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Information technology — Sensor networks: Sensor Network Reference Architecture (SNRA) —

Part 3: Reference architecture views

Technologies de l'information — Réseaux de capteurs: Architecture de référence pour réseaux de capteurs —

Partie 3: Vues de l'architecture de référence

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of the joint technical committee is to prepare International Standards. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights.

ISO/IEC 29182-3 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*.

ISO/IEC 29182 consists of the following parts, under the general title *Information technology — Sensor networks: Sensor Network Reference Architecture (SNRA)*:

- *Part 1: General overview and requirements*
- *Part 2: Vocabulary and terminology*
- *Part 3: Reference architecture views*
- *Part 4: Entity models*
- *Part 5: Interface definitions*
- *Part 6: Applications*
- *Part 7: Interoperability guidelines*

Introduction

A wide range of applications has been proposed for sensor networks. In practice, however, sensor networks have been built and deployed for a relatively small number of applications. This is partly due to the lack of a business case for certain applications and partly due to technical challenges in building a non-trivial sensor network of reasonable complexity. The main reason for this impediment is multi-disciplinary expertise – such as sensors, communications and networking, signal processing, electronics, computing, and cyber security – is required to design a sensor network. Presently, the design process is so complex that one can leverage little from one sensor network design to another. It appears as if one has to start from almost scratch every time one wishes to design and deploy a sensor network. Yet, upon closer inspection, there are many commonalities in instantiations of sensor networks that realize various applications. These commonalities include similarities in the choice of network architecture and the entities/functional blocks that are used in the architecture.

The purpose of the ISO/IEC 29182 series of International Standards (ISs) is to

— provide guidance to facilitate the design and development of sensor networks,

— improve interoperability of sensor networks, and

— make sensor network components plug-and-play, so that it becomes fairly easy to add/remove sensor nodes to/from an existing sensor network.

The ISO/IEC 29182 series can be used by sensor network designers, software developers, system integrators, and service providers to meet customer requirements, including any applicable interoperability requirements.

The ISO/IEC 29182 series comprises seven parts. Brief descriptions of these parts are given next.

ISO/IEC 29182-1 provides a general overview and the requirements for the sensor network reference architecture.

ISO/IEC 29182-2 provides definitions for the terminology and vocabulary used in the reference architecture.

ISO/IEC 29182-3 presents the reference architecture from various viewpoints, such as business, operational, system, technical, functional, and logical views.

This part of ISO/IEC 29182 categorizes the entities comprising the reference architecture into two classes of physical and functional entities and presents models for the entities.

ISO/IEC 29182-5 provides detailed information on the interfaces among various entities in the reference architecture.

ISO/IEC 29182-6 provides detailed information on the development of International Standardized Profiles.

ISO/IEC 29182-7 provides design principles for the reference architecture that take the interoperability requirements into account.

Information technology — Sensor networks: Sensor Network Reference Architecture (SNRA) —

Part 3: Reference architecture views

1 Scope

This International Standard (IS) provides Sensor Network Reference Architecture (SNRA) views. The architecture views include business, operational, systems, and technical perspectives, and these views are presented in functional, logical, and/or physical views where applicable. This IS focuses on high-level architecture views which can be further developed by system developers and implementers for specific applications and services.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 29182-1, *Information technology — Sensor networks: Sensor Network Reference Architecture (SNRA) — Part 1: General overview and requirements*

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

ISO/IEC 29182-4, *Information technology — Sensor networks: Sensor Network Reference Architecture (SNRA) — Part 4: Entity models*

ISO/IEC 29182-5, *Information technology — Sensor networks: Sensor Network Reference Architecture (SNRA) — Part 5: Interface definitions*

3 Terms and definitions

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

4 Abbreviated terms

1D	One-dimensional
2D	Two-dimensional
3D	Three-dimensional
AL	Application Layer
BFL	Basic Function Layer
CIP	Collaborative Information Processing
CLM	Cross Layer Management

CPU	Computer Processing Unit
GHL	Gateway Hardware Layer
GPS	Global Positioning System
NOAA	National Oceanic and Atmospheric Administration
IS	International Standard
OGC	Open Geospatial Consortium
OS	Operating System
PV	Physical View
RA	Reference Architecture
SL	Service Layer
SNHL	Sensor Node Hardware Layer
SNRA	Sensor Network Reference Architecture
SOA	Service-Oriented Architecture
SV	System View
TS	Technical Standards
TV	Technical View

5 Purpose of Sensor Network Reference Architecture

This International Standard provides reference architecture views consistent with the requirements which are defined in ISO/IEC 29182-1 (General overview and requirements) and can be utilized more effectively with other Parts, especially with ISO/IEC 29182-4 (Entity Models) and ISO/IEC 29182-5 (Interface Definitions).

