 U-NMS account management

In the U-NMS, every user has their own space for storing and retrieving files. The main goal of U-NMS Account Management is to check whether or not the underwater network system is effectively used by each user. Therefore, the account management provides fair resource sharing in UWASN among the users. Figure 5 shows the account management system of the U-NMS.

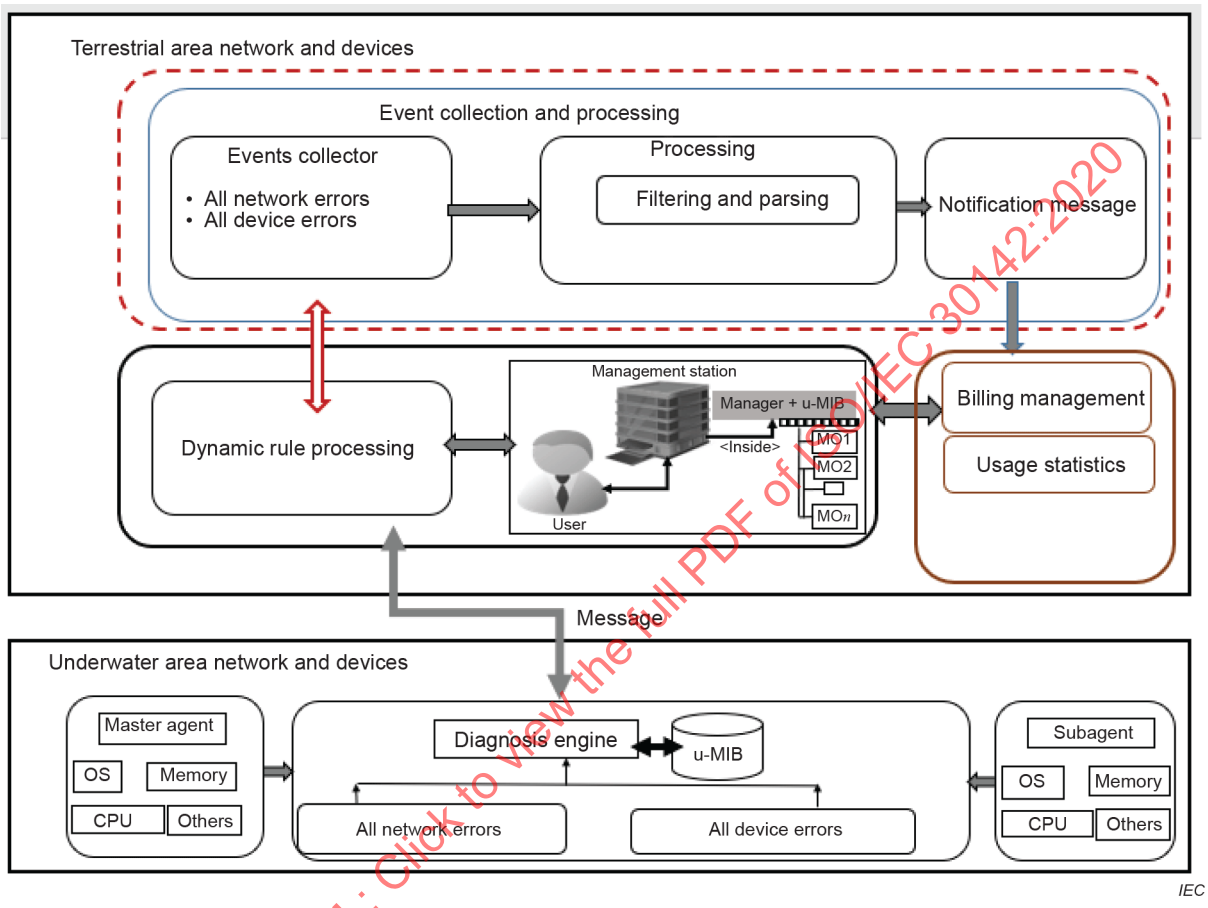

Figure 5 – Account management in U-NMS

6.5 U-NMS performance management

6.5.1 General

Performance management in the U-NMS has a set of functions that aims to calculate and record the performance of the U-NMS components and the entire network. The main aim is to monitor and maintain the performance of the entire network.

The primary goal of performance management is to monitor and control the U-NMS system. As the size of the network increases, it is difficult to maintain and monitor the performance of the U-NMS. Therefore, in order to manage the full capacity of the network and devices, the performance management is much needed in any network management system.

6.5.2 The challenges in performance management

– Identify and collect the data.

– Validate the data.

– Distribute the data.

– Analyse the data.

6.5.3 Functions of performance management

– Maintain the throughput of the system stable.
– Keep track of the use percentage.
– Identify time of response.
– Examine active log report.
– Collect statistical data.
– Evaluate element performance.
– Check device reliability.
– Calculate service time required.
– Create complete performance report as graph.
– Report the battery condition and charging status.

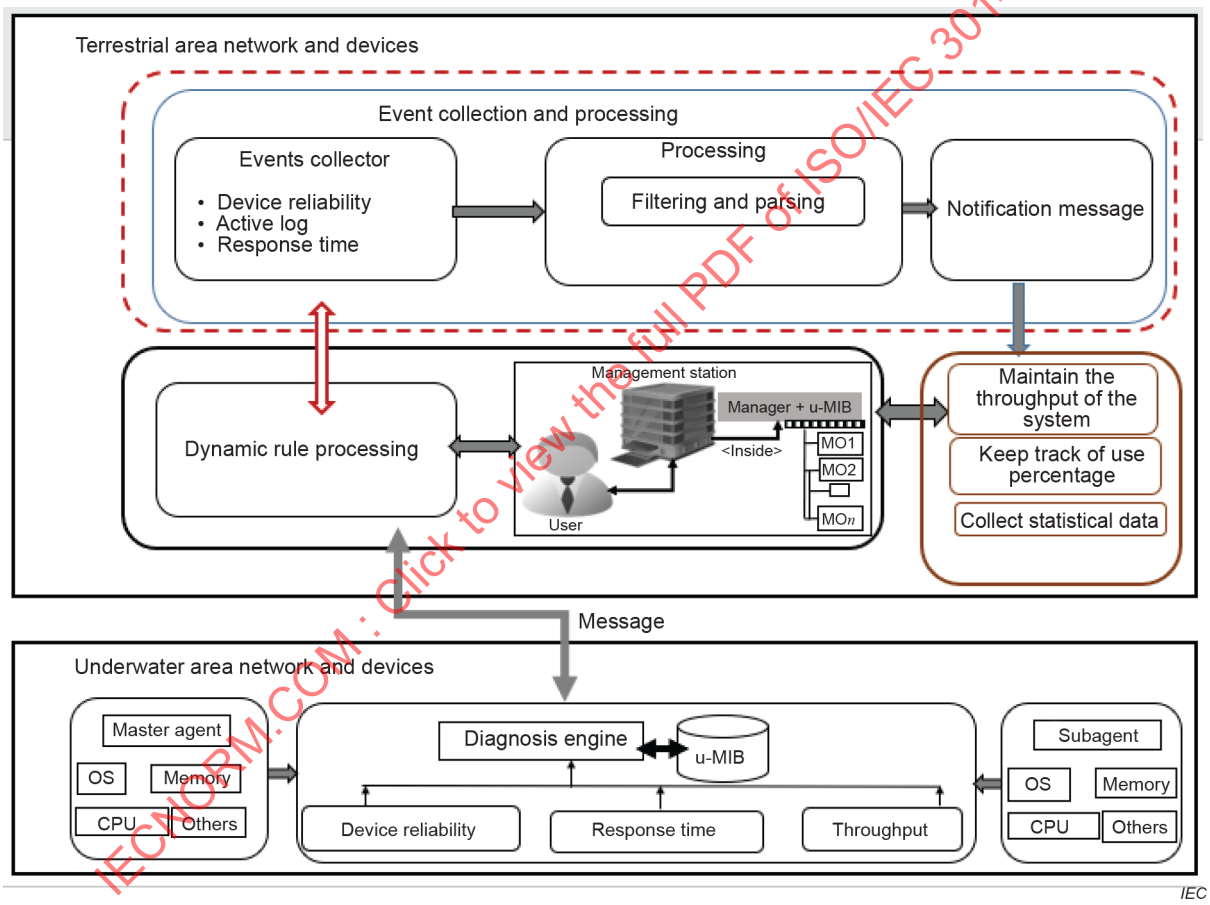

Figure 6 – Performance management in U-NMS

Figure 6 shows how the performance management mechanism works in the U-NMS. The performance of the underwater networks and devices such as device reliability, response time, etc. are collected by the diagnosis engine and sent to the dynamic data processing rules module in U-NMS. The dynamic data processing rules module can collect, process and send a notification message to the manager. Based on the notifications received by the server, the U-NMS can maintain the throughput of the system, keep track of use percentage, collect statistical data and perform other functions.

