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Part 8: eHealth/Ageing-well Domain

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Smart Machine-to-Machine communications (SmartM2M).

The present document is part 8 of a multi-part deliverable covering SmartM2M; Extension to SAREF, as identified below:

Part 1: "Energy Domain";

Part 2: "Environment Domain";

Part 3: "Building Domain";

Part 4: "Smart Cities Domain";

Part 5: "Industry and Manufacturing Domains";

Part 6: "Smart Agriculture and Food Chain Domain";

Part 7: "Automotive Domain";

Part 8: "eHealth/Ageing-well Domain";

Part 9: "Wearables Domain";

Part 10: "Water Domain".

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).

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1 Scope

The present document presents SAREF4EHAW, an extension of SAREF for the eHealth/Ageing-well Domain.

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.

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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 TS 103 264 (V3.1.1) (2020-02): "SmartM2M; Smart Applications; Reference Ontology and oneM2M Mapping".

[2] ETSI TS 103 378 (V1.1.1) (2015-12): "Smart Body Area Networks (SmartBAN) Unified data representation formats, semantic and open data model".

[3] ETSI TS 103 410-2 (V1.1.2) (2020-05): "SmartM2M; Extension to SAREF; Part 2: Environment Domain".

[4] ETSI TS 103 410-9 (V1.1.1) (2020-07): "SmartM2M; Extension to SAREF; Part 9: Wearables Domain".

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] W3C SSN documentation.

NOTE: Available at https://www.w3.org/2005/Incubator/ssn/ssnx/ssn.

[i.2] B. Gonçalves, G. Guizzardi, J. G.Pereira Filho: "Using an ECG reference ontology for semantic interoperability of ECG data", Journal of Biomedical Informatics, vol. 44, issue 1, pp. 126-136, February 2011.

[i.3] HL7 FHIR®: "Fast Healthcare Interoperability Resources".

NOTE 1: Available at http://www.hl7.org/.

NOTE 2: FHIR® is an example of an existing eHealth standard. This information is given for the convenience of users of the present document and does not constitute an endorsement by ETSI of this standard.

[i.4] S. Cox: "Observations and measurements-xml implementation" OGC document, 2011 (also published as ISO/DIS 19156).

NOTE: Available at https://www.ogc.org/standards/om.

[i.5] HL7 annotated ECG (aECG) R1 and R2 (US realm).

NOTE: Available at https://www.hl7.org/implement/standards/product_brief.cfm?product_id=102.

[i.6] Digital Imaging and Communications in Medicine (DICOM®) international standard.

NOTE 1: Available at https://www.dicomstandard.org/.

NOTE 2: DICOM® is an example of an existing eHealth standard. This information is given for the convenience of users of the present document and does not constitute an endorsement by ETSI of this standard.

[i.7] ETSI TR 103 509 (V1.1.1) (2019-10): "SmartM2M; SAREF extension investigation; Requirements for eHealth/Ageing-well".

[i.8] IETF RFC 6068: "The 'mailto' URI Scheme".

NOTE: Available at https://tools.ietf.org/html/rfc6068.

[i.9] ISO 6709: "Standard representation of geographic point location by coordinates".

NOTE: Available at https://www.iso.org/fr/standard/39242.html.

[i.10] IEEE™ 802.15.6: "IEEE Standard for Local and metropolitan area networks - Part 15.6: Wireless Body Area Networks".

NOTE: Available at https://standards.ieee.org/standard/802_15_6-2012.html.

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

ontology: formal specification of a conceptualization, used to explicit capture the semantics of a certain reality

3.2 Symbols

Void.

3.3 Abbreviations

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

aECG	annotated ECG
API	Application Programming Interface
BAN	Body Area Network
BLE	Bluetooth Low Energy
DICOM	Digital Imaging and Communications in Medicine
DL	Description Logics
dob	date of birth
EC	Eutopean Commission
ECG	ElectroCardioGram
EHAW	eHealth and Ageing Well
EHR	Electronic Health Record
ETSI	European Telecommunications Standards Institute

EWS	Early Warning System
FDA	Food and Drug Administration
FHIR	Fast Healthcare Interoperability Resources
HL7	Health Level Seven International
JSON-LD	JavaScript Object Notation for Linked Data
LA	Left Arm
LL	Left Leg
LSP	Large Scale Pilot
MAC	Medium Access Control
MIPS	Mega (Million) Instructions Per Second
O&M	Observations and Measurements
OGC	Open Geospatial Consortium
OWL2 DL	Web Ontology Language (second edition) Description Logics
OWL-DL	Web Ontology Language Description Logics
RA	Right Arm
RAM	Random Access Memory
RDF	Resource Description Framework
RDF-S	Resource Description Framework Schema
RL	Right Leg
SAREF	Smart Applications REFerence ontology
SAREF4EHAW	SAREF extension for eHealth/Ageing-Well
SAREF4ENVI	SAREF extension for the environment domain
SAREF4WEAR	SAREF extension for Wearables domain
SSN	Semantic Sensor Network
STF	Special Task Force
SWE	Sensor Web Enablement
TC	Technical Committee
TTL	Terse RDF Triple Language (Turtle)
UFO	Unified Foundational Ontology
uom	unit of measurement
URI	Uniform Resource Identifier
US	United States
UUID	Universally Unique IDentifier
UWB	ultra-wideband
WHO	World Health Organization
XML	eXtensible Markup Language

4 SAREF4EHAW ontology and semantics

4.1 Introduction and overview

The objective of SAREF4EHAW is to extend SAREF ontology (see ETSI TS 103 264 [1]) for the eHealth/Ageing-well (EHAW) vertical. Clause 4.1 of the present document shortly introduces a high level view of the envisioned SAREF4EHAW semantic model and modular ontology, with the retained concepts (i.e. classes) and their relations.

SAREF4EHAW extension has been specified and formalized by investigating EHAW domain related resources, as reported in ETSI TR 103 509 [i.7], such as: potential stakeholders, standardization initiatives, alliances/associations, European projects, EC directives, existing ontologies and data repositories. Therefore, SAREF4EHAW modular ontology shall both:

- Allow the implementation of a limited set of typical EHAW related use cases already identified in ETSI TR 103 509 [i.7], i.e.:
  - use case 1 "monitoring and support of healthy lifestyles for citizens";
  - use case 2 "Early Warning System (EWS) and Cardiovascular Accidents detection".
- Fulfil the EHAW related requirements provided in ETSI TR 103 509 [i.7], mainly the ontological ones that were mostly taken as input for the ontology specification.

SAREF4EHAW mainly reuses the following existing ontologies: SAREF (see ETSI TS 103 264 [1]), SmartBAN (see ETSI TS 103 378 [2]), SAREF4ENVI (see ETSI TS 103 410-2 [3]) and SSN (see [i.1]). SAREF4EHAW modular ontology will be fully specified and formalized in clause 4.2 of the present document. Figure 1 presents the high level view of the envisioned model of SAREF4EHAW ontology. In Figure 1, classes directly imported from SAREF ontology are in yellow, classes directly imported from SAREF4ENVI ontology are in pink and finally classes specifically developed for SAREF4EHAW are in blue.

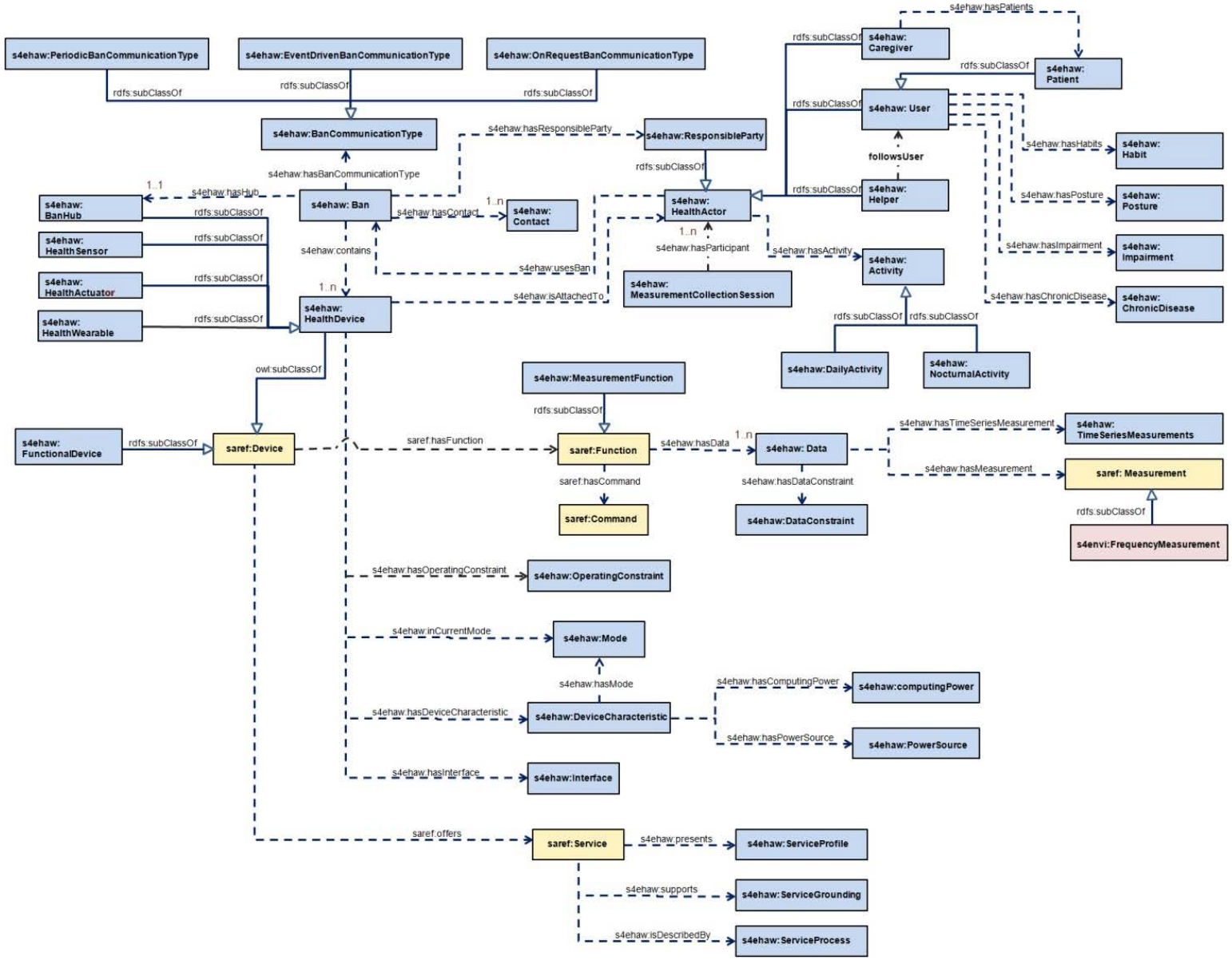

Figure 1: High level view of the envisioned semantic model for SAREF4EHAW ontology

Within Figure 1, as well as within all the figures that are depicted in clause 4 of the present document, the following conventions are used:

- arrows are used to represent properties between classes and to represent some RDF, RDF-S and OWL constructs, more precisely:
  - plain arrows with white triangles represent the *rdfs:subClassOf* relation between two classes. The origin of the arrow is the class to be declared as subclass of the class at the destination of the arrow;
  - dashed arrows between two classes indicate a local restriction in the origin class, i.e. that the object property can be instantiated between the classes in the origin and the destination of the arrow. The identifier of the object property is indicated within the arrow;
  - dashed arrows with no identifier are used to represent the *rdf:type* relation, indicating that the element in the origin of the arrow is an instance of the class in the destination of the arrow;
- datatype properties are denoted by rectangles attached to the classes, in an UML-oriented way. Dashed boxes represent local restrictions in the class, i.e. datatype properties that can be applied to the class they are attached to;
- individuals are denoted by rectangles in which the identifier is underlined.

