ETSI GS ARF 004-3 V1.1.1 (2021-10)

Augmented Reality Framework (ARF); Interoperability Requirements for AR components, systems and services; Part 3: World Capture, World Analysis and Scene Management

Disclaimer

The present document has been produced and approved by the Augmented Reality Framework (ARF) ETSI Industry Specification Group (ISG) and represents the views of those members who participated in this ISG.
It does not necessarily represent the views of the entire ETSI membership.

Reference
DGS/ARF-004-3

Keywords
API, AR Cloud, architecture, augmented reality, context capturing and analysis, framework, interoperability, model, real time, real world capture, requirements, sensor

ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - APE 7112B
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° w061004871

Contents

Intellectual Property Rights

Essential patents

IPRs essential or potentially essential to normative deliverables may have been declared to ETSI. The declarations pertaining to these essential IPRs, if any, are publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: *"Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards"*, which is available from the ETSI Secretariat. Latest updates are available on the ETSI Web server (https://ipr.etsi.org/).

Pursuant to the ETSI Directives including the ETSI IPR Policy, no investigation regarding the essentiality of IPRs, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

Trademarks

The present document may include trademarks and/or tradenames which are asserted and/or registered by their owners. ETSI claims no ownership of these except for any which are indicated as being the property of ETSI, and conveys no right to use or reproduce any trademark and/or tradename. Mention of those trademarks in the present document does not constitute an endorsement by ETSI of products, services or organizations associated with those trademarks.

DECT™, **PLUGTESTS™**, **UMTS™** and the ETSI logo are trademarks of ETSI registered for the benefit of its Members. **3GPP™** and **LTE™** are trademarks of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners. **oneM2M™** logo is a trademark of ETSI registered for the benefit of its Members and of the oneM2M Partners. **GSM**® and the GSM logo are trademarks registered and owned by the GSM Association.

Foreword

This Group Specification (GS) has been produced by ETSI Industry Specification Group (ISG) Augmented Reality Framework (ARF).

The present document is part 3 of a multi-part deliverable covering Interoperability Requirements for AR components, systems and services, as identified below:

Part 1: "Overview";

Part 2: "World Storage and AR Authoring functions";

Part 3: "World Capture, World Analysis and Scene Management".

The ISG ARF shares the following understanding for Augmented Reality: Augmented Reality (AR) is the ability to mix in real-time spatially-registered digital content with the real world. The present document specifies the interoperability requirements for Reference Points AR1 and AR2 of the reference architecture for AR solutions defined in ETSI GS ARF 003 [1].

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

1 Scope

The present document reviews the high level Reference Point requirements between the World Capture, World Authoring and Scene Management functions as they are identified in ETSI GS ARF 003 [1]. It further defines the requirements of reference points "Sensors for World Analysis" (AR1) and "Sensors for Scene Management" (AR2).

2 References

2.1 Normative 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.

Referenced documents which are not found to be publicly available in the expected location might be found at https://docbox.etsi.org/Reference/.

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 are necessary for the application of the present document.

[1] ETSI GS ARF 003 (V1.1.1): "Augmented Reality Framework (ARF) AR framework architecture".

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 are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] OGC®: "Geographic information - Observations and measurements".

NOTE: This standard can be found at https://portal.ogc.org/files/?artifact_id=41579.

[i.2] Fowler, Martin (1997): "Analysis Patterns: Reusable Object Models". Addison-Wesley. pp. 35-55. ISBN 978-0-201-89542-1.

NOTE: This document can be found at https://archive.org/details/analysispatterns00fowl_085.

[i.3] OGC®: "Sensor Web Enablement (SWE)".

NOTE: The page that describes the various parts of the standard suite can be found at https://www.ogc.org/node/698.

[i.4] OGC®: "SensorML: Model and XML Encoding Standard".

NOTE: This standard can be found at https://portal.ogc.org/files/?artifact_id=55939.

[i.5] OCG®/W3C®: "Semantic Sensor Network Ontology".

NOTE: This standard can be found at https://www.w3.org/TR/vocab-ssn/.

[i.6] W3C®: "Web of Things (WoT) Architecture 1.1".

NOTE: This standard can be found at https://www.w3.org/TR/2020/WD-wot-architecture11-20201124/.

