

# ETSI GR ISC 003 V1.1.1 (2026-02)



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".

## 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.

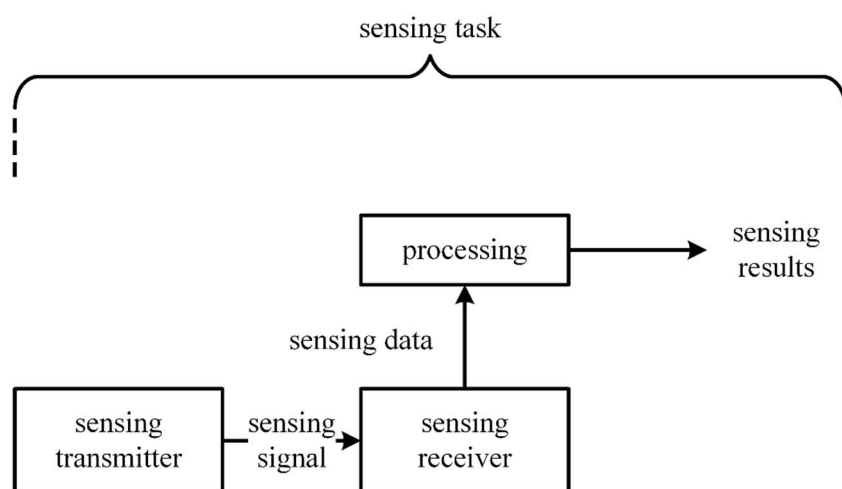


Figure 4.3-1: Workflow of conducting sensing using the terminology above

## 5 System architectures

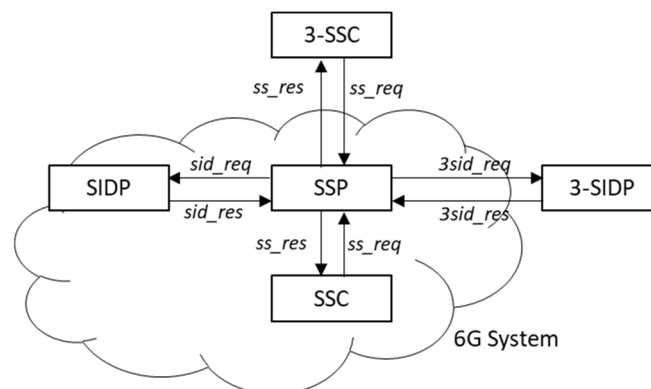
### 5.0 System reference model

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.

The challenges for reducing the network payload related to carrying sensing data include:

- Design of efficient sensing data collection and reporting protocols:
  - Including impacts on procedures for sensing data request/response, transport of sensing results, etc.
- Procedures to identify relevant data and/or relevant sensors and/or appropriate processing resources:
  - To control the overall payload from system perspective while ensuring service requirements of specific applications/sensing tasks.
  - In challenging environments, e.g. in the presence of occlusion phenomena, and subject to sensor capability, network load, operator policy.

### 5.1.6 Sensing results exposure and transport

From the reference model of Figure 5.0-1, the Sensing Service Producer (SSP) processes sensing data (received via sid\_res/3sid\_res) to generate sensing results which are then provided (ss\_res) to the Sensing Service Consumer (SSC) or 3<sup>rd</sup> party Sensing Service Consumer (3-SSC) in accordance with the sensing service request (ss\_req) that initially requested the service.

The challenges for sensing results exposure and transport therefore include:

- The definition of sensing results data types and formats.
- The definition of 3-SSC and SSC sensing results provisioning options.
- The definition of the interfaces and/or services for setting up and controlling the provisioning of sensing results to 3-SSC and SSC.
- The definition of transport mechanisms connecting SIDP and 3-SIDP to SSP as well as SSP to SSC and 3-SSC.

NOTE: Privacy and security issues related to exposure to third parties may be in the scope of ETSI GR ISC 004 [i.6] and may need to be addressed therein.

### 5.1.7 Charging and incentives

#### 1) Charging:

- A sensing service subscriber is a consumer of 6G sensing services. The 6G network should consider how to charge these subscribers that could be UEs, network entities in 6GS or 3<sup>rd</sup> parties out of 6GS.
- The challenges for sensing service charging include:
  - the definition of which 6GS network entity to manage the sensing service subscriber;
  - the definition of which 6GS network entity to be responsible for charging;
  - the definition of charging procedure, charging mode;
  - the definition of charging metrics;
  - how to calculate sensing service usage.

#### 2) Incentives:

- Unlike the existing network architecture where the UE acts as a consumer of services, in the ISAC scenario, the UE can become a provider of sensing data or sensing signals, enabling the sensing service to be offered as a new service. Therefore, a method to incentivize UEs is needed, so that UEs can participate as much as possible in the sensing services, increasing their motivation to provide resources for the sensing service, potentially leading to an increase the sensing accuracy.

- The challenges for defining an incentive mechanism for UEs participating in the sensing service include:
  - whether/how to define which 6GS network entity to be responsible for incentive;
  - whether/how to define metrics to measure the contribution of UEs to the sensing service;
  - whether/how to define incentive procedure;
  - whether/how to define the incentive methods.

### 5.1.8 Disaggregation of sensing control and processing

From the Reference Model of Figure 5.0-1, the Sensing Service Producer (SSP) delivers the 6G sensing service by:

- (i) controlling sensing data flows; and
- (ii) processing sensing data to generate sensing results.

Ideally, these tasks are performed by separate functions that can be co-located or distributed. Sensing control should remain within the 6G system, whereas sensing data processing may occur inside or outside the 6G system, requiring a flexible architecture.

### 5.1.9 Considerations for mobility of sensing entities

Mobile networks offer the ability for communication devices to exchange information with an application in the DN or other UEs while moving freely within the mobile network's coverage area. Adding sensing capabilities to mobile networks should allow mobile sensing entities to freely move as well.

As a result, the following challenges have been identified for the SSP when selecting the components of a sensing task, i.e. all 6GS components that have been selected to execute the sensing task (sensing transmitter, sensing receiver, SSP instance(s) (the functionality of processing/fusing/storing sensing data and exposing sensing results)):

- Considering sensing mobility of mobile sensing entities accounting for radio and networking resources for sensing and/or comms.
- Coordination of a sensing task while one or more sensing entities are moving.

### 5.1.10 Considerations for managing sensing entities in an ISAC system

The dense deployment of cellular networks offers significant sensing opportunities by utilizing a large number of sensing entities (comprising base stations and UEs), potentially providing robust sensing and localization performance. However, using all of the available sensing entities for a given sensing task may not be ideal due to resource constraints (e.g. radio, computation, energy) and associated service costs. Optimal management of sensing entities - comprising selection of suitable sensing entities and role assignment (transmit, receive, or both) - is a complex task that should balance performance with resource efficiency.

Several factors influence the management of sensing entities. These factors include sensing quality of service requirements, the need to balance communication and sensing performance to meet their respective requirements, and availability of sensing entities (which may be limited due to their concurrent tasks, and mobility as sensing entities enter or leave the sensing area). The management of sensing entities may also involve some interaction with the sensing RAN management function.

### 5.1.11 CN-RAN interaction for sensing task control

The reference architecture defined in Figure 5.0-1 shows the high-level building blocks and key messages for enabling the sensing service requested and the provisioning of the sensing results. This reference architecture enables the investigation of different approaches for the definition of the system architecture, in terms of entities and interfaces for supporting the sensing task.

One of the aspects that needs to be further investigated is the relationship between the CN architecture and the RAN architecture supporting the execution of sensing tasks. The following considerations should be further analysed to determine the functional split between CN and RAN for the execution of the following activities related to sensing tasks:

- what are the conditions in which the Sensing RAN management operates in coordination with the SCF in the core network, and what are the conditions that it can operate autonomously in RAN;
- what is the separation of responsibilities between CN and RAN regarding the selection of sensing entities;
- what is the functional split between CN and RAN for the definition of the configuration parameters and control information related to the sensing entities;
- whether there is the need of RAN and CN coordination for the processing of sensing input data;
- what is the functional split regarding the decisions of changes in the sensing task to continuously fulfil the sensing task requirements.

### 5.1.12 Considerations and challenges on multi-operator network sharing for sensing

A single operator's network may not always meet the required sensing KPIs for a certain sensing task. Collaborating BSs and/or UEs from different networks may enhance sensing performance and mitigate the impact on each individual network's communication resources.

For instance, operator A might have a BS with a beam directed towards the target sensing service area, serving as a sensing transmitter. However, if that operator has no BSs or UEs in the vicinity to act as sensing receivers, the sensing requirements cannot be fulfilled. In this situation, BSs and/or UEs from operator B, located in the vicinity, can function as sensing receivers.

Using multiple operator networks may benefit ISAC use cases studied in ETSI GR ISC 001 [i.1] that require extensive sensing coverage, such as airborne-based sensing for environmental reconstruction, high-resolution topographical maps, or scenarios demanding high reliability such as the use cases of real-time monitoring of health hazard and disaster risk, and emergency search and rescue.

Currently, there are no mechanisms that allow multiple operator networks to jointly serve a single sensing task. To realize multi-operator sensing, several factors including topology management, data collection, and interface design need to be considered. When developing such mechanisms, a hierarchical approach may be taken, starting from simple fusion of sensing results from multiple operators to more advanced solutions that may include sharing the resources (such as base stations and/or UEs) between multiple operators.

## 5.2 Potential approaches

### 5.2.1 Sensing function

Following the sensing function considerations outlined in clause 5.1.1, three main architectural conclusions can be drawn which are explained herein:

- 1) The coordination of sensing tasks may be conducted by the 6G Core Network.
- 2) The 6G Core Network utilizes a new functionality for coordinating sensing control tasks. This may be realized by a dedicated Network Function (NF).
- 3) The fusion, processing and storage of sensing data or sensing results may or may not be conducted by one or more dedicated functions from the NF, which coordinates sensing tasks e.g. in a single sensing NF. The sensing analytics function may additionally be realized by a separate function to the storage function. Processing of sensing data and sensing results to ensure required user privacy and data confidentiality is carried out during this processing function.

One possible resulting system architecture on the above is depicted in Figure 5.2-1, which illustrates an architecture showing the addition of two new NFs in the 6G CN, i.e. the Sensing Control Function (SCF) and the Sensing Analytics Function (SAF). To elaborate on the explanation how this proposed approach addresses the challenges in clause 5.1.1, Table 5.2-1 lists each requirement and provides the arguments for each proposed NF.

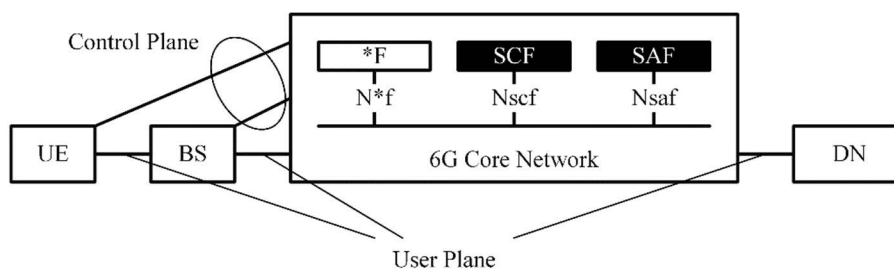


Figure 5.2-1: Proposed Sensing-Enabled 6G Core Network

Table 5.2-1: Arguments for dedicated SCF and dedicated SAF functions

Requirement	Arguments for dedicated SCF	Arguments for dedicated SAF
Learn and manage 6G RF and non-6G RF sensing capabilities	The coordination of 6G RF and non-6G RF sensors as well as their capabilities should be realized as a NF in the 6G CN, as it spans across all 6G UEs and BSs, and can be linked to a request for a sensing service and its specific details (e.g. sensing result KPIs or TSSA).	n/a
Sensing service requests from an SSC or 3-SSC	Sensing service request can be issued from 6GS entity as well as application servers and the most suitable 6GS entity to coordinate that is the 6G CN. The separation of coordinating sensing service requests in the CN from any other NF further increases the ability to manage AAA for any sensing consumer communicating with the SCF.	n/a
Mobility of Sensing Transmitter/Receivers and/or Target Object	To enable sensing mobility (mobile 6G UEs and target objects) across 6G BSs, the 6G CN is the most suitable entity to perform that, similar to mobility for 5G communications. Furthermore, as the coordination of sensing tasks is significantly different from mobility for communications, a dedicated NF is most suitable.	Based on the KPIs communicated by the system entity requesting a sensing service, the fusion and processing of sensing data into sensing results might need to be moved to different CN instances of the SAF, or even to different 6GS entities (6G UE or 6G BS). Thus, to not being required to also move states of the executing sensing service requests around the network, demanding a distributed solution from vendors, a decoupling of SCF and SAF is highly encouraged.
Fusion and Processing of sensing data across all 6GS entities	As the processing and fusion of sensing data may require to be re-located across the 6GS for a particular sensing task, the SAF could be entirely decoupled from the SCF.	
Follow SBA principles	Separate SCF allows 6G CNs to be deployed without any sensing functionality to minimize the software footprint, the resulting CAPEX when purchasing the CN and OPEX for operations (energy consumption based on lines of code loaded into memory and executed on CPUs). Furthermore, a separation also allows a better scaling of sensing-related CN functionality in load as well as failure scenarios, truly realizing cloud-native approaches.	Separate NF for analytics allows unified procedures to move sensing data Analytics across the 6GS, preparing for the option where the 6G Control Plane is unified in protocols and principles end-to-end (including the 6G UE).

Requirement	Arguments for dedicated SCF	Arguments for dedicated SAF
Built-in privacy	It should be avoided that a single NF can link sensing data/results to a specific sensing service request where privacy and confidentiality are required. Furthermore, it should be avoided that a single NF potentially implements unlawful analytics over streamed or stored sensing data beyond its potential purpose of generating sensing results or (re-)training ML-based sensing algorithms for the purpose of generating sensing results. Thus, the handling of requested sensing tasks and the coordination of them should be clearly separated from the processing and analytics.	
Implement GDPR procedures	If users request what data is known about them (or their 6G devices used for sensing) or request to delete all sensitive data according to GDPR, the coordination of understanding past sensing tasks for specific 6G UEs is required. Such mechanisms should demand a) support from the 6G CN and b) a separation from the analytics system entity to follow SBA principles. Therefore, a dedicated NF, e.g. SCF, that also implements the coordination of GDPR-related procedures justifies a new NF to handle such regulatory requirements.	As for the coordination, the SAF may hold historic data e.g. for pattern (anomaly or performance) detection to serve the 6GS in future sensing tasks with optimization recommendations. To provide answers on which sensitive data from 6G UEs and potentially human target objects are still stored in the CN, such realization requires unique methods and procedures. This provides the required rationale to decouple the analytics of sensing data from the coordination of sensing tasks in respect to supporting GDPR procedures to request and delete sensitive information.