A Reference Architecture (RA) is a *generalized* architecture of several end systems that share one or more common domains, giving direction downward and requiring compliance upward. Therefore, an architecture for a certain application will contain some, most, or all of the reference architecture. In other words, the developer can reuse entities and elements in the reference architecture that fit his or her application architecture and ignore the rest of entities and elements in the reference architecture. In addition, the RA provides standards and policies for building a specific architecture.

RAs provide a *consistent point of departure* for implementing solutions so that each implementation:

a) Follows a consistent decomposition and design pattern;

b) Reduces cost by exploiting opportunities for reuse of services, products, data definitions, etc.;

c) Reduces schedule by starting with a core architecture to be tailored for implementation; and

d) Reduces risk by:

- Incorporating required global capabilities; and
- Taking advantaged of lessons learned and related expertise.

The Sensor Network Reference Architecture (SNRA) outlines “what” the overall structured approach is for facilitating interoperability and the SNRA, from the details of this structure, indicates “how” the architecture and its entities will operate through the development of interface standards. In short, the SNRA provides rules and guidance for developing and presenting architecture descriptions.

This standard provides not only multiple perspectives of SNRA (e.g. business, information, and technical) but also multiple views of the technical architecture (e.g. physical, system, operational, etc.) describing a sensor network (e.g. business, information, application, and data). The combination of these architecture perspectives and views forms a comprehensive architectural description of the sensor network system. The reference architecture perspectives and views are to:

a) Show how Sensor Networks operate in a homogeneous or a heterogeneous system;

b) Show the systems of equipment and the flows of information that support the sensor networks; and

c) Show the technical rules and guidelines that allow these systems to interoperate.

Typically, a developer begins depicting an architecture with desires and needs for the data/information that could be provided by a sensor network or sensor networks and that could meet the desires and needs (e.g. then translated into a set of requirements). Additionally, the developer needs to have an understanding of the technology available and also the roadmap of technologies to come. For example, the desires and needs could be a computer and a set of sensor nodes (thus, a sensor network) in a car to monitor and control subsystems, or alternatively they could be a large system of systems, such as the sensor networks by National Oceanic and Atmospheric Administration (NOAA) to monitor worldwide weather in order to predict weather patterns and to provide warnings if necessary. Each developer will have specific requirements concerning the capabilities that a sensor node or sensor network should have for target applications and services. The developer also needs to make many decisions in developing a sensor network architecture including whether a sensor network will perform data processing to provide high level information to a user, or a sensor network will make the raw data available to a user who will use its own applications to process the raw data. The Sensor Network Reference Architecture (SNRA) can provide the developer with various options and understanding for the developments, and more importantly, SNRA provides the developer with the architecture starting point.

The SNRA supports the development of interoperating and interacting architectures. It defines the multiple perspectives of SNRA and the multiple views of the technical architecture. Each view is composed of sets of architecture data elements that are depicted via graphic, tabular, or textual products. The SNRA also clearly defines the relationships between these architectural views and the data elements they contain.

6 Overview of Sensor Network Reference Architecture

Sensor network is a system of distributed sensor nodes communicating with each other and also interacting with other sensor networks that monitors environments external to the sensor network in order to acquire, process, transfer, and provide information extracted from a physical world.

This Sensor Network Reference Architecture (SNRA) consists of a set of domains which are concerned with gathering raw data from each domain's physical environment, processing raw data into information, and delivering information to a user or users. The user can be a human or a machine/software (e.g. automated command and control system). In cases where a sensor network has a sensor node or sensor nodes equipped with an actuator or actuators, information in the forms of a decision can flow from the user to the actuator(s) attached to the sensor node to provide an actuation command.

