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Information technology — Sensor networks — Services and interfaces supporting collaborative information processing in intelligent sensor networks

Technologies de l'information — Réseaux de capteurs — Services et interfaces prenant en charge le traitement d'information collaboratif dans les réseaux de capteurs intelligents

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Contents

Foreword

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Introduction

Sensor networks have been widely deployed in different application domains including environment monitoring, transportation, manufacturing, chemical process, healthcare, home and buildings, and many other domains. Wired/wireless sensor networks can be regarded as an extension of the Internet interfacing the physical world. Intelligent sensor networks are increasingly attractive in a wide range of applications to meet challenges from intrinsic environment complexity, large orders of magnitude network scaling and dynamic application requirements. Intelligent sensor networks are developed to provide new system capabilities such as environment self-adaptability, dynamic task supporting and autonomous system maintenance. Collaborative information processing (CIP), which closely integrates information processing algorithms with collaboration mechanisms, is an essential technology enabling the intelligent sensor networks to enhance efficiency and to improve quality and reliability of information processing and its outputs in real application scenarios. This standard specifies services and interfaces supporting CIP in the intelligent sensor networks.

Information technology — Sensor networks — Services and interfaces supporting collaborative information processing in intelligent sensor networks

1 Scope

This international standard specifies services and interfaces supporting collaborative information processing (CIP) in intelligent sensor networks which includes:

— CIP functionalities and CIP functional model

— Common services supporting CIP

— Common service interfaces to CIP

2 Normative references

The following referenced documents are indispensable for the application 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 7498-1:1994, *Information technology — Open Systems Interconnection — Basic Reference Model: The Basic Model*

3 Terms and definitions

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

3.1
actuator
device that provides a physical output in response to a input signal in a predetermined way

[SOURCE: ISO/IEC 29182-2]

3.2
collaborative information processing
form of information processing in which multiple sensor network elements collaborate, in order to enhance efficiency and improve the quality and reliability of the output

[SOURCE: ISO/IEC 29182-2]

3.3
data registration
process of transforming different sets of data into one coordinate system

3.4
data grouping
process of identifying a time interval common among different data sources and grouping data obtained in the time interval

3.5
event
anything that happens or is contemplated as happening at an instant or over an interval of time

3.6
sensor network
system of spatially distributed sensor nodes interacting with each other and, depending on applications, possibly with other infrastructure in order to acquire, process, transfer, and provide information extracted from its environment with a primary function of information gathering and possible control capability

Note 1 to entry: Distinguishing features of a sensor network can include: wide area coverage, use of radio networks, flexibility of purpose, self-organization, openness and providing data for multiple applications.

[SOURCE: ISO/IEC 29182-2]

3.7
sensor network application
use case of sensor networks, which provide a set of functions to users to meet defined requirements

EXAMPLE Monitoring forests to detect natural fires; monitoring seismic activity; monitoring pollution levels in environment.

[SOURCE: ISO/IEC 29182-2]

3.8
sensor network service
set of functionalities offered by individual sensor network elements or the sensor network

EXAMPLE generating an alarm signal if the measurement made at a sensor exceeds drops out of certain prescribed range; providing average sensor measurements over a given geographic area.

[SOURCE: ISO/IEC 29182-2]

3.9
sensor node
sensor network element that includes at least one sensor and optionally actuators with communication capabilities and associated data processing capabilities

Note 1 to entry: It may include additional application capabilities.

[SOURCE: ISO/IEC 29182-2]

3.10
service set or service subset
group or subgroup of services organized to provide common mechanisms or facilities to meet certain requirements from users or applications

4 Abbreviations

For the purposes of this document, the following abbreviations apply.

CDE Capability Declaration Entity

CIP Collaborative Information Processing

CRSE Communication Requirement Specification Entity

CS Core Service

CSPE Collaborative Strategy Planning Entity

ES Enhanced Service

FAR False Alarming Rate

FCR Functional Capability Requirement

GSR Generalized System Requirement

OSI/RM Open Systems Interconnection/Reference Model [ISO 7498-2:1989]

QoS Quality of Service

SAP Service Access Point

5 General description

5.1 Overview

A system composed of a sensor network or sensor networks attempts to fully integrate sensing, data/information transmission and processing and information provision processes to satisfy the system's application requirements for end users. Figure 1 shows a functional overview of sensor networks system from the layered architectural view.

