

IEEE Standard for Spectrum Sensing Interfaces and Data Structures for Dynamic Spectrum Access and Other Advanced Radio Communication Systems

Sponsored by the
IEEE Communications Society
and
**IEEE Standards Coordinating Committee 41
on Dynamic Spectrum Networks**

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IEEE Standard for Spectrum Sensing Interfaces and Data Structures for Dynamic Spectrum Access and Other Advanced Radio Communication Systems

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**IEEE Standards Coordinating Committee 41
on Dynamic Spectrum Networks**

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Abstract: The interfaces and data structures required to exchange sensing-related information in order to increase interoperability between sensors and their clients developed by different manufacturers are defined in this standard. The logical interface and supporting data structures are defined abstractly without constraining the sensing technology, client design, or data link between sensor and client. The entities involved and parameters exchanged in this process. It further elaborates on the service access points, service primitives, as well as generic procedures used to realize this information exchange, are defined by this standard.

Keywords: cognitive radio, data structure, distributed spectrum sensing, dynamic spectrum access, IEEE 1900.6, logical interface, sensing information, spectrum sensor

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Introduction

This introduction is not part of IEEE Std 1900.6-2011, IEEE Standard for Spectrum Sensing Interfaces and Data Structures for Dynamic Spectrum Access and Other Advanced Radio Communication Systems.

Given the increasing proliferation of devices that use radio spectrum and the resulting shortage of capacity in allocated spectrum bands, new technologies are being introduced that allow devices to access other unused spectrum bands dynamically to serve traffic demands. These new technologies require reliable, dependable, and trusted spectrum sensing capabilities in order to make accurate assessments of spectrum availabilities in the surrounding operational area. Such capabilities will assist devices and associated radio equipment in identifying locally/temporally available spectrum that can be accessed without affecting the incumbent users of that spectrum.

The IEEE 1900 Standards Committee was established in the first quarter 2005 jointly by the IEEE Communications Society and the IEEE Electromagnetic Compatibility Society. The objective of this effort is to develop supporting standards dealing with new technologies and techniques being developed for next generation radio and advanced spectrum management. On March 22, 2007, the IEEE Standards Board approved the reorganization of the IEEE 1900 effort as Standards Coordinating Committee 41 (SCC41) on Dynamic Spectrum Access Networks (DySPAN). The IEEE Communications Society and Electromagnetic Compatibility Society are sponsoring societies for this effort, as they were for the IEEE 1900 effort.

The IEEE 1900.6 working group was launched on September 26, 2008 to address the development of spectrum sensing interfaces and data structures for the exchange of sensing-related information to increase interoperability between sensors and their clients provided by different manufacturers.

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1. Overview

Background

Given the increasing proliferation of devices that use radio spectrum and the resulting shortage of capacity in allocated spectrum bands, new technologies are being introduced that allow devices to access unused spectrum bands dynamically to serve traffic demands. These new technologies require reliable, dependable, and trusted spectrum sensing capabilities in order to make accurate assessments of spectrum availability in the surrounding operational area. Such capabilities will assist devices and associated radio equipment in identifying locally/temporally available spectrum that can be accessed without causing harmful interference to the incumbent users of that spectrum.

Problem

Recently proposed advanced radio systems based on sensing technology (e.g., those being worked on within IEEE P802.22™ [B2]¹) combine sensing and the protocols and cognitive engines (CEs) that use the

¹ The numbers in brackets correspond to those of the bibliography in Annex F.

sensing results into proprietary architectures. This model of development reduces innovation and limits the opportunities for integrating new component technologies for better system performance. Furthermore, the results of sensing extend beyond the activities of a single system and are ideally integrated into the larger spectrum management process including the development of spectrum use monitoring and enforcement activities.

Many different sensing techniques have been defined and implemented, yet there has been no effort to provide interoperability between sensors and clients developed by different manufacturers.

Solution

This standard defines the interfaces and data structures required to exchange sensing-related information for increasing interoperability between sensors and their clients developed by different manufacturers. The clients can be cognitive engines as in the focus of this standard or can be any other type of algorithms or devices (e.g., adaptive radio) that use sensing-related information. Being aware of evolving technologies, interfaces are developed to accommodate future extensions, new service primitives, and parameters.

How this standard applies

This standard provides a formal definition of data structures and interfaces for exchange of spectrum sensing-related information.

1.1 Scope

This standard defines the information exchange between spectrum sensors and their clients in radio communication systems. The logical interface and supporting data structures used for information exchange are defined abstractly without constraining the sensing technology, client design, or data link between the sensor and client.

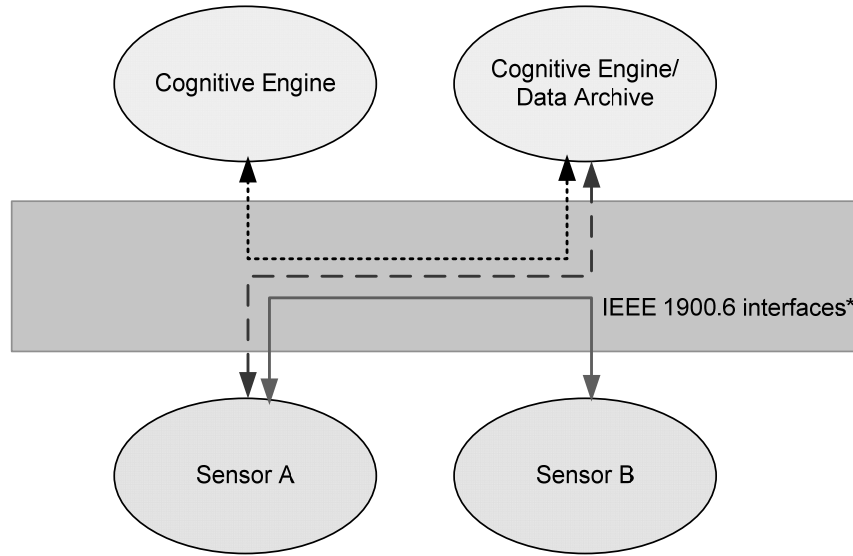
1.2 Purpose

The purpose of this standard is to define spectrum sensing interfaces and data structures for dynamic spectrum access (DSA) and other advanced radio communications systems that will facilitate interoperability between independently developed devices and thus allow for separate evolution of spectrum sensors and other system functions.

1.3 Interfaces and sample application areas

1.3.1 IEEE 1900.6 interfaces

Figure 1 illustrates IEEE 1900.6 interfaces between spectrum sensors and their clients (cf. 3.1).



*The client role can be taken by Cognitive Engine, Sensor and Data Archive

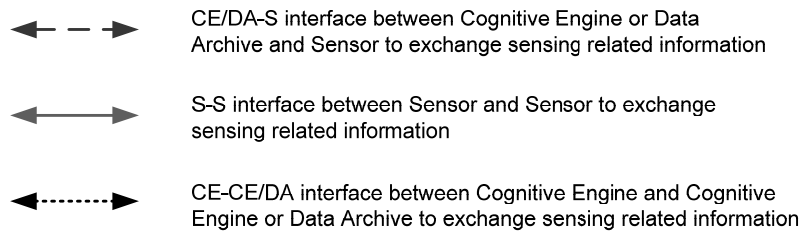


Figure 1—IEEE 1900.6 interfaces between spectrum sensors and their clients

As shown in Figure 1, there are three possible instances of the logical interface within the scope of this standard depending on the logical entities using the IEEE 1900.6 interface:

- CE/DA-S² interface between CE or data archive (DA) and Sensor
- S-S interface between Sensor and Sensor
- CE-CE/DA interface between CE and CE or DA

The CE/DA-S interface is used for exchanging sensing-related information between a CE or DA and a Sensor. As an example, the CE/DA-S interface is used in scenarios where a given CE or DA obtains sensing-related information from one or several Sensors or a given Sensor provides sensing-related information to one or several CEs or DAs.

The S-S interface is used for exchanging sensing-related information between Sensors. As an example, the S-S interface is used in scenarios when multiple Sensors exchange sensing-related information for distributed sensing (see the definition of distributed sensing in 3.1).

The CE-CE/DA interface is used for exchanging sensing-related information between CEs or between CE and DA. The CE-CE/DA interface is used in scenarios where CEs exchange sensing-related information for distributed sensing. The CE-CE/DA interface is also used in scenarios where a CE obtains sensing-

² “CE/DA” denotes CE or DA.

related information and or policy/regulatory information from a DA. For CE–CE/DA communication, a CE/DA shall be able to take the role of Sensors in terms of providing the CE/DA–S interface for the duration and purpose of exchanging sensing-related information.

The following subclauses detail sample application areas of this standard.

1.3.2 Reporting data format of the sensing-related information

The standard defines the set of sensing parameters that will allow for spectral opportunities exploitation. For example, binary values “0” for idle and “1” for occupied band or soft parameters (e.g., detected received power, cyclo-stationary features level, and direction of arrival of the licensed user signal) shall be reported by the Sensors to their clients. The standard specifies the data formats of these parameters in a protocol-independent manner.

1.3.3 Single-device sensing and multiple-device sensing

Single device sensing denotes spectrum sensing capabilities or performance measurements based on the information obtained from a single sensor. This can be considered as the reference case for more sophisticated sensing techniques based on multiple sensing devices. Multiple device sensing includes distributed sensing between different radio nodes or between sensors. Sensing information obtained from distributed sensors shall be qualified either implicitly or explicitly by time and location of the acquisition of measurement data as well as by the attributes or characteristics of the acquisition method utilized. Some concise examples are given in A.2. The standard has been developed considering different use cases which rely on the exchange of sensing-related information between multiple sensors and a client by referring to existing sensing methods, techniques, and their approaches (see Nogu  t et al. [B7]). The detailed study of protocols related to multiple device sensing is outside the scope of this standard.

1.3.4 Usage of spectrum sensing cognitive radio (CR) for the investigation of policy violations

The standard defines a logical interface to support exchange of a complete set of sensing-related information between Sensors and their clients. The logical interface defined in this standard may be applied to use cases such as the radio scene analysis and investigation of policy violations. Verification algorithms are outside the scope of this standard.

