



IEEE Standard for Spectrum Characterization and Occupancy Sensing

IEEE Computer Society

Developed by the
LAN/MAN Standards Committee

IEEE Std 802.15.22.3™-2020

STANDARDS

IEEE Standard for Spectrum Characterization and Occupancy Sensing

Developed by the

LAN/MAN Standards Committee
of the
IEEE Computer Society

Approved 24 September 2020

IEEE SA Standards Board

Abstract: The architecture, abstraction layers, interfaces, and metadata requirements for spectrum characterization and occupancy sensing (SCOS) systems are specified in this standard. This standard also defines performance parameters, units, and measures. This SCOS system comprises one or more semi-autonomous spectrum sensors, which scan electromagnetic spectrum, digitize it, and perform processing, transmitting the resultant data with appropriate metadata to a central storage and processing system.

Keywords: cognitive radio, IEEE 802.15.22.3, IEEE 802.22, radio spectrum sensing, SCOS, signal characterization, spectrum monitoring, WRAN standards

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Introduction

This introduction is not part of IEEE Std 802.15.22.3-2020, IEEE Standard for Spectrum Characterization and Occupancy Sensing.

The scope of this document is to define a standard for spectrum characterization and occupancy sensing (SCOS). It establishes a high-level architecture, defines functional entities and their interfaces, specifies command and control messages and parameters, and defines metadata describing the nature and configuration of the sensing system and the data it gathers. It also describes operating characteristics and behaviors of the components of the SCOS system, with reference implementations for common use cases. Further, it defines measurement parameters in such a way that data gathered by an IEEE 802.15.22.3 compliant system can be consistently and meaningfully interpreted by users.

The focus of this standard is on management and control of a Sensor network, the ability for a variety of users to interrogate system capabilities and task scanning functions, the definition of a simple reference implementation for the sensing devices, and for the sensed data to be transmitted to an end-point.

The SCOS architecture is intended to provide incentive for the evolution and implementation of the following three areas of specialization: sensor technology, data acquisition/distribution, and data analysis.

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IEEE Standard for Spectrum Characterization and Occupancy Sensing

1. Overview

1.1 Scope

This standard defines a spectrum characterization and occupancy sensing (SCOS) system. It defines the formats for system configuration and spectrum measurement parameters. It includes protocols for reporting measurement information that allow the coalescing of results from multiple systems. The standard leverages interfaces and primitives that are derived from IEEE Std 802.22™-2011 [B1].¹ It uses any available transport mechanism to control and manage the system, and to share sensing data. The standard provides means for conveying value-added sensing information to various spectrum database services.

1.2 Purpose

The purpose of the SCOS system is to characterize and assess the occupancy of spectrum resource towards supporting its more efficient and effective use. The intent of the SCOS system is to create a high-level architecture to support different spectrum sensing technologies and deployments, to enable specialization and provide incentive, to promote broad adoption of sensing technologies and subsequent economies of scale, and to ultimately achieve broader availability and usage of sensing information from different sources. This will enable clients to acquire and use spectrum sensing information from a multiplicity of predefined independent systems to serve their goals.

Various national regulators and government authorities are developing regulatory and policy frameworks to allow cooperative spectrum sharing approaches in order to optimize spectrum utilization. There is emphasis on greater spectrum efficiencies, spectrum sharing and spectrum utilization, which require systems that can provide spectrum occupancy at a particular location and at a particular time.

More broadly, the spectrum characterization and occupancy sensing (SCOS) system has many applications, which include the following:

- a) Policy and planning
- b) Radio planning, management, and engineering
- c) Regulatory enforcement where systems can detect (RF incursion), locate (source), classify (by type and severity), resolve/remediate
- d) Research and technology development

¹The numbers in brackets correspond to those of the bibliography in [Annex A](#).

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).^{2, 3}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEEE Std 1003.1™-1988, IEEE Standard for Information Technology—Portable Operating System Interface (POSIX).^{4, 5}

IETF RFC 2616, Hypertext Transfer Protocol—HTTP/1.1, June 1999.⁶

IETF RFC 8259, The JavaScript Object Notation (JSON) Data Interchange Format, December 2017.