[i.7] ISO/IEC 23093 (all parts): "Information technology - Internet of media things".

NOTE: This standard can be found at https://www.iso.org/search.html?q=23093.

[i.8] W3C®: "Web of Things (WoT) Thing Description".

NOTE: This standard can be found at https://www.w3.org/TR/wot-thing-description/.

[i.9] OGC®: "SensorThings API".

NOTE: This standard can be found at http://docs.opengeospatial.org/is/15-078r6/15-078r6.html.

[i.10] W3C®: "Web of Things (WoT) Discovery".

NOTE: This draft standard can be found at https://www.w3.org/TR/wot-discovery/.

[i.11] ISO/IEC 18038:2020: "Information technology - Computer graphics, image processing and environmental representation - Sensor representation in mixed and augmented reality".

NOTE: This draft standard can be found at https://www.iso.org/standard/70720.html.

[i.12] IEEE 1451™: "Standard for a Smart Transducer Interface for Sensors and Actuators".

NOTE: A tutorial about the family of standards can be found at https://standards.ieee.org/content/dam/ieee-standards/standards/web/documents/tutorials/1451d4.pdf.

[i.13] ISO/IEC 23093-2 and ISO/IEC 23093-3: "Information technology - Internet of media things - Part 2: Discovery and communication API" and "Information technology - Internet of media things - Part 3: Media data formats and APIs".

NOTE: These standards can be found at https://www.iso.org/standard/74332.html and https://www.iso.org/standard/74333.html.

[i.14] ISO/IEC 23090-5:2021 and ISO/IEC 23090-9: "Information technology -- Coded representation of immersive media -- Part 5: Visual volumetric video-based coding (V3C) and video-based point cloud compression (V-PCC)" and "Information technology -- Coded representation of immersive media -- Part 9: Geometry-based point cloud compression".

NOTE: These specifications can be found at https://www.iso.org/standard/73025.html and https://www.iso.org/standard/78990.html. More information about the MPEG PCC family of specifications can be found at https://mpeg-pcc.org/.

[i.15] ISO 19130-1 and ISO 19130-2: "Geographic information -- Imagery Sensor Models for geopositioning -- Part 1: Fundamentals" and "Geographic information -- Imagery sensor models for geopositioning -- Part 2: SAR, InSAR, lidar and sonar".

NOTE: Available at https://www.iso.org/standard/66847.html and https://www.iso.org/standard/56113.html.

[i.16] W3C®: "Generic Sensor API".

NOTE: The draft Generic Device Sensor API standard is found at https://www.w3.org/TR/generic-sensor/.

[i.17] Internet of Things standards are discussed in a blog post found at this URL https://www.postscapes.com/internet-of-things-protocols/.

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

feature: characteristics of a real world element that can be searched, recognized or tracked

NOTE: Features can be of different nature without being limited to visual patterns, UWB, Wi-Fi, Infra Red or sounds.

reference point: point located at the interface of two non-overlapping functions and representing interrelated interactions between those functions

3.2 Symbols

Void.

3.3 Abbreviations

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

API	Application Programming Interface
AR	Augmented Reality
DAS	Devices And Sensors
GPS	Global Positioning System
ISG	Industry Specification Group
JSON	JavaScript Object Notation
MPEG	Motion Pictures Experts Group
PCC	Point Cloud Compression
RFID	Radio Frequency Identifier
RGB	Red Green Blue
RGB-D	Red Green Blue + Depth
RP	Reference Point
SAR	Synthetic Aperture Radar
SC	SubCommittee
SDO	Standard Development Organization
SM	Scene Management
SOSA	Sensor, Observation, Sample and Actuator
SSN	Semantic Sensor Network
SWE	Sensor Web Enablement
TEDS	Transducer Electronic Data Sheets
UID	Unique Identifier
WA	World Analysis
WC	World Capture
WG	Working Group

4 Interoperability Requirements for AR1 and AR2

4.1 AR1 and AR2 Reference Points Scope

AR1 "Sensors for World Analysis" and AR2 "Sensor Data for Scene Management" Reference Points (RP), as specified in ETSI GS ARF 003 [1] define the dialog structure between the World Capture, World Analysis (WA) and the Scene Management (SM) functions respectively to ensure that relevant features in the real world which are captured by sensors are available, received and useable by the WA and SM subfunctions.