1.4 Conformance keywords

In this document, the word *shall* is used to indicate a mandatory requirement. The word *should* is used to indicate a recommendation. The word *may* is used to indicate a permissible action. The word *can* is used for statements of possibility and capability.

2. Normative references

The following referenced documents and URLs 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 1900.1TM-2008, IEEE Standard Definitions and Concepts for Dynamic Spectrum Access: Terminology Relating to Emerging Wireless Networks, System Functionality, and Spectrum Management.^{3,4}

IEEE Std 1900.4TM-2009, IEEE Standard for Architectural Building Blocks Enabling Network-Device Distributed Decision Making for Optimized Radio Resource Usage in Heterogeneous Wireless Access Networks.

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. *The IEEE Standards Dictionary: Glossary of Terms & Definitions* should be consulted for terms not defined in this clause.⁵ For any definition not given in this subclause, IEEE Std 1900.1TM-2008 shall apply.

cognitive engine (CE): A logical entity that contains cognitive control mechanisms, which may include policy-based control mechanisms, and uses sensing information to assess spectrum availability.

data archive (DA): A logical entity storing systematically sensing-related information.

distributed sensing: The process of sensing where sensors are distributed in acquisition time, space, frequency, and function.

IEEE 1900.6 application service access point (A-SAP): A service access point used by applications accessing services of an IEEE 1900.6 compliant server.

IEEE 1900.6 client⁶: A logical entity, application, or device (compliant to this standard) that receives sensing information and spectrum usage-related information from an IEEE 1900.6 compliant server. In general, the information exchange between IEEE 1900.6 compliant clients and servers applies to sensing-related information.

NOTE—The term “client” is used in the context of describing the IEEE 1900.6 service and denotes a conceptual functional role of an IEEE 1900.6 logical entity. It is the counterpart to an IEEE 1900.6 server.⁷

IEEE 1900.6 communication service access point (C-SAP): Used for the exchange of sensing-related information between remote IEEE 1900.6 servers and clients by means of a communication subsystem.

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⁴ IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854, USA (<http://standards.ieee.org/>).

⁵ *The IEEE Standards Dictionary: Glossary of Terms & Definitions* is available at <http://shop.ieee.org/>.

⁶ The terms “client” and “servers” refer to roles of IEEE 1900.6 logical entities that are defined by the direction of the flow of sensing-related information. These terms are used when addressing the exchange of chunks of information between logical entities and are not related to the use of service primitives and subsequent exchange of protocol messages required to realize the exchange of sensing-related information.

⁷ Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

IEEE 1900.6 logical entity: Part of the underlying logical entity–relationship model. It is defined by its functional role(s) and interfaces with other IEEE 1900.6 logical entities. The three types of logical entities in the IEEE 1900.6 logical model are Sensor, CE, and DA. Logical entities are realized through an IEEE 1900.6 service.

IEEE 1900.6 logical interface: A conceptual boundary between two or more IEEE 1900.6 logical entities. Logical interfaces exist between Sensors (S–S interface), between CE and/or DA and Sensors (CE/DA–S interface) and between CE and DA (CE–CE/DA interface). These interfaces are realized by the services or by a subset of the services available at the IEEE 1900.6 SAPs.

IEEE 1900.6 measurement service access point (M-SAP): Used for the exchange of sensing-related information between the spectrum measurement module and its M-SAP user.

IEEE 1900.6 server⁶: An IEEE 1900.6 logical entity, application, or device that provides sensing information and spectrum usage-related information to IEEE 1900.6 clients. In general, the information exchange between IEEE 1900.6 clients and IEEE 1900.6 compliant servers applies to sensing-related information.

NOTE—The term “IEEE 1900.6 server” is used in the context of describing the IEEE 1900.6 service and denotes a conceptual functional role of an IEEE 1900.6 logical entity. It is the counterpart to an IEEE 1900.6 client.

IEEE 1900.6 service: An abstraction of the totality of those functional blocks inside IEEE 1900.6 servers and clients realizing the IEEE 1900.6 logical interface.

IEEE 1900.6 service access point (SAP): A conceptual location at which an IEEE 1900.6 service user can interact with the IEEE 1900.6 service provider by means of utilizing IEEE 1900.6 service primitives. A service access point makes an IEEE 1900.6 service accessible to an IEEE 1900.6 client. The three types of service access points are IEEE 1900.6 communication service access point (C-SAP), IEEE 1900.6 application service access point (A-SAP), and IEEE 1900.6 measurement service access point (M-SAP).

IEEE 1900.6 service primitive: Describes the interaction with an IEEE 1900.6 service provider through an IEEE 1900.6 service access point (SAP) in an abstract implementation-independent way.

NOTE—The term “IEEE 1900.6 service primitive” is adopted from ITU-T Recommendation X.210 [B5].

IEEE 1900.6 service provider: An abstraction of the totality of those entities that provide an IEEE 1900.6 service to the IEEE 1900.6 service user. The IEEE 1900.6 service provider includes the IEEE 1900.6 service and the associated IEEE 1900.6 service access points (SAPs) that instantiate the logical interface for the exchange of sensing-related information between IEEE 1900.6 servers and clients.

NOTE—The term “service provider” is used in the context of protocol and procedure specifications and denotes a conceptual functional role of an IEEE 1900.6 logical entity. It is the counterpart to a service user.

IEEE 1900.6 service user: The IEEE 1900.6 logical entity that shall use the IEEE 1900.6 service and the associated IEEE 1900.6 SAPs that instantiate the logical interface with the purpose to exchange and use sensing-related information.

NOTE—The term “service user” is used in the context of protocol and procedure specifications and denotes a conceptual functional role of an IEEE 1900.6 logical entity. It is the counterpart to a service provider.

message transport service: A communication service commonly associated with the functionality of an open systems interconnection (OSI) transport layer protocol that supports transaction based exchange of messages between communication peers. In this standard, the message transport service implements the exchange of sensing-related information between remote IEEE 1900.6 servers and clients across a platform-provided communication subsystem.

regulatory requirements: A category of sensing-related information derived from regulations, including definitions of the sensing range, accuracy requirements, granularity, required measurement bandwidth, periodicity, and detection sensitivity, as well as information about sensing permission and synchronization. Regulatory requirements are expressed in the form of sensing and sensing control parameters.

NOTE—The term “regulatory information” is used synonymously in conjunction with the exchange of sensing-related information.

sensing: In the context of radio frequency spectrum, it refers to the act of measuring information indicative of spectrum occupancy (information may include frequency ranges, signal power levels, bandwidth, location information, etc.). Sensing may include determining how the sensed spectrum is used (cf. Clause 6).

sensing control information: Information describing the status and configuration of IEEE 1900.6 logical entities as well as information controlling and configuring the acquisition and processing of sensing information.

sensing information: Any information acquired by and obtained from sensors, including related spatio-temporal state information such as position, time, and confidence of acquisition.

sensor: A logical entity that performs sensing (see the definition of sensing in 3.1) within a radio system. Sensors may also act as clients of other Sensors.

NOTE—For the remainder of the document, any entity described as “IEEE 1900.6 logical entity” denotes a logical entity compliant to this standard.

3.2 Acronyms and abbreviations

A-SAP	application service access point
A/D	analog-to-digital
ADC	analog-to-digital conversion
AP	access point
BS	base station
C-SAP	communication service access point
CE	cognitive engine
CR	cognitive radio
D/A	digital-to-analog
DA	data archive
DAC	digital-to-analog conversion
DLC	data link control
DRRUO	distributed radio resource usage optimization
DSA	dynamic spectrum access
DSM	distributed sensing models
DSS	dynamic spectrum sharing
ISM	industrial, scientific, and medical
LTE	long -term evolution
M-SAP	measurement service access point
MAC	media access control
MCM	mobile node spectrum coordination model
NCM	network node spectrum coordination model
NRM	network reconfiguration manager
OSI	open systems interconnection
PHY	physical layer
PDA	personal digital assistant

PDU	protocol data unit
RAN	radio access network
RAT	radio access technology
RF	radio frequency
SAP	service access point
SeEM	sensing enhanced model
SEM	service enhanced model
SME	station management entity
SDU	service data unit
SPOLD	substitute for primary operation of longer duration
SPOSD	substitute for primary operation of shorter duration
TRM	terminal reconfiguration manager
ULME	upper layer management entity
UML	Unified Modeling Language
UTC	Coordinated Universal Time
WLAN	wireless local area network

4. System model

The IEEE 1900.6 system model describes the relationship of logical entities and interfaces detailed by subsequent clauses of this standard. The description of the interaction of these entities across their interfaces shall be the purpose of the IEEE 1900.6 reference model (Clause 5).

The system model has been derived from the requirements implied by the use cases given in Annex A. It respects various spectrum usage models, distributed sensing models, and sensing topologies as elaborated further by Annex A. The scenarios given by this clause complement each other and shall be seen as applications of the IEEE 1900.6 system model, each of them satisfying a given purpose and a certain subset of requirements as detailed by Annex A.

The two main categories of spectrum usage models are a long-term spectrum usage model and a short-term spectrum usage model. The terms “long term” and “short term” are understood within the context of use cases as related to the observed period of activity of the licensed/primary spectrum user.

- Long-term spectrum usage model: Spectrum is used over a relative long period (e.g., emergency services; please refer to A.1.1.1).
- Short-term spectrum usage model: Spectrum is used over short periods (e.g., ad hoc licensee service; please refer to A.1.2.2).

The abstract, high-level system model presented in this subclause is not dependent on topology or the spectrum usage model. Based on this system model, the use cases detailed in Annex A have been classified within each usage as shown in 4.1.

