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Recommendation

ITU-T Y.4909 (03/2023)

SERIES Y: Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities

Internet of things and smart cities and communities – Evaluation and assessment

Assessment framework of Internet of things sensing quality

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Recommendation ITU-T Y.4909

Assessment framework of Internet of things sensing quality

Summary

Internet of things (IoT) systems are implemented by relevant stakeholders to increase the effectiveness, efficiency and the quality of sensing services. All IoT systems depend on the acquisition and use of sensing information. Sensing quality directly impacts the quality of service provided by the IoT systems. The sensing quality assessment framework of IoT systems provides a unified framework for both developers and users to evaluate sensing quality in IoT systems.

Recommendation ITU-T Y.4909 specifies an assessment framework of IoT sensing quality.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Y.4909	2023-03-28	20	11.1002/1000/15488

Keywords

Assessment framework, IoT system, sensing quality, sensing service.

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FOREWORD

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Assessment framework of Internet of things sensing quality

1 Scope

This Recommendation specifies an assessment framework of Internet of things (IoT) sensing quality.

The scope of this Recommendation includes:

– Sensing services in the IoT,

– Sensing quality assessment factors of IoT systems, and

– Sensing quality assessment framework of IoT systems.

NOTE – Policy and regulation are out of the scope of this Recommendation.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

None.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 application [b-ITU-T Y.2091]: A structured set of capabilities, which provide value-added functionality supported by one or more services, which may be supported by an API interface.

3.1.2 device [b-ITU-T Y.4000]: With regard to the Internet of things, this is a piece of equipment with the mandatory capabilities of communication and the optional capabilities of sensing, actuation, data capture, data storage and data processing.

3.1.3 Internet of things (IoT) [b-ITU-T Y.4000]: A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.

NOTE 1 – Through the exploitation of identification, data capture, processing and communication capabilities, the IoT makes full use of things to offer services to all kinds of applications, whilst ensuring that security requirements are fulfilled.

NOTE 2 – From a broader perspective, the IoT can be perceived as a vision with technological and societal implications.

3.1.4 sensor [b-ITU-T Y.4105]: An electronic device that senses a physical condition or chemical compound and delivers an electronic signal proportional to the observed characteristic.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 sensing services: A collection of services including device service, security service, data service, management service, monitoring service, etc.

3.2.2 sensing service provider: An organization, which provides organization-oriented sensing services to sensing service organization consumers and/or individual-oriented sensing services to sensing service individual consumers.

3.2.3 sensing solution provider: An organization, which realizes required software and hardware for a sensing service provider, sensing service organization consumer and/or a sensing service individual consumer, in order to implement sensing services.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ALCOA Attributable, Legible, Contemporaneous, Original, Accurate

FE Functional Entity

IoT Internet of Things

PII Personal Identifiable Information

5 Conventions

In this Recommendation:

The keywords "is required" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this document is to be claimed.

The keyword "may" and "is recommended" indicates an optional requirement which is permissible, without implying any sense of being recommended. These terms are not intended to imply that the vendor's implementation must provide the option and the feature can be optionally enabled by the network operator/service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with the specification.

6 Sensing services in the IoT

Sensing services are important to Internet of things (IoT) systems. Sensing services are the fundamental basis of IoT system operation and the provision of services. In many fields, sensing services are the essential capability of IoT systems such as for example, environmental monitoring, traffic monitoring, e-health care, climate monitoring, etc. Sensing service is the basis of various services provided by IoT systems, including among others information collection, information management, and sensing quality assessment.