SAREF4EHAW is extending SAREF ontology for the EHAW vertical and thus shall logically mainly model the following concepts (i.e. classes within Figure 1):

- EHAW system actors (HealthActor class depicted in Figure 1) that are mainly responsibility parties (plays the role of the legal entity responsible for a Body Area Network - BAN -), patients/users, caregivers, helpers. A caregiver (Caregiver class depicted in Figure 1) may have one or multiple patients. A helper (Helper class depicted in Figure 1) may follow one or multiple users and or patients. As also shown in Figure 1, users and patients may have habits (e.g. smoking or overeating), impairments (e.g. visual or mobility), and postures (e.g. sitting or running).
- Health devices (HealthDevice class depicted in Figure 1) that are main components of an eHealth system and are mainly BAN hubs (i.e. Body Area Networks dedicated hubs, BanHub class depicted in Figure 1), Health-dedicated sensors (HealthSensor class depicted in Figure 1, an equivalent class to SAREF Sensor one), Health-dedicated actuators (HealthActuator class depicted in Figure 1, an equivalent class to SAREF Actuator one) and Health-dedicated wearables (HealthWearable class depicted in Figure 1, an equivalent class to SAREF4WEAR Wearable one). Those health devices have a given function (Funtion class depicted in Figure 1) necessary to the accomplishment of the task for which those devices were designed.
- A health device could be attached to one or multiples health actors, for example a caregiver that is using this device for a measurement collection session, a patient whose some vital data are measured by this device. This is modelled through the Contact class as depicted in Figure 1.
- A sensor has a measurement function (MeasurementFunction class depicted in Figure 1) and has measurement data (Data class depicted in Figure 1).
- An actuator is used for an actuation process and does action materialized via the Command class as depicted in Figure 1.
- Wearables, that are smart electronic devices, are also used for monitoring simple/complex vital parameters of patients/users. Wearables are not developed in the present document since they are already fully specified and formalized in ETSI TS 103 410-9 [4]. However, they shall also be listed as possible health-dedicated devices (i.e. through HealthWearable as sub-class of HealthDevice, as depicted in Figure 1).
- BAN (Ban class depicted in Figure 1) that is mainly used for collecting, aggregating and relaying patient or user vital parameters. It shall therefore logically contain BAN-dedicated hubs, health-dedicated sensors, health-dedicated actuators and health-dedicated wearables, as depicted in Figure 1.
- Measurement collection session (MeasurementCollectionSession class depicted in Figure 1) that logically has health actors (at least a caregiver and/or a patient/user) as participants (see Figure 1).

- Measurement data (Data class depicted in Figure 1) that logically has measurement. This measurement is measured in a given unit of measure, and is manly of two types: single value (Measurement class depicted in Figure 1), and time series (TimeSeriesMeasurement class depicted in Figure 1).

For semantic interoperability handling purposes, an ontology based solution, combined with sensing-as-a-service and WoT strategies, is retained for SAREF4EHAW. Therefore, an upper level ontology, at service level, shall also be fully modelled (Service class and sub-classes depicted in Figure 1).

Finally, SAREF4EHAW is an OWL-DL ontology. For embedded semantic analytics purposes, SAREF4EHAW shall be designed using the modularity principle (see ETSI TR 103 509 [i.7]) and can thus be mainly described by the following self-contained knowledge modules: HealthActor, Ban, HealthDevice, Function (measured data related concepts included) and Service. All these SAREF4EHAW modules will be fully detailed in clause 4.2 of the present document. The prefixes and namespaces used in SAREF4EHAW and in the present document are listed in Table 1.

Table 1: Prefixes and namespaces used within the SAREF4EHAW modular ontology

Prefix	Namespace
s4ehaw	https://saref.etsi.org/saref4ehaw/
s4envi	https://saref.etsi.org/saref4envi/
saref	https://saref.etsi.org/core/
ssn-system	http://www.w3.org/ns/ssn/systems/
owl	http://www.w3.org/2002/07/owl#
xsd	http://www.w3.org/2001/XMLSchema#
rdf	http://www.w3.org/1999/02/22-rdf-syntax-ns#
rdfs	http://www.w3.org/2000/01/rdf-schema#
foaf	http://xmlns.com/foaf/0.1/
voaf	http://purl.org/vocommons/voaf#
vann	http://purl.org/vocab/vann/
dcterms	http://purl.org/dc/terms/

4.2 SAREF4EHAW

4.2.0 Introduction

As already introduced in clause 4.1 of the present document SAREF4EHAW is an OWL-DL ontology and shall be designed using the modularity principle (see ETSI TR 103 509 [i.7]) and can thus be mainly described by the following self-contained knowledge modules:

- HealthActor module that models eHealth system actors, i.e. caregivers, patients, users, helpers and responsibility parties (see Figure 1). It is fully specified and formalized in clause 4.2.1 of the present document.

- Ban module that models Body Area Networks or BANs (see Figure 1). It is fully specified and formalized in clause 4.2.2 of the present document.

- HealthDevice module that models health devices, e.g. sensors and actuators (see Figure 1). It is fully specified and formalized in clause 4.2.3 of the present document.

- FunctionalDevice module that models functional devices (see Figure 1). Those devices are non-purely eHealth/ageing-well devices that can be used for modelling/detecting activities or behaviours of patients/users, like for example beacons that can detect indoor positioning of a patient in a house. It is fully specified and formalized in clause 4.2.4 of the present document.

- Function module that models measurement and actuation functions (via the Command class), as well as measurements (see Figure 1). It is fully specified and formalized in clause 4.2.5 of the present document.

- Service module that is introduced for semantic interoperability handling purposes and models health/functional devices as services (see Figure 1). It is fully specified and formalized in clause 4.2.6 of the present document.

4.2.1 HealthActor module

A detailed view of SAREF4EHAW HealthActor module is depicted in Figure 2.

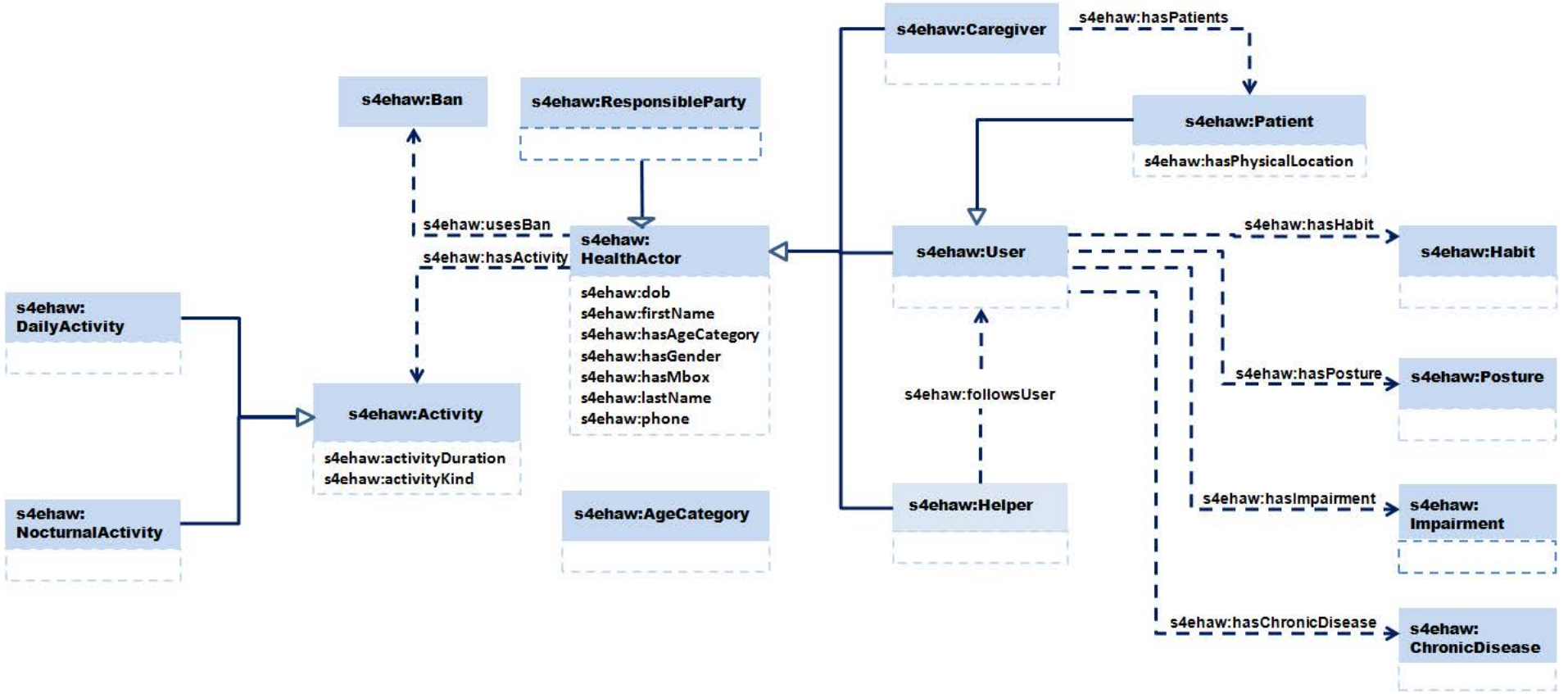

Figure 2: Detailed view of SAREF4EHAW HealthActor module

SAREF4EHAW HealthActor module models the eHealth system actors, i.e. responsible parties (the legal entity responsible for a Body Area Network - BAN -), caregivers, patients, users and helpers (see Figure 2). A health actor also uses a BAN for complex monitoring purposes.

Caregiver, Patient, User, Helper and ResponsibleParty are all sub-classes of HealthActor (*rdfs:subClassOf relation*). Patient and User may have in particular:

- One or multiple activities (*Activity class depicted in Figure 2*), characterized by a kind (e.g. sleeping in bed, sitting on a chair, using the shower, etc.) and a duration (in second).
- Habits (*Habit class depicted in Figure 2*) that should mainly be the following SAREF4EHAW individuals (non-exhaustive): Smoking, AlcoholDrinking, Overeating, Undereating.
- Postures (*Posture class depicted in Figure 2*; sub-class of SAREF Property class) that should mainly be the following SAREF4EHAW individuals (non-exhaustive): Lying, Sitting, Walking, Exercising, Running.
- Impairments (*Impairment class depicted in Figure 2*) that should mainly be the following SAREF4EHAW individuals (non-exhaustive): AuralImpairement, SkeletalImpairment, OcularImpairement, MobilityImpairment, IntellectualImpairement. Those impairments (non exhaustive) are compatible with the World Health Organization (WHO) classification (see https://apps.who.int/iris/bitstream/handle/10665/41003/9241541261_eng.pdf;jsessionid=6AB8BF561C227503A5B55496EB606C36?sequence=1).
- Chronic Disease (*ChronicDisease class depicted in Figure 2)* that should mainly be the following SAREF4EHAW individuals (non-exhaustive): Diabetes, Asthma.

The object properties defined for SAREF4EHAW HealthActor module are described in Table 2. The data properties defined for SAREF4EHAW HealthActor module are described in Table 3.

Table 2: List of object properties of SAREF4EHAW HealthActor module

Object property	Domain	Range	Definition
s4ehaw:followsUser	s4ehaw:Helper	s4ehaw:User	A helper may follow one or multiple users that can in particular be patients.
s4ehaw:hasActivity	s4ehaw:HealthActor	s4ehaw:Activity	A health actor may have one or multiple activities.
s4ehaw:hasAgeCategory	s4ehaw:HealthActor	s4ehaw:AgeCategory	The age group of a health actor, e.g. old or young.
s4ehaw:hasHabit	s4ehaw:User	s4ehaw:Habit	The habits of a user and a patient (as sub-class of user it also inherits habit), e.g. smoking or overeating.
s4ehaw:hasChronicDisease	s4ehaw:Patient	s4ehaw:ChronicDisease	A patient can suffer from one or more chronic disease like Diabetes, azma, etc.
s4ehaw:hasImpairment	s4ehaw:User	s4ehaw:Impairment	The impairment type of a user and a patient (as sub-class of user it also inherits impairment), e.g. aural, skeletal, ocular, mobility, intellectual, etc.
s4ehaw:hasPatient	s4ehaw:Caregiver	s4ehaw:Patient	A caregiver may have one or multiple patients.
s4ehaw:hasPosture	s4ehaw:User	s4ehaw:Posture	The posture of a user and a patient (as sub-class of user it also inherits posture), e.g. exercising, lying, running, sitting, walking, etc.
s4ehaw:hasPhysicalLocation	s4ehaw:Patient	s4ehaw:PhysicalLocation	Defines the physical location of the patient, i.e. its postal address and/or its geolocation (*when available*).
s4ehaw:usesBan	s4ehaw:HealthActor	s4ehaw:Ban	A health actor (*e.g. a caregiver, a patient or a helper*) uses a BAN for collecting, aggregating and relaying vital parameters.