4.1 Scenario 1: Single CE/DA and single Sensor

In this scenario as shown in Figure 2, a single Sensor provides sensing-related information to one CE/DA. It is denoted as “1:1 scenario.” The following instance of the IEEE 1900.6 logical interface is involved:

- CE/DA–S interface

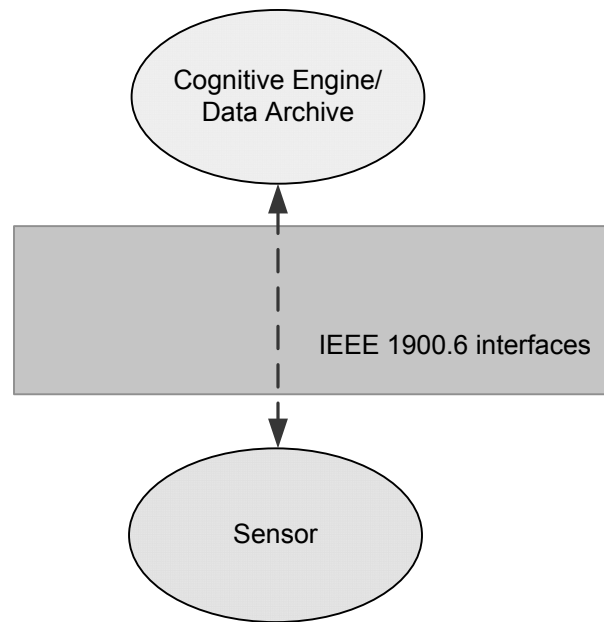


Figure 2—Single CE/DA and single Sensor scenario

4.2 Scenario 2: Single CE/DA and multiple Sensors

In this scenario as shown in Figure 3, multiple Sensors provide sensing-related information to a CE/DA. One CE/DA can access sensing-related information from multiple Sensors. It is denoted as “1:N scenario” where N is the number of Sensors.

The following instances of the IEEE 1900.6 logical interface are involved:

- CE/DA–S interface
- S–S interface

In distributed sensing, the CE/DA can access multiple Sensors and make dynamic spectrum access decisions based on sensing-related information from distributed Sensors. Also, multiple Sensors can exchange information and provide the CE/DA with an improved sensing result.

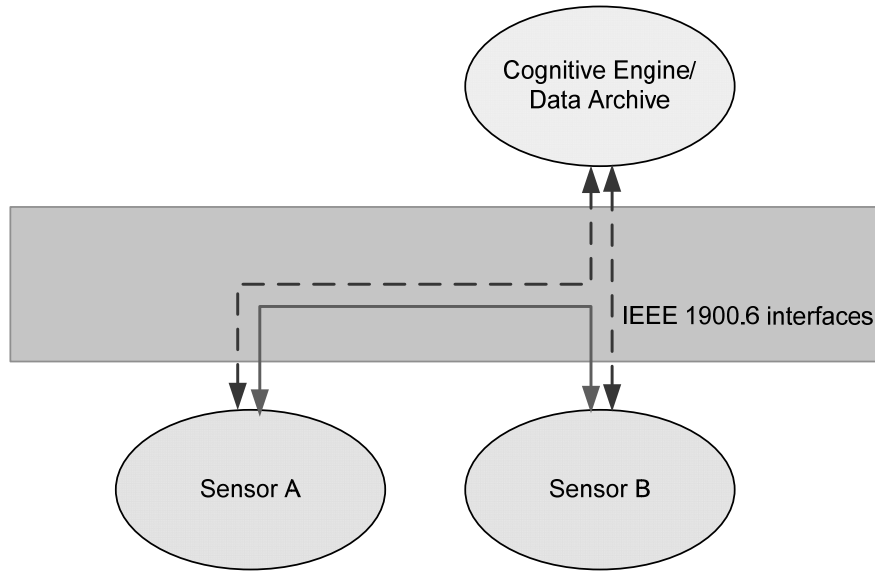


Figure 3—Single CE/DA and multiple Sensors scenario

4.3 Scenario 3: Multiple CE/DA and single Sensor

In this scenario as shown in Figure 4, multiple CE/DAs access sensing-related information from one Sensor. One Sensor provides sensing-related information to multiple CE/DAs. If some of the multiple CE/DAs are capable of accessing a Sensor, the CE/DA can exchange sensing-related information with other CE/DAs. This scenario is denoted as “M:1 scenario” where M is the number of CE/DAs.

The following instances of the IEEE 1900.6 logical interface are involved:

- CE/DA–S interface
- CE–CE/DA interface

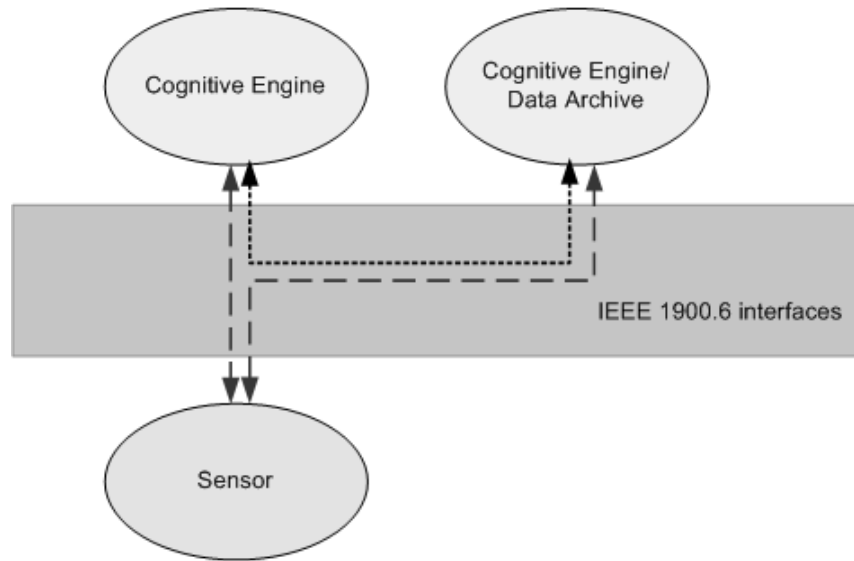


Figure 4—Multiple CE/DA and single Sensor scenario

Note that for the case of multiple CE/DAs and multiple Sensors, (i.e., the M:N scenario referred to in A.2.3), the system can be decomposed into a combination of the above three scenarios. This is understood within the context of model description. This does not imply decomposition at the implementation level.

5. The IEEE 1900.6 reference model

5.1 General description

Figure 5 shows the reference model for the IEEE 1900.6 interface and defined entities (i.e., Sensor, CE, and DA). The three SAPs shown in Figure 5 are a realization of the IEEE 1900.6 interface. Sensors and their clients may have all of the three SAPs or a subset of the SAPs depending on the implementation. The IEEE 1900.6 logical entities may also follow reference model views as depicted in Figure 6 through Figure 8, which show the instantiation of the IEEE 1900.6 interface as CE/DA–S, CE–CE/DA, S–S given in Figure 1. They are utilizing distinct SAPs to realize the IEEE 1900.6 logical interface. A compliant realization of the interface shall be sufficient to comply with the standard. No assumption is made on the realization of other functions of the device or devices involved. The figures show how the previously mentioned SAPs are involved in the sensing-related information exchange between Sensors and their clients. Subclause 5.1 provides formal definitions for each of the entities identified in Figure 5 through Figure 8.

