



GROUP REPORT

## Integrated Sensing And Communications (ISAC); System and RAN Architectures

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## Foreword

This Group Report (GR) has been produced by ETSI Industry Specification Group (ISG) Integrated Sensing And Communications (ISAC).

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## Modal verbs terminology

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## Executive summary

The present document identifies considerations and challenges related to system architecture, RAN architecture and lower layer RAN to support advanced ISAC use cases for a future 6G system. A total of 17 considerations and challenges are identified and described in the present document.

In addition to the identified challenges, the present document also presents various potential approaches for the identified considerations and challenges. These include various system and RAN architectural approaches, top level procedures and signalling between entities, and also selected message definitions and formats.

Finally, the present document draws conclusions and formulates recommendations for further ISAC work on integration of computing with ISAC and ISAC work on security, privacy, trustworthiness, and sustainability aspects. These recommendations also relate to ISAC work items which may be approved at a later time for subsequent phases of this ISG.

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## Introduction

There is an increasing interest in ISAC around the world from a wide range of global research and industrial communities. This includes worldwide Standardization Bodies, industrial stakeholder associations, academia, national and regional funded cooperation projects and individual industrial companies. In this context, the present document provides a study on system and RAN architectural challenges to support ISAC in future 6G systems.

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# 1 Scope

The present document studies and defines a System and RAN architectural framework for 6G ISAC. To this aim, the focus is on identifying considerations and challenges, with related potential approaches in the following key areas:

- System architecture.
- RAN architecture.
- Lower layer RAN.

The goal is to support future ISAC use cases and in particular the identified 6G ISAC use cases in ETSI GR ISC 001 [i.1] with their related sensing modes, integration levels and deployments.

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## 2 References

### 2.1 Normative references

Normative references are not applicable in the present document.

### 2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long-term validity.

The following referenced documents may be useful in implementing an ETSI deliverable or add to the reader's understanding, but are not required for conformance to the present document.

- [i.1] [ETSI GR ISC 001 \(V1.1.1\)](#): "Integrated Sensing And Communications (ISAC); Use Cases and Deployment Scenarios".
- [i.2] [Report ITU-R M.2516-0 \(11/2022\)](#): "Future technology trends of terrestrial International Mobile Telecommunications systems towards 2030 and beyond", November 2022.
- [i.3] [ETSI TS 122 137 \(V19.1.0\)](#): "5G; Integrated Sensing and Communication (3GPP TS 22.137 version 19.1.0 Release 19)".
- [i.4] [3GPP TR 23.700-14](#): "Study on Integrated Sensing and Communication; Stage 2 (Release 20)".
- [i.5] [Regulation \(EU\) 2016/679](#) of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation).
- [i.6] [ETSI GR ISC 004](#): "Integrated Sensing And Communications (ISAC); Security, Privacy, Trustworthiness and Sustainability".
- [i.7] [IEEE 802.11bf™-2025](#): "IEEE Standard for Information Technology -- Telecommunications and Information Exchange Between Systems Local and Metropolitan Area Networks -- Specific Requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications - Amendment 4: Enhancements for Wireless LAN Sensing".
- [i.8] [SP-250833](#): "Revised SID on Study on Stage 2 for Integrated Sensing and Communication".
- [i.9] [RP-251861](#): "New SID: Study on Integrated Sensing And Communication (ISAC) for NR".
- [i.10] [SP-241391](#): "New Study on 6G Use Cases and Service Requirements".

- [i.11] [3GPP TR 22.870](#): "Study on 6G Use Cases and Service Requirements; Stage 1".
- [i.12] [RP-251881](#): "New Study on 6G Radio".
- [i.13] [ETSI GR ISC 005](#): "Integrated Sensing And Communications (ISAC); Integration of Computing with ISAC".

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## 3 Definition of terms, symbols and abbreviations

### 3.1 Terms

Void.

### 3.2 Symbols

Void.

