SUBMISSION: Revised Section 4

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1. System Architecture
   1. System Block Diagram

Figure 1 illustrates a block diagram of the SCOS architecture. The SCOS system architecture is based on the separation of function between control and data planes. The two SCOS entities are Sensing Manager (SM) and Sensing Device (SD). A SCOS Client (SC) requests sensing data using the SCOS Control Service on the SM. The SM communicates with the SD though its Control Service to initiate spectrum sensing tasks. Data generated is made available by the SD to the SM for distribution to the Data Consumer (DC).

SCOS Control Service (API) SCOS Data Service

SD Control Service (API) SD Data Service

SCOS System

Sensing Manager

SCOS Client(s)

(Sensor and Task) Control

Sensing Device(s)

Data Consumer(s)

Data  
Distribution

Figure 1: SCOS high level system block diagram.

* 1. SCOS System Architecture Layering

**SCOS Control Plane:** Sensing task management and sensor control instructions forms the *SCOS control plane*. It involves the transfer and processing of sensing task requests from the SCOS clients and scheduling the sensing tasks to sensors. The *SCOS control plane* is exclusively defined around sensing tasks – system configuration, management and monitoring tasks are described in informative annexes (Annex XXXxx), and considered out of scope as they are implementation dependent.

**SCOS Data Plane:** This functional area involves collecting sensor data by the Sensing Device, local processing of sensor data at the Sensing Device, packaging this data and finally distributing it to the SCOS clients.

A SCOS system provides services for requesting sensing data, referred to as SCOS Data Request API, and consuming sensing data, referred to as SCOS Data Consumption API. *(<< this needs updating)*

* 1. SCOS System user roles

A SCOS system offers access for the following roles:

* **Data Client:** The individual or system that can request data and/or a sensor action to be scheduled.
* **Sensor Owner:** The individual with design and administrative control of the sensor technology. The Sensor Owner is responsible for registering a sensor with SCOS.
* **SCOS Owner:** The individual or organization that deploys and manages the SCOS network of sensors and has approving authority for all SCOS configurations and operations. The SCOS Owner approves all Data Client and Sensor Owner accounts and sensor actions.
* **SCOS Administrator:** The individual or organization with administrative and physical control over the SCOS System.

The general use case is as follows:

* SCOS Owner establishes an Authority To Operate (ATO) on the SM server application according to well-defined Service Level Agreement (SLA) that specifies system confidentiality, integrity, and availability requirements. The SCOS system offers a sensor and task control service which can be either directly controlled via a Web console or via an APIs with permissions according to specified role. Interfaces to the SCOS Control Service must meet appropriate Information Technology (IT) security requirements defined in Annex C.8 Security Requirements
* Sensor Owner establishes well-documented sensor technology with a list of possible actions available via the ~~RESTful~~ Sensor Control and Data Service. Sensor APIs must meet data transfer and network security requirements defined in Annex C.9 Transport Mechanism Requirements.
* SCOS/Sensor Owner installs network of sensors (sensorNet) and registers each sensor with the SM server application. During registration, the SM acquires sensor capabilities (i.e. possible actions) and maintains a list of available SCOS sensorNet actions.
* SCOS Owner schedules a default set of sensorNet actions that produces data acquisitions, which are moved to SM. SM retains for a relatively short period, e.g., 1 day, 1 week, 1 month, according to SCOS Owner business model. This data is available to Data Consumers, per SCOS Owner approval. ~~SM maintains a list of scheduled sensorNet actions.~~
* SCOS Client registers with SCOS and inquiries about available data and capabilities. SCOS Client can request data and/or scheduled sensorNet actions. If approved by SCOS Owner, data acquisitions are made available to SCOS Client and sensorNet actions are scheduled. SCOS Client can acquire data via SCOS Data Service.
  1. SCOS Platform System entities

The two key entities in this standard are the Sensing Manager (SM) and one or more Sensing Device (SD), which make up the SCOS Platform.

**Sensing Manager:** The Sensing Manager allows user clients (whether individuals or other systems) to interact with the SCOS Platform. It exposes the capabilities of the SCOS platform to users, and manages and mediates tasks requests by users to the sensing devices. Once sensing tasks are performed and the respective Sensing devices transmits the data back to the SM, the SM then manages distribution of that data according to its policies to one or more Data Consumer end points.

**Sensing Device:** The Sensing Device is exposed to the Sensing Manager via the SD Control Service, implemented as an API, which allows control and tasking messages to be exchanged. The SD transfers sensing data out to the Sensing Manager via a message transport mechanism through the SD Data Service.