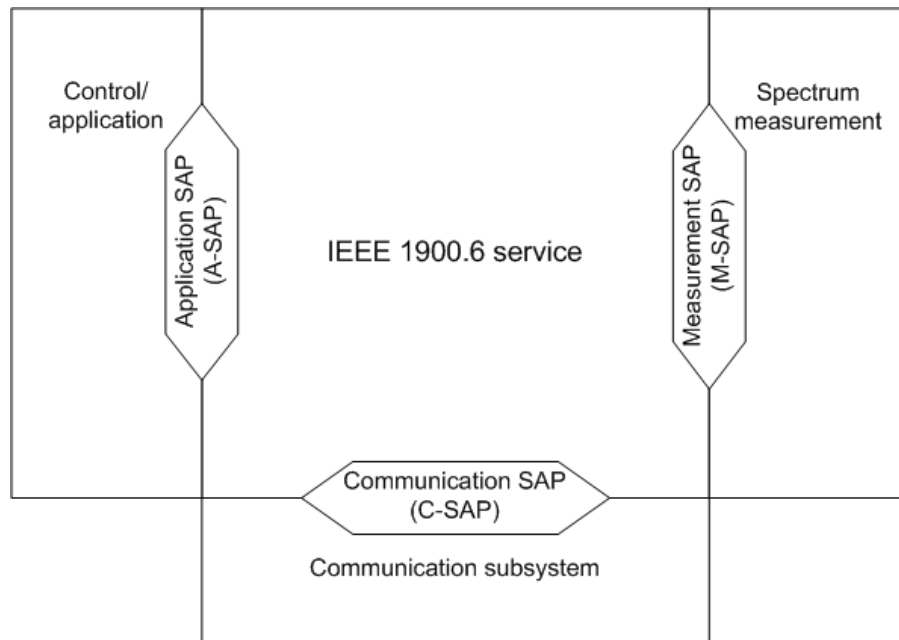


Figure 5—Reference model of the IEEE 1900.6 interface

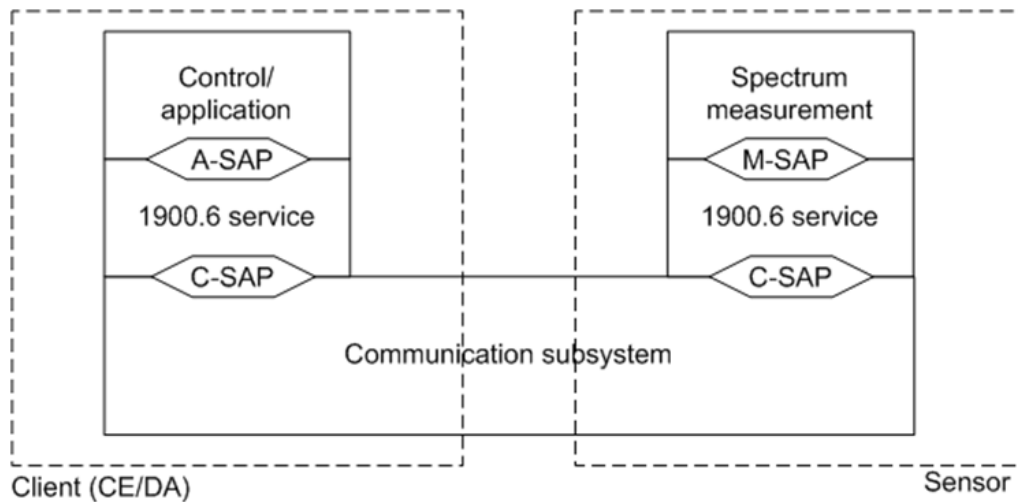


Figure 6—View of reference model when the client of Sensor is a CE or DA

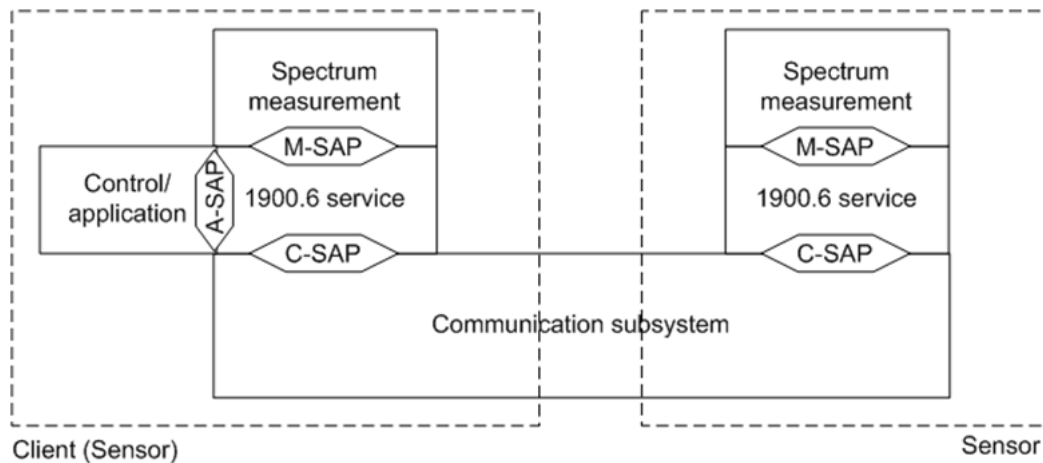


Figure 7—View of reference model when the client of Sensor is a Sensor

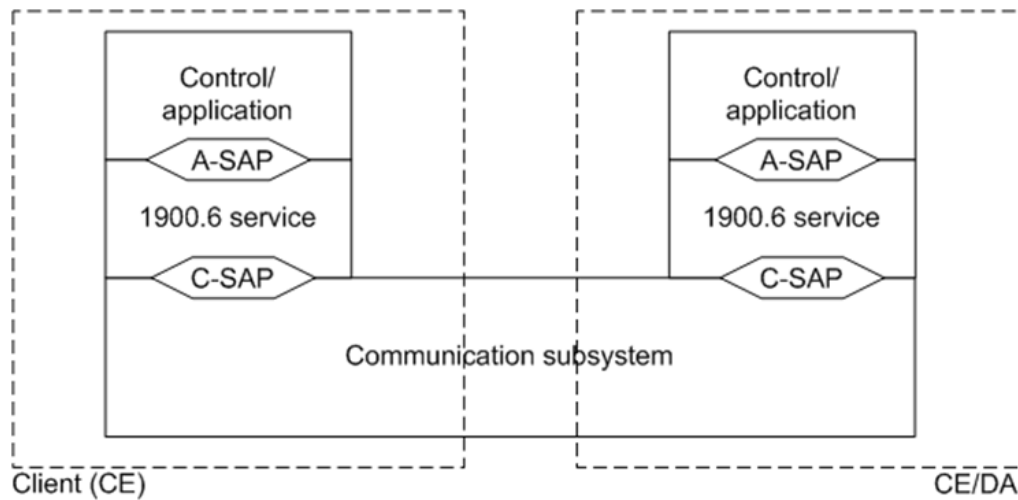


Figure 8—View of reference model for sensing-related information exchange between CE and CE/DA

The **IEEE 1900.6 service** is responsible for realizing IEEE 1900.6 service primitives and for generating data structures defined by this standard for the exchange of sensing-related information between IEEE 1900.6 servers and clients.

An **IEEE 1900.6 service access point (SAP)** is a conceptual location where an IEEE 1900.6 logical entity or an IEEE 1900.6 service user, which is not an IEEE 1900.6 logical entity by itself, can request the services provided by another IEEE 1900.6 logical entity or by an IEEE 1900.6 compliant station service (see 3.1). For example, an IEEE 1900.6 logical entity “Sensor” can utilize physical radio frequency (RF) sensor capabilities provided by the station (e.g., by the terminal radio hardware and firmware) and can provide RF measurement data to an IEEE 1900.6 logical entity CE upon request. The term “IEEE 1900.6 compliant service” here refers to the fact that primitives, parameters, and data structures defined throughout this standard are understood by this service and that measurement data returned are formatted accordingly.

The **application service access point (A-SAP)** is used by applications to access services of an IEEE 1900.6 compliant server. It defines a set of generic primitives and data structures to control the

IEEE 1900.6 logical entity and/or to obtain the sensing results for application purposes. The IEEE 1900.6 client utilizing the A-SAP takes the role of an information consumer and of a control application.

The A-SAP is used by an application (i.e., the user of the A-SAP) to utilize sensing-related information for its purpose (e.g., for policy investigation and analysis of spectrum usage). The A-SAP may provide functions to set up a configuration of IEEE 1900.6 logical entities (e.g., Sensors and CE), to configure these for collaborative sensing, to start the data acquisition and processing (e.g., policy processing), and to obtain the results of the processing in order to configure the RF interface accordingly. The A-SAP shall be instantiated by the IEEE 1900.6 logical entity.

The measurement service access point (M-SAP) is used for the exchange of sensing-related information between the spectrum measurement module and its M-SAP user. The user of the measurement module is realized by dedicated functions of the IEEE 1900.6 service. It is used by IEEE 1900.6 logical entities to access IEEE 1900.6 compliant services provided by the station's hardware and/or firmware to control the spectrum measurement module (such as a collocated physical spectrum measurement module, i.e., ADC/DAC, filtering, signal conditioning, etc.) and to acquire spectrum measurement data. For example, a station (terminal) utilizes its RF interface during idle times for spectrum measurement and provides RF spectrum data to collocated IEEE 1900.6 "sensor" entities that are registered at the local M-SAP. The M-SAP shall be instantiated by the station's IEEE 1900.6 compliant measurement function.

The communication service access point (C-SAP) exchanges sensing-related information (sensing information, sensor information, control information, and requirements derived from regulation) between remote IEEE 1900.6 servers and their clients. It abstracts communication mechanisms for use by IEEE 1900.6 service providers and service users through a dedicated set of generic service primitives. The client role can be taken by a Sensor, CE, or DA. It abstracts communication mechanisms for use by IEEE 1900.6 services through defining a set of generic primitives and mapping these primitives to transport protocols.

An IEEE 1900.6 compliant message transport service shall be provided by the station in order to locate a remote IEEE 1900.6 peer entity and to establish a communication link with this entity. Message exchange then takes place as defined by this standard and it is the responsibility of the transport service to map these message transfers to a suitable transport, network, or link layer communication. For example, an IEEE 1900.6 logical entity CE can take the role of a client to a remote IEEE 1900.6 Sensor by sending a request to configure the sensor for delivering measurement data to the requestor utilizing its C-SAP functionality. The C-SAP shall be instantiated by the IEEE 1900.6 compliant message transport service.

Control/application in the reference model refers to a hardware/software module that utilizes functions of the A-SAP to obtain sensing information or other information or to control and configure the behavior and functions of other IEEE 1900.6 logical entities and functions.

Communication subsystem in the reference model refers to a hardware/software module that provides the levels of the communications protocol stack and other communication services required by the IEEE 1900.6 services. The communication subsystem can be implemented with the IEEE 1900.6 compliant message transport service.

Spectrum measurement in the reference model is realized by the spectrum measurement module, a hardware/software module that provides radio spectrum measurement functions (e.g., analog-to-digital conversion [ADC]/digital-to-analog conversion [DAC], filtering, and signal conditioning).

5.2 An implementation example of the IEEE 1900.6 reference model

This subclause presents an informative example of realizing the IEEE 1900.6 reference model presented in 5.1 based on the reference model for an IEEE 802.11 station (see IEEE Std 802.11™-2007 [B3]). Figure 9 shows a case where the IEEE 1900.6 service and corresponding SAPs are implemented by the station

management entity (SME). The IEEE 1900.6 application (control/application) is implemented on the application layer and the sensor (spectrum measurement) is implemented on the physical layer (PHY). The IEEE 1900.6 SAPs may be provided through different sublayer management entities and their related SAPs. This figure applies to instantiation of both (IEEE 1900.6) client and server.