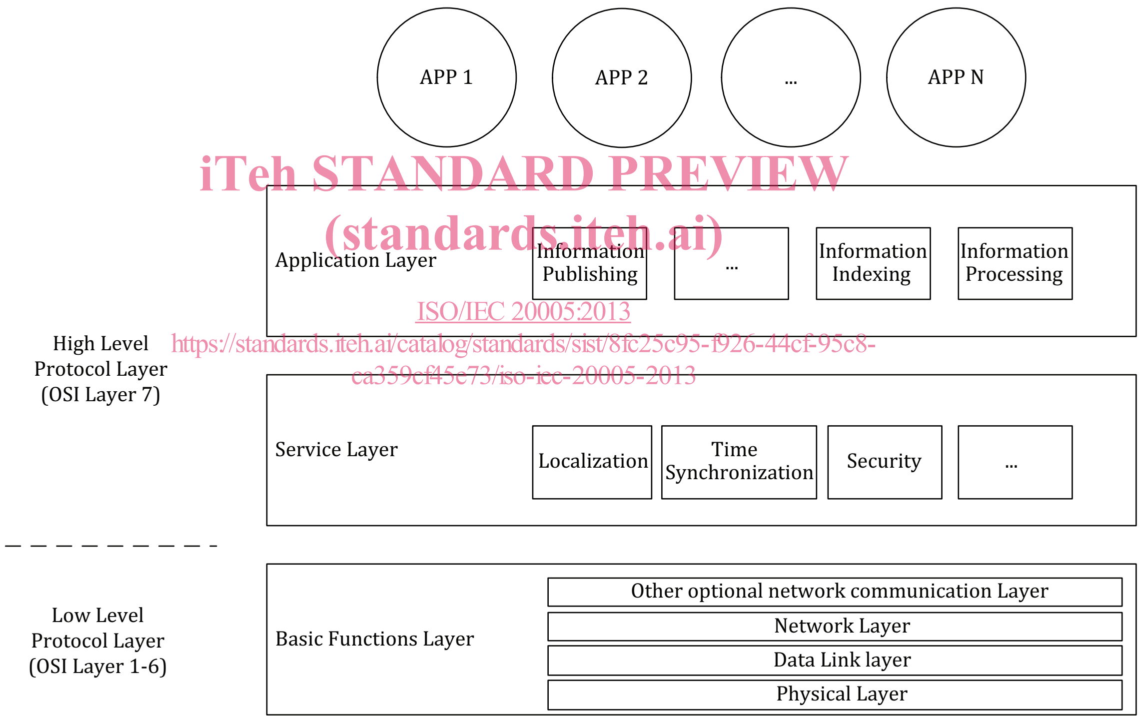

Figure 1 — Layer overview of sensor network system architecture

The Basic Functions Layer implements basic functionalities fulfilled by the lower layers in the Open Systems Interconnection Reference Model (OSI/RM in ISO/IEC 7498-1), including the physical layer, the data link layer, the network layer, and other optional network communication layers. Above the basic functions layer, there are the Application Layer and the Service Layer. The application layer provides services to individual applications and/or users and implements functions such as information publishing, information indexing and information processing, etc. Between the application layer and the basic functions layer, the service layer provides generic common services to entities in the application layer. Typical generic common services in the service layer include localization service, time synchronization service, security service, and other services.

5.2 Requirements of intelligent sensor networks

Besides the generalized system requirements (GSR) and generalized functional capability requirements (FCR) of sensor networks, there are additional unique requirements that the intelligent sensor networks have to meet the challenges from intrinsic environment complexity, large orders of magnitude network scaling and dynamic application requirements.