6.6 U-NMS security management

U-NMS should provide the facility for reporting the security-related events of the UWASN.

The main goal of security management in U-NMS is to make some conditions to access the resources and to prevent the attacks. The attacks can affect the whole network and may cause the loss of important data. So, by using some control mechanisms, only the authorized users can access the data in UWASN. Figure 7 shows the security management system of the U-NMS.

The functions of security management are as follows:

1) user authentication;
2) control access;
3) confidentiality;
4) authorization;
5) audit.

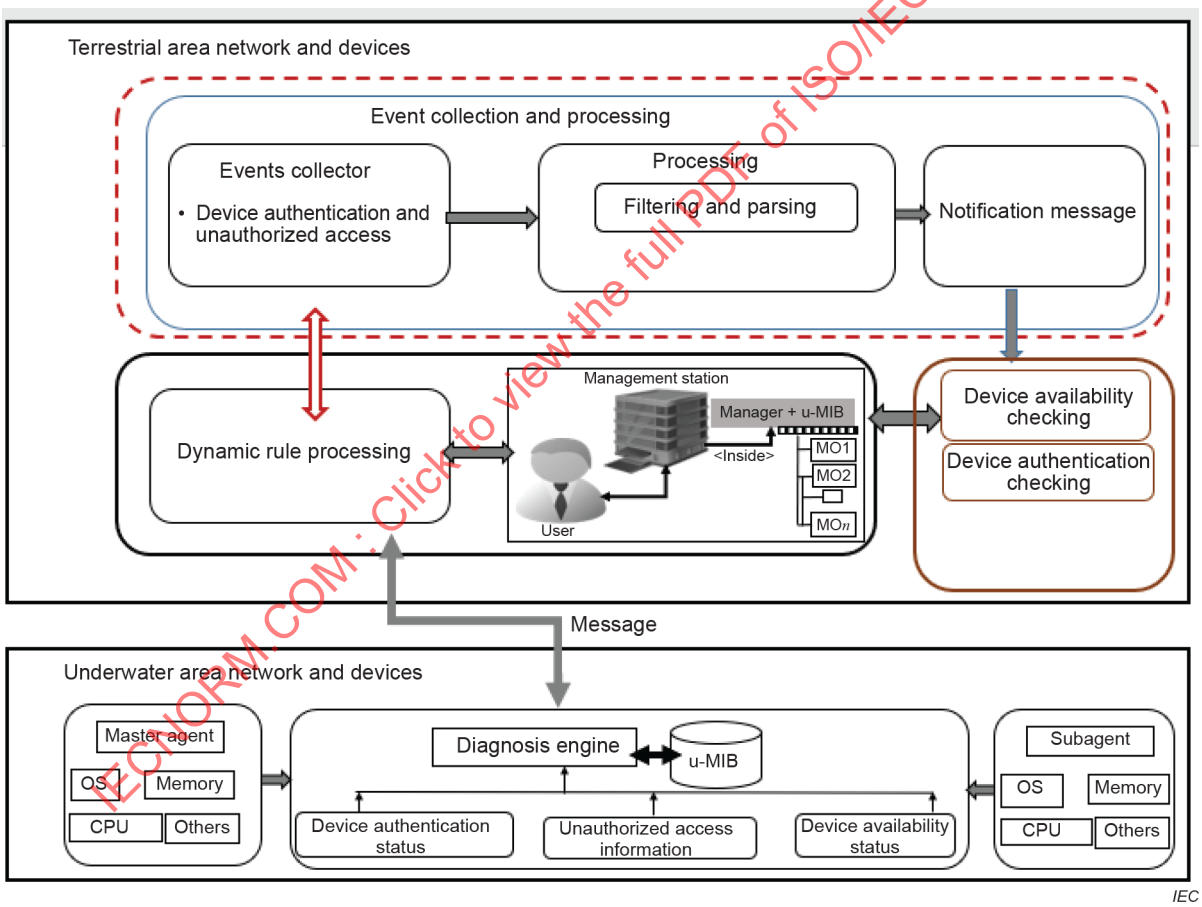

Figure 7 – Security management in U-NMS

6.7 U-NMS constrained management

6.7.1 General

The main objective of constrained management in U-NMS is to handle the constrained environment of UWASN.

The constrained management consists of two modules:

– constrained network management;
– constrained device management.

6.7.2 Constrained network management

The constrained network management module in Figure 8 shows how the constrained network management works in the underwater environments.

Diagnosis engine: The underwater network events like underwater, network status, discovery of network topology, network scalability, etc. are collected by the diagnosis engine and sent as notification using underwater communication protocols.

Dynamic data processing rules: The dynamic data processing rules module consists of sub-modules such as events collector, processing and send notification. The events collector collects all the events that occur in the constrained network and devices. The filters are used to validate the data received from different devices based on the dynamic data processing rules. The parsing is used to group similar types of data for easy communication. Send notification is used to send the message to the U-NMS.

Centralized manager: The centralized manager includes devices such as UWA-GWs that act as the manager for underwater devices. The agent and the manager are deployed in those devices for communication.

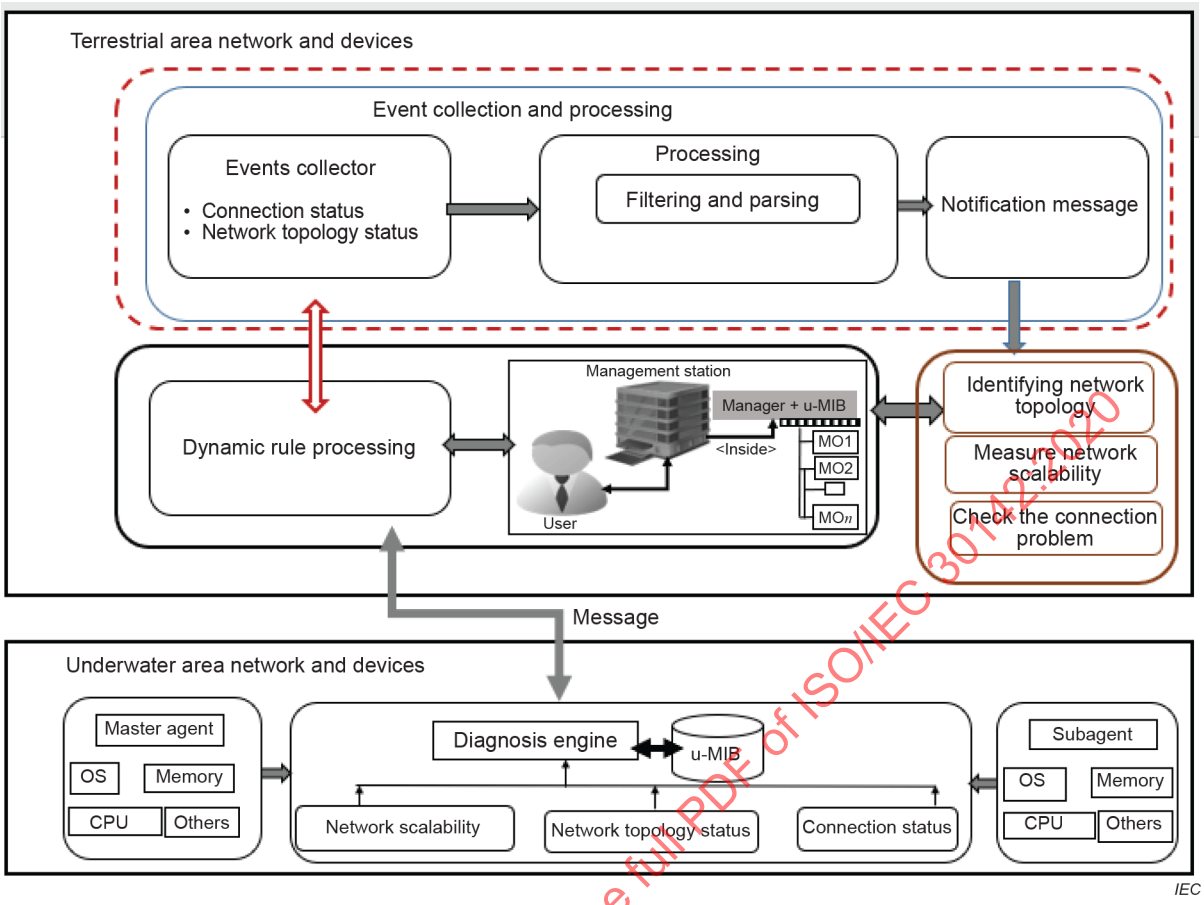

Figure 8 – Constrained network management in U-NMS

6.7.3 Constrained device management

The constrained device management module in Figure 9 shows how it works in the underwater environments.

