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Information technology — Sensor Networks: Sensor Network Reference Architecture (SNRA) — Part 1: General overview and requirements

1 Scope

This International Standard provides the general overview and the requirements identified for Sensor Network Reference Architecture (SNRA).

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 29182-2, *Information technology – Sensor Network: Sensor Network Reference Architecture (SNRA) – Part 2: Vocabulary/Terminology*

ITU-T Recommendation F.744, *Service description and requirements for ubiquitous sensor network middleware (2009)*

ITU-T Recommendation Y.2221, *Requirements for support of Ubiquitous Sensor Network (USN) applications and services in NGN environment (2009)*

3 Terms and definitions

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

3.1

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4 Overview of sensor network

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

A set of technology domains should be involved to realize various sensor network services as shown in Figure 1 which depicts the overall architecture for sensor network. The scope of sensor network in these series of International Standards is not limited to edge sensor network.

For example, physical sensor networks have to be established by wireless or wired networking technologies; a sensor network has to be connected via various access networks to a delivery network like NGN, Internet, and mobile communication network; middleware systems may be incorporated to perform intelligent and context awareness processing. And finally various sensor network applications require application-layer technologies such as integrated service, sensory information description and presentation, etc.

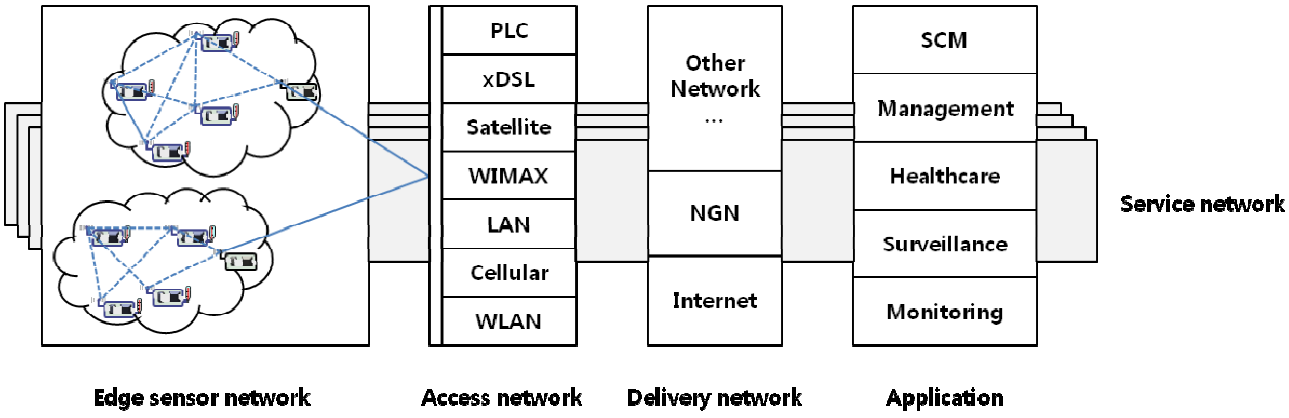

Figure 1 – Overall architecture for sensor network

From the data point of view, data is captured by sensor network and transferred to application through access network and delivery network. Service network is laid on the route of data.

A typical sensor node comprises five main components as shown in Figure 2.

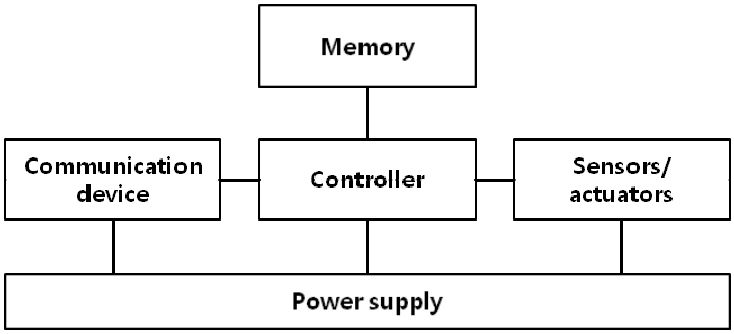

Figure 2 – Overview of main sensor node hardware components

- **Controller** processes all the relevant data and is capable of executing arbitrary code.
- **Memory** stores programs and intermediate data; usually, different types of memory are used for program and data.
- **Sensors and actuators** is actual interface to the physical world: devices that can observe or control physical parameters of the environment.
- **Communication device** enables a sensor node to send receive information over a wireless or wired channel.