The AR1 and AR2 are separate Reference Points because they connect two different functions to the World Capture function, however, their requirements are identical because both the World Analysis and Scene Management use the World Capture capabilities. They may be implemented together or separately, depending on system requirements and design.

4.2 High-level requirements

There are three high level requirements. Figure 1 shows how the high level requirements are in sequence.

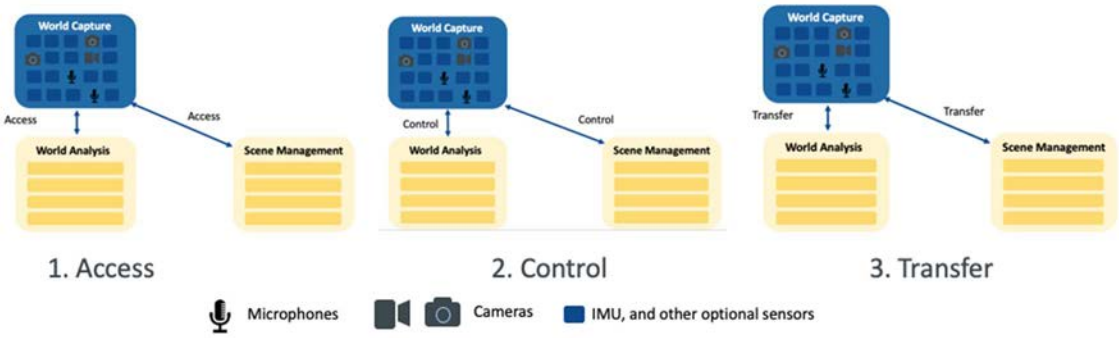

Figure 1: Sequence of AR1 and AR2 requirements

In clause 6.2 of ETSI GS ARF 003 [1], the requirements of AR1 reference point are defined as:

- Access to sensor capabilities and characteristics:
  - Type of sensor (e.g. RGB camera, RGB-D camera, accelerometer, magnetometer, microphone, or GPS).
  - Identifier of the sensor provided by the **World Capture** function.
  - Number of devices of similar type.
  - Measuring characteristics (e.g. range and resolution, acquisition frequency, conditions of use, or coverage).
  - Information about the extrinsic, intrinsic and distortion parameters of the sensors.
- Control of the sensor:
  - Initializing and shutting-down sensors.
  - Starting and stopping the access to sensors.
  - Setting of identifiers as used by the **World Analysis** function.
  - Setting of measurement characteristics (e.g. ranges, systems of units, resolutions, or acquisition frequency).
  - Switching between sensors.
  - Requesting conditions for data delivery to the AR implementation (e.g. event-based, temporal, or synchronized with other sensors).
- Transfer of captured data:
  - Sensor data as e.g. raw data or aggregated or converted data.
  - The ID of the sensor which has captured the data.
  - Metadata associated to data captured by the sensor.

In clause 6.3 of ETSI GS ARF 003 [1], the requirements are defined as:

- Access to sensor capabilities and characteristics:
  - Type of sensor (e.g. RGB camera, RGB-D camera, accelerometer, magnetometer, microphone, or GPS).
  - Identifier of the sensor provided by the **World Capture** function.
  - Number of devices of similar type.
  - Measuring characteristics (e.g. range and resolution, acquisition frequency, conditions of use, or coverage).
  - Information about the extrinsic, intrinsic and distortion parameters of the sensors.
- Control of the sensor:
  - Initializing and shutting-down sensors.
  - Starting and stopping the access to sensors.
  - Setting of identifiers as used by the **Scene Management** function.
  - Setting of measurement characteristics (e.g. ranges, systems of units, resolutions, or acquisition frequency).
  - Switching between sensors.
  - Requesting conditions for data delivery to the AR implementation (e.g. event-based, temporal, or synchronized with other sensors).
- Transfer of captured data:
  - Sensor data as e.g. raw data or aggregated or converted data.
  - The ID of the sensor which has captured the data.
  - Metadata associated to data captured by the sensor.