Diagnosis engine: The underwater device activities such as device status, device energy status, device resource availability, etc. are collected by the diagnosis engine and sent as notification using underwater communication protocols.

Dynamic data processing rules: The dynamic data processing rules module can collect, process and send notification to the server.

Centralized manager: The centralized manager includes the devices such as gateway that act as the manager for underwater devices. This can solve various problems such as underwater device recovery, device reconfiguration, etc.

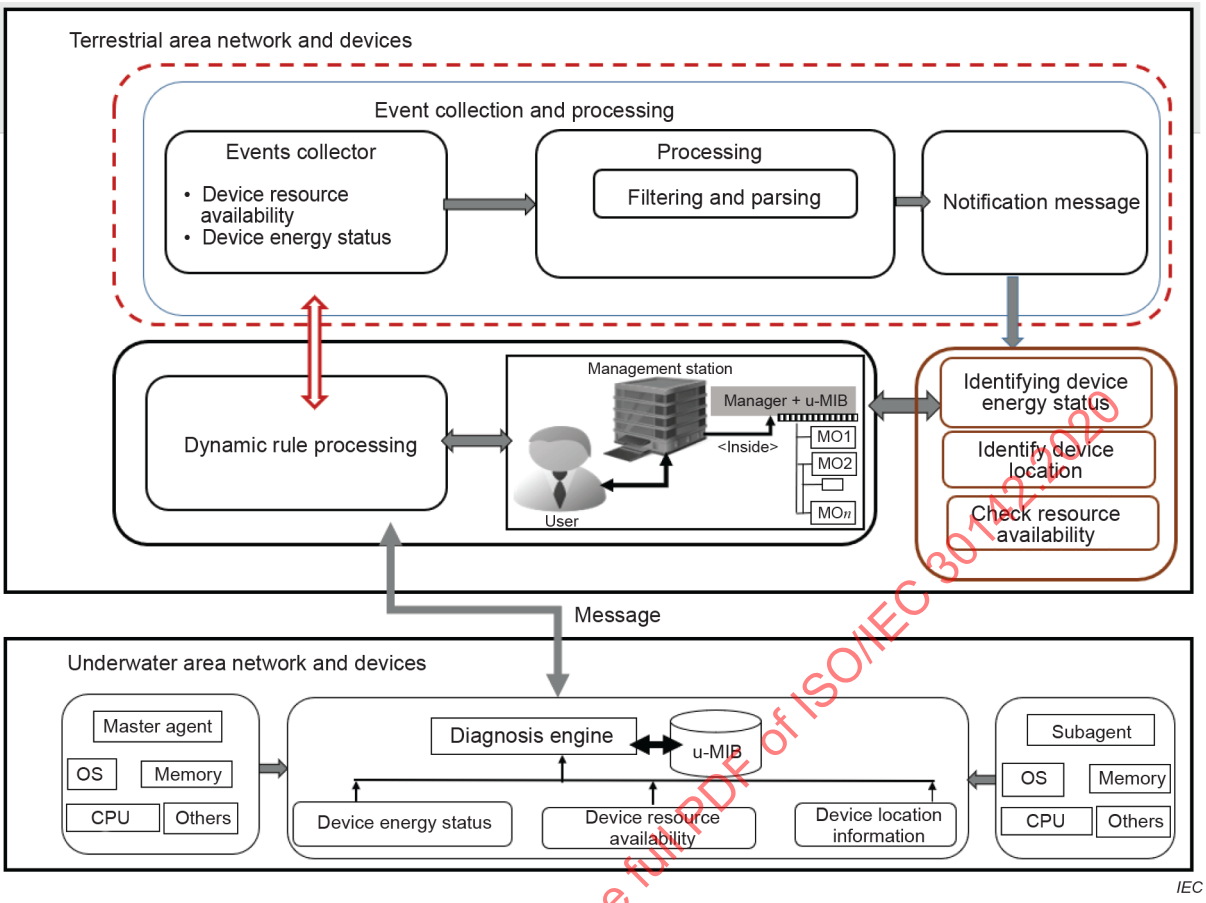

Figure 9 – Constrained device management in U-NMS

7 U-NMS components

7.1 Management station

Management station is a shared system which acts as the manager to monitor and control the underwater networks. The management station consists of DMD (device management database) for storing the information. The main operations performed by the network management station are analysis of data, fault identification, recovery, etc.

The management station includes the following modules.

1) Device Management Database (DMD) acts as the main database for storing information. The information will be aggregated and stored in DMD.
2) Object Identifiers (OID) provides a unique identifier to each Managed Object (MO) in Underwater Management Information Base (u-MIB) hierarchy.
3) Underwater Management Information Base (u-MIB) contains the collection of MOs. u-MIB acts as the database for the device management in the underwater environment.
4) Managed Object (MO), also known as u-MIB object. Managed elements contain many MOs. An MO is made up of one or more objects and its data is gathered in to the MIB. An OID uniquely identifies the managed object in the MIB hierarchy tree.
5) Management Application (MA) is the software installed in U-NMS for the management of the entire network system.
6) Communication protocols (CP) are the standards used to control the communication between Agent and Network Management Station.

7) Operating system (OS) is the software used in the server for managing the hardware and other resources inside the system.
8) Communication module is used to exchange the information between different modules.
9) Data values are the MO values in u-MIB.

Figure 10 shows the components of the management station.

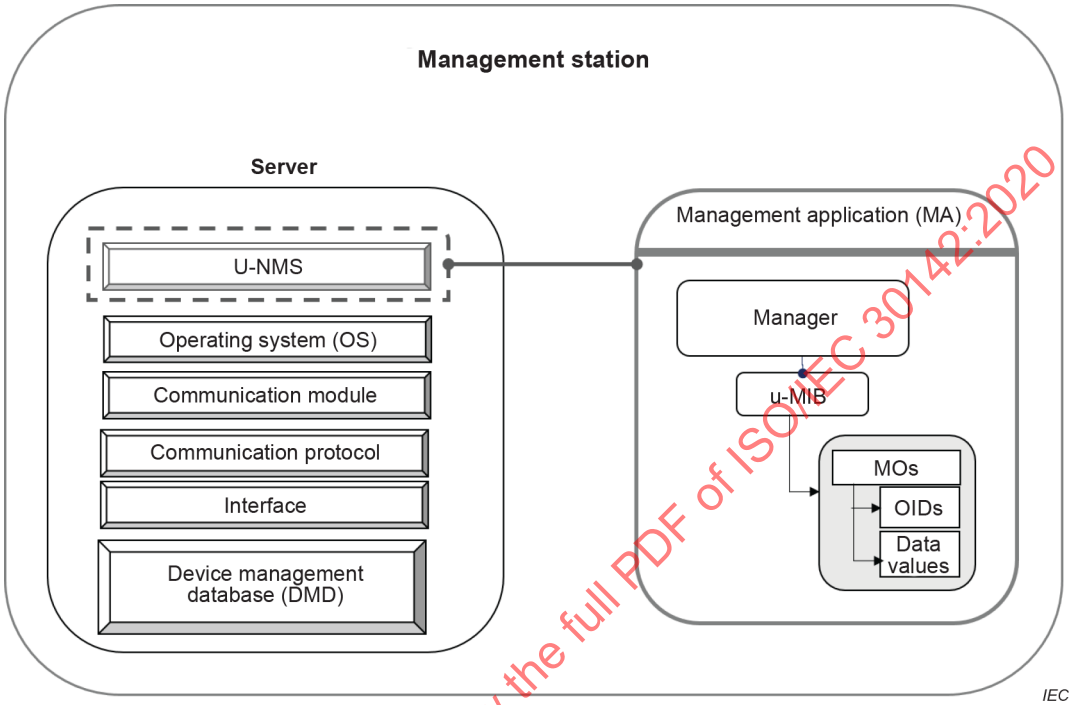

Figure 10 – Management station

7.2 U-NMS agent

7.2.1 General

In U-NMS, an agent is a software program that manages the devices installed in underwater. This program in the device allows the Network Management Station to manage the devices, e.g. UWA-SNodes, UWA-CH, UWA-GW, and UUVs.