- **Power supply** is form of batteries for providing energy or form of recharging by obtaining energy from the environment such as solar cell.

4.1 Types of sensor network applications

Sensor network applications are very vast and diverse. However, many of these sensor network applications can be classified into following types according to the way of capturing data and data processing.

Table 1 — Types of sensor network applications

Type	Description	Examples
Event detection	Sensor nodes report event that they detected the occurrence of a specified event.	Fire alarm, Intrusion detection, Health care, etc.
Periodic measurements	Sensor nodes can be tasked with periodically reporting measured values. Sometimes, these reports can be triggered by a detected event.	Building monitoring, Healthcare, Temperature monitoring, etc.
Function approximation and edge detection	The way a physical value like temperature changes from one place to another can be regarded as a function of location. Sensor network can be used to approximate this unknown function (to extract its spatial characteristics). Edge detection is to find area or points of the same given value. An example is to find the isothermal points in a forest fire application to detect the border of the actual fire.	Fire alarm, Agricultural application, etc
Tracking	The source of an event can be mobile. Sensor network can be used to report updates on the event source's position with estimates about speed and directions as well.	Supply chain management, Tracking people, etc.

4.2 Characteristics of sensor networks

Many differences can be found between the emerging wired/wireless networked sensors and traditional wired/wireless networks such as communications network. Compared with the traditional networks, not only do sensor networks perform data transmission but also perform data processing, data aggregation, data management, networking management, resource management, automation (sense and actuate), and many other functions and services. The sensor network can connect with existing infrastructures such as database, repository, and other systems through IT backbone and Internet; thus become part of systems of systems (SoS) that provides benefits to home and business. Therefore, although there are some common characteristics, sensor networks have many unique characteristics that the traditional communication networks do not.

4.2.1 Dynamicity of service

The existing legacy sensor networks (or sensors-on-the-network) have been installed for specific application purposes such as structures monitoring, street light control, agriculture monitoring and management, military surveillance, city facilities management, home utility control, and flood and fire monitoring where consumer service models are not considered. As an information service infrastructure to improve the quality of life, the sensor networks should incorporate various service technologies such as sensor data gathering from various data sources, for example, sensor nodes themselves, other service providers, and private enterprises with

functions including data filtering, data mining, context-aware decision making, estimation and forecasting, and so on. Moreover, the type of services provided depends on users' service requirements and expectations; therefore, it is very challenging to pre-determine the application/service features and relevant functions for a wide variety of users. To satisfy the different levels of services for the different users, a certain sensor data may be dynamically processed to meet individual user's requests. As in the example below, some users may ask for weather information from the weather information services, but due to their different needs, they have different service requirements demanding the different levels of services:

- Fishermen may request on-demand and periodic weather information for fishing;
- Tourists may request periodic and warning/alarming information of the nature's condition for a few days, a week, or a month by a service subscription;
- Crewmen of a ship may request long-term weather forecasting information;
- National disaster centre may request the whole weather information to observe the natural phenomena of an area and detect emergency situations.

4.2.2 Application inter-working

There are many kinds of legacy sensor network applications such as industrial automation, various types of monitoring and control applications, civil engineering, intelligent building, home automation. And these applications usually operate in a mutually exclusive manner. Technologically evolving capabilities and application of sensor networks enables business partnerships whose business areas have been mutually exclusive, e.g., auto industry and private safety/emergency monitoring services industry. Thus, for certain business cases, the sensor network capabilities and functions should be developed benefiting multiple business partnerships. Another general example is that a sensor network service provider may need to interoperate with other sensor network service providers to obtain sensor data, processed results, or information to improve the service quality.

4.2.3 Types of user

The existing legacy sensor network applications typically have a dedicated group of users. But the emerging intelligent sensor networks and their applications/services aim at arbitrary consumers and business partners. For example, weather information may be provided to arbitrary consumers such as tourists and fishermen as well as business partners such as airlines, shipping companies and travel agencies. Predefined users, i.e. business partners, by contracts or agreements result in B2B-type sensor network services. Arbitrary consumers by service subscription result in B2C-type sensor network services.