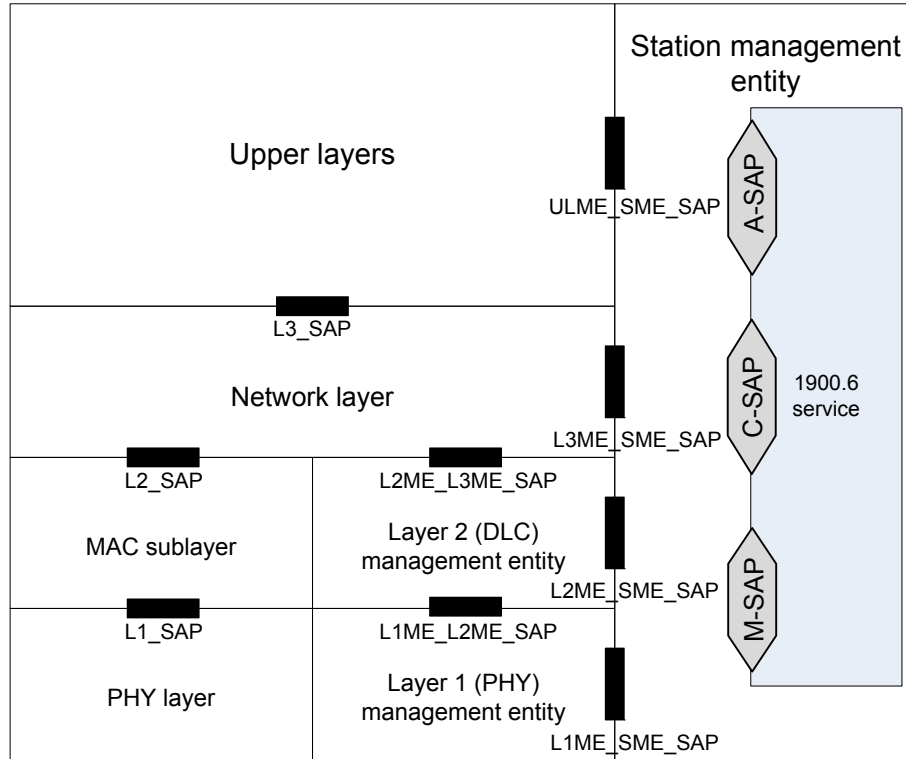


Figure 9—An implementation example of the IEEE 1900.6 service

5.3 Service access points

This standard defines the following SAPs that are involved in the exchange of sensing-related information between Sensors and their clients. Abstract service primitives describe the interaction with the IEEE 1900.6 services through SAPs in an implementation independent way.

NOTE—This standard does not distinguish between the SAPs at the local and remote entities. Hence, interaction at the SAP is only described using request and response primitives. If for implementation purposes, distinguishing of local and remote entities is necessary, the additional primitives, indication, and confirmation have the same semantics of the request and response primitives, correspondingly.

A number of parameters to primitives used throughout this clause are specified but not qualified nor detailed further in their effect on the behavior of a potential implementation. This has been done intentionally to remain neutral with respect to specific technologies and the demand for specific functions and algorithms of entities and services considered. Detailed descriptions of parameters and data representation are given in 6.3 and 6.4, respectively.

This standard specifies the information flow between sensors and their clients. The specification of a related message exchange protocol is left to future versions. Subclause 6.1 addresses the information exchange by giving the structure of the commands and parameters in that flow. The information structure

given in this subclause defines how the primitives can be implemented for the information exchange. The current standard does not cover addressing of logical entities. It is assumed that a platform service exists that performs the mapping between the IDs of logical entities and proper device or network addresses.

5.3.1 Measurement service access point

The M-SAP provides a set of generic primitives or method for IEEE 1900.6 SAP users to control spectrum sensing and to obtain sensing-related information from spectrum sensing.

The IEEE 1900.6 logical entities obtain the following services from the M-SAP:

- Measurement capabilities discovery services
- Measurement configuration discovery services
- Measurement configuration services
- Information services

5.3.1.1 Measurement capabilities discovery services

The measurement capabilities discovery services provide a set of primitives or method through which the IEEE 1900.6 SAP user obtains the information related to the measurement capabilities of the associated measurement module.

The primitives of the measurement capabilities discovery services defined as part of the M-SAP are described in the following table.

Primitives	Description
Get_Supported_Spectrum_Measurement_Description	This primitive is used by the IEEE 1900.6 SAP user to obtain the information related to the capability of the spectrum measurement module.

5.3.1.1.1 Get_Supported_Spectrum_Measurement_Description.request

Function

This primitive is used by the IEEE 1900.6 SAP user to obtain the supported measurement of the measurement module.

Semantics of the service primitive

Get_Supported_Spectrum_Measurement_Description.request
(
 MeasurementCapabilityTransID
)

Parameters

Name	Type	Description
MeasurementCapabilityTransID	Unsigned integer	MeasurementCapabilityTransID uniquely identifies one transaction of requesting a measurement feature (type and range) within the capability of the measurement module.

When used

This primitive is used by the IEEE 1900.6 SAP user when it needs to discover the spectrum measurement capabilities of the entity.

Effect of receipt

The spectrum measurement module subsequently uses a `Get_Supported_Spectrum_Measurement_Description.response` to reflect the results of the request.

5.3.1.1.2 `Get_Supported_Spectrum_Measurement_Description.response`

Function

This primitive returns the results of the request to obtain the description of spectrum measurement capabilities.

Semantics of the service primitive

```
Get_Supported_Spectrum_Measurement_Description.response  
(  
    MeasurementCapabilityTransID,  
    Status,  
    MeasuRange,  
    SensingMode,  
    DataSheet.ADDAResolution,  
    DataSheet.AngleResolution,  
    DataSheet.FrequencyResolution,  
    DataSheet.LocationTimeCapability,  
    DataSheet.LoggingFunctions,  
    DataSheet.RecordingCapability,  
    DataSheet.SweepTime,  
    LockStatus  
)
```

Parameters

Name	Type	Description
MeasurementCapabilityTransID	Unsigned integer	MeasurementCapabilityTransID uniquely identifies one transaction of requesting a measurement feature (type and range) within the capability of the measurement module.
Status	Enumeration	Status of operation. 0: success 1: unspecified failure 2: rejection 3: authorization failure
MeasuRange	Bandwidth	The MeasuRange parameter indicates the range of frequency that can be measured according to the manufacturer specification (cf. 6.3.27).
SensingMode	Enumeration	The SensingMode parameter indicates the numbers and types of standard sensing methods supported by the sensor (cf. 6.3.28).
DataSheet.ADDAResolution	Unsigned integer	The resolution of AD/DA convertor of the spectrum measurement module (cf. 6.3.32).
DataSheet.AngleResolution	Angle	The angle resolution of the spectrum measurement module (cf. 6.3.32).
DataSheet.FrequencyResolution	Frequency	Frequency resolution of the spectrum measurement module (cf. 6.3.32).
DataSheet.LocationTimeCapability	String	The capability of spectrum module in determining the location and time of the measurement (cf. 6.3.32).
DataSheet.LoggingFunctions	Unsigned integer	The ability of access log files (cf. 6.3.32).
DataSheet.RecordingCapability	String	The capability to recording data at the spectrum measurement module (cf. 6.3.32).
DataSheet.SweepTime	Microsecond	The time to sweep between two frequencies (cf. 6.3.32).
LockStatus	Enumeration	The LockStatus indicates whether the entity (i.e., the sender of this primitive) has been locked by a client for exclusive service. 1: The status of the entity is locked. The entity is locked by a client for exclusive service. 0: The status of the entity is unlocked. The entity has been unlocked by its client, or has been unlocked by a self-generated timeout event.

When used

The primitive is used in response to the Get_Supported_Spectrum_Measurement_Description.request primitive.

Effect of receipt

Upon receipt, the IEEE 1900.6 SAP user obtains the information related to the spectrum measurement capabilities of the spectrum measurement module.

5.3.1.2 Measurement configuration discovery services

The measurement configuration discovery services provide a set of primitives or method through which the IEEE 1900.6 SAP user obtains the information related to the measurement configuration of the spectrum measurement module. The following information is discovered through these services:

- Sensor PHY profile
- Sensor antenna profile
- Sensor location

The primitives of the measurement configuration services defined as part of the M-SAP are described in the following table.

Primitives	Description
<i>Sensor PHY profile</i>	
Get_Sensor_PHY_Description	This primitive is used by the IEEE 1900.6 SAP user to obtain the information related to physical configuration of the spectrum measurement module.
<i>Sensor antenna profile</i>	
Get_Sensor_Antenna_Description	This primitive is used by the IEEE 1900.6 SAP user to obtain the information related to the antenna configuration of the spectrum measurement module.
<i>Sensor location</i>	
Get_Sensor_Location_Description	This primitive is used by the IEEE 1900.6 SAP user to obtain the information related to the location of the spectrum measurement module. Note that the spectrum measurement module represents the location of the measurement.

5.3.1.2.1 Get_Sensor_PHY_Description.request

Function

This primitive is used by the IEEE 1900.6 SAP user to obtain the PHY description of the spectrum measurement module.

Semantics of the service primitive

Get_Sensor_PHY_Description.request
(
SensorPHYProfileID
)

Parameters

Name	Type	Description
SensorPHYProfileID	Unsigned integer	SensorPHYProfileID uniquely defines the PHY profile of the spectrum measurement module.

When used

This primitive is used by the IEEE 1900.6 SAP user when it needs to discover the PHY configuration of the spectrum measurement module.

Effect of receipt

The spectrum measurement module subsequently uses a Get_Sensor_PHY_Description.response to reflect the results of the request.

5.3.1.2.2 Get_Sensor_PHY_Description.response

Function

This primitive returns the results of the request to obtain the description of the PHY profile of the spectrum measurement module.

Semantics of the service primitive

```
Get_Sensor_PHY_Description.response
(
    SensorPHYProfileID,
    Status,
    Datasheet.CalibrationData,
    Datasheet.CalibrationMethod,
    Datasheet.ChannelFiltering,
    Datasheet.DynamicRange,
    Datasheet.NoiseFactor,
    Datasheet.PhaseNoise,
    LockStatus
)
```

Parameters

Name	Type	Description
SensorPHYProfileID	Unsigned integer	SensorPHYProfileID uniquely defines the PHY profile of the spectrum measurement module.
Status	Enumeration	Status of operation. 0: success 1: unspecified failure 2: rejection 3: authorization failure
Datasheet.CalibrationData	String	Data used to calibrate the spectrum measurement module (cf. 6.3.32).
Datasheet.CalibrationMethod	String	Method to calibrate the spectrum measurement module. (cf. 6.3.32).
Datasheet.ChannelFiltering	String	The filtering function of the spectrum measurement module (cf. 6.3.32).
Datasheet.DynamicRange	Float	Dynamic range in dB of signal detection of the spectrum measurement module (cf. 6.3.32).
Datasheet.NoiseFactor	Float	The ratio in linear scale of the noise produced by the spectrum measurement module to the thermal noise (cf. 6.3.32).
Datasheet.PhaseNoise	Float	Phase noise in dBc/Hz produced by the spectrum measurement module (cf. 6.3.32).
LockStatus	Enumeration	The LockStatus indicates whether the entity (i.e., the sender of this primitive) has been locked by a client for exclusive service. 1: The status of the entity is locked. The entity is locked by a client for exclusive service. 0: The status of the entity is unlocked. The entity has been unlocked by its client, or has been unlocked by a self-generated timeout event.