Table 3: List of data properties of SAREF4EHAW HealthActor module

Data Property	Domain	Range	Definition
s4ehaw:activityDuration	s4ehaw:Activity	xsd:float	The duration of an activity, in second.
s4ehaw:activityKind	s4ehaw:Activity	xsd:string	The kind of activities that a patient or a user can have, e.g. e.g. sleeping in bed, sitting on a chair, using the shower, etc.
s4ehaw:dob	s4ehaw:HealthActor	xsd:dateTime	The date of birth of a health actor.
s4ehaw:firstName	s4ehaw:HealthActor	xsd:string	The first name of a health actor.
s4ehaw:hasGender	s4ehaw:HealthActor	{"male", "female", "undetermined"}	The gender of a health actor.
s4ehaw:hasMbox	s4ehaw:HealthActor	xsd:anyURI	An email address (*or mail box*) of a health actor: a URI with the 'mailto' scheme as defined by IETF RFC 6068 [i.8].
s4ehaw:lastName	s4ehaw:HealthActor	xsd:string	The family name of a health actor.
s4ehaw:Phone	s4ehaw:HealthActor	xsd:string	The phone number of a health actor, in international format.

4.2.2 Ban module

A detailed view of SAREF4EHAW Ban module is depicted in Figure 3.

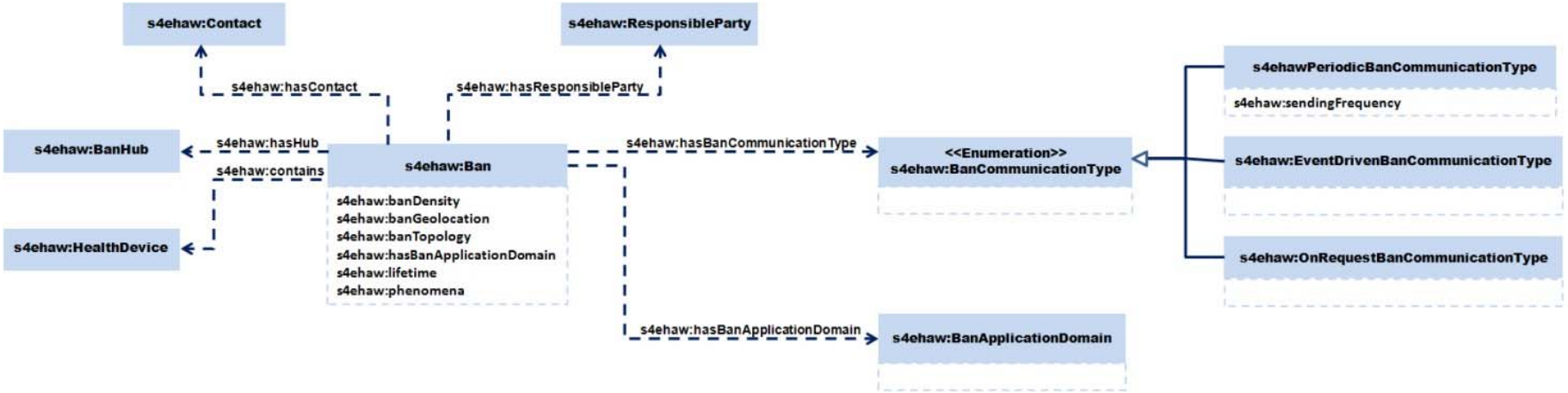

Figure 3: Detailed view of SAREF4EHAW Ban module

A BAN (*Ban* class depicted in Figure 3) is mainly used for collecting, aggregating and relaying patient or user vital parameters, thus for complex monitoring purposes. It therefore contains health devices, and has a hub (playing both the BAN network gateway and the data concentrator roles) as depicted in Figure 3. A BAN has also application domains (*class BanApplicationDomain depicted in Figure 3*) that are mainly the following SAREF4EHAW individuals: Healthcare, Telemedicine, AssistedLiving, SportTraining, PervasiveComputing, Safety, Emergency.

As shown in Figure 3, a BAN has:

- Contact that shall be a health actor. The Contact class is an equivalent class (*owl:equivalentClass* relation) of the HealthActor class (already detailed in clause 4.2.1 of the present document) and is thus not detailed again in clause 4.2.3 of the present document.
- Responsible party that plays the role of the legal entity responsible for a BAN. ResponsibleParty class, already detailed in clause 4.2.1 of the present document, is thus not detailed again in clause 4.2.3 of the present document.
- BAN communication type (*class BANCommunicationType depicted in Figure 3*) that is either periodic, event driven or on demand, as depicted in Figure 3.

The object properties defined for SAREF4EHAW Ban module are described in Table 4. The data properties defined for SAREF4EHAW Ban module are described in Table 5.

Table 4: List of object properties of SAREF4EHAW Ban module

Object property	Domain	Range	Definition
s4ehaw:contains	s4ehaw:Ban	s4ehaw:HealthDevice	A Body Area Network or BAN contains one or multiple health devices.
s4ehaw:hasHub	s4ehaw:Ban	s4ehaw:Hub	A Body Area Network or BAN has one hub mainly playing the role of both a data concentrator and a network gateway.
s4ehaw: hasBanApplicationDomain	s4ehaw:Ban	s4ehaw:BanApplicationDomain	The BAN application domain - healthcare, telemedicine, assisted living, sport training, pervasive computing, safety and emergency... -.
s4ehaw: hasBanCommunicationType	s4ehaw:Ban	s4ehaw:BanCommunicationType	A BAN has a BAN communication type that is the type of communication carried out between BAN devices and BAN Hub.
s4ehaw:hasContact	s4ehaw:Ban	s4ehaw:Contact	A BAN has one or multiple contacts (*e.g. the patient or user that is monitored through this BAN, the caregiver that is using this BAN for monitoring purposes*).
s4ehaw:hasResponsibleParty	s4ehaw:Ban	s4ehaw:ResponsibleParty	A BAN has a responsible party which plays the role of the legal entity responsible for this BAN (e.g. to contact in case of problem). It should be an organization or a person.

Table 5: List of data properties of SAREF4EHAW Ban module

Data Property	Domain	Range	Definition
s4ehaw:banDensity	s4ehaw:Ban	xsd:long	The BAN density, e.g. its number of node.
s4ehaw: banGeolocation	s4ehaw:Ban	xsd:string	The geolocation of the BAN, when available and needed, shall be given relatively to the current location - geolocation as standardized ISO 6709 [i.9] e.g. +40.75-074.00/ - of the patient wearing the BAN.
s4ehaw:banTopology	s4ehaw:Ban	{"Adhoc", "Star", "Mesh"}	The BAN physical topology type, e.g. Adhoc or Star or Mesh.
s4ehaw:lifetime	s4ehaw:Ban	xsd:float	The BAN lifetime (in month), e.g. BAN for entertainment purposes should have a lifetime of weeks or few years whereas BAN dedicated for assisted living or anomaly monitoring should last for many years.
s4ehaw:phenomena	s4ehaw:Ban	xsd:string	The BAN monitors a specific phenomenon (*burned calories during exercises, glucose level...*).
s4ehaw: sendingFrequency	s4ehaw: PeriodicBanCommunicationType	xsd:float	Defines the sending frequency (in ms) at health device level.

4.2.3 HealthDevice module

A detailed view of SAREF4EHAW HealthDevice module is depicted in Figure 4.

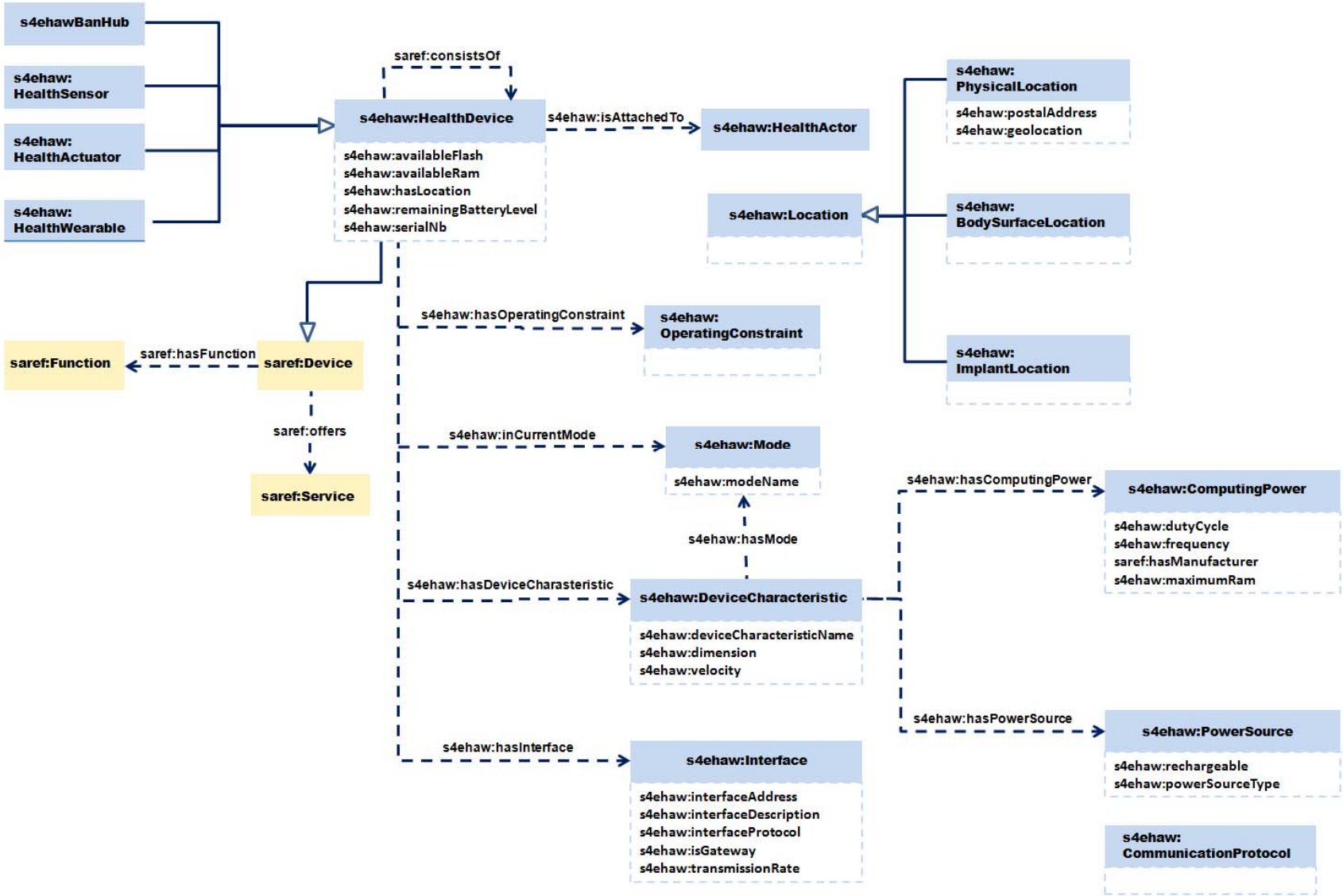

Figure 4: Detailed view of SAREF4EHAW HealthDevice module

As depicted in Figure 4, an HealthDevice is a sub-class of SAREF Device class (*rdfs:subClassOf relation*). A *HealthDevice* has a given function (e.g. a heart rate measurement function) and offers services (e.g. a heart rate measurement service), both inherited form SAREF Device, and is also attached to a health actor (e.g. a patient and/or a caregiver). It has a location (*Location class, as depicted in Figure 4*), which can be either:

- its position against the body (i.e. on the body surface - Class BodySurfaceLocation - or in the body - Class ImplantLocation -, as depicted in Figure 4);
- or its physical location (Class PhysicalLocation as depicted in Figure 4), i.e. its postal address and/or its current geolocation (when available).