## 5.2.2 Approaches for sensing service request and configuration

Following the consideration of the sensing service request in clause 5.1.2 one possible approach is described below.

6GS Sensing Service Consumers (SSC) authorized to invoke sensing service requests may include:

- 6G Core Network Function (NFs);
- 6G Access Nodes (ANs);
- 6G User Equipment (UEs).

3<sup>rd</sup> party Sensing Service Consumers (3-SSC) which may be authorized by a 6G Capability Exposure Function (CEF) to invoke sensing service requests include:

- 3<sup>rd</sup> party Application Functions (AFs), hosted by User Equipment (UEs);
- 3<sup>rd</sup> party Application Functions (AFs), hosted by Data Networks (DNs).

The authorization procedure is in the scope of ETSI GR ISC 004 [i.6].

The sensing service request message may optionally indicate the sensing result type requested by the SSC or by the 3-SSC. The sensing results types supported by the 6GS include:

- sensing data;
- processed sensing data.

NOTE: Sensing data and processed sensing data are defined in clause 4.3.

When sensing data is requested, the sensing service request message indicates the sensing result requested by the SSC or by the 3-SSC is sensing data, as received by SIDP(s) or by 3-SIDP(s).

When processed sensing data is requested, the sensing service request message indicates the sensing result requested by the SSC or by the 3-SSC. The sensing results supported by the 6GS may include:

- Point cloud - for the target area indicated by the sensing service request, the point cloud is requested.
- Object detection - for the target area indicated by the sensing service request, the indication of the presence of object(s) is requested.

- Object localization - for the target area indicated by the sensing service request, the indication of the presence of object(s) and their position information are requested.
- Object kinematics - for the target area indicated by the sensing service request, the indication of the presence of object(s) and their kinematic information (including velocity, acceleration) are requested.
- Object classification - for the target area indicated by the sensing service request, the indication of the presence of object(s) and information on the object class they belong to are requested. Object classes are configuration parameters of the Sensing Service Producer.
- Object identification - for the target area indicated by the sensing service request, the indication of the presence of object(s) belonging to object class indicated by the sensing service request are requested.
- Object material identification - for the target area indicated by the sensing service request, the indication of the presence of object(s) belonging to object class indicated by the sensing service request and information on the object material class they are made of are requested; Object material classes are configuration parameters of the Sensing Service Producer.
- Object tracking - for the target area indicated by the sensing service request, the indication of the trajectories of detected objects are requested.
- Object shape - for the target area indicated by the sensing service request, the three-dimensional shape of objects of the environment (in the supported data formats) is requested.

The sensing service request message indicates the sensing result periodicity the sensing service response message(s) needs to be sent. The sensing result periodicity supported by the 6GS include:

- Single instance - a single sensing service response is instantaneously generated, according to the latency requirements indicated by the sensing service request. It is applicable both to sensing data and to processed sensing data results.
- Periodic - a sequence of sensing service responses is generated at a time period indicated by the sensing service request. It is applicable to both to sensing data and to processed sensing data.
- Aperiodic - a sequence of aperiodic sensing service responses are generated. It is applicable to both to sensing data and to processed sensing data.

The sensing service request message indicates the required Quality of Sensing, may include the following information:

- Accuracy of localization.
- Accuracy of kinematics information (velocity, acceleration).
- Accuracy of object shape.
- Confidence level.
- Sensing resolution.
- False negative probability.
- False positive probability.
- Sensing service latency.
- Refreshing rate: rate at which the sensing result is generated by the sensing system. It is the inverse of the time elapsed between two successive sensing results.

The sensing service request message indicates the TSSA where 6GS sensing is requested.

The sensing service request message may include additional configuration parameters needed by the corresponding sensing results.

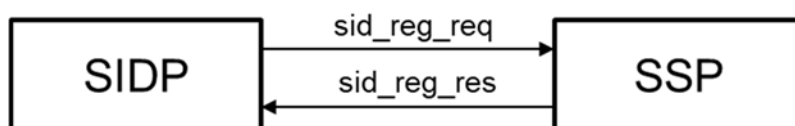
## 5.2.3 Approaches for sensing input data request

### 5.2.3.1 SIDP(s)

Following the consideration of the sensing input data request in clause 5.1.3, one possible approach is described below for registration and selection of SIDP(s).

Procedure for registration of SIDPs at SSP:

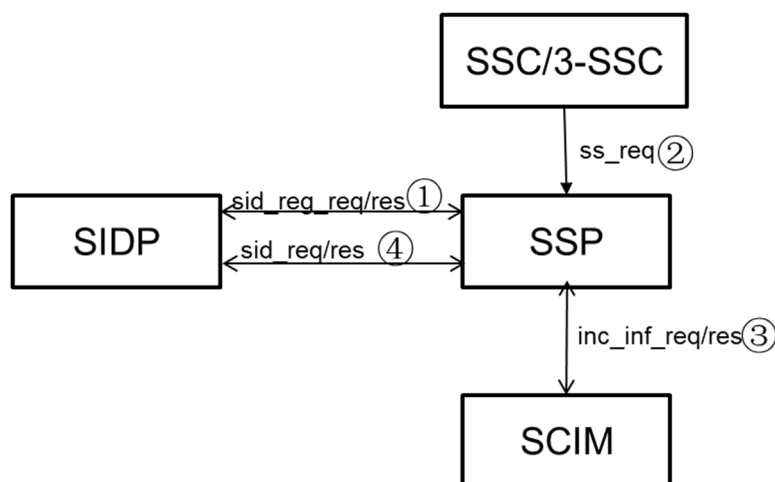
- 1) A SIDP registers its sensing capability with the SSP using registration message (`sid_reg_req`).
- 2) The SSP stores the sensing capability information from each SIDP. The sensing capability information may include:
  - `role_list`: roles in sensing signal processing, e.g. Rx, Tx, Rx & Tx;
  - mobility: fixed (e.g. BS or RSU), or mobile (e.g. UE);
  - location: e.g. GPS/Beidou/GNSS coordinates;
  - sensing data type capability: e.g. RAD (range, angle, doppler), Point-cloud, or object parameters. Indicated capability may include one or more capabilities;
  - sensing data storage capability: e.g. capacity of storage.



**Figure 5.2-2: Sensing capability registration**

**The procedure to select SIDP(s):**

- 1) SIDP registers its sensing capabilities to SSP (as per previous procedure).
- 2) SSP receives the sensing service request by SSC/3-SSC, including the parameters as defined in clause 5.2.2.
- 3) SSP selects the SIDPs based on:
  - a) Service request and sensing capabilities information, if the candidate SIDP is an access node.
  - b) Sensing service request, sensing capabilities information and incentive information if the candidate SIDP is a UE, SSP obtains the UE's incentive information (`inc_inf_req/res`) from Sensing Charging & Incentive Management (SCIM).
- 4) SSP send the sensing input data request to the selected SIDP(s).



**Figure 5.2-3: The procedure of SIDP selection**

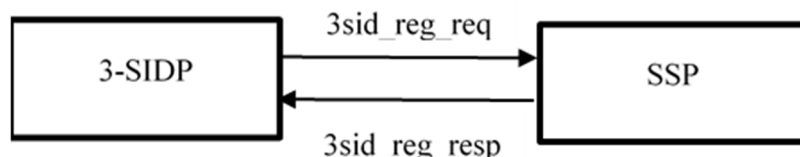
Sensing Charging & Incentive Management (SCIM) has the functionality to provide the UE's incentive and charging information to other functions. The SCIM can provide the incentive information for SIDP(s) to the SSP.

### 5.2.3.2 Non-MNO controlled Wi-Fi® enabled 3-SIDP(s)

This proposed solution addressed the identified considerations and challenges in clause 5.1.3, one possible approach for registration and sensing input data request for 3-SIDP(s) is described below.

Procedures for registration of 3-SIDP(s) at SSP:

- 1) 3-SIDP registers with SSP using registration request message (3sid\_reg\_req). Registration message includes one or more of the following sensing capabilities:
  - a) Wi-Fi sensing (e.g. 2,4 GHz, 5 GHz, 60 GHz, IEEE 802.11bf [i.7] supported).
  - b) Type for sensing results (e.g. raw (CSI/ToF), RAD, Point-cloud).
  - c) Type of configurations possible (e.g. choose result type, frequency bands, Wi-Fi specific parameters).
  - d) Location: e.g. GPS coordinates.
  - e) Time: Time where sensing services can be provided.
  - f) Number of non-6G SIDPs.
  - g) Charging and incentivisation information.
- 2) SSP stores the sensing capability registered by 3-SIDP.



**Figure 5.2-4: Sensing capability registration**

Figure 5.2-5 shows a potential procedure for 3-SIDP-based sensing task set-up and sensing data collection. The steps are described below:

- 1) The SSP receives the sensing service request from a (3-)SSC, including the parameters as defined in clause 5.2.2.
- 2) The SCF responds with a sensing service response to the (3-)SSC, indicating the status and a sensing task ID.

- 3) The SSP selects 3-SIDPs based on:
- Sensing service request and sensing capability information, SSP can discover 3-SIDPs that satisfy these requirements (Shown in the procedure of Figure 5.2-5).
  - Sensing service request, if SSP requires additional assistance information (e.g. sensing results from another modality such as Wi-Fi) based on its assessment of sensing task while a sensing task is being executed (Not shown in the procedure in Figure 5.2-5).

If needed, SSP can also interface with SCIM to obtain incentive information for 3-SIDP (inc\_inf\_req/res).

SSP also determines the configurations for the sensing task based on the capabilities registered by 3-SIDP.

- SSP sends sensing input data request to 3-SIDP with sensing task ID, TSSA, and configurations.
- 3-SIDP responds with sensing input data response to the SSP.
- 3-SIDP (e.g. AF, 6G UE, Wi-Fi AP) perform Wi-Fi sensing task and gather sensing data. For the AF to retrieve sensing data from the 6G UE, it is assumed that the 6G UE leverages an application that has registered with the AF prior to step 4.
- 3-SIDP reports sensing data report with the sensing results to the SSP (i.e. SAF).
- The SAF processes the sensing data into sensing results. The sensing results are then sent to the (3-)SSC alongside the sensing task ID.

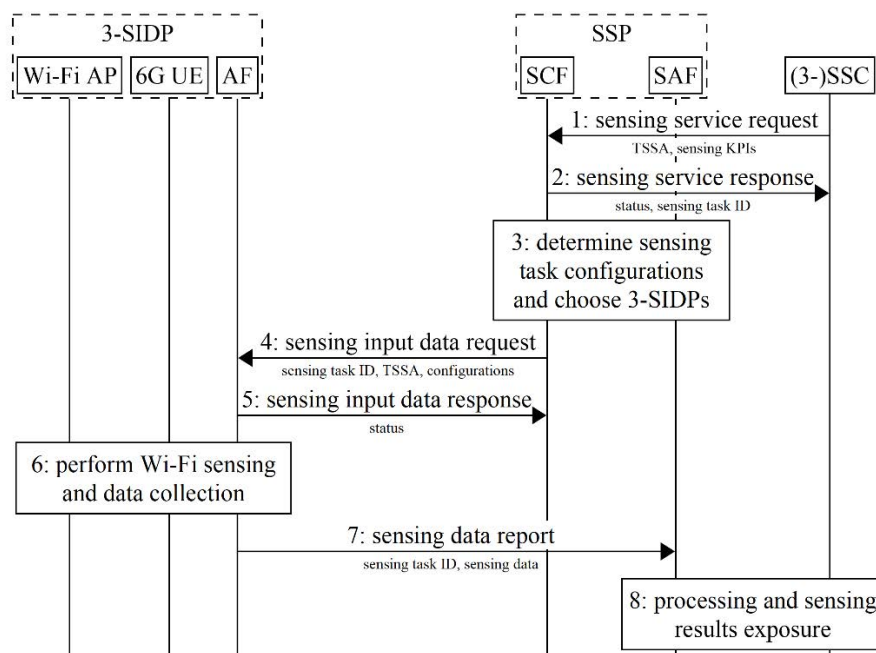


Figure 5.2-5: 3-SIDP (Wi-Fi)-based sensing service

## 5.2.4 Approaches for sensing input data response

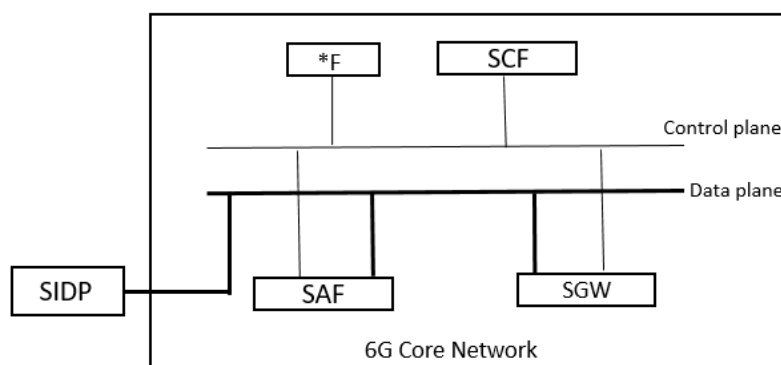
Following the consideration of the sensing input data response in clause 5.1.4 one possible approach is described below for transmitting the sensing data.

A dedicated data plane for transmitting sensing data is one approach proposed for 6GS.

This data plane is specifically designed to handle sensing data flows through the distributed paths according to requirements of sensing service requests. It can be implemented using a proposed messaging framework which effectively decouples data providers and consumers. This enables flexible sensing data distribution composed of multiple 6G/ 3<sup>rd</sup> party data providers (SIDPs, 3-SIDPs) and consumers (SSC, 3-SSC), satisfying the requirements of collaborative sensing.

With this dedicated data plane, the common same sensing data provided from SIDPs (6G UE and/or BS) and 3-SIDPs (AFs, 6G UEs) can be requested by more than one SSP (e.g. SAF) for fulfilling different sensing service requests from SSC and 3-SSC. Similarly, the same sensing service response generated by an SSP may be requested by more than one SSC. Leveraging the proposed messaging framework provided by the data plane, sensing services can be provisioned more efficiently, while also providing benefits to support asynchronous sensing data transmission.

Figure 5.2-6 depicts the proposed data transmission via the data plane.