6.1 Introduction to sensing services in the IoT

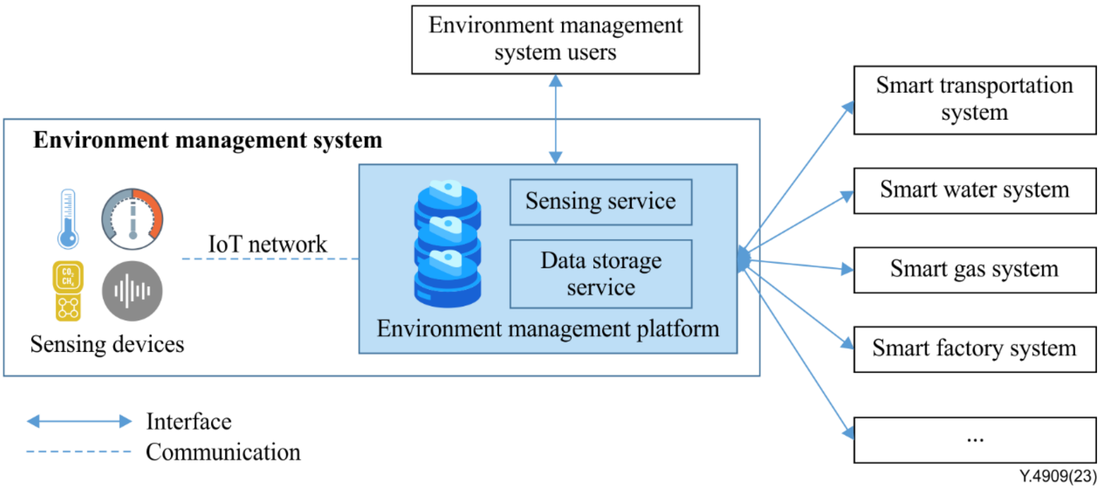

Figure 1 – Sensing services of an environment management system

Figure 1 shows a typical example of sensing services in an environment management system which includes the process, function and users of sensing services. The sensing devices can collect various environmental data, such as temperature, humidity, gas concentration, noise, etc., and upload them to the environment management platform through the IoT network. Inside the IoT system, the sensing service in the platform can evaluate the sensing quality and store data. Outside the IoT system, the platform can provide sensing services to environment management system users through interfaces to help users understand the environment sensing result, as well as sensing services to other systems, such as smart transportation systems, smart water systems, smart gas systems and smart factory systems.