### 3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

3GPP	3 <sup>rd</sup> Generation Partnership Project
3-SIDP	3 <sup>rd</sup> party Sensing Input Data Provider
3-SSC	3 <sup>rd</sup> party Sensing Service Consumer
5G	5 <sup>th</sup> Generation
5G NR	5G New Radio
5GA	5G Advanced
5GS	5 <sup>th</sup> Generation System
6G	6 <sup>th</sup> Generation
6GS	6 <sup>th</sup> Generation System
AAA	Authentication, Authorization and Accounting
AF	Application Function
AI	Artificial Intelligence
AN	Access Node
AP	Access Point
BS	Base Station
CAPEX	Capital Expenditure
CDR	Charging Data Record
CEF	Capability Exposure Function
CM	Connection Management
CN	Core Network
CPU	Central Processing Unit
CSI	Channel State Information
DL	Downlink
DN	Data Network
eMBB	enhanced Mobile Broadband
GDPR	General Data Protection Regulation
GPS	Global Positioning System
GPU	Graphics Processing Unit
HTTP	Hypertext Transfer Protocol
ID	Identifier
IDR	Incentive Data Record
IMT	International Mobile Telecommunications
ISC	Integrated Sensing and Communications
KPI	Key Performance Indicator
MAC	Medium Access Control
ML	Maximum Likelihood

mMTC	massive Machine Type Communication
MNO	Mobile Network Operator
NEF	Network Exposure Function
NF	Network Function
NPN	Non-Public Networks
PHY	Physical
PNI-NPN	Public Network-Integrated NPN
PoA	Point of Attachment
QoS	Quality of Service
RAD	Range, Angle, Doppler
RAM	Random Access Memory
RAN	Radio Access Network
R-CPS	Real time Cyber-Physical System
RF	Radio Frequency
RRC	Radio Resource Control
RS	Reference Signal
RSU	Road Side Unit
SA	System Architecture
SAF	Sensing Analytics Function
SBA	Service-Based Architecture
SCF	Sensing Control Function
SCIM	Sensing Charging and Incentive Management
SDSF	Sensing Data Storage Function
SEF	Sensing Exposure Function
SF	Sensing Function
SGW	Sensing Gateway
SIDP	Sensing Input Data Provider
SL	Sidelink
SMUS	Sensing Measurements Utilization Score
SPA	Sensing Paging Area
SSC	Sensing Service Consumer
SSP	Sensing Service Producer
STID	Sensing Task Identifier
STM	Sensing Task Management
TDD	Time Division Duplex
TR	Technical Report
TRP	Transmission/Receive Point
TSSA	Target Sensing Service Area
UAV	Unmanned Aerial Vehicle
UE	User Equipment
UL	Uplink
URLLC	Ultra Reliable Low Latency Communications

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## 4 Identified sensing modes, integration levels and system terminology

### 4.0 Introduction

Definitions of sensing modes, integration levels and system terminology build on definitions already agreed in ETSI GR ISC 001 [i.1]. Sensing modes and integration level definitions are repeated here again, to facilitate reading of the present document in a standalone way.

### 4.1 Sensing modes

The term "sensing mode" describes the topology consisting of one or more sensing nodes and their role. Sensing nodes may be User Equipment's (UEs) or Transmit/Receive Points (TRPs) that may act as a sensing transmitter and/or sensing receiver.

There are six unique sensing modes:

- TRP-TRP bistatic;
- TRP monostatic;
- TRP-UE bistatic;
- UE-TRP bistatic;
- UE-UE bistatic; and
- UE monostatic.

These basic modes may be extended to multi-static variants by adding additional UE(s) or TRP(s) to any of the six basic modes as sensing transmitter(s) and/or receiver(s).

## 4.2 Integration levels

The term "integration level" describes how communication and sensing functionalities are combined in one system. It is commonly categorized in multiple levels, reaching from loose integration to tight integration with variable granularity [i.2].