**Figure 5.2-6: Sensing data transmission via the data plane**

Sensing Control Function (SCF) processing sensing service requests, orchestrating and selecting SIDPs to execute sensing task.

Sensing Analysis Function (SAF) performing fusion and processing of the sensing data into the sensing result(s).

Sensing Gateway (SGW) which interfaces with 3-SSC and 3-SIDP to offer sensing services or obtain sensing input data.

Sensing Input Data Provider (SIDP) which can be RANs or UEs.

## 5.2.5 Approaches for efficient sensing data selection, reporting and collection

### 5.2.5.1 Use of multiple phases

Efficient sensing data collection and reporting, possibly in the presence of occlusion effects (see note), has been identified in clause 5.1.5 as a challenge related to sensing data collection. Besides the challenges identified in clause 5.1.5, the current solution also addresses specific aspects of the challenges on sensing input data request in clause 5.1.3 and sensing input data response definition in clause 5.1.4, particularly pertaining to definition of data formats, definition of SIDP and 3-SIDP functionalities and 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.

A possible solution is to have a sensing data selection phase that may run in parallel to the sensing data collection phase and which performs smart sensing data selection with the purpose of reducing the amount of sensing data that needs to be transferred within the network. Hence, the payload associated with carrying sensing data within the network is reduced, which results in more efficient network operation. The proposed approach is illustrated in Figure 5.2-7.

#### Sensing data selection phase

The SSP sends a message *sensing input data selection request* (sids\_req) to a set of SIDPs and/or 3-SIDPs requesting information on the sensing data they are currently able to provide.

SIDPs and/or 3-SIDPs send a *sensing input data selection response* (*sids\_res*) containing information on the sensing data SIDPs and/or 3-SIDPs are currently able to provide, for example:

- data samples consisting of a low-throughput representation of the available sensing data, such as a low-definition map or video, a punctured data set, a low accuracy data set; and/or
- characteristics of the available sensing data e.g. type of available sensing data, a quality indicator associated to the full available sensing data, an estimation of the volume of available sensing data of a given type, a list of angle(s) of view currently occluded/non-occluded.

Based on the information on the sensing data that different SIDPs and/or 3-SIDPs are currently able to provide, the SSP may select more precisely the sensing data to be collected at each SIDP and/or 3-SIDP.

### Sensing data collection phase

The sensing data collection phase starts with the SSP sending sensing input data request (*sid\_req*) to the selected SIDPs and/or 3-SIDPs, identified in the sensing data selection phase as being able to provide reliable/relevant sensing data. The sensing input data request may include information elements allowing to request only a sub-set of the sensing data available at the SIDP, e.g. a map portion or a map definition or an angle of view. The total amount of sensing data to be collected is reduced, since SSP takes into account overlaps and/or redundancies, while also considering possible occlusion as a supplementary constraint.

Sensing data selection phase and sensing data collection phase may run in parallel with independent periodicities.

Executing sensing data selection phase periodically allows to detect moving objects, reconsider overlaps, and consider dynamic occlusion.

**NOTE:** Occlusion refers to area portions that are masked by objects in the scene and may only be visible from specific angles at a given time. Since both sensing targets and masking objects are susceptible to move, occlusion can be dynamic by nature.

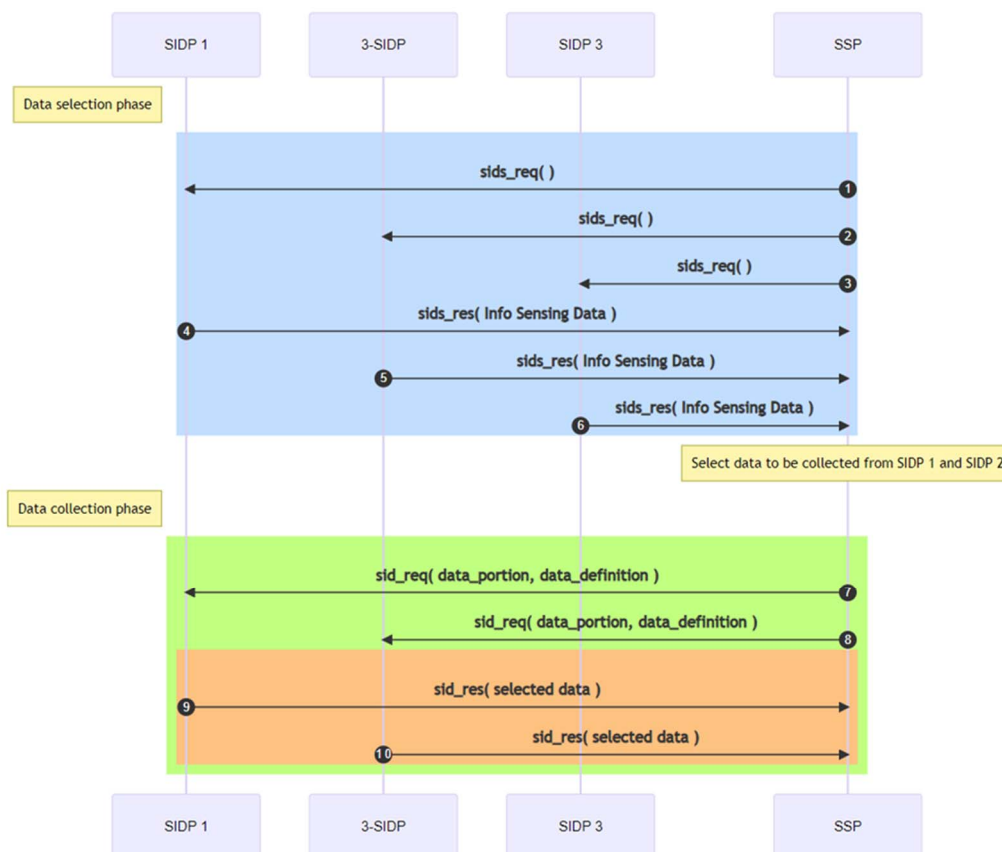
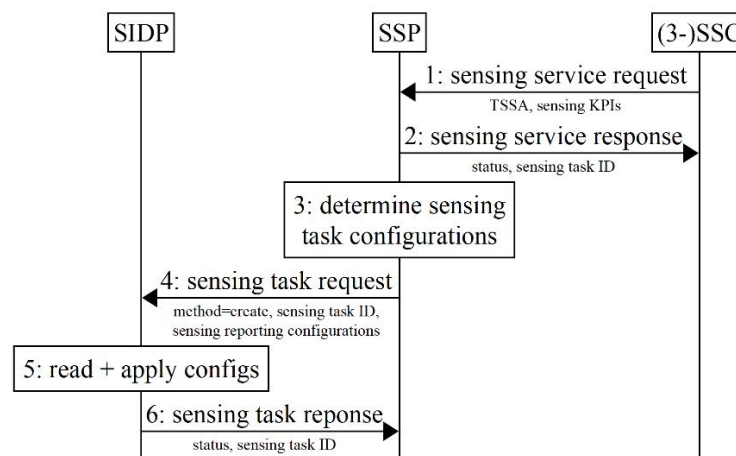


Figure 5.2-7: Sensing data selection and sensing data collection phases

### 5.2.5.2 Efficient sensing data reporting and selection

This proposed solution addresses the identified considerations and challenges on sensing input data request definition and sensing input data response.

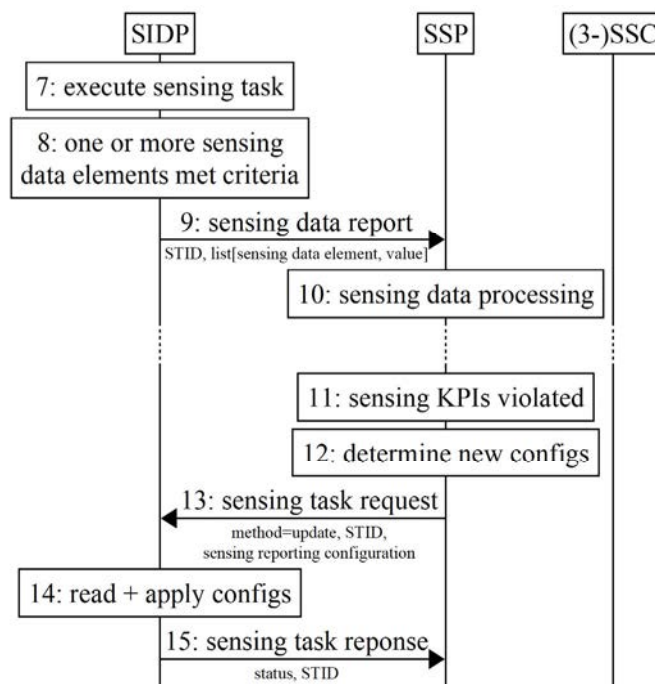
As described in clause 5.0, the SSP implements the coordination of creating, modifying and deleting sensing tasks as well as the processing and fusion of sensing data and/or sensing results. The 6GS may use the communicated KPIs from the (3-)SSC to assess whether the obtained sensing results are within the desired bounds. In case the SSP assesses that the KPI requirements for the sensing service are not met continuously, any continuation of SIDPs reporting sensing data to the network result in system resources (energy consumption, networking resources, radio resources, compute resources) going to waste. Straight forward solutions to simply stop SIDPs from performing sensing and reporting sensing data to the SSP is not a viable approach, as the network would have no way as to when to re-activate the SIDP's functionality in case the SIDP's sensing data is sufficiently high in quality. This clause provides a proposed solution to address this challenge. The call flow is shown in Figure 5.2-8 and the steps are described below.



**Figure 5.2-8: Call flow for SIDP configuration for efficient sensing data reporting**

- 1) The (3-)SSC requests a new sensing service from the SSP by providing the desired KPIs.
- 2) The SSP responds to the (3-)SSC indicating whether it was able to process the request from step 1. If so, a unique Sensing Task Identifier (STID) is shared with the (3-)SSC, identifying and further communication from the SSP to the (3-)SSC in relation to the newly accepted sensing service.
- 3) The SSP determines the members of the sensing task (sensing transmitter(s), sensing receiver(s), sensing mode, SSP instance) and their configurations.
- 4) The SSP requests a new sensing task from the SIDP. That the SSP requests a new sensing task is indicated by the method (e.g. HTTP POST method when leveraging a Service-Based Interface) and the SSP provides the STID for future communication by the SSP to the SIDP in reference to the sensing task. The sensing task request also comprises a sensing data conditional sensing reporting configuration which indicates which sensing data elements are requested from the SIDP to measure, criteria when to report them and the information where to report them when the criteria has been met. Furthermore, the configuration contains the reporting interval for all or for each sensing data element. The reporting interval can be of type periodic, aperiodic, stream, single.
- 5) The SIDP reads and applies all provided configurations.
- 6) The SIDP responds to the sensing task request from step 4 with a sensing task response, if a request/response application layer protocol is used for the SSP<>SIDP communication, e.g. HTTP. The response includes the STID and the status of the SIDP processing the request (e.g. HTTP status code 200 if the SIDP was able to read and process the request).

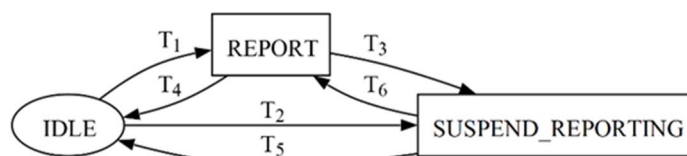
The execution call flow of the sensing task where sensing data elements were selectively configured is provided in Figure 5.2-9.



**Figure 5.2-9: Call flow for efficient sensing data reporting for selected sensing data elements**

- 7) The SIDP starts executing the sensing task using the conditional sensing reporting configuration(s) received in step 4.
- 8) The SIDP uses the criteria from the conditional sensing reporting configuration to assess individual sensing data elements and whether they meet the criteria in order to be reported to the SSP.
- 9) The SIDP reports one or more sensing data element(s) to the SSP for further processing. Which sensing data elements are reported depends on the conditional sensing reporting configuration sent by the SSP in step 2. More information on what is reported when is provided below.
- 10) The SSP processes one or more sensing data element(s) into sensing results.
- 11) The SSP detects that sensing result KPIs, communicated in step 1 by the (3-)SSC, such as accuracies, resolutions, false alarms, confidence level, etc. are not met.
- 12) The SSP determines new configurations for the SIDPs that provide one or more sensing data element(s) resulting in KPI violations. These configurations include criteria for each sensing data element whether or not it should be reported to the SSP. These criteria can range from simple thresholds for a specific sensing data element to more compute intense statistical evaluation methods.
- 13) The SSP sends the updated conditional reporting configurations to the SIDP. The sensing data request indicates that this is an update using a method field (e.g. PUT method when using HTTP), the STID the conditional reporting configuration belongs to, and the actual conditional reporting configuration.
- 14) The SIDP updates the conditional reporting configurations it had received in step 13.
- 15) The SIDP informs the SSP about the processing of the sensing task request. The sensing task response includes a status field and the STID.

For an SIDP to implement the methods and procedures described above, a conditional sensing data reporting state machine is provided in Figure 5.2-10.



**Figure 5.2-10: Conditional sensing data reporting state machine for an SIDP**

The states for the state machine above are explained in further detail in Table 5.2-2.

**Table 5.2-2: Detailed description for each state of the SIDP conditional sensing data reporting state machine**

State	Description
IDLE	The SIDP is available for receiving a request for a new sensing task.
REPORT	The SIDP is reporting one or more sensing data element and their assistance information to the SSP.
SUSPEND_REPORTING	The SIDP suspended the reporting of one or more sensing data element and their assistance information to the SSP.

The transitions between the states are described in detail in Table 5.2-3.

**Table 5.2-3: Detailed description for each state transition of the conditional reporting state machine of an SIDP**

Transition	Description
T1	The SIDP received a request for a new sensing task from the SSP. The SIDP parsed the conditional sensing data reporting configuration successfully and applies the configurations on when to report one or more sensing data element(s) and/or their assistance information. The outcome of this transition is that one or more sensing data elements and their assistance information can be reported.
T2	The SIDP received a request for a new sensing task from the SSP. The SIDP parsed the conditional reporting configuration successfully and one or more sensing data element(s) are being determined but do not meet the conditional reporting criteria configured by the SSP. The outcome of this transition is that one or more sensing data elements and their assistance information are not being reported.
T3	The SIDP determines that the conditional reporting criteria for one or more sensing data element has not been met and will stop reporting one or more sensing data element and their assistance information to the SSP.
T4	The SIDP has received a request from the SSP to stop the execution of a sensing task or determines that it can no longer serve as an SIDP for a specific sensing task.
T5	Same as T4.
T6	The SIDP determines that the conditional reporting criteria for one or more sensing data element has been met and will start reporting one or more sensing data elements and their assistance information to the SSP.