NOTE 1: Extrinsic parameters can provide the pose of the sensor relatively to reference coordinate systems related to the AR device, to another sensor, or to the real world.

NOTE 2: The metadata associated to the captured data can be an actual measurement unit or a time stamp for representing time of data acquisition (essential to merge data supplied by multiple sensors).

NOTE 3: This reference point can be used to update video background information as part of the AR scene for video see-through AR systems.

NOTE 4: This reference point can be used to update the audio background in case of an implementation offering augmented audio functions.

4.3 World Analysis Function Access to World Capture Sensors

The first set of AR1 requirements pertain to the function's access to World Capture sensors. "Access" assumes that prior to request for access, the WC registry service has discovered and registered all relevant sensors. The WC function will also perform all initialization of relevant sensors to which the World Analysis requests access.

RQ-AR1-001	The WA shall have ability to receive from the WC registration service all requested information including UID, type, data formats available, and other parameters (e.g. embedded, external, synchronization) about any, some or all sensors.

Requested information can include:

- Type of sensors available to the WA system.
- # of sensors of each type.
- Capabilities of each sensor (e.g. computation, resolution, frequency, etc.):
  - Measuring characteristics (e.g. range and resolution, acquisition frequency, conditions of use, or coverage).
  - Information about the extrinsic parameters of the sensors.

Extrinsic parameters:

- Reference (the UID, and provide information about) of the rig(s) (if one level of hierarchy is sufficient) and its position and orientation in relation to a coordinate reference system.
- Specify if rig has another "level" (if there are more than one nested rigs).

RQ-AR1-001a	For camera sensors (e.g. RGB, Depth, LiDAR), the WA function shall have the ability to receive from the WC registration service additional requested information.

The additional camera sensor information requested from WC should include:

- Intrinsic parameters: focal length, optical centre, pixel size, pixel skew, radial distortion, tangential distortion.
- Image size in pixels.
- Capture method: rolling or global shutter.
- Camera position: e.g. front-facing or rear-facing camera, left or right camera.

4.4 World Analysis Function Control of World Capture Sensors

Once the World Analysis has established access to World Capture sensors, it will have the ability to control them.

RQ-AR1-002	The WA subfunctions shall have the ability to subscribe/unsubscribe individually to data streams being sent (aka "published") by each of the chosen WC function sensors.

RQ-AR1-003	If supported by WC, WA subfunctions should specify synchronized or asynchronous data streams.

Recommendation: Each WA subfunction should specify parameters for data streams it receives from each sensor (and/or sensor type).

4.5 Transfer of Data between World Capture and World Analysis

When under the control of the World Analysis, World Capture sensors will send and World Analysis function will receive data streams.

RQ-AR1-004	Data streams from WC shall be sent to WA in formats requested during negotiation with WC registry.

RQ-AR1-005	Data streams from WC shall have time stamp(s) which shall be synchronized with the master AR system clock in use by WA.

Implementers can choose to support supplementary levels of control. In some cases, the AR1 can transmit messages regarding the availability of new data to the WA function. Alternatively, the WA will receive all data requested as configured during the control phase.

4.6 Scene Management Function Access to World Capture Sensors

The first set of AR2 requirements pertain to the function's access to World Capture sensors. "Access" assumes that prior to request for access, the WC registry service has discovered and registered of all relevant sensors. The WC function will also perform all initialization of relevant sensors to which the Scene Management requests access.

RQ-AR2-001	The SM shall have ability to receive from the WC registration service all requested information including UID, type, data formats available, and other parameters (e.g. embedded, external, synchronization) about any, some or all sensors.

Requested information can include:

- Type of sensors available to the SM system.
- # of sensors of each type.
- Capabilities of each sensor (e.g. computation, resolution, frequency, etc.):
  - Measuring characteristics (e.g. range and resolution, acquisition frequency, conditions of use, or coverage).
  - Information about the extrinsic parameters of the sensors.

Extrinsic parameters:

- Reference (the UID, and provide information about) of the rig(s) (if one level of hierarchy is sufficient) and its position and orientation in relation to a coordinate reference system.
- Specify if rig has another "level" (if there are more than one nested rigs).