Each sensor network consists of various entities such as sensor nodes, actuators, a network, processing (at a local sensor node, a gateway, and/or fusion centre), applications used by the sensor nodes, applications used by the users[1)], and finally the user. Figure 1 shows a high level physical view of multiple sensor network domains although there are other domains not captured in the figure. Most sensor network domains are designed to be disparate as each sensor network focuses on its own specific application. This figure is to emphasize the importance of interoperability among dissimilar networks, sensors, and

1) [When the user is a person] Personal information belongs to individuals. It shall be implemented with any protection means when personal information is connected to networks. [Reference: NIST-IR7628, Smart Grid Cyber Security Vol.2 "Privacy and the Smart Grid", and OECD: "Privacy Principles"]

disparate data contents and formats. Figure 1 also shows that sensing can occur in all geospatial expanses (e.g. space, air, maritime, ground, and subsurface (e.g. underground, and below ocean/lake/river surface)). In each geospatial expanse, there are many capabilities that sensor networks can provide as shown in the figure. In space, a sensor network formed by the sensor nodes in a constellation of satellites can provide data and information about Earth's weather, air pollution, oceanic current movements, and so on. In the air, air traffic control cannot be performed without sensor networks (e.g. radars). In maritime, ships rely on GPS for navigating the oceans. The sensor networks can also be effectively used for maritime container tracking, tagging of, and protection for the contents of the containers, On the ground, many different sensor networks are found as there exist many different applications, (e.g. intelligent highway, transportation, supply chain management, medical, military, industrial, finance, first responders, governmental, home, environmental monitoring, perimeter protection and intrusion prevention, health/situation monitoring of elderly or patients, and so on).