— **Environmental self-adaptability:** An intelligent sensor network shall adapt to obtain required system performances if the physical environment of the sensor network's monitoring area changes. For example, an intelligent sensor network based anti-intrusion system should guarantee consistent system performances such as detection and false alarming rate (FAR) when the environment in which the sensor network is deployed changes.

— **Dynamic task supporting:** An intelligent sensor network shall support dynamic tasking including dynamic task assignment, dynamic task ordering by prioritization, dynamic service provisioning for information users/consumers, and dynamic quality of service (QoS) adjustment.

— **Autonomous system maintenance:** An intelligent sensor network shall autonomously maintain system functionalities in case of network scaling, node mobility, new node entrances, node exits, and node failures.

5.3 Overview of collaborative information processing

The key differences between traditional telecommunication infrastructures and information service systems based on sensor networks are that (1) sensor networks systems collect raw sensory data from physical world; and (2) from these data, extract application-specific information in order to obtain feature level data, decision level information, and knowledge about the physical world.

Integrated with metadata such as sensory information description, sensor identification, and sensory information location, CIP handles efficient resource management to provide the dynamic tasking to fulfil the requests demanded by information service consumers. Though different sensor network applications normally require application-specific services, the collaborative processing is an indispensable requirement for senor network based information service to handle constraints in power (e.g. batteries), computing resources, storage, and communication bandwidth. The collaborative processing also has to deal with technical challenges such as task dynamics, measurement uncertainty, node mobility, and environmental adaptation ability.

The aims of CIP in sensor networks are to improve system efficiency, enhance quality of service, and guarantee system performance. It provides efficient mechanisms such as majority-voting fusion, decision template fusion and statistical methods for handling incomplete and/or inaccurate information. It also provides protocols to meet challenges from intrinsic environment complexity, large orders of magnitude network scaling and dynamic application requirements.

CIP can be viewed from three distinct viewpoints. Figure 2 shows a three-dimensional conceptual model of CIP.