RQ-AR2-001a	For camera sensors (e.g. RGB, Depth, LiDAR), the SM function shall have the ability to receive from the WC registration service additional requested information.

The additional camera sensor information requested from WC should include:

- Intrinsic parameters: focal length, optical centre, pixel size, pixel skew, radial distortion, tangential distortion.
- Image size in pixels.
- Capture method: rolling or global shutter.
- Camera position: e.g. front-facing or rear-facing camera, left or right camera.

4.7 Scene Management Function Control of World Capture Sensors

Once the Scene Management function has established access to World Capture sensors, it will have the ability to control them.

RQ-AR2-002	The SM subfunctions shall have the ability to subscribe/unsubscribe individually to data streams being sent (aka "published") by each of the chosen WC function sensors.

RQ-AR2-003	If supported by WC, SM subfunctions should specify synchronized or asynchronous data streams.

Recommendation: Each SM subfunction should specify parameters for data streams it receives from each sensor (and/or sensor type).

4.8 Transfer of Data between World Capture and Scene Management

When under the control of the Scene Management, World Capture sensors will send and Scene Management function will receive data streams.

RQ-AR2-004	Data streams from WC shall be sent to SM in formats requested during negotiation with WC registry.

RQ-AR2-005	Data streams from WC shall have time stamp(s) which shall be synchronized with the master AR system clock in use by SM.

Implementers can choose to support supplementary levels of control. In some cases, the AR1 can transmit messages regarding the availability of new data to the SM function. Alternatively, the SM will receive all data requested as configured during the control phase.

Annex A (informative): Other Standards of Relevance to AR1 and AR 2 Requirements

A.1 Overview

This annex includes standards identified by the ETSI ISG ARF while preparing the present document. The intention of this annex is to compile, for informational purposes, those Standards Development Organizations (SDOs) and working groups with relevant activities in the field of sensors for World Capture and a few relevant specifications. Due to limitations of time, this annex may not be exhaustive and it is expected that there are other standards and SDOs also working in this field but which are not explicitly captured in this annex.

A.2 Standards Providing World Capture System Architectures

A.2.1 Overview

There are existing standards that describe architectures for sensors and offer insights for how the sensors used for the World Capture function could be organized with respect to other functions. The standards identified include:

- OGC Observations and Measurements Abstract Specification [i.1]
- OGC Sensor Web Enablement [i.3]
- OGC SensorML [i.4]
- W3C Semantic Sensor Model and Ontology [i.5]
- W3C Web of Things Architecture 1.1 [i.6]
- MPEG Internet of Media Things Part 1: Architecture [i.7]
- W3C Web of Things Thing Description [i.8]

A.2.2 OGC Observations and Measurements (O&M) Abstract Specification

This standard [i.1] defines a conceptual schema encoding for observations, and for features involved in sampling when making observations.

Specifically, it defines the following core set of properties for an observation:

- Feature of interest.
- Observed property.
- Result.
- Procedure - the instrument, algorithm or process used (which may be described using SensorML).
- Phenomenon time - the real-world time associated with the result.
- Result time - the time when the result was generated.
- Valid time - the period during which the result may be used.

While the O&M standard was developed in the context of geographic information systems, the model is derived from generic patterns proposed by Fowler [i.2], and is not limited to spatial information.

O&M is one of the core standards in the OGC Sensor Web Enablement suite, providing the response model for Sensor Observation Service.

A.2.3 OGC Sensor Web Enablement (SWE) standards

The OGC's Sensor Web Enablement (SWE) suite of standards [i.3] enable developers to make all types of sensors, transducers and sensor data repositories discoverable, accessible and useable via the Web. SWE offers integrators:

- Open interfaces for sensor web applications.
- "Hooks" for IEEE 1451 [i.12].
- Imaging device interface support.
- Sensor location tied to geospatial standards.
- Fusion of sensor data with other spatial data.

A.2.4 OGC SensorML

OGC SensorML [i.4] provides standard models and an XML encoding for describing sensors and measurement processes. SensorML can be used to describe a wide range of sensors. Functions supported include:

- Sensor discovery.
- Sensor geolocation.
- Processing of sensor observations.
- A sensor programming mechanism.
- Subscription to sensor alerts.