* + 1. System Entity: Sensing Manager

This entity is comprised of two functional entities, the Sensor and Task Control entity (control plane) and the Data Distribution Entity (data plane), which may be hosted within the same compute environment, or virtualized and hosted in separate environments. The Control entity is exposed to the SCOS Client via the SCOS Control Service via a directly coupled interface, or via an API. The Data Distribution Entity transfers data to the Data Consumer through the SCOS Data Service, implemented as a data transfer mechanism.

* + - 1. Sensing Manager: Control System Requirements
* SM Control service: This would be a set of standardized functions that can be controlled, accessed via a hard-wired Web service, or through an API. The mechanism for control is out of scope of the standard – however, the functions and the primitives used to interact with them are defined.
* User authentication and user profile management: this would be provided by a function that allows for permissions to be assigned to users defined by their Role to access Control and Administrative functions.
* Attached Sensor management: The SM shall provide for sensor authentication, management of the inventory of capabilities of each associated SD, management of the state of each associated SD, storage on the SM of a copy of the scheduled tasks of each associated SD (i.e. table of tasks that each SD has accepted), storage on the SM of the schedule of tasks that have been requested of associated SDs (i.e. that the SCOS Clients have requested but that SDs have not yet necessarily accepted)
* SD Control: the service that manages instructions from the SM to SDs, including the transfer of scheduling requests and acceptance status by the SD.
* Business logic: intelligence to apply polices and execute workflows
  + - 1. Sensing Manager: Control System Functional Requirements

The Sensing Manager’s Control System shall operate database services for:

* Sensor Devices: store data as to each associated SD’s state, authentication data, capabilities, and the state and nature of scheduled tasks that have been accepted by SDs)
* SCOS Resources: store data describing aggregated capabilities across all associated SDs, and the state and nature of scheduled tasks that have been requested of SDs
* SCOS Users: a data store of user credentials, user role, SCOS role profiles and the relevant CRUD permissions

The Sensing Manager’s Control System shall provide data interfaces for:

* User Management: Allows users to log in, create/change users (by Role)
* Capabilities Query: Allow SD capabilities to be queried and exposed to SCOS Clients (by Role)
* State Query: Expose sensor state for display by Client systems
* Task Query: Allow SD current schedules to be exposed (by Role and user)
* Task Management: Allow entry of tasks into request schedule (by Role and user)
* Data Transfer: Transfer sensor data for consumption by Data Consumers (by policy)
  + - * 1. Sensing Manager Control Function: Task Management

The SM is primarily responsible for sensing task management. Sensing task management involves:

* Scheduling of Scan based on the requests from the Data Clients
* Enforcing policy to meet the regulatory and administrative requirements
* Communication with SDs, DCs, and DM
  + Data Request Interface with Data Clients
  + Sensing Interface with SDs
  + Sensing Coordination with DM

SCOS platform provides sensing as a service. The Sensing Manager facilitates making sensing requests in terms of frequency, start time, end time, scan duration, repetition~~. SCOS data request API provides the ability to specify additional sensing options.~~

A SCOS Client may indicate whether the desired scan slots are “Exact Time” slots or “Nearest Time” slots. The scheduler on the TM uses this indication to try meet the SCOS Client request and confirms whether scan service request is accepted or refused.

Figure 2 shows a simplified model for Sensing Manager Control.

● Sensor Management: TM maintains the information from sensors obtained during SD association message exchange. The sensor information is identified in Annex B. This information is used by the TM during task scheduling for determining which set of sensors could be used for performing the scan.

● Sensing Task Management: Task management function maintains information about to-be-scheduled, scheduled, and on-going tasks. The information about to-be-scheduled tasks is used in task scheduling, the information about scheduled tasks is synchronized with the SDs. The information about the ongoing tasks is used in task query/coordination/notification with SCOS Client, and SDs.

● Policy Enforcement: A key part of SCOS administration is enforcing policies for spectrum sensing. The TM ensures that the SCOS Client issuing a scan request is authorized to perform the requested scan, the scanning parameters comply with the regulatory policy for the location, frequency, time, and resolution

● Task scheduling: Task scheduling involves enforcing policy for the requested scan, identifying a set of eligible and available sensors using the sensor information, associating chosen sensors to the task, assigning scanTaskID to the task, updating the task status in the task information.

~~● Sensing coordination: The TM needs to coordinate the status of tasks with DM for example, TM assigns a DM for each of the scheduledTasks. The scanTaskID assigned by the TM is used by SDs when SDs provide sensing data to the DM.~~

● SCOS Data Request API: The TM communicates with the TAs using the Data Request API, provides response to the methods under the Data Request APIs, provides notification to the TAs upon task completion or error events.

