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

Part 7: Interoperability guidelines

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

Partie 7: Lignes directrices pour l'interopérabilité

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Foreword

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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 29182-7 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 is to

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

— improve interoperability of sensor networks, and

— make sensor networks 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, and service providers to meet customer requirements, including any applicable interoperability requirements.

The ISO/IEC 29182 series is comprised of 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.

ISO/IEC 29182-4 categorizes the entities comprising the reference architecture into two classes of physical and functional entities and presents models for the entities.

ISO/IEC 29182-5:2013 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.

There are no requirements for compliance in ISO/IEC 29182-1 to ISO/IEC 29182-7. Users are to ensure that the sensor nodes and the related sensor network are compliant with the application or deployment governing body.

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

Part 7: Interoperability guidelines

1 Scope

This part of ISO/IEC 29182 provides a general overview and guidelines for achieving interoperability between sensor network services and related entities in a heterogeneous sensor network.

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 29182-5:2013, *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 Symbols (and abbreviated terms)

This part of ISO/IEC 29182 uses the following abbreviations and acronyms.

ADSL Asymmetric Digital Subscriber Line

API Application Programming Interface

GSM Global System for Mobile Communication

ICT Information and Communication Technologies

SNRA Sensor Network Reference Architecture

TCP/IP Transfer Control Protocol/Internet Protocol

UWB Ultra Wideband

WCDMA Wideband Code Division Multiple Access

5 Overview of interoperability between heterogeneous sensor networks

5.1 General

A sensor network is a system of spatially distributed sensor nodes interacting with each other and, depending on applications, with ICT infrastructures, in order to acquire, process, and provide information about the physical world and optionally react to such information [ISO/IEC 29182-1].

There are many different sensor network applications in a variety of domains such as environment monitoring, logistics management, industrial automation, intelligent highway system, and perimeter protection. From one sensor network service domain to another, significant differences exist in service requirements, service types, processing functions, interfaces, operational attributes, data formats, and so on. These differences influence the interoperability of sensor networks.

Due to these differences, a sensor network may be classified into two different types of sensor network, a homogeneous sensor network and a heterogeneous sensor network.

The differentiation of the homogeneous and heterogeneous sensor networks can be viewed from sensor type perspective and from communication protocol perspective. From the sensor type perspective, the homogeneous sensor networks can be classified as having the same type or functionally identical sensor nodes while the heterogeneous sensor networks can be classified as having different types or functionally different sensor nodes. From the communication protocol perspective, the homogeneous sensor networks can be classified as having the same or interoperable protocols while the heterogeneous sensor networks can be classified as having different or not interoperable types of protocols. In this standard, the communication protocol perspective is used to differentiate the types of sensor networks.

The typical difference is the communication protocol. There are various communication protocols for sensor networks, such as IEEE 802.15.4x series, IETF 6LoWPAN, ZigBee, Bluetooth, and UWB.

From the communication protocol perspective, homogeneous sensor networks are by definition interoperable with each other, because they use the same communication protocol between entities of their service domains. On the other hand, heterogeneous sensor networks are not able to interwork with each other due to the differentiation of the communication protocols they use.

Heterogeneity is a common feature of sensor networks, but it may cause various problems. A sensor network application may rely on different sub-networks of a heterogeneous sensor network.

Therefore, the interoperability between heterogeneous sensor networks is a great challenge in the Sensor Network Reference Architecture (SNRA).

5.2 Interoperability in sensor network service framework

From a service-oriented viewpoint, the flow of information from sensor nodes to service providers for providing specific sensor network services to users, the overall architecture of sensor network can be represented in the hierarchical architecture.

This hierarchical architecture, which is called the sensor network service framework, is illustrated in Figure 1. It is the same as Figure 7 in ISO/IEC 29182-5. It has been reproduced in this document for ease of reference.