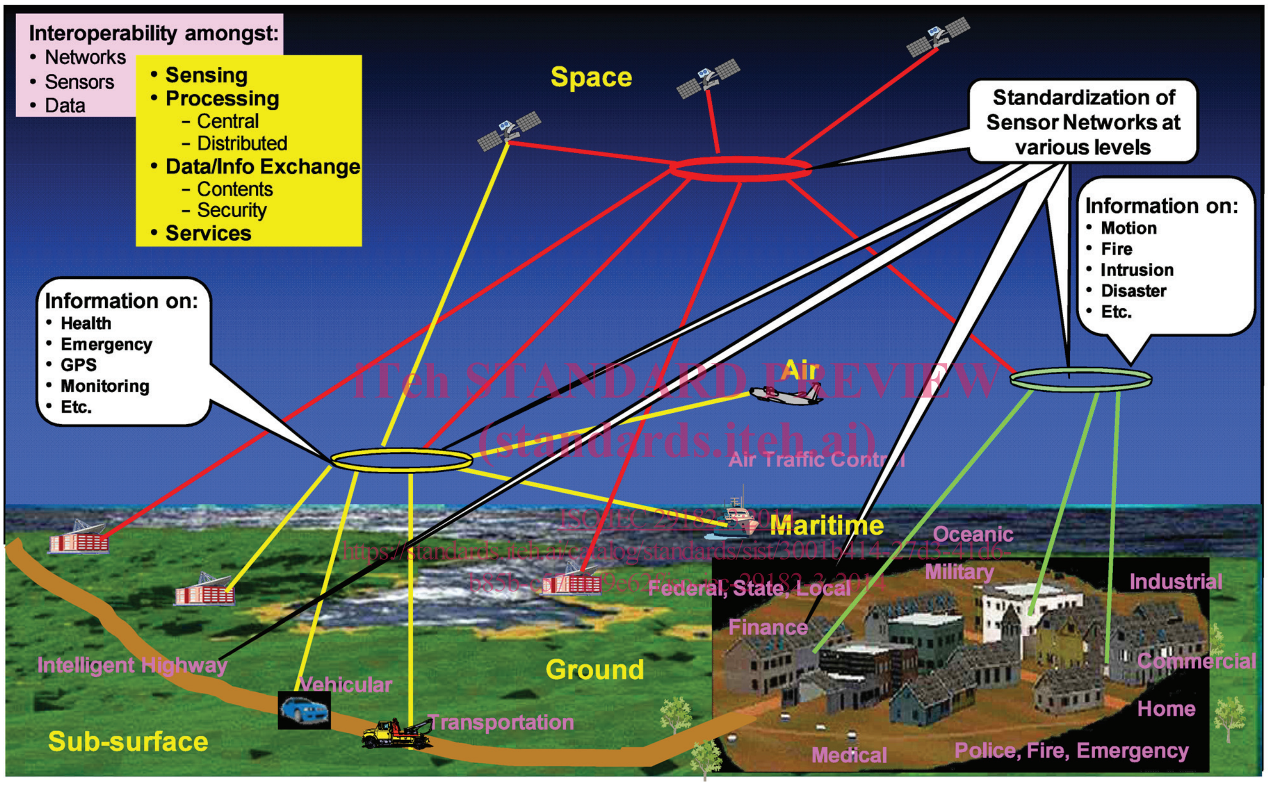

Figure 1 — High level physical graphic of sensor network domains

In summary Figure 1 shows that there are many dissimilar sensor networks in various geospatial expanses, and within each expanse, there are many disparate sensor network applications and services where the disparity exists in types of sensors in the sensor network, networks that support the sensor networks, and data formats utilized by the sensors and the communication networks.

Figure 1 also attempts to illustrate an interoperable sensor network reference architecture, consisting of multiple horizontally interoperable subsystems or modules and the interfaces between those subsystems and modules. Interoperability also needs to exist vertically to transmit the information seamlessly within the hierarchical structure of the sensor networks supporting a complex system of systems. Both horizontal and vertical interoperability can be achieved by a standard developing process that promotes open architecture and also by standardization of interfaces between subdivisions (both subsystems and sensor networks), layered structures in sensor networks and its applications. For the reference architecture to fulfil the requirements of interoperability, existing interoperability standards should be used to describe sensor network systems. Additionally, the needs for new standards, to satisfy new technologies, applications and services of sensor networks, can be identified from the sensor network reference architecture.

Figure 2 describes the sensor network reference architecture by identifying the main entities of sensor networks and the interfaces between the main entities which make up a sensor network. The detailed descriptions of the interfaces (e.g. Interface 1, Interface 2, ..., Interface 5) can be found in ISO/IEC 29182-5.

The main entities identified are:

a) Sensor Nodes, and a sensor node has:

- Sensor Node Hardware Layer (SNHL);
- Basic Functions Layer (BFL);
- Service Layer (SL);
- Application Layer (AL); and
- Cross Layer Management (CLM);

b) Gateway and a gateway is likely to have the same or similar layers and layer structure as those in the sensor node); thus, a gateway has:

- Gateway Hardware Layer (GHL);
- Basic Functions Layer (BFL);
- Service Layer (SL);
- Application Layer (AL); and
- Cross Layer Management (CLM);

c) External Environment through Access Network and Backbone Network connecting to service providers and users.

In Service Provider, it is likely to have the similar layer structure as the one in a gateway.

The interfaces between these main entities, identified in grey colour-filled boxes in Figure 2, are:

a) Within a sensor node, there are:

- Interface between Sensor Node Hardware Layer and Basic Functions Layer (SNHL / BFL);
- Interface between Basic Functions Layer and Service Layer (BFL / SL);
- Interface between Service Layer and Application Layer (SL / AL); and
- Interfaces between Cross Layer Management and Applications Layer, Service Layer, and Basic Functions Layer (CLM / AL-SL-BFL);

b) Interface between a Sensor Node to a Sensor Node within a Sensor Network; and

c) Interface between Sensor Network Gateway Node and other networks (ISO/IEC 29182-1, Figure 3 designates "Backbone Network and Access Network" as "Other Networks," which is also shown in Figure 9 of this standard).

The interfaces between Sensor Node Hardware Layer and Basic Functions Layer (SNHL / BFL) are realized by the functions reside in SNHL and those that reside in BFL.