The result of a SensorML process is typically considered to be an observation result if it is measuring or deriving some value of a physical property or phenomenon. Thus, the *output* values described in SensorML and resulting from a sensor or process may be packaged in an O&M *Observation* object or provided as a SWE Common *DataStream*.

Inversely, the *procedure* property within an *Observation* instance may reference a SensorML description of the measurement process.

A.2.5 W3C Semantic Sensor Model and Semantic Sensor Network Ontology

The W3C Semantic Sensor Network (SSN) ontology [i.5] was prepared by the Spatial Data on the Web Working Group (SDWWG) - a joint W3C-OGC project. The ontology describes sensors and their observations, the involved procedures, the features of interest, the samples used to study the features of interest, and the observed properties, as well as actuators. SSN follows a horizontal and vertical modularization architecture by including a lightweight but self-contained core ontology called SOSA (Sensor, Observation, Sample, and Actuator) for its elementary classes and properties. With their different scope and different degrees of axiomatization, SSN and SOSA are able to support a wide range of applications and use cases, including satellite imagery, large-scale scientific monitoring, industrial and household infrastructures, social sensing, citizen science, observation-driven ontology engineering, and the Web of Things.

A.2.6 W3C Web of Things Architecture 1.1

The W3C Web of Things is intended to enable interoperability across IoT platforms and application domains. The W3C Web of Things Architecture [i.6] describes the abstract architecture for the W3C Web of Things. This abstract architecture is based on a set of requirements that were derived from use cases for multiple application domains, both given in this document. A set of modular building blocks are also identified whose detailed specifications are given in other documents. This document describes how these building blocks are related and work together. The WoT abstract architecture defines a basic conceptual framework that can be mapped onto a variety of concrete deployment scenarios, several examples of which are given. However, the abstract architecture described in this specification does not itself define concrete mechanisms or prescribe any concrete implementation.

A.2.7 ISO/IEC 23093-1:2020 MPEG Internet of Media Things Part 1: Architecture

ISO/IEC 23093-1 [i.7] specifies a global architecture for media sensors that can be processed by media analysers to produce analysed data, and how the media analysers can be cascaded in order to extract semantic information. The architecture defines a set of interfaces, protocols and associated media-related information representations related to:

- User commands (setup information) between a system manager and an MThing.
- User commands (setup information) forwarded by an MThing to another MThing, possibly in a modified form.
- Sensed data (raw or processed data) (compressed or semantic extraction) and actuation information.
- Wrapped interface (e.g. for transmission).
- MThing characteristics and discovery.

ISO/IEC 23093-2 [i.13] defines an API for access and control.

A.2.8 W3C WoT Thing Description

The W3C Web of Things (WoT) Things Description [i.8] describes a formal model and a common representation for a Web of Things (WoT) Thing Description. A Thing Description describes the metadata and interfaces of Things, where a Thing is an abstraction of a physical or virtual entity that provides interactions to and participates in the Web of Things.

Thing Descriptions provide a set of interactions based on a small vocabulary that makes it possible both to integrate diverse devices and to allow diverse applications to interoperate. Thing Descriptions, by default, are encoded in a JSON format that also allows JSON-LD processing. The latter provides a way to represent knowledge about Things in a machine-understandable way. A Thing Description instance can be hosted by the Thing itself or hosted externally when a Thing has resource restrictions (e.g. limited memory space) or when a Web of Things-compatible legacy device is retrofitted with a Thing Description.

A.3 Standards Defining Access and Control Protocols

A.3.1 Overview

There are existing standards that define APIs for the World Analysis and Scene Management functions to use for requesting and confirming access to and controlling sensors such as what could be part of the World Capture function. Existing standards that describe sensor access and control include:

- OGC SensorThings API.
- W3C Web of Things Discovery.
- Sensor Representation in Mixed and Augmented Reality.
- IEEE 1451 [i.12] Family of Smart Transducer Interface Standards.

- ISO/IEC 23093 [i.7] series.

A.3.2 OGC SensorThings API

The OGC SensorThings API [i.9] provides an open, geospatial-enabled and unified way to interconnect the Internet of Things (IoT) devices, data, and applications over the Web.