Loose integration refers to the case where the two functionalities are realized rather on a standalone basis with some level of coordination, e.g. on application level, or by combining dedicated sensors and communication hardware on a site.

Tight integration refers to a joint waveform or joint signal design that is suitable for both tasks.

Intermediate integration may refer to anything in between.

## 4.3 System terminology for sensing-enabled 6G systems

For the purposes of the present document, the following terms apply:

- **Sensing signal** is a transmitted signal from a sensing transmitter for the purpose of sensing. The signal can be 6G or non-6G.
- A **sensing transmitter** is a 6G or non-6G entity that transmits a sensing signal.
- A **sensing receiver** is a 6G or non-6G entity that receives a sensing signal and produces sensing data. A sensing receiver can be co-located with a sensing transmitter.
- **Sensing data** is the 6G or non-6G data produced for sensing purposes.
- A **sensing entity** is an entity referring to a sensing transmitter or to a sensing receiver.
- A **sensing service** is a feature of the 6GS that is offered to service consumers. A sensing service provides sensing results based on communicated requirements and KPIs.
- **Sensing function**: indicates the logical function, which is involved to support a Sensing Service.

NOTE 1: The sensing function cannot be a sensing entity.

- A **sensing task** is communicated from a sensing function to sensing entities and functions and consists of configuration information of the required sensing transmitter(s) and sensing receiver(s) (if applicable), the collection of sensing data, the processing of the sensing data and the exposure of the sensing results. Each sensing task fulfils a Sensing Service request.
- A **Target Sensing Service Area (TSSA)** is defined as a cartesian location area that needs to be sensed by deriving characteristics of the environment and/or objects within the environment with certain sensing service quality from the impacted (e.g. reflected, refracted, diffracted) 6G or non-6G sensing signals. This includes both indoor and outdoor environments.

- The **sensing results** are processed or non-processed sensing data which may include characteristics of objects (e.g. type, distance, velocity, trajectory, size, shape, material), or other contextual information (e.g. time of generation, environmental information) about objects in the Target Sensing Service Area.

NOTE 2: It is not precluded that the sensing result exposed to an entity within 6GS or to an authorized 3<sup>rd</sup> party may in some cases consist of the sensing data itself.

- **Sensing contextual information** is information that is exposed with the sensing results which provides context to the conditions under which the sensing results were derived (e.g. time of generation, environmental information). This information does not contain sensing data or sensing results.
- **Fusion** refers to a process to join two or more streams of sensing data or sensing results together to form one or more sensing data or sensing result stream(s). Fusion can take place at the origin of the sensing data, along the system entities of a 6GS. The fusion of sensing results can also take place along all 6GS system entities. Fusion can also take place in non-6GS entities.

Figure 4.3-1 uses the terminology defined above and illustrates the described information flow.