### 5.2.5.3 Efficient sensing task management

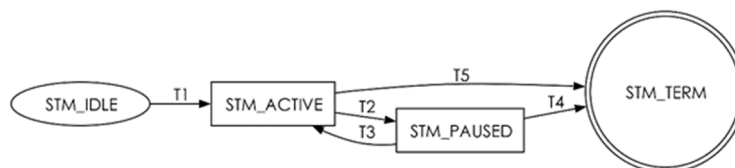
This proposed solution addressed the identified considerations and challenges in clauses 5.1.3, 5.1.4 and 5.1.5.

Many identified use cases in ETSI GR ISC 001 [i.1] come with precise potential performance requirements for sensing results which depend on the ability of the 6GS to dynamically adjust radio, compute and networking resources to cope and ideally mitigate any shortcomings in resources. However, there can be also external factors that negatively impact the 6GS to perform sensing and prohibits the 6GS to meet the potential performance requirements for sensing results, e.g. a change in water density in the air (light rain fall, snow fall, fog, humidity/temperature change), more severe change in the environment (e.g. monsoon-like rain fall, power outages or other infrastructure-related conditions) or potential privacy-related conditions where personal identifiable information may be collected, processes and/or exposed without a previously collected consent. These external factors are denoted as transient condition that are outside of the control of the 6GS and usually occur for a certain time within the possibility of recovery.

During the occurrence of a long-lived transient condition, the 6GS may aim to mitigate the issue by increasing or changing the configured resources which may not result in meeting the required performance requirements. Consequently, the 6GS has no means to serve the requested sensing service, resulting in radio, compute and networking wastages with the ultimate outcome of the energy consumed for this sensing task not resulting in a sensing service that can be monetised by the Mobile Network Operator (MNO).

Thus, this clause presents how sensing-enabled 6GS may pause sensing tasks for the duration of transient conditions using an understanding of performance requirement violations and external knowledge about the detection of one or more transient conditions.

Pausing a sensing task requires the functional requirement of each 6GS component that is part of executing a sensing task. Figure 5.2-11 illustrate the Sensing Task Management (STM) state machine for 6GS components that execute one or more functionalities of a sensing task (1, clause 4.3). The change between two states is illustrated by a transition T.



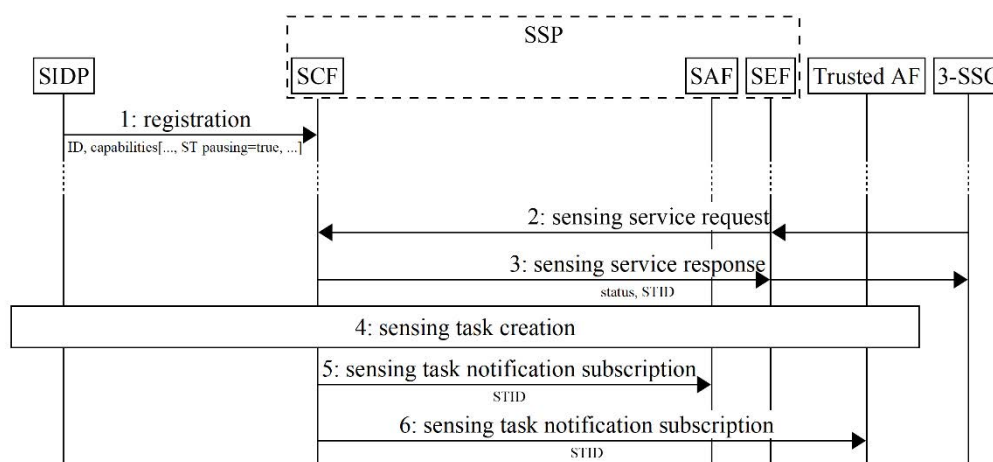
**Figure 5.2-11: Sensing Task Management (STM) state machine for a component of a sensing task**

The illustrated states and their description are presented in Table 5.2-4 with an explanation of the transitions T between STM states.

**Table 5.2-4: Detailed description for each state transition of the conditional reporting state machine of an SIDP**

Sensing Task Management State	Description
STM_IDLE	This state allows the sensing task component to receive a new sensing task request from the SSP (e.g. SCF). Hence, sensing components should have been registered with the SSP (e.g. SCF) to be configured to execute a sensing task. Output transition T1: The SSP (e.g. SCF) requested the creation of a new sensing task.
STM_ACTIVE	In this state the sensing task component executes a sensing task (e.g. receiving a 6G or non-6G sensing signal or sending a 6G sensing signal, reporting sensing data, processing/fusion sensing data or exposing sensing results). Output transition T2: The SSP (e.g. SCF) request the pausing of a sensing task. Output transition T5: The SSP (e.g. SCF) requested the termination of the execution of a sensing task.
STM_PAUSED	In this state the sensing task component pauses the execution of a sensing task (e.g. receiving a 6G or non-6G sensing signal or sending a 6G sensing signal, reporting sensing data, processing/fusion sensing data or exposing sensing results). The sensing task component does not delete any state related to the execution of the sensing task. Output transition T3: The SSP (e.g. SCF) requested a paused sensing task to be resumed. Output transition T4: The SSP (e.g. SCF) request to terminate the execution of a sensing task.
STM_TERM	In this state the sensing task component terminates the execution of a sensing task and deletes all state related to this activity.

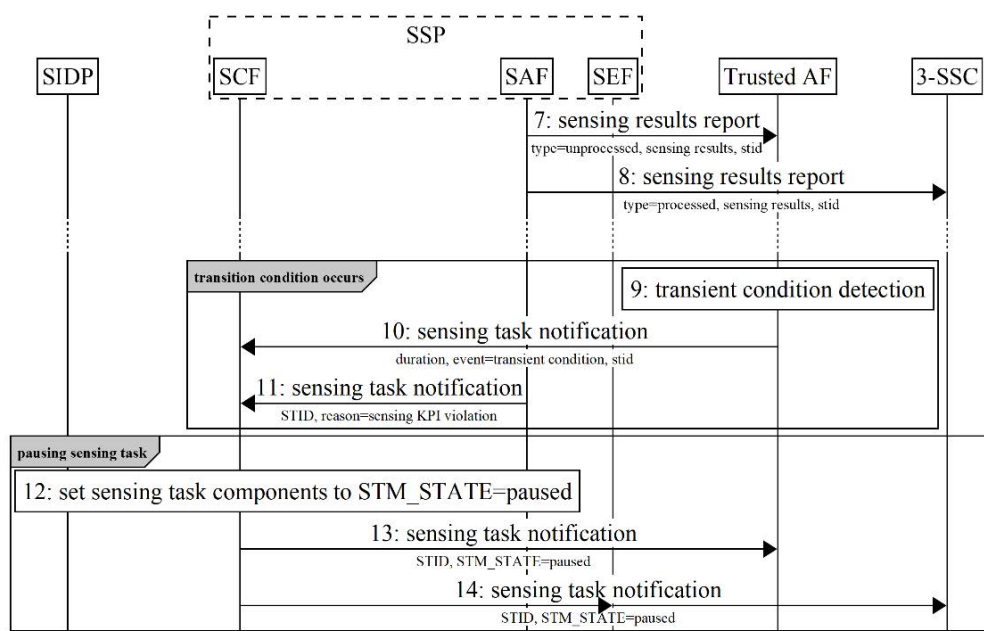
The pausing of sensing tasks may be an optional capability by sensing task components (especially SIDPs) and therefore is communicated as such to the SSP (e.g. SCF) at registration time. The procedures as well as the set-up of a sensing task with all 6GS components involved in the sensing task offering the pausing of a sensing task are provided in Figure 5.2-12.



**Figure 5.2-12: Registration and sensing service creation**

- 1) An SIDP registers with the SSP (e.g. SCF), provides its own identifier and indicates in the list of sensing capabilities its own ability to pause sensing tasks.
- 2) A 3-SSC requests a sensing service from the 6GS by issuing a sensing service request to the SSP (e.g. SCF).
- 3) The SSP (e.g. SCF) validates the request and accepts the request for a new sensing service by sending a sensing service response back to the 3-SSC. The SSP includes a STID for future correspondence in relation to this sensing task.
- 4) The SSP (e.g. SCF) identifies all components the sensing task and sends sensing task requests to sensing task components. The SCF includes an STID in all requests. Upon the reception of a sensing task response from all sensing task components, the SCF then notifies the trusted AF about the newly established sensing task by sharing the STID.
- 5) The SCF sends a sensing task notification subscription to the SAF, subscribing to KPI violation events related to the STID indicated in the request.
- 6) The SCF also sends a sensing task notification subscription to the trusted AF, subscribing to the occurrence of transient conditions.

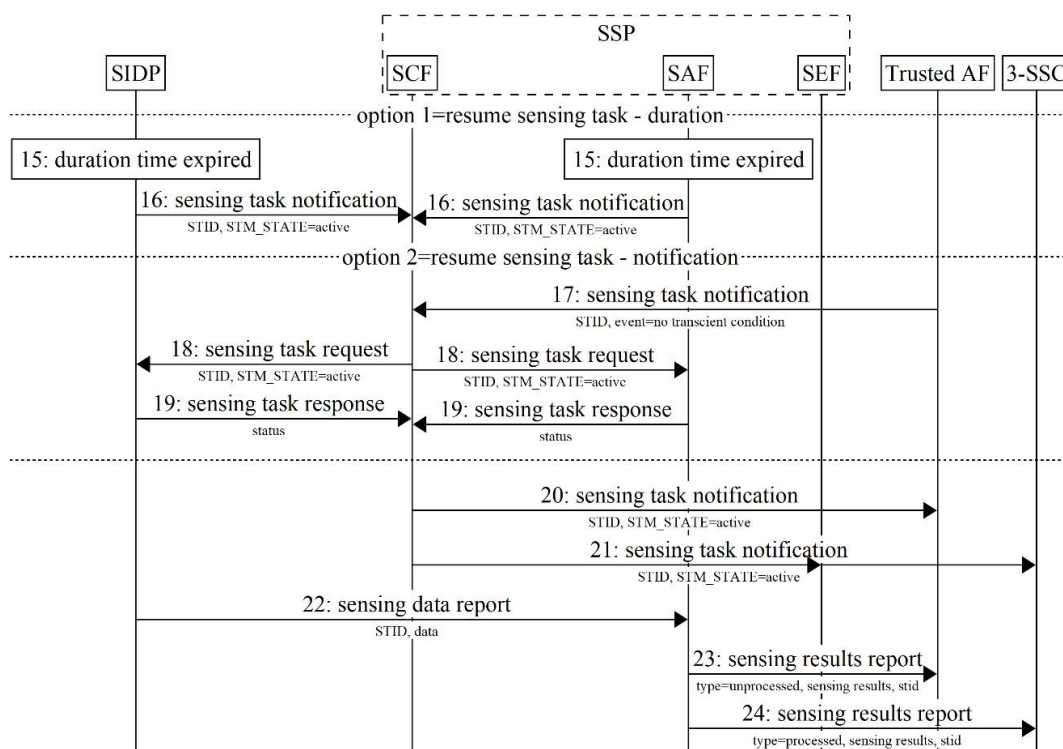
This completes the creation of the sensing task and the necessary subscriptions to be informed about transient conditions. Figure 5.2-13 provides the call flow for when a transient condition occurs, how the 6GS detects such a condition and how an active sensing task is paused.



**Figure 5.2-13: Pausing of a sensing task due to a transient condition**

- 7) The SAF continuously sends sensing results reports to the trusted AF which comprised unprocessed sensing data and the STID. This allows the trusted AF to perform any processing needed to detect a transient condition, e.g. heavy rainfall.
- 8) The 3-SSC continuously receives the requested sensing results, i.e. processed sensing data, including a STID to distinguish multiple reports from each other.
- 9) Assuming a transient condition has occurred, the trusted AF detects that by processing the sensing data it has continuously received from the SAF.
- 10) The trusted AF sends a sensing task notification to the SSP (e.g. SCF), informing the SSP about the occurrence of a transient condition. The trusted AF includes the STID the transient condition belongs to and - if available - an expected duration of the transient condition. For example, if the transient condition is related to heavy rainfall, the trusted AF can use historical data knowing how long these events occur (e.g. monsoon rain) and/or has access to nation-wide weather forecast data to determine the duration.
- 11) Assuming the SSP is separated into SCF and SAF, the SCF also receives a notification from the SAF about the violations of the sensing results KPIs provided by the 3-SSC when requesting the sensing results.
- 12) Using the notifications from the trusted AF and the SAF, the SCF can now determine that the sensing results KPIs have been violated due to a transient condition. The SCF may aim to reconfigure the sensing task with available unutilized radio, networking and/or compute resources to overcome the transient condition. If these actions still result in KPI violations reported by the SAF to the SCF, the SCF checks whether the selected sensing task components (SIDP and SAF) support the STM\_STATE=parsed. If so, the SCF issues a request to all sensing task components (SIDP and SAF) to pause the sensing task using a sensing task request comprising the STID, the new STM state and an optional transient condition duration if provided by the trusted AF.
- 13) Upon pausing the sensing task across all its sensing task components, the SSP (e.g. SCF) informs the trusted AF about this new STM state for a specific STID, so that the trusted AF knows no further sensing results will arrive.
- 14) The SSP (e.g. SCF) also informs the 3-SSC about the pausing of the sensing task using the STID and that no further sensing results will arrive.

The call flow in Figure 5.2-14 provides the steps to resume a sensing task.



