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Internet of Things (IoT) – Overview and general requirements of IoT system for ecological environment monitoring

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INTERNET OF THINGS (IoT) – OVERVIEW AND GENERAL REQUIREMENTS OF IoT SYSTEM FOR ECOLOGICAL ENVIRONMENT MONITORING

FOREWORD

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ISO/IEC 30179 has been prepared by subcommittee 41: Internet of Things and Digital Twin, of ISO/IEC joint technical committee 1: Information technology. It is an International Standard.

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

Draft	Report on voting
JTC1/SC41/316/FDIS	JTC1/SC41/329/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1, available at www.iec.ch/members_experts/refdocs and www.iso.org/directives.

INTRODUCTION

The IoT-based ecological environment monitoring system is mainly for collecting data and monitoring the ecological environment entities (i.e. physical things in the IoT sense – air, water, soil, and living organisms) using various types of sensing devices. Such sensing devices include but are not limited to the following: growth meters for plant growth; infrared digital cameras and video cameras for identifying animal movements; tracking devices for position and location reporting; and physical, biological or chemical sensors for air, water, and soil monitoring. The collected data are transmitted via a network infrastructure, analysed for their relationships and evaluated for the trends of the eco-environment being monitored. With the current IoT and related technologies, for example, information and communication technologies, all these capabilities can be performed in real-time. Therefore, the IoT-based monitoring system satisfies the requirement of the real-time eco-environment monitoring and management in terms of data capture, data analytics, early warning services, and disaster management and emergency management. This system supports the decision-makers, for example, eco-environment managers, government agencies, and citizens, in the maintenance of the ecosystem and in correcting and restoring the ecosystem when damaged or polluted ecological environment is detected.

Eco-environment has been greatly altered with the development of the economy and humanity. The alteration of the eco-environment endangers the health of all living organisms including humans. More efforts to monitor and protect the earth's eco-environment will improve understanding and support corrective actions.

A number of regional scale eco-environment observation networks are constructed to monitor the ecosystem of air, water, soil, plants, animals. Examples of these regional eco-environment observation networks are GEMS (Global Environment Monitoring System), GTOS (Global Terrestrial Observing System), and ILTER (International Long Term Ecological Research). National scale eco-environment observation stations also exist to monitor water, forest, grassland, farmland, lakes, rivers and coastline. These national scale observation stations are parts of global eco-environment observation networks.

The trends of the eco-environment observation stations require united data sharing and networking, being standardized and automated, and likely to become intelligent. These trends are likely to become the requirements of eco-environment monitoring systems. Therefore, IoT-based systems can be applied to the eco-environment observation systems and networks to meet these requirements. The IoT-based eco-environment monitoring system can provide the accurate and comprehensive sensing of the physical entities (i.e. air, water, soil, and living organisms), reliable data transmission and reception, and intelligent information processing.

Since the 1990s, sensor network systems, which transitioned to the most essential part of the IoT-based systems in the 2000s, have been used for monitoring the environment quality, pollution, and living organisms. For example: the CitySense system in the US was developed for real-time monitoring of the environmental pollution in the city; multitudes of air quality monitoring systems have been deployed to monitor air quality and pollution all over the world; China has initiated the sandstorm and acid rain monitoring system; UC Berkeley is monitoring the birds in Great Duck Island; and Australia monitors underwater temperature and brightness of light to protect the coral reef.

Using the IoT technologies for ecological environment monitoring brings the following advantages in the ecosystem monitoring and management:

1) transforming from a single-point monitoring station to a multi-point network monitoring application through networking and data sharing;
2) ensuring the real-time and dynamic observation and measurements by effectively adapting to the monitored objects' complexity and variability compared to the measurements made manually and by legacy systems;
3) enabling pro-active actions toward ecological events in advance rather than reacting after the events take place;

4) realizing a multi-level and unified management of the observation stations and systems;
5) observing the entire ecosystem rather than geographically divided areas or regions (i.e. by using a single point observation) in both macro and micro perspectives; and
6) analysing the relationships among ecological entities to ensure the sustainable ecosystem and its development.

Standardizing the IoT-based eco-environment monitoring systems brings the benefits such as the enablement of on-demand, real-time monitoring for eco-environment, the improvement in the interoperability among all standardized eco-environmental monitoring systems which include hardware and software to realize the EEM worldwide, the full utilization of the observed data for various kinds of eco-environment applications referring to comprehensive functions and services of EEM system including analysis of the relationships between various ecological entities, and the study of the changing trends of the ecosystem.