As shown in Figure 4, a health device also has:

- DeviceCharacteristic that models the physical characteristics of the device (e.g. its dimension). The DeviceCharacteristic has predefined modes that are used to model the dynamic characteristic of an eHealth device (i.e. modes can vary during the health device lifetime) and that are mainly the following: active, hold, beacon.
- Interface that models the data transmission and network protocol related interface of the device (e.g. serial or wireless interface, address, transmission rate, etc.).

The power source characteristics (i.e. everything related to energy sources and batteries) and the computing power characteristics (i.e. everything related to processing power and memory) of a health device are also modelled within dedicated classes (respectively *PowerSource* and *ComputingPower* classes, as depicted in Figure 4).

Figure 4 also shows that *HealthSensor*, *HealthActuator*, *HealthWearable* and BanHub classes are all sub-classes of HealthDevice class (*rdfs:subClassOf relation*). *HealthSensor* and *HealthActuator* classes are both equivalent to SAREF Sensor/Actuator ones. They will therefore not be described within clause 4.2.3 of the present document in order to reduce duplication with SAREF documentation (see ETSI TS 103 264 [1] for details). *HealthWearable* class is equivalent to SAREF4WEAR Wearable class. It will therefore not be described within clause 4.2.3 of the present document in order to reduce duplication with SAREF4WEAR documentation (see ETSI TS 103 410-9 [4] for details).

Finally and for reducing duplication with SAREF documentation, the reader is referred to the SAREF specification ETSI TS 103 264 [1] for details about all the classes that are reused from SAREF within Figure 4.

The object properties defined for SAREF4EHAW HealthDevice module are described in Table 6. The data properties defined for SAREF4EHAW HealthDevice module are described in Table 7.

Table 6: List of object properties of SAREF4EHAW HealthDevice module

Object property	Domain	Range	definition
saref:consistsOf	s4ehaw: HealthDevice	s4ehaw: HealthDevice	Defines the fact that an eHealth device can be a composite health device that consists of one or multiple sub-devices.
s4ehaw: hasComputingPower	s4ehaw: DeviceCharacteristic	s4ehaw: ComputingPower	A health device characteristic describing the processing power or capabilities of the device (*e.g. processor ID and manufacturer, duty cycle, available flash/RAM memory, maximum flash/RAM memory, etc.*).
s4ehaw: hasDeviceCharacteristic	s4ehaw:HealthDevice	s4ehaw: DeviceCharacteristic	A health device has device characteristic describing the physical characteristics of the health device, e.g. its dimensions.
s4ehaw:hasInterface	s4ehaw:HealthDevice	s4ehaw:Interface	A health device has one or multiple interfaces (Bluetooth, UWB, IEEE 802.15.6 [i.10], serial interface, etc.).
s4ehaw:hasLocation	s4ehaw:HealthDevice	s4ehaw:Location	The location of an eHealth device, i.e. its position against the body (*on - body surface - or in the body - implant -*) and its physical location (*i.e. its postal address and/or its current geolocation when available*).
s4ehaw:hasMode	s4ehaw: DeviceCharacteristic	s4ehaw:Mode	Each device has modes of operations that model its dynamic characteristic varying during its lifetime, e.g. active, hold, beacon, etc.
s4ehaw: hasOperatingConstraint	s4ehaw:HealthDevice	s4ehaw: OperatingConstraint	The operating constraints of a health device, e.g. recommended humidity and temperature range, etc.
s4ehaw:hasPowerSource	s4ehaw: DeviceCharacteristic	s4ehaw:PowerSource	A health device type has power sources, mainly describing energy source and battery related capabilities of the health device (*number of power source, source type, rechargeable or not, available power level, etc.*).
s4ehaw:inCurrentMode	s4ehaw:HealthDevice	s4ehaw:Mode	Each eHealth device has modes of operations that model its dynamic characteristic varying during its lifetime, e.g. active, hold, beacon, etc.
s4ehaw:interfaceProtocol	s4ehaw:Interface	s4ehaw: CommunicationProtocol	The interface communication protocol can be e.g. BLE, serial, Ethernet, etc.
s4ehaw:isAttachedTo	s4ehaw:HealthDevice	s4ehaw:HealthActor	A health Device is attached to a health actor such as a patient, a user and or a caregiver.

Table 7: List of data properties of SAREF4EHAW HealthDevice module

Data Property	Domain	Range	Definition
s4ehaw:availableFlash	s4ehaw:HealthDevice	xsd:long	The available flash memory (in byte) of a health device. It is a dynamic attribute.
s4ehaw:availableRam	s4ehaw:HealthDevice	xsd:long	Indicates the available volatile memory space (in byte) of a health device. It is a dynamic attribute.
s4ehaw: deviceCharacteristicName	s4ehaw: DeviceCharacteristic	xsd:string	The commercial name of a device.
s4ehaw:dimension	s4ehaw: DeviceCharacteristic	xsd:string	The dimension of the device i.e. height*weight*length string.
s4ehaw:dutyCycle	s4ehaw:ComputingPower	xsd:int	The duty cycle for each health device embedded processor, in percent.
s4ehaw:frequency	s4ehaw:ComputingPower	xsd:float	The frequency is the number of instructions an embedded processor - within a health device - can perform per second (MIPS).
s4ehaw:geolocation	s4ehaw:PhysicalLocation	xsd:string	The geolocation, when available, shall be given relatively to the current location - geolocation as standardized in ISO 6709 [i.9], e.g. +40.75-074.00/ -.
s4ehaw:interfaceAddress	s4ehaw:Interface	xsd:string	The interface address. The interface may have many addresses like MAC address, IP address or others.
s4ehaw:interfaceDescription	s4ehaw:Interface	xsd:string	The interface type description.
s4ehaw:isGateway	s4ehaw:Interface	xsd:boolean	This boolean variable indicates if the interface is a gateway or not.
saref:hasManufacturer	s4ehaw:ComputingPower	xsd:string	The manufacturer name of the embedded processor of a health device, e.g. Intel.
s4ehaw:maximumFlash	s4ehaw:ComputingPower	xsd:long	Indicates the maximum flash memory space (in byte) of a health device.
s4ehaw:maximumRam	s4ehaw:ComputingPower	xsd:long	Indicates the maximum volatile memory space (in byte) of a health device.
s4ehaw:modeName	s4ehaw:Mode	xsd:string	The mode name of a device, e.g. sleeping.
s4ehaw:postalAddress	s4ehaw:PhysicalLocation	xsd:string	Defines the postal address.
s4ehaw:rechargeable	s4ehaw:PowerSource	xsd:boolean	This boolean variable indicates if the power source is rechargeable or not, e.g. a rechargeable battery.
s4ehaw: remainingBatteryLevel	s4ehaw:HealthDevice	xsd:int	The level of remaining battery (*if any, in percent*) for a health device. It is a dynamic attribute.
s4ehaw:serialNb	s4ehaw:HealthDevice	xsd:string	The serial number of a health device.
s4ehaw:powerSourceType	s4ehaw:PowerSource	xsd:string	The type of power source of a health device. It can be solar, battery, electricity, etc.
s4ehaw:transmissionRate	s4ehaw:Interface	xsd:float	The transmission rate of the interface, i.e. the number of bits transmitted per second (*usually expressed in kbps or Mbps*).
s4ehaw:velocity	s4ehaw: DeviceCharacteristic	xsd:float	The velocity of a moving device (in m/s).

4.2.4 FunctionalDevice module

FunctionalDevice are non-purely eHealth/ageing-well devices that can be used for modelling/detecting activities or behaviours of patients/users, like for example beacons that can detect indoor positioning of a patient in a house.

A functional device is a sub-class of SAREF *Device* class (*rdfs:subClassOf relation*) and shall thus have exactly the same object and data properties. Therefore and for reducing duplication with SAREF documentation, It will not be detailed in clause 4.2.4 of the present document and the reader is referred to the SAREF specification (ETSI TS 103 264 [1]).

4.2.5 Function module

A detailed view of SAREF4EHAW Function module is depicted in Figure 5.

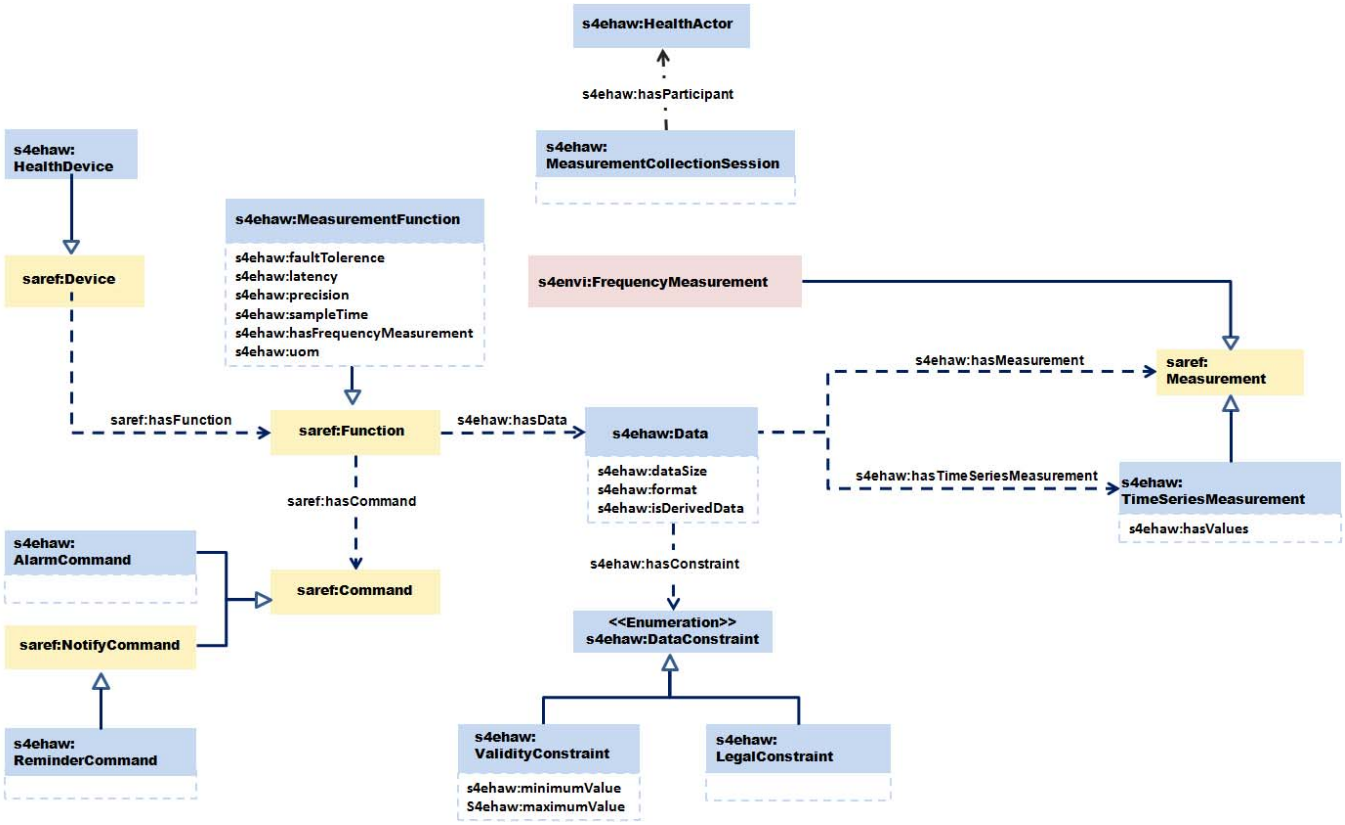

Figure 5: Detailed view of SAREF4EHAW Function module

SAREF4EHAW Function module models the measurement and actuation functions, as well as measurements (see Figure 5).

As shown in Figure 5, a function has:

- Command (e.g. an actuation command or a command for getting a body temperature measurement). Alarms (*class AlarmCommand*) are considered as SAREF commands (*rdfs:subClassOf relation*) and reminders (*class ReminderCommand*) are considered as SAREF notify commands (*rdfs:subClassOf relation*), as depicted in Figure 5.