**Figure 5.2-14: Resumption of sensing task after transient condition ends**

- 15) For option 1, the sensing task components were paused by the SCF and were provided with a transient condition duration. Using this duration, the sensing task components SIDP and SAF leverage a timer to count down the duration time and determine that this timer has expired.
- 16) The SIDP and SAF sensing task components notify the SCF that their STM timer expired and update the SCF about their new STM, e.g. active. It is up to the sensing task components to indicate another STM state based on internal logic.
- 17) For option 2, the sensing task components were paused by the SCF without any transient condition duration. In this step, the trusted AF notifies the SCF about the end of a transient condition for a specific sensing task leveraging the STID to specify which sensing task this notification relates to.
- 18) The SCF sends a sensing task request to all sensing task components (SIDP and SAF) and provides the STID for which the STM state should be changed; in this scenario the SCF request to resume a paused sensing task and sets the STM\_STATE to active.
- 19) The sensing task components SIDP and SAF response back to the SCF with a sensing task response indicating whether they have successfully accepted the request in step 18 using a status field.
- 20) As an outcome of option 1 and 2, the sensing task components are all set to active again and the SCF informs the trusted AF that a sensing task has resumed by sending a sensing task notification to the trusted AF providing the STID and the new state of the sensing task, i.e. STM\_STATE=active.
- 21) As an outcome of option 1 and 2, the sensing task components are all set to active again and the SCF informs the (3-)SSC that the sensing task has resumed by sending a sensing task notification with the STID and the new state of the sensing task, i.e. STM\_STATE=active.
- 22) After resuming the sensing task, the SIDP reports sensing data to the SAF again by sending a sensing data report with the STID this report belongs to and the actual sensing data.
- 23) The SAF sends the unprocessed sensing data as sensing results to the trusted AF for potentially detecting transient conditions.
- 24) The SAF processes the sensing data into sensing results and sends the sensing results to the (3-)SSC by providing the STID and the actual sensing results.

### 5.2.5.4 Efficient SIDP selection using sensing measurements utilization score

This proposal addresses the identified considerations and challenges in clauses 5.1.3 and 5.1.6.

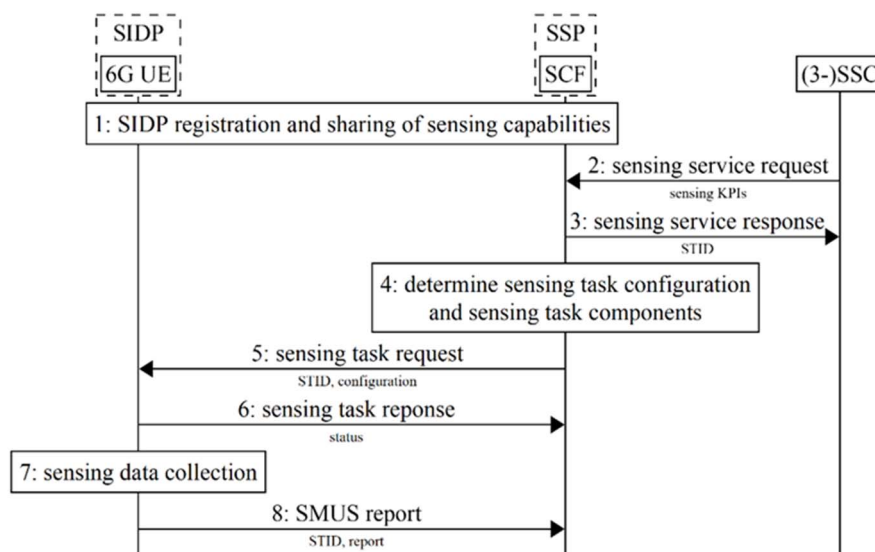
To support a sensing service SIDPs can be 6G UEs or 6G BSs that are contribution in the execution of a sensing task with their limited resources such as computing, storage or energy. Sensing measurements over time needs these resources and lacking any of these resources may render an SIDP unavailable to take part in the sensing task. Currently, there is no way to determine the availability of an SIDP for sensing tasks.

When a new sensing service is requested from the system, the network needs to create a sensing task to execute the sensing service; this involves selecting SIDPs. The network would greatly benefit from information about the resource utilization of sensing receivers to be able to determine whether they are available for a sensing task. This proposal addresses the reporting of a utilization score to the 6G Network to determine the availability of a sensing receiver. Here a Sensing Measurement Utilization Score (SMUS) is introduced. The SMUS a unitless metric calculated by a sensing receiver and reported to the SSP to assist the SSP in the process to selecting available SIDPs for a particular sensing task.

The sensing receivers can become unavailable to take part in the sensing task and the SMUS can help the network to determine the components of a sensing task dynamically.

The SMUS can be determined by averaged measurement of e.g.:

- CPU/GPU load, compute resources, CPU cycles, GPU cores utilization for the purpose of sensing.
- Utilized RAM storage, utilized GPU memory.
- Energy consumption per active sensing task or each sensing data element.
- Compute latency for each sensing data element.



**Figure 5.2-15: Call flow for determination of SIDPs using SMUS**

Procedure to determine components of sensing task based on SMUS based on Figure 5.2-15:

- 1) All SIDPs (6G UEs) register with the SSP (e.g. SCF). In this registration, sensing capabilities are shared with the SSP as well as any assistance information such as node identifiers.
- 2) The (3-)SSC requests a new sensing service from the SSP by providing the desired sensing result KPIs.
- 3) The SSP responds to the (3-)SSC indicating whether it was able to process the sensing service request. If so, a unique STID is shared with the (3-)SSC, identifying and further communication from the SSP to the (3-)SSC in relation to the newly accepted sensing service.
- 4) The SSP determines sensing task configuration and the components of the sensing task leveraging any SMUS report it is receiving from SIDPs that execute other on-going sensing tasks.

- 5) The SSP sends a sensing task request to the selected SIDP and includes the sensing task and SMUS reporting configuration alongside the STID.
- 6) The SIDP sends a sensing task response back to the SSP with the status whether the sensing task request has been accepted.
- 7) The SIDP executes the sensing task and determines sensing data from sensing signals.
- 8) Using the SMUS configuration received in the sensing task request, the SIDP determines the SMUS and reports the updated SMUS to the SSP. The reporting frequency is determined from the configuration received by the SIDP from SSP and can be periodic or even-driven.

#### Example of report from SIDP:

```
{
  "stid": "xxx",
  "available_energy_percent": 45,
  "available_memory_MB": 64,
  "channel_quality": 0.6,
  "assigned_tasks": [
    {
      "data_point": "Micro-Doppler",
      "duration_s": 600,
      "cost_energy": 30,
      "cost_memory": 120,
      "cpu/gpu_util": 40
    },
    {
      "data_point": "RCS",
      "duration_s": 300,
      "cost_energy": 10,
      "cost_memory": 50,
      "cpu/gpu_util": 25
    }
  ],
  "utilization_components": {
    "energy_pressure": 0.55,
    "memory_pressure": 0.78,
    "cpu/gpu_util_pressure": 0.36
  },
  "utilization_score": 0.8
}
```

## 5.2.6 Approaches for sensing results exposure and transport

Following the considerations of the sensing results exposure in clause 5.1.6, one possible approach is described below.

### Architectural Entities

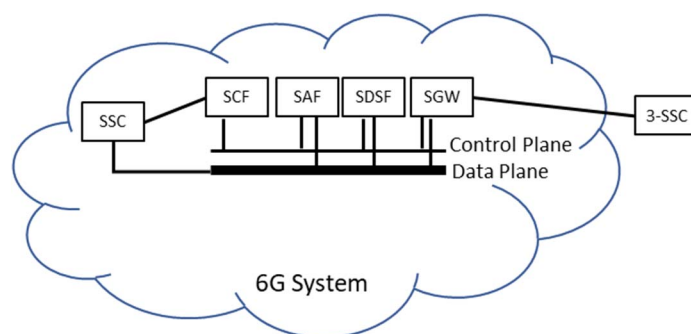
This solution introduces and utilizes the following logical functions:

- **Sensing Control Function (SCF):** Control part of the sensing service, defined in clauses 5.2.1 and 5.2.4.
- **Sensing Analytics Function (SAF):** performing fusion and processing of the sensing data into the sensing result(s) defined in clauses 5.2.1 and 5.2.4, which may hold historical sensing data as it needs.
- **Sensing Gateway (SGW):** A function that acts as a gateway for sensing results provisioning. It is responsible for managing provisioning requests from 3-SSC and provisions the sensing results to 3-SSC. It is defined in clause 5.2.4.
- **Sensing Data Storage Function (SDSF):** A function that provides storage for long-term and large-scale sensing results, allowing various authorized services and network functions to retrieve historical sensing results.

### Sensing Results Provisioning Options

To ensure interoperability, the provisioning of sensing results should be based on a standardized set of data types and formats that can be requested by a consumer. The sensing results may include processed sensing results and sensing data which are described in clause 5.2.2.

This clause details the procedures for provisioning sensing results.



**Figure 5.2-16: Example architecture of the sensing result provisioning**

### Sensing result provisioning for 3-SSC

For a 3-SSC, which is considered an untrusted entity, a provisioning procedure via the SGW is proposed to ensure security. The procedure is as follows:

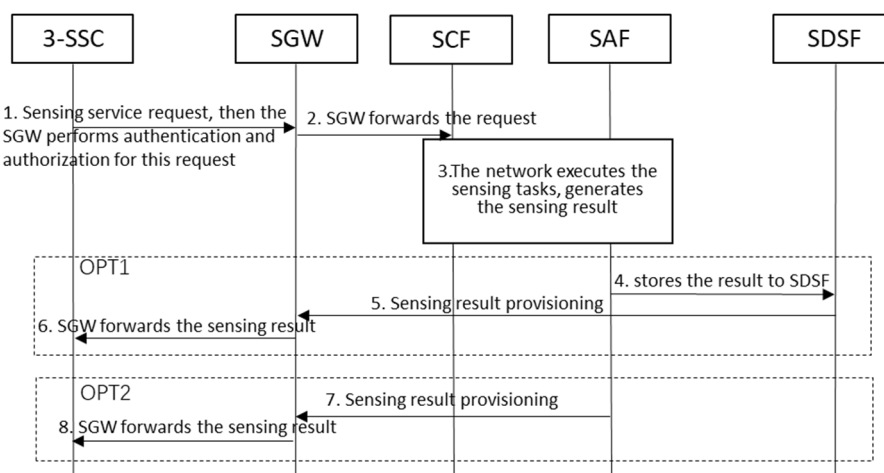
- 1) A 3-SSC sends a sensing service request to the SGW (which may be in or outside of the SSP) to receive specific sensing results, then the SGW performs authentication and authorization for this request.
- 2) After the authentication and authorization, the SGW forwards the request to the SCF. The interface between 3-SSC and SGW is defined in clause 5.2.4.
- 3) The network executes the sensing tasks and the SAF generates the sensing result.

#### Option 1:

- 4) The SAF stores the result to the SDSF via the data plane.
- 5) The SDSF sends sensing result to the SGW via the data plane.
- 6) The SGW forwards the sensing result to 3-SSC.

#### Option 2:

- 7) The SAF sends sensing result to the SGW via the data plane.
- 8) The SGW forwards the sensing result to 3-SSC.



**Figure 5.2-17: Procedure of sensing result provisioning to 3-SSC**

## Sensing result provisioning for SSC

The procedure for SSC is as follows:

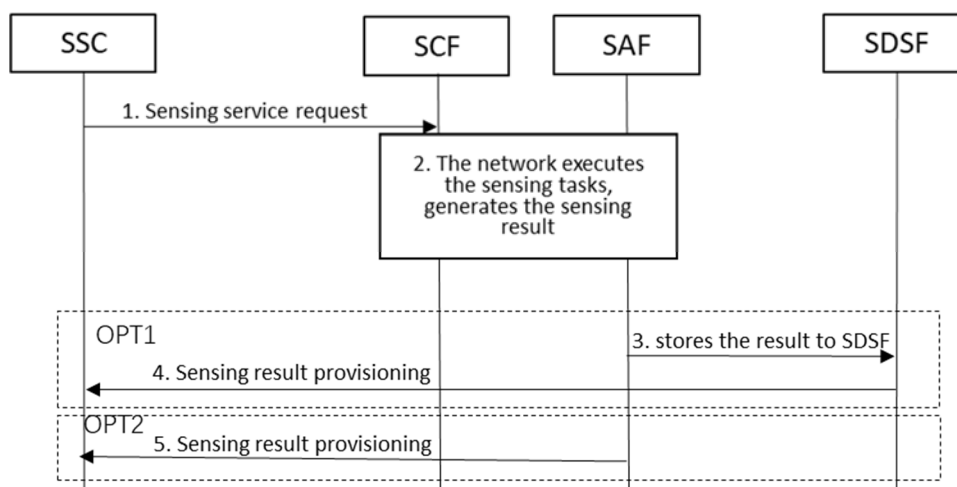
- 1) An SSC sends a sensing service request to the SCF.
- 2) The network executes the sensing tasks and the SAF generates the sensing result.

### Option 1:

- 3) The SAF stores the result to the SDSF via the data plane.
- 4) The SDSF sends the sensing result to SSC

### Option 2:

- 5) The SAF sends sensing result to the SSC directly.



**Figure 5.2-18: The procedure of sensing result provisioning to SSC**

## 5.2.7 Approaches for charging and incentives

Following the consideration of charging and incentives in clause 5.1.7, one possible approach for addressing both charging and incentives is described below.

The Sensing Charging and Incentives Management (SCIM) (defined in clause 5.2.3) which stores the incentive information about each UEs is also introduced here.

The example procedure for charging and incentives is shown in Figure 5.2-19 and consists of the following steps:

- 1) When a new sensing service initiates, SCF requests information of event triggers from SCIM. SCIM returns the corresponding information. For example, the trigger for reporting charging/incentive info may include period length, volume threshold, time threshold, etc.
- 2) SCF selects the corresponding SAFs (defined in clause 5.2.4) related to the subscribers/UEs, and delivers information of event triggers to the selected SAFs.
- 3) SAF calculates the service usage by a predetermined criteria (e.g. data traffic, service duration), generates a charging/incentive event and reports the event information to SCF when the trigger conditions occur. For example, the charging event info may include time, used data traffic, the sensing service task's id, etc.; for incentive event info, the UE's identity is mandatory.
- 4) SCF receives charging/incentive event info from the selected SAFs, aggregates data from these SAFs related to the same subscribers/UEs, then sends this info to the SCIM.

SCIM processes the charging/incentive event info reported by SCF, generates a Charging/Incentive Data Record (CDR/IDR) and forwards the record to the Billing Domain. In some scenarios, when the UE acts as the transmitter of the sensing signal, it may not directly generate sensing data (unless it is performing monostatic sensing). For this case, the network needs to assess the contribution of the transmitted sensing signal provided by the UE and provide suitable incentives. The UE's incentive may include discounts on bill or free data traffic, etc.

#### Charging/Incentive Data Record (CDR/IDR):

A CDR/IDR is a collection of information (such as service setup time, service duration, and transmitted data volume) related to a charging/incentive event. A CDR is based on subscribers and used to collect statistics on the service usage of a subscriber and generate a final bill. It is the minimum unit for recording the service usage of a subscriber in the charging events reported by the SCIM. An IDR is based on UEs which provides sensing service and it is the minimum unit for recording the sensing data generated by a UE in the incentive events.