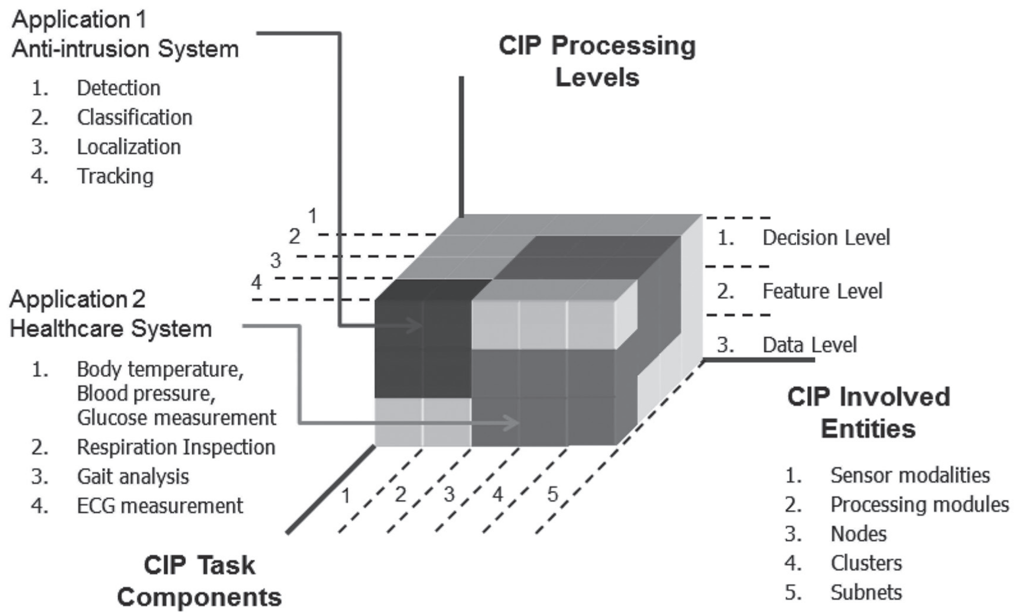

Figure 2 — Conceptual model of collaborative information processing

The first viewpoint is CIP Processing Level viewpoint. In this viewpoint, CIP can be implemented on different processing levels, which includes data, feature and decision processing levels. The second viewpoint is CIP Involved Entity viewpoint. Involved Entities in CIP could be sensor modalities, processing modules, nodes, clusters, and even subnets. CIP can thirdly be viewed from Task Component viewpoint. The task components in this viewpoint depend on the specific application scenarios of sensor networks. In anti-intrusion application system, the task components can be target detection, localization, classification, and tracking for security services. In healthcare system, task components may include blood pressure/temperature measurement, respiration inspection, and gait analysis. Figure 2 shows that tracking is one of the main CIP task components in Application 1. Decision-level and feature-level processing are applied, and both sensor modalities and processing modules are involved for CIP in the application. Specific selections and combinations using components from these three viewpoints correspond to different application task implementations, or personalized services using sensor networks.

5.4 Functional model of collaborative information processing

Figure 3 shows a functional model of collaborative information processing from a functional entities point of views. In this model, CIP can be characterized by three distinct entities, which are named as capability declaration entity (CDE), collaborative strategy planning entity (CSPE) and communication requirement specification entity (CRSE).

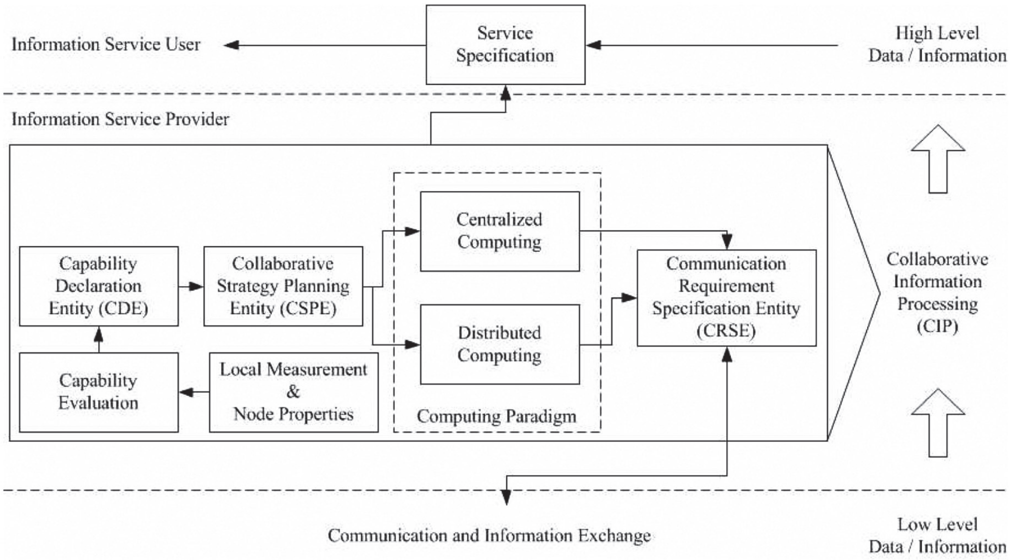

Figure 3 — Functional model of collaborative information processing

Capability Declaration Entity (CDE) declares capabilities of sensor nodes in a sensor network. Capabilities include not only individual node information such as sensing modality and its configuration, sensing range, remaining life on power, location, remaining storage capacity, and communication bandwidth, etc., but also certain characteristic information of sensory data collected by individual sensor node. One of the representative characteristics on sensory data are signal-to-noise ratio (SNR) value. Other characteristics include signal strength, estimated distance between a target (or targets) and sensor nodes, and state parameter prediction, etc. In other words, one sensor node should be qualified by the Capability Evaluation model to be a CIP participant before any actual CIP procedure is triggered. CDE requires a preliminary capability evaluation process which uses information of local measurement and node property.

Collaborative Strategy Planning Entity (CSPE) is probably the most important entity in CIP. CSPE uses available information provided by CDE and decides how collaborative information processing will be implemented. With certain cost functions or utility measures, CSPE tries to find a resource-efficient solution to collaborative strategy planning problem while the best information processing performance can also concurrently be achieved. Two computing paradigms can be used in the implementation of resulting solution from CSPE – One is centralized computing paradigm; the other is distributed computing paradigm. In distributed computing paradigm, there are several local computing/fusion centres. In centralized computing paradigm, only one central computing/fusion centre exists. The paradigm used is decided by the CSPE entity. Both the spatial and temporal correlation among different local centres, which may be dynamic, is also indicated by the CSPE entity.