- Data, that has both data constraints (such as validity or legal constraints) and measurement (single or time series measurements) that are measured in a given unit of measure, as depicted in Figure 5 (*DataConstraint, Measurement* and *TimeSeriesMeasurement classes*).

- The *TimeSeriesMeasurement* is inspired on existing classes from other standards in the health domain (listed in Table 8). This class represents a sequence of data in a successive equally spaced points in time (i.e. with a fixed frequency) measured by a health device, e.g. ECG time series data measured by an ECG device during a recording session.

Table 8: Classes representing Time Series from other data models

Class	Source(s)	Definition
Sample sequence	UFO ECG [i.2]	Collective: "ordered sequence of samples resulting from an *Observation series*" (*ecgOnto:095*).
Observation series	UFO ECG [i.2]	Complex event: "Series of observations evenly spaced in time carried out in an ECG Recording session" (*ecgOnto:093*).
Sampled data (Observation.component.value SampledData)	HL7 FHIR® [i.3]	"Data that come from a series of measurements taken by a device, which may have upper and lower limits".
Time Series Observation	OGC O&M (*ISO 19156*) [i.4]	"observation whose result is a time-series".
Series	HL7 aECG [i.5]	"Contains one or more sequence sets sharing a common frame of reference".
Series (General Series Module)	DICOM® [i.6]	A property of General ECG that "specifies the attributes that identify and describe general information about the *Series* within a *Study*". A *Series* is as a sequence of data elements sharing a common frame of reference.

Figure 5 also shows that a measurement function (a sub-class of SAREF *Function* class, *rdfs:subClassOf relation*), in case of complex measurements such as time series provided by ECG devices (sequences of data in a successive equally spaced points in time), shall have a frequency measurement attribute (*hasFrequencyMeasurement*) that is the frequency in which the measurements are made.

Finally and for reducing duplication with both SAREF and SAREF4ENVI documentation, the reader is referred to the SAREF and SAREF4ENVI specifications (ETSI TS 103 264 [1], ETSI TS 103 410-2 [3]) for details about all the classes that are reused from SAREF within Figure 5.

The object properties defined for SAREF4EHAW Function module are described in Table 9. The data properties defined for SAREF4EHAW Function module are described in Table 10.

Table 9: List of object properties of SAREF4EHAW Function module

Object property	Domain	Range	definition
saref:hasCommand	saref:Function	saref:Command	A function has a command (*a directive that a health device is supporting to perform a given function*).
s4ehaw:hasDataConstraint	s4ehaw:Data	s4ehaw:DataConstraint	Defines the relationship between a data that has constraints (*validity, legal, etc.*).
s4ehaw:hasData	saref:Function	s4ehaw:Data	A function has one or many data, for example a tracking function shall include latitude, longitude and speed data.
s4ehaw: hasFrequencyMeasurement	s4ehaw: MeasurementFunction	s4envi: FrequencyMeasurement	A measurement function, in case of complex measurement like time series, has frequency measurement, i.e. the frequency in which it makes measurements.
s4ehaw:hasMeasurement	s4ehaw:Data	saref:Measurement	Defines the relationship between data that has measurement.
s4ehaw:hasParticipant	s4ehaw: MeasurementSession	s4ehaw:HealthActor	A measurement session has health actors as participants (*caregiver controlling the session, patient monitored during the session*).
s4ehaw: hasTimeSeriesMeasurement	s4ehaw:Data	s4ehaw: TimeSeriesMeasurement	Data has time series measurements, a sequence taken at successive equally spaced points in time.
s4ehaw:precision	s4ehaw: MeasurementFunction	ssn-system:Precision	Precision refers to the degree of reproducibility of a measured quantity (*when the same quantity is measured several times how close are the measurements from each other*).
s4ehaw:uom	s4ehaw: MeasurementFunction	saref:UnitOfMeasure	Defines the unit of measure of a measurement function.

Table 10: List of data properties of SAREF4EHAW Function module

Data Property	Domain	Range	Definition
s4ehaw:dataSize	s4ehaw:Data	xsd:positiveInteger	The data size represents the size of the data in bytes
s4ehaw: faultTolerence	s4ehaw: MeasurementFunction	xsd:double	Defines the error rate tolerated for a measurement function.
s4ehaw:format	s4ehaw:Data	xsd:anyURI	The format is a URI for a standard format like e.g. integer.
s4ehaw:hasValues	s4ehaw: TimeSeriesMeasurement	xsd:decimal	A relationship defining the set of values (*an ordered array of numbers*) of a certain property, e.g. heart rate. Attention: to assure ordering in the serialization format, it is necessary to use either rdf:Seq (*RDF/XML*) or @list (*JSON-LD*).
s4ehaw:isDerivedData	s4ehaw:Data	xsd:boolean	Is derived data is a Boolean property to indicate if the data is a row data or a calculated/derived data from other one.
s4ehaw:latency	s4ehaw: MeasurementFunction	xsd:float	The latency is the time interval between the stimulation and response of a measurement function (in ms).
s4ehaw:maximumValue	s4ehaw:ValidityConstraint	xsd:decimal	The maximum allowable value of a measurement.
s4ehaw:minimumValue	s4ehaw:ValidityConstraint	xsd:decimal	The minimum allowable value of a measurement.
s4ehaw:sampleTime	s4ehaw: MeasurementFunction	xsd:int	The sample time of a measurement function (a discrete integer).

4.2.6 Service module

A detailed view of SAREF4EHAW Service module is depicted in Figure 6.

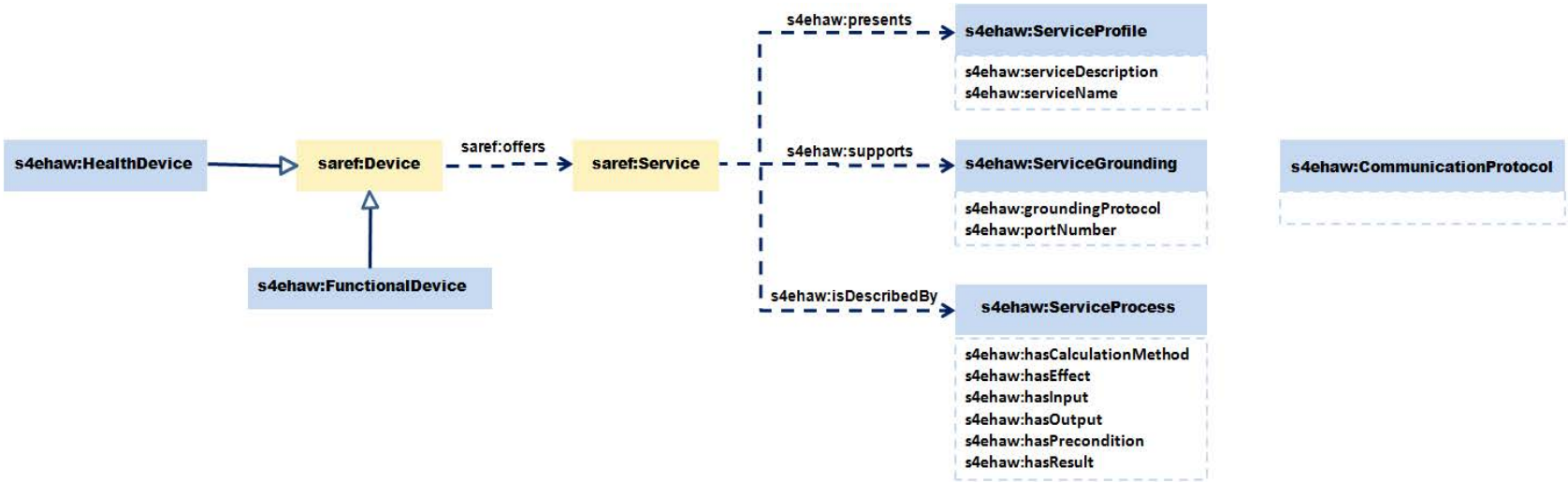

Figure 6: Detailed view of SAREF4EHAW Service module

SAREF4EHAW Service module is introduced for semantic interoperability handling purposes and models health/functional devices as services. Therefore and as depicted in Figure 6, a health device (as well as a functional device) offers services (inherited from SAREF Device).

As shown in Figure 6, a service:

- presents a service profile that models what the service does and enables automatic service discovery;
- supports service grounding that models data exchange and communication protocol related information (i.e. how to access the service);
- is described by a service process that models the ways a service is working, i.e. how to invoke it.

Finally and for reducing duplication with SAREF documentation, the reader is referred to the SAREF specification [1] for details about the Service class that is reused from SAREF within Figure 6.

The object properties defined for SAREF4EHAW Service module are described in Table 11. The data properties defined for SAREF4EHAW Service module are described in Table 12.

Table 11: List of object properties of SAREF4EHAW Service module

Object property	Domain	Range	definition
s4ehaw:groundingProtocol	s4ehaw: ServiceGrounding	s4ehaw:CommunicationProtocol	The grounding protocol is the protocol used to transmit the message by the service, e.g. BLE.
s4ehaw:isDescribedBy	saref:Service	s4ehaw:ServiceProcess	A service is described by a service process (*how the service works*).
s4ehaw:presents	saref:Service	s4ehaw:ServiceProfile	A service presents a service profile (*what the service does*).
s4ehaw:supports	saref:Service	s4ehaw:ServiceGrounding	A service supports a service grounding (*how to access the service*).

Table 12: List of data properties of SAREF4EHAW Function module

Data Property	Domain	Range	Definition
s4ehaw: hasCalculationMethod	s4ehaw:ServiceProcess	xsd:string	The service process has a calculation method to get the output or result, e.g. the calculation formula to determine the posture of a patient.
s4ehaw:hasEffect	s4ehaw:ServiceProcess	xsd:string	The effect of a service can be an alert, nothing, an activation of another process, etc.
s4ehaw:hasInput	s4ehaw:ServiceProcess	xsd:string	The service process has data input like e.g. the patient ID, the timestamp, the read value from a sensor, etc.
s4ehaw:hasOutput	s4ehaw:ServiceProcess	xsd:string	The output is e.g. the calculated value returned by the process, e.g. the posture of a patient.
s4ehaw:hasPrecondition	s4ehaw:ServiceProcess	xsd:string	The conditions that are imposed over the inputs of the process and the process is holding to be successfully invoked.
s4ehaw:hasResult	s4ehaw:ServiceProcess	xsd:string	The process can have many results for the same output. Those results may include a message that should be displayed, an alert, etc.
s4ehaw:portNumber	s4ehaw: ServiceGrounding	xsd:positiveInteger	The port number used to offer the service.
s4ehaw: serviceDescription	s4ehaw:ServiceProfile	xsd:string	The service description should describe the offered service like e.g. heart rate measurement.
s4ehaw:serviceName	s4ehaw:ServiceProfile	xsd:string	The service name identifies the offered service, e.g. heart rate.

4.3 Instantiating SAREF4EHAW

4.3.1 Monitoring and support of healthy lifestyles for citizens, in the current context of Covid-19

This use case is about a patient of around 50 years old, Bob, with overeating habit. In the actual context of Covid-19, Bob as a risky patient is thus remotely followed/monitored/controlled by a caregiver, Dr. Knock, for Covid-19 signs detection purposes. Our patient is equipped with a BAN with an android smartphone as the BAN hub, as well as three COVID-19 related devices (wearables, sensors). Bob is equipped with SpireStone wearable device for breathing rate monitoring, a ScanWatch wearable for monitoring the SPO2 level and a TUCKY thermometer for the body temperature monitoring. Thus, using SAREF4EHAW ontology and has depicted in Figure 7:

- Bob is created as a `s4ehaw:Patient` that uses (`s4ehaw:usesBan` property) Bob monitoring BAN (a `s4ehaw:Ban`).
- Bob has a habit (a `s4ehaw:Habit`) of `Overeating` (`s4ehaw:hasHabit` property).
- Dr. Knock is created as a `s4ehaw:Caregiver` that has Bob as patient (`s4ehaw:hasPatient` property).
- SpireStone and ScanWatch wearables, as well as TUCKY thermometer, are health devices (`s4ehaw:HealthDevice`) that are attached to Bob (`s4ehaw:isAttachedTo` property).
- Finally Bob monitoring BAN has Bob has contact (`s4ehaw:hasContact` property).