Figure 5.2-19: The procedure of charging and incentives

### 5.2.8 Approaches for disaggregation of sensing control and processing

Considering the distinct functions for sensing control and sensing data processing introduced in clauses 5.1.8 and 5.2.1, one potential approach is outlined below.

The Sensing Control Function (SCF) identifies the sensing input data providers (i.e. SIDPs and/or 3-SIDPs) and manages sensing data flows within the 6G system through the Sensing Control Plane (sc), as shown in Figure 5.2-20. In the presence of a 3<sup>rd</sup> party Sensing Service Consumer (3-SSC), it also controls the sensing data flows between the sensing input data providers and the 3-SSC as shown in Figure 5.2-20.

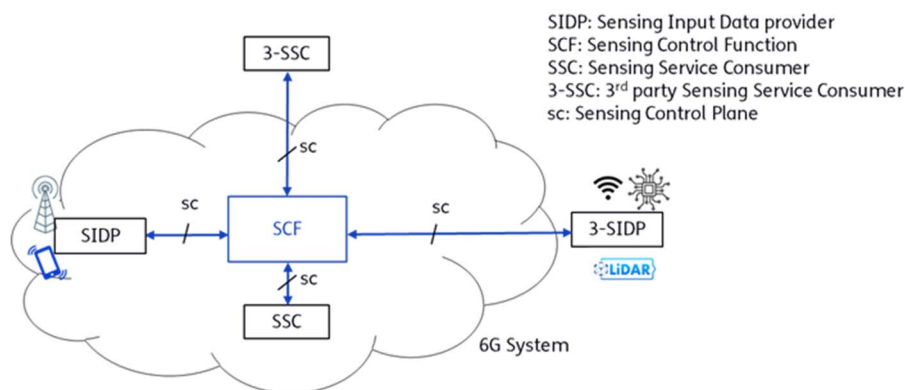


Figure 5.2-20: Proposed sensing-enabled 6G Core Network

The Sensing Analytics Function (SAF) processes the sensing data gathered from the sensing input data providers (i.e. SIDPs and/or 3-SIDPs) using the sensing data plane (sd) to be consumed by the sensing service consumers (i.e. SSC and/or 3-SSC), depicted in Figure 5.2-21. Multiple SAFs may exist. The functionality of SAFs can be integrated either within or outside of the 6G system. When situated inside the 6G system, SAFs can be located in the Core Network (CN), Radio Access Network (RAN), or both. Note that only SAFs within the 6G system are visualized in Figure 5.2-21.

Conversely, when sensing data processing is conducted outside the 6G system, under the control of the SCF, a sensing data plane (sd) could facilitate the direct delivery of sensing data from the SIDP to the 3-SSC for potential processing outside the 6G system and subsequent consumption as shown in Figure 5.2-21.

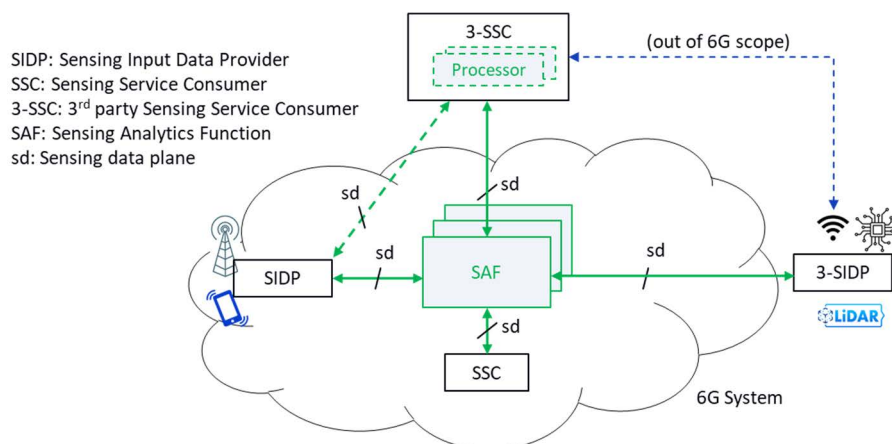


Figure 5.2-21: Sensing Analytics Function (SAF) and sensing data planes (sd) in a 6G system

### 5.2.9 Approaches for UE centric monostatic sensing

Based on the approach for disaggregation of sensing control and processing introduced in clause 5.1.8, a potential approach that enables UE-centric monostatic sensing for the in-coverage case is outlined below.

The aspects that define UE-centric monostatic sensing include that the UE is:

- i) in control of issuing sensing service requests;
- ii) executing the sensing measurement by transmitting and receiving 6G sensing signals; and
- iii) processing the sensing data to obtain sensing results at the UE, where the sensing results are eventually consumed.

The operator has full control over the radio resources the UE utilizes for this purpose and can charge for the usage of their radio resources.

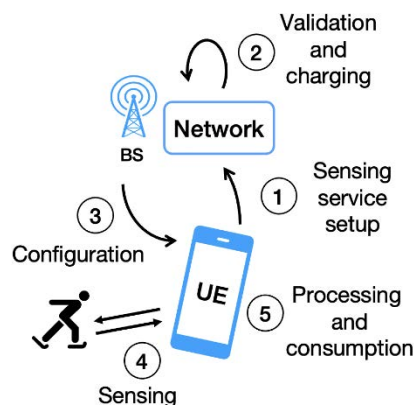
As visualized in Figure 5.2-22, UE-centric monostatic sensing follows the procedure as described below in five steps:

**Pre-condition:** Capability exchange and registration: It is assumed that the UE is connected to the 6G network and the 6G network is aware of the capabilities of the UE:

- 1) **Sensing service setup:** The UE is the sensing service consumer and requests a sensing service from the network. During the request the UE may indicate its requirements, e.g. by communicating the required sensing KPIs such as range resolution. Additionally, it may indicate the desired physical signal parameters such as bandwidth of the sensing signal during subsequent RAN procedures that are triggered by the service request.
- 2) **Validation and charging:** The management entity in the 6G network validates and authenticates the request via the corresponding network functions and interacts with the responsible network functions for charging (AAA). This may include additional communication steps with the access nodes or the UE.
- 3) **Sensing configuration:** The sensing control functionality in the 6GS requests the serving base station to configure the UE to perform the sensing operations. This includes that the 6G network/ base station determines suitable resources and grants these resources to the UE to perform monostatic sensing.
- 4) **Sensing measurements:** The UE transmits and receives a 6G sensing signal utilizing the granted resources.
- 5) **Processing and consumption:** Following the sensing process, the UE processes the received sensing signal in order to obtain a sensing result. The processed sensing result may eventually be consumed by an application on the UE.

**Termination:** After completion of the sensing task, the UE requests from the 6GS to terminate the sensing session.

NOTE: Potential privacy and security considerations regarding the handling of sensing data and sensing results are in the scope of ETSI GR ISC 004 [i.6].



**Figure 5.2-22: High-level procedure for UE-centric sensing**

While this potential approach is fully compatible with the reference model in clause 5, it demonstrates the unique aspects of co-locating SSC and SIDP functionality at the UE, while the SSP is the counterpart in the network.

Specifically, the UE acts as SSC during step 1 and 5 and as SIDP during steps 3, and 4 in the procedure above. Yet the procedure relies on the sensing service provided by the network (SSP), specifically the control aspects it offers. To this end, it may utilize the Sensing Control Function (SCF) that implements the control functionality of the SSP, as described in the potential approach for disaggregating sensing control and processing in clause 5.2.8, during steps 1 and 3.

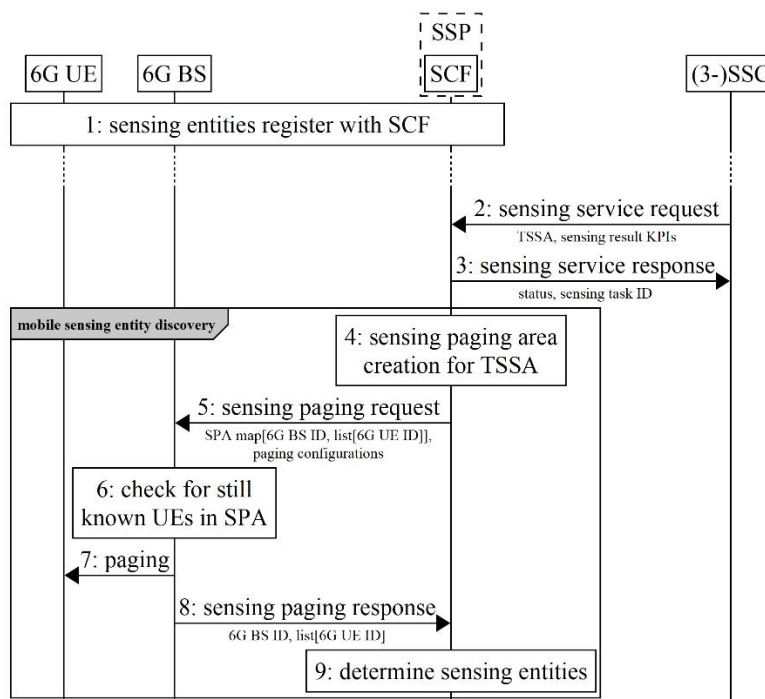
## 5.2.10 Approaches for mobile sensing entity discovery and selection

The proposed solution in this clause addresses the identified considerations and challenges in clauses 5.1.9 and 5.1.10.

ISAC use cases that demonstrate a high dynamicity (e.g. movement, communications activities, velocity) of mobile sensing entities and/or mobile target objects, monostatic sensing of a BS may not allow to meet the sensing results KPIs, as requested by the (3-)SSC. Thus, mobile sensing entities (i.e. 6G UEs) may be required to participate in a sensing task to fulfil the sensing results KPIs.

While any sensing entity registers with the SSP (i.e. SCF) so that the SCF is aware about their existence and capabilities, mobile sensing entities may move and change their point of attachment (e.g. 6G BS or cell of the 6G BS it is attached to) over time. With current procedures in 5G, the SCF has means to receive updates of a change in point of attachment (PoA) of a 6G UE. However, those updates provided by 6G BSs are only triggered if the 6G UE is in an RRC\_CONNECTED state. Once the 6G UE moves to an RRC\_INACTIVE state (while being still in CM\_CONNECTED potentially), there are no updates from 6G BSs about a change in the PoA to the CN. Consequently, when the SCF receives the request for a sensing service and mobile sensing entities are required to meet the KPIs requested by the (3-)SSC, the SCF may not have up-to-date information where mobile sensing entities are in order to consider them for members of the sensing task.

This challenge is addressed in this proposed solution and illustrated in a call flow in Figure 5.2-23. The call flow illustrates the system components 6G UE, 6G BS, SCF and (3-)SSC and the steps are described below.



**Figure 5.2-23: Call flow for proposed solution for mobile sensing entity discovery and selection**

- 1) In this step, all sensing entities (6G UEs and 6G BSs) register with the SCF. In this registration, capabilities are shared with the SCF as well as any assistance information; for 6G UEs, the SCF also receives PoA information (6G BS ID, Cell IDs); for 6G BSs the SCF also receives BS ID, BS's location (e.g. GPS coordinates), BS's Cell IDs and their coverage area.
- 2) A (3-)SSC requests a sensing service from the 6GS by sending a sensing service request and provides the TSSA. The usage of a Network Exposure Function (NEF) for the sensing service request to arrive at the SCF may be required.
- 3) The SCF responds back to the (3-)SSC confirming it has accepted the sensing service request and provides a unique Sensing Task Identifier to the (3-)SSC as a reference for any future information exchange between the SCF and (3-)SSC.
- 4) The SCF now uses the information about all registered sensing entities from step 1 to select the sensing entities that will be used to deliver the sensing service. If the SCF requires 6G UEs to be selected for the sensing task and the SCF uses the information provided in steps 1 and 2, the SCF uses the provided TSSA information to determine the Sensing Paging Area (SPA), i.e. identify all known 6G BSs and their coverage areas that cover the TSSA in parts. Once identified, the SCF uses the SPA to check for all 6G UEs that are known to the in that SPA (irrespective to their RRC and CM states). The resulting 6G UEs are checked for UEs that are in RRC\_CONNECTED state first and the SCF uses this resulting list to determine whether these 6G UEs can be used as sensing entities. If the SCF concludes these 6G UEs are not suitable, the SCF determines all 6G UEs that are not in RRC\_CONNECTED state. The result is a list of 6G BS IDs and 6G UE IDs that are not in RRC\_CONNECTED state, e.g. an SPA map with the 6G BS ID as the key and a value of type list with all 6G UE IDs.
- 5) The SCF uses the resulting SPA map to send a sensing paging request to each 6G BS ID in the map and includes the entire SPA map as well as paging configurations, e.g. paging timing information and/or max number of paging occasions.
- 6) The 6G BS checks all provided 6G UE IDs in the map whether they are still attached.
- 7) If the 6G BS identified a 6G UE to be still attached, the 6G BS pages the 6G UE using the paging configuration provided in step 5. Note, if the 6G UE is not known to the 6G BS any longer, the 6G BS checks with other 6G BSs listed in the SPA map whether they know about the 6G UE and whether they are able to page it. As a result, the 6G BS prepares a sensing paging report with all 6G UE IDs that are not available any longer.

- 8) The 6G BS sends a sensing paging response to the SCF and includes the list of unavailable 6G UEs as well as its own 6G BS ID.
- 9) Upon receiving all sensing paging reports from all 6G BSs in the SPA map and receiving the PoA updates from all 6G UEs that responded to the paging request, the SCF now has the up-to-date list of all 6G UE IDs in the SPA and can continue with setting up the sensing task by selecting the sensing entities from the list of available 6G UEs.

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## 6 Radio Access Network (RAN)

### 6.1 RAN architecture and related network interfaces

#### 6.1.1 Identified considerations and challenges

##### 6.1.1.1 Considerations for ISAC RAN architecture and additional RAN functionalities

The 6G system should enable RF sensing capability to provide novel wireless services and business potential.