When used

The primitive is used in response to the Get_Sensor_PHY_Description.request primitive.

Effect of receipt

Upon receipt, the IEEE 1900.6 SAP user obtains the information related to the PHY profile of the spectrum measurement module.

5.3.1.2.3 Get_Sensor_Antenna_Description.request

Function

This primitive is used by the IEEE 1900.6 SAP user to obtain the antenna description of the spectrum measurement module.

Semantics of the service primitive

Get_Sensor_Antenna_Description.request
(
 SensorAntennaProfileID
)
Parameters

Name	Type	Description
SensorAntennaProfileID	Unsigned integer	SensorAntennaProfileID uniquely defines the antenna profile of the spectrum measurement module.

When used

This primitive is used by the IEEE 1900.6 SAP user when it needs to discover the antenna configuration of the spectrum measurement module.

Effect of receipt

The spectrum measurement module subsequently uses a Get_Sensor_Antenna_Description.response to reflect the results of the request.

5.3.1.2.4 Get_Sensor_Antenna_Description.response

Function

This primitive returns the results of the request to obtain the description of the antenna profile of the spectrum measurement module.

Semantics of the service primitive

Get_Sensor_Antenna_Description.response
(
 SensorAntennaProfileID,
 Status,
 Datasheet.AntennaBandwidth,
 Datasheet.AntennaBeamPointing,

Datasheet.AntennaBeamwidth,
Datasheet.AntennaDirectivityGain,
Datasheet.AntennaGain,
Datasheet.AntennaHeight,
Datasheet.AntennaPolarization,
LockStatus
)

Parameters

Name	Type	Description
SensorAntennaProfileID	Unsigned integer	SensorAntennaProfileID uniquely defines the antenna profile of the spectrum measurement module.
Status	Enumeration	Status of operation. 0: success 1: unspecified failure 2: rejection 3: authorization failure
Datasheet.AntennaBandwidth	Array(Frequency)	Bandwidth of the antenna used at the spectrum measurement module (cf. 6.3.32).
Datasheet.AntennaBeamPointing	Array(Angle)	The DataSeet.AntennaBeamPointing parameter specifies the beam pointing direction of the antenna used at the spectrum measurement module by giving the azimuthal angle with respect to North and elevation angle with respect to the horizon (cf. 6.3.32).
Datasheet.AntennaBeamwidth	Array(Angle)	Beamwidth of the antenna used at the spectrum measurement module, normally specified as half-power horizontal and vertical beamwidth (cf. 6.3.32).
Datasheet.AntennaDirectivityGain	Float	Directivity gain in dBi of the antenna radiation pattern at the spectrum measurement module (cf. 6.3.32).
Datasheet.AntennaGain	Float	Power gain in dB of the antenna used at the spectrum measurement module (cf. 6.3.32).
Datasheet.AntennaHeight	Float	Height of the antenna in meters with respect to sea level (cf. 6.3.32).
Datasheet.AntennaPolarization	Enumeration	Polarization of the antenna used at the spectrum measurement module (cf. 6.3.32). 0: Linear polarization 1: Circular polarization 2: Elliptical polarization
LockStatus	Enumeration	The LockStatus indicates whether the entity (i.e., the sender of this primitive) has been locked by a client for exclusive service. 1: The status of the entity is locked. The entity is locked by a client for exclusive service. 0: The status of the entity is unlocked. The entity has been unlocked by its client, or has been unlocked by a self-generated timeout event.

When used

The primitive is used in response to the Get_Sensor_Antenna_Description.request primitive.

Effect of receipt

Upon receipt, the IEEE 1900.6 SAP user obtains the information related to the antenna profile of the spectrum measurement module.

5.3.1.2.5 Get_Sensor_Location_Description.request

Function

This primitive is used by the IEEE 1900.6 SAP user to obtain the location information of the spectrum measurement module.

Semantics of the service primitive

```
Get_Sensor_Location_Description.request  
(  
    SensorLocationTransID  
)
```

Parameters

Name	Type	Description
SensorLocationTransID	Unsigned integer	SensorLocationTransID uniquely defines one transaction of a requesting the location of the spectrum measurement module.

When used

This primitive is used by the IEEE 1900.6 SAP user when it needs to discover the location of the spectrum measurement module.

Effect of receipt

The spectrum measurement module subsequently uses a Get_Sensor_Location.response to reflect the results of the request.

5.3.1.2.6 Get_Sensor_Location_Description.response

Function

This primitive returns the results of the request to obtain the location information of the spectrum measurement module.

Semantics of the service primitive

```
Get_Sensor_Location_Description.response  
(  
    SensorLocationTransID,  
    Status,  
    AbsSensorLocation,  
    RelSensorLocation,  
    LockStatus  
)
```

Parameters

Name	Type	Description
SensorLocationTransID	Unsigned integer	SensorLocationTransID uniquely defines one transaction of a requesting the location of the spectrum measurement module.
Status	Enumeration	Status of operation. 0: success 1: unspecified failure 2: rejection 3: authorization failure
AbsSensorLocation	RGeolocation	The absolute location of the spectrum measurement module (cf. 6.3.25).
RelSensorLocation	RGeolocation	The RelSensorLocation parameter is used when the position of the sensor is measured by triangulation with respect to known reference positions (cf. 6.3.26).
LockStatus	Enumeration	The LockStatus indicates whether the entity (i.e., the sender of this primitive) has been locked by a client for exclusive service. 1: The status of the entity is locked. The entity is locked by a client for exclusive service. 0: The status of the entity is unlocked. The entity has been unlocked by its client, or has been unlocked by a self-generated timeout event.

When used

The primitive is used in response to the Get_Sensor_Location_Description.request primitive.

Effect of receipt

Upon receipt, the IEEE 1900.6 SAP user obtains the location information of the spectrum measurement module. The sensor location can be expressed by either AbsSensorLocation or RelSensorLocation. If RelLocation is used, the reference positions are assumed to be known.

5.3.1.3 Measurement configuration services

The measurement configuration services provide a set of primitives or method through which the IEEE 1900.6 SAP user configures the spectrum measurement module. The following configuration is set through these services:

- Measurement objective
- Measurement profile
- Measurement performance

The primitives of the measurement configuration services are defined as part of the M-SAP and are described in the following table.

Primitives	Description
<i>Measurement objective</i>	
Set_Sensor_Measurement_Obj	This primitive is used by the IEEE 1900.6 SAP user to set the measurement objective of the spectrum measurement module.
<i>Measurement profile</i>	
Set_Sensor_Measurement_Profile	This primitive is used by the IEEE 1900.6 SAP user to set the measurement profile of the spectrum measurement module.
<i>Measurement performance</i>	
Set_Sensor_Measurement_Performance	This primitive is used by the IEEE 1900.6 SAP user to set the target performance of the spectrum measurement module.

5.3.1.3.1 Set_Sensor_Measurement_Obj.request

Function

This primitive is used by the IEEE 1900.6 SAP user to set the measurement objective of the spectrum measurement module.

Semantics of the service primitive

Set_Sensor_Measurement_Obj.request
(
SensorMeasurementObjID,
StartTime,
EndTime,
Bandwidth
)

Parameters

Name	Type	Description
SensorMeasurementObjID	Unsigned integer	SensorMeasurementObjID uniquely defines the measurement objective of the spectrum measurement module.
StartTime	TimeStamp	The StartTime parameter specifies the time stamp when spectrum measurement starts (cf. 6.3.8).
EndTime	TimeStamp	The EndTime parameter specifies the time stamp when spectrum measurement finishes (cf. 6.3.8).
Bandwidth	Array(Frequency)	Bandwidth parameter specifies the bandwidth, by giving the start frequency and stop frequency, to perform spectrum measurement (cf. 6.3.11).

When used

This primitive is used by the IEEE 1900.6 SAP user to set the measurement objective of the spectrum measurement module.

Effect of receipt

Parameters of the spectrum measurement module are subsequently set to the values given by the primitive. The spectrum measurement module subsequently uses a Set_Sensor_Measurement_Obj.response primitive to reflect the results of the request.

5.3.1.3.2 Set_Sensor_Measurement_Obj.response

Function

This primitive returns the results of the request to set the measurement objective of the spectrum measurement module.

Semantics of the service primitive

Set_Sensor_Measurement_Obj.response
(
 SensorMeasurementObjID,
 Status,
 LockStatus
)

Parameters

Name	Type	Description
SensorMeasurementObjID	Unsigned integer	SensorMeasurementObjID uniquely defines the measurement objective of the spectrum measurement module.
Status	Enumeration	Status of operation. 0: success 1: unspecified failure 2: rejection 3: authorization failure
LockStatus	Enumeration	The LockStatus indicates whether the entity (i.e., the sender of this primitive) has been locked by a client for exclusive service. 1: The status of the entity is locked. The entity is locked by a client for exclusive service. 0: The status of the entity is locked. The entity has been unlocked by its client, or has been unlocked by a self-generated timeout event.

When used

The primitive is used in response to the Set_Sensor_Measurement_Obj.request primitive.

Effect of receipt

Upon receipt, the spectrum measurement module sets the measurement objective.

5.3.1.3.3 Set_Sensor_Measurement_Profile.request

Function

This primitive is used by the IEEE 1900.6 SAP user to set the measurement profile of the spectrum measurement module.