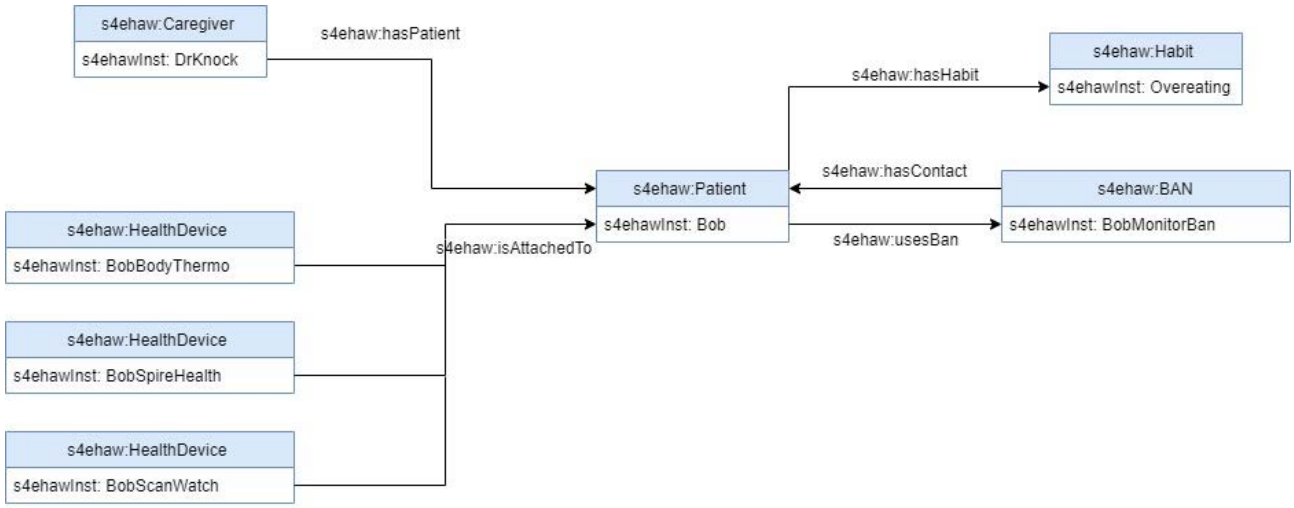

Figure 7: Patient Bob individuals

Figure 8 depicts the SpireStone wearable device (a `s4ehaw:HealthDevice`) of Bob (a `s4ehaw:Patient`), as described using SAREF4EHAW extension.

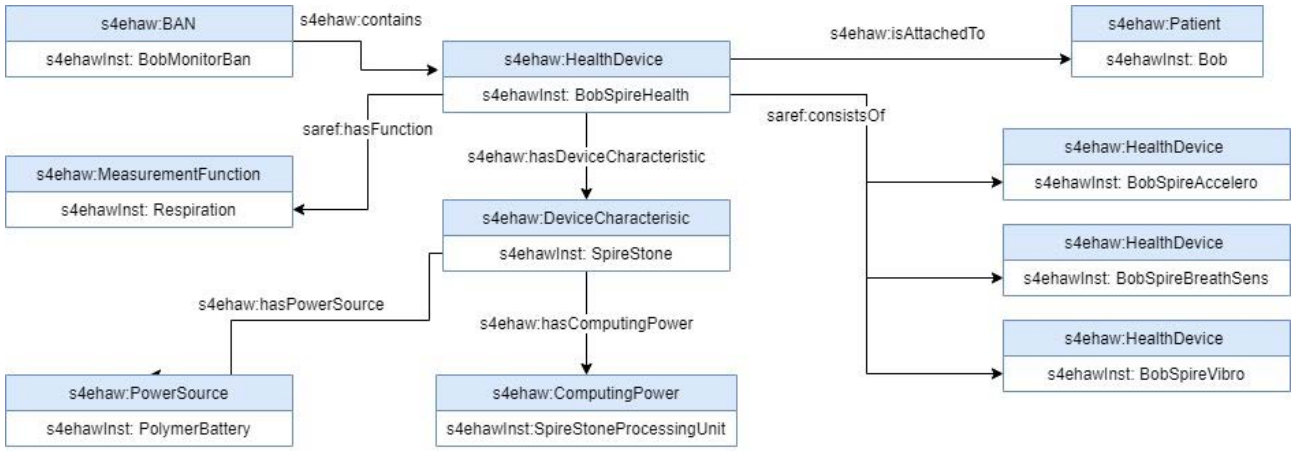

Figure 8: BobSpireStone HealthDevice individuals

As depicted in Figure 8, Bob SpireStone wearable, called `BobSpireHealth`, consists of three embedded sensors (`s4ehaw:consistsOf` property) that are health devices (`s4ehaw:HealthDevice`): an accelerometer (`BobSpireAccelero`), a vibration monitor (`BobSpireVbro`) and a breath rate sensor (`BobSpireBreathSens`). In the case presented in clause 4.3.1 of the present document, the Respiration function of this device will only be described as it measures the respiratory rate in bpm which is one of the key COVID-19 indicators to monitor. Figure 8 also shows that the SpireStone wearable (`BobSpireHealth`) is contained in Bob monitoring BAN (`s4ehaw:contains` property) and is also attached to Bob (`s4ehaw:isAttachedTo` property).

Each of `BobSpireHealth` sensors has a certain function (`saref:hasFunction` property), as depicted in Figure 8. For example, the `BobSpireBreathSens` sensor has a respiration measurement function (a `s4ehaw:MeasurementFunction`), called `Respiration` and described in Figure 9.

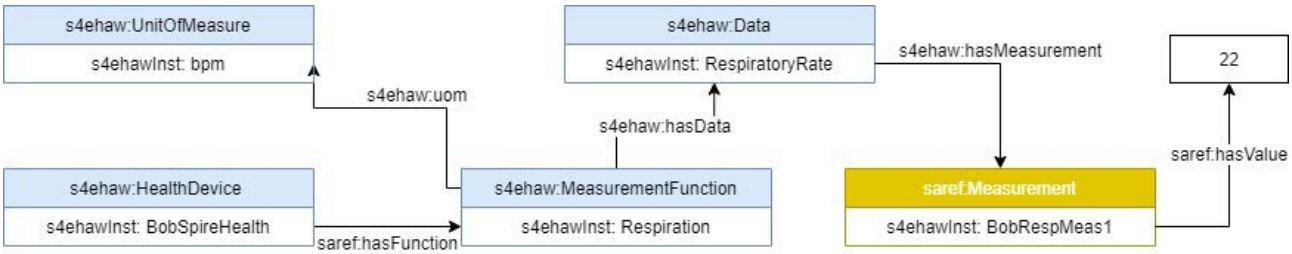

Figure 9: Respiration function individuals

Figure 9 shows that `Respiration` measurement function has data (`s4ehaw:hasData` property), a respiratory rate (a `s4ehaw:Data`) that has bpm (a `saref:UnitOfMeasure`) as unit of measure (`s4ehaw:uom` property).

Figure 10 depicts the ScanWatch wearable device (a `s4ehaw:HealthDevice`) of Bob (a `s4ehaw:Patient`), as described using SAREF4EHAW extension.

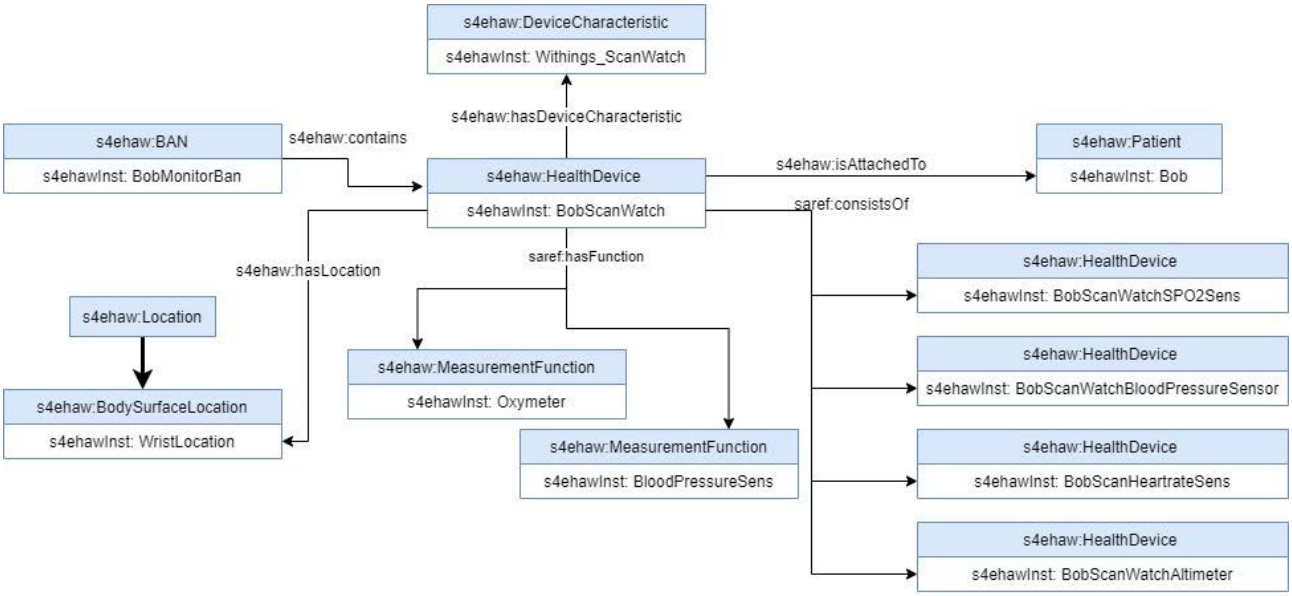

Figure 10: Bob's Scan Watch individuals

As depicted in Figure 10, Bob is using the Withings_ScanWatch wearable (a `s4ehaw:HealthDevice`) that consists of many embedded sensors (`s4ehaw:consistsOf` property): an altimeter, a combined SPO2/heart rate sensor, and three electrodes for ECG. In the case of COVID-19 prevention, SPO2 level and heart rate can be described. This Scan watch is placed (`s4ehaw:hasLocation` property) around the wrist (`WristLocation`) and has two functions (`s4ehaw:hasFunction`): an oxymeter measurement and a systolic pressure measurement.

Figure 11 describes the `Oxymeter` measurement function (a `s4ehaw:MeasurementFunction`): it has data (`s4ehaw:hasData` property), a SPO2 level (a `s4ehaw:Data`).

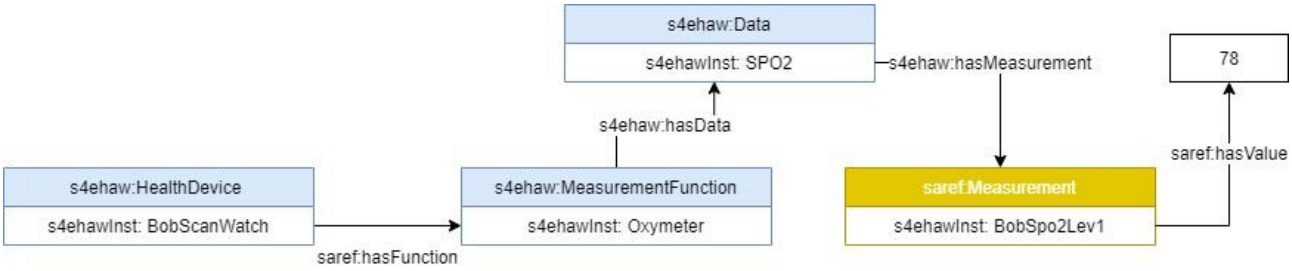

Figure 11: Oxymeter Function individuals

Figure 12 shows the `SystolicPressureSens` measurement function which has data (`s4ehaw:hasData` property) the `SystolicPressure` (a `s4ehaw:Data`). It is measured in (a `s4ehaw:unitOfMeasure`) mmHG.