4.2.4 Extension of Internet

Wired/wireless sensor networks have to be regarded as an extension of Internet towards the physical world ("Internet of Things") connecting physical world with users which cannot simply be regarded as a communication network. Sensors which never have been able to communicate with their environment start to process sensor data and produce information which is routed to a user. The "user" might be a man or machine. In most cases, the human user does not stand in the foreground. Sensor nodes detect and monitor environment conditions (i.e. "the physical world") and/or other physical beings. The raw data from the sensor's observation (includes detect & monitor) is then transformed into different formats of data and/or information by various types of processing. These data and information are routed to different users according to their requests.

4.2.5 Data gathering and pre-processing

The main objective of a sensor network implementation is to gather and pre-process sensor data. Therefore, intelligence on the sensor node is necessary. Sensor networks have to ensure that all the information is available and comprehensive for the tasks given. Communication/data links in the sensor network system have to be reliable and robust. If one of the links is terminated, the wired/wireless sensor network has to self-organize and find other ways to route the data or information to the gateway as no human intervention is available to fix the broken link by rearranging or reconfiguring the sensor network.

To bring intelligence to a sensor node, a level of comprehensive data processing (e.g., data compaction, signal/image processing, etc.) is required. The "a level" is determined by the sensor network's target application. To enable the intelligence in the node, the following needs should be considered:

- Sensor nodes in the network are automatically selected and organized to work collaboratively and perform certain tasks or functions after processing their own data collected from physical world;
- Users take action according to information provided by the sensor networks. Therefore, information provided to the users should be comprehensive and reliable;
- Nodes process data without the intervention of human decisions.

4.2.6 Association with location information

For many wired/wireless sensor network applications, sensor data are required to be associated with sensor's location information. Thus, a sensor network needs to offer a service to provide the sensor location information by a type of localization process, e.g., triangulation, data routing latencies, etc. For certain cases, sensors or sensor nodes in a network have the ability to determine their own location, especially for mobile sensor nodes, e.g., on-board GPS. Producing the location information of a sensor is one of the most important services provided by a sensor network. The location information is then associated with the sensor data. The localization processing in the sensor network should be scalable because the networks may become very large and complex.

4.2.7 Collaboration of work

In many sensor network applications, the sensor nodes have to collaboratively work to solve complex sensing problems, such as measurement, detection, classification, and tracking in physical world. The data from a sensor may have to be pre-processed and refined at the sensor node. Depending on applications, intermediary data/information, such as features or estimated parameters, need to be extracted from raw sensor data during the pre-processing. The results from this pre-processing should be shared among the sensor nodes in the sensor network. Once shared, the intermediary data from multiple sensor nodes can be transformed into context data and situation information by data fusion. For data sharing in the network, the bandwidth must be considered. In many applications, the sensor data processing may require a transmission of large amount of data over the network; while other applications may only require transmitting a few bits and bytes. Thus, sensor network standards should be sufficiently flexible and scalable to facilitate collaboration information processing (CIP) and data/information transmission in order to support various sensor network applications.

4.2.8 Non existing communication infrastructure-based communication

Sensor nodes must communicate with each other without an existing communication infrastructure. For this reason, a multi-hop capability and clustering algorithms will be required. Efficient data communications among the sensor nodes are one of the important traits for the measure of performance which is affected by bandwidth and latency. For example, different applications dictate different requirements on latency time. For certain applications, an alarm message has to be routed through a large network in less than a few seconds; for other applications a minute or an hour may be acceptable. Therefore, designing a flexible sensor network for different applications should carefully select data routing schemes and communication protocols that support both types of applications. The design must also consider the cost-effectiveness in developing and operating such a sensor network.

4.2.8 Efficiency of power

One of the most important characteristics of a wireless sensor network is the fact that sensor nodes are energy-limited as they typically run on batteries; therefore, computing has to consider the resource-limited nature of the sensor nodes. The more frequent the sensor nodes become active to transmit data, the shorter life the sensor node has. It is said that "every bit processed or transmitted is one bit closer to the dead battery[1]."

[1] Ken Arnold, "Tutorial T11: Wireless sensor networks – An enabling technology," Oceans 2003.

For example, in the theft prevention system, its batteries need to be quite large in order to operate sensor nodes and networks for two or three months. In other applications, sophisticated energy management algorithms are needed to keep the same energy level in all sensor nodes in a network so that the life time of each sensor node and network can be predicted for maintenance. The wireless sensor network power budget requirements are influenced by power consumption on average and on frequency of peaks per given time period, low overall cost of installation and maintenance, data rate, transmission bandwidth, and communication range. For wireless sensor networks, low data rate, narrow transmission bandwidth, and short communication range (when not using wireless relays to extend the range) are typical.