● SCOS Sensing API: The TM communicates with SDs using the Sensing API, receives the sensor capabilities, and provides a spectrum scan schedule to the sensors along with necessary information for sending sensing data to the DM.

* + - 1. Sensing Manager: Data Distribution Service Functional Requirement
* SCOS Data Distribution Service: manages the transfer of sensor data northbound to the eventual Data Consumer(s).
* SD Data Distribution Service listener: receives northbound data transfers coming from each associated SD’s Data Distribution Service into the SM.

Figure 3 shows a simplified model for SM Data Distribution Service.

* Sensing data management: DM maintains data for the on-going tasks. The data received from the SDs needs to be stored internally for distribution to DCs. The DM may also need to have the capability to hold data for certain privileged tasks for a short duration identified by policy for the sensing data.
* Sensing data distribution: DM interprets the information associated with each scan request passed through with the scan data regarding SCOS Clients and their associated scanning tasks. Sensing data distribution involves providing necessary reliability depending on the chosen transport.
* Policy enforcement: A key part of SCOS administration is enforcing policies on the sensing data. The Data Distribution Service ensures that the Data Consumers issuing a subscription request for the sensing data are authorized to receive the data.
* Data validation and consolidation: The Data Distribution Service validates the data received from the SDs against the specified details from the task such as location, frequency, time, and measured data format. It consolidates data based on scanning task requirements.
* ~~Sensing coordination: The DM needs to coordinate the status of tasks with TM for example, the expected sensing data from specific SDs for specific sensing tasks; also, availability of DM resources for future scanning tasks which could be used TM in choosing the DM~~.
* ~~SCOS Sensing Data Collection API: The DM communicates with the SDs using the Data Collection API. It receives data for specific sensing tasks from specified SDs as coordinated with the TM~~.
* SCOS Sensing Data Distribution ~~API~~: The Data Distribution Service communicates with Data Consumers, implements the data transport mechanism for distributing the sensing data to the authorized Data Consumers.
  + 1. System Entity: Sensing Device

SDs gather, condition and sample the radio frequency environment, taking the processed samples, and package them within a compute platform into a standardised format along with relevant metadata. This is transmitted them to the Sensing Manager for final transmission to the appropriate Data Consumer.

Sensing Devices are stateless and offer an API (SD Control Service) to allow SCOS Clients, via the Sensing Manager, to schedule actions. The SD can operate either as a slave device to the Sensing Manager, i.e. it performs scans on instruction, or it can operate semi-autonomously, i.e. it manages a schedule of scans that it periodically synchronizes with the Task Manager.

To allow the SD to be given an instruction to perform sensing activity, it is able to initiate an association with the Task Manager and perform the required authentication and authorization functions.

Sensors execute on schedule actions to sample the radiofrequency environment, process the data, package the data with appropriate metadata, and make the acquisition data package available to the sensor client.

* + - 1. Sensing Device System Requirements
* SD Control Service: A stateless API (e.g. REST) that allows the SM to query the SD, and give it tasks to schedule.
* Capabilities Discovery: The SD shall have a system to itemise and expose its capabilities to the SM
* Sensing Task Scheduler: The SD shall have an onboard task scheduling capability to receive and make decisions about tasks, and communicate if the tasks are accepted/rejected, and locally store this schedule.
* Sensing Task Execution: the SD shall have a capability to execute defined sensing tasks itemised in the scheduler, and be able to communicate the status of these tasks back to the SM.
* Data Packager: The SD shall have a capability to package sensed data with relevant metadata into a format suitable for transmission.
* Data Transfer: The SD shall have a capability to transfer the data packages to the SM Data Distribution Service
* SD Activation Service: the SD shall have the capability to advertise itself to an SM to allow association with it, including secure authentication with the SM.
  + - 1. Sensing Device Functional Requirements
         1. Sensing Device Software Model

Software requirements shall include Sensing Device Control API with the following requirements to allow the SM Control Service to:

(1) Query possible actions

(2) Insert tasks into scheduler

(3) Manage version control back to the SM Control Service

Further it shall provide a Sensing Device Data Manager API with the following requirements:

(1) Perform data packaging to meet SCOS Data/Metadata format specification

(2) Perform data transmission to the SM Data Distribution Service

* + - * 1. SD Security Requirements

To be completed.

* + - * 1. SD Algorithm Model

The algorithm model is described in terms of

● inputs into black box: the identity of the USER and TM requesting the scan, the measurement parameters, which algorithm is to be used; and

● outputs from the black box: the identity of the USER and TM requesting the scan, the requested scan parameters, the identification of the algorithm model, and the processed results.