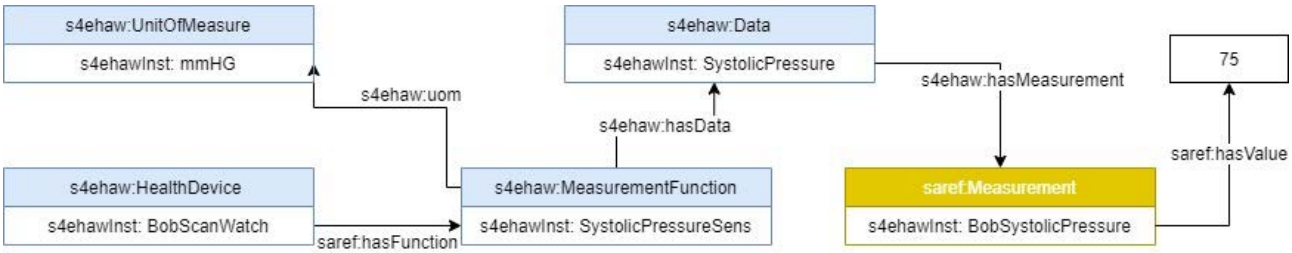

Figure 12: Systolic Pressure function Individuals

Figure 13 describes the third device which is the TUCKY Thermometer (a `s4ehaw:HealthDevice`) of Bob (a `s4ehaw:Patient`) called `BobBodyThermo`. It is a sensor patch that is ideally placed (`s4ehaw:hasLocation` property) on the body surface under the armpit (`ArmpitLocation`, a `s4ehaw:BodySurfaceLocation`) and which function is to measure accurately the body temperature in degree Celsius.

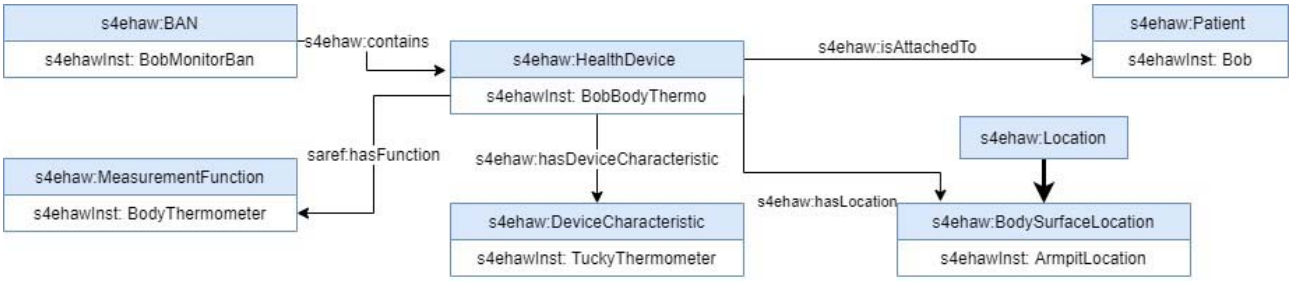

Figure 13: Bob's Thermometer Health device individuals

Figure 14 describes the `BodyThermometer` measurement function (a `s4ehaw:MeasurementFunction`).

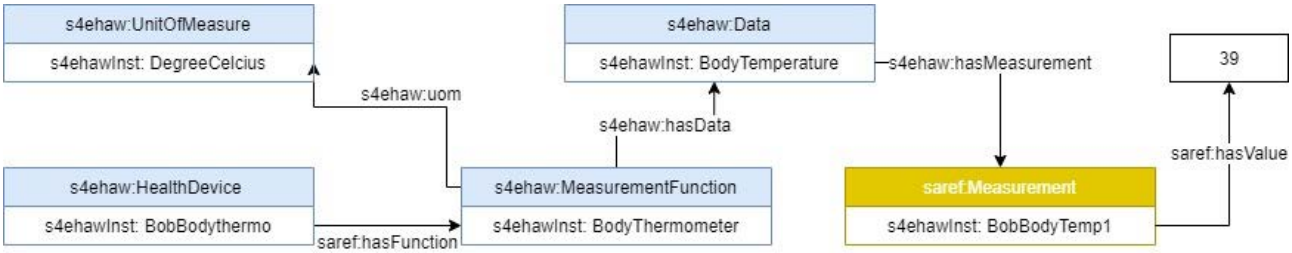

Figure 14: Body's temperature function individuals

As depicted in Figure 14, the `BodyThermometer` measurement function has data (`s4ehaw:hasData` property), the `BodyTemperature` (a `s4ehaw:Data`) that has `DegreeCelcius` (a `saref:UnitofMeasure`) as unit of measure (`s4ehaw:uom` property).

Figure 15 describes `BobMonitorBan`, the BAN (a `s4ehaw:Ban`) that Bob (a `s4ehaw:Patient`) uses (`s4ehaw:usesBan` property) for vital parameters monitoring purposes.

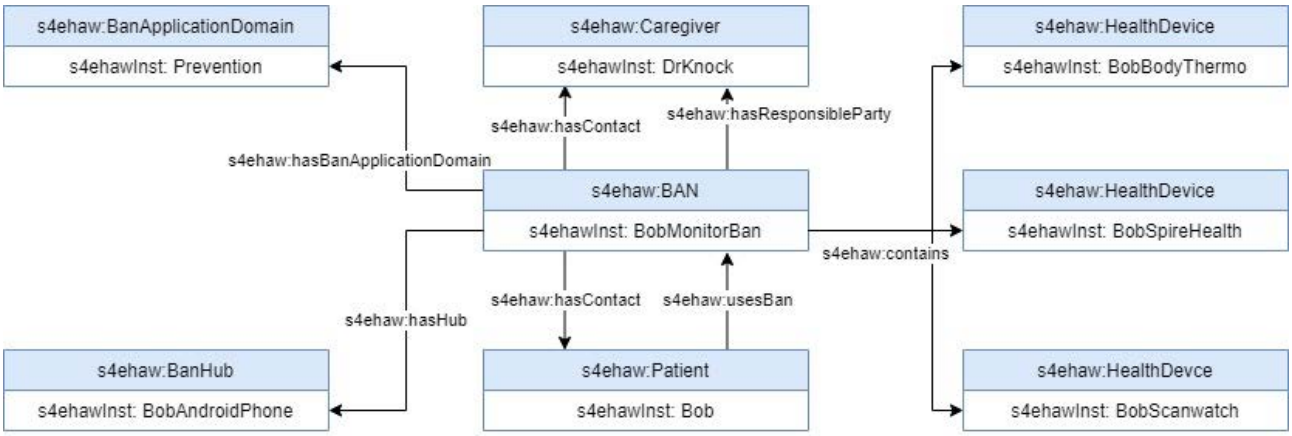

Figure 15: Bob's BAN individuals

Since Bob is using three s4ehaw:`HealthDevice`, these health devices should be part of Bob's BAN. Therefore and as shown in Figure 15, `BobMonitorBan` contains (`s4ehaw:contains` property) the tree aforementioned health devices: `BobSpireHealth`, `BobScanWatch`, and `BobBodyThermometer` (all `s4ehaw:HealthDevice`). Within SAREF4EHAW ontology, `BobMonitorBan` has the following contacts (`s4ehaw:hasContact`): Bob (a `s4ehaw:Patient`) and Dr. Knock (a `s4ehaw:Caregiver`) which is in particular the responsible party of the BAN (`s4ehaw:hasResponsibleParty` property). The application domain of `BobMonitorBan` (`s4ehaw:hasBanApplicationDomain` property) is related to COVID-19 prevention (`Prevention` BAN application domain depicted in Figure 15). As also shown in Figure 15, `BobMonitorBan` has a hub (`s4ehaw:hasHub` property), which plays the role of the data aggregator/collector and gateway of the BAN. This hub (a `s4ehaw:BanHub`) is called `BobAndroidPhone` (see Figure 15).

A warningCovid19 service is finally created to inform the doctor if and interaction is needed. The message will be sent via SMS. Thus a service called `AlertforHosp` (`a saref:Service`) is created. This service supports (`s4ehaw:supports` property) SMS and Presents (`s4ehaw:presents` property) a service called "`HospProfile`" that is described based on the hospital characteristics (*e.g. name, address...*).

This scenario supports a set of rules, as described below.

As general rule, the doctor who is monitoring a patient should be inferred as using the ban used by this patient.

As COVID-19 early detection rules, the first scenario consists of early detection of suspected COVID-19 symptoms. When the body temperature rises above 37,5 degrees Celsius and the breathing rate exceeds 22 breaths/min a warning is sent to the BAN hub, in our case `s4ehawInst:BobAndroidPhone`.

The second scenario consists of another, more severe symptom of COVID-19. When the breathing rate rises above 22 breaths/min, the ambient SPO2 level is below 90 %, and the systolic pressure < 90 % an immediate alert is sent for hospitalisation of the patient.

In these two cases, if the caregiver/doctor confirms that this user has COVID-19, the user is automatically inferred as patient that has (`s4ehaw:hasChronicDisease` property) COVID-19 disease (`a s4ehaw:ChronicDisease`).

The third scenario focuses on detecting the users that met a COVID-19 patient. It is done by monitoring the distance maintained between Bob (or any patient) and any nearby COVID-19 patient. Thus, the distance between two nearby patients (`s4ehaw:Patient`) is computed using the geolocation property (`s4ehaw:hasPhysicalLocation` property) of these patients. Whenever this computed distance is below 1 meter, and if one of nearby patients is infected with COVID-19, an alarm is sent to the Ban Hub indicating that there is a high risk of COVID-19. The distance is computed using the latitude and longitude of the geolocation properties (`s4ehaw:hasPhysicalLocation` property) of patients (`s4ehaw:Patient`) with Haversine formula as follows:

- R = radius of earth, 6 371 km
- $A = \sin^2(\Delta lat/2) + \cos(lat1).\cos(lat2).\sin^2(\Delta long/2)$, angle in rad
- $C = 2.\text{atan2}(\sqrt{A}, \sqrt{(1-A)})$
- D = R.C × 1 000 is the distance in meters between the two patients (`s4ehaw:Patient`)

4.3.2 Early Warning System (*EWS*) for Cardiovascular Accidents

This example describes how a cardiovascular Early Warning System (EWS) instantiates SAREF4EHAW. In this use case, the EWS collects data from an e-Health solution that allows monitoring the ECG data of a person (the patient) using the device. The chosen ECG solution for this example includes the Shimmer3 ECG, which is an ECG unit (device), a mobile application responsible for receiving high-frequency data (e.g. 256 Hz) via Bluetooth from the ECG device and sending the aggregated data to a service deployed in a cloud vendor. Therefore, the mobile app aggregates the ECG data and sends the aggregated data to an cloud IoT Hub (a publish/subscribe cloud gateway), allowing a service in the cloud to detect and warn possible emergency situations with the patient based on ECG time series and acceleration data.

An `ECG Device` registers the `Heart Electrical Activity` through electrodes attached to different places of the body, under the assumption that the heart is beating inside the body of a living person. Two electrodes enable an *ECG lead* to be measured, which is an electrical vector characterized by the depolarization of the heart resulted by the electrical signal between the atria and the ventricles. Manufacturers commonly characterize an *ECG device* by its number of `ECG leads`. An ECG device is composed by extremity electrodes, which are attached close to the left arm (LA), right arm (RA), left leg (LL) and the right leg (RL); and the chest (precordial), varying from one to six units ($V_{1\text{-}6}$). By convention, `lead I` measures the electrical activity from the electrodes RA to LA, `lead II` measures of the electrical activity from RA to LL, *lead III* measures the electrical activity from LA to LL. The rule `lead I + lead III = lead II` makes it possible to derive a lead based on the other two. `Lead I`, `Lead II` and `Lead III` are known as `Bipolar Limb`. `Unipolar leads` measure the electrical activity from the Wilson's central terminal (negative pole) to each of the chest electrodes (positive poles). For example, the Shimmer3 ECG is a four-lead ECG device wired with four extremity electrodes and one chest electrode, enabling the measurement of three bipolar and one unipolar lead.