IoT-based monitoring systems also bring benefits for relevant stakeholders, including the users and builders of the IoT-based eco-environment monitoring systems. The users include the following:

– public users, citizens, data scientists for eco-environment;
– the monitoring organizations such as city environment monitoring organizations and wild area ecosystem monitoring organizations; and
– government agencies responsible for managing the entire ecosystem.

The builders are the developers of the communication modules and integrated devices, sensing devices, and monitoring service platforms for the IoT-based eco-environment monitoring systems.

INTERNET OF THINGS (IoT) – OVERVIEW AND GENERAL REQUIREMENTS OF IoT SYSTEM FOR ECOLOGICAL ENVIRONMENT MONITORING

1 Scope

This document specifies the Internet of Things system for ecological environment monitoring in terms of the following:

– system infrastructure and system entities of the IoT system for ecological environment monitoring for natural entities such as air, water, soil, living organisms; and

– the general requirements of the IoT system for ecological environment monitoring.

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 9834-8:2014, *Information technology – Procedures for the operation of object identifier registration authorities – Part 8: Generation of universally unique identifiers (UUIDs) and their use in object identifiers*

3 Terms and definitions

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

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

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

3.1
ecological environment monitoring
EEM
process or activity that uses physical, chemical, biochemical, ecological and other technologies for the purpose of reflecting accurately, comprehensively, and in a timely manner the various elements of the ecological environment, the relationship between organisms and the environment, and the change trend of the ecosystem

Note 1 to entry: Elements of the ecological environment include air, water, soil, and living things.

4 Symbols and abbreviated terms

ASD	Application and Service Domain
EEM	ecological environment monitoring
GDPR	General Data Protection Regulation
GIS	geographic information service
HMI	human–machine interface

IoT Internet of Things
IP Internet Protocol
OMD Operations and Management Domain
PED Physical Entity Domain
QR quick response
RAID Resource Access and Interchange Domain
RFID radio frequency identification
SCD Sensing and Controlling Domain
TCP Transfer Control Protocol
UD User Domain
UDP User Datagram Protocol

5 IoT system overview for ecological environment monitoring

5.1 System infrastructure overview

The system infrastructure of the IoT-based ecological environment (i.e. eco-environment) monitoring (EEM) system is described by the Domain-based IoT Reference Model in the IoT Reference Architecture of which the entities are specifically defined for eco-environment monitoring as shown in Figure 1. The system infrastructure of the IoT system of EEM follows the reference architecture of ISO/IEC 30141:2018.