The API provides two main functionalities:

- The **Sensing part** provides a standard way to manage and retrieve observations and metadata from heterogeneous IoT sensor systems.
- The **Tasking part** provides a standard way for parameterizing - also called tasking - of taskable IoT devices, such as individual sensors and actuators, composite consumer / commercial / industrial / smart cities *in-situ* platforms, mobile and wearable devices, or even unmanned systems platforms such as drones, satellites, connected and autonomous vehicles, etc.

A.3.3 W3C Web of Things Discovery

The W3C Web of Things [i.10] is intended to enable interoperability across IoT platforms and application domains. One key mechanism for accomplishing this goal is the definition and use of metadata describing the interactions an IoT device or service makes available over the network at a suitable level of abstraction. The WoT Thing Description specification [i.8] satisfies this objective.

However, in order to use a Thing its Thing Description first has to be obtained. The WoT Discovery [i.10] process described in this document addresses this problem. WoT Discovery needs to support the distribution of WoT Thing Descriptions in a variety of use cases. This includes ad-hoc and engineered systems; during development and at runtime; and on both local and global networks. The process also needs to work with existing discovery mechanisms, be secure, protect private information, and be able to efficiently handle updates to WoT Thing Descriptions and the dynamic and diverse nature of the IoT ecosystem.

The WoT Discovery process is divided into two phases, Introduction, and Exploration. The Introduction phase leverages existing discovery mechanisms but does not directly expose metadata; they are simply used to discover Exploration services, which provide metadata but only after secure authentication and authorization. This document normatively defines two Exploration services, one for WoT Thing self-description with a single WoT Thing Description and a searchable WoT Thing Description Directory service for collections of Thing Descriptions. A variety of Introduction services are also described and where necessary normative definitions are given to support them.

A.3.4 ISO/IEC 18038:2020

ISO/IEC 18038:2020 [i.11] is an ISO standard published by ISO/IEC JTC1 SC 24 WG9. It defines how physical sensors are integrated into a 3D virtual world, and how their physical properties can be represented precisely in the virtual world. Sensor-based mixed reality is obtained by this convergence of 3D with physical sensors in the real world.

For sensor-based mixed reality, sensors in a 3D virtual world are defined, and their information should be able to be transferred between applications, and between a virtual world and a real world.

This work is intended to define how to exchange AR/MR application data in heterogeneous computing environments, and how physical sensors can be managed and controlled with their physical properties in a 3D virtual world.

A.3.5 IEEE 1451

IEEE 1451 [i.12] is a set of smart transducer interface standards developed by the Institute of Electrical and Electronics Engineers (IEEE) Instrumentation and Measurement Society's Sensor Technology Technical Committee describing a set of open, common, network-independent communication interfaces for connecting transducers (sensors or actuators) to microprocessors, instrumentation systems, and control/field networks. The goal of the IEEE 1451 family of standards is to allow the access of transducer data through a common set of interfaces whether the transducers are connected to systems or networks via a wired or wireless means.

One of the key elements of these standards is the definition of Transducer Electronic Data Sheets (TEDS) for each transducer. The TEDS is a memory device attached to the transducer, which stores transducer identification, calibration, correction data, and manufacturer-related information. The 1451 family of standards includes:

- IEEE 1451.0-2007: "IEEE Standard for a Smart Transducer Interface for Sensors and Actuators - Common Functions, Communication Protocols, and Transducer Electronic Data Sheet (TEDS) Formats".
- IEEE 1451.1-1999: "IEEE Standard for a Smart Transducer Interface for Sensors and Actuators - Network Capable Application Processor Information Model".
- IEEE 1451.2-1997: "IEEE Standard for a Smart Transducer Interface for Sensors and Actuators - Transducer to Microprocessor Communication Protocols & TEDS Formats".
- IEEE 1451.3-2003: "IEEE Standard for a Smart Transducer Interface for Sensors and Actuators - Digital Communication & TEDS Formats for Distributed Multidrop Systems".
- IEEE 1451.4-2004: "IEEE Standard for a Smart Transducer Interface for Sensors and Actuators - Mixed-Mode Communication Protocols & TEDS Formats".
- IEEE 1451.5-2007: "IEEE Standard for a Smart Transducer Interface for Sensors and Actuators - Wireless Communication Protocols & Transducer Electronic Data Sheet (TEDS) Formats".
- IEEE 1451.7-2010: "IEEE Standard for a Smart Transducer Interface for Sensors and Actuators - Transducers to Radio Frequency Identification (RFID) Systems Communication Protocols and Transducer Electronic Data Sheet Formats".