Communication Requirement Specification Entity (CRSE) acts as interface between information service provider and Communication and Information Exchange. CRSE defines parameters and protocols to clearly describe requirements on communication and information exchange. For example requirements such as end-to-end delay, time jitter, bit error, and other QoS parameters should be specified.

5.5 Overview of services supporting CIP

Generic common services in the service layer could be divided into different subsets according to the types of service consumer entities in the application layer. This standard specifies a subset of generic common services which interface with the CIP entities in the application layer and support implementation of the corresponding CIP entity functionalities.

Services supporting CIP can be conceptually divided into two classes: core services (CS) and enhanced services (ES), as shown in Figure 4. Core services include fundamental and essential services which can be provided directly and individually to the CIP entities. Enhanced services are implemented through combining services, for example, integrating two or more core services or other generic common services provided in the service layer.

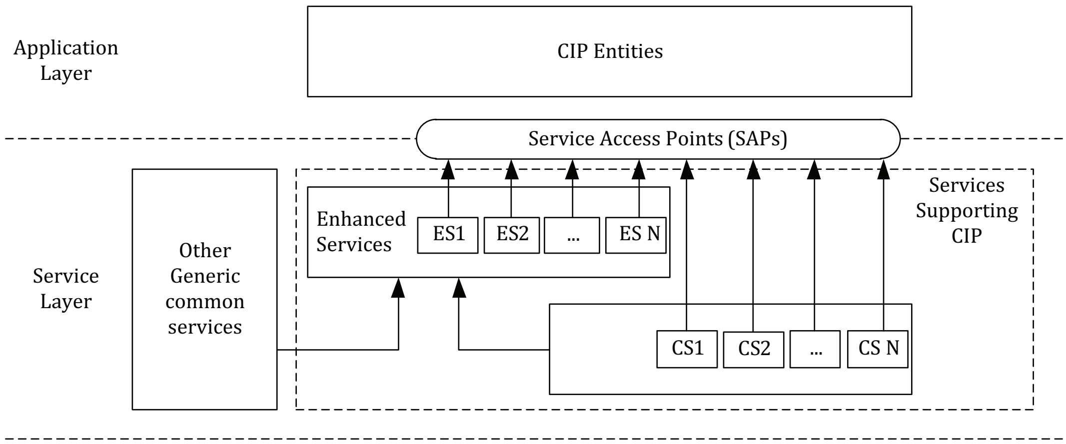

Figure 4 — Overview of services supporting CIP

5.5.1 Core services supporting CIP

The core services (CS) supporting CIP includes:

— **Event service:** This service implements functionalities concerning the process of event subscription, registration, cancellation and un-subscription. Event may be generated due to environmental changes, new physical signal occurrence, and network status dynamics.

— **Logical grouping service:** This service implements functionalities concerning the establishment and management processes of logical group for the implementation of CIP in the application layer. The logical group is a logical set of sensor network entities involved in specific information processing tasks such as target detection, localization, recognition and target tracking. Logical grouping service provides mechanism for establishing collaborative relationship among the entities in intelligent sensor networks.

— **Data grouping service:** Data are generated by various sensors in different time intervals and scales. This service identifies or specifies a time interval common to all sensors participating in CIP, and groups all sensor data obtained during that time interval for processing. Data grouping service uses a time synchronization service to support CIP.

— **Data registration service:** Data generated from sensors in distributed sensor nodes may be described in different spatial reference coordinate systems. Data registration is a necessary process in order to transform or integrate different sets of data into one coordinate system. Based on reference coordinate system description, this service provides functionalities to keep the spatial reference coordinate system consistency among participators in CIP.

— **Information description service:** This service provides mechanisms to establish ways or methods to describe information in intelligent sensor network. Information can be the input parameters to CIP processes, and it can also be the results from CIP processes.