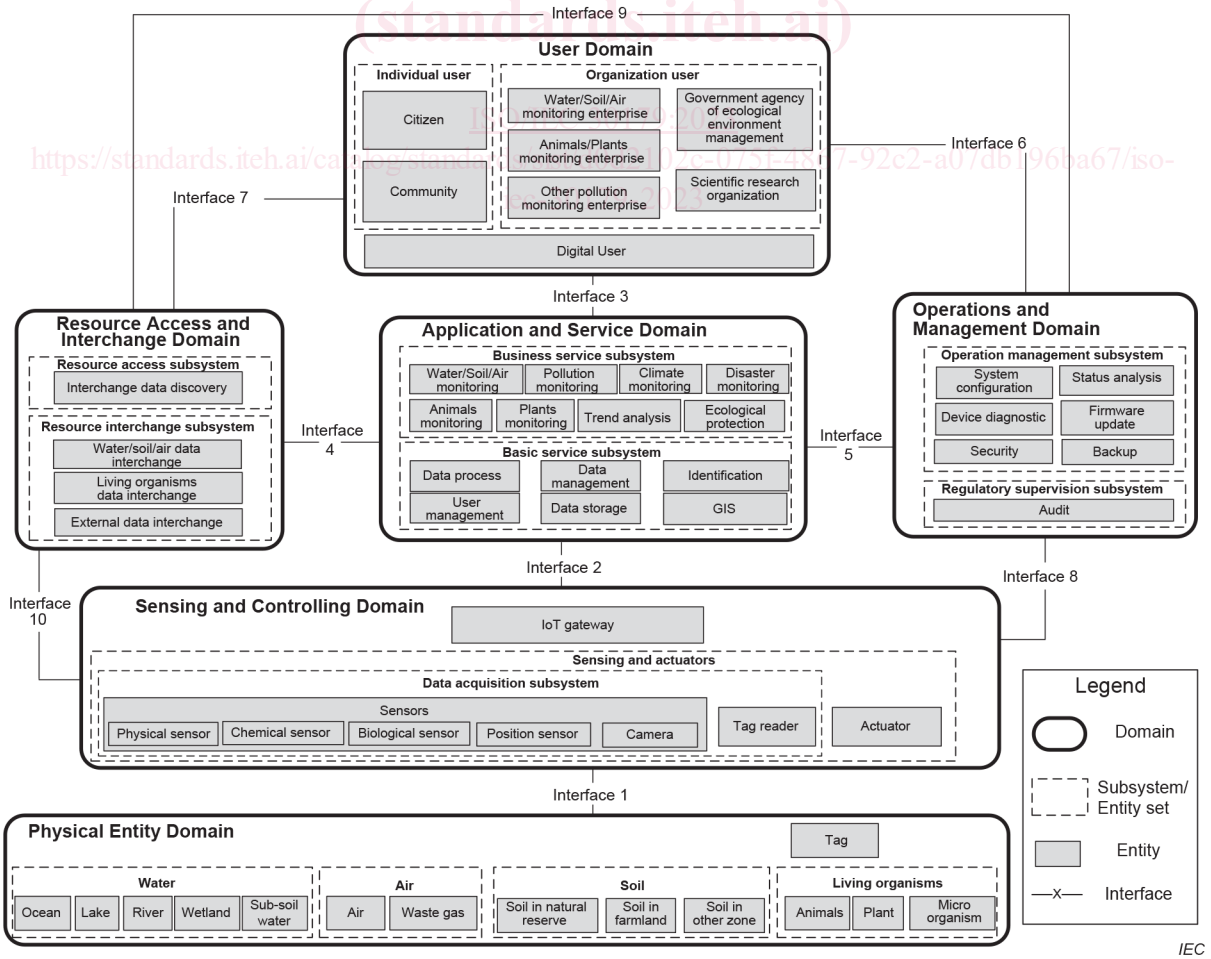

Figure 1 – System infrastructure of IoT system for EEM

5.2 Entities description

5.2.1 Entities in Physical Entity Domain (PED)

The PED mainly consists of the physical objects being sensed by various types of sensors and, for some instances, controlled by certain actuators. Additionally, tags (e.g. barcode, QR code, and RFID) can be attached to some physical objects such as animals and plants. These physical objects are designated as the physical entities which are not only for the IoT-based EEM applications but also are of interest to the users in the User Domain. Typically, four types of physical entities, namely the entity sets, are in the PED, including air, water, soil, and living organisms in grassland, wetland, desert, water body, farmland, city, as shown in Table 1.

Table 1 – Entity descriptions in PED

Entity set	Entity	Entity description
Air	Air	The parameters and quality of air (including temperature, humidity, precipitation and air pressure).
	Waste gas	The component of waste gas (including greenhouse gas).
Water	Ocean	Water quality, salt water body, and acoustic noise and signals.
	Lake	Water quality, immobile fresh water body, and acoustic noise and signals.
	River	Water quality, moving water body, acoustic noise and signals.
	Wetland	Water quality, land area covered or saturated by water.
	Sub-soil water	Water quality, water body immediately below the surface of the soil.
Soil	Soil in natural reserve	The composition, pollution index, geology and other characteristics of soil in the areas of the natural reserve protected by official agency or organization and key areas such as water source zone, tea garden and pasture.
	Soil in farmland	The composition, pollution index, geology, and other characteristics of soil for growing grain, vegetables, fruits, etc.
	Soil in other zone	The composition, pollution index, geology, and other characteristics of soil in other areas such as city, construction areas, pollution accident.
Living organisms	Animals	The growth, activity, living status, and other parameters of all types of animals including water-borne animals, fish, and marine mammals.
	Plant	The growth process and status of all types of plants (e.g. forest.) in grassland, wetland, desert, water body, farmland, city, and also including water-borne plants and planktons (e.g. bacteria, archaea, algae) in water or surface of water body.
	Microorganism	The parameters of the microorganism including the number, type, growth process, status of the microbe or microbes.

5.2.2 Entities in Sensing and Controlling Domain (SCD)

In the SCD, the entities are deployed to collect and integrate data from the PED and receive data from domains through different ways which consist primarily of sensors, actuators, tag readers and IoT gateways.