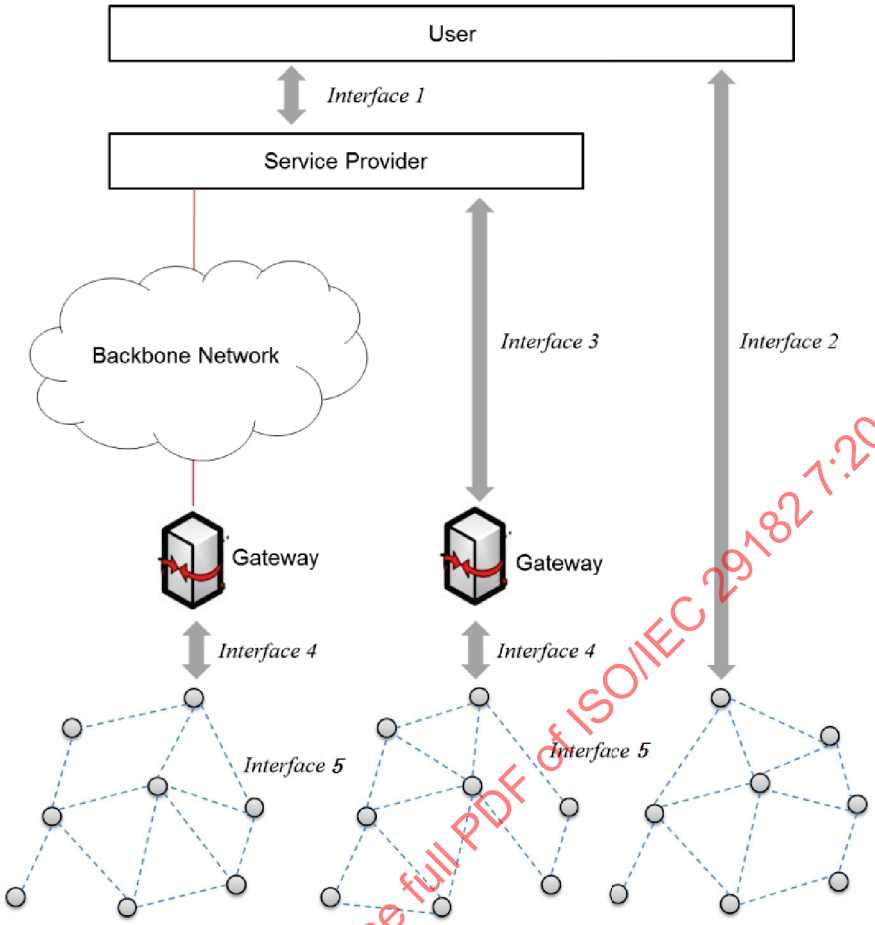

Figure 1 — Interfaces and entities of the sensor network service framework

There are various communication protocols or interfaces for each entity in Figure 1. Interoperability implies an internetworking capability between the entities in the sensor network service framework. Figure 2 is a graphical representation of an interoperable sensor network service framework with the arrows representing the interfaces that enable seamless interoperability between the entities.

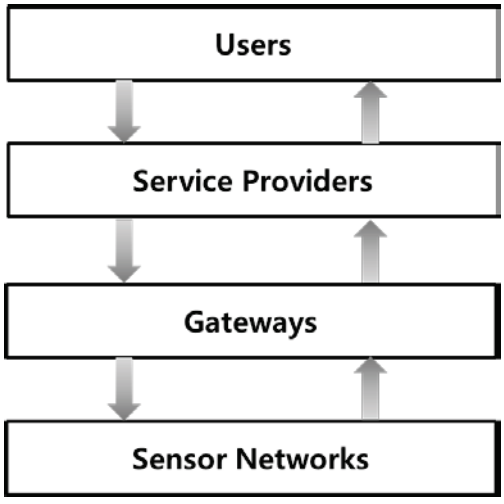

Figure 2 — Graphical representation of an interoperable sensor network service framework

Interoperability also needs to exist vertically so that information may be exchanged seamlessly within the hierarchical structure of the sensor networks supporting a complex system of systems. Therefore,

various cases for the interoperability of sensor networks need to be considered. Figure 3 illustrates the complexity of interoperability within this system of systems.