The agent performs the following operations:

- storing information locally;
- transmitting the collected information to the manager;
- providing status information of each node; and
- giving the response in accordance with the manager's request.

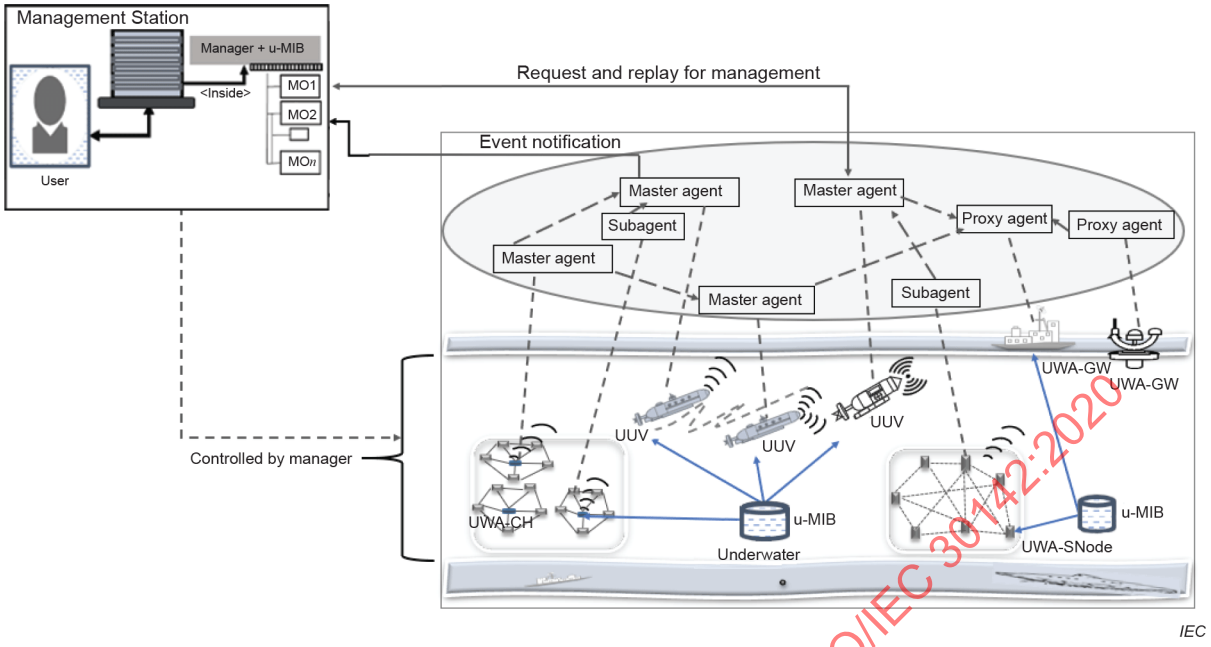

Figure 11 – U-NMS agent architecture

Figure 11 shows the agent architecture of different devices in underwater. The U-NMS consists of devices such as management station, UUV, UWA-GW, UWA-CH and UWA-SNode. Each device is installed with different types of agents such as master agent, subagent and proxy agent, as shown in Table 1.

Table 1 – Types of agents in different devices of U-NMS

Devices	Agents
UUVs	Installed with master agent
UWA-GWs	Installed with proxy agent
UWA-CHs	Installed with master agent
UWA-SNodes	Installed with subagent
Management station	Installed with manager

7.2.2 Types of agents

7.2.2.1 Master agent

Master agents are the programs installed in the devices such as UUVs and UWA-CHs, which receive the message from the subagent and transfer the message to the manager via the proxy agent.

7.2.2.2 Subagent

The subagent can collect the data from the environment or from other sensor nodes and then pass the data to the master agent. For example, mines, minerals, fish source, etc.

7.2.2.3 Proxy agent

The proxy agent is the software program installed in UWA-GWs that acts as the interface between UUVs and management station. Therefore, in the U-NMS the proxy agent can transfer the message from master agent to management station.

7.2.3 Elements of agent

Figure 12 shows the components of agents in the U-NMS.

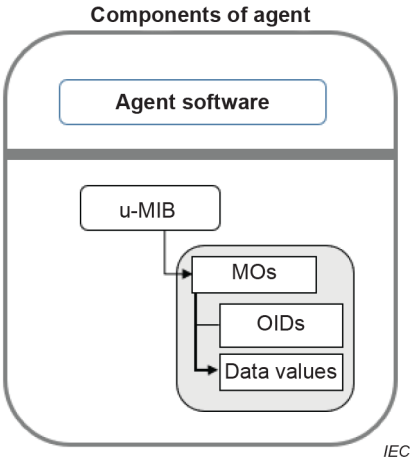

Figure 12 – Components of Agent

- u-MIB acts as the database for each device in the underwater environment. It contains the collection of MOs, OIDs.
- MOs consist of managed value for management system.
- OIDs are the unique number for each object.
- Agent software is the application installed in each device for management.

7.2.4 Underwater Management Information Base (u-MIB)

u-MIB is the collection of managed objects (MOs) and it acts as the database for the management of each device in the underwater environment. The u-MIB shall be known to agent and the manager. The devices like UWA-SNode, UWA-CH, UWA-GW, UUVs, etc. consist of u-MIB for the individual management of each device. MOs are the components inside the u-MIB and the MO consists of OID and values.

Figure 13 shows the u-MIB structure of different devices.

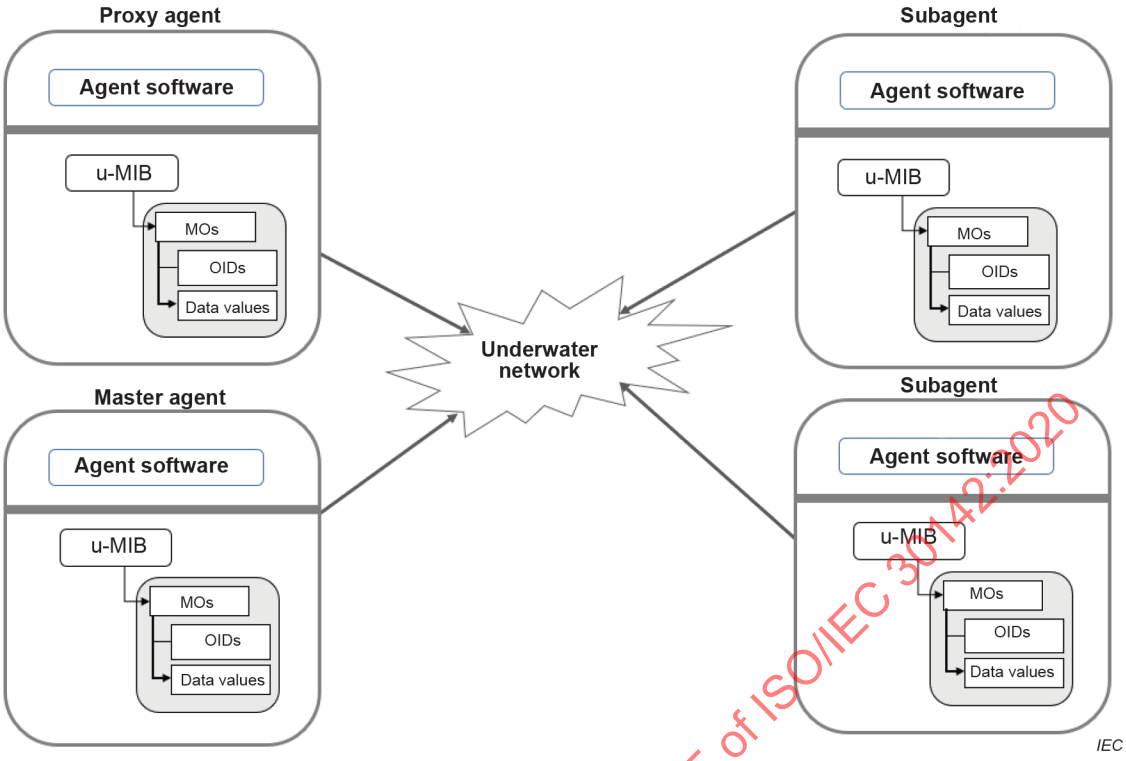

Figure 13 – u-MIB in different devices

7.3 Managed elements

Figure 14 shows the description of managed elements in U-NMS. Managed elements are the devices installed with agent software, which are properly monitored and controlled underwater devices. The managed elements consist of u-MIB. The data is stored inside the u-MIB of each device.