— **Node-to-node inter-activation service:** This service provides mechanisms not only to initiate the execution of tasks in one sensor node commended by another sensor node, but also to trigger modules from one sensor node from another sensor node. Dynamic tasking can be supported by this core service.

— **Parameter adaptation service:** This service provides mechanisms to adapt or reconfigure parameters for CIP. Parameter adaptation service is one of the essential services to guarantee system performance in case of dynamic changes in deploying environment and application requirements.

5.5.2 Enhanced services supporting CIP

The enhanced services (ES) supporting CIP includes:

— **QoS management service:** This service provides mechanisms to define and update QoS profiles, and to apply QoS profiles. In intelligent sensor networks, QoS shall be considered from both information processing perspective and communication processing perspective. The QoS management service uses the logical grouping service and the parameter adaptation service.

— **CIP-driven scheduling service:** This service provides functions to control and schedule node states upon the request of the CIP entities instead of node management entities in intelligent sensor networks. This service can help to implement application-oriented networking and on-demand task scheduling. CIP-driven scheduling service use the event service, the logical grouping service, the parameter adaptation service and the node-to-node inter-activation service, and other generic common services including neighbour finding service.

— **Adaptive sensing service:** This service provides mechanisms to adaptively apply sensing rules according to different event occurrence and different contexts in intelligent sensor networks. Adaptive sensing service can provide autonomous system maintenance and system adaptability in intelligent sensor network. Adaptive sensing service uses the event service, the information description service, and other generic common services including sensor configuration service.

6 Core services and interfaces specifications

6.1 Overview

This clause specifies core services (CS) supporting CIP in intelligent sensor networks. Service primitives and parameters of primitives are defined for each core service. Table 1 shows the names of service access points (SAPs) through which specific service is provided.

Table 1 — Core services and the names of SAPs

Service name	SAP name
Event service	EVENT-SAP
Logical grouping service	LG-SAP
Data grouping service	DG-SAP
Data registration service	REG-SAP
Information description service	INFO-SAP
Node-to-node inter-activation service	N2NACT-SAP
Parameter adaptation service	PAR-SAP

6.2 Event service

Event service is provided through EVENT-SAP. The EVENT-SAP is the logical interface between the event service entity in the service layer and the CIP entity in the application layer. This logical interface incorporates a set of primitives and their definitions. These primitives and definitions are described conceptually here, but through this, the process of the parameters exchanged between the service layer and the application layer can be understood. Table 2 lists the primitives supported by the EVENT-SAP. Table 3 outlines the primitive parameters.

Table 2 — EVENT-SAP primitive summary

Name	Request	Indication	Response	Confirm
EVENT-SUB	6.2.1	6.2.2		6.2.3
EVENT-REG		6.2.4		
EVENT-UNSUB	6.2.5			6.2.6

Table 3 — EVENT-SAP primitive parameters

Parameter Name	Description
EVSubSourceID	Source node ID of event subscription.
EVSubDestinationID	Destination node ID of event subscription.
EVSubModel	Event subscription models.
EVSubValue	Value for specific event subscription model.
EV_Time	A time indication for the event occurrence, as provided by the service layer. Return from destination node.
EVSubResultCode	Result code of event service operation.

6.2.1 EVENT-SUB.request

This primitive requests the process of event subscription from the application layer. The parameters of this primitive are:


```
EVENT-SUB.request {
        EVSubSourceID,
        EVSubDestinationID,
        EVSubModel,
        EVSubValue
        }
```

Table 3 defines the parameters of this primitive.

This primitive is used by the CIP entity to subscribe the event service from the entity of the service layer. On receipt of this primitive, the entity providing the event service implements event subscription in the EVSubDestinationID node for the EVSubSourceID node.

6.2.2 EVENT-SUB.indication

This primitive indicates the event subscription from the service layer to CIP entity. The parameters of this primitive are:

```
EVENT-SUB.indication {
        EVSubSourceID,
        EVSubDestinationID,
        EVSubModel,
        EVSubValue
        }
```