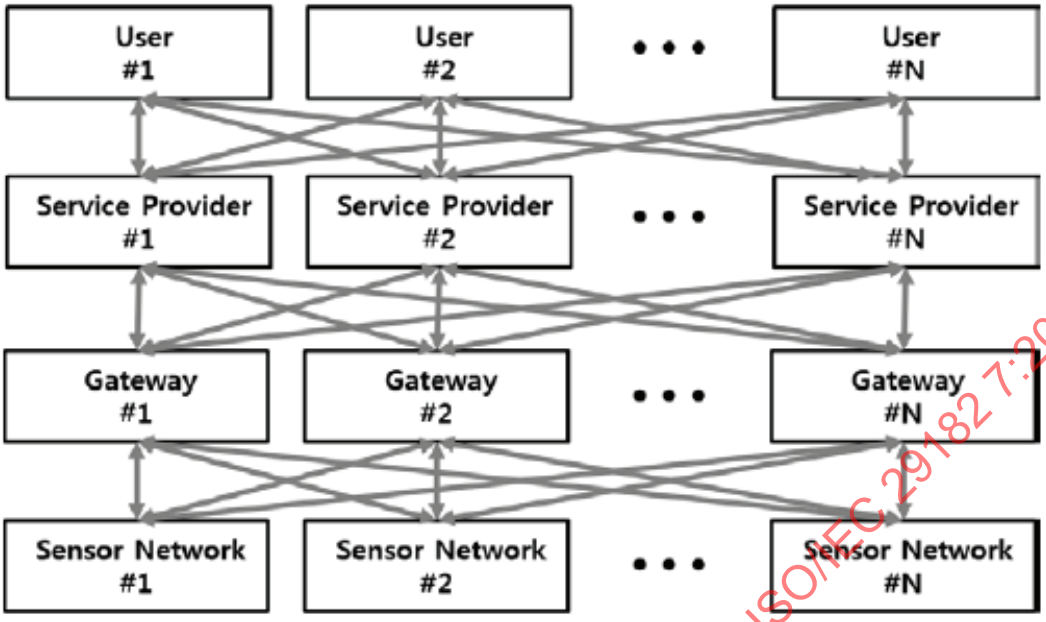

Figure 3 — Interoperability of sensor network service framework in detail

Various entities of the sensor network service framework shown in Figure 3 may use different communication technologies, protocols and data formats. Therefore, data flow between various entities must be interoperable.

The advantages of interoperability between heterogeneous sensor networks are:

— Improving sensor network service scalability

— Extending sensor network functionality

— Reusability

— Potential cost and development/implementation time reduction

— Interchangeability of components for ease of maintenance and upgrade

6 Guidelines for interoperability between heterogeneous sensor networks

6.1 General

This clause describes ways of maintaining interoperability within the sensor network service framework. Also, It provides guidelines for interoperability.

Interoperability can be achieved by a standard development process that promotes open architectures and a standardization of interfaces between subdivisions (both subsystems and sensor networks), layered structures in sensor networks and its applications. For the reference architecture to fulfill the requirements of interoperability, existing interoperability standards should be used to describe sensor network systems. In addition, new standards are needed as new technologies are introduced and new sensor network services and applications identified.

The capability of reading and processing information and exchanging data between the entities of the sensor network service framework is a mandatory requirement for interoperability, as shown in Figure 3.

Therefore, interoperability between heterogeneous sensor networks can be achieved by standardizing the interfaces in Figure 1. Standardized interfaces ensure service interoperability. Defining standardized interfaces for sensor network is arguably the most efficient way to make sensor networks interoperable. Standardized interfaces should include:

— Standardized data format, type, name, definition and data processing rules

— Standardized communication interfaces between entities of the sensor network service framework

6.2 Interoperability between the user and the service provider (Interface 1)

The user sends requests to the service provider through Interface 1 shown in Figure 1 in order to obtain the required information, such as sensor nodes' identification and location information, monitoring or observation plan, or controlling protocols for devices or actuators attached to the sensor nodes. The service provider sends processed data or requested information to the user through Interface 1.

Different users may interact with service providers via Interface 1. The interface defines functions, such as authentication, communication, and management.

Sensor network applications may be categorized into many classes according to the data delivery model, such as event-driven applications and query-driven applications. Data exchange protocols, frame formats in the application layer and the service layer should be defined.

To ensure interoperability between the user and the service provider, standardized data exchange mechanisms and application data formats between the user and the service provider needed to be developed.

The Interface 1 between the user and the service provider may use a standardized communication protocol, such as TCP/IP, GSM, ADSL, and WCDMA. TCP/IP is the most widely used protocol in real-world implementation.

One of the main challenges is to make sensor network protocols "transparent" to applications. Providing standard interfaces to service providers in a network-independent way will allow sensor network service portability and interoperability. An application could provide services via different sensor networks using different technologies as long as a standard Application Programming Interface (API) is supported and used. The communication interfaces should support the functionality of the API so that different sensor networks supporting the API would be interoperable. From the service point of view, the open API is provided to ensure application interoperability among heterogeneous sensor networks adopting different lower layer protocols. This API supports the functionality of interface between the gateway/router and the service provider.

Therefore, a set of standard APIs would provide a set of core services and capabilities that can be utilized by sensor network applications to achieve interoperability.