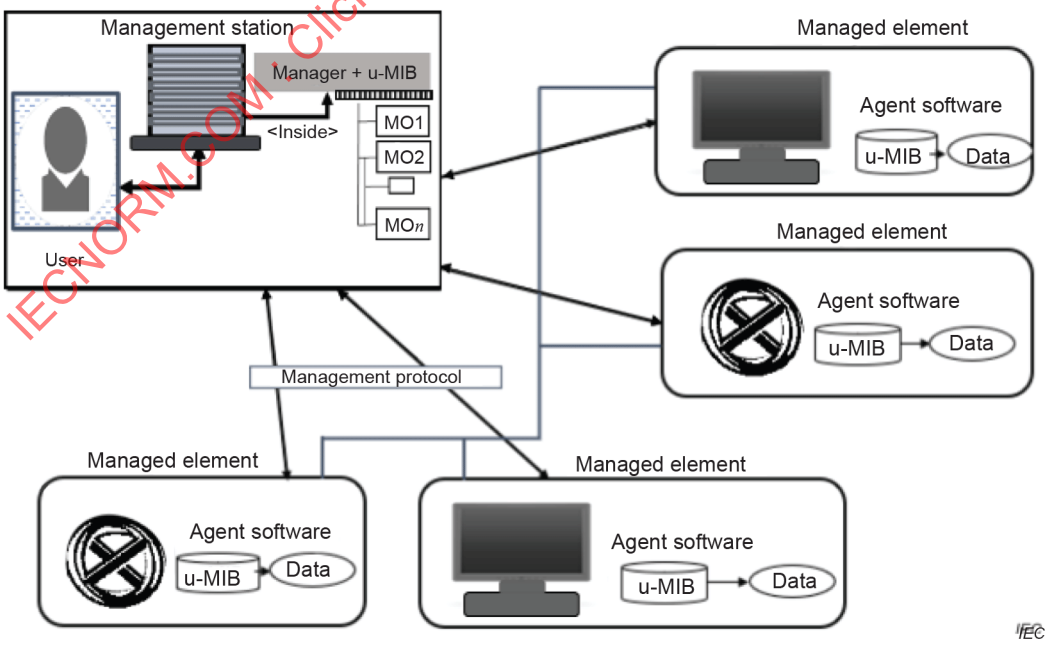

Figure 14 – Managed elements

7.4 Management protocol

Figure 15 shows the structure of management protocols. In U-NMS, the management protocols are the standards used to control the communication between agent and manager. The management protocols run between the management station and the managed elements. The management station can send the query to a managed element and will get a response through agents.

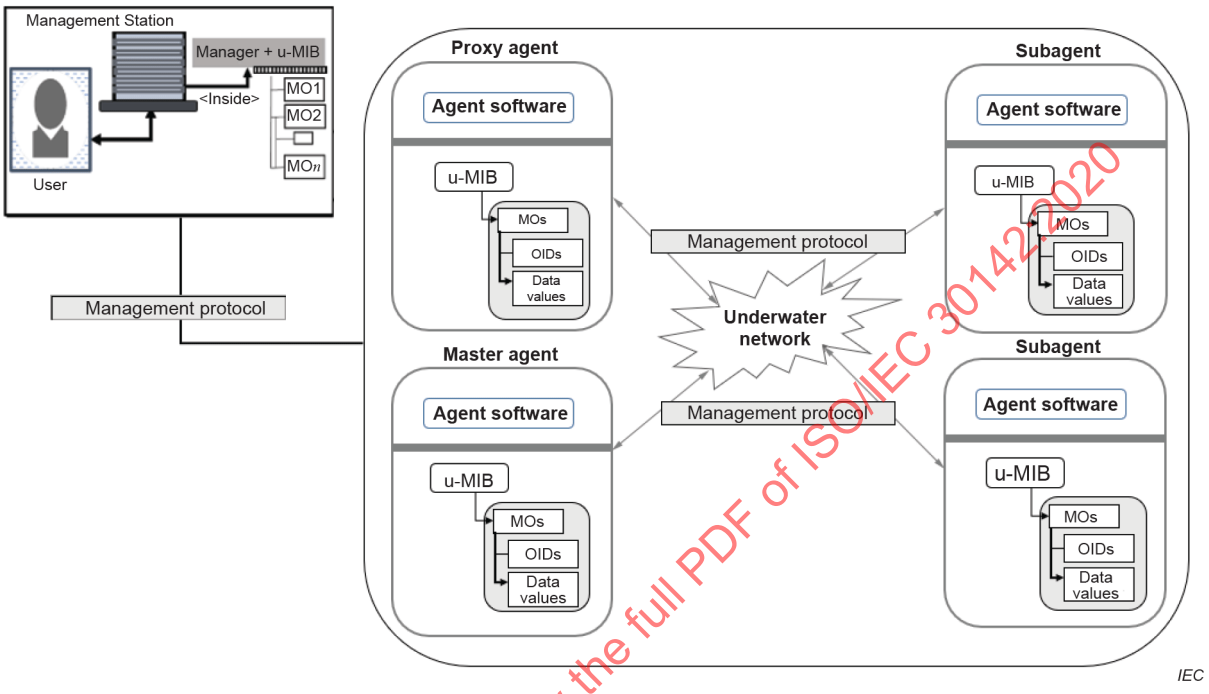

Figure 15 – Management protocol in U-NMS system

The methods performed by U-NMS protocols are as follows.

– Get request: The get request message is used to request specific data from the agent. The get request message is used by the manager.

– Get response: To provide the corresponding response to the request message, the get response message is used. The get response message is used by the agent.

– Set request: In agent, the set request message is used to modify the value of MO.

– Set response: To provide the corresponding response to the set request message, the set response message is used.

– Trap: This message is used by the agent. If the device has some problems, the agent in the device sends the trap messages to the manager.

8 Requirements of U-NMS

8.1 U-NMS general requirements

The general requirements for U-NMS are shown in Table 2.

Table 2 – General requirements of U-NMS

General requirements	Description
Manager console	In the U-NMS, the manager console shall be the user or the device that is used to control the whole functions of underwater network.
Management station	In the U-NMS, the management station consists of DMD, manager, manager console and application. It shall be used for the data management.
DMD	In the U-NMS, device management database (DMD) acts as the main database. It shall be used for storing and managing information.
Managed elements	These are the devices which are installed with agents, e.g. gateway, nodes, etc. This should be used for the management of individual devices.
User	Users are the people who should use the service of the U-NMS.
Agent	The agent should be used in each device for management process. Agent is the program installed in each device for communication. The communication with each device is possible only through agent.
Management protocol	In the U-NMS, the management protocols are the standards that should be used to control the communication between the manager and agent.
u-MIB	In the U-NMS, u-MIB is the collection of MOs, acts as the database that shall be used to store information of individual devices.
Service provider	The service provider shall support the communication services for the U-NMS.
Power management system	Power management system should be used to control the energy in whole system.
MOs	A managed object (MO), also known as u-MIB object. Managed elements contain many MOs. An MO is made up of one or more objects and its data is gathered into u-MIB. An OID uniquely identifies the managed object in the u-MIB hierarchy tree.
Scalability	In the U-NMS, scalability is much needed to scale with the number of underwater devices. It should be operating efficiently in any network size and topology.
Timeliness	Timeliness shall be used in the U-NMS to evaluate the quality of service provided by the system.
Affordability	The U-NMS should be affordable to the users who need to use the management system.
Adaptability	The adaptability shall be used for the adaptation of each device in the underwater environment.
Supportability	The U-NMS should support the operation performed by the system.
Security	In the U-NMS the security should be to support authentication, authorization, integrity and confidentiality.
Deployment	In the U-NMS, the deployment shall be used for setting up the system with required hardware and software.