ISO 8601-1:2019, Date and time—Representations for information interchange—Part 1: Basic rules.⁷

The GNU Radio Foundation, Inc., “The Signal Metadata Format (SigMF)”, v0.0.2, July 2018.⁸

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.⁹

² The use of the word *must* is deprecated and cannot be used when stating mandatory requirements, *must* is used only to describe unavoidable situations.

³ The use of *will* is deprecated and cannot be used when stating mandatory requirements, *will* is only used in statements of fact.

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⁵ IEEE publications are available from The Institute of Electrical and Electronics Engineers (<https://standards.ieee.org/>).

⁶ Internet Requests for Comments (RFCs) are available on the World Wide Web at the following ftp site: venera.isi.edu; login: anonymous; password: user's e-mail address; directory: in-inotes.

⁷ ISO publications are available from the International Organization for Standardization (<https://www.iso.org/>) and the American National Standards Institute (<https://www.ansi.org/>).

⁸ The SigMF specification is available at: <https://sigmf.org>.

action: Sensor function that the Sensor developer implements and exposes to the API. Actions give the Sensor owner control over what the Sensor can be tasked to do, for example: instrument control, data acquisition, data processing.

acquisition: The combination of data and metadata created by an action (though an action does not have to create data).

antenna: Required Sensor hardware components that convert environmental electromagnetic fields into a voltage. An RF cable connects the antenna with the next hardware component.

association: The process by which SCOS entities join the SCOS system.

capability: Available actions, installation specifications (e.g., mobile or stationary), and hardware specification (e.g., frequency range of receiver).

Data Client: An external application that may utilize the services exposed from the Manager. For example, a Data Client could be an application that provides long term storage, analysis, and visualization of Sensor data.

computer: Required Sensor hardware components that can provide control signals and messages to the preselector and receiver. Computers may also provide data processing, data packaging, and web-accessible services.

JSON: JavaScript Object Notation is a lightweight data interchange format (IETF RFC 8259¹⁰).

Manager: SCOS entity that allows Users and Data Clients to interact with a distributed network of Sensors via web-based graphical user interface (GUI) and/or remotely accessible API. It exposes the capabilities of the SCOS system to Users and Data Clients, manages schedule requests by Users and Data Clients, provides control over the network of Sensors, and distributes data to Data Clients.

message: A discrete unit of communication utilized to transfer information or invoke a behavior.

object: A data abstraction used to encapsulate related information and behaviors.

preselector: Optional Sensor hardware components that can provide preselection filtering, improved sensitivity via low noise amplification, and calibration signal sources.

property: Data with a type and name that is encapsulated within an object.

protocol: A standard set of rules that allow electronic devices to communicate with each other.

schedule: The collection of all schedule entries (active and inactive) on the Sensor.

scheduler: A Sensor process responsible for executing the schedule.

schedule entry: Input to the Sensor schedule that describes action, start and stop times, interval, and priority.

Sensor: SCOS entity that provides distributed RF sensing through a remotely accessible API. The API allows Manager Users to discover capabilities, schedule actions, and download data. Sensors package data with SigMF metadata in a SigMF TAR archive.

⁹IEEE Standards Dictionary Online is available at: <http://dictionary.ieee.org>. An IEEE Account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

¹⁰ Information on references can be found in [Clause 2](#).

SigMF: Signal Metadata Format (SigMF) is a specification to describe sets of recorded digital signal samples with metadata written in JSON.

signal analyzer: Required Sensor hardware components, for example software defined radios (SDRs), which capture discrete raw data (e.g., baseband representation of the signal) and can apply digital signal processing algorithms to the raw data to achieve a desired metric.

subscription: The process by which Data Clients specify what acquisitions they will receive from Manager.

TAR: A software utility for collecting many files into one archive file.

task: An action that was or will be executed at a specific time as part of a schedule entry.

task result: A record of the outcome of a task.

User: An individual using a Data Client or Manager.