Semantics of the service primitive

```
Set_Sensor_Measurement_Profile.request
(
    SensorMeasurementProfileID,
    SensingMode,
    ChOrder,
    ChList,
    ReportRate,
    Scan.LowerThreshold,
    ReportingMode
)
```

Parameters

Name	Type	Description
SensorMeasurementProfileID	Unsigned integer	SensorMeasurementProfileID uniquely defines the measurement profile of the spectrum measurement module.
SensingMode	Enumeration	The SensingMode parameter indicates the numbers and types of standard sensing methods supported by the sensor (cf. 6.3.28).
ChOrder	Vector(Unsigned integer)	The ChOrder specifies the scanning order of the channels. The channel order is represented by a predefined vector of step indices (sequence vector should use a bounded type rather than the generic Vector type). The default for this parameter is “sequential scanning in ascending order” (cf. 6.3.13).
ChList	Structured	The ChList specifies a list of frequency bands by providing a vector of channel numbers along with a corresponding vector of bandwidth parameters (cf. 6.3.32).
ReportRate	Structured	The ReportRate parameter is issued by the IEEE 1900.6 client to specify how often the measurement result should be reported or updated (e.g., every 2 s or every 100 ms) (cf. 6.3.14).
Scan.LowerThreshold	NoisePower	The Scan.LowerThreshold parameter specifies the noise floor (cf. 6.3.24).
ReportingMode	Enumeration	The ReportMode parameter is issued by the IEEE 1900.6 client to indicate in what form the sensing-related information should be reported (cf. 6.3.15).

When used

This primitive is used by the IEEE 1900.6 SAP user to set the measurement profile of the spectrum measurement module.

Effect of receipt

Parameters of the spectrum measurement module are subsequently set to the values given by the primitive. The spectrum measurement module subsequently uses a Set_Sensor_Measurement_Profile.response primitive to reflect the results of the request.

5.3.1.3.4 Set_Sensor_Measurement_Profile.response

Function

This primitive returns the results of the request to set the measurement profile of the spectrum measurement module.

Semantics of the service primitive

```
Set_Sensor_Measurement_Profile.response  
(  
    SensorMeasurementProfileID,  
    Status,  
    LockStatus  
)
```

Parameters

Name	Type	Description
SensorMeasurementProfileID	Unsigned integer	SensorMeasurementProfileID uniquely defines the measurement profile of the spectrum measurement module.
Status	Enumeration	Status of operation. 0: success 1: unspecified failure 2: rejection 3: authorization failure
LockStatus	Enumeration	The LockStatus indicates whether the entity (i.e., the sender of this primitive) has been locked by a client for exclusive service. 1: The status of the entity is locked. The entity is locked by a client for exclusive service. 0: The status of the entity is unlocked. The entity has been unlocked by its client, or has been unlocked by a self-generated timeout event.

When used

The primitive is used in response to the Set_Sensor_Measurement_Profile.request primitive.

Effect of receipt

Upon receipt, the IEEE 1900.6 SAP user sets the measurement profile of the spectrum measurement module.

5.3.1.3.5 Set_Sensor_Measurement_Performance.request

Function

This primitive is used by the IEEE 1900.6 SAP user to set the measurement performance of the spectrum measurement module.

Semantics of the service primitive

```
Set_Sensor_Measurement_Performance.request  
(  
    SensorMeasurementPerformanceID,  
    PerfMetric.Pd,  
    PerfMetric.Pf  
)
```

Parameters

Name	Type	Description
SensorMeasurementPerformanceID	Unsigned integer	SensorMeasurementPerformanceID uniquely defines the measurement performance of the spectrum measurement module.
PerfMetric.Pd	Unsigned integer	The PerfMetric.Pd specifies the rate of detection that the spectrum measurement should achieve (cf. 6.3.16).
PerfMetric.Pf	Unsigned integer	The PerfMetric.Pf specifies the rate of false alarm that the spectrum measurement should achieve (cf. 6.3.16).

When used

This primitive is used by the IEEE 1900.6 SAP user to set the measurement performance of the spectrum measurement module.

Effect of receipt

Parameters of the spectrum measurement module are subsequently set to the values given by the primitive. The spectrum measurement module subsequently uses a Set_Sensor_Measurement_Performance.response to reflect the results of the request.

5.3.1.3.6 Set_Sensor_Measurement_Performance.response

Function

This primitive returns the results of the request to set the measurement performance of the spectrum measurement module.

Semantics of the service primitive

```
Set_Sensor_Measurement_Performance.response  
(  
    SensorMeasurementPerformanceID,  
    Status,  
    LockStatus  
)
```

Parameters

Name	Type	Description
SensorMeasurementPerformanceID	Unsigned integer	SensorMeasurementPerformanceID uniquely defines the measurement performance of the spectrum measurement module.
Status	Enumeration	Status of operation. 0: success 1: unspecified failure 2: rejection 3: authorization failure 4: function not supported
LockStatus	Enumeration	The LockStatus indicates whether the entity (i.e., the sender of this primitive) has been locked by a client for exclusive service. 1: The status of the entity is locked. The entity is locked by a client for exclusive service. 0: The status of the entity is unlocked. The entity has been unlocked by its client, or has been unlocked by a self-generated timeout event.

When used

The primitive is used in response to the Set_Sensor_Measurement_Performance.request primitive.

Effect of receipt

Upon receipt, the spectrum measurement module sets the measurement performance.

5.3.1.4 Information services

The information services provide a set of primitives or methods through which the IEEE 1900.6 SAP user collects the information related to the measurement configuration of the spectrum measurement module. The following information is collected through these services:

- Sensor profile
- Measurement profile
- Signal measurement
- Channel measurement
- Radio access technology (RAT) measurement
- Management

The primitives of information services are defined as part of the M-SAP in the following table.

Primitives	Description
<i>Sensor profile collection</i>	
Get_Sensor_Manufacturer_Profile	This primitive is used by the IEEE 1900.6 SAP user to collect the information related to the manufacturer of the spectrum measurement module.
Get_Sensor_Power_Profile	This primitive is used by the IEEE 1900.6 SAP user to collect the information related to the power consumption of the spectrum measurement module.
<i>Measurement profile collection</i>	
Get_Measurement_Profile	This primitive is used by the IEEE 1900.6 SAP user to obtain the information related to the spectrum measurement that has been carried out.
Get_Measurement_Location_Information	This primitive is used by the IEEE 1900.6 SAP user to collect the information related to the location where the spectrum measurement has been carried out.
<i>Signal measurement collection</i>	
Get_Signal_Measurement_Value	This primitive is used by the IEEE 1900.6 SAP user to collect the measured value related to the measured signals.
<i>Channel measurement collection</i>	
Get_Channel_Measurement_Value	This primitive is used by the IEEE 1900.6 SAP user to collect the measured value related to the measured channels.
<i>RAT measurement collection</i>	
Get_RAT_ID_Value	This primitive is used by the IEEE 1900.6 SAP user to collect the measured value related to the measured RAT.
<i>Management</i>	
Notify	This primitive is used by the measurement module to report its status to IEEE 1900.6 SAP user.

5.3.1.4.1 Get_Sensor_Manufacturer_Profile.request

Function

This primitive is used by the IEEE 1900.6 SAP user to obtain the manufacturer information of the spectrum measurement module.

Semantics of the service primitive

Get_Sensor_Manufacturer_Profile.request
(
SensorManufacturerProfileID,
)

Parameters

Name	Type	Description
SensorManufacturerProfileID	Unsigned integer	SensorManufacturerProfileID uniquely defines the manufacturer profile of the spectrum measurement module.

When used

This primitive is used by the IEEE 1900.6 SAP user when it needs to collect the manufacturer profile of the spectrum measurement module.

Effect of receipt

The spectrum measurement module subsequently uses a `Get_Sensor_Manufacturer_Profile.response` primitive to reflect the results of the request.

5.3.1.4.2 `Get_Sensor_Manufacturer_Profile.response`

Function

This primitive returns the results of the request to collect the manufacturer profile of the spectrum measurement module.

Semantics of the service primitive

```
Get_Sensor_Manufacturer_Profile.response  
(  
    SensorManufacturerProfileID ,  
    Status,  
    SensorID.VendorID,  
    SensorID.ProductID,  
    LockStatus  
)
```

Parameters

Name	Type	Description
SensorManufacturerProfileID	Unsigned integer	SensorManufacturerProfileID uniquely defines the manufacturer profile of the spectrum measurement module.
Status	Enumeration	Status of operation. 0: success 1: unspecified failure 2: rejection 3: authorization failure
SensorID.VendorID	String	The SensorID.VendorID uniquely identifies the manufacturer of the sensor (cf. 6.3.29).
SensorID.ProductID	String	The SensorID.ProductID uniquely identifies the product of a manufacturer (cf. 6.3.29).
LockStatus	Enumeration	The LockStatus indicates whether the entity (i.e., the sender of this primitive) has been locked by a client for exclusive service. 1: The status of the entity is locked. The entity is locked by a client for exclusive service. 0: The status of the entity is unlocked. The entity has been unlocked by its client, or has been unlocked by a self-generated timeout event.

When used

The primitive is used in response to the `Get_Sensor_Manufacturer_Profile.request` primitive.

Effect of receipt

Upon receipt, the IEEE 1900.6 SAP user collects the manufacturer profile of the spectrum measurement module.

5.3.1.4.3 Get_Sensor_Power_Profile.request

Function

This primitive is used by the IEEE 1900.6 SAP user to obtain the power profile of the spectrum measurement module.

Semantics of the service primitive

Get_Sensor_Power_Profile.request
(
SensorPowerProfileID,
)

Parameters

Name	Type	Description
SensorPowerProfileID	Unsigned integer	SensorPowerProfileID uniquely defines the power profile of the spectrum measurement module.

When used

This primitive is used by the IEEE 1900.6 SAP user when it needs to collect the power profile of the spectrum measurement module.

Effect of receipt

The spectrum measurement module subsequently uses a Get_Sensor_Power_Profile.response primitive to reflect the results of the request.

5.3.1.4.4 Get_Sensor_Power_Profile.response

Function

This primitive returns the results of the request to collect the power profile of the spectrum measurement module.