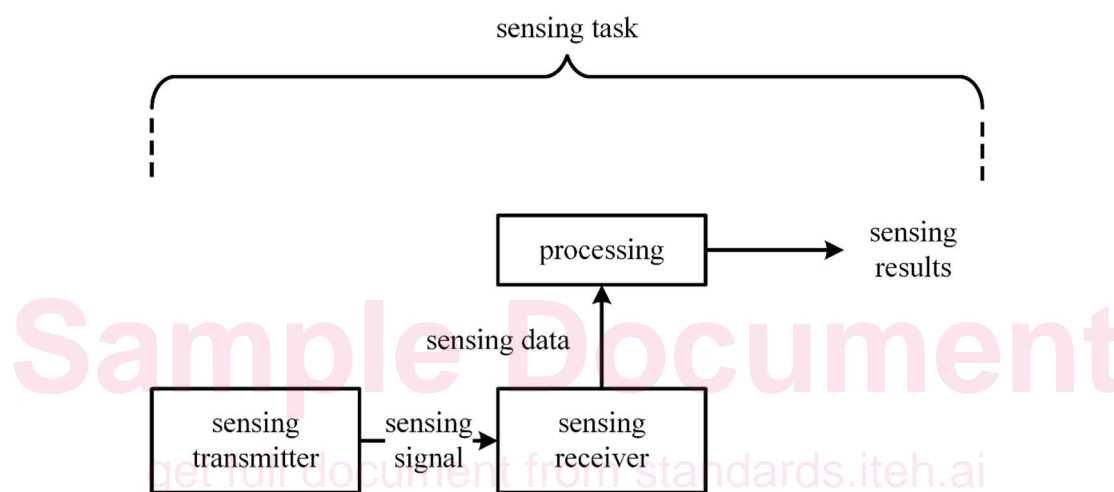


Figure 4.3-1: Workflow of conducting sensing using the terminology above

## 5 System architectures

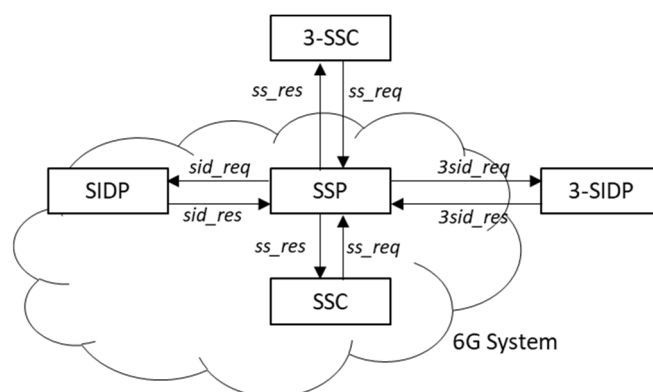
### 5.0 System reference model

To derive a reference model for the 6GS system architecture at a top level, the requirements of the 18 identified 6G ISAC use cases accepted in ETSI GR ISC 001 [i.1] were analysed. Specifically, the required sensing input data sources (or sensing input data providers) and the expected sensing service results consumers for each of these use cases were studied. The results of this analysis are shown in Table 5.0-1.

**Table 5.0-1: Sensing input data providers and sensing service consumers for each of the use cases in ETSI GR ISC 001 [i.1]**

6G ISAC use case in ETSI GR ISC 001 [i.1]	Source / Provider of the sensing input data	Consumer of the sensing service
Human motion recognition	6GS entities (UEs, ANs)	6G UEs, 3 <sup>rd</sup> party application(s)
Airborne-based sensing for environmental reconstruction	6GS entities (UEs, ANs)	6GS entities (UEs, ANs, NFs), 3 <sup>rd</sup> party application(s)
Real-time monitoring of health hazard and disaster risk	6GS entities (UEs, ANs), 3 <sup>rd</sup> party sensing input(s)	6G UEs, 3 <sup>rd</sup> party application(s)
Emergency search and rescue	6G UEs	6G UEs, 3 <sup>rd</sup> party application(s)
Remotely controlled robots for senior citizen monitoring and care	6GS entities (UEs, ANs), 3 <sup>rd</sup> party sensing input(s)	3 <sup>rd</sup> party application(s)
Precise localization for robot grasping	6GS entities (UEs, ANs), 3 <sup>rd</sup> party sensing input(s)	6GS entities (UEs, ANs, NFs), 3 <sup>rd</sup> party applications(s)
Micro-deformation sensing	6GS entities (UEs, ANs)	3 <sup>rd</sup> party application(s)
Traffic throughput and safety on road intersections	6GS entities (UEs, ANs)	3 <sup>rd</sup> party application(s)
Collaborative robots based on digital twinning	6GS entities (UEs, ANs)	6GS entities (UEs, ANs, NFs), 3 <sup>rd</sup> party application(s)
Body proximity sensor	6GS entities (UEs, ANs)	6GS entity (UEs, ANs)
High resolution topographical maps	6GS entities (UEs, ANs), 3 <sup>rd</sup> party sensing input(s)	3 <sup>rd</sup> party application(s)
Outdoor healthcare sensing and monitoring	6GS entities (UEs, ANs)	3 <sup>rd</sup> party application(s)
R-CPS in industrial worksites	6GS entities (UEs, ANs), 3 <sup>rd</sup> party sensing input(s)	3 <sup>rd</sup> party application(s)
Use case on safe & economic UAV transport	6GS entities (UEs, ANs), 3 <sup>rd</sup> party sensing input(s)	3 <sup>rd</sup> party application(s)
Use case on emergency vehicle route planning	6GS entities (UEs, ANs), 3 <sup>rd</sup> party sensing input(s)	3 <sup>rd</sup> party application(s)
Sensing-aided communications	6GS entities (UEs, ANs),	6GS entities (UEs, ANs, NFs), 3 <sup>rd</sup> party application(s)
Use case for automated guided vehicles travelling in airports	6GS entities (UEs, ANs), 3 <sup>rd</sup> party sensing input(s)	3 <sup>rd</sup> party application(s)
Vision-aided sensing	6GS entities (UEs, ANs), 3 <sup>rd</sup> party sensing input(s)	3 <sup>rd</sup> party application(s)