6.2 The sensing quality assessment framework and its benefits for sensing service of IoT systems

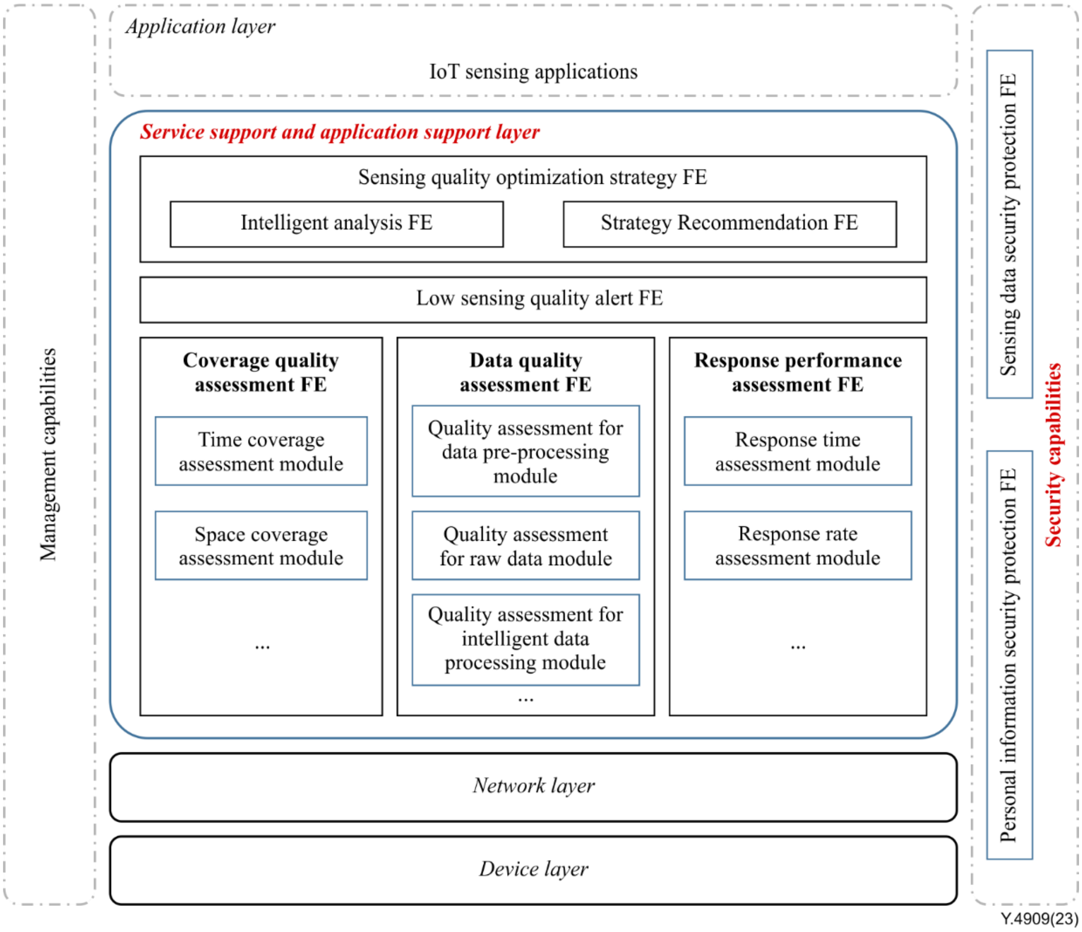

Figure 2 – Sensing service framework of IoT system

In Figure 2, the IoT system contains three major functions: sensing quality assessment, low sensing quality alert and sensing quality optimization. Sensing quality assessment includes coverage quality assessment (time coverage and space coverage), data quality assessment (raw data, pre-processed data, and intelligent processed data) and response performance assessment (response time and response rate) which are evaluated by the coverage quality assessment functional entity (FE), data quality assessment FE and response performance assessment FE. Then, the sensing quality assessment result will be passed to the low sensing quality alert FE. If the sensing quality does not meet the requirements of the system, the result will be passed to the sensing quality optimization strategy FE, so as to analyse the causes of low sensing quality by the intelligent analysis FE and develop the sensing quality optimization strategy by the strategy recommendation FE.

Sensing quality is an important factor affecting IoT applications. The acquisition and use of sensing information is a basis of IoT services provided by many IoT systems, and thus their services are directly affected by the sensing quality.

A sensing quality assessment framework is required by considering many factors such as coverage, data, response time, etc., in order to help the users of IoT systems. This performance assessment framework will identify the requirements of IoT systems and will in turn help in providing solutions.

The sensing quality assessment framework of IoT has the following benefits:

- The sensing quality assessment framework can improve the performance of the IoT systems and applications;

- The sensing assessment framework can assist in selecting an IoT systems with better sensing quality.

7 Sensing quality assessment factors of IoT systems

The IoT sensing quality assessment framework includes three major parts: coverage quality, data quality, and response time. The indicators of each part are closely related to the sensing quality evaluation results.

7.1 Coverage quality

Coverage quality is divided into time coverage quality and space coverage quality. The time coverage quality focuses on measuring time-sensitive sensing tasks, which indicates whether the sensing node has collected a certain amount of data during the task time.

For example, in order to monitor urban traffic congestion during peak hours, sensors such as location and speed need to upload data at a certain time during the peak hour period (for every single sensor).

The space coverage quality focuses on sensing tasks that are sensitive to space coverage. It indicates whether the sensing node can cover the sensing range required by the sensing task.

For example, the percentage of the manhole covers that can be captured by the cameras in the city can be calculated with the accounts for the total number of urban manhole covers (for the sensor group).

The quality of coverage indicates whether the sensing nodes in the IoT systems can meet the basic criteria for sensing task completion.

7.2 Data quality

The IoT systems have three types of data: raw data, pre-processed data, and intelligent processed data. The quality of data directly affects sensing quality. Data quality evaluation indicators include: data validity, reliability, completeness, accuracy, timeliness, consistency, redundancy, etc. The data assessment services include:

- Raw data assessment service: The raw data is divided into static data and dynamic data according to the different sensing devices. Raw data assessment services are based on verifying the integrity, validity, consistency, etc. of sensing information and provide the assessment results.
- Pre-processed data assessment service: Pre-processed data assessment services are based on data cleaning, data fusion, data unification of different data sources, identification of valuable data and evaluating data quality, thus providing assessment results.
- Intelligent processed data assessment service: According to the needs of different tasks and the situation of data preprocessing, intelligent data processing can provide artificial intelligence-based sensing quality management service such as data enhancement, key information extraction, and removal of redundant data, etc. Sensing services will evaluate the sensing quality of intelligently processed data and provide the assessment results.