Figure 16 illustrates the composition of the ECG device (a `s4heaw:HealthWearable`) of this example. The ECG device `ECG_unit_T9JRN42` is an `s4ehaw:HealthDevice` and an `s4ehaw:HealthWearable` that is composed of 4 leads (`ECGLead_I_`, `ECGLead_II_`, `ECGLead_III_` and `ECGLead_Vx_RL`) and three accelerometer sensors (X, Y and Z). The acceleration data can be used by the EWS to detect collisions (e.g. car accidents) and correlate with the ECG data for detecting heart damages. The ECG device plays the role of a recorder in the complex event (action) of a `s4ehaw:MeasurementCollectionSession` (the ECG recording session `s4ehawInst:RecordingECGSession_01`). In SAREF, this complex action can be classified as a `saref:Task` that an ECG device `saref:accomplishes`. The `s4ehaw:hasParticipant` (same meaning as in UFO-B [i.2]) relationship between the ECG Recording Session and the person under ECG monitoring is represented through the `s4ehaw:hasActivity`.

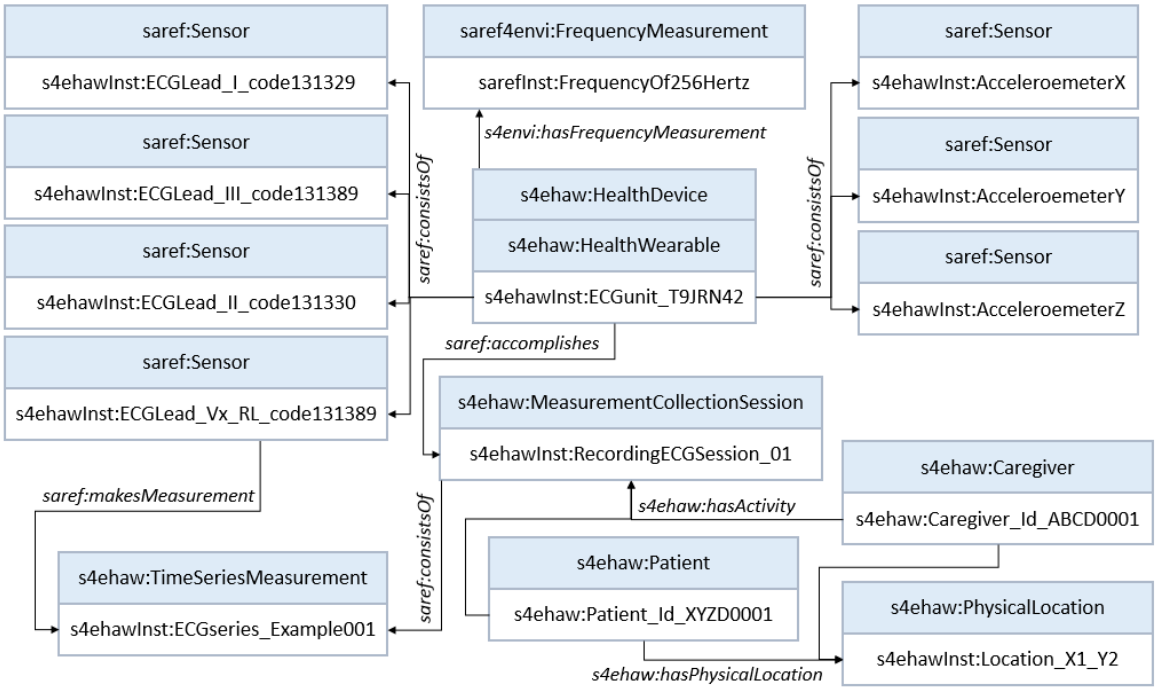

Figure 16: Composition of ECG device with a recording measurement session

The frequency of an ECG device can be set through an API, which becomes the frequency of each ECG Sample Sequence measured during a recording session (a `s4ehaw:MeasurementCollectionSession`). The `saref4envi:hasFrequencyMeasurement` property with range of only `s4envi:FrequencyMeasurement` were reused. This approach is required to differentiate the current frequency of a device from a frequency used in prior sample sequences. For example, the device Shimmer3 ECG can be set for sampling frequency (rate) of 512 Hz, which is recommended for clinical grade ECG, i.e. 512 data samples per second or an interval of 0,002 seconds between two consecutive data samples, from 0,05 Hz to 8 000 Hz range. Suppose that after collecting some sample sequences and before sending the message to the gateway, the frequency is set to 256 Hz and new sample sequences are collected. With SAREF4EHAW approach, the message describes the current frequency of the device (256 Hz) and the frequencies used in each collected sample sequence (512 Hz and 256 Hz).

The term `s4ehaw:TimeSeriesMeasurement` refers to a time series of a sequence of measurements made by a device, in line with the terminology often used in the measurement science (metrology). This term can be applied to several types of measurements, such as ECG time series. As illustrated in Figure 17, the `ECGseries_Example002` is a `s4ehaw:TimeSeriesMeasurement` that is measured in `ElectricPotential` units (an array) and relates to the `HeartElectricalActivity` property. `s4ehaw:TimeSeriesMeasurement` is classified as `saref:Measurement` in SAREF for two reasons:

i) this representation adheres to the definition of *Measurement*, i.e. measured value (*Electric Potential units*) of a property (`HeartElectricalActivity`);

ii) reuse of SAREF structure regarding class axioms of object properties, e.g. `saref:hasTimestamp`, `saref:isMeasuredIn` and `saref:relatesToProperty`.

The `saref:hasValue` property limits the value domain of a `Measurement` to exactly one number. The `s4ehaw:hasValues` property was added to overcome this issue, in which a `s4ehaw:TimeSeriesMeasurements` can instantiate this property multiple times as an ordered (depending on the serialization format) array of numbers. The size of this array should reflect the frequency of the time series measurement and, if not, it shows a possible issue on missing measurements in the Bluetooth communication between the ECG device and the mobile application.

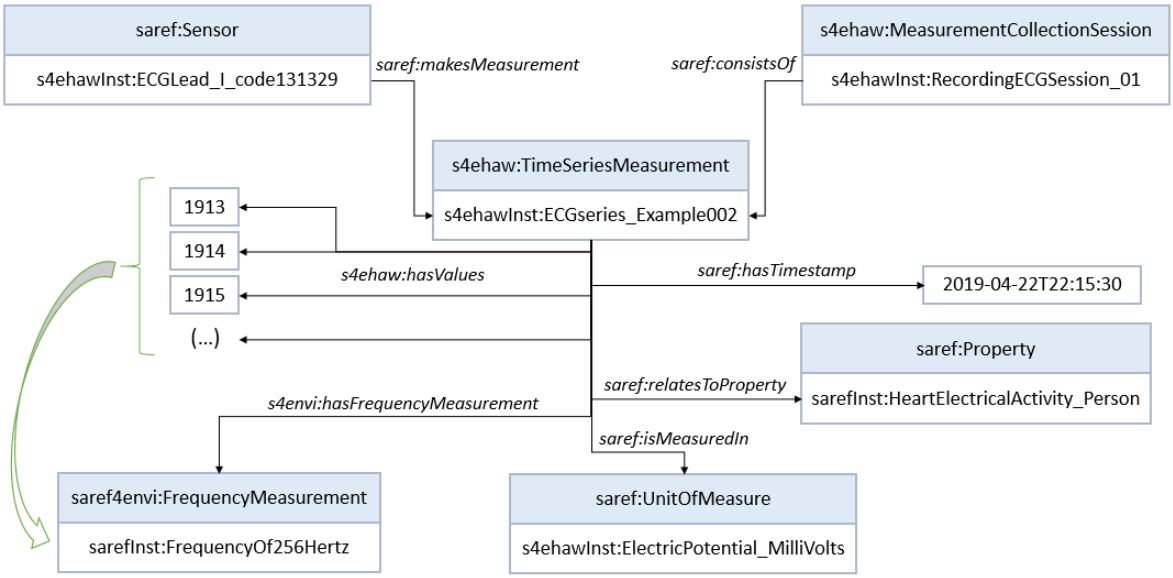

Figure 17: An ECG time series measurement

4.4 Observations

In the following, several observations about the SAREF4EHAW ontology and its usage are mentioned.

The hierarchies and individuals defined for SAREF4EHAW extension in the present document should not be considered as exhaustive. It might be needed to extend the hierarchies and lists of individuals for particular use cases, as well as to specialize some of the defined classes. Furthermore, SAREF4EHAW is a dynamic semantic model that can thus evolve over the time. Therefore, eHealth/Ageing Well domain stakeholders are invited to use and validate SAREF4EHAW extension, as well as to give feedbacks on it and to collaborate with SAREF experts so that amendments and improvements can be incorporated in future releases of the present document.

Apart from this, some of the concepts and properties defined for all the SAREF4EHAW sub-ontologies are quite generic (e.g. `s4ehaw:hasComputingPower`, `s4ehaw:MeasurementFunction`, `s4ehaw:Data`, `s4ehaw:Constraint`, `s4ehaw:TimeSeriesMeasurement`, `s4ehaw:ServiceProfile`, …) and could be applicable to other domains. Therefore, they could also be moved to SAREF.

Regarding `s4ehaw:TimeSeriesMeasurement` and its values property (`s4ehaw:hasValues`), it shall be highlighted that this approach has a formalization issue regarding the ordering of the values. Although the RDF language syntax provides the *rdf:Seq* element for ordered lists, ordering of triples may be an issue for OWL2 DL reasoners. Some serialization formats dealing with this issue, e.g. RDF/XML and JSON-LD (via @list), was taken into account. Particularly, JSON-LD is recommended for the serialization since it addresses some data exchange needs of modern e-Health solutions that rely on IoT technologies, such as dealing with the verbosity issue of messages. Verbosity relies on message size (payload), which is one of the most common non-functional requirement affecting performance and costs of IoT solutions. JSON-LD is one of the most recommended type of serialization for "semantic IoT" solutions and the other types of serializations (e.g. XML and TTL) are more verbose for ordered data.

Finally, a last attention point is related to the possibility that this extension will overlap with existing key initiatives and standards partially related to eHealth/Ageing Well, in particular:

- SAREF4WEAR, extension of SAREF for the Wearable domain. During STF 566 phase of specification and design of SAREF extensions, special attention was drawn to avoid overlapping in particular between SAREF4EHAW and SAREF4WEAR. However, further alignments may be required.
- HL7 Fast Healthcare Interoperability Resources (FHIR®) [i.3]. FHIR® is intended for providing reasoning and decision making supports about healthcare processes and clinical systems, which means that it is more at the organizational level while SAREF4EHAW ontology is more at the engineering level (i.e. one layer below FHIR®). In that sense, SAREF4EHAW ontology is rather complementary with FHIR®. However, further mapping and alignments may be required and could also be investigated.
- HL7 annotated ECG (aECG) [i.5] standard is a medical record data format for storing and retrieving electrocardiogram (ECG), chosen by the US Food and Drug Administration (FDA) for clinical trials, implemented as a lexicon approach, i.e. using XML schemas, running nowadays in several hospital information systems.
- Digital Imaging and Communications in Medicine (DICOM®) [i.6] is the international standard to transmit, store, retrieve, print, process, and display medical imaging information. It is one of the most used standards in e-Health solutions, being a lexicon approach that makes medical imaging information interoperable.
- OGC Observations and Measurements (O&M) [i.4] is one of the core standards in the OGC Sensor Web Enablement (SWE) suite standard and defines a conceptual schema encoding for observations, and for features involved in sampling when making observations, adhering to ISO 19156. The model is derived from generic patterns and is not limited to spatial information.
- Unified Foundational Ontology ECG (UFO ECG) [i.2] is a well-founded ECG ontology designed through an ontological analysis of existing health standards based on the ontology-driven conceptual modelling approach with the Unified Foundational Ontology. The main goal of UFO ECG is to serve as a reference "unified Electronic Health Record (EHR) model", providing mappings to the most common standards that support the representation of ECG data.

- ACTIVAGE Data Model. ACTIVAGE LSP (see http://www.activageproject.eu) is a European Large Scale Pilot (9 deployment sites in seven European countries) on Smart Living Environments that in particular specified and designed a dedicated data model for such environments. Therefore, it might be required to investigate possible alignments and/or mappings between SAREF4EHAW ontology and ACTIVAGE Data Model. Contact has already been established between ACTIVAGE LSP representatives and SAREF4EHAW ontology designers for that purpose.

History

Document history		
V1.1.1	July 2020	Publication