8.2 U-NMS functional requirements

The functional requirements for U-NMS are shown in Table 3.

Table 3 – Functional requirements of U-NMS

Functional requirements	Description
FCAPSC	In the U-NMS, FCAPSC shall be used for the solid management of each device in the underwater environment.
Fault management	In the U-NMS, the fault management should be used to perform the functions such as fault detection, isolation and correction.
Fault occurrence	These are the types of data sent from the agent to manage the fault notification, e.g. alarm generation. Should be used to identify the faults in the U-NMS.
Fault location identification and type	This function shall be used to identify the location of fault and type of fault, e.g. fault in power system, network service failure.
Fault correction	This function should be used to correct the faults occurring in devices or the network.
Configuration management	In the U-NMS, configuration management shall be used for reconfiguration, change detection and software updating in the U-NMS.
Configuration of devices	Configuration of devices shall be used to send the data from the manager to the agents for making connections between them.
Operations	The U-NMS should use methods such as GET, SET, TRAP, etc. for the management of devices in underwater.
Account management	Account management shall be used to check that the underwater network and the system are used efficiently by each user who is using them.
Discovery of devices	The U-NMS enabler should provide a mechanism for a device to discover the URL or other method of booting managed devices.
Security management	User authentication, control access and confidentiality should be performed here.
Management authority	Management authority has the mechanism to assess the data priority when multiple users try to access the object at same instance.
Time synchronization	In the U-NMS, the time synchronization should be used for the synchronization of each device in underwater.
Address management	Each of the devices has the individual address which is stored and managed in DMD. So address management should be used for the identification.
Performance management	It shall be used to control the memory performance, storage capacity, processor performance and operating system performance of a system in the underwater environment.
Constrained management	Constrained management in the U-NMS should be used to handle the constrained environment of underwater and to provide good service.
Data forwarding	The U-NMS should require data forwarding techniques for transferring the information between one node and another node.
Management of object	The system should be used for the devices and the attributes of each device in it.
Energy status monitoring	The U-NMS should require energy status monitoring function to collect and expose information about device energy parameters and usage. There are battery level and average power consumption.
Network management	The U-NMS should manage routing, traffic control, name management, etc. in the U-NMS. The U-NMS supports manager and an underwater agent (agent). Especially, the agent can deploy individually in each underwater device.
Discovery of network	In the U-NMS, the communication protocol should be used for the discovery of subnets.
Capacity planning	The capacity planning shall be used to minimize the power usage. For example, by keeping the unused nodes in sleeping mode.
Inventory management	The U-NMS should support inventory mechanism with optional management capability of devices and their exposure via at least one management protocol.
Interface support	The U-NMS enabler should maintain interfaces to manipulate the Management Information Base tree.
Interoperability support	In U-NMS, the interoperability shall be used to maintain the communication in heterogeneous network.

8.3 U-NMS constrained requirements

The constrained requirements for U-NMS are shown in Table 4.

Table 4 – Constrained requirements of the U-NMS

Constrained requirements	Description
Support localization	In underwater application some of the nodes such UUVs, AUVs, etc. need to move from one place to another for collecting data. In this case the localization should be used to find the location of the nodes.
Network scalability	Network scalability is related to the expansion of network coverage and the increase in the number of devices.
Interoperable management	In the U-NMS, interoperable structure is essential for the management of scalability and robustness in constrained environment. So, the interoperable management is needed.
Automatic resynchronization	Used in large scale network, if some devices are in offline mode. The automatic resynchronization should be used to pass the configuration parameters and it will make the temporary coverages.
Link support for unreachable devices	Device links are identified based on transmission loss or latency. Using the "sleep" label the whole network can get disconnected for a long period. So, the link support for unreachable device is needed.
Notifications	All the devices in the constrained environment should use the notify method to send a notification message when some critical events occur.
Self-healing	In case of some device failures, the devices should use the self-healing functions such as self-reset, self-configuration, etc.
Discovery of network topology	In constrained network the discovery of network topology function should be used to find the state of the network and to explore the information about the network.
Device recovery mechanism	The constrained devices should use individual recovery mechanism.
Network recovery mechanism	Constrained network should need the central underwater recovery mechanism.
Passive monitoring mechanism	Passive monitoring mechanism should monitor and collect the group of information about the network and the devices, and then do the analysis process.
Reactive monitoring mechanism	If some events occur in the network or devices, the underwater central manager should react automatically with the help of some applications such as reactive monitoring mechanism.
Self-monitoring	Self-monitoring mechanism should be used to monitor the activities of each device by itself.
Network status	This function should be used to check and monitor the connection and status of the network.
Energy status	This function should be used for each device to monitor its average battery usage and current battery level.
Device resource availability checking	This function should be used to estimate the available resources of individual devices such as battery, memory, consumption power, etc.
Underwater device status	This function should be used for sudden fault identification and problem solving. For example, if some of the devices are not working properly, the nearby nodes need to send the status of node.
Underwater network reconfiguration	In case of node failure and the communication failure in the network, the hierarchical network reconfiguration should be used in the U-NMS.
Support extensibility of protocol	The extensibility of protocol should be ensured if a new protocol mechanism is inserted, which shall be compatible with the older format without any problem with interoperability and the large number of devices.
Data compression	The data compression techniques should be used for exchanging the data, which can in turn reduce the time for data transmission.
Local recovery mechanism	This function should be used to resolve the problems of each device by its own mechanics.
Hierarchical recovery mechanism	This mechanism should operate inside the network management station for the recovery of the whole network in the U-NMS.
Central recovery mechanism	This mechanism should be used by the master agent for the recovery of the whole network if some problem occurs in the network management station.

Constrained requirements	Description
Support logging event	The logs of events should be used for the proper management of the U-NMS; therefore, this can support fault management (when crossing the limit).
User management	The user management shall be used for accessing the U-NMS, by setting username and password for every user.

9 Model for underwater network management

9.1 FCAPSC modelling for the U-NMS

The FCAPSC modelling for the U-NMS is shown in Figure 16. The processing and connection between FCAPSC functions are described. The FCAPSC functions in the U-NMS are designed inside the management station, when a fault occurs that can affect all other functions inside the system. The hierarchical structure of FCAPSC modelling is shown here; once a fault occurs, it can affect the configuration between devices and so it will decrease the performance of the system.