Based on this analysis a reference model for the definition of 6GS architecture is introduced. This model supports all of the identified 6G ISAC use cases in [i.1]. This reference model is illustrated in Figure 5.0-1.



**Figure 5.0-1: 6GS reference model**

The reference model includes the following definitions:

- 6GS Sensing Service Producer (SSP): a 6GS entity providing the 6G Sensing Service(s);
- 6GS Sensing Service Consumer (SSC): a 6GS entity which can be authorized to request and consume 6G Sensing Service(s). SSC may include UEs, Access Nodes, and Core Network Functions;

- 3<sup>rd</sup> party Sensing Service Consumer (3-SSC): an entity, not part of 6GS, which can be authorized to request and consume 6G Sensing Service(s);
- 6GS Sensing Input Data Provider (SIDP): a 6GS entity which can provide input data needed to provide the 6G Sensing Service. SIDP may include UEs and Access Nodes;
- 3<sup>rd</sup> party Sensing Input Data Provider (3-SIDP): an authorized entity, not part of 6GS, which can provide input sensing data needed to provide the 6G Sensing Service.

The Sensing Service Consumer and the 6GS Sensing Service Producer interact according to service-based request/response paradigm, e.g. via Sensing Service request/response (ss\_req/ss\_res).

The 3<sup>rd</sup> party Sensing Service Consumer and the 6GS Sensing Service Producer interact according to service-based request/response paradigm, e.g. via Sensing Service request/response (ss\_req/ss\_res).

The 6GS Sensing Service Producer and the 6GS Sensing Input Data Provider interact (possibly according to service-based request/response paradigm), e.g. via Sensing Input Data request/response (sid\_req/sid\_res).

The 6GS Sensing Service Producer and the 3<sup>rd</sup> party Sensing Input Data Provider interact (possibly according to service-based request/response paradigm), e.g. via 3<sup>rd</sup> party Sensing Input Data request/response (3sid\_req/3sid\_res).

NOTE 1: The defined entities and messages do not necessarily correspond to 6GS network entities, 6GS network functions, 6GS interfaces, 6GS protocol messages and relating interfaces.

NOTE 2: The defined entities and messages do not necessarily correspond to 3GPP defined [i.3], [i.4] network entities, network functions, interfaces, protocol messages and relating interfaces.

NOTE 3: When sensing data is requested from a SIDP for 3-SIDP or sensing results, regulatory requirements regarding user privacy and sharing of personally identifiable information (including as a result of fused sensing data from multiple sources) should be maintained.