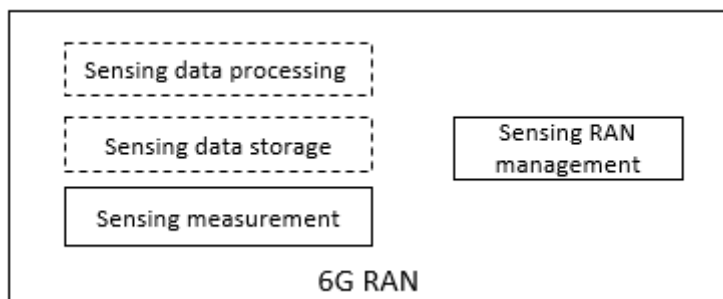
Most of the features, protocols, and corresponding RAN architectural design for 5G NR and previous generation systems were optimized for communication connectivity. On the other hand, 6G sensing will integrate non-connected targets with and without communication capability from the physical world into the 6G system. This motivates the following challenges and considerations for the 6G RAN architectural design to support ISAC:

- How to support sensing functionalities within the Radio Access Network (RAN).
- How to interwork and split sensing functionalities between RAN and 6G CN.
- How to determine the optimal configuration of RAN nodes to perform sensing, which requires to discover and select the most suitable combination of BSs and UEs, and configuration of the corresponding the sensing signal resources.
- How to ensure seamless sensing service continuity in cases of UE or sensing target mobility within a designated sensing service area.

#### 6.1.2 Potential approaches

##### 6.1.2.1 Approaches for ISAC RAN architecture and additional RAN functionalities

Following the considerations of ISAC RAN architecture outlined in clause 6.1.1.1, a possible resulting ISAC RAN architecture is depicted in Figure 6.1-1, which introduces four additional functionalities in the RAN side, some of which are optional. When not located in the RAN, optional functionalities might reside in the CN or be part of a computing infrastructure integrated with ISAC in the 6GS. Figure 6.1-1 is a simplified figure based on information from IMT2030 (<https://www.imt2030.org.cn/>). The name of sensing control in IMT2030 is modified to sensing RAN management for better understanding.



**Figure 6.1-1: ISAC RAN Architecture (optional functionalities shown in dotted boxes)**

These four additional RAN functionalities for BSs and UEs (if applicable) are as follows:

- 1) **Sensing RAN management:** This functionality orchestrates sensing tasks (e.g. it performs selection and configuration of BSs and UEs for receiving and/or transmitting sensing signals). Its operation can be coordinated with the SCF in the core network, or it can operate autonomously in RAN. Some considerations why this new functionality should be in the RAN architecture are as follows:
  - a) As real-time channel information is available at 6G Access Node, it is highly beneficial that RAN performs selection of the optimal BSs and UEs of 6G network for a given sensing task.
  - b) When communication handover occurs related with a UE involved in a sensing task, the sensing transmitters and/or receivers should be adjusted immediately to ensure sensing service continuity.
  - c) The 6G network should dynamically adjust RAN sensing operations to address any sensing quality degradations or adapt to any movement of the sensing target.
- 2) **Sensing measurement:** This functionality performs the measurements of the received sensing signals as configured by the 6G network, and if needed, reports sensing measurements to the 6G network. This RAN functionality is mandatory.
- 3) **Sensing data processing:** This functionality is optional and its purpose is to process sensing measurements or sensing data, and additionally have the ability to fuse multiple data sources according to the required type of sensing data. It could also be part of a wider logical component to process multiple types of data. Some related considerations related to sensing data types include:
  - a) Which type(s) of sensing data that can be processed in RAN is subject to operator's policy.
  - b) The specific contents/types of sensing data should be jointly determined by RAN/CN according to desired sensing task.
- 4) **Sensing data storage:** This functionality is also optional and its purpose is to preserve and store sensing data for RAN functionalities, e.g. for sensing-assisted communication, AI training data for AI RAN, or as assistance data for sensing tasks, etc. It could also be part of a wider logical component to store multiple types of data:
  - Sensing data processing and sensing data storage could be located anywhere in the RAN, in either localized or distributed form (e.g. across several layers).

## 6.2 Lower layer RAN (PHY, MAC and RRC)

### 6.2.1 Identified considerations and challenges

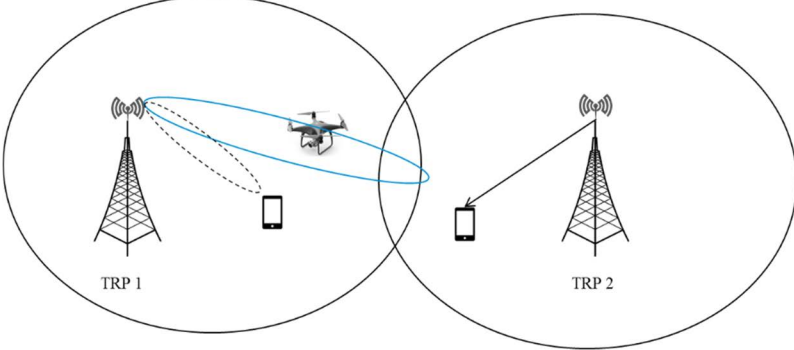
#### 6.2.1.1 Interference considerations

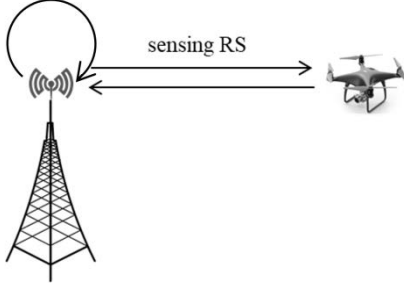
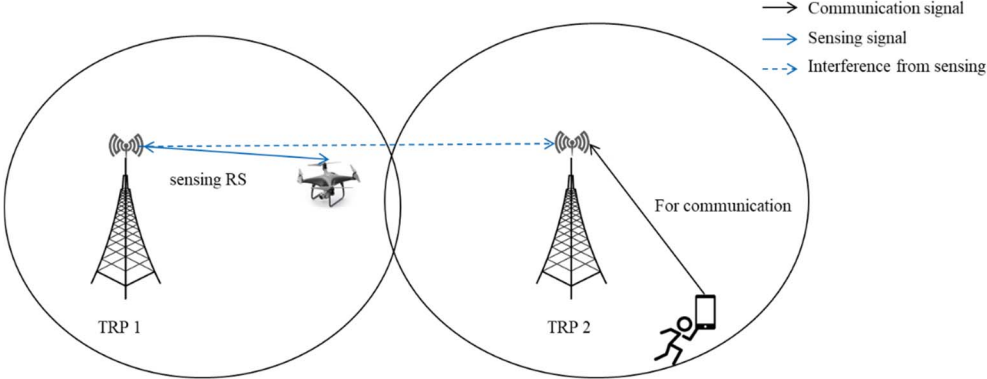
Interference in ISAC presents a significant challenge, as the system's dual-purpose nature necessitates a careful equilibrium between sensing and communication functions. Compared to interference in a communication-only system, there are two differences which should be taken in to consideration. One is that adjusting the antenna downtilt upward to sense aerial objects can lead to further significant cross-link interference. The other is that in monostatic sensing mode, simultaneous uplink and downlink transmission of signals on the same frequency may lead to severe self-interference. Therefore, it is necessary to implement ISAC-tailored interference suppression and elimination techniques.

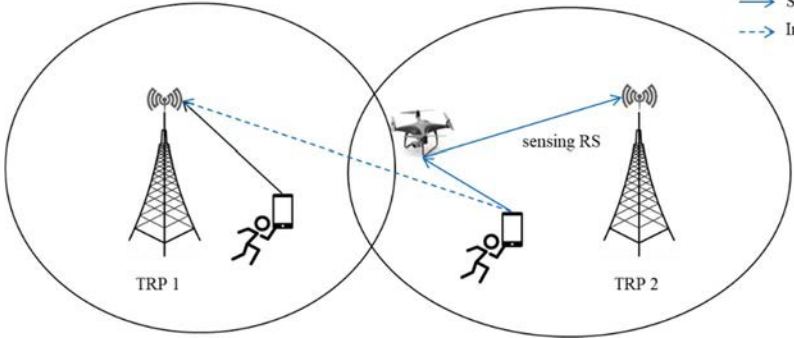
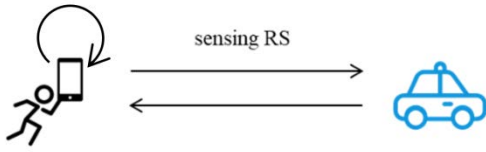
There are different integration levels describing how sensing and communication functionalities are combined in ISAC. A common waveform/signal may be employed for both sensing and communication, or the communication channels and signals are reused for sensing. It is also possible to have dedicated RS designed and used for sensing purpose only.

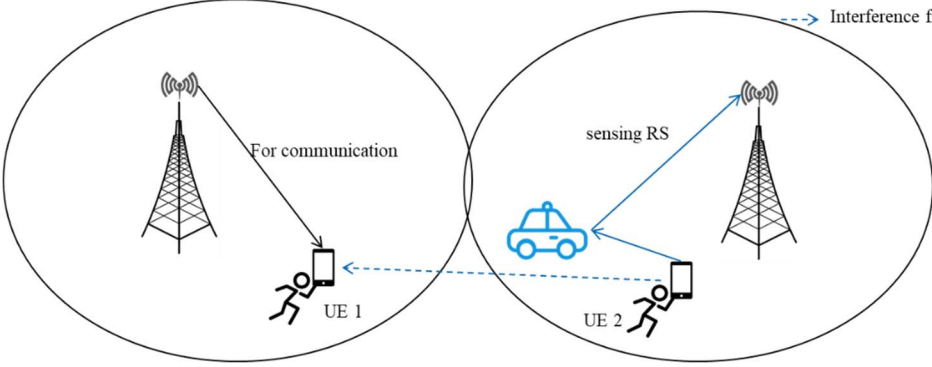
In ISAC there may be numerous interference issues between sensing and communication as summarized in Table 6.2-1. Generally, there are six types of interference: BS self-interference, BS-BS interference, BS-UE interference, UE-BS interference, UE self-interference, UE-UE interference. The details are provided below in Table 6.2-1.

**Table 6.2-1: Interference types for ISAC**

Interference type	Details
BS-UE interference	<p>This interference is similar as the DL interference type in legacy TDD network with static TDD UL/DL configuration, but it becomes potentially more severe when the antenna tilt is changed for some sensing tasks, e.g. detecting aerial objects.</p> <p>Specifically:</p> <ul style="list-style-type: none"> <li>• Case 1: Interference between sensing and communication: <ul style="list-style-type: none"> <li>– DL sensing RS transmissions in the adjacent cells interfere with the DL communication signal/channel(s) received at a UE.</li> <li>– DL communication signal/channel transmissions in the adjacent cells interfere with the DL sensing RS received at a UE.</li> </ul> </li> <li>• Case 2: Interference between different sensing nodes: <ul style="list-style-type: none"> <li>– DL sensing RS transmissions in one TRP interfere with DL sensing RS from a different TRP) received at a UE.</li> </ul> </li> </ul> <p>As shown in Figure 6.2-1, for sensing a target, the coverage area of sensing and communication can be different. The DL sensing RS transmitted by TRP1, used for detection or tracking of UAVs, can therefore interfere with UEs under TRP2's coverage.</p>  <p style="text-align: center;"><b>Figure 6.2-1: DL sensing RS transmissions in the adjacent cells interfere with UE's communication signal/channel(s) reception</b></p>

Interference type	Details
BS self-interference	<p>For BS monostatic sensing mode, the BS is required to transmit and receive the sensing RS simultaneously (radar like sensing). The component that leaks directly from the Tx antenna to the Rx antenna is self-interference, while the component reflected/scattered/diffracted by the environment or target is a useful signal for sensing.</p>  <p style="text-align: center;"><b>Figure 6.2-2: BS self-interference</b></p>
BS-BS interference	<ul style="list-style-type: none"> <li>• This interference is similar to BS-to-BS cross interference when adjacent cells use different DL/UL configurations (i.e. dynamic TDD), but it becomes potentially more severe when the antenna tilt is changed for some sensing tasks, e.g. detecting aerial objects.</li> <li>• Case 1: Interference between sensing and communication: <ul style="list-style-type: none"> <li>– DL sensing RS transmissions in the adjacent cells interfere with the UL communication signal/channel(s) received at a TRP. (as shown in Figure 6.2-3.</li> <li>– DL communication signal/channel transmissions in the adjacent cells interfere with the UL sensing RS received at a TRP.</li> </ul> </li> <li>• Case 2: Interference between different sensing nodes: <ul style="list-style-type: none"> <li>– DL sensing RS transmissions in adjacent cells interfere with the UL sensing RS received at a TRP.</li> <li>– Two BS for monostatic sensing interfere with each other.</li> </ul> </li> </ul>  <p style="text-align: center;"><b>Figure 6.2-3: DL sensing RS transmissions in the adjacent cells interfere with the UL communication signal/channel(s) reception of TRP 2</b></p>

Interference type	Details
UE-BS interference	<p>This interference is similar as the UL interference type in legacy TDD network with static TDD UL/DL configuration, but it becomes potentially more severe when the antenna tilt is changed for some sensing tasks, e.g. detecting aerial objects.</p> <p>A TRP receiving UL signal/channel(s) suffers from interference caused by the UL transmission in the adjacent cells. Specifically:</p> <ul style="list-style-type: none"> <li>• Interference between sensing and communication: <ul style="list-style-type: none"> <li>– UL sensing RS transmissions in the adjacent cells interfere with the UL communication signal/channel(s) received at a TRP (as shown in Figure 6.2-4).</li> <li>– UL communication signal/channel transmissions in the adjacent cells interfere with the UL sensing RS received at a TRP.</li> </ul> </li> <li>• Interference between different sensing nodes: <ul style="list-style-type: none"> <li>– UL sensing RS transmissions in adjacent cells interfere with the UL sensing RS reception of a TRP.</li> </ul> </li> </ul> <div style="text-align: right; margin-right: 50px;"> <p>→ Communication signal</p> <p>→ Sensing signal</p> <p>--&gt; Interference from sensing</p> </div>  <p style="text-align: center;"><b>Figure 6.2-4: UL sensing RS transmissions in the adjacent cells interfere with the UL communication signal/channel(s) reception of TRP 1</b></p>
UE self-interference	<p>For UE monostatic sensing mode, the UE is required to transmit and receive the sensing RS simultaneously. The component that leaks directly from the Tx antenna to the Rx antenna is self-interference, while the component reflected/scattered/diffracted by the environment or target is a useful signal for sensing.</p>  <p style="text-align: center;"><b>Figure 6.2-5: UE self-interference</b></p>

Interference type	Details
UE-UE interference	<p>This UE-to-UE cross interference is similar to interference when different base stations use different DL/UL/SL configurations (i.e. dynamic TDD), but it becomes potentially more severe when UE transmits sensing signals away from the serving base station.</p> <p>A UE receiving DL/SL signal/channel(s) suffer from interference caused by the UL/SL transmission in the adjacent cells. Specifically:</p> <ul style="list-style-type: none"> <li>• Interference between sensing and communication: <ul style="list-style-type: none"> <li>– UL/SL sensing RS transmissions in the adjacent cells interfere with the DL/SL communication signal/channel(s) reception of a UE (as shown in Figure 6.2-6).</li> <li>– UL/SL communication signal/channel transmissions in the adjacent cells interfere with the DL/SL sensing RS reception of a UE.</li> </ul> </li> <li>• Interference between different sensing nodes: <ul style="list-style-type: none"> <li>– UL/SL sensing RS transmissions in adjacent cells interfere with the DL/SL sensing RS reception of a UE.</li> </ul> </li> </ul> <div style="text-align: right; margin-top: 10px;"> <p>→ Communication signal</p> <p>→ Sensing signal</p> <p>- - - Interference from sensing</p> </div>  <p style="text-align: center;"><b>Figure 6.2-6: UL sensing RS transmissions of UE2 in the adjacent cells interfere with the DL communication signal/channel(s) reception of a UE 1</b></p>

In summary, both self-interference and cross-interference exist in ISAC system. On top of that, the interference between communication and sensing should also be considered. The interference mitigation solutions should be considered to ensure performance and reliability for both sensing and communication.