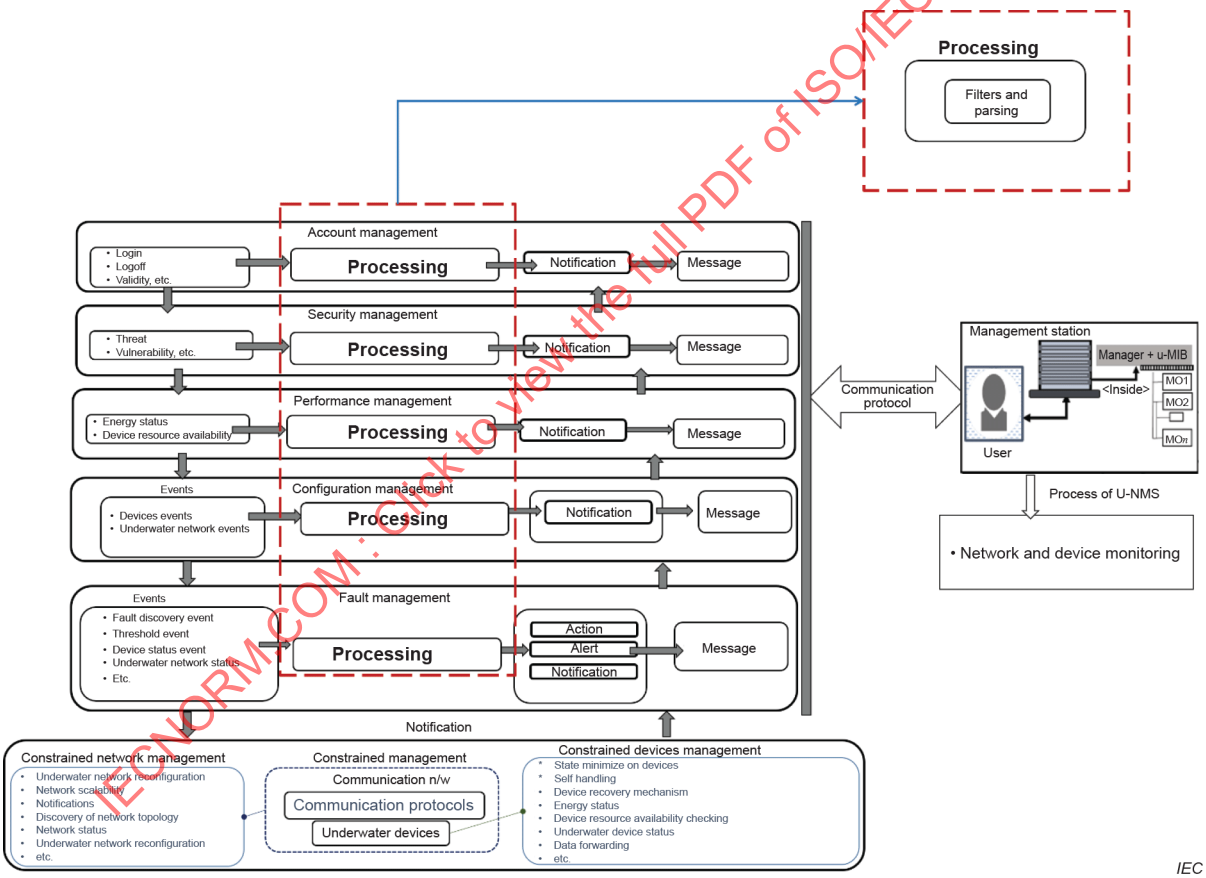

Figure 16 – FCAPSC modelling for the U-NMS

9.2 U-NMS architectural model

An architectural model is a blueprint for designing the system. Using this architecture, the developers can model the U-NMS system for new applications.

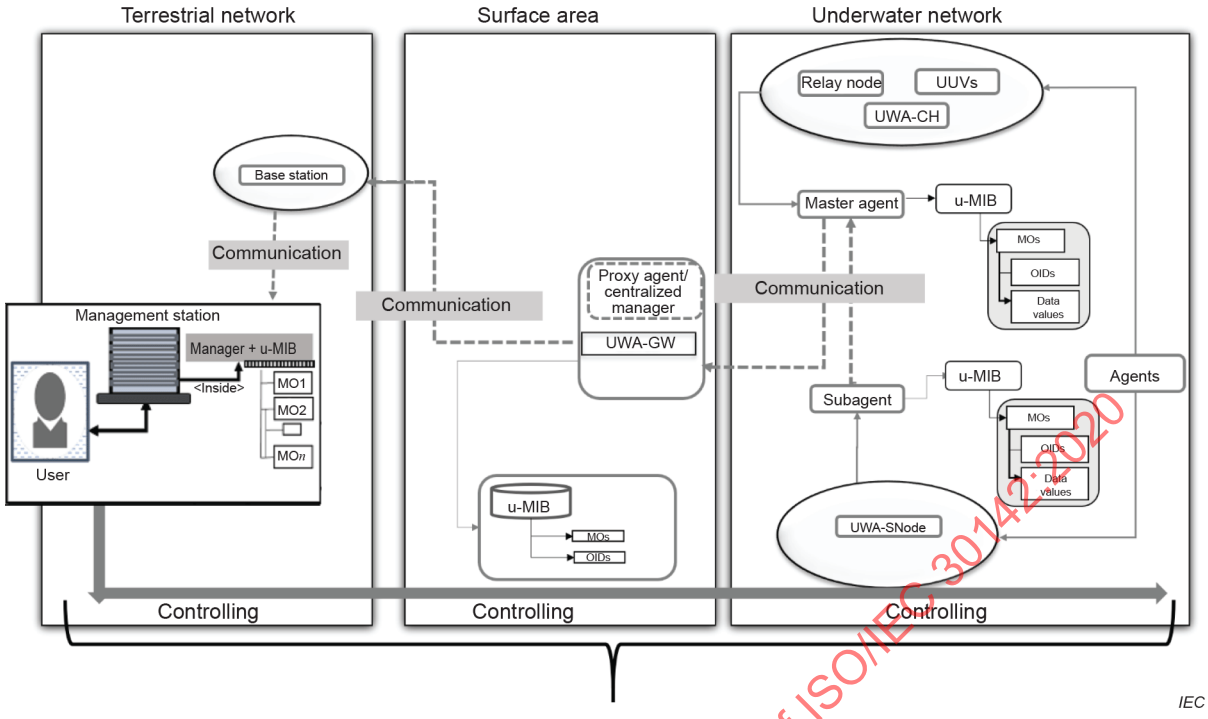

Figure 17 – U-NMS architectural model

Figure 17 shows the architecture model of the U-NMS. Using this architectural model, the users can understand the management process of the U-NMS. In the U-NMS, the management processes are done in the underwater network, surface area network and terrestrial network. In the underwater network, the subagents collect the data and are managed independently. The master agents collect the data from subagents and send it to the proxy agents. The proxy agents transfer the data to a base station. Finally, all data are stored and managed within the underwater network management station. The proxy agent can also act as the manager in the U-NMS. The management functions, FCAPSC, are managed in the underwater network management station. The manager monitors and controls all the activities. Every component in the agents such as MOs, OIDs are combined for the management of each device.

9.3 U-NMS specific architecture

Figure 18 shows the U-NMS architecture for the management of the underwater network (see Annex A). The architecture is designed using the components such as management station, u-MIB, protocols, MOs, proxy agent, master agent, subagent, etc.

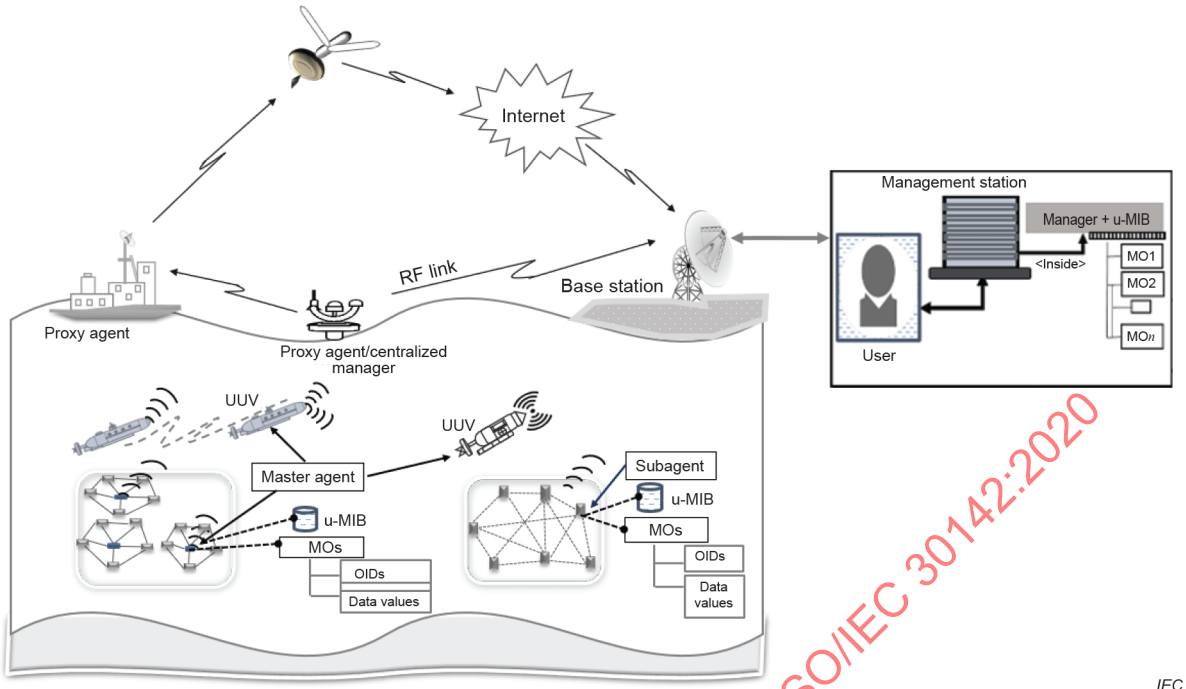

Figure 18 – U-NMS specific architecture

Annex A
(informative)

U-NMS use cases

A.1 General

UWASN is a constrained environment as compared to the terrestrial network environment. For this reason, a different underwater network management process or system should be defined for efficient management of UWASN. Environmental monitoring, detection of pipeline leakages, exploration of natural resources, fish farming and harbour security use cases are considered for efficient design of U-NMS for UWASN.