4.2.9 Dynamic topology of network

The topology of the wireless sensor network is rarely fixed. Normally, it has to adapt to the availability of data/communication links between sensor nodes, to the changing positions of objects to which sensor nodes are attached (e.g., mobility), to energy levels (e.g., node drop out as battery runs out) and roles of sensor nodes. Applications where all the nodes are fixed are relatively easy to handle. Applications where nodes move within the network are more difficult to manage. The routing and communication protocols have to be very fast and flexible, yet energy efficient. This flexibility in the sensor network topology should not affect networks' performance when sensor nodes enter or leave the network, e.g., the self-healing and self-organizing nature of sensor networks.

4.2.10 Long operation time

A wireless sensor network has to operate for a long period of time without maintenance. For wireless sensor network's operations, no operator is typically available to resolve any problem. Maintenance and problem solution capabilities are restricted to remote maintenance and resolution operations. Thus, the sensor networks are desired to have basic functions such as self-maintenance, self-organization, redundancy and failure tolerance. These functions are, in fact, based on the key concepts of sensor networks. Without these embedded key functions, a sensor network-based product will have a very difficult time to find its market in the real world.

4.2.11 Human-user oriented application

Functions and services provided by sensor networks are quite diverse in many applications and in various market segments. This diversity requires developing an application profile to define an application's requirements and operation concepts for each sensor network application. In developing the application profile, the developer must focus on the end-user of the system, typically the human users. The ultimate goal of sensor networks is "to improve quality of life and change the life style."

For example, the application profile for a subway station security monitoring network should define types of sensor to be deployed (detectors for explosive, poisonous gas, etc.), typical deployment locations, quantity of sensor nodes, information publish mode, function and parameter set, etc. And the application profile should address how the sensor network for the security monitoring system can benefit those people who use subway stations in case of emergency.

5 General requirement of sensor network applications

In this section, general requirements of sensor network applications are explored. The general requirements are considered to be general for all types of sensor network applications, and are used to define functional requirements of sensor network reference architecture.

5.1 Communication

Sensor networks shall have communication ability between sensor nodes, between sensor nodes and a gateway, between a gateway and another gateway. Also, one sensor network shall communicate with another sensor network.

Sensor network communication can be performed by either wired or wireless connections, or a combination of both connections. The communication ranges can vary from short to long distances depending on applied communication protocol, situations and applications. The data rate can vary from low to high data rates.

5.2 Security and privacy

In general, sensor network applications highly require strong security and privacy, as the sensed data are very sensitive. There are various security issues which need consideration, such as protection against unauthorized use of network resources and unauthorized access to information and authentication of users.

5.3 Robustness

Sensor networks shall provide and maintain operational robustness. A sensor network should be able to keep working when some sensor nodes die or leave the sensor network.

5.4 Scalability

Sensor networks shall adapt dynamically to provide scalability for various sensor network applications.

5.5 QoS support

Mission-critical applications and services should be carefully managed. QoS may be a key technical issue in some scenarios. For example, emergency notification of fire in national treasure monitoring system must be delivered by time-critical and reliable way. Sensor network applications have different QoS requirements, such as data accuracy, reliability, latency, etc.

5.6 Heterogeneity

Sensor network application may consist of several different types of networks. Heterogeneous sensor networks supporting an application or applications shall have interoperability among the sensor networks.

5.7 Deployment and coverage

A sensor network shall provide information on deployment and coverage for its prospective application.

5.8 Mobility support

A sensor network with mobile sensor nodes shall support sensor node mobility within the sensor network and shall support the mobility of its sensor node to another sensor network. Also, a sensor network shall accept the transition of a sensor node from another sensor network.

5.9 Power and energy management

Sensor networks with battery powered devices, e.g., sensor nodes, gateway, etc., shall provide a power and energy management scheme.

5.10 Sensor network management

There are different types of sensor network such as IP based sensor networks or non-IP based sensor networks, and wired or wireless sensor networks can co-exist. These diverse types of sensor networks should be managed in transparent way.

5.11 Service registration and discovery

In order to discover the sensor network services, they should be registered beforehand. The association of senor network and sensor data should be registered to service registry. The registered services are needed to be discovered by applications or end-users.

Bibliography

ISO/IEC JTC1 SGSN N149, *SGSN Technical Document Version 3*

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