### 6.2.1.2 Power control considerations

The transmission power of sensing signals affects the maximum range for sensing. For example, if the object to be sensed is far away from the receiver, the detection/tracking/sensing performance maybe lower than needed. Therefore, for such cases, it may be desirable to have higher transmission power. However, if the transmission power is high, this may also create additional interference and result in increased energy consumption at the transmitter. There is therefore a potential need for adaptive power control for the sensing signals.

### 6.2.1.3 Sensing signal design considerations

Sensing signal design, which includes the use of reference signals and the potential use of payload data signals includes many different aspects, including the following:

- a) Periodicity:
  - To support the requirements for the identified use cases, which have a large range of object motion speed (i.e. stationary objects to high-speed vehicles), a sufficient large set of different periodicities for the transmission of sensing signal needs to be supported. Furthermore, when beam sweeping or beam tracking is required, adaptive periodicities will be needed to handle different spatial areas or objects speeds as required. If there are concurrent KPI requirements for communications, it is also essential to strike a balance between the periodicity of reference signal transmissions and the overall resource efficiency of the ISAC system.

- b) Beamwidth:
- Sensing signals with fully adaptive beamwidths should be supported, to enable sensing of different spatial areas, object sizes and furthermore to reduce the influence of unwanted clutter and interference.
- c) Sequence design for reference signals and resource mapping:
- To meet the requirements for objects detection, object identification, and corresponding range and doppler accuracy resolution requirements, sequence design and the correspond resource mapping needs to be optimized and adaptable to fulfil the needs of the different use cases.
- d) Repurposing existing signals:
- For 6GS, a wide range of sensing services will coexist alongside communication services. Traditional sensing methods often rely on continuous or periodic transmissions, which can significantly reduce spectral efficiency - especially in densely deployed environments. To enhance resource utilization, existing signals - originally intended for communication or other functions such as positioning - can be repurposed for sensing tasks. Potential candidates for such reuse include reference signals and payload signals. This reuse can be achieved without substantially compromising the quality of their primary functions. Therefore, repurposing existing signals for sensing should be a key consideration in sensing signal design. However, in some scenarios - such as when the periodicity or availability of existing signals is insufficient in the target sensing area, repurposing existing signals may not lead to satisfactory sensing performance. Thus, this approach should be evaluated alongside alternatives, such as the use of dedicated sensing signals.

#### 6.2.1.4 Cooperative scheduling and resource allocation

5G NR was primarily designed to meet communication requirements rather than addressing the nuanced demands of ISAC applications.

In the context of ISAC, the need for adaptive resource allocations may require additional considerations that were not considered for 5G NR. ISAC use cases and applications often entail unique sensing tasks that will require adaptively adjusting bandwidth allocations to optimize sensing performance. For example, scenarios such as high-resolution wireless imaging or detecting minute objects and motions may necessitate bandwidth configurations that are not readily available within the predefined mechanisms for 5G NR.

The selection of carrier frequency is also closely tied to the available bandwidths, as higher frequencies offer wider bandwidths, enabling the detection of small location changes with higher resolution. However, these higher frequencies may produce multiple point clouds for larger objects or motions, potentially making lower frequency bands more suitable for certain sensing tasks, albeit at the cost of reduced resolution. Additionally, operating frequency impacts the sensing range due to varying attenuation properties, requiring careful consideration of carrier frequency for each specific ISAC use case.

## 6.2.2 Potential approaches

### 6.2.2.1 Approaches for ISAC interference

In the following paragraph potential interference mitigation solutions for self-interference and cross-interference are discussed.

#### Self-interference

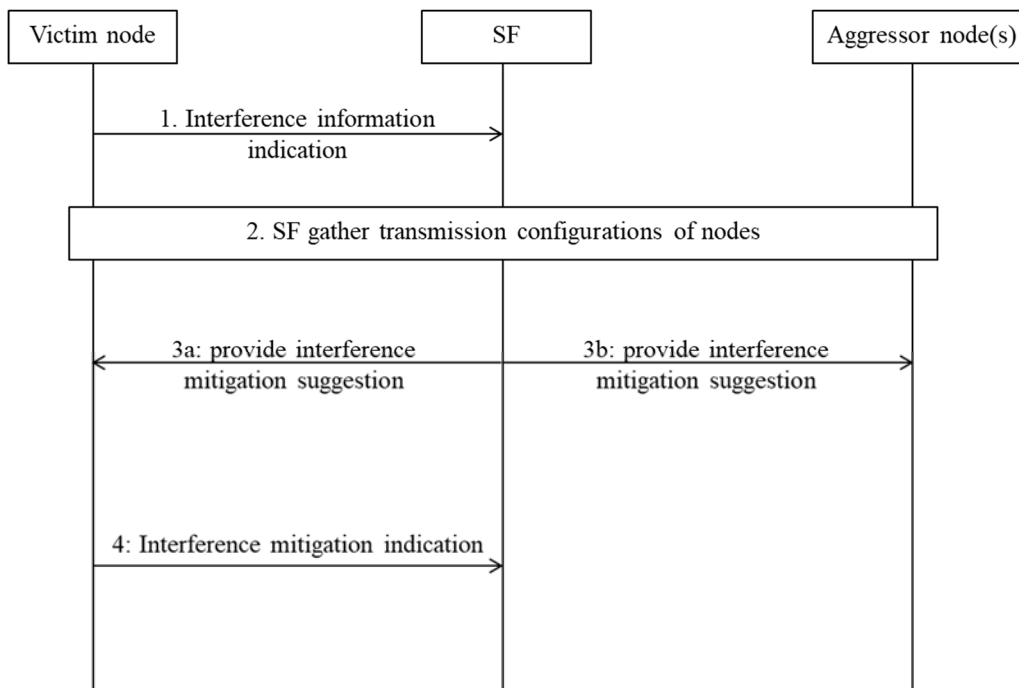
To enable monostatic sensing, it is necessary to study how to effectively suppress the signals transmitted by itself. The following can be studied:

- **Reference signal design:** designing sensing waveforms to avoid or minimize self-interference is a critical challenge as the self-interference is much stronger than the echo signals. Waveforms designed in radar system can be referred to avoid interference or enhance interference mitigation processing.
- **Physical isolation:** an isolator can be inserted between transmitting and receiving antennas to improve the isolation between the transmitting and receiving antennas, enhances the antenna's radiation performance and increases the antenna gain.

## Interference between ISAC nodes

For the study of interference mitigation between ISAC nodes, a variety of approaches including coordinated resource allocation, spatial domain mitigation and power domain mitigation can be used for interference mitigation. Figure 6.2-7 shows an example of procedures for ISAC interference mitigation with SF's coordination:

- 1) Interference information indication from victim: victim node can send its interference information to SF and request for interference mitigation solution. The interference information indication can include the following: victim resource ID, time stamp or a time duration, Rx beam indication, interference power.
- 2) SF gather and coordinate transmission configurations, interference tolerance and interference status of nodes.
- 3) SF provide interference mitigation suggestions or solutions to victim node and/or to possible aggressor nodes:
  - a) **Coordinated resource allocation:** SF can be involved for resource scheduling and allocation to avoid strong interference.
  - b) **Spatial domain interference mitigation:** the direction of Tx beam can be adjusted to improve the received performance of the desired signal or the direction of Rx beam can be adjusted to be orthogonal to the direction of interference signal. Specifically, the SF can provide preferred or non-preferred Tx beam information to aggressor node, or SF can provide preferred or non-preferred Rx beam information to victim node.
  - c) **Power control interference mitigation:** increase the desired signal power or reduce the interference power. SF can provide suggested power adjustment value to the node to mitigate the interference.
- 4) Interference mitigation response: after applying interference mitigation solution, the victim node can further provide interference mitigation indication to SF. The interference mitigation indication provides information on whether the interference disappear.

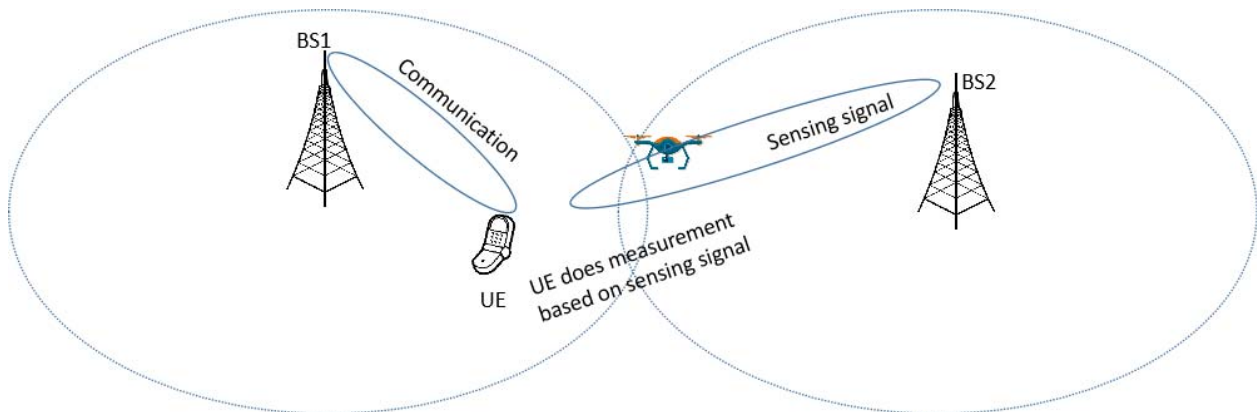


**Figure 6.2-7: General procedure for SF to coordinate interference between ISAC nodes**

## Interference from sensing to communication

For sensing to communication interference, a measurement report from UE to BS based on sensing signal can be considered. Then the BS can adjust the scheduling communication/sensing resources accordingly to avoid serious interference.

As shown in Figure 6.2-8, for communication from a BS to a UE, the sensing signal from a neighbour cell causes interference to the communication UE. Then, it is better to inform UE the sensing signal configuration for CSI measurement, e.g. for interference measurement.



**Figure 6.2-8: UE performs measurement based on sensing signal**

## 7 Conclusions and recommendations

The scope of the present document is to identify 6G ISAC considerations and challenges, with related potential approaches in the following key areas:

- system architecture;
- RAN architecture;
- lower layer RAN; and

thereby derive a system and RAN architectural framework for 6G ISAC.

In particular the top-level focus has been on supporting the identified 6G ISAC use cases in ETSI GR ISC 001 [i.1] with their 6 identified related sensing modes (TRP-TRP bistatic, TRP monostatic, TRP-UE bistatic, UE-TRP bistatic, UE-UE bistatic and UE monostatic). To this aim, a top-level system architecture reference model has been proposed in the present document which supports these sensing modes and the variety of sensing results required by these use cases.

The present document is very timely, since 3GPP has not yet started detailed 6G ISAC system and RAN architectural discussions. Additionally, the work is also placed in the framework of ongoing related 3GPP ISAC activities.

With regards to 3GPP 5GA ISAC, a SA 2 system architecture study item [i.8] and RAN 1 led study [i.9] on performance evaluation and RAN-CN signalling procedures have been approved in June 2025. These 5GA ISAC study items will focus on the 5GA gNB based monostatic sensing mode (TRP based monostatic) for the 5GA UAV use case.

For 6G, 3GPP approved a new study item in September 2024 to explore 6G use cases and requirements [i.10] and the ongoing new use cases (including 6G ISAC ones) with their respective requirements are contained in the draft 3GPP TR 22.870 [i.11]. Additionally in June 2025, 3GPP approved a 6G RAN study item [i.12] which included sensing as one of the objectives.

In terms of the identified 6G ISAC system architecture considerations and challenges in the present document, the following topics have been identified:

- 1) Sensing function.
- 2) Sensing service request and configuration.
- 3) Sensing input data request.
- 4) Sensing input data response.

- 5) Network payload related to sensing data.
- 6) Sensing results exposure and transport.
- 7) Charging and incentives.
- 8) Disaggregation of sensing control and processing.
- 9) Mobility of sensing entities.
- 10) Management of sensing entities.
- 11) CN-RAN interaction for sensing task control.
- 12) Multi-operator network sharing for sensing.

For system architecture considerations 1) to 9), possible architectural approaches to address these topics have also been described in the present document. Possible approaches for challenges 10) to 12) are open for future study.

In terms of the 6G RAN architecture, consideration and challenges for 6G ISAC RAN architecture and additional RAN function have been considered and a possible approach for this is also presented. Further RAN architectural issues were openly discussed in the ISG, including RAN interfaces, fusion consideration and reporting formats, but these topics are proposed to be handled in a future study.

For lower layer RAN, the following considerations and challenges topic were identified:

- 1) Interference.
- 2) Power control.
- 3) Sensing signal design.
- 4) Cooperative scheduling and resource allocation.

For the lower layer RAN interference topic, a possible approach has also been presented. Possible approaches for lower layer RAN topics 2), 3) and 4) are open for further study.

In summary it is recommended that the proposed challenges and potential approaches in the present document are considered in any further studies and/or specifications work related to 6G ISAC systems e.g. ETSI GR ISC 004 [i.6] on Security, Privacy, Trustworthiness and Sustainability, ETSI GR ISC 005 [i.13] on Integration of Computing with ISAC or any related work items in subsequent phases of this ISG which may be approved in the future.

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## History

<b>Version</b>	<b>Date</b>	<b>Status</b>
V1.1.1	February 2026	Publication