A.2 Environmental management use case

A.2.1 Description

A huge number of UWA-SNodes, UWA-GW and other devices deployed in underwater – combined with network management components such as agent, network management station u-MIB, internet service, MOs, etc. – are used for the management of the underwater environmental monitoring application. In this case, the management is done automatically and reduces the human efforts. With this environment monitoring system, services like water quality monitoring, depth monitoring, sound source monitoring, etc. are managed at the underwater network management station.

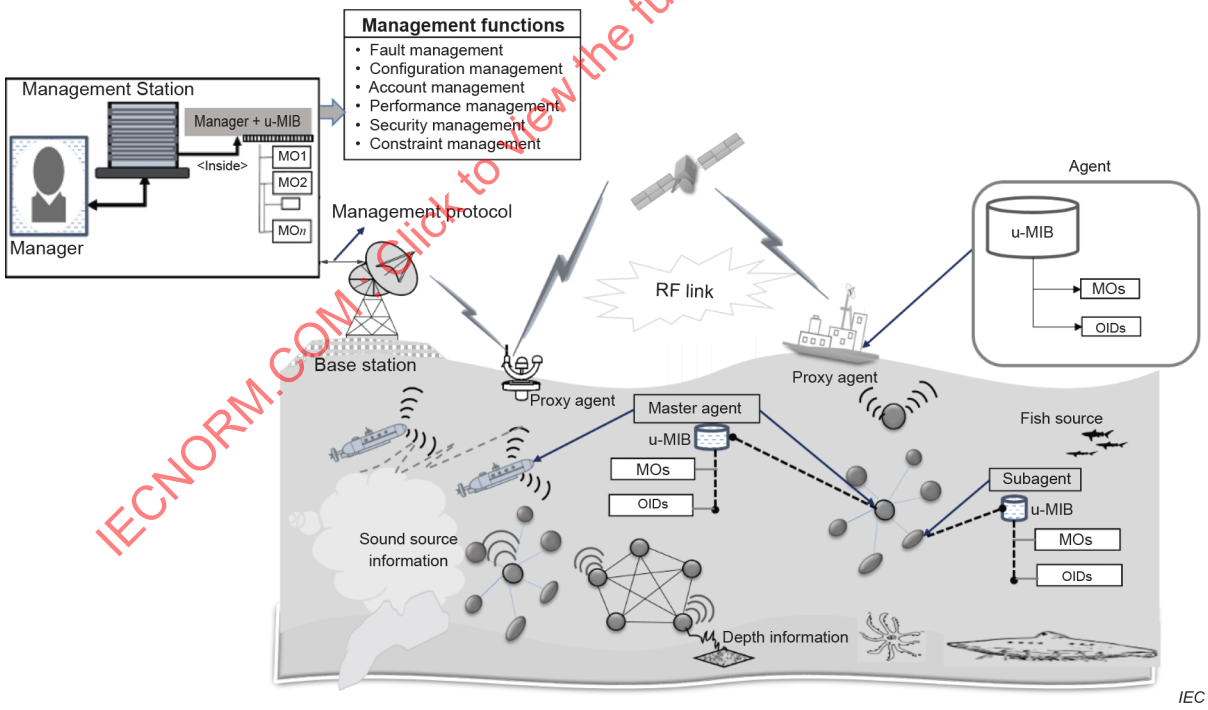

Figure A.1 – Environmental management use case

Figure A.1 shows that the management components such as agent, network management station, manager, management protocols, etc. are used for the management of environmental monitoring application. The UWA-SNodes are the subagents and UWA-CH and UUVs are the master agents in this application. The information collected from the subagents is passed to the master agents such as UWA-CH, UUVs, etc. From the master agent, the proxy agents are used to collect and transfer the data to the network management station via a base station. The agents are managed individually using u-MIB. Every information is finally stored and managed by the network management station. The management protocols are used for the underwater condition. Using this environmental monitoring use case, the information like fish source, sound source, depth, etc. is managed properly.

A.2.2 Actors

The actors used for the management of environmental monitoring application are listed below.

- Underwater-network management station: This is commonly known as network management station. The information such as sound source, fish source, depth, etc. is stored and managed in the station.
- Manager: The underwater network management station is controlled by the manager.
- Service provider: The service provider supports the communication services for U-NMS.
- Agent: Agents are software programs installed in devices used for the management of the environmental monitoring application, e.g. UWA-GW, UUV, UWA-SNodes, etc.

A.2.3 Potential requirements

The requirements for the management of environmental monitoring application are shown in Table A.1.

Table A.1 – Potential U-NMS requirements of environmental monitoring application

Requirements	Description
Device management database	DMD acts as the main database for storing information.
Agents	Agents are the software program installed in devices for communication process.
Management protocol	The management protocols are the standards used to control the communication between the agent and management station.
u-MIB	u-MIB is the collection of MOs, and acts as the database for the management of individual devices.
MOs	The MOs act as the device drivers that can communicate with the devices.
Network services	The network services are provided by the services provider for terrestrial and the underwater environments.
Manager console	The manager console can be the user or the device which can control the whole functions of the underwater network.
RF communication	In the U-NMS, the RF communication is used in the terrestrial area network for transferring data.
Acoustic communication	In the U-NMS, the acoustic communication is used in the underwater area network for transferring data.

A.2.4 Environmental monitoring and management use case diagram

In Figure A.2, the use case representation for the management of environmental monitoring application is shown. The manager will control the network management station for the management of all agents in the underwater and terrestrial environments. The subagent collects the information and sends it to the master agent, and the master agent sends to the proxy agent. From the proxy agent the data are transferred to the network management station via a base station. The received data are properly managed in the network management station.

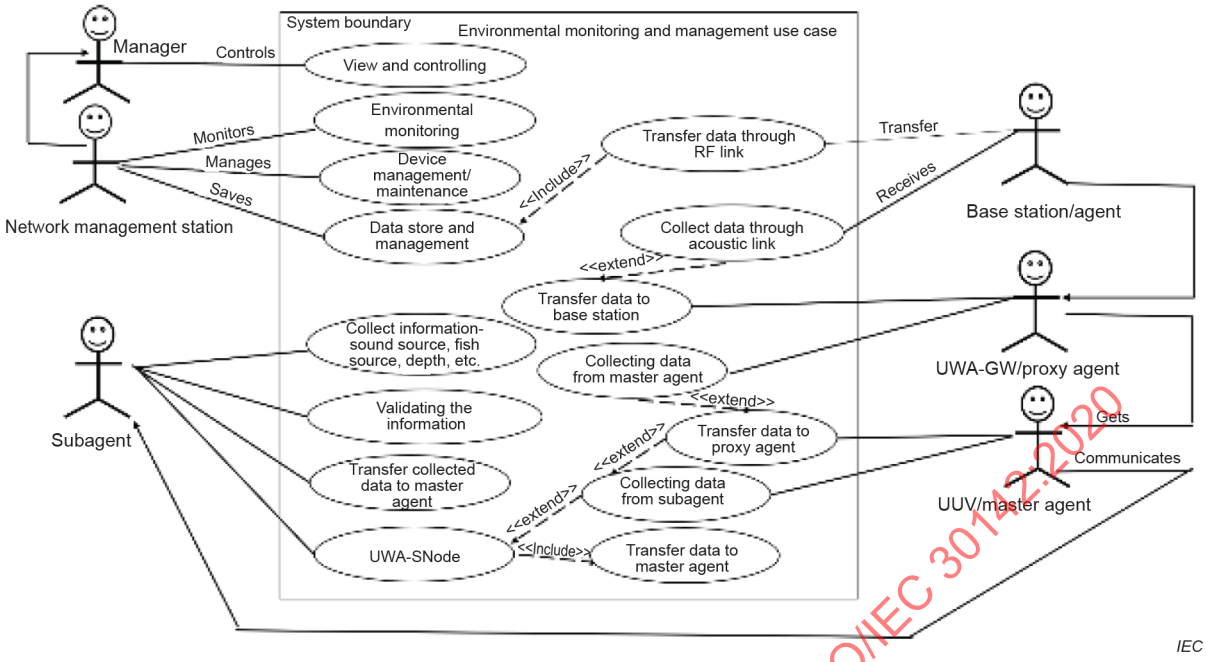

Figure A.2 – Environmental management use case diagram

Figure A.3 shows the use case for environmental management in the network management station. In this case, the network management station can perform operations such as fault management, configuration management, account management, performance management, security management and constrained management.