## 5.1 Identified considerations and challenges

### 5.1.1 Sensing Function (SF) considerations

The ability to enable sensing in mobile networks addresses one of the three newly added IMT 2030 usage scenarios and numerous 6G use cases have been studied in ETSI ISG ISAC and is published as ETSI GR ISC 001 [i.1]. ETSI GR ISC 001 [i.1] identifies the need to add new functionality across the entire 6G system to enable sensing, with the need for 6G RF sensing capabilities in 6G UEs and 6G BSs are foundational towards enabling sensing in a mobile network. Furthermore, non-RF sensing capabilities may be present at 6G UEs and 6G BSs and/or sensing data from non-6GS sources may be available either within the 6GS or connected from trusted or untrusted domains. In several use cases described in ETSI GR ISC 001 [i.1], fusion of 6GS and non-6GS sensing data is assumed. Thus, the sheer complexity of coordinating sensing tasks based on sensing capabilities requires new functionality in the 6GS.

Additionally, requests for a new Sensing Service may arrive from within the 6GS [i.1], e.g. from an application server in the DN or an application on the UE. These Sensing Service requests will carry more detailed data describing what is expected from the Sensing Service, e.g. KPIs for sensing results, TSSA or specific 6G UE IDs that should be used in the Sensing Service. Also, the consumer of the sensing results can be either an SSC [i.1] or a 3-SSC which requires coordination. This increases the complexity of coordinating sensing tasks to fulfil a requested Sensing Service.

The majority of sensing use cases presented in [i.1] indicate the movement of either the target object(s) and/or the 6G UEs that are part of a sensing task. In many use cases these movements require a change of involved Sensing Transmitter or Receiver, as they are no longer suitable to maintain the requested Sensing Service sensing results. And given the nature of mobile networks, a handover of a sensing task to Sensing Transmitters and/or Receivers that are attached to a different 6G BS requires coordination across 6G BSs for continuous execution of sensing tasks.

Sensing data is of significant sensitive nature, as it theoretically allows facial recognition, behavioural human pattern building and tracking of individuals without their knowledge. To protect the privacy of individuals and allowing them to understand who collects, processes and exposes private data to whom, the 6GS should implement official General Data Protection Regulation (GDPR) [i.5] and be consistent with the practices and principles captured in [i.6].

In 5G, 3GPP adopted Service-Based Architecture (SBA) principles for a range of reasons:

- 1) multi-vendor deployments of operator CNs, allowing to choose the best vendor for a specific NF based on the operator needs;
- 2) flexibility in which NF is selected and deployed against the service requirements the mobile network is supposed to serve;
- 3) leveraging cloud-native software approaches of CN NFs for developing, deploying and managing NFs on-demand in an agile fashion.

Furthermore, the proposition of mobile networks being used as private networks (NPNs or PNI-NPN) requires customized but still standard-compliant deployments of 5G networks, yielded by SBA principles of the 5GS. Similar to eMBB, URLLC and mMTC, sensing should be seen as a unique service which not all 6G networks will need in their service offering and any system approaches to enable sensing should follow SBA principles.

## 5.1.2 Sensing service request and configuration

Sensing service request:

- From the reference model of Figure 5.0-1, the 6GS sensing service is exposed by the Sensing Service Producer (SSP) via a service-based interface. A sensing service request (ss\_req) can be issued by a 6GS Sensing Service Consumer (SSC) (which may include UEs, Access Nodes, Core Network Functions) and by 3<sup>rd</sup> party Sensing Service Consumer (3-SSC).

The challenges for sensing service request therefore include:

- the definition of which 6GS entities and which 3<sup>rd</sup> party entities may be authorized to invoke the sensing service requests;
- the definition of the supported sensing results types by 6GS (e.g. sensing data, processed sensing data, others);
- for processed sensing data type, the definition of the supported sensing results by 6GS (e.g. object recognition, motion recognition, deformation recognition, others);
- the definition of the supported sensing results timing by 6GS (e.g. single instance, interrupt, periodic, stream, others);
- the definition of the QoS profiles for the sensing service supported by 6GS (QoS profiles e.g. including accuracy, latency, resolution, others);
- the definition of the interface to invoke the sensing service requests;
- the definition of the format of the sensing service requests;
- the definition of possible data formats and their structures for describing the Target Sensing Service Area.