3.2 Acronyms and abbreviations

API	application programming interface
GNSS	global navigation satellite system
GUI	graphical user interface
HTTP	Hypertext Transfer Protocol (IETF RFC 2616)
ID	identifier
JSON	JavaScript Object Notation
N/A	not applicable
SCOS	spectrum characterization and occupancy sensing
SDR	software defined radio
SigMF	Signal Metadata Format
SLA	service level agreement
RF	radio frequency
URL	Uniform Resource Locator

4. System concept

4.1 Context

[Figure 1](#) depicts the boundaries, entities, and high-level interactions of the SCOS system. Users and/or Data Clients interact with the system through the Manager to access a distributed network of one or more Sensors to perform RF sensing.

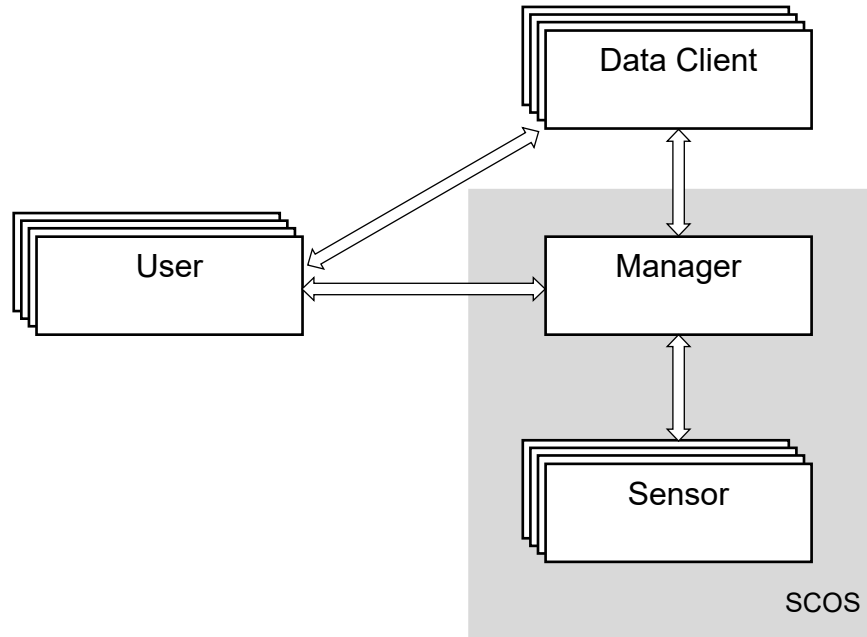


Figure 1—SCOS context diagram

4.2 Entities

The two entities that comprise the SCOS system are the Manager (server application) and one or more Sensor(s) operating in the field. The Manager API also allows third party applications, referred to as Data Clients, to integrate with the SCOS system.

- **Manager:** SCOS entity that allows Users and Data Clients to interact with a distributed network of Sensors via a web-based graphical user interface (GUI) and/or remotely accessible API. It exposes the capabilities of the SCOS system to Users and Data Clients, manages schedule requests by Users and Data Clients, provides control over the network of Sensors, and distributes data to Data Clients.
- **Sensor:** SCOS entity that provides distributed RF sensing through a remotely accessible API. The API allows Manager Users to discover capabilities, schedule actions, and download data. Sensors package data with SigMF metadata (The GNU Radio Foundation, Inc) in a SigMF TAR archive (IEEE Std 1003.1-1988).

4.3 Interactions

Figure 2 describes the basic interactions between a User, Data Client, Manager, and Sensor. The SCOS system supports the following interactions:

- **Association:** Sensors may associate themselves with a Manager by sending an association request (defined in Table 1), but that does not preclude Users from registering a Sensor manually within the Manager. Similarly, a Data Client may associate itself with the Manager with a Data Client association request (defined in Table 15), but that does not preclude a User from manually registering a Data Client within the Manager. The Manager replies to an association request with an association response (defined in Table 2 and Table 16) indicating the status of the request.
- **Capabilities:** Upon registration, or user action, the Manager may request a description of the Sensor's capabilities (Table 5). Data Clients may also send a capabilities request to the Manager to

discover a Sensor's capabilities. A capabilities response message (Table 6) may be returned from the Sensor to the Manager and from the Manager to a Data Client.