7.3 Response performance

The response time is determined by the performance of the sensing system and the network state, etc.

The response rate is determined by the number of sensing devices, device idle rate and other factors.

7.4 Security

As an IoT sensing system can perform different sensing tasks, involving multi-user access and data reception of multi-sensing nodes, etc., a large amount of personal identifiable information (PII) and sensing data are stored in the system, and therefore security protection services for relevant data and information are required.

7.5 Ease of use

Ease of use is a reflection of the applicability, functionality and effectiveness of the interoperability between an IoT sensing system and other third-party systems. Ease of use can ensure that IoT sensing system users can quickly learn how to deliver sensing tasks, view the execution process and check the results. The IoT sensing system is recommended to be easy to use in order to improve operational efficiency.

Ease of use includes but is not limited to easy to understand, easy to learn, and easy to operate.

7.6 System openness

IoT sensing system needs to consider the requirements of existing users, it also needs to consider the scalability, so as to better meet the expansion of future applications of IoT sensing systems.

System openness includes the potential information interaction mechanism and external interface guarantee. Potential information interaction mechanism can support the expansion of information interaction modes, such as the cooperation of different types of sensing devices, supporting different communication protocols, and the information interaction between an IoT sensing system and different applications, etc. External interface guarantee can provide diverse interfaces to interact with other systems, such as IoT sensing systems, software service systems, etc.

8 Sensing quality assessment framework of IoT systems

The sensing quality assessment framework of IoT systems includes six factors: coverage quality, data quality, response performance, security, ease of use and system openness of IoT systems. These factors together determine whether the IoT system can provide users with sensing services that meet the requirements of sensing tasks.

Figure 3 shows the sensing quality assessment framework of IoT systems.

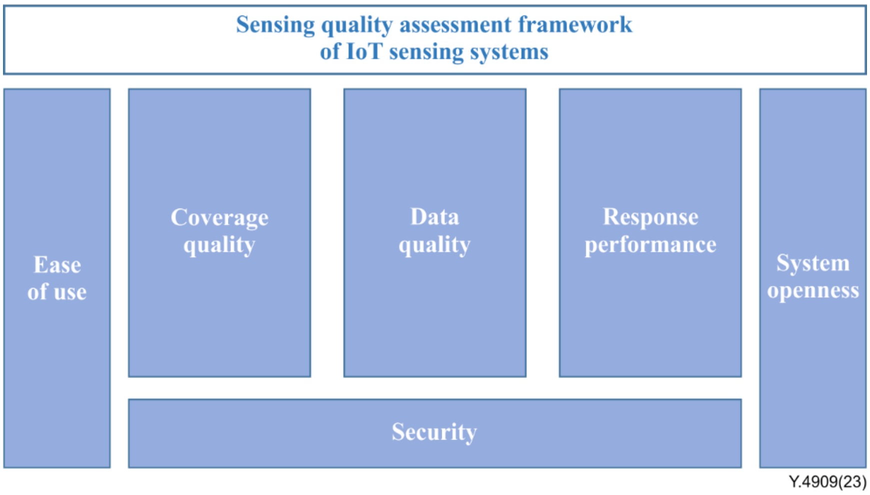

Figure 3 – Sensing quality assessment framework of IoT systems

8.1 Coverage quality

Coverage quality includes two parameters (see Table 1): time coverage quality and space coverage quality. Time coverage quality indicates whether the time period of sensing data collection meets the task requirements, and space coverage quality indicates whether the spatial distribution of collected sensing data meets the task requirements.

Table 1 – Parameters of coverage quality

Parameter	Details
Time coverage quality	The interval of sensing grid area be covered twice in a row.
Space coverage quality	Proportion of effective sensing area to overall sensing area.