## 5.1.3 Sensing input data request definition

From the reference model of Figure 5.0-1, upon reception and processing of a sensing service request, the Sensing Service Producer (SSP) selects SIDP(s) and 3-SIDP(s), the SSP configures the parameters of SIDP(s) and the SSP configures (if possible) the parameters of 3-SIDPs. The purpose of selecting and configuring (if possible) (3-)SIDP(s) is to execute a sensing task and for the SSP to collect sensing data in order to provide the requested sensing service. The SSP generates and sends the sensing input data request (sid\_req) to the selected SIDP(s) and 3-SIDP(s).

The quality of the sensing data is assessed based on the Sensing Service KPI requirements of the sensing results communicated from the SSC/3-SSC.

The challenges of the sensing input data request definition include:

- The definition of SSP functionalities to discover and select the SIDP(s) and 3-SIDP(s) to provide the requested sensing service, and means to coordinate the processing of sensing data provided by the (3-)SIDP.

- The definition of interfaces, procedures and protocol stacks to interact with other 6GS components to discover and select the SIDP(s) and 3-SIDP(s).
- The supported sensing data format by SIDP(s) and 3-SIDP(s).
- SIDP(s) and 3-SIDP(s) sensing data provisioning options.
- The sensing input data request message format(s) supported by SIDP(s) and 3-SIDP(s). This includes the terminology definition of the content of the sensing input data request message formats, for flexible configuration of 6G RF sensing receivers.
- Mechanisms to configure SIDPs for efficient sensing data management purposes (i.e. selective measurement and reporting) allowing the SSP to meet the KPI requirements of the sensing results provided by the (3-)SSC in the sensing service request.

NOTE: Other aspects relating to the sensing input data request (e.g. authorization, authentication security, etc.) may be in the scope of ETSI GR ISC 004 [i.6] and may need to be addressed therein.

### 5.1.4 Sensing input data response

From the reference model of Figure 5.0-1, upon reception and processing of a sensing input data request (sid\_req), the SIDP and the 3-SIDP, if capable, may configure radio resources to generate the requested sensing data, and may process, filter, format the sensing data to generate the sensing input data response (sid\_res).

The challenges of the sensing input data response definition include:

- the definition of sensing data characteristics supported by SIDP and 3-SIDP;
- the definition of sensing data format supported by SIDP and 3-SIDP;
- the definition of SIDP and 3-SIDP sensing data exposure options;
- the definition of SIDP and 3-SIDP functionalities needed to generate the supported sensing data;
- the definition of the sensing input data response format, including:
  - the message format and terminology definitions of the content of sensing input data response;
  - the interfaces, procedures and protocol stacks SIDP/3-SIDP - SSP to transfer the Sensing Input Data Response messages.

NOTE: Other aspects relating to the sensing input data response (e.g. authorization, authentication, security, etc.) may be in the scope of ETSI GR ISC 004 [i.6] and may need to be addressed therein.

### 5.1.5 Considerations and challenges on network payload related to sensing data

Collecting and transferring through the 6G network data related to sensing will likely generate a large payload. Reducing redundancy by selecting in a smart way sensing data to be collected and/or reported in multi-sensor 6G systems can significantly reduce the payload carrying sensing data for ISAC systems and allow more efficient operations.

Smart data selection solutions (e.g. SIDP selection, data selection, etc.) need to be designed to reduce the payload associated with carrying sensing data. Smart data selection may consist of, for example, selecting a specific angle of view among several redundant ones, or a most representative angle of interest among complementary ones, or a sufficient subset of measurements in the context of cooperative data fusion. Only relevant data should be effectively transferred through the network, thus leading to efficient sensing data collection and reporting procedures. Additionally, such data collection would be beneficial for sensing data fusion allowing efficient utilization of processing resources.

In the process of SIDP and/or data selection, particular attention should be given to factors such as the occlusion phenomena, sensor capability, network load, and operator policy.