The following table enumerates the parameter definition object for the Algorithm Model.

Table 1 SD Algorithm Model Description

|  |  |  |
| --- | --- | --- |
| Parameter | R/O/C | Description |
| NAME: AlgorithmSet  DATA TYPE: Array of String | Required | Names of algorithms supported by the SD.  The maximum length of the ID string is 64 octets. |

The following algorithms can be specified. At least once algorithm model needs to be supported by SD. Support for GenericEnergyDetection is normative. The standard allows development of advanced algorithms, which shall be identified in the table.

Table 2 SD Detection Algorithm Options

|  |  |
| --- | --- |
| Scan Algorithm | Description |
| GenericEnergyDetection | Normative. |
| CyclicFeatureDetection | Optional |
| CustomScanAlgorithm | Optional |

It is the responsibility of the SCOS Administrator to publish algorithm definitions externally. The implementation does not need to be publicly accessible. Where these algorithms are non-proprietary, the metadata should include explicit links to repositories providing algorithm details, sample code and definition, on open access sites such as GitHub.

Annex B defines how control plane and data plane information specification. In Annex B, different categories of metadata are identified and described.

* + - * 1. Sensing Device Hardware Model

A simplified hardware block diagram of a general SD model is depicted in Figure 4: SD Simplified Hardware Model Block Diagram. SD hardware designs are not required to have each component shown in the block diagram. Metadata that describe each component (e.g., presence, model, operational parameters), however, are required in response to queries for sensor capabilities and to accompany data acquisitions.

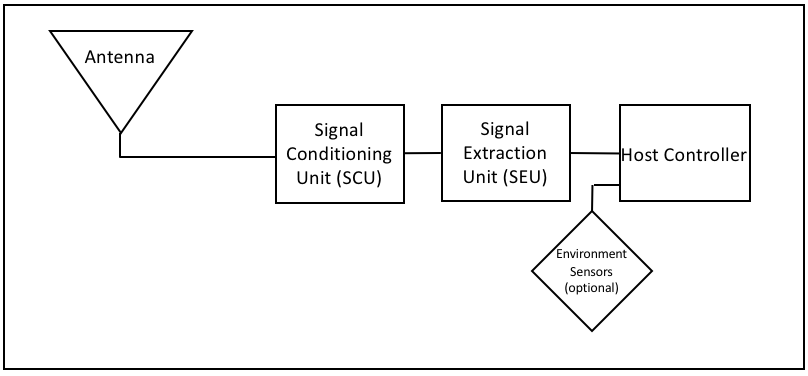


Figure 4: SD Simplified Hardware Model Block Diagram

● Functional element 1 – Antenna: An antenna converts environmental electromagnetic fields into a voltage. An RF cable connects the antenna with the next hardware component.

● Functional element 2 – Signal Conditioning Unit (SCU): An RF front end that could provide (among other things) preselection filtering, improved sensitivity via low noise amplification, and a calibration signal source. An RF cable connects the SCU with the next hardware component.

● Functional element 3 – Signal Extraction Unit (SEU): Analog Digital Converter (ADC), spectrum analyzer, Software Defined Radio (SDR), or other sampling device that also typically provides down-conversion and signal processing. A typical output of the SEU is a discrete baseband representation of the acquired signal.

● Functional element 4 – Host Controller: that provides

o The Host Controller provides control signals and messages to SCU and DEU. Raw data can be processed, e.g., to calculate calibrated absolute power at a reference point in the sensor RF path. Data acquisitions are packaged with metadata from sensor configuration onboard instruments, e.g., GPS. Furthermore the Host Controller receives configure and control metadata and sends necessary command and control signals to Functional Element 2 (Conditioning Unit), Functional Element 3 (Extraction Unit) and Functional Element 1 (Antenna), if the Antenna is a reconfigurable unit. It receives data from the Sensor/SDR, and polls any environment sensor input devices for necessary metadata items, such as GPS location. Interaction of the various elements is described in Figure 5: SD Functional Elements.

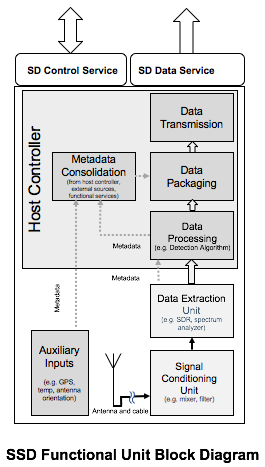


Figure 5: SD Functional Elements

This block diagram can be split into the hardware layer and the software processes that run alongside. These hardware blocks or software services generate metadata that is associated with each item.