6.3 Interoperability between the gateway and the service provider (Interface 3)

A sensor network gateway is an intermediate entity that interconnects appropriate service providers and sensor networks. The data collected from the sensor networks and management command messages such as local sensor network registration and deregistration, data acquirement, and device management are exchanged via this interface.

The gateway must be capable of exchanging information with any service provider no matter which communication protocol is used. In this regard, a standardized interface specification and data format between the gateway and the service provider, shown as Interface 3 in Figure 1, is defined in ISO/IEC 29182-5 is mandatory. Therefore, using a generic sensor network application interface is one way to ensure interoperability between the gateway and the service provider, as illustrated in Figure 4.

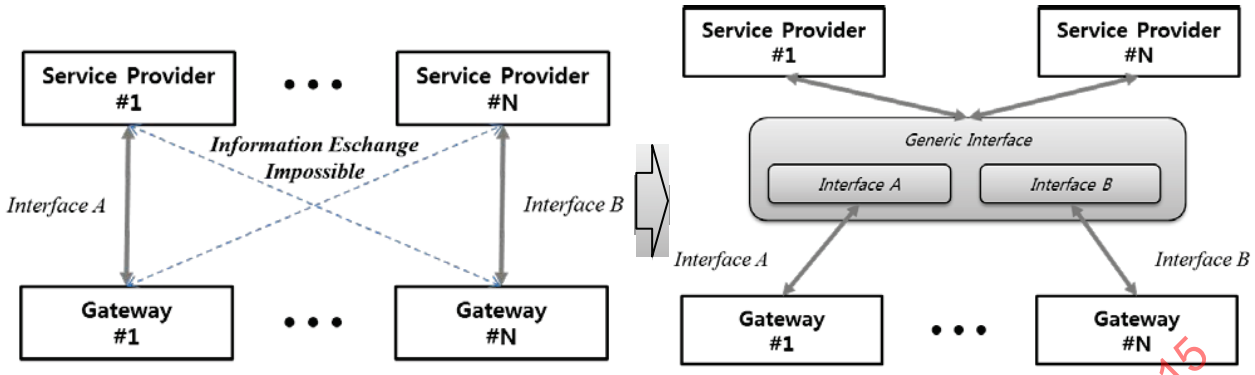

Figure 4 — Using a generic standardized sensor network interface for interoperability

The generic sensor network application interface consists of a mandatory interface and an optional interface. The mandatory interface is the interface which must be implemented by sensor networks and service providers. It includes a registration interface, a deregistration interface, and a sensor data report interface. Meanwhile, the optional interface may be implemented by sensor networks and service providers. Based on the constraints and policies on sensor networks and requirements of service providers, the optional interface can be implemented selectively. A pull mode sensor manipulation interface, a actuator manipulation interface, a sensor network monitoring and controlling interface, a scalability interface, and a message handling interface are classified as optional interfaces [ISO/IEC 30128].

From an interface perspective, standardized communication protocols such as TCP/IP, GSM, ADSL, and WCDMA, as discussed in 6.2 for use in Interface 1, may also be used in Interface 3 (see Figure 1). The communication protocols used in Interface 1 and Interface 3 should be compatible to enable unified service to the user.

There are many approaches to ensure interoperability through this interface. One possible approach is that a service provider should have multiple communication interfaces to communicate with gateways that use different communication protocols. Another possible approach is to use an intermediate entity implemented as middleware, which has a capability to manage all common communication protocols.

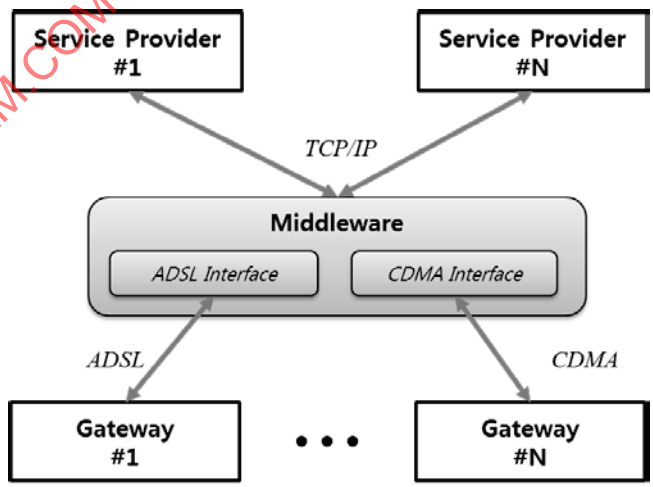

Figure 5 — Example of using middleware for interoperability from a communication protocol viewpoint