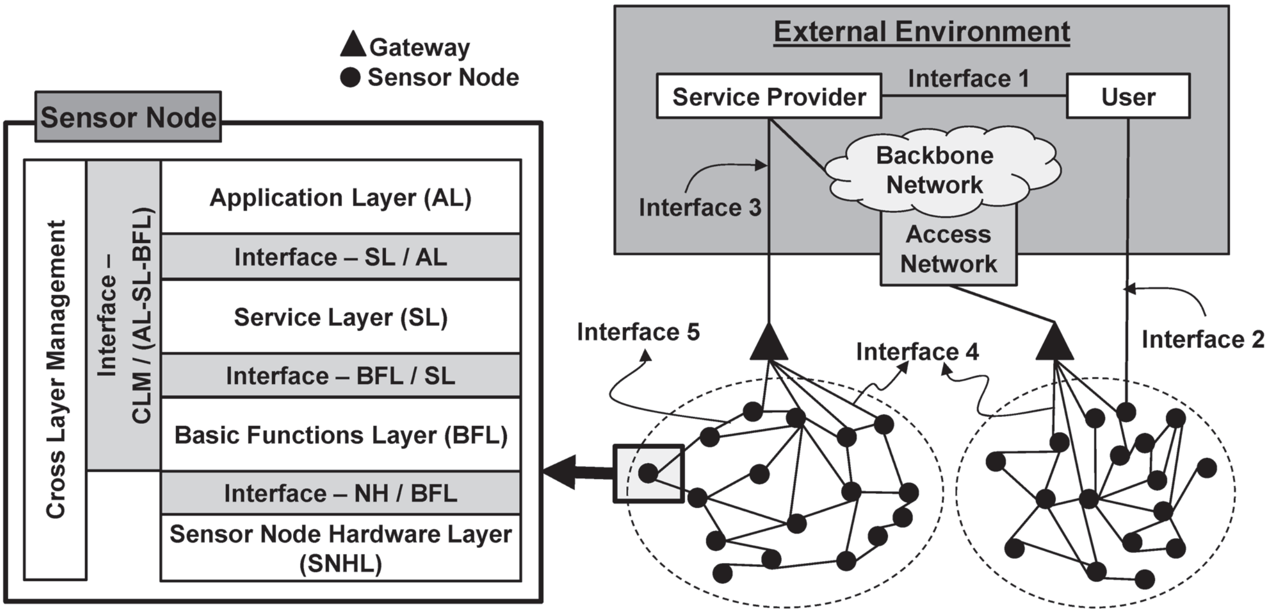

Figure 2 — Overview of sensor network interfaces in a sensor node, sensor node to sensor node, and sensor node to the External Environment

Figure 3 describes the physical architecture of a sensor node, which can be mapped to the Sensor Node Hardware depicted in Figure 2, sensor node physical reference architecture. The sensor node physical reference architecture includes:

— Computer processing unit (CPU): A CPU embedded in a sensor node enables the node become intelligent. It hosts an Operating System (OS), application algorithms, and other software. A CPU could be located outside of a sensor node and a sensor node transmits its measurements to the CPU for processing.

— Storage: A storage device is a memory unit which can be embedded in a sensor node or can be located outside of the node. The memory unit stores various event data experienced by the node, e.g. measurements, processed data if an on-the-node processing is performed, and other event data.

— Sensor: Sensor or sensing element is a measuring device of external environment of a certain phenomenology. Typically, this device converts raw measurements into a stream of measureable electrical signal. Depending on the type of a sensing device, the device can measure acoustics, seismic or vibration, magnetic, various light spectra (e.g. visual, infrared, etc.), electromagnetic (e.g. radio frequencies), temperature, gas, pressure, motion, contaminants, objects, etc. Depending on the complexity and technology implemented in the sensor, the sensor can measure 1-dimensional, 2-dimensional, and 3-dimensional signals along with time tagging.

— Communication unit: A communication unit is an essential component of a sensor node. This communication unit provides either wired or wireless data link which is used to transmit the data collected by the sensor or sensing element and any processed data if available in real-time or in non-real-time. For the case of non-real-time data transmission, a type of storage device is required.

— Actuator(s): An actuator may reside in a sensor node or outside of the sensor node. Actuators are means to interact with physical environments, e.g. automatic temperature control. Actuator(s) can receive information (e.g. command) directly from sensor after data processing through wired or wireless data link.

— Power supply: A sensor node will require a power supply. If a sensor node is physically connected via a wire, such sensor node typically does not require on-board power supply, e.g. batteries. In case of a wireless sensor node, a battery is required. Power management for a sensor node is a critical matter, and a power management utility firmware may be hosted in the CPU, especially for the sensor nodes remotely located wirelessly.