A.3.6 ISO/IEC 23093 series

The ISO/IEC 23093 series [i.7] specifies data formats of input and output for media sensors, media actuators, media storages and media analysers which are components described in Part 1. Part 2 specifies an API to discover Media Things and to enable communication between them. ISO/IEC 23093-3 [i.13] covers data formats and API for communications with Media Things.

ISO/IEC 23093-4 [i.7] describes reference software and conformance for IoMT.

A.4 Media Transfer

A.4.1 Overview

In preparation of the AR1 and AR2 interoperability requirements, one specification has been identified as covering media transfer, including compression of data flowing from the World Capture function. This is the MPEG Internet of Media Things.

A.4.2 ISO/IEC 23093-3

ISO/IEC 23093-3 [i.13] provides an architecture and specifies APIs and compressed representation of data flowing between media things.

A.4.3 ISO/IEC 23090 MPEG Point Cloud Compression Standards

MPEG has specified the compression of point clouds. ISO/IEC 23090 [i.14] consist in two classes of solutions:

- Video-based, equivalent to V-PCC, appropriate for point sets with a relatively uniform distribution of points.
- Geometry-based (G-PCC), equivalent to the combination of L-PCC and S-PCC, appropriate for more sparse distributions.

A.5 Miscellaneous

A.5.1 Overview

In addition to the standards identified for World Capture function architecture, those potentially meeting one or more requirements for AR1 and AR2, other standards that define APIs for requesting and confirming access to and controlling sensors have been identified. These include:

- IEEE 1451 [i.12]
- ISO 19130 [i.15]
- W3C Device and Sensors Working Group

There are also numerous standards developed for the Internet of Things that could be relevant.

A.5.2 IEEE 1451

IEEE 1451 [i.12] is a set of smart transducer interface standards developed by the Institute of Electrical and Electronics Engineers (IEEE) Instrumentation and Measurement Society's Sensor Technology Technical Committee describing a set of open, common, network-independent communication interfaces for connecting transducers (sensors or actuators) to microprocessors, instrumentation systems, and control/field networks. See clause A.3.5 above for more information.

A.5.3 ISO 19130 Imagery Sensor Models for Geopositioning

ISO 19130 [i.15] includes:

- ISO 19130-1:2018: "Geographic information - Imagery sensor models for geopositioning - Part 1: Fundamentals".
- 19130-2:2014: "Geographic information - Imagery sensor models for geopositioning - Part 2: SAR, InSAR, lidar and sonar".

A.5.4 W3C Devices and Sensors Working Group Standards

The W3C Devices And Sensors (DAS) WG defines client-side APIs that allow web applications to make use of widely available device capabilities, including sensors, that enable modern, context-aware, and interactive application experiences. These capabilities in the scope of the DAS working group include:

- reacting to device power status;
- preventing the screen or system from turning off;
- monitoring the presence of nearby objects without physical contact;
- monitoring the ambient light level of the device's environment;
- monitoring changes in motion and orientation of the hosting device;

- obtaining and monitoring the location of the hosting device.

The Generic Device Sensor API specification [i.16] defines a framework for exposing sensor data to the Open Web Platform in a consistent way. It does so by defining a blueprint for writing specifications of concrete sensors along with an abstract Sensor interface that can be extended to accommodate different sensor types.

Specifications that use the generic framework and on which this WG focuses include:

- Proximity Sensor API
- Ambient Light Sensor API
- Accelerometer API
- Gyroscope API
- Magnetometer API
- Orientation API
- Device Orientation Event API
- Geolocation Sensor API

A.5.5 Internet of Things

There are also IoT standards. These include [i.17]:

- Infrastructure
- Identification
- Comms / Transport
- Discovery
- Data Protocols
- Device Management
- Semantic
- Multi-layer Frameworks

History

Document history		
V1.1.1	October 2021	Publication