8.2 Data quality

Data quality includes seven parameters (see Table 2): validity, reliability, completion, malicious data, redundant data, timeliness and consistency. These parameters together determine whether the collected sensing data is available for sensing task and whether it can be used as the basis for subsequent analysis.

Table 2 – Parameters of data quality

Parameter	Details
Validity	Whether the data is valid needs to be judged whether the data meets the requirements of sensing task. The methods of judgment include but are not limited to: whether the data reporting time is within the specified time, whether the data is within the specified interval, whether the data type is the specified type, and the data format is correct.
Reliability	Data reliability requirements meet ALCOA principles: attributable, legible, contemporaneous, original or true copy, accurate.
Completion	Data completion refers to the logical consistency, correctness, validity and compatibility of data.
Malicious data	There may be malicious sensing nodes in the sensing task, and this part of data needs to be evaluated and removed. NOTE – Malicious data may be correct, but not derived from the required sensing node.
Redundant data	Duplicate and invalid data.
Timeliness	Valid duration of data.
Consistency	The parameter of data consistency includes missing updates, undetermined dependencies, inconsistent analysis and processing.

8.3 Response performance

Response performance includes two parameters (see Table 3): response time and response rate. The response time indicates the efficiency of the IoT sensing system to complete a sensing task, and the response rate indicates how many sensing nodes of the IoT sensing system can provide for a sensing task.

Table 3 – Parameters of response performance

Parameter	Details
Response time	The time from the initiation of the task to the completion of the task.
Response rate	The ratio of the tasks with sensing nodes response to total number of tasks.

8.4 Security

Security includes two parameters (see Table 4): sensing data security and personal identifiable information (PII) security. The security factor indicates the capability and level of data and information security protection provided by IoT sensing system.

NOTE – PII in this context is defined as a user's username and password.

Table 4 – Parameters of security

Parameter	Details
Sensing data security	The degree of security for sensing data storage and processing in the IoT perception system, including prevention of malicious data attacks, data theft, data insecurity, etc.
PII security	The degree of security for PII registration, management, and deletion in the IoT sensing system, including prevention of malicious data attacks, data theft, data insecurity, etc.

8.5 Ease of use

Ease of use includes three parameters (see Table 5): easy to understand, easy to learn and easy to operate. The ease of use factor allows users to better use IoT sensing systems, including, but not limited to, initiating and completing a sensing task, and understanding the results.

Table 5 – Parameters of ease of use

Parameter	Details
Easy to understand	How easy it is for users to recognize the structure, function, logic, concept, application scope, interface and other content of the IoT sensing system. All documents formed in the system development process are required to have a concise language, consistent, easy to understand, and unambiguous sentences, including: 1) function names, icons, prompt information, etc. should be straightforward, clear, without ambiguity, and easy to understand; 2) the user manual fully considers the acceptance level of ordinary users, the language is straightforward, the description is detailed, and the logic is clear; 3) try to avoid professional terms, etc.
Easy to learn	How easy it is for users to learn software applications (operation control, input, output). This feature requires: 1) detailed user documentation, clear structure and accurate language; 2) intuitive operation interface information, easy for users to find the required function menu; 3) prevent the stacking of irrelevant information; 4) The prompt information for operation or handling errors is clear and sufficient; the

Table 5 – Parameters of ease of use

Parameter	Details
	user manual is detailed and clear, allowing users to easily get help.
Easy to operate	How easy it is for users to operate and run the IoT sensing system. It requires that the software has a friendly human-machine interface, a scientific and reasonable interface design, and a simplified operation process.

8.6 System openness

System openness includes two parameters (see Table 6): number and types of information interaction mechanism and number and types of external interfaces. System openness reflects the diversity and expandability of IoT services.

Table 6 – Parameters of system openness

Parameter	Details
Number and types of information interaction mechanism	The number and types of information interaction mechanism reflects the diversity and expandability of IoT services. NOTE 1 – example of information interaction: data protocols, communication protocols.
Number and types of external interfaces	The number and types of external interfaces reflects the diversity and expandability of IoT services. NOTE 2 – example of interfaces: platform interfaces, system interfaces, device interfaces.

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