- **Subscription:** A Data Client may send a subscription request (defined in Table 19) to the Manager, but depending upon the implementation a User may configure a Data Client subscription within the Manager as well.
- **Schedule:** After a Sensor has been associated with a Manager, a User may use the Manager to define a schedule request. Different implementations may choose to introduce manual approval processes, but any approval processes are implementation specific and beyond the scope of the standard. After the User specifies the schedule parameters, the Manager sends the request (defined in Table 7) to the Sensor. In response, the Sensor will notify the Manager if the schedule entry was accepted with a schedule entry response (defined in Table 8). If the Sensor accepts the schedule request, the Sensor will begin executing the action as defined in the schedule entry. Schedule entry requests may also be sent from a Data Client to a Manager.
- **Data Distribution:** Each time the Sensor executes the action it will result in an acquisition that may contain sensed data and the Sensor sends the Manager an acquisition notification (defined in Table 13). If the Manager has Data Clients that have subscribed to receive the acquisition it will send the Data Clients an acquisition notification. In addition, the Manager may download archives from Sensors, and provide Users and Data Clients the ability to download archives.

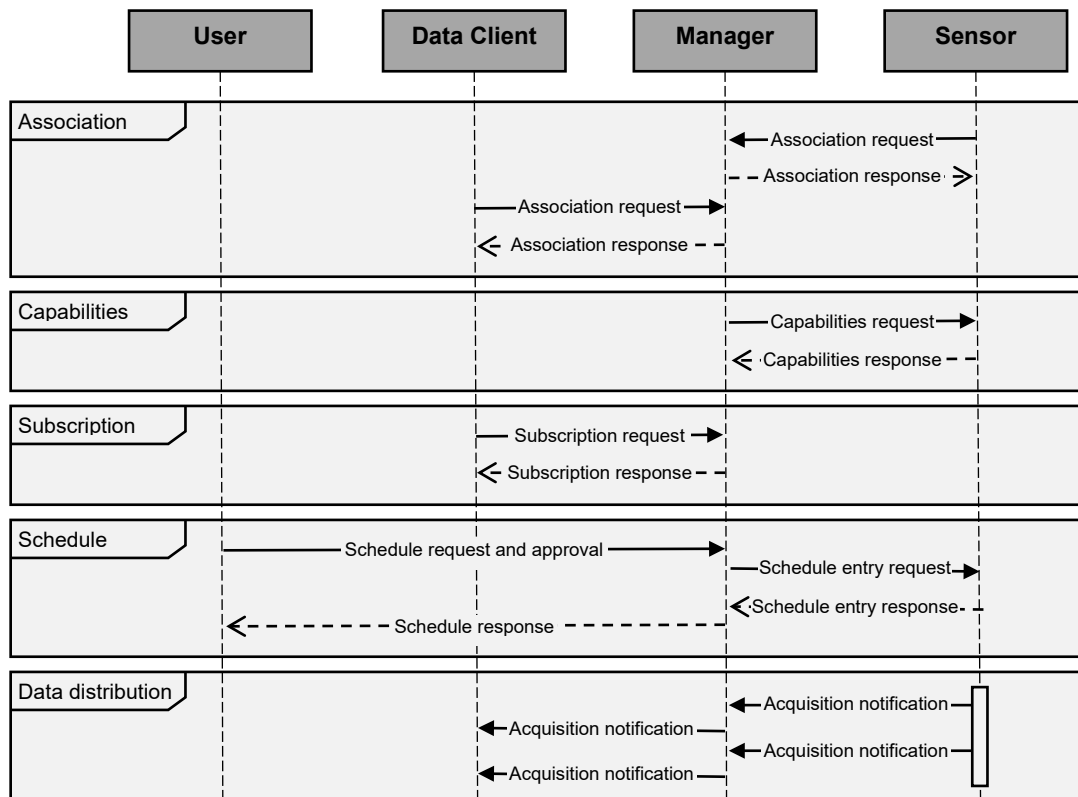


Figure 2—System interactions