Semantics of the service primitive

Get_Sensor_Power_Profile.response
(
SensorPowerProfileID,
Status,
BatteryStatus,
Datasheet.PowerConsumption,
LockStatus
)

Parameters

Name	Type	Description
SensorPowerProfileID	Unsigned integer	SensorPowerProfileID uniquely defines the power profile of the spectrum measurement module.
Status	Enumeration	Status of operation. 0: success 1: unspecified failure 2: rejection 3: authorization failure
BatteryStatus	Unsigned integer	The BatteryStatus parameter indicates the remaining battery power in percentage (cf. 6.3.31).
Datasheet.PowerConsumption	String	The Datasheet.PowerConsumption parameter indicates the power consumption profile of the spectrum measurement module (cf. 6.3.32).
LockStatus	Enumeration	The LockStatus indicates whether the entity (i.e., the sender of this primitive) has been locked by a client for exclusive service. 1: The status of the entity is locked. The entity is locked by a client for exclusive service. 0: The status of the entity is unlocked. The entity is has been unlocked by its client, or has been unlocked by a self-generated timeout event.

When used

The primitive is used in response to the Get_Sensor_Power_Profile.request primitive.

Effect of receipt

Upon receipt, the IEEE 1900.6 SAP user collects the power profile of the spectrum measurement module.

5.3.1.4.5 Get_Sensor_Measurement_Profile.request

Function

This primitive is used by the IEEE 1900.6 SAP user to obtain the measurement profile of the spectrum measurement module.

Semantics of the service primitive

```
Get_Sensor_Measurement_Profile.request
(
    SensorMeasurementProfileID,
)
```

Parameters

Name	Type	Description
SensorMeasurementProfileID	Unsigned integer	SensorMeasurementProfileID uniquely defines the profile of spectrum measurement that has been carried out by the spectrum measurement module.

When used

This primitive is used by the IEEE 1900.6 SAP user when it needs to collect the measurement profile of the spectrum measurement module.

Effect of receipt

The spectrum measurement module subsequently uses a `Get_Sensor_Measurement_Profile.response` to reflect the results of the request.

5.3.1.4.6 Get_Sensor_Measurement_Profile.response

Function

This primitive returns the results of the request to collect the measurement profile of the spectrum measurement module.

Semantics of the service primitive

```
Get_Sensor_Measurement_Profile.response
(
    SensorMeasurementProfileID,
    Status,
    ConfidenceLevel,
    ReportMode,
    SensingMode,
    ReportRate,
    TimeStamp,
    Scan.LowerThreshold,
    MeasuBandwidth,
    LockStatus
)
```

Parameters

Name	Type	Description
SensorMeasurementProfileID	Unsigned integer	SensorMeasurementProfileID uniquely defines the profile of spectrum measurement that has been carried out by the spectrum measurement module.
Status	Enumeration	Status of operation. 0: success 1: unspecified failure 2: rejection 3: authorization failure
ConfidenceLevel	Structured	ConfidenceLevel indicates the degree of certainty of estimated value (cf. 6.3.33).
ReportMode	Enumeration	The ReportMode indicates either hard information or soft information (cf. 6.3.15).
SensingMode	Enumeration	The SensingMode parameter indicates what sensing method is used to carry out the spectrum measurement (cf. 6.3.28).
ReportRate	Structured	The ReportRate parameter is issued by the IEEE 1900.6 client to specify how often the measurement result should be reported or updated (e.g., every 2 s or every 100 ms) (cf. 6.3.14).
TimeStamp	Structured	This parameter indicates the time that the spectrum measurement has been carried out (cf. 6.3.8).
Scan.LowerThreshold	NoisePower	The Scan.LowerThreshold parameter indicates the noise threshold used in the spectrum experiment. This value is set to satisfy certain detection requirement (cf. 6.3.24).
MeasuBandwidth	Array(Frequency)	The MeasuBandwidth parameter is the same as the bandwidth used by the control parameter, but when the value is returned by the sensor, it indicates the measurement bandwidth that is actually used by the sensor (cf. 6.3.34).
LockStatus	Enumeration	The LockStatus indicates whether the entity (i.e., the sender of this primitive) has been locked by a client for exclusive service. 1: The status of the entity is locked. The entity is locked by a client for exclusive service. 0: The status of the entity is unlocked. The entity has been unlocked by its client, or has been unlocked by a self-generated timeout event.

When used

The primitive is used in response to the Get_Sensor_Measurement_Profile.request primitive.

Effect of receipt

Upon receipt, the IEEE 1900.6 SAP user collects the measurement profile of the spectrum measurement module.

5.3.1.4.7 Get_Measurement_Location_Information.request

Function

This primitive is used by the IEEE 1900.6 SAP user to obtain the measurement location information of the spectrum measurement module.

Semantics of the service primitive

```
Get_Measurement_Location_Information.request  
(  
    MeasurementLocationTransID,  
)
```

Parameters

Name	Type	Description
MeasurementLocationTransID	Unsigned integer	MeasurementLocationTransID uniquely defines one transaction of requesting the location where the spectrum measurement has been carried out by the spectrum measurement module.

When used

This primitive is used by the IEEE 1900.6 SAP user when it needs to collect the information related to the location where the spectrum measurement has been carried out by the spectrum measurement module.

Effect of receipt

The spectrum measurement module subsequently uses a Get_Measurement_Location_Information.response primitive to reflect the results of the request.

5.3.1.4.8 Get_Measurement_Location_Information.response

Function

This primitive returns the results of the request to collect the measurement location information of the spectrum measurement module.

Semantics of the service primitive

```
Get_Measurement_Location_Information.response  
(  
    MeasurementLocationTransID,  
    Status,  
    AbsSensorLocation,  
    RelSensorLocation,  
    LockStatus  
)
```

Parameters

Name	Type	Description
MeasurementLocationTransID	Unsigned integer	MeasurementLocationTransID uniquely defines one transaction of requesting the location where the spectrum measurement has been carried out by the spectrum measurement module.
Status	Enumeration	Status of operation. 0: success 1: unspecified failure 2: rejection 3: authorization failure
AbsSensorLocation	RGeolocation	The AbsSensorLocation parameter is the absolute location that the experiment has carried out (cf. 6.3.25).
RelSensorLocation	RGeolocation	The RelSensorLocation parameter is the relative location with respect to a known reference location that the experiment has been carried out (cf. 6.3.26).
LockStatus	Enumeration	The LockStatus indicates whether the entity (i.e., the sender of this primitive) has been locked by a client for exclusive service. 1: The status of the entity is locked. The entity is locked by a client for exclusive service. 0: The status of the entity is unlocked. The entity has been unlocked by its client, or has been unlocked by a self-generated timeout event.

When used

The primitive is used in response to the Get_Measurement_Location_Information.request primitive.

Effect of receipt

Upon receipt, the IEEE 1900.6 SAP user collects the measurement location information of the spectrum measurement module.

5.3.1.4.9 Get_Signal_Measurement_Value.request

Function

This primitive is used by the IEEE 1900.6 SAP user to collect signal measurement values of the spectrum measurement module.

Semantics of the service primitive

Get_Signal_Measurement_Value.request
(
 SignalMeasurementID
)

Parameters

Name	Type	Description
SignalMeasurementID	Unsigned integer	SignalMeasurementID uniquely defines the set of measurement values of a signal obtained by the spectrum measurement module.

When used

This primitive is used by the IEEE 1900.6 SAP user when it needs to collect the signal measurement values of the spectrum measurement module.

Effect of receipt

The spectrum measurement module subsequently uses a `Get_Signal_Measurement_Value.response` primitive to reflect the results of the request.

5.3.1.4.10 `Get_Signal_Measurement_Value.response`

Function

This primitive returns the results of the request to collect the signal measurement values of the spectrum measurement module.

Semantics of the service primitive

`Get_Signal_Measurement_Value.response`
(
 SignalMeasurementID,
 Status,
 SignalDesc,
 LockStatus
)

Parameters

Name	Type	Description
SignalMeasurementID	Unsigned integer	SignalMeasurementID uniquely defines the set of measurement values of the signal obtained by the spectrum measurement module.
Status	Enumeration	Status of operation. 0: success 1: unspecified failure 2: rejection 3: authorization failure
SignalDesc	Structured	The signal description parameter represents a set of information elements that describe the behavior of the signal (e.g., traffic pattern type and modulation scheme (cf. 6.3.41)).
LockStatus	Enumeration	The LockStatus indicates whether the entity (i.e., the sender of this primitive) has been locked by a client for exclusive service. 1: The status of the entity is locked. The entity is locked by a client for exclusive service. 0: The status of the entity is unlocked. The entity has been unlocked by its client or has been unlocked by a self-generated timeout event.

When used

The primitive is used in response to the `Get_Signal_Measurement_Value.request` primitive.

Effect of receipt

Upon receipt, the IEEE 1900.6 SAP user collects the measurement values of signals by the spectrum measurement module.

5.3.1.4.11 Get_Channel_Measurement_Value.request

Function

This primitive is used by the IEEE 1900.6 SAP user to collect channel measurement values of the spectrum measurement module.

Semantics of the service primitive

```
Get_Channel_Measurement_Value.request  
(  
    ChannelMeasurementID  
)
```

Parameters

Name	Type	Description
ChannelMeasurementID	Unsigned integer	ChannelMeasurementID uniquely defines the set of measurement values of the channel obtained by the spectrum measurement.

When used

This primitive is used by the IEEE 1900.6 SAP user when it needs to collect the channel measurement values of the spectrum measurement module.

Effect of receipt

The spectrum measurement module subsequently uses a Get_Channel_Measurement_Value.response primitive to reflect the results of the request.

5.3.1.4.12 Get_Channel_Measurement_Value.response

Function

This primitive returns the results of the request to collect the channel measurement values of the spectrum measurement module.

Semantics of the service primitive

```
Get_Channel_Measurement_Value.response  
(  
    ChannelMeasurementID,  
    Status,
```